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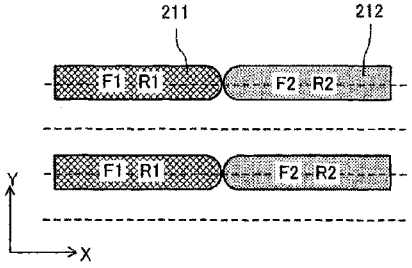
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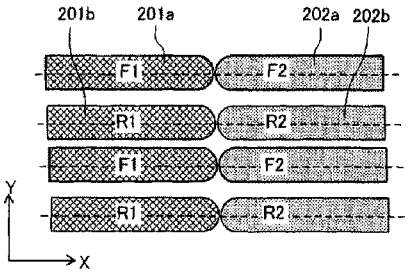
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(54) Title: THREE-DIMENSIONAL OBJECT FORMING APPARATUS, THREE-DIMENSIONAL OBJECT FORMING METHOD, AND PROGRAM

[Fig. 4A]



[Fig. 4B]



(57) Abstract: [Technical Problem] An object is to improve object forming quality upon performing material-discharging object forming process. [Solution to Problem] A three-dimensional object forming apparatus includes a plurality of discharging units configured to discharge a modelling material and a supporting material, respectively; a forming stage on which a three-dimensional object is formed; one or more flattening units configured to flatten a surface of each of the discharged modelling material and supporting material; one or more curing units configured to cure each of the discharged modelling material and supporting material; and at least one controlling unit configured to control an object forming operation. The at least one controlling unit is configured to relatively move the forming stage and the plurality of discharging units, perform a modelling material layer forming operation of causing a corresponding discharging unit of the plurality of discharging units to discharge the modelling material at each of forward and return strokes, and causing the one or more flattening units and the one or more curing units to flatten and cure the modelling material immediately after the discharging of the modelling material at the return stroke, and perform a supporting material layer forming operation of causing a corresponding discharging unit of the plurality of discharging units to discharge the supporting material at each of forward and return strokes, and causing the one or more flattening units and the one or more curing units to flatten and cure the supporting material immediately after the discharging of the supporting material at the return stroke.

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Description

Title of Invention: THREE-DIMENSIONAL OBJECT FORMING APPARATUS, THREE-DIMENSIONAL OBJECT FORMING METHOD, AND PROGRAM

Technical Field

[0001] The present invention relates to a three-dimensional object forming apparatus, a three-dimensional object forming method, and a program.

Background Art

[0002] A material jetting method is known in which a three-dimensional object is formed by using a modelling material that is used to form the three-dimensional object and a supporting material that supports the shape of the modelling material; repeatedly discharging, flattening, and curing the modelling material and the supporting material; and finally removing the supporting material.

[0003] It is known that one of a modelling material and a supporting material is discharged first and cured, and then, the other is discharged and cured, to prevent mixing of uncured modelling material and supporting material (see PTL 1).

Summary of Invention

Technical Problem

[0004] In the case disclosed in PTL 1, there may be a problem that, only by simply discharging and curing a modelling material or a supporting material first, the uncured modelling material may spread after being discharged, and the edge accuracy may be degraded.

[0005] One aspect of the present invention has been devised in view of the problem and has an object to improve the forming quality in forming a three-dimensional object.

Solution to Problem

[0006] In order to solve the problem, a three-dimensional object forming apparatus according to the aspect of the present invention includes a plurality of discharging units configured to discharge a modelling material and a supporting material, respectively; a forming stage on which an object is formed; one or more flattening members configured to flatten a surface of each of the discharged modelling material and supporting material; one or more curing units configured to cure each of the discharged modelling material and supporting material; and at least one controlling unit configured to control an object forming operation. In this regard, the at least one controlling unit is configured to relatively move the forming stage and the plurality of discharging units, perform a modelling material layer forming operation of causing a

corresponding discharging unit of the plurality of discharging units to discharge the modelling material at each of forward and return strokes, and causing the one or more flattening members and the one or more curing units to flatten and cure the modelling material immediately after the discharging of the modelling material at the return stroke, and perform a supporting material layer forming operation of causing a corresponding discharging unit of the plurality of discharging units to discharge the supporting material at each of forward and return strokes, and causing the one or more flattening members and the one or more curing units to flatten and cure the supporting material immediately after the discharging of the supporting material at the return stroke.

Advantageous Effects of Invention

[0007] According to the aspect of the present invention, the forming quality in forming a three-dimensional object can be improved.

Brief Description of Drawings

[0008] [fig.1]Fig. 1 depicts a schematic view illustrating an example of a three-dimensional object forming apparatus according to the present invention;

[fig.2A]Fig. 2A depicts a block diagram of elements related to control of object forming operation of the three-dimensional object forming apparatus;

[fig.2B]Fig. 2B depicts a block diagram of elements related to control of object forming operation of the three-dimensional object forming apparatus;

[fig.3]Fig. 3 depicts a flowchart illustrating object forming operation according to an embodiment 1-1 of the present invention.

[fig.4A]Fig. 4A depicts a plan view illustrating an example of object forming operation;

[fig.4B]Fig. 4B depicts a plan view illustrating an example of object forming operation;

[fig.5A]Fig. 5A depicts a cross-sectional view illustrating an example of object forming operation;

[fig.5B]Fig. 5B depicts a cross-sectional view illustrating an example of object forming operation;

[fig.5C]Fig. 5C depicts a cross-sectional view illustrating an example of object forming operation;

[fig.5D]Fig. 5D depicts a cross-sectional view illustrating an example of object forming operation;

[fig.6]Fig. 6 depicts a flowchart illustrating object forming operation according to an embodiment 1-2 of the present invention;

[fig.7]Fig. 7 depicts a plan view illustrating an example of object forming operation;

[fig.8A]Fig. 8A depicts a cross-sectional view illustrating an example of object forming operation;

[fig.8B]Fig. 8B depicts a cross-sectional view illustrating an example of object forming operation;

[fig.8C]Fig. 8C depicts a cross-sectional view illustrating an example of object forming operation;

[fig.8D]Fig. 8D depicts a cross-sectional view illustrating an example of object forming operation;

[fig.9]Fig. 9 depicts a cross-sectional view illustrating a surface form when a supporting material in the embodiment is discharged;

[fig.10A]Fig. 10A depicts a cross-sectional view illustrating a formed object for a case where the height of the modelling material and the height of the supporting material are the same;

[fig.10B]Fig. 10B depicts a cross-sectional view illustrating a formed object for a case where the height of the modelling material and the height of the supporting material are the same;

[fig.10C]Fig. 10C depicts a cross-sectional view illustrating a formed object for a case where the height of the modelling material and the height of the supporting material are the same;

[fig.11A]Fig. 11A depicts a cross-sectional view illustrating a formed object for a case where the height of the supporting material is greater than the height of the modelling material;

[fig.11B]Fig. 11B depicts a cross-sectional view illustrating a formed object for a case where the height of the supporting material is greater than the height of the modelling material;

[fig.11C]Fig. 11C depicts a cross-sectional view illustrating a formed object for a case where the height of the supporting material is greater than the height of the modelling material;

[fig.12]Fig. 12 depicts a view illustrating a slice layer;

[fig.13]Fig. 13 depicts a cross-sectional view illustrating an embodiment 1-3 of the invention;

[fig.14]Fig. 14 depicts a flowchart illustrating object forming operation according to the embodiment 1-3;

[fig.15]Fig. 15 depicts a schematic diagram for illustrating a three-dimensional object forming apparatus according to an embodiment 2-1;

[fig.16]Fig. 16 depicts a schematic diagram for illustrating a cross-section of a three-dimensional object according to the embodiment 2-1;

[fig.17]Fig. 17 depicts a block diagram for illustrating a configuration of the three-

dimensional object forming apparatus according to the embodiment 2-1;

[fig.18]Fig. 18 depicts a view for illustrating a purge area in the three-dimensional object forming apparatus according to the embodiment 2-1;

[fig.19]Fig. 19 depicts a view for illustrating positional relationships at a time of performing a maintenance sequence of the three-dimensional object forming apparatus according to the embodiment 2-1;

[fig.20]Fig. 20 depicts a view for illustrating positional relationships at a time to start discharging by the three-dimensional object forming apparatus according to the embodiment 2-1;

[fig.21]Fig. 21 depicts a block diagram for illustrating a configuration of a program executed by a main control unit of the three-dimensional object forming apparatus according to the embodiment 2-1;

[fig.22]Fig. 22 depicts a flowchart for illustrating a processing procedure performed by the main control unit of the three-dimensional object forming apparatus according to the embodiment 2-1;

[fig.23]Fig. 23 depicts a view for illustrating a cross-section of a three-dimensional object formed by the three-dimensional object forming apparatus according to the embodiment 2-1;

[fig.24]Fig. 24 depicts a diagram for illustrating waveform data of a voltage when a discharge control unit of the embodiment 2-1 discharges a modelling material at a forward stroke;

[fig.25]Fig. 25 depicts a diagram for illustrating waveform data of a voltage when the discharge control unit of the embodiment 2-1 discharges the modelling material at a return stroke;

[fig.26]Fig. 26 depicts a diagram for illustrating waveform data of a voltage when the discharge control unit according to the embodiment 2-1 discharges a supporting material;

[fig.27]Fig. 27 depicts a flowchart for illustrating a processing procedure performed by a main control unit of a three-dimensional object forming apparatus of a variant 2-1;

[fig.28]Fig. 28 depicts a view for illustrating a cross-section of a three-dimensional object formed by the three-dimensional object forming apparatus of the variant 2-1;

[fig.29]Fig. 29 depicts a flowchart for illustrating a processing procedure performed by a main control unit of a three-dimensional object forming apparatus according to a variant 2-2;

[fig.30]Fig. 30 depicts a view for illustrating a cross-section of a three-dimensional object formed by the three-dimensional object forming apparatus of the variant 2-2;

[fig.31]Fig. 31 depicts a schematic diagram for illustrating an example of object forming layers using a three-dimensional object forming apparatus according to an em-

bodiment of the present invention;

[fig.32]Fig. 32 depicts a schematic plan view for illustrating a front view of the three-dimensional object forming apparatus;

[fig.33]Fig. 33 depicts a schematic diagram for illustrating a position of a head and a forming stage at the start of printing;

[fig.34]Fig. 34 depicts a cross-sectional view for illustrating a purge process;

[fig.35]Fig. 35 depicts a schematic diagram for illustrating an example of a method of forming a three-dimensional object using a three-dimensional object forming apparatus according to an embodiment of the invention;

[fig.36]Fig. 36 depicts a schematic diagram for illustrating a method of generating a pulse voltage for a droplet of an object forming material at a return stroke greater than or equal to a pulse voltage for a droplet of an object forming material at a forward stroke to increase a size of a droplet of an object forming material at a return stroke;

[fig.37]Fig. 37 depicts a graph for illustrating relationships of a droplet of an object forming material (a weight of an object forming material) to a pulse voltage;

[fig.38]Fig. 38 depicts a graph for illustrating relationships of a film thickness to a pulse voltage;

[fig.39]Fig. 39 depicts a graph for illustrating relationships between a film thickness and a discharge amount at a return stroke;

[fig.40]Fig. 40 depicts a diagram for illustrating a method of increasing a size of a droplet of an object forming material at a return stroke by setting the number of pulses for droplets of an object forming material at a return stroke before landing to be not less than the number of pulses for droplets of an object forming material at a forward stroke before landing, and combining a plurality of droplets of an object forming material discharged while flying;

[fig.41]Fig. 41 depicts a schematic diagram for illustrating an object forming material at a return stroke and a flattening member at a stage after a stage of (E) of Fig. 35;

[fig.42]Fig. 42 depicts a diagram for illustrating a state in which the flattening member scrapes, off a surface, extra object forming material at a return stroke at a stage after a stage of (E) of Fig. 35;

[fig.43]Fig. 43 depicts a schematic diagram for illustrating an object forming material and the flattening member at a return stroke when a roller scraping margin ratio is 12% at a stage after a stage of (E) of Fig. 35;

[fig.44]Fig. 44 depicts a schematic diagram for illustrating an object forming material and the flattening member at a return stroke when a roller scraping margin ratio is 30% at a stage after a stage of (E) of Fig. 35;

[fig.45]Fig. 45 depicts a schematic diagram for illustrating an object forming material and the flattening member at a return stroke when a roller scraping margin ratio is 4%

at a stage after a stage of (E) of Fig. 35;

[fig.46]Fig. 46 depicts a schematic diagram for illustrating an object forming material and the flattening member at a return stroke when a roller scraping margin ratio is 0% at a stage after a stage of (E) of Fig. 35;

[fig.47]Fig. 47 depicts a diagram for schematically illustrating the order in which layers are formed;

[fig.48]Fig. 48 depicts a view for illustrating an example of an object forming sequence corresponding to the schematic diagram of Fig. 47;

[fig.49A]Fig. 49A depicts a flowchart for illustrating an example of scanning operations at forward and return strokes corresponding to the schematic diagram of Fig. 47;

[fig.49B]Fig. 49B depicts a diagram for illustrating an example of scanning operations at forward and return strokes corresponding to the schematic diagram of Fig. 47;

[fig.49C]Fig. 49C depicts a diagram for illustrating an example of scanning operations at forward and return strokes corresponding to the schematic diagram of Fig. 47;

[fig.50]Fig. 50 depicts an example of waveforms applied to a head corresponding to the schematic diagram of Fig. 47;

[fig.51A]Fig. 51A depicts an example of scanning operations for solving a Y step problem;

[fig.51B]Fig. 51B depicts an example of scanning operations for solving a Y step problem;

[fig.52A]Fig. 52A depicts an example of scanning operations for solving a Y step problem;

[fig.52B]Fig. 52B depicts an example of scanning operations for solving a Y step problem;

[fig.52C]Fig. 52C depicts an example of scanning operations for solving a Y step problem;

[fig.53A]Fig. 53A depicts an example of scanning operations for solving a Y step problem;

[fig.53B]Fig. 53B depicts an example of scanning operations for solving a Y step problem;

[fig.53C]Fig. 53C depicts an example of scanning operations for solving a Y step problem;

[fig.54]Fig. 54 depicts a photograph of a side having a Y step;

[fig.55A]Fig. 55A depicts a flowchart for illustrating an example of scanning operations at forward and return strokes corresponding to the photograph of Fig. 54;

[fig.55B]Fig. 55B depicts a diagram for illustrating an example of scanning operations at forward and return strokes corresponding to the photograph of Fig. 54;

[fig.55C]Fig. 55C depicts a diagram for illustrating an example of scanning operations at forward and return strokes corresponding to the photograph of Fig. 54;
[fig.56]Fig. 56 depicts a block diagram for illustrating a control unit of a three-dimensional object forming apparatus;
[fig.57]Fig. 57 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method of an embodiment of the present invention;
[fig.58]Fig. 58 depicts a flowchart for illustrating another example of a process flow of a three-dimensional object forming method of an embodiment of the present invention;
[fig.59]Fig. 59 depicts schematic views (A)-(G) for illustrating an example of a three-dimensional object forming method using a three-dimensional object forming apparatus according to an embodiment of the invention;
[fig.60]Fig. 60 depicts a schematic view of an object forming material of a return stroke and a flattening member at a later stage of Fig. 59,(E);
[fig.61]Fig. 61 depicts a view for illustrating a state in which the flattening member scrapes, off the surface, extra object forming material at a later stage of Fig. 59,(E);
[fig.62]Fig. 62 depicts a schematic view for illustrating an object forming material and the flattening member at a return stroke when the roller scraping margin ratio is 12% in the later stage of Fig. 59, (E);
[fig.63]Fig. 63 depicts a schematic view for illustrating the object forming material and the flattening member at a return stroke when the roller scraping margin ratio is 30% in the later stage of Fig. 59, (E);
[fig.64]Fig. 64 depicts a schematic view for illustrating the object forming material and the flattening member at a return stroke when the roller scraping margin ratio is 4% in the later stage of Fig. 59, (E);
[fig.65]Fig. 65 depicts a schematic view for illustrating the object forming material and the flattening member at a return stroke when the roller scraping margin ratio is 0% in the later stage of Fig. 59, (E);
[fig.66A]Fig. 66A depicts a magnified photograph of an end of a three-dimensional object formed with a 0% roller scraping margin ratio;
[fig.66B]Fig. 66B depicts a magnified photograph of an end of a three-dimensional object formed with a 12% roller scraping margin ratio;
[fig.66C]Fig. 66C depicts a magnified photograph of an end of a three-dimensional object formed with a 30% roller scraping margin ratio;
[fig.67]Fig. 67 depicts a graph for illustrating relationships of a radius of a virtual circle overlapping an end of a three-dimensional object to a roller scraping ratio.
[fig.68]Fig. 68 depicts a schematic diagram for illustrating a method of making a pulse voltage for firing a droplet of an object forming material at a return stroke equal to or greater than a pulse voltage for firing a droplet of an object forming material at a

forward stroke and increasing a size of a droplet of the object forming material at a return stroke;

[fig.69]Fig. 69 depicts a graph for illustrating relationships of a droplet of an object forming material (weight of the object forming material) to a pulse voltage;

[fig.70]Fig. 70 depicts a graph for illustrating relationships of a film thickness to a pulse voltage;

[fig.71]Fig. 71 depicts a graph for illustrating relationships between a film thickness and a discharge amount at a return stroke;

[fig.72]Fig. 72 depicts a diagram for illustrating a method of increasing a size of a droplet of an object forming material at a return stroke by changing the number of pulses for firing droplets of the object forming material at a return stroke before landing to not less than the number of pulses of an object forming material at a forward stroke before landing, and combining a plurality of droplets of object forming material discharged while flying;

[fig.73]Fig. 73 depicts an example of a front view of a main part of a three-dimensional object forming apparatus;

[fig.74]Fig. 74 depicts an example of a plan view of the main part of the three-dimensional object forming apparatus;

[fig.75]Fig. 75 depicts an example of a side view for illustrating the main part of the three-dimensional object forming apparatus;

[fig.76]Fig. 76 depicts a diagram for illustrating a state in which an object forming material is discharged by changing of nozzle positions at forward and return strokes to form an object forming layer;

[fig.77]Fig. 77 depicts a block diagram for illustrating a control unit of the three-dimensional object forming apparatus;

[fig.78]Fig. 78 depicts a diagram for illustrating an example of a functional configuration of the three-dimensional object forming apparatus;

[fig.79]Fig. 79 depicts a flowchart for illustrating a processing procedure for a three-dimensional object forming program in the control unit of the three-dimensional object forming apparatus;

[fig.80]Fig. 80 depicts a schematic view for illustrating a sub-scanning direction and a main scanning direction in a material jetting method;

[fig.81]Fig. 81 depicts a diagram for illustrating a roller and a height of an object at each scanning operation;

[fig.82]Fig. 82 depicts an example of a front view for illustrating a main part of a three-dimensional object forming apparatus;

[fig.83]Fig. 83 depicts an example of a plan view for illustrating the main part of the three-dimensional object forming apparatus;

[fig.84]Fig. 84 depicts an example of a side view for illustrating the main part of the three-dimensional object forming apparatus;

[fig.85]Fig. 85 depicts a block diagram for illustrating a control unit of the three-dimensional object forming apparatus;

[fig.86A]Fig. 86A depicts a schematic diagram for illustrating an example of a movement of a head in a sub-scanning direction of Comparison example 5-1;

[fig.86B]Fig. 86B depicts a roller as a flattening member being not completely horizontal with respect to a stage, and a slight difference $\Delta 1$ existing in the gap between the roller and the stage between front and rear the roller;

[fig.86C]Fig. 86C depicts a diagram for illustrating a case in which the roller collides with a modelling material of an nth layer with a head position similar to that of Fig. 87A during a scanning operation for forming a supporting layer of the nth layer, causing distortion and/or scratches in the structure;

[fig.87A]Fig. 87A depicts a schematic diagram for illustrating an example of a movement of a head position in the sub-scanning direction of Example 5-1;

[fig.87B]Fig. 87B depicts a schematic diagram for illustrating another example of a movement of the head position in the sub-scanning direction of Example 5-1;

[fig.88A]Fig. 88A depicts a schematic diagram for illustrating an example of a movement of a head position in the sub-scanning direction of Example 5-2;

[fig.88B]Fig. 88B depicts a schematic diagram for illustrating another example of a movement of a head position in the sub-scanning direction of Example 5-2;

[fig.89A]Fig. 89A depicts a schematic diagram for illustrating an example of a movement of a head position in the sub-scanning direction of Examples 5-3 and 5-4;

[fig.89B]Fig. 89B depicts a schematic diagram for illustrating another example of a movement of a head position in the sub-scanning direction of Examples 5-3 and 4-4;

[fig.90]Fig. 90 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method of Comparison example 5-1;

[fig.91]Fig. 91 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method of Example 5-1;

[fig.92]Fig. 92 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method of Example 5-2;

[fig.93]Fig. 93 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method of Example 5-3;

[fig.94]Fig. 94 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method of Example 5-4;

[fig.95]Fig. 95 depicts a schematic view for illustrating an example of a three-dimensional object forming apparatus according to an embodiment of the present invention;

[fig.96]Fig. 96 depicts a block diagram of a section related to control of an object forming operation of the three-dimensional object forming apparatus; and

[fig.97]Fig. 97 depicts a cross-sectional view for illustrating an object forming operation according to an embodiment of the present invention.

Description of Embodiments

[0009] <Mode I for carrying out the invention>

[0010] Hereinafter, embodiments of a mode I for carrying out the invention of the present invention will be described with reference to the accompanying drawings. An example of a three-dimensional object forming apparatus according to the mode I for carrying out the invention of the present invention will be described with reference to FIG. 1. Fig. 1 is a schematic diagram illustrating the three-dimensional object forming apparatus.

[0011] The three-dimensional object forming apparatus is a material-jetting object forming apparatus and includes a forming stage 11 on which an object 10 is formed and a forming unit 20 for forming the object 10 while placing layers on top of each other on the forming stage 11.

[0012] The forming stage 11 moves in X directions, Y directions, and Z directions. The forming unit 20 may move in the X directions. In this way, it is possible to implement object forming operations at forward and return strokes.

[0013] The forming unit 20 includes, as a plurality of discharging units, a first head 21 that is a discharging unit for discharging a modelling material 201 and a second head 22 that is a discharging unit for discharging a supporting material 202. In addition, the forming unit 20 may move in the X directions without moving of the forming stage 11, thereby implementing object forming operations at forward and return strokes.

[0014] The forming unit 20 includes one flattening roller 23, which is a flattening member for flattening (smoothing) each of a discharged modelling material 201 and a discharged supporting material 202; and two curing units 24A and 24B, which irradiate the modelling material 201 and the supporting material 202, respectively, with ultraviolet rays as active energy rays to cure the modelling material 201 and the supporting material 202.

[0015] When the forming stage 11 moves in the forward direction of the X directions, the flattening roller 23 is positioned on the upstream side of the first head 21 and the curing unit 24A is positioned on the upstream side of the flattening roller 23. Similarly, the second head 22 is positioned on the downstream side of the first head 21 and the curing unit 24B is positioned on the downstream side of the second head 22, side by side.

[0016] An outline of the elements related to control of the object forming operation of the

three-dimensional object forming apparatus will be described with reference to Figs. 2A and 2B. Figs. 2A and 2B depict block diagrams of the elements related to the control.

[0017] A forming control unit 501 controls object forming operation, and includes, for example, a CPU 501-1, a ROM 501-2 storing a program according to an embodiment of the present invention for controlling object forming operation according to the embodiment of the present invention and other data, and a RAM 501-3 for temporarily storing three-dimensional object forming data.

[0018] The forming control unit 501 receives three-dimensional object forming data from an external object forming data generating apparatus 600. The object forming data generating apparatus 600 is an information processing apparatus such as a personal computer and generates forming data (cross-section data) which is slice data obtained from slicing a three-dimensional object to be finally obtained.

[0019] The forming control unit 501 transmits the forming data to a head driving control unit 508 which drives and controls the first head 21 discharging the modelling material 201, and the head driving control unit 508 causes the first head 21 to discharge the modelling material 201 in accordance with the forming data.

[0020] The forming control unit 501 transmits the forming data to a head driving control unit 509 which drives and controls the second head 22 discharging the supporting material 202, and the head driving control unit 509 causes the second head 22 to discharge the supporting material 202 in accordance with the forming data.

[0021] The forming control unit 501 drives a motor included in a X-direction scanning mechanism 550 for moving the forming stage 11 in a forward and return manner in the X-directions relative to the forming unit 20 through a motor driving unit 510.

[0022] The forming control unit 501 drives a motor included in a Y-direction scanning mechanism 551 for moving the forming stage 11 in a forward and return manner in the Y-directions relative to the forming unit 20 through a motor driving unit 511.

[0023] The forming control unit 501 drives a motor included in a Z-direction lifting and lowering mechanism 552 for moving the forming stage 11 up and down in the Z-directions relative to the forming unit 20 through a motor driving unit 512.

[0024] The forming control unit 501 thus moves the forming stage 11 in the X, Y, or Z direction through the motor driving unit 510, 511, or 512. Alternatively, the first head 21 or the second head 21 may be moved in the X, Y, or Z direction.

[0025] The forming control unit 501 rotates a motor 556 that rotates the flattening roller 23 through the motor driving unit 516 to flatten the modelling material 201 and the supporting material 202 discharged on the forming stage 11.

[0026] The forming control unit 501 controls curing of the discharged modelling material 201 and the supporting material 202 by controlling irradiation of ultraviolet light from

the curing units 24A and 24B through the curing control unit 519.

[0027] According to the program in accordance with an embodiment of the present invention, the forming control unit 501 controls a modelling material layer forming operation in which the first head 21, the second head 22, and the forming stage 11 are moved relative to each other, and the modelling material 201 is discharged at each of both the forward and return strokes, and the modelling material 201 is flattened and cured by the flattening roller 23 and the curing unit 24 immediately after the discharging of the modelling material 201 at the return stroke; and a supporting material layer forming operation in which the supporting material 202 is discharged at each of both the forward and return strokes, and the supporting material 202 is flattened and cured by the flattening roller 23 and the curing unit 24 immediately after the discharging of the supporting material 202 at the return stroke.

[0028] Next, the object forming operation according to an embodiment 1-1 will be described with reference to Figs. 3-5D. Fig. 3 depicts a flowchart illustrating object forming operation, Figs. 4A and 4B each depict a plan view for illustrating an example of the object forming operation, and Figs. 5A-5D depict cross-sectional views for illustrating examples of the object forming operation.

[0029] Referring to Fig. 3, the modelling material 201 is discharged from the first head 21 at a first forward stroke F1 to form a layer of the modelling material 201 having a thickness t1, and is cured by the curing unit 24A, in step S1 (hereinafter, the word "step" may be omitted as "S1", for example). In S1, the surface of the layer of the modelling material 201 is not flattened by the flattening roller 23.

[0030] Then, the modelling material 201 is discharged from the first head 21 at a first return stroke R1 to form a layer of the modelling material 201 having a thickness t2. Immediately after the discharging, the surface of the layer of the modelling material 201 is flattened by the flattening roller 23, resulting in the layer of the modelling material 201 having a thickness t3 ($t3 \leqq t2$), and the modeling material 201 is cured by the curing unit 24A (S2). In these steps S1 and S2, the modelling material layers 211 are thus formed at the forward and return strokes (a modelling material layer forming operation).

[0031] At this time, the thickness t2 of the modelling material 201 discharged at the return stroke R1 is greater than the thickness t1 of the modelling material 201 discharged at the forward stroke F1 ($t2>t1$), so that the thickness t3 can be ensured even after the flattening is performed.

[0032] Then, the supporting material 202 is discharged from the second head 22 at a second forward stroke F2 to form a layer of the supporting material 202 having a thickness t4, and is cured by the curing unit 24A (S3). In step S3, the surface of the supporting material 202 is not flattened by the flattening roller 23, similarly with step S1.

[0033] Then, the supporting material 202 is discharged from the second head 22 at a second return stroke R2 to form a layer of the supporting material 202 having a thickness t5. Immediately after the discharging, the surface of the supporting material 202 is flattened by the flattening roller 23 to form the layer of the supporting material 202 having the thickness t6 ($t6 \leqq t5$), and the supporting material 202 is cured by the curing unit 24A (S4). The supporting material layers 212 are thus formed at the forward and return strokes in these steps S3 and S4 (a supporting material layer forming operation).

[0034] At this time, the thickness t5 of the supporting material 202 discharged at the return stroke R2 is greater than the thickness t4 of the supporting material 202 discharged at the forward stroke F2 ($t5 > t4$), so that the thickness t6 can be ensured even after the flattening is performed.

[0035] Next, an actual example of object forming operation according to the present embodiment will be described with reference to Figs. 4A-5D. For example, as depicted in Fig. 5A, the modelling material 201 is discharged at the first forward stroke F1 to form the layer 201a having the thickness t1. Then, the modelling material 201 is discharged at the first return stroke R1 to form the layer 201b of the thickness t2. Immediately after the discharging, the surface of the modelling material 201 of the thickness t2 is flattened to come to have the thickness t3 and cured. Thus, as depicted in Figs. 4A, 4B, and 5B, the modelling material layer 211 including the layers 201a and 201b is formed.

[0036] Then, as depicted in Fig. 5C, the supporting material 202 is discharged at the second forward stroke F2 to form the layer 202a of the thickness t4. Then, the supporting material 202 is discharged in the second return stroke R2 to form the layer 202b of the thickness t5. Immediately after the discharging, the supporting material 202 of the thickness t5 is flattened to have the thickness t6, and the supporting material 202 is cured. Thus, the supporting material layer 212 including the layers 202a and 202b is formed, as depicted in FIGs. 4A, 4B, and 5D.

[0037] The modelling material layer 211 and the supporting material layer 212 form one object forming layer 210.

[0038] Thus, the modelling material 201 and the supporting material 202 are discharged and cured at the different scanning operations. For example, curing the modelling material 201, and then discharging the supporting material 202 (or vice versa) prevent the adjacent modelling material 201 and supporting material 202 from mixing in the uncured states.

[0039] In addition, according to the present embodiment, the modelling material 201 or the supporting material 202 is flattened by the flattening roller 23 and cured by the curing unit 24 during discharging of the modelling material 201 or the supporting material 202 at the return stroke, so that flattening and curing can be performed immediately after discharging of the modelling material and the supporting material.

[0040] This allows for obtaining a satisfactory edge with a small radius (R) and improves the forming quality of a three-dimensional object.

[0041] As depicted in Figs. 4A and 4B, the Y coordinates of the forward and return strokes may be the same or different. For example, in the example of Fig. 4A, the Y-coordinates of the discharge positions at the first forward stroke F1 and the first return stroke R1 of the modelling material 201 are set to be the same. The Y-coordinates of the discharge positions at the second forward stroke F2 and the second return stroke R2 of the modelling material 201 are set to be the same. In this regard, the Y coordinates of the discharge positions of the modelling material 201 and the supporting material 202 are set to be the same.

[0042] In the example depicted in Fig. 4B, the Y-coordinates of the discharge positions at the first forward stroke F1 and the first return stroke R1 of the modelling material 201 differ. Further, the Y-coordinates of the discharge positions at the second forward stroke F2 and the second return stroke R2 of the modelling material 201 differ. The Y coordinates of the discharge positions at the first and second forward strokes F1 and F2 of the modelling material 201 and the supporting material 202 are set to be the same. The Y-coordinates of the discharge positions at the first and second return strokes R1 and R2 of the modelling material 201 and the supporting material 202 are set to be the same.

[0043] Next, object forming operation according to an embodiment 1-2 will be described with reference to Figs. 6-8D. Fig. 6 depicts a flowchart for illustrating object forming operation, Fig. 7 depicts a plan view for illustrating an example of object forming operation, and Figs. 8A-8D depict cross-sectional views for illustrating examples of object forming operation.

[0044] Referring to Fig. 6, the modelling material 201 is discharged from the first head 21 at a first forward stroke F1 to form a layer of the modelling material 201 having a thickness t1, and is cured by the curing unit 24A (S11). In step S11, the surface of the modelling material 201 is not flattened by the flattening roller 23.

[0045] Thereafter, the modelling material 201 is discharged from the first head 21 at a first return stroke R1, and, during thus forming of the layer of the modeling material 201 having the thickness t2, immediately after the discharging, the surface of the modelling material 201 is flattened by the flattening roller 23, so that the layer of the modelling material 201 having the thickness t3 ($t3 \leqq t2$) is formed, and the modelling material 201 having the thickness t3 ($t3 \leqq t2$) is cured by the curing unit 24A (S12).

[0046] In these steps S11-S12, a first layer of a modelling material layer 211 is formed at the forward and return strokes F1 and R1 (a first modelling material layer forming operation).

[0047] Then, the modelling material 201 is discharged from the first head 21 at a second

forward stroke F2 to form a layer of the modelling material 201 having a thickness t11, and is cured by the curing unit 24A (S13). In step 13, similar to step S11, the surface of the modelling material 201 is not flattened by the flattening roller 23.

[0048] Thereafter, the modelling material 201 is discharged from the first head 21 at a second return stroke R2 to form a layer of the modelling material 201 having a thickness t12. During the thus forming of the layer of the modeling material 201, immediately after the discharging, the surface of the modelling material 201 is flattened by the flattening roller 23, the layer of the modelling material 201 comes to have a thickness t13 ($t13 \leqq t12$), and the modelling material 201 is cured by the curing unit 24A (S14).

[0049] In these steps S13-S14, a second layer of the modelling material layer 211 is formed at the forward and return strokes F2 and R2 (a second modelling material layer forming operation).

[0050] As described above, the modelling material layer 211 is formed by performing of two times of modelling material layer forming operations in steps S11 and S12 and steps S13 and S14.

[0051] Then, the supporting material 202 is discharged from the second head 22 at a third forward stroke F3 to form a layer of the supporting material 202 having a thickness t7 ($t7 > t1+t3$) and is cured by the curing unit 24A (S15). In step S15, the surface of the supporting material 202 is not flattened by the flattening roller 23.

[0052] Thereafter, the supporting material 202 is discharged from the second head 22 at a third return stroke R2 to form a layer of the supporting material 202 having a thickness t8. During the thus forming of the layer of supporting material 202, immediately after the discharging, the surface of the supporting material 202 is flattened by the flattening roller 23, the layer of the supporting material 202 comes to have a thickness t9 ($t9 \leqq t8$), and the supporting material 202 is cured by the curing unit 24A (S16).

[0053] As described above, in steps S15 and S16, the supporting material layer 212 having the thickness ($t7+t9$) almost the same as the thickness ($t1+t3+t11+t13$) of the modelling material layer 211 formed by the plurality of times of modelling material layer forming operations is formed by the supporting material layer forming operation (one time) less than the number (two times) of the modelling material layer forming operations.

[0054] The one-time discharge amount of the first head 21 discharging the modelling material 201 in steps S11 to S14 is less than the one-time discharge amount of the second head 22 discharging the supporting material 202 in step S15.

[0055] Next, an actual example of object forming operation according to the present embodiment will be described with reference to Figs. 7-8D. For example, as depicted in Fig. 8A, as described above for the embodiment 1-1, the modelling material 201 is

discharged at a first forward stroke F1 to form a layer 201a having a thickness t1. Then, the modelling material 201 is discharged at a first return stroke R1 to form a layer 201b of a thickness t2. During the thus forming of the layer 201b, immediately after the discharging, the surface of the modelling material 201 of the thickness t2 is flattened, and the layer 201b comes to have a thickness t3 and is cured.

[0056] Further, the modelling material 201 is discharged at a second forward stroke F2 to form a layer 201c of a thickness t12. The modelling material 201 is further discharged at a second return stroke R1 to form a layer 201d of a thickness t12. During the thus forming of the layer 201d, immediately after the discharging, the surface of the modelling material 201 of the thickness t12 is flattened, and the layer 201d comes to have a thickness t13 and then is cured. Thus, as depicted in Figs. 7 and 8B, the modelling material layer 211 including the layers 202a-202d is obtained.

[0057] Thereafter, as depicted in Fig. 8C, the supporting material 202 is discharged at a third forward stroke F3 to form a layer 202a of a thickness t7. The supporting material 202 is further discharged at a third return stroke R3 to form a layer 202b of a thickness t8. During the thus forming of the layer 202b, immediately after the discharging, the supporting material 202 of the thickness t8 is flattened to have a thickness t9, and the supporting material 202 is cured. This forms the supporting material layer 212 including the layers 202a and 202b, as depicted in FIGs. 7 and 8D.

[0058] Thus, a single object forming layer 210 including the modelling material layer 211 and the supporting material layer 212 is obtained.

[0059] Thus, the advantageous effects of the embodiment 1-1 can be obtained, and also, it is possible to increase the height of the object forming layer 210 with the small number of times of scanning operations, thereby improving the forming speed.

[0060] That is, in the present embodiment, the two layers (t1+t3+t11+t13) of the modelling material 201 (the modelling material layer) are formed in the preceding two times of forward and return scanning operations. Then, the layer (t7+t9) of the supporting material 202 (the supporting material layer) is formed in the subsequent one time of forward and return scanning operations to obtain substantially the same height (the thickness) as the two modelling material layers.

[0061] Thus, the thickness of the object forming layer 210 that can be obtained by 8 times of scanning operations (four times of forward and return movements) according to the embodiment 1-1 can be obtained by 6 times of scanning operations (three times of forward and return movements) according to the embodiment 1-2.

[0062] Next, the relationships between the height (thickness) of the supporting material and the modelling material according to the present embodiment will be described with reference to Figs. 9-11C. Fig. 9 depicts a cross-sectional view illustrating the surface shape when the supporting material is discharged. Figs. 10A-10C depict cross-

sectional views for illustrating the formed object when the height of the modelling material and the height of the supporting material are made to be the same. Figs. 11A-11C depict cross sectional views for illustrating the formed object when the height of the supporting material is made greater than the height of the modelling material.

[0063] As depicted in Fig. 9, when the modelling material layer 211 is formed, and then, the supporting material 202 is discharged to form a layer, the height Z2 at the top end of the abutting area at which the supporting material 202 abuts on the modelling material 201 is lower than the height Z1 of the center of the supporting material 202.

[0064] Therefore, as depicted in Fig. 10A, in a case where the thickness of the layer 202a when the supporting material 202 is discharged at the third forward stroke F3 is insufficient, after the layer 202b of the supporting material 202 discharged at the third return stroke R3 is flattened and cured, there is a high possibility that the abutting area between the layer 202b of the supporting material 202 and the modelling material layer 211 is incomplete (a space 203 may be generated).

[0065] Then, when an overhanging shape is formed by a layer 201e and a layer 201f of the modelling material 201 as a next slice layer with the above-mentioned incomplete abutting area in Fig. 10B, the shape of the inner edge 301 of the formed object 300 may be degraded as depicted in Fig. 10C.

[0066] Therefore, in the present embodiment, when the layer 202a of the supporting material 202 is formed at the third forward stroke F3 as depicted in Fig. 11A, a thickness t7 of the layer 202a is made greater than a thickness (t1+t3) of the two layers 201a and 201b of the modelling material. More desirably, the thickness of the layer 202a of the supporting material may be greater than the thickness of the two layers 201a and 201b of the modelling material at the time of discharging such as $(t1+t2) \leqq t7$.

[0067] This ensures that the abutting area between the modelling material layer 211 and the layer 202a of the supporting material 202 is satisfactory formed, and, even in a case where an overhanging shape is formed by layers 201e and 201f of the modelling material 201 as a next slice layer as depicted in Fig. 11B, the shape of the inner edge 301 of the formed object 300 is satisfactory (the radius is reduced) as depicted in Fig. 11C.

[0068] the term "slice layer" will now be described with reference to Fig. 12. Fig. 12 depicts an example for illustrating a slice layer.

[0069] When a thickness of the modelling material layer 211 formed by a plurality of times (n times) of forward and return scanning operations of discharging the modelling material 201 is approximately the same as a thickness of the supporting material layer 212 formed by a plurality of times (smaller than the n times) of forward and return scanning operations of discharging the supporting material 202 performed thereafter,

the thus-obtained layer having the height (thickness) t at this time is referred to as a "slice layer SL".

[0070] An embodiment 1-3 of the present invention will now be described with reference to Fig. 13. Fig. 13 depicts a cross-sectional view for illustrating the present embodiment.

[0071] Depending on the shape, orientation, or forming mode of a three-dimensional object, there may be a slice layer SL that includes only the modelling material 201 or the supporting material 202.

[0072] For example, as depicted in Fig. 13, when slice layers SL1-SL4 are formed on top of each other into a lamination, a slice layer SL2 includes only the modelling material 201, whereas a slice layer SL3 includes only the supporting material 202.

[0073] Thus, when a slice layer to be formed includes only either the modelling material or the supporting material, a scanning stroke is not performed to discharge the other material from among the supporting material and the modelling material. In this regard, a slice layer including only the supporting material may be formed for the purpose of separating two three-dimensional objects that have been formed as being piled vertically.

[0074] According to the present embodiment, due to omitting of a scanning stroke as described above, the object forming time can be shortened and the object forming speed can be improved.

[0075] Next, an object forming operation according to the embodiment 1-3 will be described with reference to a flowchart depicted in Fig. 14.

[0076] Here, an example is such that a slice layer SL is formed as a result of the modelling material 201 being discharged by preceding two times of forward and return scanning operations and the supporting material 202 being discharged by subsequent one time of forward and return scanning operation.

[0077] When forming of a (n-1)th slice layer is completed (S20), and then, a nth slice layer is formed, it is determined whether modelling material data is provided for the nth slice layer (i.e., whether area section data is provided) (S21).

[0078] Assuming that modelling material data is provided for the nth slice layer (Yes in step S21), the modelling material 201 is discharged and cured for a thickness t1 at a first forward stroke (S22). Then, at a first return stroke, the modelling material 201 is discharged for a thickness t2, then flattened to a thickness t3, and cured (S23).

[0079] Thereafter, the modelling material 201 is discharged and cured for a thickness t11 at a second forward stroke (S24). Then, at a second return stroke, the modelling material 201 is discharged for a thickness t12, flattened to a thickness t13, and then cured (S25).

[0080] Thereafter or when modelling material data is not provided for the nth slice layer in step S21 (No in step S21), it is determined whether supporting material data is provided for the nth slice layer (whether supporting section data is provided) (S26).

[0081] Assuming that supporting material data is provided for the nth slice layer (Yes in step S26), the supporting material 202 is discharged and cured for a thickness t7 (t7>t1+t2) at a third forward stroke (S27). Then, at a third return stroke, the supporting material 202 is discharged for a thickness t8, flattened to a thickness t9, and cured (S28). Then, the number of the next slice layer is set to "n=n+1" (S29), and the process returns to step S21.

[0082] When supporting material data is not provided for the nth slice layer (No in step S26), the number of the next slice layer is set to "n=n+1" (S29), the process returns to step S21, and thus, forward and return scanning operations of discharging the supporting material 202 for the nth slice layer are omitted.

[0083] Thus, the object forming time can be further reduced compared to the embodiment 1-2.

<Mode II for carrying out the invention>

[0084] Hereinafter, a mode II for carrying out the invention of the present invention will be described.

[0085] The mode II for carrying out the invention of the present invention relates to a three-dimensional object forming apparatus, a three-dimensional object forming methods, and a program.

[0086] A 3D printer is becoming familiar as an apparatus forming a three-dimensional object.

[0087] For example, a technique of discharging a modelling material and a supporting material separately has been proposed (see PTL 2).

[0088] However, in a case where a modelling material and a supporting material are discharged separately, when a surface of a supporting material and a surface of a modelling material are formed at the same heights, a flattening member used for flattening the surface of the later formed layer may collide with the surface of the previously formed layer (for example, the surface of the layer of the modelling material) during flattening of the surface of the later formed layer (the layer of the supporting material). Thus, for example, the dimensional accuracy of a three-dimensional object may be degraded.

[0089] It is an object of an embodiment of the mode II for carrying out the invention of the present invention to provide a three-dimensional object forming apparatus, a three-dimensional object forming method, and a program for preventing a flattening member from colliding with a surface of a discharged material and improving the quality of the formed three-dimensional object.

[0090] In order to achieve the object, a three-dimensional object forming apparatus according to the embodiment of the mode II for carrying out the invention of the present invention repeats a scanning operation to form a laminate of a plurality of

modelling and supporting layers. The three-dimensional object forming apparatus includes a discharging unit configured to cause a modelling layer to be formed at a first scanning operation and causing a supporting layer to be formed at a second scanning operation; a flattening member configured to cause a layer from among the modelling layer and the supporting layer whichever higher to be flattened, and a curing unit configured to cause the layer from among the modelling layer and the supporting layer which has been flattened by the flattening unit to be cured.

[0091] According to the embodiment of the mode II for carrying out the invention of the present invention, it is possible to obtain an advantageous effect of preventing the flattening member from colliding with the surface of the discharged material and improving the quality of the three-dimensional object.

[0092] Referring now to the accompanying drawings, a three-dimensional object forming apparatus, a three-dimensional object forming method, and a program will be described. The present invention is not limited by the following embodiments.

(Embodiment 2-1)

[0093] As an embodiment 2-1, an example of a three-dimensional object forming apparatus that forms a three-dimensional object using a material jetting method will be described. The embodiment 2-1 that will now be described is not limited to a configuration using a material jetting method. Alternatively, a three-dimensional object forming apparatus that forms a three-dimensional object formed using any other forming method may be applied to the embodiment 2-1.

[0094] Fig. 15 depicts a schematic diagram for illustrating a three-dimensional object forming apparatus according to the embodiment 2-1.

[0095] A three-dimensional object forming apparatus 10010 for forming a three-dimensional object depicted in Fig. 15 is a material-jetting object forming apparatus that includes a forming stage 10014 on which a three-dimensional object 10030 is formed and a forming unit 10020 forming the object 10030 using modelling layers formed on top of each other on the forming stage 10014. Fig. 15 depicts an example of a modelling material 10301 and a supporting material 10302 as object forming materials. Specifically, Fig. 15 depicts a three-dimensional object 10030 that is a laminate of a plurality of layers 10030A-10030E that are modelling layers 10311 of the modelling material 10301 and supporting layers 10312 of the supporting material 10302 formed on top of each other as depicted.

[0096] The forming unit 10020 includes a first head 10011, second heads 10012, UV ir-radiators 10013, and flattening rollers 10016. The first head 10011 discharges the modelling material 10301 as a first discharging unit. The second heads 10012 discharge the supporting material 10302 as a second discharging unit. The UV ir-radiators 10013 emit ultraviolet light as active energy radiation as a curing unit. The

UV irradiators 10013 cure the modelling layers 10311 and the supporting layers 10312. Examples of the UV irradiators 10013 include, for example, high-pressure mercury lamps, ultra-high-pressure mercury lamps, metal halide lamps, and so forth. A high-pressure mercury lamp is a point source. However, a DeepUV type lamp, in which light utilization efficiency is improved in combination with an optical system, can implement short-wavelength irradiation. A metal halide lamp is effective for a colored material because of having a wide wavelength range, and uses a metal halide of a metal such as Pb, Sn, or Fe. A metal to be used is selected according to the absorption spectrum of the polymerization initiator. As a lamp used for curing, there is no particular limitation, and a lamp may be selected according to the purpose.

[0097] The flattening rollers 16 flatten the modelling layers 10311 and the supporting layers 10312 as flattening members. The flattening rollers 10016 need not flatten all of the modelling layers 10311 and the supporting layers 10312.

[0098] In the example of Fig. 15, along the X directions, the first head 10011 is provided between the two second heads 10012, the UV irradiators 10013 are provided outside the two second heads 10012, and the flattening rollers 10016 are disposed outside the UV irradiators 10013.

[0099] The forming unit 10020 is driven to go forward and return in the X directions and is movable relative to the forming stage 10014 in the Y directions. The forming unit 10020 may be moved relative to the forming stage 10014, or the forming stage 10014 may be moved relative to the forming unit 10020.

[0100] The forming stage 10014 is lifted and lowered in the Z directions by using a Z-direction lifting and lowering unit 10015. The forming stage 10014 may be fixed while the forming unit 10020 may be lifted and lowered in the Z directions.

[0101] Next, an outline of a forming operation by the three-dimensional object forming apparatus 10010 will be described with reference to Fig. 16. Fig. 16 depicts a diagram schematically depicting a cross-section of a three-dimensional object according to the embodiment. For convenience, the example depicted in Fig. 16 expresses a droplet shape as a rectangular shape.

[0102] While the forming unit 10020 is moved in the X directions relative to the forming stage 10014, the modelling material 10301 is discharged from the first head 10011 to a forming section on the forming stage 10014 at a first scanning operation to form a modelling layer 10311. At a second scanning operation, the supporting material 10302 is discharged from the second heads 10012 to a supporting section on the forming stage 10014 to form a supporting layer 10312. The first and second scanning operations differ in time. The supporting section is different from the forming section and the supporting layer is removed after the object forming operation is completed.

[0103] The UV irradiator 10013 emits ultraviolet light onto the modelling layer 10311 of the

modelling material 10301 and the supporting layer 10312 of the supporting material 10302 to cure the layers to form a single layer of the object 10030 including the modelling layer 10311 and the supporting layer 10312.

[0104] Such a process of forming a single layer of the object 10030 is repeated so that the desired shape of the three-dimensional object 10030 that is a laminate of thus obtained plurality of modelling layers 10311 made of the modelling material is obtained.

[0105] For example, in the example of Fig. 15, the laminate of the five layers 10030A-10030E is obtained. In the example of Fig. 16, the laminate of the three layers 10030A-10030C is obtained. Thus, the modelling material laminate 10321 is formed of the modeling layers 10311 and the supporting material laminate 10322 is formed of the supporting layers 10312.

[0106] In the present embodiment, the flattening rollers 10016 are used to press the top side of the modelling layers 10311 and the supporting layers 10312 of the object 10030 each time when the number of layers are formed, of which the number need not be a fixed value. This ensures the thickness accuracy and flatness of the object 10030.

[0107] When roller-shaped members such as the flattening rollers 10016 are used as flattening members, the flattening effect is more effectively exerted by rotating of the flattening rollers 10016 in the direction reverse to the direction of the movement of the flattening rollers 10016 in the X directions.

[0108] Also, in order to maintain a constant gap between the forming unit 10020 and the top side of the already formed layers of the object 10030, the forming stage 10014 is lowered by the Z-direction lifting and lowering unit 10015 at each formation of a pre-determined number of layers. In this regard, the forming unit 10020 instead may be lifted.

[0109] The three-dimensional object forming apparatus 10010 may further include a collecting and recycling mechanism for the modelling material 10301 and the supporting material 10302. In addition, a cleaning unit for cleaning the nozzle surfaces of the first head 11 and the second heads 10012 and/or a discharge condition detecting unit for detecting non-discharge nozzles may be provided. It is also desirable to control the ambient temperature in the three-dimensional object forming apparatus 10010 during a three-dimensional object forming operation.

[0110] Next, an outline of the control unit of the three-dimensional object forming apparatus will be described. Fig. 17 depicts a block diagram for illustrating the configuration of the three-dimensional object forming apparatus 10010 according to the present embodiment.

[0111] The control unit 10500 includes a main control unit 10500A including a CPU 10501 for controlling the entire apparatus, a ROM 10502 for storing a program for causing the CPU 10501 to execute control of a three-dimensional object forming operation and

other fixed data, and a RAM 10503 for temporarily storing three-dimensional object forming data and so forth.

[0112] The control unit 10500 includes a non-volatile memory (NVRAM) 10504 for storing data even after the power of the apparatus has been turned off. The control unit 10500 includes an ASIC 10505 for performing image processing including various signal processing, and the like on image data and performing input/output signal processing for controlling the entire apparatus.

[0113] The control unit 10500 includes an external I/F 10506 for transmitting and receiving data and signals used to receive three-dimensional object forming data from an external object forming data generating apparatus 10600.

[0114] The object forming data generating apparatus 10600 generates three-dimensional object forming data (cross-section data) which is slice data of slices of respective layers of a desired shape of a three-dimensional object. The object forming data generating apparatus 10600 may be an information processing apparatus such as a personal computer.

[0115] The control unit 10500 includes an I/O 10507 for receiving detection signals from various sensors.

[0116] The control unit 10500 includes a head drive control unit 10508 for driving and controlling the first head 10011 of the forming unit 10020 and a head drive control unit 10509 for driving and controlling the second heads 10012 of the forming unit 10020.

[0117] The control unit 10500 includes a motor driving unit 10510 for driving a motor included in a X-direction scanning mechanism 10550 for moving the forming unit 10020 in the X-directions (the main scanning directions) and a motor driving unit 10511 for driving a motor included in a Y-direction scanning mechanism 10552 for moving the forming unit 10020 in the Y-directions (the sub scanning directions). The motor driving unit 10510 for driving the motor included in the X-direction scanning mechanism 10550 or the motor driving unit 10511 for driving the motor included in the Y-direction scanning mechanism 10552 can be operated in order to move the forming stage 10014 in the X-directions or the Y-directions relative to the forming unit 10020.

[0118] The control unit 10500 includes a motor driving unit 10512 for driving a motor included in the Z-direction lifting and lowering unit 10015 for lifting or lowering the forming stage 10014 in the Z directions. Such a Z-direction movement of the forming stage 10014 relative to the forming unit 10020 may be implemented by a Z-direction movement of the forming unit 10020 relative to the forming stage 10014 that is not moved. In such a case, the forming unit 10020 is driven by the motor driving unit 10512 to lift and lower the forming unit 10020 in the Z directions.

[0119] The control unit 10500 includes a motor driving unit 10516 for driving a motor

10026 for rotating the flattening rollers 10016, and a maintenance driving unit 10518 for driving the maintenance mechanism 10061 for the first head 10011 and the second heads 10012.

[0120] The control unit 10500 includes an irradiation control unit 10519 for controlling ultraviolet irradiation by the UV irradiators 10013.

[0121] The I/O 10507 of the control unit 10500 receives a detection signal of a temperature and humidity sensor 10560 which detects the temperature and the humidity as an environmental condition of the apparatus, and detection signals of other sensors.

[0122] An operation panel 10522 is connected to the control unit 10500 for inputting and displaying information necessary for the apparatus.

[0123] The control unit 10500 receives three-dimensional object forming data from the object forming data generating apparatus 10600 as described above. Three-dimensional object forming data is modelling section data as slice data obtained from slicing the desired shape of the object 10030 to form the modelling layers 10311.

[0124] The main control unit 10500A generates data that includes supporting section data for providing the supporting material 10302 to the modelling layers 10311 in addition to the modelling section data, and provides the thus generated data to the head driving control units 10508 and 10509. The head driving control units 10508 and 10509 respectively cause liquid of the modelling material 10301 to be discharged from the first head 10011 to a forming section and cause liquid of the supporting material 10302 to be discharged from the second heads 10012 to a supporting section.

[0125] The object forming data generating apparatus 10600 and the three-dimensional object forming apparatus 10010 are included in a three-dimensional object forming arrangement. In the three-dimensional object forming apparatus 10010, waste liquid of the modelling material 10301 and the supporting material 10302 generated from cleaning the first and second heads 10011 and 10012 are desired to be disposed. Next, a procedure for disposing of waste liquid of the modelling material 10301 and the supporting material 10302 in the three-dimensional object forming apparatus 10010 will be described.

[0126] Fig. 18 depicts a view for illustrating a purge area 10101 in the three-dimensional object forming apparatus 10 according to the present embodiment. As depicted in Fig. 18, the three-dimensional object forming apparatus 10010 has the purge area 10101 immediately beneath the first head 10011 included in the forming unit 10020. A rail 10102 is provided on the Z-direction lifting and lowering unit 10015. The forming stage 10014 moves in the X directions, while sliding on the rail 10102, to retract at a predetermined position (a home position).

[0127] The purge area 10101 has a unit that collects waste liquid of the modelling material 10301 and the supporting material 10302 purged through discharging from the first

head 10011. The waste liquid thus collected at the purge area 101 is then collected in a waste liquid tank.

[0128] Fig. 19 depicts a diagram for illustrating positional relationships at a time of performing a maintenance sequence of the three-dimensional object forming apparatus 10010 according to the present embodiment. As depicted in Fig. 19, during performing the maintenance sequence, the first head 10011 is lowered to near the purge area 10101 for purging of the modelling material 10301. The forming stage 10014 is then moved along the rail 10102 to a position (e.g., the left end) such that the forming stage 10014 does not obstruct a space between the first head 10011 and the purge area 10101. In order to cause the first head 10011 to become close to the purge area 10101, the first head 10011 may be lowered or the purge area 10101 may be lifted.

[0129] Fig. 20 depicts a diagram for illustrating positional relationships at a start of discharging operation in the three-dimensional object forming apparatus 10010 according to the present embodiment. At a start of discharging operation, relationships between the first head 10011 and the forming stage 10014 is such that the first head 10011 is controlled to reach a discharging start gap, and the forming stage 10014 is moved to a discharging start position.

[0130] With reference to the example depicted in Figs. 18-20, the case in which the first head 10011 discharges the modelling material 10301 for purging into the purge area 10101 has been described. In this regard, the same process is performed also for the second heads 10012 to discharge the supporting material 10302 for purging into the purge area 10101.

[0131] Fig. 21 depicts a block diagram for illustrating an example of functional units of the main control unit 10500A of the three-dimensional object forming apparatus 10010 according to the present embodiment. The functional unit example depicted in Fig. 21 is implemented as a result of executing of a program stored in the ROM 10502 by the CPU 10501.

[0132] The main control unit 10500A according to the present embodiment performs control such that the modelling material 10301 and the supporting material 10302 are discharged at different scanning operations. Thus, the present embodiment solves problems that, due to mixing of the modelling material 10301 and the supporting material 10302, the dimensions of the object is different from the target values, the surface of the object has a crack, or microstructures such as columns and/or holes of the object cannot be formed.

[0133] Along with the above-described control, flattening of a modelling layer 10311 made of the modelling material 10301 and flattening of a supporting layer 10312 made of the supporting material 10302 are performed at different times. In this regard, for example, in a case where flattening of a modelling layer 10311 is performed and then flattening

of a supporting layer 10312 is performed, when the modelling layer 10311 and the supporting layer 10312 have the same heights, the flattening roller 10016 may collide with the modelling layer 10311 for which the flattening has been performed. As a result, the accuracy of the three-dimensional object may be degraded and/or the lives of the flattening rollers 16 may be reduced.

[0134] Therefore, according to the present embodiment, a modelling layer 10311 made of the modelling material 10301 is caused to be higher than a supporting layer 10312 before flattening of the modelling layer 10311; and a supporting layer 10312 made of the supporting material 10302 is caused to be higher than a modelling layer 10311 before flattening of the supporting layer 10312. Detail of actual processing procedures will be described later.

[0135] As depicted in Fig. 21, the main control unit 10500A includes a stage movement control unit 10701, a discharge control unit 10702, a curing control unit 10703, a flattening control unit 10704, and a lifting and lowering control unit 10705.

[0136] The stage movement control unit 10701 performs movement control of the forming stage 10014 by outputting an instruction to the motor driving units 10510 and 10511.

[0137] The discharge control unit 10702 performs discharge control of the first head 10011 and the second heads 10012. Actually, the discharge control unit 10702 performs control to form a modelling layer 10311 at a first scanning operation and a supporting layer 10312 at a second scanning operation. The discharge control unit 10702 controls the first head 10011 to cause the modelling material 10301 to be discharged and form each modelling layer included in a three-dimensional object at a forward stroke and a return stroke of the first scanning operation.

[0138] In this regard, although the example in which the modelling material 10301 is discharged at the forward and return strokes of the first scanning operation including the first scanning operation will be described, the present embodiment is not limited to the example in which the modelling material 10301 is discharged at the forward and return strokes of the first scanning operation, and, alternatively, the modelling material 10301 may be discharged at the forward stroke or the return stroke of the first scanning operation.

[0139] Similarly, the present embodiment is not limited to the example in which the supporting material 10302 is discharged at the forward and return strokes of the second scanning operation, and, alternatively, the supporting material 10302 may be discharged at the forward stroke or the return stroke of the second scanning operation.

[0140] The forward and return strokes mean movements of the forming unit 10020 and the forming stage 10014 relative to each other in the X or Y directions.

[0141] The supporting material 10302, discharging of which is controlled by the discharge control unit 10702, may be water insoluble or water soluble. It is desirable that the

supporting material 10302 is water soluble due to its ease of removal. Water soluble means a feature that when immersed in water, a cured material is broken down into smaller pieces, and the original shape and properties cannot be maintained.

[0142] The flattening control unit 10704 performs, for example, rotation control of the flattening rollers 10016 through the motor drive unit 10516. For example, the flattening control unit 10704 causes a modelling layer 10311 or a supporting layer 10312, whichever is higher, to be flattened by the flattening members. The flattening control unit 10704 causes a modelling layer 10311 or a supporting layer 10312, whichever is higher, to be flattened at a time when the height of the modelling layer 10311 formed by discharging of the modelling material 10301 is different from the height of the supporting layer 10312 formed by discharging of the supporting material 10302.

[0143] In the present embodiment, when the modelling material 10301 is discharged at forward and return strokes of a first scanning operation, the flattening control unit 10704 causes the thus formed modelling layer 10311 to be flattened by the flattening rollers 10016 at the return stroke.

[0144] When the supporting material 10302 is discharged at forward and return strokes of a second scanning operation, the flattening control unit 10704 causes the thus formed supporting layer 10312 to be flattened at the return stroke by the flattening rollers 10016.

[0145] The curing control unit 10703 controls the UV irradiators 10013 through the irradiation control unit 10519 to cure a modelling layer 10311 formed of the modelling material 10301 and a supporting layer 10312 formed of the supporting material 10302.

[0146] The curing control unit 10703 of the present embodiment cures a modelling layer 10311 at each of a forward stroke and a return stroke of a first scanning operation and cures a supporting layer 10312 at each of a forward stroke and a return stroke of a second scanning operation. Thus, when one of a modelling layer 10311 and a supporting layer 10312 is flattened by the flattening control unit 10704, the curing control unit 10703 cures the flattened one from among the modelling layer 10311 and the supporting layer 10312.

[0147] The lifting and lowering control unit 10705 performs lifting and lowering control of the forming stage 10014 by outputting an instruction to the motor driving unit 10512. The lifting and lowering control unit 10705 may perform lifting and lowering control of the forming unit 10020 instead.

[0148] Next, a processing procedure performed by the main control unit 10500A of the three-dimensional object forming apparatus 10010 according to the present embodiment will be described. Fig. 22 depicts a flowchart for illustrating a processing procedure performed by the main control unit 10500A of the three-dimensional object

forming apparatus 10010 according to the present embodiment. In the following processing procedure, scanning operations of forward and return strokes may be implemented in such a manner that the forming unit 10020 and the forming stage 10014 are moved relative to each other. Further, the lifting and lowering control may also be implemented in such a manner that the forming unit 10020 and the forming stage 10014 are moved relative to each other in the Z directions.

[0149] First, the stage movement control unit 10701 is moving the forming stage 10014 in the forward direction, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702, and the modelling layer 10311 is cured under the control of the curing control unit 10703 (S10801).

[0150] Next, the stage movement control unit 10701 is moving the forming stage 10014 in the return direction, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702, the flattening of the modelling layer 10311 is performed by the flattening rollers 10016 under the control of the flattening control unit 10704, and curing of the modelling layer 10311 is performed under the control of the curing control unit 10703 (S10802).

[0151] The lifting and lowering control unit 10705 performs lifting and lowering control (movements in the Z directions) of the forming stage 10014 for discharging of the supporting material 10302 (S10803).

[0152] Next, the forming stage 10014 is being moved in the forward direction by the stage movement control unit 10701, a supporting layer 10312 is formed by discharging of the supporting material 10302 under the control of the discharge control unit 702, and the supporting layer 10312 is cured under the control of the curing control unit 10703 (S10804).

[0153] The forming stage 10014 is being moved in the return direction by the stage movement control unit 10701, a supporting layer 10312 is formed by discharging of the supporting material 10302 under the control of the discharge control unit 10702, the supporting layer 10312 is flattened by the flattening rollers 10016 controlled by the flattening control unit 10704, and the supporting layer 10312 is cured under the control of the curing control unit 10703 (S10805).

[0154] The lifting and lowering control unit 10705 performs lifting and lowering control (movements in the Z directions) of the forming stage 10014 for discharging of the modelling material 10301 (S10806).

[0155] Next, the stage movement control unit 10701 is moving the forming stage 10014 in the forward direction, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702, and the modelling layer 10311 is cured under the control of the curing control unit 10703

(S10807).

[0156] The stage movement control unit 10701 is moving the forming stage 10014 in the return direction, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702, and the modelling layer 10311 is cured under the control of the curing control unit 10703 (S10808).

[0157] Next, the stage movement control unit 10701 is moving the forming stage 10014 in the forward direction, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702, and the modelling layer 10311 is cured under the control of the curing control unit 10703 (S10809).

[0158] The stage movement control unit 10701 is moving the forming stage 10014 in the return direction, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702, the flattening of the modelling layer 10311 is performed by the flattening rollers 10016 under the control of the flattening control unit 10704, and the curing of the modelling layer 10311 is performed under the control of the curing control unit 10703 (S10810).

[0159] Then, the main control unit 10500A determines whether forming of the three-dimensional object has been completed (S10811). When it is determined that the forming of the three-dimensional object has not been completed yet (S10811: No), the lifting and lowering control unit 10705 performs lifting and lowering control (Z-direction movements) of the forming stage 10014 so as to ensure an appropriate arrangement for discharging the supporting material 10302 (S10812) and returns to step S10804.

[0160] On the other hand, when it is determined that forming of the three-dimensional object has been completed (S10811: Yes), the process ends.

[0161] Fig. 23 depicts an example for illustrating a cross-section of a three-dimensional object formed by the three-dimensional object forming apparatus 10010 of the present embodiment. The example of the cross-section of the three-dimensional object 10900 depicted in Fig. 23 includes a plurality of modelling layers 10311 formed of the modelling material 10301 and a plurality of supporting layers 10312 formed of the supporting material 10302. In the example depicted in Fig. 23, the layers 10901, 10902, 10903, 10904, 10905, and 10906 that are the modelling layers 10311 are formed and the layers 10911, 10912, and 10913 that are the supporting layers 312 are formed.

[0162] The three-dimensional object 10900 depicted in Fig. 23 are formed according to a processing procedure depicted in Fig. 22. For example, the layer 10901 (the modelling layer 10311) is formed and cured at step S10801, and the layer 10902 (the modelling

layer 10311) is formed, flattened, and cured at step S10802. Because flattening is performed at step S10802, the top side 10951 of the layer 10902 is flat.

[0163] At step S10802, the flattening rollers 16 flatten only the layer 10902 (the modelling layer 10311) because the layer 10902 (the modelling layer 10311) is higher than the supporting layer 10312.

[0164] Subsequently, the layer 10911 (the supporting layer 10312) is formed and cured at step S10804, and the layer 10912 (the supporting layer 10312) is formed, flattened, and cured at step S10805. Because flattening is performed in step S10805, the top side 10961 of the layer 10912 is flat.

[0165] At the S10805 stage, the layer 10912 (the supporting layer 10312) is higher than the layer 10902 (the modelling layer 10311), so that the flattening rollers 10016 flatten only the layer 10912 (the supporting layer 10312) without flattening the layer 10902 (the modelling layer 10311).

[0166] In the same way, at steps S10807-S10810, the layers 10903, 10904, 10905, and 10906 (the modelling layers 10311) are formed. Because flattening is performed at S10810, the top side 10952 of the layer 10906 is flat.

[0167] At step S10810, because the layer 10906 (the modelling layer 10311) is higher than the layer 10912 (the supporting layer 10312), the flattening rollers 16 flatten only the layer 10906 (the modelling layer 10311) without flattening the layer 10912 (the supporting layer 10312).

[0168] Thereafter, as a result of it being determined in step S10811 that forming of the three-dimensional object has not been completed yet, the layer 10913 (the supporting layer 10312) is formed again at step S10804. Concerning the subsequent processing, description will be omitted.

[0169] In the present embodiment, when flattening of a layer (a supporting layer 10312) is performed, due to the above-described processing, the flattening roller 10016 is prevented from colliding with a modelling layer 10311. In the same way, when flattening of a layer (a modelling layer 10311) is performed, the flattening roller 10016 is prevented from colliding with a supporting layer 10312.

[0170] In addition, as depicted in Fig. 23, discharge control is performed by the discharge control unit 702 in such a manner that the layers 10902, 10904, and 10906 (the modelling layers 10311) formed at the return strokes are thicker than the layers 10901, 10903, and 10905 (the modelling layers 10311) formed at the forward strokes.

[0171] For example, when a piezo system using a piezo element contracted when a voltage is applied as a method of discharging the modelling material 10301 and the supporting material 10302, the discharge control unit 10702 controls the voltage applied at the return strokes to be higher than the voltage applied at the forward strokes. Therefore, it is possible to increase the modelling material 10301 discharged at one time in the

return strokes rather than the forward strokes.

[0172] In contrast, if the layers formed at the forward strokes were thicker than the layers formed at the return strokes, the widths of the layers formed at the return strokes would be reduced, so that when forming flat surfaces of the modelling layer 10311, it would be difficult to adjust the thickness of the modelling layers 10311.

[0173] In the present embodiment, the layers 10902, 10904, and 10906 (the modelling layers 10311) formed at the return strokes are formed to be thicker than the layers 10901, 10903, and 10905 (the modelling layers 10311) formed at the forward strokes. Therefore, when forming flat surfaces (e.g., 10951 and 10952) of the modelling layers 10311 at the return strokes, it is easy to adjust the thickness of the modelling layers 10311. This reduces the possibility that the flattening roller 10016 causes collision.

[0174] Further, the present embodiment is not limited to a method of controlling the voltage applied at the return strokes to be higher than the voltage applied at the forward strokes as a method of adjusting the thickness. The thickness of the layers (the modelling layers 10311) may be adjusted by, instead, adjusting the number of pulses of the applied voltage.

[0175] Fig. 24 depicts an example for illustrating waveform data of the voltage when the discharge control unit 10702 causes the modelling material 10301 to be discharged from the first head 10011 at a forward stroke, and Fig. 25 depicts an example for illustrating waveform data of the voltage when the discharge control unit 10702 causes the modelling material 10301 to be discharged from the first head 10011 at a return stroke.

[0176] In the example depicted in Fig. 24, the discharge control unit 10702 performs control to decrease the voltage from the voltage V_{11} to the voltage V_{12} (near the voltage 0), and then to increase the voltage to the voltage V_{11}. Thus, the discharge control unit 10702 causes a drop of the modelling material 10301 to be discharged.

[0177] In the example depicted in Fig. 25, the discharge control unit 10702 performs control to decrease the voltage from the voltage V_{21} to the voltage V_{22}, and then to increase to the voltage V_{21}, so that a drop of the modelling material 10301 is discharged from the first head 10011. Thereafter, the discharge control unit 10702 performs control of decreasing the voltage from the voltage V_{21} to the voltage V_{23} and then performs control of increasing the voltage again to the voltage V_{21}, so that a drop of the modelling material 10301 is discharged from the first head 10011. Thereafter, the discharge control unit 10702 performs control of decreasing the voltage from the voltage V_{21} to the voltage V_{24} and then performs control of increasing the voltage to the voltage V_{21}, so that a drop of the modelling material 10301 is discharged from the first head 10011. The thus discharged three drops of the modelling material 10301 are combined in the air to be discharged as a large drop of the modelling material 10301.

[0178] Therefore, the modelling layers 10311 formed at the return strokes which are flattened by the flattening rollers 10016 can be thicker than the modelling layers 10311 formed at the forward strokes which are not flattened by the flattening rollers 10016. As a result, the thickness of the layers can be easily adjusted, and therefore, it is possible to form more accurate flat surfaces. This prevents the flattening roller 10016 from colliding with the modelling layer 10311.

[0179] Fig. 26 depicts an example for illustrating waveform data of the voltage when the discharge control unit 10702 causes the supporting material 10302 to be discharged from the second heads 10012. In the example depicted in Fig. 26, the discharge control unit 10702 performs control to decrease the voltage from the voltage V_{31} to the voltage V_{32} and then again to increase to the voltage V_{31}, so that a drop of the supporting material 10302 is discharged from the second heads 10012. Thereafter, the discharge control unit 10702 performs control of decreasing the voltage from the voltage V_{31} to the voltage V_{32} and then performs control of increasing the voltage again to the voltage V_{31}, so that a drop of the supporting material 10302 is discharged from the second heads 10012. Thereafter, the discharge control unit 10702 performs control of decreasing the voltage from the voltage V_{31} to the voltage V_{33} and then performs control of increasing the voltage again to the voltage V_{31}, so that a drop of the supporting material 10302 is discharged from the second head 10012. The thus discharged three drops of the supporting material 10302 are combined in the air and discharged as a large drop of the supporting material 302.

[0180] The voltage V_{31} depicted in Fig. 26 is higher than the voltage V_{11} and the voltage V_{21}. This allows the supporting layers 10312 formed of the supporting material 10302 to be thicker than the modelling layers 10311 formed of the modelling material 10301. This results in a cross-section of the three-dimensional object as depicted in Fig. 23.

[0181] In the present embodiment, when flattening of a layer (a supporting layer 10312) is performed through the above-described processing, the flattening roller 10016 is prevented from colliding with a modelling layer 10311. Further, when flattening of a layer (a modelling layer 10311) is performed, the flattening roller 10016 is prevented from colliding with a supporting layer 10312.

[0182] Next, the supporting material used in the embodiment will be described. A liquid supporting material is called a shape supporting liquid, and a cured supporting material is called a cured object. The supporting material retains a predetermined shape of the modelling material by being in contact with the modelling material, for the purpose of forming a detailed shape, warp prevention, and so forth. Not only does it support an overhang shape, but it may also contact a side surface of the modelling material or retain the shape of an object.

[0183] The surface tension of the liquid supporting material (shape retaining liquid) is not

particularly limited, and can be appropriately selected depending on the purpose. For example, it is desirable that the surface tension be 20 mN/m or more and 45 mN/m or less, and it is more desirable that the surface tension be 25 mN/m or more and 34 mN/m or less. When the surface tension is 20 mN/m or more, it is possible to prevent discharging from becoming unstable (for example, prevent the discharging direction from being bent or prevent discharging from being not performed) at a time of forming an object, and when the surface tension is 45 mN/m or less, it is possible to easily fill a nozzle for discharging a material with the material.

[0184] The surface tension can be measured by, for example, a surface tension meter.

- Viscosity -

[0185] The viscosity of the liquid supporting material (shape retaining liquid) is 100 mPa?s or less at 25°C, desirably 3 mPa?s or more and 70 mPa?s or less at 25°C, and more desirably 6 mPa?s or more and 50 mPa?s or less. When the viscosity is 100 mPa?s or less, the discharge stability can be improved.

[0186] The viscosity can be measured under an environment of 25°C using of, for example, a rotating viscometer.

- Viscosity change rate -

[0187] As the liquid supporting material (shape retaining liquid), it is desirable that the viscosity change rate between before and after leaving the liquid at 50°C for 2 weeks be ±20% or less, and more desirably ±10% or less. When the viscosity change rate is ±20% or less, storage stability is appropriate and discharge stability is satisfactory.

[0188] The viscosity change rate between before and after being left at 50°C for 2 weeks can be measured as follows:

[0189] The shape retaining liquid is placed in a polypropylene wide-mouth bottle (50 mL) and is allowed to stand for 2 weeks in a thermostat at 50°C. Then, the liquid is removed from the thermostat and is left at room temperature (25°C) and the viscosity is measured. The viscosity of the shape retaining liquid before it is placed in the thermostat is determined as the viscosity before storage, and the viscosity of the shape retaining liquid after it is removed from the thermostat is determined as the viscosity after storage, and the viscosity change rate can be calculated by the following equation. The viscosity before storage and the viscosity after storage can be measured at 25°C using of, for example, an R-type viscometer.

[0190] Rate of viscosity change (%) = {(Viscosity after storage)-(Viscosity before storage)}/(Viscosity before storage) × 100

<Supporting force after curing of supporting material>

[0191] The bearing force (simply referred to as "bearing force of supporting material") of the liquid supporting material (shape retaining liquid) after curing is the performance of the supporting material to support the modelling material and can be expressed in

terms of compressive stress at 1% compression.

[0192] It is desirable that the supporting force of the supporting material be 0.5 kPa or more and more desirably 2 kPa or more at a time of compression of 1% or more under an environment of 25°C in view of the modelling accuracy of a three-dimensional object and the solubility of the supporting material.

(Variant 2-1)

[0193] The above-described embodiment is an example of discharging, flattening, and curing processes of the modelling material 10301 and the supporting material 10302, and is not limited to the above-described processing procedure. As a variant 2-1, another example of discharging, flattening, and curing processes of the modelling material 301 and the supporting material 10302 will now be described. The configuration of the three-dimensional object forming apparatus 10010 is similar to the configuration according to the embodiment 2-1 and will not be described again.

[0194] A processing procedure performed by the main control unit 10500A of the three-dimensional object forming apparatus 10010 according to the variant 2-1 will now be described. Fig. 27 depicts a flowchart for illustrating a processing procedure performed by the main control unit 10500A of the three-dimensional object forming apparatus 10010 according to the variant 2-1.

[0195] In the processing procedure depicted in Fig. 27, through a processing procedure similar to the procedure depicted in Fig. 22, a process is performed up to step S10808 where, when the forming stage 10014 is moved in the return direction by the stage movement control unit 10701, a modelling layer 10311 is formed by discharging of the modelling material 10301 by the discharge control unit 10702 and curing of the modelling layer 10311 is performed under the control of the curing control unit 10703 (steps S10801-S10808).

[0196] Next, the stage movement control unit 10701 moves in the forward direction of the forming stage 10014 (S11301). At that time, a modelling layer 10311 is not formed by discharging of the modelling material 10301, and also, curing of a modelling layer 10311 is not performed.

[0197] Thereafter, as depicted in step S10810, when the stage movement control unit 10701 moves the forming stage 10014 in the return direction, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702, flattening of the modelling layer 10311 by the flattening rollers 10016 is performed under the control of the flattening control unit 10704, and curing of the modelling layer 10311 by the curing control unit 10703 is performed. For the subsequent processing, the description is omitted because the same manner, similarly with Fig. 22 of the embodiment is applied.

[0198] Fig. 28 depicts an example for illustrating a cross-section of a three-dimensional

object formed by the three-dimensional object forming apparatus 10010 of the variant 2-1. In the example of the cross-section of the three-dimensional object 11400 depicted in Fig. 28, a plurality of modelling layers 10311 formed of the modelling material 10301 and a plurality of supporting layers 10312 formed of the supporting material 10302 are formed. In the example depicted in Fig. 28, the layers 10901, 10902, 11401, 11402, and 11403 (the modelling layers 10311) are formed and the layers 10911, 10912, and 10913 (the supporting layers 10312) are formed.

[0199] The three-dimensional object 11400 depicted in Fig. 28 is formed according to the processing procedure depicted in Fig. 27. Therefore, by performing steps S10801-S10806, the layers 10901 and 10902 (the modelling layers 10311) and the layers 10911 and 10912 (the supporting layers 10312) are formed. This processing procedure is the same as the processing procedure of the embodiment described above.

[0200] Then, steps S10807 and S10808 are performed, so that the layers 11401 and 11402 (the modelling layers 10311) are formed.

[0201] Thereafter, in step S11101, only movement of the forming stage 10014 in the forward direction is performed, and discharging of the modelling material 10301 is not performed. Then, in step S10810, the layer 11403 (the modelling layer 10311) is formed, flattened, and cured. This results in the top surface 11451 of the layer 11403 being a flat surface.

[0202] In the present variant, the above-described process can improve the yield of the discharged modelling material 10301 and reduce the collision risk of the flattening rollers 10016. As described above, in the present variant, the same effect as the effect of the embodiment can be obtained in step S11101 even in a case where only the movement of the forming stage 10014 in the forward direction is performed.

(Variant 2-2)

[0203] For the above-described embodiment and variant, examples of discharging, flattening, and curing processes of the modelling material 10301 and the supporting material 10302 have been described, and the embodiment and variant are not limited to the above-described processing procedures. As a variant 2-2, other examples of discharging, flattening, and curing of the modelling material 10301 and the supporting material 10302 will be described. The configuration of the three-dimensional object forming apparatus 10010 is similar to the configuration of the embodiment 2-1 and will not be described again.

[0204] In the above-described embodiment and variant, an example in which the discharge amount of the modelling material 10301 is made different from the discharge amount of the supporting material 10302 in order to form layers of predetermined thicknesses has been described. That is, in the above-described embodiment and variant, the discharge amount of the supporting material 10302 at a forward stroke or return stroke

corresponds to a sum of the discharge amounts of the modelling material 10301 at a forward stroke and the discharge amount of the modelling material 10301 at a return stroke.

[0205] As the variant 2-2, an example in which the discharge amount of the modelling material 10301 at each of forward and return strokes is made to be the same as the discharge amount of the supporting material 10302 at each of forward and return strokes will be described.

[0206] A processing procedure performed by the main control unit 10500A of the three-dimensional object forming apparatus 10010 according to the variant 2-2 will now be described. Fig. 29 is a flowchart for illustrating a processing procedure performed by the main control unit 10500A of the three-dimensional object forming apparatus 10010 according to the variant 2-2.

[0207] In the processing procedure illustrated in Fig. 29, through a processing procedure similar to the procedure depicted in Fig. 22, a process is performed including step S10802 where, while the forming stage 10014 is being moved in the return direction under the control of the stage movement control unit 10701, a modelling layer 10311 is formed by discharging of the modelling material 10301 under the control of the discharge control unit 10702 and the curing of the modelling layer 10311 is performed under the control of the curing control unit 703 (steps S10801-S10803).

[0208] Next, during a forward direction movement and a return direction movement of the forming stage 10014 under the control of the stage movement control unit 10701, a supporting layer 10312 is formed by discharging of the supporting material 10302 under the control of the discharge control unit 10702, and a supporting layer 10312 is cured under the control of the curing control unit 10703 (steps S11501 and S11502).

[0209] Thereafter, during a forward direction movement of the forming stage 10014 under the control of the stage movement control unit 10701, a supporting layer 10312 is formed by discharging of the supporting material 10302 under the control of the discharge control unit 10702 and the supporting layer 10312 is cured under the control of the curing control unit 10703 (S11503). While the forming stage 10014 is being moved in the return direction under the control of the stage movement control unit 10701, a supporting layer 10312 is formed by discharging of the supporting material 10302 under the control of the discharge control unit 10702, flattening of the supporting layer 10312 is performed by the flattening rollers 10016 under the control of the flattening control unit 10704, and curing of the supporting layer 10312 is performed under the control of the curing control unit 10703 (S11504).

[0210] As described above, in the present variant, the control of discharging of the modelling material 10301 and the supporting material 10302 and so forth includes two times of movement control for a forward stroke and movement control for a return

stroke.

[0211] The description of the subsequent processes (starting from step S10806) will be omitted because the same manner as the manner in Fig. 22 of the embodiment is applied.

[0212] Fig. 30 is a view for illustrating a cross-section of a three-dimensional object formed by the three-dimensional object forming apparatus 10010 of the variant 2-2. The example of the cross-section of the three-dimensional object 11600 depicted in Fig. 30 includes a plurality of modelling layers 10311 made of the modelling material 10301 and a plurality of supporting layers 10312 made of the supporting material 10302. In the example depicted in Fig. 30, the layers 10901, 10902, 10903, 10904, 10905, 10906, 11601, and 11602 (the modelling layers 10311) are formed and the layers 11611, 11612, 11613, 11614, 11615, 11616, 11617, and 11618 (the supporting layers 10312) are formed.

[0213] The three-dimensional object 11600 depicted in Fig. 30 is formed according to the processing procedure depicted in Fig. 29. Therefore, through steps S10801-S10803, the layers 10901 and 10902 (the modelling layers 10311) are formed, and through steps S11501-S11504, the layers 11611, 11612, 11613, and 11614 (the supporting layers 10312) are formed.

[0214] When the supporting layer 10312 is formed, the discharge control unit 10702 controls the discharge amount of the supporting material 10302 at a return stroke to be larger than the discharge amount of the supporting material 10302 at a forward stroke, similar to a case of the modelling layer 10311. Thereafter, through repetition of the same process, the modelling layers 10311 and the supporting layers 10312 are formed.

[0215] In this variant, the discharge amount of the supporting material 10302 is made to be the same as the discharge amount of the modelling material 10301. In other words, the quality of the supporting material 10302 can be improved by reducing the discharge amount of the supporting material 10302 per scanning operation compared to the above-described embodiment and variant. This can improve the quality of the exterior surface (in other words, the interface between the supporting material 10302 and the modelling material 10301) of the three-dimensional object to be formed.

(Variant 2-3)

[0216] For the above-described embodiment and variants, examples of discharging, flattening, and curing processes of the modelling material 10301 and the supporting material 10302 have been described, and the embodiment and variants are not limited to the above-described processing procedures. As a variant 2-3, another example of discharging, flattening, and curing of the modelling material 10301 and the supporting material 10302 will be described. The configuration of the three-dimensional object forming apparatus 10010 is similar to the configuration of the embodiment 2-1 and

will not be described again.

[0217] In the above-described embodiment and variant 2-2, an example in which discharging of the modelling material 10301 is performed at two times of forward and return strokes (steps S10807-S10810) when the top side of the modelling layers 10311 is flattened (S10810) is described.

[0218] At this time, according to the variant 2-2, the discharge amount of the modelling material 10301 at the forward stroke which is performed twice until flattening being performed by the flattening rollers 10016 and the discharge amount of the modelling material 10301 at the return stroke which is performed twice are not to be made different. As the variant 2-3, an example will be described in which the discharge amount of the modelling material 10301 at a return stroke performed twice until flattening is performed by the flattening rollers 10016 is changed depending on whether the flattening roller 10016 is in contact with the modelling layer.

[0219] That is, from among the two times of discharging operations of the modelling material 10301 at the return strokes until flattening is performed by the flattening rollers 10016, the discharging operation of the modelling material 10301 at the first return stroke is performed from a position where the flattening roller 10016 does not come into contact with the discharged material. When the surface to which the modelling material 10301 is discharged is thus apart, the discharging target position of the modelling material 10301 may be missed. Therefore, the discharge control unit 10702 controls the discharge amount of the modelling material 10301 at the first return stroke to be smaller than the discharge amount of the modelling material 10301 at the second return stroke.

[0220] In contrast, from among the two times of discharging operations of the modelling material 10301 at the return strokes until flattening is performed by the flattening rollers 10016, the discharging operation of the modelling material 10301 at the second return stroke is performed at a position where the flattening roller 10016 comes into contact with the discharged material. When the surface to which the modelling material 10301 is discharged is thus close, the discharging target position of the modelling material 10301 is hardly missed. Therefore, the discharge control unit 702 controls the discharge amount of the modelling material 10301 at the second return stroke to be greater than the discharge amount of the modelling material 10301 at the first return stroke.

[0221] According to the present variant, relationships between the discharge amount of the modelling material 10301 discharged at a forward stroke and the discharge amount of the modelling material 10301 discharged at a return stroke are not limited. Similarly with the above-described embodiment, the discharge amount discharged at a return stroke may be made greater than the discharge amount discharged at a forward stroke.

It is also possible that the discharge amount discharged at a return stroke is made to be equal to the discharge amount discharged at a forward stroke.

[0222] In the above described embodiment and variants, the three-dimensional object forming apparatus 10010 includes the configuration described above, so that at a time of flattening by the flattening rollers 10016, the height of the modelling layers 10311 of the modelling material 10301 and the height the supporting layers 10312 of the supporting material 10302 can be made different. This prevents the flattening roller 10016 from colliding with the already flattened modelling layer 10311 (or supporting layer 10312).

[0223] Accordingly, it is possible to prevent destruction or chipping of the modelling layer 10311 (or the supporting layer 10312) due to collision, and at the same time, it is possible to prevent the flat surface from becoming corrugated due to a bounce of the flattening roller 10016 against the flat surface. By preventing destruction or deformation of the modelling layer 10311 (or the supporting layer 10312) in this manner, the accuracy of the three-dimensional object can be improved.

[0224] Further, the load of the motor 10026 otherwise borne by flattening again of an already flattened surface by the flattening roller 10016 can be eliminated.

<Mode III for carrying out the invention>

[0225] A mode III for carrying out the invention of the present invention will now be described.

[0226] The mode III for carrying out the invention of the present invention relates to a three-dimensional object forming apparatus, a three-dimensional object forming method, and a program.

[0227] A material jetting system is known as a three-dimensional object forming apparatus in which an object forming material for forming a three-dimensional object is discharged into an object forming section, then is cured to form a layer, and layers are sequentially formed on top of each other into a laminate to form a three-dimensional object. In the material jetting method, two types of materials are used: a modelling material and a supporting material to support modelling material layers during forming of a three-dimensional object.

[0228] PTL 3 discloses a method where discharging is performed from a plurality of nozzles during a main scanning direction in order to solve a problem that a groove extending in the main scanning direction is otherwise formed in a three-dimensional object because a nozzle discharge failure influence continues in the main scanning direction in a case where a discharge failure occurs at an inkjet nozzle.

[0229] However, in this method, a step is formed on a side parallel to the main scanning direction of the object (hereinafter, which may be referred to as a "Y step"), and the surface characteristics of the completed object may be degraded

[0230] Accordingly, an object of the mode III for carrying out the invention of the present invention is to provide a method for forming a three-dimensional object in which a three-dimensional object having excellent surface characteristics can be obtained and high productivity can be achieved.

[0231] A three-dimensional object forming method according to the mode III for carrying out the invention of the present invention for solving the above-described problem includes: discharging an object forming material at a forward stroke to form an object forming layer included in one layer; discharging an object forming material at a return stroke to form an object forming layer included in the one layer; and causing a flattening member to touch a surface of the object forming layer formed at the return stroke, wherein a discharging position of the object forming material at the return stroke is adjacent to the discharge position of the object forming material at the forward stroke.

[0232] According to the mode III for carrying out the invention of the present invention, a method of forming a three-dimensional object having excellent surface characteristics and achieving high productivity can be provided.

(Three-dimensional object forming method, three-dimensional object forming apparatus, and program)

[0233] A three-dimensional object forming method according to an embodiment of the mode III for carrying out the invention of the present invention includes: a forward stroke layer forming step of discharging an object forming material at a forward stroke to form an object forming layer included in one layer; a return stroke layer forming step of discharging an object forming material at a return stroke to form an object forming layer included in the one layer; and a flattening step of causing a flattening member to touch the surface of the object forming layer formed at the return stroke, wherein the discharging position of the object forming material at the return stroke is adjacent to the discharge position of the object forming material at the forward stroke. The three-dimensional object forming method may further include steps as required.

[0234] The three-dimensional object forming apparatus according to an embodiment of the mode III for carrying out the invention of the present invention includes: a forward stroke layer forming unit for discharging an object forming material at a forward stroke to form an object forming layer included in one layer; a return stroke layer forming unit for discharging an object forming material at a return stroke to form an object forming layer included in the one layer; and a flattening member for causing a flattening member to touch a surface of the object forming layer formed at the return stroke, wherein, with respect to the one layer, the discharging position of the object forming material at the return stroke is adjacent to the discharge position of the object forming material at the forward stroke. The three-dimensional object forming

apparatus may further include units as required.

[0235] A program according to an embodiment of the mode III for carrying out the invention of the present invention performs a process of discharging an object forming material at a forward stroke to form an object forming layer included in one layer, discharging an object forming material at a return stroke to form an object forming layer included in the one layer, causing a flattening member to touch a surface of the object forming layer formed at the return stroke, and making the discharging position of the object forming material at the return stroke adjacent to the discharging position of the object forming material at the forward stroke with respect to the one layer.

[0236] The control unit used in the "three-dimensional object forming apparatus" of the embodiment of the present invention is equivalent to implementation of the "three-dimensional object forming method" of an embodiment of the present invention. Therefore, the details of the "a three-dimensional object forming method" of the embodiment of the present invention will be clarified through the description of the "a three-dimensional object forming apparatus" of the embodiment of the present invention. Because the "program" of the embodiment of the present invention is implemented as the "three-dimensional object forming apparatus" of the embodiment of the present invention by using a computer as a hardware resource, the details of the "program" of the embodiment of the present invention will also be clarified through the description of the "three-dimensional object forming apparatus" of the embodiment of the present invention.

[0237] Although the mode III for carrying out the invention of the present invention is described in detail below with reference to specific embodiments, it is merely an example for ease of understanding of the present invention, and is not intended to limit of the present invention. Accordingly, the contents described in such embodiments may be modified or improved in any manner without departing from the spirit of the invention, and the scope of the invention includes equivalents thereof.

<Three-dimensional object forming apparatus>

[0238] Fig. 31 depicts an outline of a three-dimensional object forming apparatus of an embodiment of the mode III for carrying out the invention of the present invention.

[0239] A forming stage 20214 moves in X and Y directions in Fig. 31 and object forming materials are discharged from heads while the forming stage 20214 is moving in an X direction (a main scanning direction). The forming stage 20214 moves in an Y direction (a sub-scanning direction) when a position where a droplet of an object forming material is discharged is changed. Such movement implies a shift in a relative position between the heads and the forming stage 20214, and thus, the manner in which the forming stage 20214 is fixed and the heads move is also applicable to the three-dimensional object forming apparatus of the embodiment of the present

invention. The heads are units that discharge object forming materials at forward strokes. As such object forming material discharging units, there is no particular limitation as long as the object forming materials can be discharged from the object forming material discharging units. Such object forming material discharging units can be appropriately selected depending on a particular purpose. For example, piezoelectric element (piezo element) heads, thermal expansion (thermal) heads, or the like can be used. Among these types, piezoelectric (piezo-element) heads are desirable.

[0240] The three-dimensional object forming apparatus 20210 uses head units having arrays of the heads to discharge a modelling material from a modelling material head unit 20211 and a supporting material from supporting material head units 20212 onto the forming stage 20214, performs a smoothing process by flattening rollers 20213, and forms layers of the modelling material on top of each other into a laminate while curing the layers by adjacent UV irradiators 20216.

[0241] Then, every time lamination is performed to a certain extent, for example every ten layers, smoothing (flattening) of the surface of the laminate by a smoothing unit is performed. When a roller-shaped smoothing (flattening) unit is used, the smoothing effect is more effective when the rollers are rotated in the direction reversed to the moving direction. It is also possible to cause the rollers to touch the surface of layers on a per layer basis.

[0242] In addition, the head units 20211 and 20212 are lifted while forming of layers on top of each other into a laminate according to the number of layers that have been formed on top of each other into a laminate in order to keep the gap from the head units 20211 and 20212 and the UV irradiators 20216 to the modelling layers 20217 and the supporting layers 20218 constant. Such a movement of the head units may also be a movement relative to the forming stage, and thus, the forming stage instead may be lowered while forming of layers on top of each other into a laminate.

[0243] The three-dimensional object forming apparatus 20210 may be supplemented with an ink recovery mechanism and/or a recycling mechanism. In addition, a blade for removing object forming materials adhered to nozzle surfaces and/or a detection mechanism for detecting non-discharging nozzles may be provided. Further, it is desirable to control the internal environmental temperature of the three-dimensional object forming apparatus 20210 during three-dimensional object forming operation.

[0244] Figs. 32 to 33 depict views of the three-dimensional object forming apparatus 20210 viewed from the front.

[0245] In Fig. 32, there is a purge area 20101 immediately below a head module (including the head units 20211 and 20212) in relation to the head module 1 and the forming stage 20214 in standby. The forming stage 20014 moves in the X directions sliding over a rail 20102. The purge area 20101 has a unit for collecting the object forming

materials purged from the head units 20211 and 20212 and the collected object forming materials are then collected in a waste liquid tank, not illustrated.

[0246] Fig. 33 depicts the relationships between the head module 1 and the forming stage 20014 at the start of object forming operation. The head module 20001 is lowered up to a position corresponding to the object forming start gap, and the forming stage 20014 moves to the right up to the object forming start position.

[0247] In Fig. 34, the head module 20001 is moved down to the purge area 20101 in relation between the head module 20001 and the forming stage 20014 when the object forming materials are purged in a maintenance sequence.

[0248] An embodiment of the mode III for carrying out the invention of the present invention includes a forward stroke layer forming step of discharging an object forming material at a forward stroke and forming an object forming layer; a return stroke forming layer forming step of discharging an object forming material at a return stroke and forming an object forming layer; and a flattening step of causing a flattening member to touch a surface of the object forming layer formed at the return stroke. According to the embodiment, the discharge position of the object forming material at the return stroke is adjacent to the discharge position of the object forming material at the forward stroke for one object forming layer. Therefore, a three-dimensional object having excellent surface property can be obtained and a high productivity can be achieved.

[0249] A specific method of making the discharge position of the object forming material at the return stroke adjacent to the discharge position of the object forming material at the return stroke for one object forming layer is, for example, a method of discharging the object forming material from a nozzle adjacent to a nozzle discharging the object forming material at the return stroke.

[0250] In one aspect of the mode III for carrying out the invention of the present invention, the object forming material is discharged at the return stroke such as to overlap at least partially with the object forming material discharged at the forward stroke.

[0251] In one aspect of the mode III for carrying out the invention of the present invention, the object forming material is discharged at the return stroke in such a manner that at least two sides of a layer obtained from the object forming material being discharged at the forward stroke come into contact with layers obtained from the object forming material being discharged at the return stroke.

[0252] In one aspect of the mode III for carrying out the invention of the present invention, an object forming layer is formed on a surface at a height in a Z direction, and the co-ordinates of the forward and return strokes are switched with respect to one layer at a different height in the Z direction. Because such a method eliminates the step (Y step) of the side parallel to the main scanning direction, the surface of the three-dimensional

object is improved.

[0253] A three-dimensional object forming method of an embodiment of the mode III for carrying out the invention of the present invention is depicted in Fig. 35, (A)-(G), and includes a forward stroke layer forming step and a return stroke layer forming step.

[0254] In a forward stroke layer forming process, when a high viscosity liquid-like object forming material is discharged from a discharging unit such as nozzles at a forward stroke (see Fig. 35, (A)), the discharged object forming material has a recess at the center due to surface tension and has rounded ends (see Fig. 35, (B)). Thereafter, the object forming material is cured by a curing unit such as a UV irradiator unit to form an object forming layer (see Fig. 35, (C)).

[0255] In a return stroke forming process, a liquid object forming material having a high viscosity is discharged from a discharging unit, such as nozzles, in a larger amount than the amount of the above-described case of the forward stroke, so as to overlap on the cured object forming layer of the forward stroke (see Fig. 35, (D) and (E)), and the flattening member is in contact with the surface of the discharged object forming material to flatten the object forming material of the return stroke (see Fig. 35, (F)). Thereafter, the object forming material is cured with a curing unit such as a UV irradiator to form an object forming layer (see Fig. 35, (G)).

[0256] In the three-dimensional object forming method of an embodiment of the present invention, at a step later than the step of Fig. 35, (E), extras of the object forming material are scraped off by causing a flattening member, such as a roller, to touch the surface of the object forming material before the object forming material cures, as depicted in Figs. 35, (F) and (G). As a result, the surface of the object forming material can be flattened (see Fig. 35, (F)) and the ends of the object forming material can be sharpened as depicted by "X" in Fig. 35, (F).

[0257] In addition, as depicted in Fig. 35, (G), after the surface of the object forming material is flattened, the object forming material is cured to form the object forming layer. Therefore, the three-dimensional object forming method according to the embodiment of the present invention is capable of forming a laminate structure without a recess at the center and having a flat surface, and, by repeating a lamination process into a laminate structure, a high-definition three-dimensional object having sharp ends and excellent flatness can be obtained.

[0258] In the embodiment of the mode III for carrying out the invention of the present invention, it is desirable that the total discharge amount of the object forming material at the return stroke be greater than the total discharge amount of the object forming material at the forward stroke.

<Object forming material>

[0259] There is no particular limitation as to the object forming material of the object

forming layer of the forward stroke, and a suitable choice can be made based on the performance required for forming the body of the three-dimensional object.

[0260] Examples of the object forming material include a modelling material and a supporting material.

[0261] The modelling material of an embodiment of the mode III for carrying out the invention of the present invention is not particularly limited as long as the material is a liquid that is cured by applying of energy, such as light or heat, and can be appropriately selected depending on the purpose, but desirably includes polymerizable monomers such as mono-functional monomers, poly-functional monomers, oligomers, and may optionally include other components. Desirably, the modelling material has a liquid property such as viscosity and surface tension such that the modelling material can be discharged by an object forming material discharging head used in an object forming material jetting printer.

-- Polymerizable monomers --

[0262] Examples of polymerizable monomers include, for example, monofunctional monomers, polyfunctional monomers, and the like. These types of monomers may be used alone, and also, two or more of these types of monomers may be combined and used.

-- Monofunctional monomers --

[0263] Examples of monofunctional monomers include, for example, acrylamide, N-substituted acrylamide derivatives, N,N-disubstituted acrylamide derivatives, N-substituted methacrylamide derivatives, N,N-disubstituted methacrylamide derivatives, acrylic acid, and the like. These types of monomers may be used alone or two or more of these types of monomers may be combined and used. Among these types of monomers, acrylamide, N,N-dimethylacrylamide, N-isopropylacrylamide, acryloylmorpholine, hydroxyethylacrylamide, and isoboryl (meth)acrylate are desirable.

[0264] As monofunctional monomers, organic polymers can be obtained by polymerization.

[0265] It is desirable that the content of monofunctional monomers be not less than 0.5 wt% and not more than 90 wt% of the total amount of the object forming material.

[0266] Examples of other monofunctional monomers include, but are not limited to and a suitable choice can be made depending on the purpose from among 2-ethylhexyl (meth)acrylate, 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, caprolactone-modified tetrahydrofurfuryl (meth)acrylate, 3-methoxybutyl (meth)acrylate, tetrahydrofurfuryl (meth)acrylate, lauryl (meth)acrylate, 2-phenoxyethyl (meth)acrylate, isodecyl (meth)acrylate, isooctyl (meth)acrylate, tridecyl (meth)acrylate, caprolactone (meth)acrylate, ethoxy nonylphenol (meth)acrylate, and the like.

-- Polyfunctional monomers --

[0267] Examples of polyfunctional monomers include, but are not limited to and a suitable choice can be made depending on the purpose from among bifunctional monomers, trifunctional monomers, and the like, which are not particularly limited and can be appropriately selected depending on the purpose. These types of monomers may be used alone, and also, some of these types of monomers may be combined and used.

[0268] Examples of bifunctional monomers include tripropylene glycol di (meth) acrylates, triethylene glycol di (meth) acrylates, tetraethylene glycol di (meth) acrylates, polypropylene glycol di (meth) acrylates, neopentyl glycol hydroxypipyrinate di (meth) acrylates, hydroxypyrinate neopentyl glycol esterdi (meth) acrylates, 1,3-butanediol di (meth) acrylates, 1,4-butanediol di (meth) acrylates, 1,6-hexanediol di (meth) acrylates, 1,9-nonandiol di (meth) acrylates, diethylene glycol di (meth) acrylates, neopentyl glycol di (meth) acrylates, tripropylene glycol di (meth) acrylates, caprolactone-modified hydroxypipyrinate neopentyl glycol esterdi (meth) acrylates, propoxy neopentyl glycol di (meth) acrylate, ethoxy-modified bisphenol A di (meth) acrylate, polyethylene glycol 200 di (meth) acrylate, polyethylene glycol 400 di (meth) acrylate, and the like. These types of monomers may be used alone, and some of these types of monomers may be combined and used.

[0269] Examples of tri or more functional monomers include trimethylol propanetri (meth)acrylate, pentaerythritol tri (meth)acrylate, dipentaerythritol hexa(meth)acrylate, triallyl isocyanurate, ε-caprolactone modified dipentaerythritol tri (meth)acrylate, ε-caprolactone modified dipentaerythritol tetra (meth) acrylate, meth) acrylate, ε-caprolactone modified dipentaerythritol penta (meth)acrylate, ε-caprolactone modified dipentaerythritol penta (meth)acrylate, ε-caprolactone modified dipentaerythritol hexa(meth)acrylate, tris (2-hydroxyethyl) isocyanurate tri(meth)acrylate, ethoxylated trimethylolpropanetri(meth)acrylate, propoxylated glyceryl tri(meth)acrylate, pentaerythritol tetra(meth)acrylate, ditrimethylol propanetetra(meth)acrylate, dipentaerythritol hydroxypenta(meth)acrylate, ethoxylated pentaerythritol tetra(meth)acrylate, penta(meth)acrylate ester, and the like. These types of monomers may be used alone, and some of these types of monomers may be combined and used.

-- Oligomers --

[0270] As oligomers, low polymers of the above-mentioned monomers or oligomers having reactive unsaturated binding groups at ends may be used alone, and also, two or more of these types of oligomers may be combined and used.

-- Other ingredients --

[0271] Examples of other ingredients include, but are not limited to and a suitable choice may be made depending on the purpose from among surfactants, polymerization inhibitors, polymerization initiators, colorants, viscosity modifiers, adherence providing agents, antioxidants, antiaging agents, cross-linking promoters, ultraviolet absorbers,

plasticizers, preservatives, dispersants, and the like.

-- Surfactant --

[0272] Surfactant may be, for example, surfactant having a molecular weight of 200 or more and 5,000 or less, specifically, a PEG nonionic surfactant (ethylene oxide of nonylphenol (hereinafter, referred to as "EO") 1-through-400-mol adduct, stearate 1-through-40-mol adduct, etc.), a polyhydric alcoholic nonionic surfactant (sorbitan palmitate monoester, sorbitan stearate monoester, triester of sorbitan stearate, etc.), a fluorine-containing surfactant (perfluoroalkyl EO 1-through-50-mol adduct, perfluoroalkyl carboxylate salt, perfluoroalkyl betaine, etc.), a modified silicone oil (polyether modified silicone oil, (meth)acrylate modified silicone oil, etc.), or the like. These types of surfactant may be used alone, and also, two or more of these types of surfactant may be combined and used.

[0273] It is desirable that the content of the surfactant be 3 wt% or less with respect to the total amount of the object forming material, and it is more desirable that the content be 0.1 wt% or more and 5 wt% or less from the viewpoint of the inclusion effect and the physical properties of the photo-setting material.

-- Polymerization inhibitor --

[0274] Examples of the polymerization inhibitor include a phenolic compound (hydroquinone, hydroquinone monomethyl ether, 2,6-di-t-butyl-p-cresol, 2,2-methylene-bis-(4-methyl-6-t-butylphenol), 1,1,3-tris-(2-methyl-4-hydroxy-5-t-butylphenyl)butane), a sulfur compound (dilauryl thiodipropionate, etc.), a phosphorus compound (triphenylphosphite, etc.), an amine compound (phenothiazine, etc.), and the like. These inhibitors may be used alone, and also, two or more of these inhibitors may be combined and used.

[0275] It is desirable that the content of the polymerization inhibitor be not more than 5 wt% of the total amount of the object forming material, and it is more desirable that the content of the polymerization inhibitor be not less than 0.1 wt% and not more than 5 wt% of the total amount of the object forming material from the viewpoint of the stability of the monomers and the polymerization speed.

-- Polymerization initiators --

[0276] Examples of polymerization initiators include, for example, thermal polymerization initiators, photopolymerization initiators, and the like. Among these materials, a photopolymerization initiator is desirable from the viewpoint of storage stability.

[0277] As the photopolymerization initiator, any material that produces radicals by irradiation with light (particularly ultraviolet light of wavelengths from 220 nm to 400 nm) can be used.

[0278] Examples of photopolymerization initiators include, for example, acetophenone, 2,2-diethoxyacetophenone, p-dimethylaminoacetophenone, benzophenone,

2-chlorobenzophenone, p,p'-dichlorobenzophenone, p,p-bis-diethylaminobenzophenone, mihiraketone, benzyl, benzoin, benzoin methyl ether, benzoin ethyl ether, benzoin isopropyl ether, benzoin-n-propyl ether, benzoin isobutyl ether, benzoin-n-butyl ether, benzyl methyl ether, benzyl methyl ketal, thioxanthone, 2-chlorothioxanthone, 2-hydroxy-2-methyl-1-phenyl-1-one.1-(4-Isopropylphenyl)2-methylpropane-1-one, methylbenzoylformate, 1-hydroxycyclohexylphenyl ketone, azobityronitrile, benzoylperoxide, di-tert-butyl peroxide, and the like. These initiators may be used alone, and also, two or more of these initiators may be combined and used.

[0279] As a thermal polymerization initiator, there is no particularly limitation, and any thermal polymerization initiator may be appropriately selected depending on the purpose, for example, an azo-based initiator, a peroxide initiator, a persulfate initiator, a redox initiator, or the like may be selected.

[0280] Examples of azo-based initiators include VA-044, VA-46B, V-50, VA-057, VA-061, VA-067, VA-086, 2,2'-azobis (4-methoxy-2,4-dimethylvaleronitrile) (VAZO 33), 2,2'-azobis (2-amidinopropane) dihydrochloride (VAZO 50), 2,2'-azobis (2,4-dimethylvaleronitrile) (VAZO 52), 2,2'-azobis (isobutyronitrile) (VAZO 64), 2,2'-azobis-2-methylbutyronitrile (VAZO 67), 1,1-azobis (1-cyclohexanecarbonitrile) (VAZO 88) (all being made by DuPont Chemical Company), 2,2'-azobis (2-cyclopropylpropionitrile), and 2,2'-azobis (V-601) (the last two materials being made by Wako Pure Chemical Industries).

[0281] Examples of the peroxide initiators include benzoyl peroxide, acetyl peroxide, lauroyl peroxide, decanoyl peroxide, dicetyl peroxydicarbonate, di(4-t-butylcyclohexyl), peroxydicarbonate (trade name: Perkadox 16S, made by Akzo Nobel N.V.), di(2-ethylhexyl) peroxydicarbonate, t-butylperoxy-2-ethylhexanoate (trade name: Lupersol 11, Elf Atochem), t-butylperoxy-2-ethylhexanoate (trade name: Trigonox 21-C50, made by Akzo Nobel N.V.), dicumyl peroxide, and the like.

[0282] Examples of persulfate initiators include potassium persulfate, sodium persulfate, ammonium persulfate, and the like.

[0283] Examples of redox (oxidation-reduction) initiators include persulfate initiators in combination with reducing agents such as sodium bisulfite and sodium bisulfite, systems based on an organic peroxide and tertiary amine (e.g., systems based on benzoyl peroxide and dimethyl aniline), and systems based on organohydroperoxides and transition metals (e.g., systems based on cumene hydroperoxide and cobalt naphtate).

[0284] It is desirable that the content of the polymerization initiator be 10 wt% or less and, more desirably, 5 wt% or less for the total amount of the object forming material.

-- Colorant --

[0285] As a colorant, a dye or pigment that dissolves or stably disperses in the object forming material and has excellent thermal stability is suitable. Among these materials, a solvent dye is desirable. In addition, it is possible to mix two or more types of coloring agents for the purpose of color adjustment, for example.

[0286] The supporting material of an embodiment of the present invention includes monomers (A) having hydrogen bonding capacity, a solvent (B) having hydrogen bonding capacity, and a polymerization initiator (C), wherein the solvent (B) having hydrogen bonding capacity is at least one selected from diols having 3 through 6 carbons, carboxylic acid compounds, amine compounds, ester compounds, ketone compounds, and urea compounds, and further optionally includes other components.

[0287] The above-described supporting material is based on the knowledge that in the related art, when the solubility of the supporting material is increased, it is easier to remove the supporting material, but the support performance may be insufficient; and, when a three-dimensional object forming apparatus is increased in size and the three-dimensional object forming volume capability is increased, there may be a problem that the shape supporting capacity may be insufficient. Desirably, the supporting material has water disintegration property. The water disintegration property means that when a cured object is immersed in water, the cured object is finely broken, and the original shape and properties of the cured object cannot be maintained. It is desirable that the supporting material satisfies the following requirements.

<Requirements>

[0288] A cured object 20 mm long by 20 mm wide by 5 mm high irradiated with 500 mJ/cm ^{2} of ultraviolet radiation by an ultraviolet irradiator, placed in 20 mL of water, and allowed to stand at 25°C for 1 hour, then comes to be broken into solid objects each having a dimension of 1 mm or less in at least one direction or completely dissolved.

[0289] The cured object 20 mm long by 20 mm wide by 5 mm high may be obtained as follows:

[0290] The supporting material is poured into a silicone rubber mold 20 mm long by 20 mm wide by 5 mm high, is then irradiated with UV light at an irradiation dose of 500 mJ/cm^2 (illumination intensity: 100 mW/cm^2, irradiation time: 5 seconds) by the ultraviolet irradiator (device name: SubZero-LED, manufactured by Integration Technology Co., Ltd.) to obtain the cured object of the supporting material (2 g) 20 mm long by 20 mm wide by 5 mm high. It is desirable that the above-mentioned supporting material satisfy the following requirements.

<Requirements>

[0291] A cured object irradiated with 500 mJ/cm^2 of ultraviolet light by the ultraviolet irradiator is a solid with a compressive stress of 2.0 kPa or more at a time of compression of 1% at 25°C. When the solid is placed in 20 mL of water and allowed to

stand for 1 hour at 25°C, the volume of the remaining solid is not more than 50% by volume. The volume of the remaining solid can be determined by the Archimedes method.

[0292] The function of the supporting material can be improved when the cured object obtained by being irradiated with 500 mJ/cm^2 of ultraviolet light by the ultraviolet irradiator satisfies each of the above requirements.

[0293] In addition, it is desirable that the compressive stress at a time of 1% compression of the cured object obtained by being irradiated with 500 mJ/cm^2 of ultraviolet light by the ultraviolet irradiator at 25°C is 5 kPa or more. If the compression stress at a time of 1% compression is 0.5 kPa or more, the functionality of the supporting material can be improved. The compressive stress at a time of 1% compression is influenced by the size of a three-dimensional object of the modelling material for which the shape is supported by the supporting material, and, when the size of a three-dimensional object of the modelling material is large, 2.0 kPa or more is desirable from the viewpoint of supporting the shape. The compression stress at a time of 1% compression can be measured using a universal testing machine (device name: AG-I, Shimadzu Corporation, using a load cell 1 kN and a compression jig for 1 kN).

[0294] As the ultraviolet irradiator, there is no particular limit, and the device can be appropriately selected depending on the purpose. For example, the device name: AG-I (Shimadzu Corporation) can be used for the measurement. At the above-described dose of 500 mJ/cm^2, it is desirable that the illumination intensity be 100 mW/cm^2 and the irradiation time be 5 seconds.

<Monomers (A) having hydrogen bonding capability>

[0295] The above-mentioned monomers (A) having hydrogen bonding capability are not particularly limited as long as the monomers have hydrogen bonding capability, and can be appropriately selected depending on the purpose, for example, mono-functional monomers, polyfunctional monomers, or the like. These types of monomers may be used alone, and also, two or more of these types of monomers may be combined and used. Among these types of monomers, monofunctional monomers are desirable in order to improve the water degradability of the cured object. Examples of the monomers (A) having hydrogen bonding capacity include monomers include monomers having an amide group, amino group, hydroxyl group, tetramethylammonium group, silanol group, epoxy group, sulfo group, and the like.

[0296] Examples of polymerization reaction of the monomers (A) having hydrogen bonding capacity include radical polymerization, ionic polymerization, coordinating polymerization, ring-opening polymerization, and the like. Among these types of polymerization, radical polymerization is desirable from the viewpoint of controlling the polymerization reaction. Therefore, ethylenically unsaturated monomers are desirable

as the monomers (A) having the hydrogen bonding capacity, water-soluble mono-functional ethylenically unsaturated monomers, water-soluble poly-functional ethylenically unsaturated monomers are more desirable, and water-soluble mono-functional ethylenically unsaturated monomers are particularly desirable from the viewpoint of improving the water degradability of the cured object.

<Water-soluble monofunctional ethylenically unsaturated monomers with hydrogen bonding capacity>

[0297] Examples of water-soluble monofunctional ethylenically unsaturated monomers with hydrogen bonding capacity include monofunctional vinylamido group-containing monomers (N-vinyl-ε-caprolactam, N-vinylformamide, N-vinylpyrrolidone, etc.); monofunctional hydroxy group-containing (meth)acrylates (hydroxyethyl (meth)acrylates, hydroxypropyl (meth)acrylates, 4-hydroxybutyl (meth)acrylates, etc.); hydroxyl group-containing (meth)acrylates (polyethylene glycol mono (meth)acrylates, monoalkoxy (C1 through 4)polyethylene glycol mono (meth)acrylates, polypropylene glycol mono (meth)acrylates, monoalkoxy (C1 through 4) polypropylene glycol mono (meth) acrylates, mono (meth) acrylates of PEG-PPG block polymers, etc.); (meth)acrylamide derivatives include (meth)acrylamide, (meth)acrylamide, N-methyl(meth)acrylamide, N-ethyl(meth)acrylamide, N-propyl(meth)acrylamide, N-butyl(meth)acrylamide, N,N'-dimethyl(meth)acrylamide, N-hydroxyethyl(meth)acrylamide, N-hydroxypropyl(meth)acrylamide, N-hydroxybutyl(meth)acrylamide, and the like), (meth)acryloylmorpholine, and the like. These types of monomers may be used alone, and also, two or more these types of monomers may be combined and used. Among these types of monomers, hydroxyethyl acrylates, hydroxypropyl acrylates, 4-hydroxybutyl acrylates, acrylamide, acryloyl morpholine, N-methyl acrylamide, N-ethyl acrylamide, N-propyl acrylamide, N-butyl acrylamide, N,N'-dimethyl acrylamide, N-hydroxyethyl acrylamide, N-hydroxypropyl acrylamide, N-hydroxypropyl acrylamide, N-hydroxybutyl acrylamide, and diethyl acrylamide are more desirable from the viewpoint of photoreactivity, and acryloyl morpholine (molecular weight: 141.17) and N-hydroxyethyl acrylamide (molecular weight: 115.15) are particularly desirable from the viewpoint of skin irritation to the human body.

<Water-soluble polyfunctional ethylenically unsaturated monomers having hydrogen bonding capacity>

[0298] As water-soluble polyfunctional ethylenically unsaturated monomers having hydrogen bonding capacity, for example, as monomers of bifunctional groups, tripropylene glycol di (meth) acrylate, triethylene glycol di (meth) acrylate, tetraethylene glycol di (meth) acrylate, polypropylene glycol di (meth) acrylate, neopentyl glycol hydroxypivalate di (meth) acrylate (MANDA), hydroxy pivalate

neopentyl glycol esterdi (meth) acrylate (HPNDA), 1,3-butanediol di (meth) acrylate (BGDA), 1,6-hexanediol di (meth) acrylate (HDDA), 1,9-nonanediol di (meth) acrylate, diethylene glycol di (meth) acrylate (DEGDA), neopentyl glycol di (meth) acrylate (NPGDA), tripropylene glycol di (meth) acrylate (TPGDA), caprolactone modified hydroxypipyrinate neopentyl glycol ester di (meth) acrylate, propoxylated pentyl glycol di (meth) acrylate, polyethylene glycol 200 di (meth) acrylate, polyethylene glycol 400 di (meth) acrylate, triallyl isocyanate, tris(2-hydroxyethyl) isocyanurate tri (meth) acrylate, and the like. These types of monomers may be used alone, and also, two or more of these types of monomers may be combined and used.

[0299] The molecular weight of the monomers (A) having hydrogen bonding capacity is desirably 70 or more and 2,000 or less, and more desirably, 100 or more and 500 or less. When the molecular weight is 70 or more and 2,000 or less, it is possible to adjust the viscosity optimum for an ink jet system.

[0300] It is desirable that the content of the monomers (A) having hydrogen bonding capability be not less than 30 wt% and not more than 60 wt% of the total amount of the supporting material. When the content is 30 wt% or more and 60 wt% or less, sufficient compressive stress as the supporting material and water disintegration can be achieved.

<Solvent (B) having hydrogen bonding capacity>

[0301] The above-mentioned solvent (B) having hydrogen bonding capability has hydrogen bonding capability with respect to the monomers (A) having hydrogen bonding capability and can perform the function of the supporting material by having hydrogen bonding with the monomers (A) having hydrogen bonding capability. The solvent (B) having hydrogen bonding capacity is at least one selected from diols having 3 through 6 carbons, carboxylic acid compounds, amine compounds, ester compounds, ketone compounds, and urea compounds. Among these materials, a diol having 3 through 6 carbons are desirable.

<Diol having 3 through 6 carbons>

[0302] As the diol having 3 through 6 carbons, it is desirable that the diol is not reactive with water-soluble acrylic monomers, the diol does inhibit radical polymerization reaction during photo-setting, and the diol is flowable and water-soluble at ordinary temperatures. Further, both of a monofunctional diol and a polyfunctional diol can be used as the diol having 3 through 6 carbons. Examples of the diol having 3 to 6 carbons include propanediol, butanediol, pentanediol, hexanediol, and the like. These diols may be used alone, and also, two or more of these diols may be combined and used. Among these materials, 1,3-propanediol, 1,4-butanediol, 1,5-pentanediol, and 1,6-hexanediol are desirable. Desirably, the number of carbons is 3 or more and 6 or less, and, more desirably, 3 or more and 5 or less. When the number of carbon atoms is

3 or more, the compressive stress at a time of 1% compression can be improved, and when the number of carbon atoms is 6 or less, the supporting material viscosity can be reduced. The carbon chain of the diol having the above number of carbons 3 or more and not more than 6 may be a straight chain or may be branched.

<Carboxylic acid compound>

[0303] Examples of the above-mentioned carboxylic acid compound include linear aliphatic acids such as a formic acid, an acetic acid, a propionic acid, a butanoic acid, a pentanoic acid, and a hexyl acid; various branched-chain aliphatic carboxylic acids such as an isobutyl acid, a tert-butyl acid, an isopentylic acid, an isooctylic acid, and a 2-ethylhexyl acid; aromatic carboxylic acids such as a benzoic acid and a benzene-sulfonic acid; hydroxy carboxylic acids such as a glycolic acid, and a lactic acid, and the like. These acids may be used alone, and also, two or more these acids may be combined and used. Among these acids, an acetic acid, a propionic acid, a butanoic acid, and a lactic acid are desirable from the viewpoint of solubility in water, and a butanoic acid and a lactic acid are more desirable.

<Amine compound>

[0304] Examples of the above-mentioned amine compounds include primary to tertiary amines such as a monoalkylamine, a dialkylamine, and a trialkylamine; divalent amines such as an ethylenediamine; trivalent amines such as a triethylenediamine; and aliphatic amines such as a pyridine and aniline. These amines may be used alone, and also, two or more of these amines may be combined and used. Among these amines, a divalent or trivalent primary amine is desirable and an ethylenediamine is more desirable from the viewpoint of the strength of the crosslinking by hydrogen bonding and the solubility in water.

<Ester compound>

[0305] Examples of the above-mentioned ester compound include monofunctional esters such as an ethyl acetate, a butyl acetate, an ethyl propionate, etc.; polyfunctional aliphatic esters such as a dimethyl succinate, a dimethyl adipate, etc.; polyfunctional aromatic esters such as a dimethyl terephthalate, etc. These esters may be used alone, and also, two or more of these esters may be combined and used. Among these esters, a dimethyl adipate is desirable from the viewpoint of water solubility, evaporation and odor during three-dimensional object forming process, and safety.

<Ketone compound>

[0306] Examples of the above-mentioned ketone compound include monofunctional ketones such as an acetone and a methyl ethyl ketone, polyfunctional ketones such as an acetyl acetone, and a 2,4,6-heptatrion, and the like. These ketones may be used alone, and also, two or more of these ketones may be combined and used. Among these ketons, an acetylacetone is desirable from the viewpoint of volatility and water solubility.

[0307] It is desirable that the content of the solvent (B) having hydrogen-bonding capacity be 10 wt% or more and 50 wt% or less with respect to the total amount of the supporting material. When the content is 10 wt% through 50 wt%, it is possible to achieve sufficient compressive stress and water disintegration as the supporting material.

<Mass ratio (A/B)>

[0308] The mass ratio (A/B) between the content (wt%) of the monomers (A) and the content (wt%) of the solvent (B) is desirably 0.3 through 2.5, and more desirably 0.5 through 2.5 or less. When the mass ratio (A/B) is 0.3 or more and 2.5 or less, the compressive stress at the time of 1% compression can be improved.

<Polymerization initiator (C)>

[0309] As the above-mentioned polymerization initiator (C), any material that produces radicals by irradiation with light (in particular, ultraviolet rays having a wavelength of 220 nm through 400 nm) can be used. The polymerization initiator (C) is, for example, acetophenone, 2,2-diethoxyacetophenone, p-dimethylaminoacetophenone, benzophenone, 2-chlorobenzophenone, p,p'-dichlorobenzophenone, p,p-bis-diethylaminobenzophenone, mihiraketone, benzyl, benzoin, benzoin methyl ether, benzoin ethyl ether, benzoin isopropyl ether, benzoin-n-propyl ether, benzoin isobutyl ether, benzoin-n-butyl ether, benzyl methyl ketal, thioxanthone, 2-chlorothioxantone, 2-hydroxy-2-methyl-1-phenyl-1-one, 1-(4-Isopropylphenyl)-2-methylpropane-1-one, methylbenzoylformate, 1-hydroxycyclohexylphenyl ketone, azobityronitrile, benzoylperoxide, di-tert-butyl peroxide, and the like. These initiators may be used alone, and also, two or more of these initiators may be combined and used. In addition, it is desirable to select a polymerization initiator corresponding to the ultraviolet wavelength of the ultraviolet irradiator. It is desirable that the content of the polymerization initiator (C) be not less than 0.5 wt% and not more than 10 wt% of the total amount of the supporting material.

- Viscosity -

[0310] The viscosity of the supporting material is desirably 100 mPa?s or less at 25°C, desirably 3 mPa?s or more and 70 mPa?s or less at 25°C, and more desirably 6 mPa?s or more and 50 mPa?s or less. The discharge stability can be improved when the viscosity is 100 mPa?s or less. The viscosity can be measured under an environment of 25°C using, for example, a rotating viscometer (VISCOMATE VM-150III, manufactured by TOKI SANGYO Co., Ltd.).

- Viscosity change rate -

[0311] As the supporting material, it is desirable that the viscosity change rate before and after leaving at 50°C for 2 weeks be ±20% or less, and it is more desirable that the viscosity change rate be ±10% or less. When the viscosity change rate is ±20% or less,

storage stability and discharge stability are satisfactory. The viscosity change rate before and after leaving at 50°C for 2 weeks can be measured as follows. The supporting material is placed in a polypropylene wide-mouth bottle (50 mL) and left in a constant-temperature bath at 50°C for 2 weeks. Then, the supporting material is removed from the bath and left at room temperature (25°C) to measure the viscosity. The viscosity of the supporting material before the supporting material is placed in the bath is determined as the viscosity before storage, and the viscosity of the supporting material after the supporting material is removed from the bath is determined as the viscosity after storage, and the viscosity change rate can be calculated by the following equation. The viscosity before storage and the viscosity after storage can be measured at 25°C using, for example, an R-type viscometer (manufactured by TOKI SANGYO Co., Ltd.).

[0312] viscosity change rate (%) = {(viscosity after storage)-(viscosity before storage)}/(viscosity before storage) × 100

<Other ingredients>

[0313] Examples of the above-mentioned other ingredients include, without limitation, and a suitable choice can be made depending on the purpose from among, solvents, polymerization inhibitors, minerals that can be dispersed in the supporting material, polymerizable monomers in addition to the above-mentioned element (A), thermal polymerization initiators, colorants, antioxidants, chain transfer agents, antiaging agents, cross-linking agents, ultraviolet absorbers, plasticizers, preservatives, dispersants, and the like.

-- Solvents --

[0314] Examples of the above-mentioned solvents include, for example, alcohols, ether compounds, triols, triethylene glycols, polypropylene glycols, and the like. These solvents may be used alone, and also, two or more of these solvents may be combined and used. The SP value of the solvent is desirably 18 $MPa^{1/2}$ or more and, more desirably, 23 $MPa^{1/2}$ or more from the viewpoint of water degradability. The content of the solvent is desirably 50 wt% or less, and more desirably 30 wt% or less.

-- Polymerization inhibitor --

[0315] Example of the above-mentioned polymerization inhibitor includes, for example, phenolic compounds (hydroquinone, hydroquinone monomethyl ether, 2,6-di-t-butyl-p-cresol, 2,2-methylene-bis-(4-methyl-6-t-butylphenol), 1,1,3-tris-(2-methyl-4-hydroxy-5-t-butylphenyl)butane, and the like), a sulfur compound (dilauryl thiodipropionate and the like), phosphorus compounds (triphenyl phosphite and the like), amine compounds (phenothiazine and the like), and the like. These initiators may be used alone, and also, two or more of these initiators. It is desirable that the content of the polymerization inhibitor be 30 wt% or less, and, more

desirably, 20 wt% or less with respect to the entire amount of the supporting material, from the viewpoint of compressive stress.

-- Minerals that can be dispersed in supporting material --

[0316] The above-mentioned minerals that can be dispersed in the supporting material are not particularly limited and can be selected as appropriate depending on the purpose, such as layered clay minerals. Examples of the layered clay minerals include smectites such as montmorillonite, beidellite, hectorite, saponite, nontronite, and stevensite; vermiculite; bentonite; layered sodium silicate such as kanemite, kenyanite, macanite, or the like, and so forth. These minerals may be used alone, and also, two or more of these minerals may be combined and used. The layered clay mineral may be obtained as a natural mineral or may be produced by a chemical synthesis method.

[0317] As the layered clay mineral, the surface may be organically treated. A layered mineral, such as the above-mentioned layered clay mineral, can be treated with an organic cationic compound to allow cations between layers to be ionically exchanged with cationic groups, such as a quaternary salt. Examples of the above-mentioned cations of the layered clay mineral are metal cations such as sodium ions, calcium ions, and the like. The layered clay minerals treated with an organic cationic compound swell and disperse easily into polymers or polymerizable monomers. The layered clay mineral treated with an organic cationic compound may be, for example, a Lucentite series (manufactured by Co-op Chemical Co.,), or the like. Examples of the above-mentioned Lucentite series (manufactured by Co-op Chemical Co.,) include Lucentite SPN, Lucentite SAN, Lucentite SEN, Lucentite STN, and the like. These types of cations may be used alone, and also two or more of these types of cations may be combined and used.

-- Polymerizable monomers --

[0318] The polymerizable monomers are not particularly limited and may be selected according to the purpose, such as (meth)acrylates. Examples of the (meth) acrylates include, for example, 2-ethylhexyl (meth)acrylate (EHA), isoboryl (meth)acrylate, 3-methoxybutyl (meth)acrylate, lauryl (meth)acrylate, 2-phenoxyethyl (meth)acrylate, isodecyl (meth)acrylate, isooctyl (meth)acrylate, tridecyl (meth)acrylate, caprolactone (meth)acrylate, ethoxy nonylphenol (meth)acrylate, and the like. These types of (meth)acrylates may be used alone, and also, two or more types of (meth)acrylates may be combined and used.

-- Thermal Polymerization Initiator --

[0319] The thermal polymerization initiator is not particularly limited and may be selected according to the purpose. Examples of the thermal polymerization initiator includes, for example, azo-based initiators, peroxide initiators, persulfate initiators, redox initiators and the like. However, from the viewpoint of storage stability, a pho-

toinitiator is desirable in comparison to a thermal polymerization initiator. As the azo-based initiator, for example, VA-044, VA-46B, V-50, VA-057, VA-061, VA-067, VA-086, 2,2'-Azobis (4-methoxy-2,4-dimethylvaleronitrile) (VAZO 33), 2,2'-azobis (2-amidinopropane) dihydrochloride (VAZO 50), 2,2'-azobis (2,4-dimethylvaleronitrile) (VAZO 52), 2,2'-azobis (isobutyronitrile) (VAZO 64), 2,2'-azobis-2-methylbutyronitrile (VAZO 67), 1,1-azobis (1-cyclohexanecarbonitrile) (VAZO 88) (all being made by DuPont Chemical Company), 2,2'-azobis (2-cyclopropylpropionitrile), 2,2'-azobis (methylisobutyle), V-601 (the last two materials being made by Wako Pure Chemical Industries).

[0320] Examples of the peroxide initiators include, for example, benzoyl peroxide, acetyl peroxide, lauroyl peroxide, decanoyl peroxide, dicetyl peroxydicarbonate, di(4-t-butylcyclohexyl) peroxydicarbonate (Perkadox 16S) (available from Akzo Nobel), di(2-ethylhexyl) peroxydicarbonate, t-butyl peroxy-2-ethylhexanoate (available from Elf Atochem, Inc.), t-butylperoxy-2-ethylhexanoate (Trigonox 21-C50) (available from Akzo Nobel), dicumyl peroxide, and the like.

[0321] Examples of the persulfate initiator include potassium persulfate, sodium persulfate, ammonium persulfate, and the like. Examples of the redox initiator include persulfate initiators in combination with reducing agents such as sodium bisulfite and sodium bisulfite, systems based on the organic peroxide and tertiary amine (e.g., systems based on benzoyl peroxide and dimethyl aniline), and systems based on organohydroperoxides and transition metals (e.g., systems based on cumene hydroperoxide and cobaltonaftate).

-- Colorants --

[0322] Examples of the colorants include, for example, pigments, dyes, etc. Examples of the pigments include, for example, organic pigments, inorganic pigments, etc. Examines of the organic pigments include, for example, azo pigments, polycyclic pigments, adine pigments, daylight fluorescent pigments, nitroso pigments, nitro pigments, natural pigments, and the like. Examples of the inorganic pigments include metal oxides (iron oxide, chromium oxide, titanium oxide, etc.), carbon black, and the like.

-- Antioxidant --

[0323] Examples of the above-mentioned antioxidant include, for example, phenolic compounds (monocyclic phenol (2,6-di-t-butyl-p-cresol, etc.), bisphenol (2,2'-methylenebis(4-methyl-6-t-butylphenol), etc.), polycyclic phenol (1,3,5-trimethyl-2,4,6-tris(3,5-di-t-t-butyl-4-hydroxybenzyl)benzene, etc.), sulfur compounds (dilauryl 3,3'-thiodipropionate, etc.), phosphorus compounds (triphenylphosphite, etc.), amine compounds (octylated diphenylamine, etc.), and the like.

-- Chain Transfer Agent --

[0324] Examples of the above-mentioned chain transfer agent include, for example, hydrocarbons (compounds having 6 through 24 carbon atoms, e.g., aromatic hydrocarbons (toluene, xylene, etc.), unsaturated aliphatic hydrocarbons (1-butene, 1-nonene, etc.); halogenated hydrocarbons (compounds having 1 through 24 carbon atoms, e.g., dichloromethane, carbon tetrachloride, etc.); alcohols (compounds having 1 through 24 carbon atoms, e.g., methanol, 1-butanol, etc.); thiols (compounds having 1 through 24 carbon atoms, e.g., ethylthiol, 1-octylthiol, etc.); ketones (compounds having 3 through 24 carbon atoms, e.g., acetone, methyl ethyl ketone, etc.); aldehydes (compounds having 2 through 18 carbon atoms, e.g., 2-methyl-2-propylaldehyde, 1-pentyl aldehyde); phenols (compounds having 6 through 36 carbon atoms, e.g., compounds having 6 through 36 carbon atoms, e.g., phenol, m-cresol, p-cresol, o-cresol, etc.); quinone (compounds having 6 through 24 carbons, e.g., hydroquinone); amines (compounds having 3 through 24 carbons, e.g., diethylmethylamine and diphenylamine); disulfides (compounds having 2 through 24 carbons, e.g., diethyldisulfide, di-1-octyldisulfide, etc.); and the like.

<Supporting Force of Supporting Material>

[0325] The supporting force of the supporting material is the ability of the supporting material to support the modelling material and can be expressed in terms of compressive stress at 1% compression. The supporting force of the above-mentioned supporting material is desirably 0.5 kPa or more and, more desirably, 2 kPa or more at a time of 1% compression under a 25°C environment, in view of the accuracy of forming a three-dimensional object and the solubility of the supporting material. The supporting force of the supporting material can be adjusted to the above range by selecting the types and contents of the elements (A) and (B) included in the supporting material. The compression stress at 1% compression can be measured using a universal testing machine (AG-I, Shimadzu Corporation). As the supporting force of the supporting material according to an embodiment of the present invention, it is considered that the high supporting force is guaranteed by hydrogen bonding of the (B) element to polymers obtained from polymerization of the element (A).

<Removability of Supporting Material>

[0326] As noted above, the supporting force of the supporting materials in an embodiment of the present invention is provide by hydrogen bonding. The supporting force of the supporting material is weakened by immersion in water and can be collapsed and removed. In addition, when the above-described element (B) has a low molecular weight, the diffusion can be fast and can be removed in a short time.

-- Solvent --

[0327] Examples of the above-mentioned solvent include, for example, a solvent having hydrogen bonding capacity. Examples of the solvent include water, butanol or hexanol

as an alcohol, hexylamine or pentylamine as an amine, and benzene or toluene as an aromatic compound. These materials may be used alone, and also, two or more materials may be combined and used. Among these materials, water and alcohol are desirable from the viewpoint of safety. Additives may also be added to the solvent. Examples of the additives include surfactants and the like. The affinity for a linear alkyl chain can be increased by adjusting the type and amount of the surfactant. The solvent desirably has a temperature of 40°C or higher in order to soften the supporting material and facilitate penetration into an inner section, but a temperature below 40°C can be selected to prevent warping of a three-dimensional object.

<Object forming material curing unit>

[0328] An object forming material curing unit is a unit that cures the object forming material discharged at a forward stroke to form an object forming layer.

[0329] As long as it is possible to cure the object forming material discharged at a forward stroke to form an object forming layer, there is no particular restriction, and the object forming layer can be appropriately selected according to the purpose. For example, an ultraviolet irradiator is included.

-- Ultraviolet (UV) irradiator --

[0330] Examples of the ultraviolet irradiator include, for example, a high-pressure mercury lamp, a ultra-pressure mercury lamp, a metal halide lamp, and the like.

[0331] The high-pressure mercury lamp is a light source, but a DeepUV type, which has improved light utilization efficiency in combination with an optical system, is capable of short-wavelength irradiation.

[0332] The metal halide lamp is effective in coloring a material because of its wide wavelength range, a metal halide of a metal such as Pb, Sn, or Fe is used, and the metal halide lamp can be selected according to the absorption spectrum of the polymerization initiator. The lamp used for curing is not particularly limited and may be selected according to the purpose, and a commercially available lamp such as a H lamp, a D lamp, or a V lamp provided by the Fusion System company may be used.

[0333] Desirably, the three-dimensional object forming apparatus is of heater-less, and can form a three-dimensional object at room temperature.

<Return stroke layer forming unit and a return stroke layer forming step>

[0334] The return stroke layer forming unit is a unit for discharging the object forming material and forming an object forming layer. The return stroke layer forming unit may cause the flattening member to touch the surface of a layer of the object forming material discharged at a return stroke to flatten the surface of the layer of the object forming material, and then cure the layer of the object forming material to form an object forming layer.

[0335] The return stroke layer forming step is a step of discharging the object forming

material and forming an object forming layer. The return stroke layer forming step may be implemented by causing the flattening member to touch the surface of a layer of the discharged object forming material and flattening the layer of the object forming material, and then curing the layer of the object forming material to form an object forming layer.

[0336] Discharging of the object forming material is desirably implemented with the use of an object forming material discharging unit.

[0337] Desirably, the object forming material is cured with the use of an object forming material curing unit.

<Object forming material discharging unit>

[0338] The object forming material discharging unit is a unit that discharges the object forming material at a return stroke.

[0339] As for the object forming material discharging unit for a return stroke, there is no particular restriction, and the object forming material discharging unit can be appropriately selected according to the purpose.

[0340] The object forming material discharging unit for a return stroke may be the same as or different from the object forming material discharging unit for a forward stroke.

[0341] The object forming material discharging unit for a forward stroke may be used also as the object forming material discharging unit for a return stroke, for example, by making the object forming material discharging unit for a forward stroke movable in both directions. Further, for example, by making the forming stage on which a three-dimensional object is formed movable in both directions while the position of the object forming material discharging unit is fixed, the object forming material discharging unit for a forward stroke may be used also as the object forming material discharging unit for a return stroke.

[0342] It is desirable that the object forming material be discharged at a return stroke precisely over the object forming layer formed at a forward stroke that has been already cured. However, the layer of the object forming material formed at the return stroke may include an area where the layer formed at the forward stroke does not overlap, and the layer of the object forming material of the return stroke and the layer of the object forming material of the forward stroke may be somewhat different in the formed positions.

[0343] For example, after the layer is formed at the forward stroke and cured as depicted in Fig. 35,(C), the layer of the object forming material is formed at the return stroke at the position different approximately 80 μm in the Y direction (sub-scanning direction) from the position of the layer of the object forming material of the forward stroke in Fig. 35, (D).

[0344] The total discharge amount of the object forming material at the return stroke is

greater than the total discharge amount of the object forming material of the forward stroke.

[0345] It is desirable that the total discharge amount of the object forming material at the return stroke be not less than 1.2 times and not more than 3 times the total discharge amount of the object forming material at the forward stroke.

[0346] A method of controlling the total discharge amount of the object forming material at the return stroke to be larger than the total discharge amount of the object forming material at the forward stroke is, for example, a method of increasing the size of a droplet of the object forming material fired at the return stroke to be larger than the size of a droplet of the object forming material fired at the forward stroke.

[0347] Examples of the method of making a droplet of the object forming material at the return stroke larger than a droplet of the object forming material at the forward stroke include a method of making a pulse voltage for filing a droplet of the object forming material at the return stroke greater than a pulse voltage for firing the object forming material at the forward stroke to increase the size of a droplet of the object forming material at the return stroke; and a method of making the number of pulses for firing droplets of the object forming material before landing at the return stroke greater than the number of pulses for firing droplets of the object forming material before landing at the forward stroke, thereby increasing the size of a droplet of the object forming material at the return stroke obtained from combining of the droplets of the discharged object forming material together while flying of the droplets.

[0348] Referring to Fig. 36, a method of making a pulse voltage for firing a droplet of the object forming material at the return stroke greater than a pulse voltage for firing a droplet of the object forming material at the forward stroke to increase the size of the droplet of the object forming material at the return stroke will be now described.

[0349] Hereinafter, an example of a liquid discharging head using a piezoelectric element as a pressure generating unit will be described.

[0350] By applying a driving pulse P1 at the forward stroke to the piezoelectric element of the head 20011 (see Fig. 36, (a)), a droplet D1 of the object forming material at the forward stroke is fired from the nozzle (see Fig. 36, (b)). Thereafter, by applying a driving pulse P2 at the return stroke to the piezoelectric element of the head 20011 (see Fig. 36, (a)), a droplet D2 of the object forming material at the return stroke is fired from the nozzle (see Fig. 36, (b)).

[0351] As depicted in Fig. 36, (a), the driving pulse P1 of the forward stroke is formed of a waveform element a at which the voltage falls from an intermediate potential Ve to a predetermined fallen potential, a waveform element b at which the voltage is kept at the fallen potential, and a waveform element c at which the voltage rises up from the fallen potential to the intermediate potential Ve. By providing the waveform elements

a-c, a droplet is fired from the nozzle.

[0352] The driving pulse P2 of the return stroke is similar to the driving pulse P1 of the forward stroke.

[0353] Here, as depicted in Fig. 37, the higher the pulse voltage, the greater the droplet volume (in pL) of the object forming material.

[0354] Fig. 38 depicts relationships with the pulse voltage when the longitudinal axis is changed to the thickness from the volume of Fig. 37. The higher the pulse voltage becomes, the greater the film thickness becomes. The waveform used is the waveform of the return stroke.

[0355] Fig. 39 depicts relationships between the discharge amount at the return stroke and the film thickness. As depicted, the film thickness is proportional to the discharge amount of the return stroke. From the result of Fig. 39, the target discharge amount of the forward stroke is set at 25 pL to obtain the film thickness of approximately 14 μm.

[0356] Accordingly, as depicted in Fig. 36,(a), when the fallen potential of the driving pulse P2 at the return stroke is set to be lower than the fallen potential of the driving pulse P1 at the forward stroke, that is, the pulse voltage for firing a droplet of the object forming material at the return stroke is set to be greater than the pulse voltage for firing a droplet of the object forming material at the forward stroke, the volume of the droplet D2 fired by the driven pulse P2 at the return stroke can be made greater than the volume of the droplet D1 fired by the driven pulse P1 at the forward stroke (see Fig. 36, (b)).

[0357] Referring to Fig. 40, a method for increasing the number of pulses for firing droplets of the object forming material at a return stroke before landing to not less than the number of pulses for firing droplets at a forward stroke before landing, and combining the droplets of the discharged object forming material while flying of the droplets to increase the size of a droplet of the object forming material in the return stroke will be described.

[0358] Hereinafter, an example of a liquid discharge head in which a piezoelectric element is used as a pressure generating unit will be described.

[0359] Fig. 40 depicts a view for illustrating a method for forming one drop of the object forming material at a forward stroke and forming two droplets of the object forming material and combining the droplets at a return stroke.

[0360] As a result of applying of a driving pulse P1 at a forward stroke to the piezoelectric element of the head 20011 (see Fig. 40, (a)), a droplet D1 of the object forming material in the forward stroke is fired from a nozzle (see Fig. 40, (b)). Thereafter, two droplets D2 and D3 of the object forming material are sequentially fired (see Fig. 40, (b)) from a nozzle at a return stroke as a result of applying of driving pulses P2 and P3 to the piezoelectric element of the head (see Fig. 40, (a)).

[0361] As depicted in Fig. 40, (a), as a result of the fallen potential of the driving pulse P3 at the return stroke is set lower than the fallen potential of the driving pulse P2 at the return stroke, that is, the pulse voltage for firing the droplet D3 of the object forming material at the return stroke is set greater than the pulse voltage for firing the droplet D2 of the object forming material at the return stroke, the speed Vj3 of the droplet D3 by the driving pulse P3 at the return stroke becomes faster than the speed Vj2 of the droplet D2 by the driving pulse P2 at the return stroke (see Fig. 40, (b)).

[0362] Accordingly, at the return stroke, the droplet D3 can catch up with the droplet D2 during the flight so that the droplets D3 and D2 are combined into one droplet D2+D3 that has a larger volume than the droplet D1 of the object forming material at the forward stroke (see Fig. 40, (b)).

[0363] In an embodiment of the mode III for carrying out the invention of the present invention, it is desirable that the nozzle for discharging the object forming material at the forward stroke and the nozzle for discharging the object forming material at the return stroke are the same (i.e., the one common nozzle is used) in order to accurately control the landing positions at the forward stroke and the return stroke.

[0364] It is important to accurately control the landing positions of the object forming material droplets from the viewpoint of achieving high-precision shaping and forming a precisely dimensioned object. Even with precise control of the positional accuracy with respect to X-Y coordinates, the nozzle position may vary within the geometric tolerance, and this variation cannot be canceled even if the positional accuracy with respect to X-Y coordinates is implemented. In this regard, as a result of using of the common nozzle, there is only the single nozzle position, so that the geometric tolerance is virtually eliminated, and thus it is possible to obtain precise landing positions.

[0365] Hereinafter, the order in which a first forming material (e.g., the modelling material) and a second forming material (e.g., the supporting material) are discharged and cured for forming a laminate structure of a three-dimensional objects will be described.

[0366] In an embodiment of the mode III for carrying out the invention of the present invention, because object forming material discharging amounts are different between a forward stroke and a return stroke, when the first forming material and the second forming material are alternately discharged, i.e., when the first forming material is discharged at a forward stroke and the second forming material is discharged at a return stroke, it may be that the heights of the layers of the two cured materials do not coincide and the desired three-dimensional shape cannot be achieved. Therefore, by discharging the first forming material at a first forward stroke and the first forming material at a first return stroke, and discharging the second forming material at a second forward stroke and the second forming material at a second return stroke, it is

possible to form the layers having the same heights.

[0367] As a method of curing the second object forming material after curing the first object forming material, a method in which an object forming layer at which each of the first and second object forming materials is cured is made different may be used.

[0368] That is, layers of the first forming material are formed started at an nth layer by m times of forward and return strokes, resulting in the n+m-1 layers formed and cured. Then, the (n+m)th layer of the first forming material is formed and cured, and at the same time, the nth layer of the second forming material is formed and cured. As a result, it is possible to obtain a three-dimensional object having a smooth surface of a modelling material part after the supporting material part is removed. There n is a natural number and m is a positive or negative integer. Desirably m is 2. When m=1, the surface roughness Rz is high. When $m \geqq 3$, the surface roughness Rz does not change, and this case is not desirable because of the decrease in productivity.

<<Flattening member>>

[0369] The flattening member is a unit that flattens a layer of the object forming material at the return stroke by touching the surface of the layer of the discharged object forming material at the return stroke.

[0370] As the flattening member, as long as the layer of the object forming material at the return stroke is flattened by touching of the surface of the layer of the discharged object forming material at the return stroke, there is no particular limit, and the flattening member can be appropriately selected according to the purpose. For example, a roller, a blade, or the like can be used.

[0371] In the three-dimensional object forming apparatus, the total discharge amount of the object forming material at the return stroke is greater than the total discharge amount of the object forming material at the forward stroke. Accordingly, the thickness of the object forming material layer (RSL) formed at the return stroke is greater than the thickness of the object forming material layer (GSL) formed at the forward stroke.

[0372] As depicted in Fig. 41, in the three-dimensional object forming apparatus, a rotating roller as the flattening member FM is caused to touch laterally against an end of a layer of the object forming material formed at a return stroke, which is thicker than the thickness of a layer of the object forming material formed at a forward stroke. This allows the extra portion of the layer of the object forming material, including rounded ends, to be scraped off, the surface of the layer of the object forming material to be flattened, and the ends of the layer of the object forming material to be sharpened.

[0373] The angle (θ in Fig. 41) between the wall surface of the end of the object forming material layer formed at the return stroke and the forming stage on which the three-dimensional object is formed is desirably 80 degrees or more and 100 degrees or less, and more desirably, the angle is close to 90 degrees (vertical). When the angle is 80

degrees or more and 100 degrees or less, when the flattening member FM comes into contact with the object forming material layer formed at the return stroke from the lateral direction, the edge of the object forming material layer formed at the return stroke can be scraped off so that the surface of the object forming material layer formed at the return stroke is flattened.

[0374] In the three-dimensional object forming apparatus according to an embodiment of the present invention, the thickness of the object forming material layer formed at the return stroke is formed to be thicker than the thickness of the object forming material layer formed at the forward stroke, so that a greater roller scraping margin (the distance between the roller FM and the object forming material layer formed at the forward stroke) can be secured.

[0375] It is desirable that the ratio of the roller scraping margin to the minimum thickness of the laminate structure after the object forming material layer is formed at the return stroke on the object forming material layer formed at the forward stroke (that is, the height to the recess at the center of the object forming material layer formed at the return stroke) be 10% or more. When the ratio of the roller scraping margin to the minimum thickness of the laminate structure is 10% or more, it is possible to prevent collision between the roller and the object forming material layer of the forward stroke which has been cured, and further, it is possible to prevent the surface of the object forming material layer of the return stroke from waving or being damaged.

[0376] It is desirable that the thickness of the roller scraping margin be 3 μm or more, and more desirably 5 μm or more.

[0377] As depicted in Fig. 42, the thus scraped portion of the object forming material layer of the return stroke is conveyed on the roller FM as the roller FM rotates and collected by a collecting member CM.

[0378] The collecting member CM is not particularly limited and can be appropriately selected depending on the purpose, for example, a blade.

[0379] As the shape of the roller as the flattening member FM, there is no particular limitation as long as the object forming material layer of the return stroke can be scraped off, and the roller can be appropriately selected according to the purpose. For example, the roller may have a circular cross section, the cross section having a true circle, or the like.

[0380] The flattening member FM may have a vibration, which may cause a shift FMS in the direction of gravity, as depicted in Figs. 43-46.

[0381] It is desirable that such a shift FMS in the gravity direction of the flattening member FM between the forward stroke and the return stroke be 10 μm or less, and more desirably 5 μm or less.

[0382] In FIG. 43, the roller scraping margin RSM is 3 μm; the above-mentioned ratio is

12%; the shift FMS is 5μm; the Z-directional distance ZS between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 9 μm.

[0383] In FIG. 14, the roller scraping margin RSM is 9.5 μm; the above-mentioned ratio is 30%; the shift FMS is 5μm; the Z-directional distance ZS between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 9 μm.

[0384] In FIG. 45, the roller scraping margin RSM is 1 μm; the above-mentioned ratio is 4%; the shift FMS is 5μm; the Z-directional distance ZS between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 9 μm.

[0385] In FIG. 46, the roller scraping margin RSM is 0 μm (i.e., a collision with the flattening member FM); the above-mentioned ratio is 0%; the shift FMS is 5μm; the Z-directional distance ZS between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 18 μm.

[0386] Next, the three-dimensional object forming sequence will be described.

[0387] Fig. 47 schematically depicts the order in which layers are formed at the top of each other, and Fig. 48 is an example of the three-dimensional object forming sequence corresponding to Fig. 47.

[0388] In Fig. 48, the head performs a scanning operation at a forward stroke (moving of the forming stage) while discharging the modelling material, and a UV curing operation is performed (in step (1)).

[0389] Then, the head performs a scanning operation at a retuning stroke (moving of the forming stage) while discharging the modelling material, flattening operation is performed with the roller, and UV curing is performed (in step (2)).

[0390] Then, the head is lifted in the Z direction.

[0391] Then, the head performs a scanning operation at a forward stroke (moving of the forming stage) while discharging the supporting material, and a UV curing operation is performed (in step (3)).

[0392] Then, the head performs a scanning operation at a retuning stroke (moving of the forming stage) while discharging the supporting material, flattening operation is performed with the roller, and a UV curing operation is performed (in step (4)).

[0393] Then, the head performs a scanning operation at a forward stroke (moving of the forming stage) while discharging the modelling material, and a UV curing operation is performed (in step (5)).

[0394] Then, the head performs a scanning operation at a forward stroke (moving of the forming stage) while discharging the modelling material, and a UV curing operation is performed (in step (6)).

[0395] Then, the head is lifted in the Z direction.

[0396] The same operations as the operation of steps (1)-(6) are performed after step (4) or (6); and the series of steps are repeated appropriately.

[0397] Fig. 47 schematically depicts a X-Z plane, wherein the object forming material discharging head is caused to perform scanning operations from left to right (forward stroke) and from right to left (return stroke) to discharge the object forming materials. The corresponding operations are depicted in Fig. 48.

[0398] In addition, the left-hand diagram in Fig. 47 represents modelling material layers. The right-hand side of Fig. 47 represents supporting material layers.

[0399] The surfaces including the round portions depicted in Fig. 47 correspond to surfaces obtained from discharging and curing operations.

[0400] The smooth surfaces depicted in Fig. 47 correspond to the surfaces on which the flattening operations have been performed with the roller.

<Embodiment 3-1>

[0401] Figs. 49A-49C depict methods for performing scanning operations at forward and return strokes. Fig. 49B depicts forward strokes and Fig. 49C depicts return strokes together with the forward strokes. In Fig. 49B and Fig. 49C, the gray represents the forward strokes and the black represents the return strokes.

[0402] As depicted in FIG. 49A, in step S20001, the head is caused to perform a scanning operation at a forward stroke (by moving of the forming stage) while the object forming material is discharged, and then, the thus formed layer is cured through a UV curing operation.

[0403] In step S20002, the head is shifted in the Y direction.

[0404] In step S20003, the head is caused to perform a scanning operation at a return stroke (by moving of the forming stage) while the object forming material is discharged, then, the roller as the flattening unit is used to flatten the thus formed layer, and the flattened layer is cured through a UV curing operation.

[0405] In step S20004, the head is lifted and prepared for forming a next layer.

[0406] Steps S20001-S20004 are repeated

[0407] As depicted in Fig. 49C, the forward strokes are sandwiched between the return strokes.

[0408] Comparing between Figs. 49B and 55B, a presence or an absence of the forward stroke at the top in Figs. 49B and 55B is different. Also in Fig. 55B and Fig. 55C, the gray represents the forward strokes and the black represents the return strokes.

[0409] In Fig. 49B, there is no forward stroke at the top in Figs. 49B and 55B. Therefore, when the return stroke of Fig. 49C is performed, the forward strokes are sandwiched by the return strokes. The reduction of one stroke results in a smaller size of an object in a precise sense, but in consideration of other errors, such a reduction in size is not of

practical concern.

[0410] Also in this case, as depicted in FIG. 55A, in step S20011, the head is caused to perform a scanning operation at a forward stroke (by moving of the forming stage) while the object forming material is discharged, and then, the thus formed layer is cured through a UV curing operation.

[0411] In step S20012, the head shifted in the Y direction.

[0412] In step S20013, the head is caused to perform a scanning operation at a return stroke (by moving of the forming stage) while the object forming material is discharged, then, the roller as the flattening unit is used to flatten the thus formed layer, and the flattened layer is cured through a UV curing operation.

[0413] In step S20014, the head is lifted and prepared for forming a next layer.

[0414] Steps S20011-S20014 are repeated.

[0415] Fig. 50 depicts waveforms applied to the head at forward and return strokes for a case of forming a laminate structure as depicted in Fig. 47. The object forming material discharging amounts at forward and return strokes are 25 pl and 70 pl, respectively, and film thicknesses at forward and return strokes are different. Note that, a case where a "Y step" is produced as depicted in FIG. 54 is a case where scanning operations with the head are performed as depicted in Figs. 55A-55C as described above.

<Embodiment 3-2>

[0416] Figs. 51A and 51B depict another scanning method.

[0417] In Figs. 51A and 51B, between an odd and even layers, the Y coordinates of forward and return strokes are switched from each other, so that, in the z direction, the layers formed at the forward and return strokes are formed on top of each other. As described above for Figs. 49B, 49C, 55B, and 55C, the gray represents the forward strokes and the black represents the return strokes.

[0418] In this way, the thicknesses can be made uniform regardless of the scanning positions, and no "Y step" is produced.

<Embodiment 3-3>

[0419] FIGS. 52A-52C depict yet another scanning method.

[0420] In Figs. 52A-52C, every three layers is set as a cycle where, at a side, three scanning operations for forming three layers include two return strokes and one forward stroke. By performing a return stroke twice and increasing the total discharge amount, it is possible to increase the amount of the object forming material to be removed at a flattening operation using the roller. As a result, the edge of each layer can be sharpened and the side surface of the laminate structure can be smoothed.

<Embodiment 3-4>

[0421] FIGS. 53A-53C depicts yet another scanning method.

[0422] In FIGS. 53A-53C, every three layers is set as a cycle where, at a side surface, three

scanning operations for forming the three layers include two forward strokes and one return stroke. Smoothness of the side surface can be obtained because the discharge amount at a forward stroke is smaller.

[0423] (Three-dimensional object forming program)

[0424] The three-dimensional object forming program of an embodiment of the present invention performs a process of discharging an object forming material at a forward stroke to form an object forming layer, discharging an object forming material at a return stroke to form an object forming layer, causing a flattening member to touch a surface of the object forming layer formed at the return stroke, and making the discharging position of the object forming material at the return stroke adjacent to the discharging position of the object forming material at the forward stroke in the same object forming layer.

[0425] A process of thus making the discharge position of the object forming material at a return stroke adjacent to the discharge position of the object forming material at a forward stroke in the same object forming layer includes a process of, at the return stroke, discharging the object forming material from a nozzle adjacent to a nozzle discharging the object forming material at the forward stroke.

[0426] Processing according to the three-dimensional object forming program of an embodiment of the present invention can be implemented by a computer having a control unit corresponding to the three-dimensional object forming apparatus.

[0427] An outline of the control unit will be described with reference to Fig. 56. Fig. 56 is a block diagram illustrating the control unit.

[0428] The control unit 20500 includes a main control unit 20500A including a CPU 20501 for controlling the entire apparatus, a ROM 20502 for storing the three-dimensional object forming program including instructions for controlling three-dimensional object forming operations of the CPU 20501 including control operations according to an embodiment of the present invention as well as other fixed data, and a RAM 20503 for temporarily storing object forming data.

[0429] The control unit 20500 also includes a non-volatile memory (NVRAM) 20504 for storing data even after the power of the apparatus is cut off. The control unit 20500 includes an ASIC 20505 for processing image processing for performing various signal processing on image data or for processing input/output signals for controlling the entire apparatus.

[0430] The control unit 20500 further includes an I/F 20506 for transmitting and receiving data and signals used to receive object forming data from an external object forming data generating apparatus 20600.

[0431] The object forming data generating apparatus 20600 is an apparatus that produces object forming data (cross-sectional data) which is slice data obtained from slicing the

final shape of a three-dimensional object on an object forming layer basis, and may be an information processing apparatus such as a personal computer.

[0432] The control unit 20500 includes an I/O 20507 for receiving sensing signals from various sensors.

[0433] The control unit 20500 includes a head driving control unit 20508 for driving and controlling the first head 20211 of an object forming unit and a head driving control unit 20509 for driving and controlling the second head 20212.

[0434] The control unit 20500 further includes a motor driving unit 20510 for driving a motor included in an X-direction moving mechanism 20550 for moving the object forming unit in the X-direction, and a motor driving unit 20511 for driving a motor included in a Y-direction scanning mechanism 20552 for moving the object forming unit in the Y-direction (a sub-scanning direction).

[0435] The control unit 20500 includes a motor driving unit 20513 for driving a motor included in a stage X-direction scanning mechanism 20553 that moves the forming stage 20214 in the X-direction together with the lifting and lowering unit 20215, and a motor driving unit 20514 for driving a motor included in the lifting and lowering unit 20215 that moves the forming stage 20214 in the Z-direction. The Z-direction movement may be implemented instead by lifting and lowering the object forming unit as described above.

[0436] The control unit 20500 includes a motor driving unit 20516 for driving a motor 20026 for rotating the flattening roller 20213, and a maintenance drive section 20518 for driving a maintenance mechanism 20061 for the first head 20211 and the second head 20212.

[0437] The control unit 20500 includes a curing control unit 20519 for controlling UV irradiation by the UV irradiator 20216.

[0438] The I/O 20507 of the control unit 20500 receives a sensing signal, such as a sensing signal from a temperature and humidity sensor 20560, which detects the temperature and humidity as an environmental condition of the apparatus, and other sensing signals from other sensors.

[0439] An operation panel 20522 is connected to the control unit 20500 for inputting and displaying various information.

[0440] The control unit 20500 receives object forming data from the object forming data generating apparatus 20600 as described above. Object forming data is data (object forming section data) for determining a shape of each object forming layer as slice data of a desired three-dimensional object.

[0441] A main control unit 20500A generates data in which data of a supporting section to provide the supporting material is added to the object forming data (object forming section data) and provides the data to the head driving control units 20508 and 20509.

The head driving control units 20508 and 20509 respectively fire droplets of the modelling material from the first head 20011 to an object forming section and fire droplets of the liquid supporting material 20302 from the second head 20012 to a supporting section.

[0442] A combination of the object forming data generating apparatus 20600 and the three-dimensional object forming apparatus may be referred to as a three-dimensional object forming apparatus.

[0443] Next, the processing procedure of the three-dimensional object forming program of an embodiment of the present invention will be described. Fig. 57 depicts a flowchart for illustrating a processing procedure of the three-dimensional object forming program in the control unit 20500 of the three-dimensional object forming apparatus. Referring to the flowchart, a processing flow of a three-dimensional object forming method of an embodiment of the present invention will be described.

[0444] In step S20021, when the object forming material is discharged at a forward stroke and cured, the process proceeds to step S20022.

[0445] In Step S20022, at a return stroke, the object forming material is discharged in such a manner as to overlap at least partially with the object forming material discharged at the forward stroke, flattened, and cured, and then, the process proceeds to step S20023.

[0446] In step S20023, steps S20021 and S20022 are repeated a predetermined number of times so that the object forming process is completed. Thus, the present process ends.

[0447] Fig. 58 is a flowchart illustrating another example of a process flow of a three-dimensional object forming method of an embodiment of the present invention. A process flow of a process of forming a three-dimensional object of an embodiment of the present invention will be described with reference to the flowchart.

[0448] In step S20031, when the object forming material is discharged at a forward stroke and cured, the process proceeds to step S20032.

[0449] In step S20032, at a return stroke, the object forming material is discharged in such a manner as to come into contact with at least two sides of the object forming material discharged at the forward stroke, flattened, and cured, and then, the process proceeds to step S20033.

[0450] In step S20033, steps S20031 and S20032 are repeated a predetermined number of times so that the object forming process is completed. Thus, the present process ends.

[0451] Examples of the mode III for carrying out the invention of the present invention are as follows:

<1>

[0452] A three-dimensional object forming method includes a forward stroke layer forming step of discharging an object forming material at a forward stroke to form an object forming layer; a return stroke layer forming step of discharging an object forming

material at a return stroke to form an object forming layer; and a flattening step of causing a flattening member to touch the object forming layer formed at the return stroke. In this regard, in the same object forming layer, the discharging position of the object forming material at the return stroke is adjacent to the discharge position of the object forming material at the forward stroke.

<2>

[0453] In the three-dimensional object forming method according to the above-mentioned method <1>, the object forming material is discharged at the return stroke in such a manner as to overlap at least partially with the object forming material discharged at the forward stroke.

<3>

[0454] In the three-dimensional object forming method according to the above-mentioned method <1> or <2>, the object forming material is discharged at the return stroke in such a manner as to touch at least two sides of the object forming material discharged at the forward stroke.

<4>

[0455] In the three-dimensional object forming method according to the above-mentioned method of any one of <1> through <3>, coordinates of the forward and return strokes are switched from each other in an object forming layer of a different height.

<5>

[0456] In the three-dimensional object forming method according to the above-mentioned method of any one of <1> through <4>, wherein a total discharge amount of the object forming material at the return stroke is greater than the total discharge amount of the object forming material at the forward stroke.

<6>

[0457] In the three-dimensional object forming method according to the above-mentioned method of any one of <1> through <5>, in the same object forming layer, after a first object forming material is discharged and cured, a second object forming material is discharged and cured.

<7>

[0458] In the three-dimensional object forming method according to the above-mentioned method <6>, the second forming material is a water soluble material.

<8>

[0459] A three-dimensional object forming apparatus includes a forward stroke layer forming unit configured to discharge an object forming material at a forward stroke to form an object forming layer; a return stroke layer forming unit configured to discharge an object forming material at a return stroke to form an object forming layer; and a flattening unit configured to touch the object forming layer formed at the return

stroke. In this regard, in the same object forming layer, the discharging position of the object forming material at the return stroke is adjacent to the discharge position of the object forming material at the forward stroke.

<9>

[0460] In the three-dimensional object forming apparatus according to the above-mentioned apparatus <8>, the object forming material is discharged at the return stroke in such a manner as to overlap at least partially with the object forming material discharged at the forward stroke.

<10>

[0461] In the three-dimensional object forming apparatus according to the above-mentioned apparatus <1> or <2>, the object forming material is discharged at the return stroke in such a manner as to touch at least two sides of the object forming material discharged at the forward stroke.

<11>

[0462] In the three-dimensional object forming apparatus according to the above-mentioned apparatus of any one of <1> through <3>, coordinates of the forward and return strokes are switched from each other in an object forming layer of a different height.

<12>

[0463] In the three-dimensional object forming apparatus according to the above-mentioned apparatus of any one of <1> through <4>, a total discharge amount of the object forming material at the return stroke is greater than the total discharge amount of the object forming material at the forward stroke.

<13>

[0464] In the three-dimensional object forming apparatus according to the above-mentioned apparatus of any one of <1> through <5>, in the same object forming layer, after a first object forming material is discharged and cured, a second object forming material is discharged and cured.

<14>

[0465] In the three-dimensional object forming apparatus according to the above-mentioned apparatus <13>, the second forming material is a water soluble material.

<15>

[0466] A program causing a computer to discharge an object forming material at a forward stroke to form an object forming layer; discharge an object forming material at a return stroke to form an object forming layer; cause a flattening member to touch the object forming layer formed at the return stroke; and perform control in such a manner that, in the same object forming layer, the discharging position of the object forming material at the return stroke is adjacent to the discharge position of the object forming material at the forward stroke.

[0467] The three-dimensional object forming apparatuses <1> through <7>, the three-dimensional object forming methods <8> through <14>, and the program <15> make it possible to solve the various problems of the related art and achieve the object of the embodiments of the mode III for carrying out the invention of the present invention.

<Mode IV for carrying out the invention>

[0468] A mode IV for carrying out the invention of the present invention will now be described.

[0469] The mode IV for carrying out the invention of the present invention relates to a three-dimensional object forming apparatus, a three-dimensional object forming method, and a program.

[0470] A material jetting system is known as a three-dimensional object forming apparatus of discharging an object forming material to an object forming section, then curing of the discharged object forming material to form an object forming layer, and forming the layer on top of each other sequentially to obtain a laminate structure of a three-dimensional object. In the material jetting method, two types of materials are used: a modelling material and a supporting material to support the modelling material during an object forming process.

[0471] As a material jetting object forming apparatus, for example, a three-dimensional object forming apparatus including a roller for pressing while being rotated to remove an excess of the object forming material is proposed (see, for example, PTL 4).

[0472] A method is known where a head that discharges an object forming material is smaller than an object forming area, and, after performing a scanning operation to discharge the object forming material, the head or a stage is moved in a head nozzle direction (a sub-scanning direction) several times to form an object larger than the head nozzle length.

[0473] However, in such a configuration, when a scanning area overlaps with the previously scanned area, there may be a problem that the material discharged at the previous scanning is collided (or hit) by the roller. Therefore, it is necessary to perform a scanning operation for a large amount in the sub-scanning direction, and thus, there may be a problem that the non-discharging time is increased and the object forming speed, that is, the productivity, is decreased.

[0474] When the moving operation in the sub-scanning direction is reduced so as not to impair the productivity, there may be a problem that the roller collides (hit) with the already discharged material, causing vibration of the roller and the apparatus, resulting in roughness of the surface of the formed object, an unstable roller rotation speed, and a possibility of stopping of the roller.

[0475] Therefore, for example, it has been proposed that the width of the roller is made narrower than the distance between the orifices located at both ends of the modelling

material discharge nozzles with respect to the sub-scanning direction provided in an object forming material discharging unit and the distance between the orifices located at both ends of the supporting material discharge nozzles with respect to the sub-scanning direction, for the purpose of preventing collision between the roller and the discharged object forming material (see, for example, PTL 5).

[0476] An object of an embodiment of the mode IV for carrying out the invention of the present invention is to provide a three-dimensional object forming method enables obtaining excellent surface characteristics and achieving high productivity.

[0477] For solving the above-mentioned problem, a three-dimensional object forming method according to an embodiment of the mode IV for carrying out the invention of the present invention includes a forming layer forming step of discharging an object forming material to form an object forming layer during a main scanning operation. In the forming step for forming one object forming layer, when main scanning areas overlap, an object forming material discharge amount at a previous scanning operation with respect to an overlapping area is made smaller than an object forming material discharge amount of a final scanning operation.

[0478] According to the embodiment of the mode IV for carrying out the invention of the present invention, a three-dimensional object forming method enables obtaining excellent surface characteristics and achieving high productivity can be provided.

(Three-dimensional object forming method, three-dimensional object forming apparatus, and three-dimensional object forming program of mode IV for carrying out the invention)

[0479] The three-dimensional object forming method of an embodiment of the mode IV for carrying out the invention of the present invention includes a forming layer forming step of discharging an object forming material to form an object forming layer during a main scanning operation. In this regard, when main scanning areas of a head overlap, an object forming material discharge amount at a previous scanning operation with respect to an overlapping area is made to be less than an object forming material discharge amount at a final scanning operation.

[0480] In the embodiment of the present invention, the term "main scanning area" means an area where an object forming material discharging head performs scanning (moves) in a main scanning operation. That is, the main scanning area is an area in which an object forming material can be discharged from the object forming material discharging head for forming an object forming layer during a main scanning operation. When such areas overlap (that is, when there is an area to be scanned by the object forming material discharging head a plurality of times), from among such a plurality of times of scanning operations, the final scanning operation is referred to as a "final scanning operation", and the other scanning operations are referred to as "previous

scanning operations".

[0481] The three-dimensional object forming apparatus according to an embodiment of the mode IV for carrying out the invention of the present invention includes a layer forming unit configured to discharge an object forming material to form an object forming layer during a main scanning operation. When main scanning areas of a head overlap, an object forming material discharge amount at a previous scanning operation with respect to an overlapping area is made smaller than an object forming material discharge amount at a final scanning operation.

[0482] A three-dimensional object forming program of an embodiment of the mode IV for carrying out the invention of the present invention causes a computer to perform a process of discharging an object forming material to form the object forming layer during a main scanning operation. When main scanning areas of a head overlap in forming of one object forming layer, an object forming material discharge amount at a previous scanning operation with respect to an overlapping area is made smaller than an object forming material discharge amount at a final scanning operation.

[0483] A control unit used in a "three-dimensional object forming apparatus" of an embodiment of the mode IV for carrying out the invention of the present invention is equivalent to implementation of a "three-dimensional object forming method" of the present invention. Therefore, the details of the "three-dimensional object forming method" of the embodiment of the present invention will be clarified through the description of the "three-dimensional object forming apparatus" of the embodiment of the present invention. Because the "three-dimensional object forming program" of an embodiment of the mode IV for carrying out the invention of the present invention is implemented as a "three-dimensional object forming apparatus" of an embodiment of the mode IV for carrying out the invention of the present invention by using a computer as a hardware resource, the details of the "three-dimensional object forming program" of the embodiment of the present invention will also be clarified through the description of the "three-dimensional object forming apparatus" the embodiment of the present invention.

[0484] An embodiment of the mode IV for carrying out the invention of the present invention includes a layer forming step of discharging an object forming material to form an object forming layer during a main scanning operation. In the layer forming step with respect to one object forming layer, when main scanning areas of a head overlap, an object forming material discharge amount at a previous scanning operation with respect to an overlapping area is made smaller than an object forming material discharge amount at a final scanning operation. As a result, the height of the object forming material can be reduced, thereby avoiding collision between a roller and the object forming material. In addition, the amount of movement of the head can be

minimized and productivity can be increased.

[0485] A method of, with respect to overlapping area, reducing an object forming material discharge amount at a forward stroke with respect to an overlapping area to less than an object forming material discharge amount at a return stroke may be, for example, a method in which a pulse voltage for firing a droplet of the object forming material at a forward stroke is made less than a pulse voltage for firing a droplet of the object forming material at a return stroke, and by thus reducing the size of a droplet of the object forming material at a forward stroke, the object forming material discharge amount at the forward stroke is adjusted to be smaller.

[0486] In the overlapping area, it is desirable not to discharge the object forming material at a scanning operation of a forward stroke. Because the height of a three-dimensional object can be thus further lowered, the productivity can be increased by minimizing the amount of movement of the head while avoiding collision between the roller and the discharged object forming material.

[0487] In one aspect of the mode IV for carrying out the invention of the invention, the head is moved in the sub-scanning direction relatively within the same object forming layer.

[0488] In one aspect of the mode IV for carrying out the invention of the invention, scanning at a forward stroke and a return stroke in the same object forming layer corresponds to bi-directional printing, and the head moves in the sub-scanning direction during the bi-directional printing.

[0489] In one aspect of the mode IV for carrying out the invention of the present invention, after the object forming material is discharged at a forward stroke, the head moves in the sub-scanning direction during acceleration or deceleration in the main scanning direction.

[0490] In one aspect of the mode IV for carrying out the invention of the invention, the movement of the head in the sub-scanning direction corresponds to rendering.

[0491] Rendering means moving in the sub-scanning direction after scanning at forward and return strokes with respect to the same layer.

[0492] A three-dimensional object forming method of an embodiment of the mode IV for carrying out the invention of the present invention is depicted in Fig. 59, (A)-(G), and includes a forward stroke layer forming step and a return stroke layer forming step.

[0493] In a forward stroke layer forming process, when a high viscosity liquid-like object forming material is discharged from a discharging unit such as nozzles at a forward stroke (see Fig. 59, (A)), the discharged object forming material has a recess at the center due to surface tension and has rounded ends (see Fig. 59, (B)). Thereafter, the object forming material is cured by a curing unit such as a UV irradiator unit to form an object forming layer (see Fig. 59, (C)).

[0494] In a return stroke forming process, a liquid-shaped object forming material having a

high viscosity is discharged from a discharging unit, such as nozzles, in a larger amount than the amount of the case of the forward stroke, so as to overlap on the cured object forming layer of the forward stroke (see Fig. 59, (D) and (E)), and the flattening member is in contact with the surface of the discharged object forming material to flatten the object forming material of the return stroke (see Fig. 59, (F)). Thereafter, the object forming material is cured with a curing unit such as a UV irradiator unit to form the return-stroke object forming layer (see Fig. 59, (G)).

[0495] In the three-dimensional object forming method of an embodiment of the mode IV for carrying out the invention of the present invention, at a step later than the step of Fig. 59, (E), excessive portions of the object forming material are scraped off by causing a flattening member, such as a roller, to touch the surface of the object forming material before the object forming material cures, as depicted in Fig. 59, (F) and (G). As a result, the surface of the object forming material of the return stroke can be flattened (see Fig. 59, (F)) and the ends of the object forming material of the return stroke can be sharpened as depicted by "X" in Fig. 59, (F).

[0496] In addition, as depicted in Fig. 59, (G), after the surface of the object forming material of the return stroke is flattened, the object forming material is cured to form the object forming layer of the return stroke. Therefore, the three-dimensional object forming method according to an embodiment of the mode IV for carrying out the invention of the present invention is capable of forming a laminate structure without a recess at the center and having a flat surface, and, by repeating a lamination process into a laminate structure, a high-definition three-dimensional object having sharp ends and excellent flatness can be formed.

[0497] In the embodiment of the present invention, it is desirable that the total object forming material discharge amount at a return stroke is greater than the total object forming material discharge amount at a forward stroke. An effect of securing a thicker roller scraping margin and improving the sharpness of an end portion will be described with reference to Figs. 66A-66C.

[0498] Figs. 66A-66C depict magnified photographs of an end of a three-dimensional object when a roller scraping margin ratio (i.e., the distance between a roller and a cured object forming layer) to the minimum thickness of the object forming layer (i.e., the height to the recess at the center of the object forming layer formed at a return stroke) after the object forming material is discharged at the return stroke onto the object forming layer formed at the forward stroke is 0%, 12%, or 30%.

[0499] When the total object forming material discharge amount at a return stroke is the same as the total object forming material discharge amount at a forward stroke, and the roller scraping margin ratio is 0%, an end of an obtained three-dimensional object is rounded and has insufficient sharpness, as depicted in Fig. 66A (magnification: 100

times).

[0500] On the other hand, when the total object forming material discharge amount at a return stroke is greater than the total object forming material discharge amount at a forward stroke, and the roller scraping margin ratio is 12%, as depicted in Fig. 66B (magnification: 100 times), an end of the thus obtained three-dimensional object has better sharpness in comparison to the case where the roller scraping margin ratio is 0% (Fig. 66A).

[0501] In addition, when the total object forming material discharge amount at a return stroke is greater than the total object forming material discharge amount at a forward stroke, and the roller scraping margin ratio is 30%, as depicted in Fig. 66C (magnification: 100 times), an end of the thus obtained three-dimensional object is sharper in comparison to a case where the roller scraping margin ratio is 12% (Fig. 66B).

[0502] Figs. 66A-66C are magnified using a microscope (device name: VHX-500, manufactured by Keyence Co., Ltd.).

[0503] In Figs. 66A-66C, a virtual circle is superimposed at an end of a three-dimensional object to determine the radius (mm) of the virtual circle superimposed at the end. Similarly, a radius (mm) of a virtual circle is obtained when the roller scraping margin ratio is 10.0% or more and 45.0% or less. Fig. 67 depicts the radius (mm) of a virtual circle superimposed at an end of a three-dimensional object with respect to the roller scraping margin ratio at a constant Z-direction spacing (22.5 μm).

[0504] In Fig. 67, the smaller the radius (mm) of the virtual circle is, the higher the sharpness is, and the greater the radius (mm) of the virtual circle is, the rounder the edge is. In Fig. 67, X, Y, and Z represent the directions of the three-dimensional object.

[0505] As can be seen from Fig. 67, the larger roller scraping ratio is, the smaller the radius (mm) of the virtual circle superimposed at an end of a three-dimensional object is. Accordingly, it can be seen that, when the total object forming material discharge amount at a return stroke is greater than the total object forming material discharge amount at a forward stroke, the greater the roller scraping margin ratio is, the higher the sharpness of an end portion of an obtained three-dimensional object.

<Experiment>

[0506] A three-dimensional printer was used to form No.1 through No.5 three-dimensional objects in which a modelling material abuts a supporting material on a X-Z plane, based on the object forming conditions depicted in Table 1, using a first object forming material (modelling material) and a second object forming material (supporting material) of the composition depicted below.

-- First object forming material --

[0507] The first object forming material was prepared by stirring 60 wt% of isobonyl acrylate (manufactured by Tokyo Chemical Industry Co., Ltd.), 23 wt% of tricyclodecanmethanol diacrylate (manufactured by Daicel Ornerk Co., Ltd.), 10 wt% of UB-6600 (manufactured by Nippon Gohsei Chemical Industry Co., Ltd.), 3 wt% of IRUGACURE TPO (manufactured by BASF Co., Ltd.), and 4 wt% of IRUGACURE 184 (manufactured by BASF Co., Ltd.) in a beaker for 30 min.

-- Second object forming material --

[0508] The second object forming material was prepared by stirring and mixing 40.0 g of acryloyl morpholine (manufactured by KJ Chemicals, Inc.), 10.0 g of 1,5-pentanediol (manufactured by Tokyo Chemical Industry Co., Ltd.), 50.0 g of polypropylene glycol 1 (tradename: Actochol D-1000, manufactured by Mitsui Chemical SKC Polyurethane Co., Ltd., number average molecular weight: 1,000), and 2.0 g of bis(2,4,6-trimethylbenzoyl)-phenyl phosphine oxide (tradename: IRGACURE 819, manufactured by BASF).

[0509] Next, obtained three-dimensional objects were evaluated for surface roughness Rz and generation cracks on the surface of the modelling material after the supporting material was removed in the three-dimensional objects, as follows. The results are depicted in Table 1.

-- Surface roughness Rz --

[0510] The surface roughness Rz was evaluated using VK-X150 (Keyence) in a range of 1 mm x 1 mm at the interface between modelling material and the supporting material.

-- Cracks --

[0511] Cracks were observed visually.

[Table 1]

No.		1	2	3	4	5
object forming conditions	stroke	forward or return	forward and return	forward and return	forward and return	forward and return
	first object forming material (modelling material) and second object forming material (supporting material) same time or separately	same time	same time	separately	same time	same time
	layer of discharging and curing first object forming material (modelling material)	nth layer	nth layer	nth layer	nth layer	nth layer
	layer of discharging and curing second object forming material (supporting material)	nth layer	nth layer	nth layer	(n+1)th layer	(n+2)th layer
object characteristics	crack	none	present	none	none	none
	surface roughness Rz (μ m)	250	800	200	230	200

[0512] From the results of Table 1, as depicted in No.2, it is found that, when the first object forming material (the modelling material) and the second object forming material (the supporting material) are discharged at forward and return strokes at the same time and cured, cracks are generated and surface roughness Rz is larger than the surface roughness Rz of No.1 and No.3.

[0513] On the other hand, as depicted in Nos. 4 and 5, it is found that, when the first object

forming material is discharged and cured, and then, the second object forming material is discharged and cured, there are no cracks, the surface roughness Rz is small, and the smooth modelling section surface is obtained after the supporting material section is removed.

<Forward stroke layer forming unit and forward stroke layer forming step>

[0514] The forward stroke layer forming unit discharges the object forming material at a forward stroke and forms an object forming layer. The forward stroke layer forming unit may cure the discharged object forming material to form an object forming layer.

[0515] The forward stroke object forming step is a step of discharging the object forming material at a forward stroke to form an object forming layer. In the forward stroke layer forming step, the discharged object forming material may be cured to form an object forming layer.

[0516] Discharging of the object forming material is performed desirably using an object forming material discharging unit.

[0517] Desirably, the object forming material is cured by using an object forming material curing unit.

<Object forming material discharging unit>

[0518] The object forming material discharging unit is a unit that discharges the object forming material at a forward stroke.

[0519] As the object forming material discharging unit, there is no particular limit on the object forming material to be discharged, and the object forming material discharging unit can be appropriately selected according to the purpose. For example, a publicly known device, such as a head, can be used.

[0520] As the head, there is no particular limitation and the head can be appropriately selected depending on the purpose, for example, a piezoelectric (piezo element) head, a thermal expansion (thermal) head, or the like. Among these devices, a piezoelectric (piezo-element) head is desirable.

<<Object forming material at forward stroke>>

[0521] There is no particular limitation as to the object forming material at a forward stroke, and a suitable choice can be made based on the performance required in forming the body for forming the three-dimensional object.

[0522] Examples of the object forming material include a modelling material and a supporting material.

[0523] The object forming material at a forward stroke is not particularly limited as long as the material is a liquid that is cured by applying of energy, such as light or heat, and can be appropriately selected depending on the purpose, but desirably includes polymerizable monomers such as mono-functional monomers, poly-functional monomers, oligomers, and may optionally include other components. Desirably, the material has a

liquid property such as viscosity and surface tension that can be discharged by an object forming material discharging head used in an object forming material jetting printer.

-- Polymerizable monomers --

[0524] Polymerizable monomers include, for example, monofunctional monomers, polyfunctional monomers, and the like. These types of monomers may be used alone, and also, two or more of these types of monomers.

-- Monofunctional monomers --

[0525] Monofunctional monomers include, for example, acrylamide, N-substituted acrylamide derivatives, N,N-disubstituted acrylamide derivatives, N-substituted methacrylamide derivatives, N,N-disubstituted methacrylamide derivatives, acrylic acid, and the like. These types of monomers may be used alone, and also, two or more these types of monomers may be combined and used. Among these monomers, acrylamide, N,N-dimethylacrylamide, N-isopropylacrylamide, acryloylmorpholine, hydroxyethylacrylamide, and isoboryl (meth)acrylate are desirable.

[0526] As monofunctional monomers, organic polymers can be obtained by polymerization.

[0527] It is desirable that the content of monofunctional monomers be not less than 0.5 wt% and not more than 90 wt% of the total amount of the object forming material.

[0528] Other monofunctional monomers include, but are not limited to, 2-ethylhexyl (meth)acrylate, 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, caprolactone-modified tetrahydrofurfuryl (meth)acrylate, 3-methoxybutyl (meth)acrylate, tetrahydrofurfuryl (meth)acrylate, lauryl (meth)acrylate, 2-phenoxyethyl (meth)acrylate, isodecyl (meth)acrylate, isooctyl (meth)acrylate, tridecyl (meth)acrylate, caprolactone (meth)acrylate, ethoxy nonylphenol (meth)acrylate, and the like.

-- Polyfunctional monomers --

[0529] Polyfunctional monomers include bifunctional monomers, trifunctional monomers, and the like, which are not particularly limited and can be appropriately selected depending on the purpose. These types of monomers may be used alone, and also, two or more of these types of monomers may be combined and used.

[0530] Examples of bifunctional monomers include tripropylene glycol di (meth) acrylates, triethylene glycol di (meth) acrylates, tetraethylene glycol di (meth) acrylates, polypropylene glycol di (meth) acrylates, neopentyl glycol hydroxypipyrinate di (meth) acrylates, hydroxypyrinate neopentyl glycol esterdi (meth) acrylates, 1,3-butanediol di (meth) acrylates, 1,4-butanediol di (meth) acrylates, 1,6-hexanediol di (meth) acrylates, 1,9-nonandiol di (meth) acrylates, diethylene glycol di (meth) acrylates, neopentyl glycol di (meth) acrylates, tripropylene glycol di (meth) acrylates, caprolactone-modified hydroxypipyrinate neopentyl glycol esterdi (meth) acrylates,

propoxy neopentyl glycol di (meth) acrylate, ethoxy-modified bisphenol A di (meth) acrylate, polyethylene glycol 200 di (meth) acrylate, polyethylene glycol 400 di (meth) acrylate, and the like. These types of monomers may be used alone, and also, two or more of these types of monomers may be combined and used.

[0531] Examples of tri or more functional monomers include trimethylol propanetri (meth)acrylate, pentaerythritol tri (meth)acrylate, dipentaerythritol hexa(meth)acrylate, triallyl isocyanurate, ε-caprolactone modified dipentaerythritol tri (meth)acrylate, ε-caprolactone modified dipentaerythritol tetra (meth) acrylate, meth) acrylate, ε-caprolactone modified dipentaerythritol penta (meth)acrylate, ε-caprolactone modified dipentaerythritol penta (meth)acrylate, ε-caprolactone modified dipentaerythritol hexa(meth)acrylate, tris (2-hydroxyethyl) isocyanurate tri(meth)acrylate, ethoxylated trimethylolpropanetri(meth)acrylate, propoxylated glyceryl tri(meth)acrylate, pentaerythritol tetra(meth)acrylate, ditrimethylol propanetetra(meth)acrylate, dipentaerythritol hydroxypenta(meth)acrylate, ethoxylated pentaerythritol tetra(meth)acrylate, penta(meth)acrylate ester, and the like. These types of monomers may be used alone, and also, two or more of these types of monomers may be combined and used.

-- Oligomers --

[0532] As oligomers, low polymers of the above-mentioned monomers or oligomers having reactive unsaturated binding groups at ends may be used alone, and also, two or more types of oligomers may be combined and used.

-- Other ingredients --

[0533] Other ingredients include, but are not limited to, surfactants, polymerization inhibitors, polymerization initiators, colorants, viscosity modifiers, adherence providing agents, antioxidants, antiaging agents, cross-linking promoters, ultraviolet absorbers, plasticizers, preservatives, dispersants, and the like.

-- Surfactant --

[0534] Surfactant may be, for example, surfactant having a molecular weight of 200 or more and 5,000 or less, specifically, a PEG nonionic surfactant (ethylene oxide of nonylphenol (hereinafter, referred to as "EO") 1-through-400-mol adduct, stearate 1-through-40-mol adduct, etc.), a polyhydric alcoholic nonionic surfactant (sorbitan palmitate monoester, sorbitan stearate monoester, triester of sorbitan stearate, etc.), a fluorine-containing surfactant (perfluoroalkyl EO 1-through-50-mol adduct, perfluoroalkyl carboxylate salt, perfluoroalkyl betaine, etc.), a modified silicone oil (polyether modified silicone oil, (meth)acrylate modified silicone oil, etc.), and the like. These types of surfactant may be used alone, and also, two or more these types of surfactant may be combined and used.

[0535] It is desirable that the content of the surfactant be 3 wt% or less with respect to the

total amount of the object forming material, and it is more desirable that the content be 0.1 wt% or more and 5 wt% or less from the viewpoint of the inclusion effect and the physical properties of the photo-setting material.

-- Polymerization inhibitor --

[0536] Examples of the polymerization inhibitor include a phenolic compound (hydroquinone, hydroquinone monomethyl ether, 2,6-di-t-butyl-p-cresol, 2,2-methylene-bis-(4-methyl-6-t-butylphenol), 1,1,3-tris-(2-methyl-4-hydroxy-5-t-butylphenyl)butane), a sulfur compound (dilauryl thiodipropionate, etc.), a phosphorus compound (triphenylphosphite, etc.), an amine compound (phenothiazine, etc.), and the like. These inhibitors may be used alone, and also, two or more of these types of inhibitors may be combined and used.

[0537] It is desirable that the content of the polymerization inhibitor be not more than 5 wt% of the total amount of the object forming material, and it is more desirable that the content of the polymerization inhibitor be not less than 0.1 wt% and not more than 5 wt% of the total amount of the object forming material from the viewpoint of the stability of the monomers and the polymerization speed.

-- Polymerization initiator --

[0538] Examples of the polymerization initiators include, for example, thermal polymerization initiators, photopolymerization initiators, and the like. Among these examples, a photopolymerization initiator is desirable from the viewpoint of storage stability.

[0539] As the photopolymerization initiator, any material that produces radicals by irradiation with light (particularly ultraviolet light of wavelengths from 220 nm to 400 nm) can be used.

[0540] Photopolymerization initiators include, for example, acetophenone, 2,2-diethoxyacetophenone, p-dimethylaminoacetophenone, benzophenone, 2-chlorobenzophenone, p,p'-dichlorobenzophenone, p,p-bis-diethylaminobenzophenone, mihiraketone, benzyl, benzoin, benzoin methyl ether, benzoin ethyl ether, benzoin isopropyl ether, benzoin-n-propyl ether, benzoin isobutyl ether, benzoin-n-butyl ether, benzyl methyl ether, benzyl methyl ketal, thioxanthone, 2-chlorothioxanthone, 2-hydroxy-2-methyl-1-phenyl-1-one.1-(4-Isopropylphenyl)2-methylpropane-1-one, methylbenzoylformate, 1-hydroxycyclohexylphenyl ketone, azobityronitrile, benzoylperoxide, di-tert-butyl peroxide, and the like. These examples may be used alone, and also, two or more of these examples may be combined and used.

[0541] As a thermal polymerization initiator, there is no particularly limitation, and any thermal polymerization initiator may be appropriately selected depending on the purpose, for example, an azo-based initiator, a peroxide initiator, a persulfate initiator,

a redox initiator, or the like may be selected.

[0542] Examples of azo-based initiators include VA-044, VA-46B, V-50, VA-057, VA-061, VA-067, VA-086, 2,2'-azobis (4-methoxy-2,4-dimethylvaleronitrile) (VAZO 33), 2,2'-azobis (2-amidinopropane) dihydrochloride (VAZO 50), 2,2'-azobis (2,4-dimethylvaleronitrile) (VAZO 52), 2,2'-azobis (isobutyronitrile) (VAZO 64), 2,2'-azobis-2-methylbutyronitrile (VAZO 67), 1,1-azobis (1-cyclohexanecarbonitrile) (VAZO 88) (all being made by DuPont Chemical Company), 2,2'-azobis (2-cyclopropylpropionitrile), and 2,2'-azobis (V-601) (the last two materials being made by Wako Pure Chemical Industries).

[0543] Examples of the peroxide initiators include benzoyl peroxide, acetyl peroxide, lauroyl peroxide, decanoyl peroxide, dicetyl peroxydicarbonate, di(4-t-butylcyclohexyl), peroxydicarbonate (trade name: Perkadox 16S, made by Akzo Nobel N.V.), di(2-ethylhexyl) peroxydicarbonate, t-butylperoxy-2-ethylhexanoate (trade name: Lupersol 11, Elf Atochem), t-butylperoxy-2-ethylhexanoate (trade name: Trigonox 21-C50, made by Akzo Nobel N.V.), dicumyl peroxide, and the like.

[0544] Examples of persulfate initiators include potassium persulfate, sodium persulfate, ammonium persulfate, and the like.

[0545] Examples of redox (oxidation-reduction) initiators include persulfate initiators in combination with reducing agents such as sodium bisulfite and sodium bisulfite, systems based on an organic peroxide and tertiary amine (e.g., systems based on benzoyl peroxide and dimethyl aniline), and systems based on organohydroperoxides and transition metals (e.g., systems based on cumene hydroperoxide and cobalt naphtate).

[0546] It is desirable that the content of the polymerization initiator be 10 wt% or less and, more desirably, 5 wt% or less for the total amount of the object forming material.

-- Colorant --

[0547] As a colorant, a dye or pigment that dissolves or stably disperses in the object forming material and has excellent thermal stability is suitable. Among these materials, a solvent dye is desirable. In addition, it is possible to mix two or more types of coloring agents for the purpose of color adjustment, for example.

<Object forming material curing unit>

[0548] An object forming material curing unit is a unit that cures the object forming material discharged at a forward stroke to form an object forming layer.

[0549] As long as it is possible to cure the object forming material discharged at a forward stroke to form an object forming layer, there is no particular restriction, and the object forming layer can be appropriately selected according to the purpose. For example, an ultraviolet irradiator is included.

-- Ultraviolet (UV) irradiator --

[0550] Examples of the ultraviolet irradiator include, for example, a high-pressure mercury lamp, an ultra-pressure mercury lamp, a metal halide lamp, and the like.

[0551] The high-pressure mercury lamp is a light source, but a DeepUV type, which has improved light utilization efficiency in combination with an optical system, is capable of short-wavelength irradiation.

[0552] The metal halide lamp is effective in coloring a material because of its wide wavelength range, a metal halide of a metal such as Pb, Sn, or Fe is used, and the metal halide lamp can be selected according to the absorption spectrum of the polymerization initiator. The lamp used for curing is not particularly limited and may be selected according to the purpose, and a commercially available lamp such as a H lamp, a D lamp, or a V lamp provided by the Fusion System Company may be used.

[0553] Desirably, the three-dimensional object forming apparatus is of heater-less, and can form a three-dimensional object at room temperature.

<Return stroke layer forming unit and a return stroke layer forming step>

[0554] The return stroke layer forming unit is a unit for discharging the object forming material and forming an object forming layer. The return stroke layer forming unit may cause the flattening member to touch the surface of a layer of the object forming material discharged at a return stroke to flatten the surface of the layer of the object forming material, and then cure the layer of the object forming material to form an object forming layer.

[0555] The return stroke layer forming step is a step of discharging the object forming material and forming an object forming layer. The return stroke layer forming step may be implemented by causing the flattening member to touch the surface of a layer of the discharged object forming material and flattening the layer of the object forming material, and then curing the layer of the object forming material to form an object forming layer.

[0556] Discharging of the object forming material is desirably implemented with the use of an object forming material discharging unit.

[0557] Desirably, the object forming material is cured with the use of an object forming material curing unit.

<Object forming material discharging unit>

[0558] The object forming material discharging unit is a unit that discharges the object forming material at a return stroke.

[0559] As for the object forming material discharging unit for a return stroke, there is no particular restriction as long as the object forming material is discharged at a return stroke, and the object forming material discharging unit can be appropriately selected according to the purpose. For example, it is possible to use an object forming material discharging unit the same as or similar to the object forming material discharging unit

for a forward stroke.

[0560] The object forming material discharging unit for a return stroke may be the same as or different from the object forming material discharging unit for a forward stroke.

[0561] The object forming material discharging unit for a forward stroke may be used also as the object forming material discharging unit for a return stroke, for example, by making the object forming material discharging unit for a forward stroke movable in both directions. Further, for example, by making the forming stage on which a three-dimensional object is formed movable in both directions while the position of the object forming material discharging unit is fixed, the object forming material discharging unit for a forward stroke may be used also as the object forming material discharging unit for a return stroke.

[0562] It is desirable that the object forming material be discharged at a return stroke precisely over the object forming layer formed at a forward stroke that has been already cured. However, the layer of the object forming material formed at the return stroke may include an area where the layer formed at the forward stroke does not overlap, and the layer of the object forming material of the return stroke and the layer of the object forming material of the forward stroke may be somewhat different in the formed positions.

[0563] For example, after the layer is formed at the forward stroke and cured as depicted in Fig. 59,(C), the layer of the object forming material is formed at the return stroke at the position different approximately 80 μm in the Y direction (sub-scanning direction) from the position of the layer of the object forming material of the forward stroke in Fig. 59, (D).

[0564] The total discharge amount of the object forming material at the return stroke is greater than the total discharge amount of the object forming material of the forward stroke.

[0565] It is desirable that the total discharge amount of the object forming material at the return stroke be not less than 1.2 times and not more than 3 times the total discharge amount of the object forming material at the forward stroke.

[0566] A method of controlling the total discharge amount of the object forming material at the return stroke to be larger than the total discharge amount of the object forming material at the forward stroke is, for example, a method of increasing the size of a droplet of the object forming material fired at the return stroke to be larger than the size of a droplet of the object forming material fired at the forward stroke.

[0567] Examples of the method of making a droplet of the object forming material at the return stroke larger than a droplet of the object forming material at the forward stroke include a method of making a pulse voltage for firing a droplet of the object forming material at the return stroke greater than a pulse voltage for firing the object forming

material at the forward stroke to increase the size of a droplet of the object forming material at the return stroke; and a method of making the number of pulses for firing droplets of the object forming material before landing at the return stroke greater than the number of pulses for firing droplets of the object forming material before landing at the forward stroke, thereby increasing the size of a droplet of the object forming material at the return stroke obtained from combining of the droplets of the discharged object forming material together while flying of the droplets.

[0568] Referring to Fig. 68, a method of making a pulse voltage for firing a droplet of the object forming material at the return stroke greater than a pulse voltage for firing a droplet of the object forming material at the forward stroke to increase the size of the droplet of the object forming material at the return stroke will be now described.

[0569] Hereinafter, an example of a liquid discharging head using a piezoelectric element as a pressure generating unit will be described.

[0570] By applying a driving pulse P1 at the forward stroke to the piezoelectric element of the head 11 (see Fig. 68, (a)), a droplet D1 of the object forming material at the forward stroke is fired from the nozzle (see Fig. 68, (b)). Thereafter, by applying a driving pulse P2 at the return stroke to the piezoelectric element of the head 30011 (see Fig. 68, (a)), a droplet D2 of the object forming material at the return stroke is fired from the nozzle (see Fig. 68, (b)).

[0571] As depicted in Fig. 68, (a), the driving pulse P1 of the forward stroke is formed of a waveform element a at which the voltage falls from an intermediate potential Ve to a predetermined fallen potential, a waveform element b at which the voltage is kept at the fallen potential, and a waveform element c at which the voltage rises up from the fallen potential to the intermediate potential Ve. By providing the waveform elements a-c, a droplet is fired from the nozzle.

[0572] The driving pulse P2 of the return stroke is the same as the driving pulse P1 of the forward stroke.

[0573] Here, as depicted in Fig. 69, the higher the pulse voltage, the greater the droplet volume (in pL) of the object forming material.

[0574] Fig. 70 depicts relationships with the pulse voltage when the longitudinal axis is changed to the thickness from the volume of Fig. 69. The higher the pulse voltage becomes, the greater the film thickness becomes. The waveform used is the waveform of the return stroke.

[0575] Fig. 71 depicts relationships between the discharge amount at the return stroke and the film thickness. As depicted, the film thickness is proportional to the discharge amount of the return stroke. From the result of Fig. 71, the target discharge amount of the forward stroke is set at 25 pL to obtain the film thickness of approximately 14 μm.

[0576] Accordingly, as depicted in Fig. 68,(a), when the fallen potential of the driving pulse

P2 at the return stroke is set to be lower than the fallen potential of the driving pulse P1 at the forward stroke, that is, the pulse voltage for firing a droplet of the object forming material at the return stroke is set to be greater than the pulse voltage for firing a droplet of the object forming material at the forward stroke, the volume of the droplet D2 fired by the driven pulse P2 at the return stroke can be made greater than the volume of the droplet D1 fired by the driven pulse P1 at the forward stroke (see Fig. 68,(b)).

[0577] Referring to Fig. 72, a method for increasing the number of pulses for firing droplets of the object forming material at a return stroke before landing to not less than the number of pulses for firing droplets at a forward stroke before landing, and combining the droplets of the discharged object forming material while flying of the droplets to increase the size of a droplet of the object forming material in the return stroke will be described.

[0578] Hereinafter, an example of a liquid discharge head in which a piezoelectric element is used as a pressure generating unit will be described.

[0579] Fig. 72 depicts a view for illustrating a method for forming one drop of the object forming material at a forward stroke and forming two droplets of the object forming material and combining the droplets at a return stroke.

[0580] As a result of applying of a driving pulse P1 at a forward stroke to the piezoelectric element of the head 11 (see Fig. 72, (a)), a droplet D1 of the object forming material in the forward stroke is fired from a nozzle (see Fig. 72, (b)). Thereafter, two droplets D2 and D3 of the object forming material are sequentially fired (see Fig. 72, (b)) from a nozzle at a return stroke as a result of applying of driving pulses P2 and P3 to the piezoelectric element of the head (see Fig. 72, (a)).

[0581] As depicted in Fig. 72, (a), as a result of the fallen potential of the driving pulse P3 at the return stroke is set lower than the fallen potential of the driving pulse P2 at the return stroke, that is, the pulse voltage for firing the droplet D3 of the object forming material at the return stroke is set greater than the pulse voltage for firing the droplet D2 of the object forming material at the return stroke, the speed Vj3 of the droplet D3 by the driving pulse P3 at the return stroke becomes faster than the speed Vj2 of the droplet D2 by the driving pulse P2 at the return stroke (see Fig. 72, (b)).

[0582] Accordingly, at the return stroke, the droplet D3 can catch up with the droplet D2 during the flight so that the droplets D3 and D2 are combined into one droplet D2+D3 that has a larger volume than the droplet D1 of the object forming material at the forward stroke (see Fig. 72, (b)).

[0583] In an embodiment of the present invention, it is desirable that the nozzle for discharging the object forming material at the forward stroke and the nozzle for discharging the object forming material at the return stroke are the same (i.e., the one

common nozzle common is used) in order to have the precise landing positions at the forward stroke and the return stroke.

[0584] It is important to accurately control the landing positions of the object forming material droplets from the viewpoint of achieving high-precision shaping and forming a precise dimension object. Even with precise control of the positional accuracy with respect to X-Y coordinates, the nozzle position may vary within the geometric tolerance, and this variation cannot be canceled even if the positional accuracy with respect to X-Y coordinates is implemented. In this regard, as a result of using of the common nozzle, there is only the single nozzle position, so that the geometric tolerance is virtually eliminated, and thus it is possible to achieve precise landing positions.

[0585] Hereinafter, the order in which a first forming material (e.g., the modelling material) and a second forming material (e.g., the supporting material) are discharged and cured for forming a laminate structure of a three-dimensional objects will be described.

[0586] In an embodiment of the present invention, because object forming material discharge amounts are different between a forward stroke and a return stroke, when the first forming material and the second forming material are alternately discharged, i.e., when the first forming material is discharged at a forward stroke and the second forming material is discharged at a return stroke, the heights of the layers of the two cured materials do not coincide, and the desired three-dimensional shape cannot be achieved. Therefore, by discharging the first forming material at a first forward stroke and the first forming material at a first return stroke, and discharging the second forming material at a second forward stroke and the second forming material at a second return stroke, it is possible to form the layers having the same heights.

[0587] As a method of curing the second object forming material after curing the first object forming material, a method in which an object forming layer at which each of the first and second object forming materials is cured is made different may be used.

[0588] That is, layers of the first forming material are formed started at an nth layer by m times of forward and return strokes, resulting in the n+m-1 layers formed and cured. Then, the (n+m)th layer of the first forming material is formed and cured, and at the same time, the nth layer of the second forming material is formed and cured. As a result, it is possible to obtain a three-dimensional object having a smooth surface of a modelling material part after the supporting material part is removed. There n is a natural number and m is a positive or negative integer. Desirably m is 2. When m=1, the surface roughness Rz is high. When $m \geqq 3$, the surface roughness Rz does not change, and this case is not desirable because of the decrease in productivity.

<<Object forming material at return stroke>>

[0589] As the object forming material at a return stroke, there is no particular limitation, and

the object forming material at a return stroke can be appropriately selected depending on the purpose, for example, a material similar to the object forming material at a forward stroke can be used.

[0590] As for the viscosity of the object forming material at a return stroke, there is no particular limit, and appropriate selection can be made depending on the purpose. However, because it is necessary to maintain the discharged shape from the time when the object forming material is discharged to the time when the object forming material is flattened by the flattening member and is cured, it is desirable that the viscosity is 100 mPa?s or less at a temperature of 25°C, it is more desirable that the viscosity is 3 mPa?s or more and 20 mPa?s or less at 25°C, and it is particularly desirable that the viscosity is 6 mPa?s or more and 12 mPa?s or less at 25°C.

[0591] The viscosity can be measured under an environment of 25°C using, for example, a rotating viscometer (VISCOMATE VM-150III, manufactured by TOKI SANGYO CO., LTD.).

[0592] The surface tension of the object forming material at a return stroke is not particularly limited and can be appropriately selected depending on the purpose. However, from the viewpoint of flattening the surface of the object forming material, it is desirable that the surface tension be not less than 20 mN/m and not more than 45 mN/m, and it is more desirable that the surface tension be not less than 25 mN/m and not more than 34 mN/m.

[0593] The surface tension can be measured by, for example, a surface tension meter (an automatic contact angle meter DM-701, manufactured by Kyowa Interface Science Co., Ltd.).

<<Flattening member>>

[0594] The flattening member is a unit that flattens a layer of the object forming material at the return stroke by touching the surface of the layer of the discharged object forming material at the return stroke.

[0595] As the flattening member, as long as the layer of the object forming material at the return stroke is flattened by touching of the surface of the layer of the discharged object forming material at the return stroke, there is no particular limit, and the flattening member can be appropriately selected according to the purpose. For example, a roller, a blade, or the like can be used.

[0596] In the three-dimensional object forming apparatus, the total discharge amount of the object forming material at the return stroke is greater than the total discharge amount of the object forming material at the forward stroke. Accordingly, the thickness of the object forming material layer (RSL) formed at the return stroke is greater than the thickness of the object forming material layer (GSL) formed at the forward stroke.

[0597] As depicted in Fig. 60, in the three-dimensional object forming apparatus, a rotating

roller as the flattening member FM is caused to touch laterally against an end of a layer of the object forming material formed at a return stroke, which is thicker than the thickness of a layer of the object forming material formed at a forward stroke. This allows the extra portion of the layer of the object forming material, including rounded ends, to be scraped off, the surface of the layer of the object forming material to be flattened, and the ends of the layer of the object forming material to be sharpened.

[0598] The angle (θ in Fig. 60) between the wall surface of the end of the object forming material layer formed at the return stroke and the forming stage on which the three-dimensional object is formed is desirably 80 degrees or more and 100 degrees or less, and more desirably, the angle is close to 90 degrees (vertical). When the angle is 80 degrees or more and 100 degrees or less, when the flattening member FM comes into contact with the object forming material layer formed at the return stroke from the lateral direction, the edge of the object forming material layer formed at the return stroke can be scraped off so that the surface of the object forming material layer formed at the return stroke is flattened.

[0599] In the three-dimensional object forming apparatus according to an embodiment of the present invention, the thickness of the object forming material layer formed at the return stroke is formed to be thicker than the thickness of the object forming material layer formed at the forward stroke, so that a greater roller scraping margin (the distance between the roller FM and the object forming material layer formed at the forward stroke) can be secured.

[0600] It is desirable that the ratio of the roller scraping margin to the minimum thickness of the laminate structure after the object forming material layer is formed at the return stroke on the object forming material layer formed at the forward stroke (that is, the height to the recess at the center of the object forming material layer formed at the return stroke) be 10% or more. When the ratio of the roller scraping margin to the minimum thickness of the laminate structure is 10% or more, it is possible to prevent collision between the roller and the object forming material layer of the forward stroke which has been cured, and further, it is possible to prevent the surface of the object forming material layer of the return stroke from waving or being damaged.

[0601] It is desirable that the thickness of the roller scraping margin be 3 μm or more, and more desirably 5 μm or more.

[0602] As depicted in Fig. 70, the thus scraped portion of the object forming material layer of the return stroke is conveyed on the roller FM as the roller FM rotates and collected by a collecting member CM.

[0603] The collecting member CM is not particularly limited and can be appropriately selected depending on the purpose, for example, a blade.

[0604] As the shape of the roller as the flattening member FM, there is no particular

limitation as long as the object forming material layer of the return stroke can be scraped off, and the roller can be appropriately selected according to the purpose. For example, the roller may have a circular cross section, the cross section having a true circle, or the like.

[0605] The flattening member FM may have a vibration, which may cause a shift FMS in the direction of gravity, as depicted in Figs. 62-65.

[0606] It is desirable that such a shift FMS in the gravity direction of the flattening member FM between the forward stroke and the return stroke be 10 μm or less, and more desirably 5 μm or less.

[0607] In Fig. 62, the roller scraping margin RSM is 3 μm; the above-mentioned ratio is 12%; the shift FMS is 5μm; the Z-directional distance ZS between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 9 μm.

[0608] In Fig. 63, the roller scraping margin RSM is 9.5 μm; the above-mentioned ratio is 30%; the shift FMS is 5μm; the Z-directional distance between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 9 μm.

[0609] In Fig. 64, the roller scraping margin RSM is 1 μm; the above-mentioned ratio is 4%; the shift FMS is 5μm; the Z-directional distance ZS between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 9 μm.

[0610] In Fig. 65, the roller scraping margin RSM is 0 μm (i.e., a collision with the flattening member FM); the above-mentioned ratio is 0%; the shift FMS is 5μm; the Z-directional distance ZS between the flattening member FM and the forming stage is 22.5μm; and the height EP of an end projection is 18 μm.

<Object forming material curing unit>

[0611] The object forming material curing unit for a return stroke cures a flattened object forming material discharged at a return stroke to form an object forming layer.

[0612] As long as the object forming material discharged at a return stroke having been flattened can be cured to form an object forming layer, there is no particular limitation, and the object forming material curing unit may be appropriately selected depending on the purpose. For example, an object forming material curing unit similar to or the same as the object forming material curing unit for a forward stroke described above may be used.

[0613] The object forming material curing unit for a return stroke may be the same as or different from the object forming material curing unit for a forward stroke.

[0614] According to the three-dimensional object forming method, by repeating a forward stroke layer forming step and a return stroke layer forming step a plurality of times, it is possible to obtain a three-dimensional object.

[0615] Desirably, the flattening member is in contact with each object forming layer. This

allows the edges to be sharpened and the flatness to be improved for each object forming layer.

[0616] Desirably, an object forming layer is formed by two strokes, i.e., a forward stroke and a return stroke.

[0617] Repeated forming of object forming layers on top of each other allows for sharp edges and high-resolution of a three-dimensional object with excellent flatness.

[0618] Hereinafter, an outline of a three-dimensional object forming apparatus according to an embodiment of the present invention will be described. Fig. 73 depicts a front view of a main part of the three-dimensional object forming apparatus, Fig. 74 depicts a plan view of the three-dimensional object forming apparatus, and Fig. 75 depicts a side view of the three-dimensional object forming apparatus.

[0619] The three-dimensional object forming apparatus 30010 is a material jetting apparatus, including a stage 30014, which is a forming stage on which object forming layers 30030 are formed on top of each other to form a three-dimensional object, and a forming unit 30020, which forms a three-dimensional object by forming object forming layers 30030 on top of each other sequentially on the stage 30014.

[0620] The forming unit 30020 includes in a unit holder 30021 including a first head 30011 as a discharging unit for discharging the object forming material, UV irradiators 30013 for irradiating ultraviolet light as an active energy ray, and flattening rollers 30016 as flattening members for flattening an object forming layer 30030. In addition, second heads 30012 may be provided for discharging the supporting material supporting the shape of a three-dimensional object in addition to the object forming material as the modelling material for forming the shape of the three-dimensional object.

[0621] In the X-direction, the two second heads 30012 are disposed on both sides of the first head 30011, the UV irradiators 30013 are disposed on the outside of the two second heads 30012, and the flattening rollers 30016 are disposed on the outside of the UV irradiators 30013 as the flattening members.

[0622] The object forming material is supplied to the first head 30011 from a cartridge 30060 which is interchangeably loaded in a cartridge loading unit 30056 through a feed tube or the like. When color object forming materials having colors such as black, cyan, magenta, and yellow are used, a plurality of nozzle arrays for discharging droplets of these colors may be disposed in the first head 30011.

[0623] The UV irradiators 30013 cure the object forming material discharged from the first head 30011. The UV irradiators 30013, when the supporting material is used, cure an object forming layer 30030 made of the supporting material discharged from the second heads 30012.

[0624] When ultraviolet irradiation lamps are used, it is desirable to provide a mechanism to remove the ozone generated by the ultraviolet irradiation.

[0625] Examples of the ultraviolet irradiation lamp include, for example, a high-pressure mercury lamp, an ultrahigh-pressure mercury lamp, a metal halide lamp, and so forth. Although an ultrahigh-pressure mercury lamp is a light source, an ultraviolet irradiation lamp, for which the light utilization efficiency is improved by combination with an optical system, is capable of irradiating in a short wavelength range. A metal halide lamp is effective for curing colorants because of having a wide wavelength range. A metal halide, such as Pb, Sn, or Fe, may be used and can be selected to match the absorption spectrum of the polymerization initiator.

[0626] The flattening rollers 30016 flatten the surface of a cured object forming layer 30030 on the stage 30014 by a relative movement with respect to the stage 30014 while being rotated.

[0627] The term "on the stage 30014" means, unless otherwise specified, on the stage 30014 and on an object forming layer 30030 formed on the stage 30014.

[0628] The unit holder 30021 of the forming unit 30020 is movably held by guide members 30054 and 30055 disposed in the X-direction.

[0629] A maintenance mechanism 30061 for maintaining and recovering the first head 30011 is disposed on one side of the forming unit 30020 in the X direction.

[0630] Also, the guide members 30054 and 30055 holding the unit holder 30021 of the forming unit 30020 are held by side plates 30070. The side plates 30070 include a slider portion 30072 which is movably held by the guide member 30071 disposed on a base member 30007, and the forming unit 30020 is movable in forward and return ways along the Y direction perpendicular to the X direction.

[0631] The stage 30014 is lifted and lowered in the Z-direction by a lifting and lowering unit 30015. The lifting and lowering unit 30015 is movably disposed on the guide members 30075 and 30076 disposed in the X-direction on the base member 30007.

[0632] Next, an outline of object forming operation by the three-dimensional object forming device 30010 will be described with reference to Fig. 73.

[0633] First, the forming unit 30020 is moved in the Y direction to position above the stage 30014. Next, while the stage 30014 is moved relative to the forming unit 30020 which is stopped, the modelling material 30301 is discharged from the first head 30011 to an object forming section (the section where the three-dimensional object is formed). When the supporting material is used, the supporting material 30302 is discharged from the second heads 30012 to the supporting section (the section from where the supporting material is removed after object forming operation) other than the object forming section.

[0634] The UV irradiators 30013 then irradiate ultraviolet rays onto the modelling material 30301 and the supporting material 30302 to cure the materials to form a single object forming layer 30030 including the modelling section 30017 of the modelling material

30301 and the supporting section 30018 of the supporting material 30302.

[0635] An object forming layer 30030 is repeatedly formed and sequentially formed on top of each other to form a three-dimensional object formed of the modelling material 30301 while the modelling material 30301 is supported by the supporting material 30302. For example, in the example of Fig. 73, the five object forming layers 30030A-30030E are formed on top of each other.

[0636] For example, the flattening rollers 30016 are pressed against the surface of an object forming layer 30030 to flatten the object forming layer 30030 each time when some object forming layers 30030 (the actual number of the layers not necessarily having a fixed value) are formed on top of each other, for example, when every 10 layers are formed on top of each other. Thus, the thickness accuracy and flatness of the object forming layers 30030 are ensured.

[0637] When the flattering members have roller shapes, such as the flattening rollers 30016, the flattening rollers 30016 are rotated in a direction reversed to the moving direction in the X direction, so that the flattening effect can be improved.

[0638] In order to keep the gap between the forming unit 30020 and the top object forming layer 30030 constant, the stage 30014 is lowered by the lifting and lowering unit 30015 for each object forming layer 30030 being formed. The forming unit 30020 may be moved up and down instead.

[0639] The three-dimensional object forming apparatus may include a collection unit collecting the modelling material 30301 and the supporting material 30302, a recycling mechanism for the modelling material and the supporting material, and the like. The first head 30011 and the second heads 30012 may be provided with discharge condition detecting units detecting non-discharge nozzles. In addition, the ambient temperature in the three-dimensional object forming apparatus during object forming operation may be controlled.

[0640] Fig. 76 depicts a diagram for illustrating a manner in which the object forming material is discharged while nozzle positions are changed between forward and return strokes to form an object forming layer.

[0641] At a return stroke, a head is shifted 1 mm in the Y direction from a forward stroke in a manner of interlacing. In addition, at the return stroke, nozzles to be used are overlapped with nozzles used at the forward stroke.

[0642] No movement in the Y direction may be performed at a return stroke, and discharging may be performed at the same coordinates. Then, the head is moved to the next block for discharging.

[0643] Further, the starting position for the next layer is shifted by the 1 mm in the Y coordinate from the current layer. After the shifting by 1 mm per layer is repeated four times, the position is returned to the original position. That is, the starting positions are

repeated every five layers.

[0644] The reason for shifting 1 mm between forward and return strokes and shifting 1 mm per layer is to improve a margin for a nozzle defect.

(Three-dimensional object forming program)

[0645] The three-dimensional object forming program of an embodiment of the present invention performs a process of discharging the object forming material at a forward stroke to form an object forming layer, and discharging the object forming material at a return stroke to form an object forming layer. In this regard, in the same object forming layer, the object forming material discharge amount at the forward stroke is reduced at an overlapping portion where scanning operations at the forward stroke and the return stroke overlap, to less than the object forming material discharge amount discharged at the return stroke.

[0646] For example, the above-mentioned process of reducing the object forming material discharge amount at the forward stroke at the overlapping portion or preventing discharging of the object forming material at the forward stroke at the overlapping portion may be a process of adjusting the pulse voltage for firing droplets of the object forming material at the forward stroke to be less than the pulse voltage for firing droplets of the object forming material at the return stroke to reduce the size of the droplets of the object forming material at the forward stroke, thus the object forming material discharge amount in the forward stroke being reduced.

[0647] Processing according to the three-dimensional objecting program of an embodiment of the present invention can be implemented by using a computer having a control unit corresponding to a three-dimensional object forming apparatus.

[0648] An outline of the control unit will be described with reference to Fig. 77. Fig. 77 is a block diagram illustrating a control unit.

[0649] The control unit 30500 includes a main control unit 30500A including a CPU 30501 for controlling the entire apparatus, a ROM 30502 for storing the three-dimensional object forming program including instructions for controlling three-dimensional object forming operations of the CPU 30501 including control operations according to an embodiment of the present invention as well as other fixed data, and a RAM 30503 for temporarily storing object forming data.

[0650] The control unit 30500 also includes a non-volatile memory (NVRAM) 30504 for storing data even after the power of the apparatus is cut off. The control unit 30500 includes an ASIC 30505 for processing image processing for performing various signal processing on image data or for processing input/output signals for controlling the entire apparatus.

[0651] The control unit 30500 further includes an I/F 30506 for transmitting and receiving data and signals used to receive object forming data from an external object forming

data generating apparatus 30600.

[0652] The object forming data generating apparatus 30600 is an apparatus that produces object forming data (cross-sectional data) which is slice data obtained from slicing the final shape of a three-dimensional object on an object forming layer basis, and may be an information processing apparatus such as a personal computer.

[0653] The control unit 30500 includes an I/O 30507 for receiving sensing signals from various sensors.

[0654] The control unit 30500 includes a head driving control unit 30508 for driving and controlling the first head 30211 of an object forming unit and a head driving control unit 30509 for driving and controlling the second head 30212.

[0655] The control unit 30500 further includes a motor driving unit 30510 for driving a motor included in an X-direction moving mechanism 30550 for moving the object forming unit in the X-direction, and a motor driving unit 30511 for driving a motor included in a Y-direction scanning mechanism 30552 for moving the object forming unit in the Y-direction (a sub-scanning direction).

[0656] The control unit 30500 includes a motor driving unit 30513 for driving a motor included in a stage X-direction scanning mechanism 30553 that moves the forming stage 30214 in the X-direction together with the lifting and lowering unit 30215, and a motor driving unit 30514 for driving a motor included in the lifting and lowering unit 30215 that moves the forming stage 30214 in the Z-direction. The Z-direction movement may be implemented instead by lifting and lowering the object forming unit as described above.

[0657] The control unit 30500 includes a motor driving unit 30516 for driving a motor 30026 for rotating the flattening roller 30213, and a maintenance drive section 30518 for driving a maintenance mechanism 30061 for the first head 30211 and the second head 30212.

[0658] The control unit 30500 includes a curing control unit 30519 for controlling UV irradiation by the UV irradiator 30216.

[0659] The I/O 30507 of the control unit 30500 receives a sensing signal, such as a sensing signal from a temperature and humidity sensor 30560, which detects the temperature and humidity as an environmental condition of the apparatus, and other sensing signals from other sensors.

[0660] An operation panel 30522 is connected to the control unit 30500 for inputting and displaying various information.

[0661] The control unit 30500 receives object forming data from the object forming data generating apparatus 30600 as described above. Object forming data is data (object forming section data) for determining a shape of each object forming layer as slice data of a desired three-dimensional object.

[0662] A main control unit 30500A generates data in which data of a supporting section to provide the supporting material is added to the object forming data (object forming section data) and provides the data to the head driving control units 30508 and 30509. The head driving control units 30508 and 30509 respectively discharge droplets of the modelling material from the first head 30011 to an object forming section and discharge droplets of the liquid supporting material 30302 from the second head 30012 to a supporting section.

[0663] A combination of the object forming data generating apparatus 30600 and the three-dimensional object forming apparatus may be referred to as a three-dimensional object forming apparatus.

[0664] Fig. 78 is a diagram illustrating an example of a functional configuration of the three-dimensional object forming apparatus 30100.

[0665] As depicted in Fig. 78, the three-dimensional object forming apparatus 30100 includes an input unit 30110, an output unit 30120, a control unit 30130, and a storage unit 30140.

[0666] The control unit 30130 includes a forward stroke object forming material discharge amount adjusting unit 30131 and a return stroke object forming material discharge amount adjusting unit 30132. The control unit 30130 controls the three-dimensional object forming apparatus 30100.

[0667] The storage unit 30140 includes a forward stroke object forming material discharge amount database 30141 and a return stroke object forming material discharge amount database 30142. Hereinafter, a "database" may be referred to as a "DB".

[0668] The forward stroke object forming material discharge amount adjusting unit 30131 adjusts so as to reduce the object forming material discharge amount at a forward stroke or not to discharge the object forming material at the forward stroke. For example, a process of reducing the object forming material discharge amount at a forward stroke at the overlapping portion to less than the object forming material discharge amount at a return stroke may include, for example, a process of adjusting the pulse voltage for firing droplets of the object forming material at the forward stroke to be less than the pulse voltage for firing droplets of the object forming material at the return stroke to reduce the object forming material discharge amount at the forward stroke by reducing the size of the droplets of the object forming material at the forward stroke.

[0669] The return stroke object forming material discharge amount adjusting unit 30132 adjusts the object forming material discharge amount at the return stroke so as to increase the object forming material discharge amount. For example, (1) a method of adjusting the total discharge amount of the object forming material at the return stroke to be increased by increasing the size of the droplets of the object forming material at

the return stroke, (2) a method of adjusting the total discharge amount of the object forming material at the return stroke to be increased by combining a plurality of droplets of the object forming material discharged at the return stroke while flying of the droplets.

[0670] Information indicating the thus adjusted object forming material discharge amount at the return stroke is stored in the return stroke object forming material discharge amount DB 30142.

[0671] Next, the processing procedure of the three-dimensional objecting program of an embodiment of the present invention is described. Fig. 79 depicts a flowchart for illustrating a processing procedure of the three-dimensional object forming program executed by the control unit 30130 of the three-dimensional object forming apparatus 30100.

[0672] In step S30110, when the control unit 30130 of the three-dimensional object forming apparatus 30100 acquires the information of the forward stroke object forming material discharge amount A for the overlap portion stored in the forward stroked object forming material discharge amount DB 30141 of the storage unit 30140, the process proceeds to step S30111.

[0673] In step S30111, when the control unit 30130 of the three-dimensional object forming apparatus 30100 acquires the information of the return stroke object forming material discharge amount B for the overlap portion stored in the return stroked object forming material discharge amount DB 30142 of the storage unit 30140, the process proceeds to step S30112.

[0674] In step S30112, if the forward stroke object forming material discharge amount A is greater than or equal to the return stroke object forming material discharge amount B, the process proceeds to step S30113. If the forward stroke object forming material discharge amount A is smaller than the return stroke object forming material discharge amount B, the process ends.

[0675] In step S30113, the process of reducing the object forming material discharge amount at the forward stroke is performed, and the changed object forming material discharge amount at the forward stroke is stored in the forward stroke object forming material discharge amount DB 141, and the process returns to step S30110.

<Examples>

[0676] Hereinafter, examples of an embodiment of the present invention will be described, but the present invention is not limited in any way to these examples.

[0677] Here, Fig. 80 depicts a schematic diagram for illustrating a sub-scanning direction and a main scanning direction of a material-jetting object forming process.

[0678] Fig. 81 depicts a diagram for illustrating a roller and a height of a discharged object forming material at each scanning operation. In the related art, when rendering in the

sub-scanning direction is performed in a third scanning operation and an overlapping portion is generated between the second scanning operation and the third scanning operation, the roller moves at the same height as the third scanning operation, so that a collision occurs with a discharged object forming material.

[0679] On the other hand, in an embodiment of the present invention, by not discharging the object forming material at the second scanning operation or reducing the object forming material discharge amount at the second scanning operation at the overlapping portion, there is no discharged object forming material at the same position as the roller, and a collision does not occur at the third scanning operation.

(Example 4-1)

<Object forming material>

[0680] The modelling material was obtained as a result of 60 parts by weight of isoboryl acrylate (manufactured by Tokyo Chemical Industry Co., Ltd.), 10 parts by weight of tripropylene glycol (manufactured by Tokyo Chemical Industry Co., Ltd.), 5 parts by weight of dipropylene glycol (manufactured by Tokyo Chemical Industry Co., Ltd.), 20 parts by weight of UB-6600 (manufactured by Nippon Gohsei Co., Ltd.), and 5 parts by weight of IRGCURE-TPO (manufactured by IGM) being mixed, stirred with a magnetic stirrer for 12 hours, and filtered through 13JP050AN (manufactured by Advantech Co., Ltd.).

[0681] The supporting material was obtained as a result of 40 parts by weight of acryloyl-morpholine (KJ Chemicals, Inc.), 40 parts by weight of polypropylene glycol molecular weight 700 (Nikko Co., Ltd.), 8 parts by weight of 1,6-hexanediol (Tokyo Chemical Industry Co., Ltd.), 8 parts by weight of octanol (Tokyo Chemical Industry Co., Ltd.), and 4 parts by weight of IRGCURE-819 (IGM) being mixed, and filtered in the same manner as the modelling material.

<Object forming method>

[0682] An inkjet head MH2420 (manufactured by Ricoh Company, Ltd.) was used for an object forming process. The starting position of the first scanning operation was the origin (X0, Y0), and the modelling material was discharged from all the 192 nozzle channels and cured. At the second scanning operation, the modelling material was discharged from 182 channels after a movement for a distance corresponding to 192 channels in the sub-scanning direction (Y) and cured. Here, the 182 channels correspond to 10 (= m) overlapping nozzles in the sub-scanning direction at the time of movement. At the third scanning operation, the modelling material was discharged from all the 192 channels after a movement for a distance corresponding to 182 channels in the sub-scanning direction and cured. The total movement amount per layer corresponds to 566 channels (= 192 × 3 - 10).

[0683] Thus, a three-dimensional object of Example 4-1 was obtained.

(Example 4-2)

[0684] A three-dimensional object according to Example 4-2 was obtained in the same manner as Example 1, except that the discharge amount at the first scanning operation corresponds to 182 channels, the movement amount before the second scanning operation corresponds to 182 channels, the discharge amount at the second scanning operation was 192 channels, and the movement amount before the third scanning operation corresponds to 192 channels. The total movement distance corresponds to 566 channels.

(Comparison example 4-1)

[0685] A three-dimensional object according to Comparison example 4-1 was obtained in the same manner as Example 1, except that the discharge amount at the second scanning operation corresponds to 192 channels and the discharge amount at the third scanning operation was 182 channels. The total movement distance corresponds to 566 channels.

(Comparison example 4-2)

[0686] A three-dimensional object according to Comparison example 4-2 was obtained in the same manner as Example 1, except that the discharge amount at the second scanning operation corresponds to 192 channels and the movement amount before the third scanning operation was 192 channels. The total movement distance corresponds to 576 channels.

(Comparison example 4-3)

[0687] A three-dimensional object according to Comparison example 4-3 was obtained in the same manner as Example 4-1, except that the starting position of the first scanning operation was (X0, Y-10) and the movement amount before the third scanning operation was 192 channels. The total movement distance corresponds to 576 channels.

[0688] Next, the characteristics of Examples 4-1 and 4-2 and Comparison examples 4-1 through 4-3 are evaluated as follows. The results are depicted in Table 2.

<Total movement distance>

[0689] The total movement distance is the sum of the movement amounts in the sub-scanning direction for the first through third scanning operations. There are relationships such that productivity decreases as the total movement distance increases.

<Collision>

[0690] A collision was evaluated based on whether a three-dimensional object with dimensions: X=5mm, Y=60mm, and Z=60mm was being able to formed. When there was a substantial collision between the roller and the discharged object forming material, an object was not being able to be obtained because the discharged object forming material (i.e., an incomplete three-dimensional object) fallen in the object

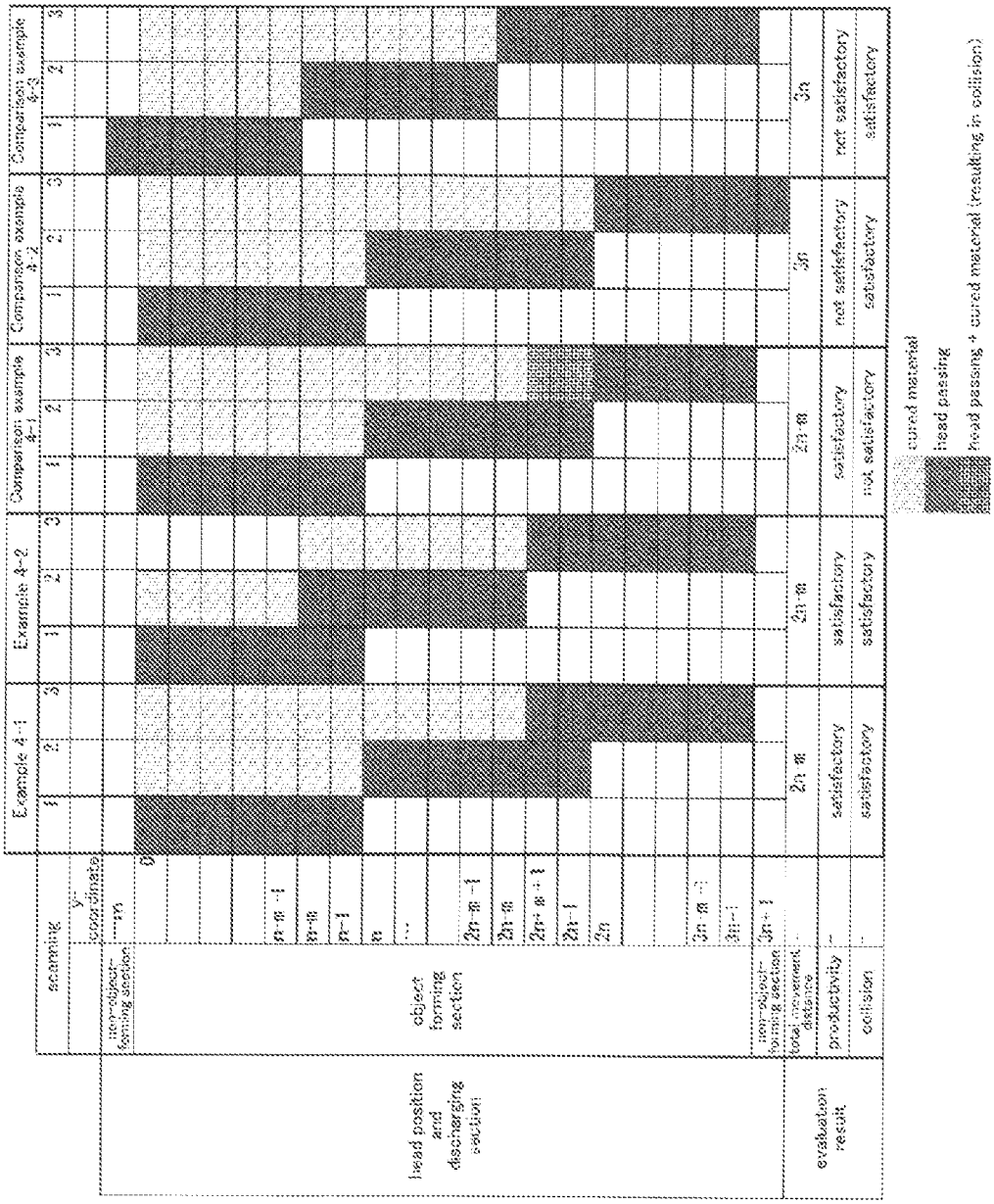
forming area or was flipped out of the object forming area during the object forming process.

<Evaluation criteria>

[0691] satisfactory: a three-dimensional object of Z=60mm was being able to be obtained.

[0692] not satisfactory: a three-dimensional object fallen when the three-dimensional object of Z=60mm was being formed.

[Table 2]



[0693] In Table 2, the origin is a point at which an object forming process was started from among the four corners of the object forming area, "n" denotes the number of all

nozzles of the material discharging head, and "m" denotes the number of nozzles to be overlapped upon a scanning operation.

[0694] Examples of the mode IV for carrying out the invention of the present invention included in the fourth embodiment group are as follows.

<1>

[0695] A three-dimensional object forming method includes a layer forming step of discharging an object forming material to form an object forming layer during a main scanning operation. When a main scanning area of a head overlaps with respect to forming one object forming layer, an object forming material discharge amount at a previous scanning operation at an overlapping portion is made less than an object forming material discharge amount at a final scanning operation.

<2>

[0696] In the three-dimensional object forming method according to item <2>, at the overlapping portion, the object forming material is not discharged at the previous scanning operation.

<3>

[0697] In the three-dimensional object forming method according to item <1> or <2>, a head moves in a sub-scanning direction relatively for forming one object forming layer.

<4>

[0698] In the three-dimensional object forming method according to item <3>, the layer forming step includes a step of discharging the object forming material at both a forward stroke and a return stroke in the main scanning direction; and the step of discharging the object forming material at both a forward stroke and a return stroke in the main scanning direction includes a step of moving the head in the sub-scanning direction with respect to discharging the object forming material at both a forward stroke and a return stroke in the main scanning direction.

<5>

[0699] In the three-dimensional object forming method according to item <3> or <4>, the head is moved in the sub-scanning direction during acceleration or deceleration of the head in the main scanning direction, after discharging the object forming material at the forward stroke.

<6>

[0700] In the three-dimensional object forming method according to any one of items <3> through <5>, movement of the head in the sub-scanning direction corresponds to rendering.

<7>

[0701] The three-dimensional object forming method according to any one of items <1> or

<6> includes a flattening step of flattening the surface of the object forming layer formed at the return stroke.

<8>

[0702] In the three-dimensional object forming method according to any one of items <1> through <7>, the total object forming material discharge amount at the return stroke is greater than the total object forming material discharge amount at the forward stroke.

<9>

[0703] In the three-dimensional object forming method according to any one of items <1> through <8>, for forming one object forming layer, the first forming material is discharged and cured, and then, the second forming material is discharged and cured.

<10>

[0704] In the three-dimensional object forming method according to item <9>, the first forming material is discharged and cured for an nth object forming layer and the second forming material is discharged and cured for an (n+m)th object forming layer (provided that n means a natural number and m means an integer which is positive or negative).

<11>

[0705] In the three-dimensional object forming method according to item <9>, the first forming material is discharged and cured for an nth object forming layer and the second forming material is discharged and cured for an (n+2)th object forming layer (provided that n means a natural number).

<12>

[0706] A three-dimensional object forming apparatus includes a layer forming unit of discharging an object forming material to form an object forming layer during a main scanning operation. When a main scanning area of a head overlaps with respect to forming one object forming layer, an object forming material discharge amount at a previous scanning operation at an overlapping portion is made less than an object forming material discharge amount at a final scanning operation.

<13>

[0707] In the three-dimensional object forming apparatus according to item <12>, at the overlapping portion, the object forming material is not discharged at the previous scanning operation.

<14>

[0708] In the three-dimensional object forming apparatus according to item <12> or <13>, a head moves in a sub-scanning direction relatively for forming one object forming layer.

<15>

[0709] In the three-dimensional object forming apparatus according to item <13>, the layer

forming unit includes a unit of discharging the object forming material at both a forward stroke and a return stroke in the main scanning direction and the unit of discharging the object forming material at both a forward stroke and a return stroke in the main scanning direction performs moving the head in the sub-scanning direction with respect to discharging the object forming material at both a forward stroke and a return stroke in the main scanning.

<16>

[0710] In the three-dimensional object forming apparatus according to any one of items <13> through <15>, the head is moved in the sub-scanning direction during acceleration or deceleration of the head in the main scanning direction, after discharging the object forming material at the forward stroke.

<17>

[0711] In the three-dimensional object forming apparatus according to any one of items <13> through <15>, movement of the head in the sub-scanning direction corresponds to rendering.

<18>

[0712] The three-dimensional object forming apparatus according to any one of items <13> through <17> includes a flattening unit of flattening the surface of the object forming layer formed at the return stroke.

<19>

[0713] In the three-dimensional object forming apparatus according to any one of items <12> through <18>, the total object forming material discharge amount at the return stroke is greater than the total object forming material discharge amount at the forward stroke.

<20>

[0714] In the three-dimensional object forming apparatus according to any one of items <12> through <19>, for forming one object forming layer, the first forming material is discharged and cured, and then, the second forming material is discharged and cured.

<21>

[0715] A program causes a computer to execute a layer forming step of discharging an object forming material to form an object forming layer during a main scanning operation. When a main scanning area of a head overlaps with respect to forming one object forming layer, an object forming material discharge amount at a previous scanning operation at an overlapping portion is made less than an object forming material discharge amount at a final scanning operation.

[0716] The three-dimensional object forming method according to any one of the items <1> through <11>, the three-dimensional object forming apparatus according to any one of items <12> through <20>, and the program of item <21> can solve the above-

described problem and achieve the above-described object of the mode IV for carrying out the invention of the present invention.

<Mode V for carrying out the invention>

[0717] Hereinafter, a mode V for carrying out the invention of the present invention will be described.

[0718] The mode V for carrying out the invention of the present invention relates to a three-dimensional object forming apparatus, a three-dimensional object forming method, and a three-dimensional object forming program.

[0719] A technique called additive manufacturing (AM) is known as a technique for forming a three-dimensional object. This technique calculates a thin cut cross-sectional shape along the direction of lamination, and then forms each layer according to the shape to form a laminate three-dimensional object.

[0720] In recent years, material jetting technology that forms a three-dimensional object by forming a curable resin on top of each other has attracted attention from among the additive manufacturing technologies. According to the material jetting method, when a modelling section that is a three-dimensional object body is formed, a supporting section supporting the modelling section can be formed so that a shape that is difficult to form in principle (for example, a shape having an overhang portion) can be formed.

[0721] In an object forming method of the related art, there may be a problem that a roller as s flattening member collides with a discharged material when a supporting layer is formed. In particular, the material jetting method in some way discharges a modelling material and a supporting material, flattens the material by a flattening member, and irradiates UV light thereon to obtain an object forming layer. Therefore, in order to reduce mixing of the modelling material with the supporting material, it is necessary to discharge and cure the modelling and supporting material at different scanning operations.

[0722] Accordingly, for example, at a scanning operation of discharging the modelling material, an object forming apparatus in which a head position in the sub-scanning direction is shifted for each layer has been proposed (see, for example, PTL 6).

[0723] It is an object of an embodiment of the mode V for carrying out the invention of the present invention to provide a three-dimensional object forming apparatus in a material jetting method, which is capable of reducing mixing between a modelling material and a supporting material at an interface and also of reducing collision of a flattening member with a discharged material.

[0724] A three-dimensional object forming apparatus according to an embodiment of the mode V for carrying out the invention of the present invention for solving the above-described problem includes a layer forming unit that discharges a modelling material from a head at first forward and return scanning operations in order to form a plurality

of modelling layers, and subsequently discharges a supporting material from a head in a second forward and return scanning operations in order to form a plurality of supporting layers. For at least some of the plurality of modelling layers and the plurality of supporting layers, the positions of the heads for discharging the materials to form the layers in the sub-scanning direction are different for forming one object forming layer.

[0725] According to the embodiment of the present invention, in a material jetting method, a three-dimensional object forming apparatus in which mixing of a modelling material with a supporting material at an interface is reduced and collision of a flattening member with a discharged material is reduced can be achieved.

(Three-dimensional object forming apparatus, three-dimensional object forming method, and three-dimensional object forming program of mode V for carrying out the invention)

[0726] A three-dimensional object forming apparatus of an embodiment of the mode V for carrying out the invention of the present invention includes a layer forming unit for discharging a modelling material from a head at first forward and return scanning operations to form a plurality of modelling layers and subsequently discharging a supporting material at second forward and return scanning operations to form a plurality of supporting layers. At least for some of the plurality of modelling layers and the plurality of supporting layers, head positions in the sub-scanning direction are different.

[0727] A three-dimensional object forming method of an embodiment of the mode V for carrying out the invention of the present invention includes a layer forming step of discharging a modelling material from a head at first forward and return scanning operations to form a plurality of modelling layers and subsequently discharging a supporting material at second forward and return scanning operations to form a plurality of supporting layers. At least for some of the plurality of modelling layers and the plurality of supporting layers are, head positions in the sub-scanning direction are different.

[0728] A three-dimensional object forming program of an embodiment of the mode V for carrying out the invention of the present invention causes a computer to execute a layer forming step of discharging a modelling material from a head at first forward and return scanning operations to form a plurality of modelling layers and subsequently discharging a supporting material at second forward and return scanning operations to form a plurality of supporting layers. At least for some of the plurality of modelling layers and the plurality of supporting layers, head positions in the sub-scanning direction for discharging the materials to form the layers are different.

[0729] A control unit included in the "three-dimensional object forming apparatus" of the

embodiment of the present invention is equivalent to implementation of the "three-dimensional object forming method" of the embodiment of the present invention. Therefore, the details of the "three-dimensional object forming method" of the embodiment of the present invention will be clarified through the description of the "three-dimensional object forming apparatus" of the embodiment of the present invention. Because the "three-dimensional object forming program" the embodiment of the present invention is implemented the "three-dimensional object forming apparatus " of the embodiment of the present invention by using a computer as a hardware resource, the details of the "three-dimensional object forming program" of the embodiment of the present invention will also be clarified through the description of the "three-dimensional object forming apparatus" of the embodiment of the present invention.

[0730] In the related art, because a position of a head is shifted in the sub-scanning direction for each layer, when, for example, a modelling layer is formed at a preceding first scanning operation and a supporting layer is formed at a subsequent second scanning operation, a roller as a flattening member may collide severely with the modelling layer when the supporting layer is formed, and there may be a problem that the surface of the discharged material may have a rippled shape, the roller is broken, and/or the sharpness of an end portion of the three-dimensional object may be insufficient.

[0731] According to the mode V for carrying out the invention, in a material jetting method, a modelling material is discharged from a head at first forward and return scanning operations in which a plurality of modelling layers are formed, and a supporting material is discharged from a head at subsequent second forward and return scanning operations in which a plurality of supporting layers are formed. In this regard, head positions for discharging the materials to form at least some of the plurality of modelling layers and the plurality of supporting layers may be different in the sub-scanning direction. As a result, it is possible to reduce mixing at an interface between the modelling material and the supporting material, and a collision of the flattening member with the discharged material can be reduced.

[0732] Here, the above-described feature that "head positions for discharging the materials to form at least some of the plurality of modelling layers and the plurality of supporting layers may be different in the sub-scanning direction" means that, upon forming of one slice layer, the positions of the heads are different in the sub-scanning direction between forward and return scanning operations forming modelling layers and the forward and return scanning operations forming supporting layers.

[0733] In one aspect of the mode V for carrying out the invention of the present invention, it is desirable that the position of the head in the sub-scanning direction at a scanning operation for discharging the supporting material for an nth layer from among the plurality of supporting layers is made to be the same as the position of the head in the

sub-scanning direction at any scanning operation from among the scanning operations of discharging the modelling material for the nth layer from among the plurality of modelling layers to reduce a collision of the roller as a flattening member with a discharged material.

[0734] In one aspect of the mode V for carrying out the invention of the present invention, it is desirable that the position of the head at a scanning operation for discharging the supporting material at an nth slice layer of a plurality of slice layers including the plurality of modelling layers and the plurality of supporting layers is made to be the same as the position of the head at the scanning operation for discharging the modelling material for the top layer included in of the nth slice layer of the plurality of slice layers, to reduce the object forming time and a collision of the roller as the flattening member with the discharged material.

[0735] The term "slice layer" means a set of a modelling layer and a supporting layer.

[0736] In one aspect of the mode V for carrying out the invention of the present invention, it is desirable that, with respect to forming of a supporting layer at the earliest first scanning operation included in a layer or a slice layer, it is desirable that the supporting layer is formed from a position in the sub-scanning direction opposite to a position in the sub-scanning direction from which a scanning operation for forming a modelling layer formed at the immediately preceding scanning operation is started, to reduce the object forming time.

[0737] In another aspect of the mode V for carrying out the invention of the invention, it is desirable to use a flattening member for flattening at least one of a modelling layer and a supporting layer, and, upon a scanning operation of the flattening member, at least one of the modelling material and the supporting material is discharged, so that it is possible to produce a three-dimensional object having a satisfactory edge.

<Layer forming unit and layer forming step>

[0738] The layer forming step includes a step of discharging the modelling material from the head at first forward and return scanning operations to form a plurality of modelling layers and a step of subsequently discharging the supporting material from the head at second forward and return scanning operations to form a plurality of supporting layers. The layer forming step is performed by the layer forming unit.

[0739] It is desirable that the layer forming step is performed by moving the stage in a forward and return manner in mutually opposite directions.

[0740] In the above-described layer forming step, the discharged forming material may be cured to form an object forming layer.

[0741] Discharging of the object forming material is desirably performed using an object forming material discharging unit.

[0742] Desirably, the object forming material is cured using an object forming material

curing unit.

<Object forming material discharging unit>

[0743] As the object forming material discharging unit, there is no particular restriction as long as the object forming material (the modelling material and the supporting material) is discharged, and the object forming material discharging unit can be appropriately selected according to the purpose. For example, a publicly known device such as a head can be used.

[0744] As the head, there is no particular limitation and the head can be appropriately selected depending on the purpose, for example, a piezoelectric (piezo element) head, a thermal expansion (thermal) head, or the like. Among these devices, a piezoelectric (piezo-element) head is desired.

<Object forming material>

[0745] There is no particular limitation as to the object forming material, and a suitable choice can be made based on the performance required in forming the body of a three-dimensional object.

[0746] Examples of the object forming material include the modelling material and the supporting material.

[0747] The object forming material is not particularly limited as long as the material is a liquid that is cured by applying of energy, such as light or heat, and can be appropriately selected depending on the purpose, but desirably includes polymerizable monomers such as mono-functional monomers, poly-functional monomers, oligomers, and may optionally include other components. Desirably, the object forming material has a liquid property such as viscosity and surface tension such that the object forming material can be discharged by an object forming material discharging head used in an object forming material jetting printer or the like.

-- Polymerizable monomers --

[0748] Polymerizable monomers include, for example, monofunctional monomers, poly-functional monomers, and the like. These examples may be used alone, and also, two or more of these examples may be combined and used.

-- Monofunctional monomers --

[0749] Monofunctional monomers include, for example, acrylamide, N-substituted acrylamide derivatives, N,N-disubstituted acrylamide derivatives, N-substituted methacrylamide derivatives, N,N-disubstituted methacrylamide derivatives, acrylic acid, and the like. These examples may be used alone, and also, two or more of these examples may be combined and used. Among these materials, acrylamide, N,N-dimethylacrylamide, N-isopropylacrylamide, acryloylmorpholine, hydroxyethylacrylamide, and isoboryl (meth)acrylate are desirable.

[0750] As monofunctional monomers, organic polymers can be obtained by polymerization.

[0751] It is desirable that the content of monofunctional monomers be not less than 0.5 wt% and not more than 90 wt% of the total amount of the object forming material.

[0752] Other monofunctional monomers include, but are not limited to, 2-ethylhexyl (meth)acrylate, 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, caprolactone-modified tetrahydrofurfuryl (meth)acrylate, 3-methoxybutyl (meth)acrylate, tetrahydrofurfuryl (meth)acrylate, lauryl (meth)acrylate, 2-phenoxyethyl (meth)acrylate, isodecyl (meth)acrylate, isooctyl (meth)acrylate, tridecyl (meth)acrylate, caprolactone (meth)acrylate, ethoxy nonylphenol (meth)acrylate, and the like.

-- Polyfunctional monomers --

[0753] Polyfunctional monomers include bifunctional monomers, trifunctional monomers, and the like, which are not particularly limited and can be appropriately selected depending on the purpose. These examples may be used alone, and also, two or more of these examples may be combined and used.

[0754] Examples of bifunctional monomers include tripropylene glycol di (meth) acrylates, triethylene glycol di (meth) acrylates, tetraethylene glycol di (meth) acrylates, polypropylene glycol di (meth) acrylates, neopentyl glycol hydroxypipyrinate di (meth) acrylates, hydroxypyrinate neopentyl glycol esterdi (meth) acrylates, 1,3-butanediol di (meth) acrylates, 1,4-butanediol di (meth) acrylates, 1,6-hexanediol di (meth) acrylates, 1,9-nonandiol di (meth) acrylates, diethylene glycol di (meth) acrylates, neopentyl glycol di (meth) acrylates, tripropylene glycol di (meth) acrylates, caprolactone-modified hydroxypipyrinate neopentyl glycol esterdi (meth) acrylates, propoxy neopentyl glycol di (meth) acrylate, ethoxy-modified bisphenol A di (meth) acrylate, polyethylene glycol 200 di (meth) acrylate, polyethylene glycol 400 di (meth) acrylate, and the like. These examples may be used alone, and also, two or more of these examples may be combined and used.

[0755] Examples of tri or more functional monomers include trimethylol propanetri (meth)acrylate, pentaerythritol tri (meth)acrylate, dipentaerythritol hexa(meth)acrylate, triallyl isocyanurate, ε-caprolactone modified dipentaerythritol tri (meth)acrylate, ε-caprolactone modified dipentaerythritol tetra (meth) acrylate, meth) acrylate, ε-caprolactone modified dipentaerythritol penta (meth)acrylate, ε-caprolactone modified dipentaerythritol penta (meth)acrylate, ε-caprolactone modified dipentaerythritol hexa(meth)acrylate, tris (2-hydroxyethyl) isocyanurate tri(meth)acrylate, ethoxylated trimethylolpropanetri(meth)acrylate, propoxylated glyceryl tri(meth)acrylate, pentaerythritol tetra(meth)acrylate, ditrimethylol propanetetra(meth)acrylate, dipentaerythritol hydroxypenta(meth)acrylate, ethoxylated pentaerythritol tetra(meth)acrylate, penta(meth)acrylate ester, and the like. These examples may be used alone, and also, two or more of these examples may be combined and used.

-- Oligomers --

[0756] As oligomers, low polymers of the above-mentioned monomers or oligomers having reactive unsaturated binding groups at ends may be used alone, and also, two or more of these types of oligomers may be combined and used.

-- Other ingredients --

[0757] Other ingredients include, but are not limited to, surfactants, polymerization inhibitors, polymerization initiators, colorants, viscosity modifiers, adherence providing agents, antioxidants, antiaging agents, cross-linking promoters, ultraviolet absorbers, plasticizers, preservatives, dispersants, and the like.

-- Surfactant --

[0758] Surfactant may be, for example, surfactant having a molecular weight of 200 or more and 5,000 or less, specifically, a PEG nonionic surfactant (ethylene oxide of nonylphenol (hereinafter, referred to as "EO") 1-through-400-mol adduct, stearate 1-through-40-mol adduct, etc.), a polyhydric alcoholic nonionic surfactant (sorbitan palmitate monoester, sorbitan stearate monoester, triester of sorbitan stearate, etc.), a fluorine-containing surfactant (perfluoroalkyl EO 1-through-50-mol adduct, perfluoroalkyl carboxylate salt, perfluoroalkyl betaine, etc.), a modified silicone oil (polyether modified silicone oil, (meth)acrylate modified silicone oil, etc.), and the like. These examples may be used alone, and also, two or more of these examples may be combined and used.

[0759] It is desirable that the content of the surfactant be 3 wt% or less with respect to the total amount of the object forming material, and it is more desirable that the content be 0.1 wt% or more and 5 wt% or less from the viewpoint of the inclusion effect and the physical properties of the photo-setting material.

-- Polymerization inhibitor --

[0760] Examples of the polymerization inhibitor include a phenolic compound (hydroquinone, hydroquinone monomethyl ether, 2,6-di-t-butyl-p-cresol, 2,2-methylene-bis-(4-methyl-6-t-butylphenol), 1,1,3-tris-(2-methyl-4-hydroxy-5-t-butylphenyl)butane), a sulfur compound (dilauryl thiodipropionate, etc.), a phosphorus compound (triphenylphosphite, etc.), an amine compound (phenothiazine, etc.), and the like. These examples may be used alone, and also, two or more of these examples may be combined and used.

[0761] It is desirable that the content of the polymerization inhibitor be not more than 5 wt% of the total amount of the object forming material, and it is more desirable that the content of the polymerization inhibitor be not less than 0.1 wt% and not more than 5 wt% of the total amount of the object forming material from the viewpoint of the stability of the monomers and the polymerization speed.

-- Polymerization initiators --

[0762] Polymerization initiators include, for example, thermal polymerization initiators, photopolymerization initiators, and the like. Among these materials, a photopolymerization initiator is desirable from the viewpoint of storage stability.

[0763] As the photopolymerization initiator, any material that produces radicals by irradiation with light (particularly ultraviolet light of wavelengths from 220 nm to 400 nm) can be used.

[0764] Photopolymerization initiators include, for example, acetophenone, 2,2-diethoxyacetophenone, p-dimethylaminoacetophenone, benzophenone, 2-chlorobenzophenone, p,p'-dichlorobenzophenone, p,p-bis-diethylaminobenzophenone, mihiraketone, benzyl, benzoin, benzoin methyl ether, benzoin ethyl ether, benzoin isopropyl ether, benzoin-n-propyl ether, benzoin isobutyl ether, benzoin-n-butyl ether, benzyl methyl ether, benzyl methyl ketal, thioxanthone, 2-chlorothioxanthone, 2-hydroxy-2-methyl-1-phenyl-1-one.1-(4-Isopropylphenyl)2-methylpropane-1-one, methylbenzoylformate, 1-hydroxycyclohexylphenyl ketone, azobityronitrile, benzoylperoxide, di-tert-butyl peroxide, and the like. These examples may be used alone, and also, two or more of these examples may be combined and used.

[0765] As a thermal polymerization initiator, there is no particularly limitation, and any thermal polymerization initiator may be appropriately selected depending on the purpose, for example, an azo-based initiator, a peroxide initiator, a persulfate initiator, a redox initiator, or the like may be selected.

[0766] Examples of azo-based initiators include VA-044, VA-46B, V-50, VA-057, VA-061, VA-067, VA-086, 2,2'-azobis (4-methoxy-2,4-dimethylvaleronitrile) (VAZO 33), 2,2'-azobis (2-amidinopropane) dihydrochloride (VAZO 50), 2,2'-azobis (2,4-dimethylvaleronitrile) (VAZO 52), 2,2'-azobis (isobutyronitrile) (VAZO 64), 2,2'-azobis-2-methylbutyronitrile (VAZO 67), 1,1-azobis (1-cyclohexanecarbonitrile) (VAZO 88) (all being made by DuPont Chemical Company), 2,2'-azobis (2-cyclopropylpropionitrile), and 2,2'-azobis (V-601) (the last two materials being made by Wako Pure Chemical Industries).

[0767] Examples of the peroxide initiators include benzoyl peroxide, acetyl peroxide, lauroyl peroxide, decanoyl peroxide, dicetyl peroxydicarbonate, di(4-t-butylcyclohexyl), peroxydicarbonate (trade name: Perkadox 16S, made by Akzo Nobel N.V.), di(2-ethylhexyl) peroxydicarbonate, t-butylperoxy-2-ethylhexanoate (trade name: Lupersol 11, Elf Atochem), t-butylperoxy-2-ethylhexanoate (trade name: Trigonox 21-C50, made by Akzo Nobel N.V.), dicumyl peroxide, and the like.

[0768] Examples of persulfate initiators include potassium persulfate, sodium persulfate, ammonium persulfate, and the like.

[0769] Examples of redox (oxidation-reduction) initiators include persulfate initiators in

combination with reducing agents such as sodium bisulfite and sodium bisulfite, systems based on an organic peroxide and tertiary amine (e.g., systems based on benzoyl peroxide and dimethyl aniline), and systems based on organohydroperoxides and transition metals (e.g., systems based on cumene hydroperoxide and cobalt naphtate).

[0770] It is desirable that the content of the polymerization initiator be 10 wt% or less, and, more desirably, 5 wt% or less for the total amount of the object forming material.

-- Colorant --

[0771] As a colorant, a dye or pigment that dissolves or stably disperses in the object forming material and has excellent thermal stability is suitable. Among these materials, a solvent dye is desirable. In addition, it is possible to mix two or more types of coloring agents for the purpose of color adjustment, for example.

<Object forming material curing unit>

[0772] An object forming material curing unit is a unit that cures the object forming material discharged to form an object forming layer.

[0773] As long as it is possible to cure the object forming material discharged to form an object forming layer, there is no particular restriction, and the object forming layer can be appropriately selected according to the purpose. For example, an ultraviolet ir-radiator is included.

-- Ultraviolet (UV) irradiator --

[0774] Examples of the ultraviolet irradiator include, for example, a high-pressure mercury lamp, an ultra-pressure mercury lamp, a metal halide lamp, and the like.

[0775] The high-pressure mercury lamp is a light source, but a DeepUV type, which has improved light utilization efficiency in combination with an optical system, is capable of short-wavelength irradiation.

[0776] The metal halide lamp is effective in coloring a material because of its wide wavelength range, a metal halide of a metal such as Pb, Sn, or Fe is used, and the metal halide lamp can be selected according to the absorption spectrum of the polymerization initiator. The lamp used for curing is not particularly limited and may be selected according to the purpose, and a commercially available lamp such as a H lamp, a D lamp, or a V lamp provided by the Fusion System Company may be used.

<Stage>

[0777] The stage is not particularly limited as long as, onto the stage, the object forming material is discharged by the object forming material discharging unit and object forming layers can be formed on top of each other. Therefore, the stage can be selected according to the purpose.

[0778] As the shape of the stage, there is no particular limitation, and it is possible to appropriately select the shape depending on the purpose, but desirably the stage has a flat

surface.

[0779] As the direction of the stage, there is no particular limit, and it is possible to appropriately select the direction according to the purpose. However, it is desirable that the stage extends along a direction perpendicular to a direction in which the object forming material discharging unit discharges the object forming material is discharged.

[0780] The flattening member is a member for flattening at least one of the modelling material and the supporting material.

[0781] As the flattening member, as long as the flattening member comes into contact with a surface of at least one of the modelling layer and the supporting layer, there is no particular limitation, and the flattening member can be appropriately selected depending on the purpose, for example, a roller, a blade, or the like.

<Other units and other steps>

[0782] Other units include, without limitation, a drying unit, a control unit, and the like, which may be selected according to the purpose.

[0783] Other steps include, for example, a drying step, a control step, and the like, which are not particularly limited and may be selected according to the purpose.

[0784] Hereinafter, an outline of a three-dimensional object forming apparatus according to an embodiment of the present invention will be described. Fig. 82 depicts a front view of a main part of the three-dimensional object forming apparatus, Fig. 83 depicts a plan view of the three-dimensional object forming apparatus, and Fig. 84 depicts a side view of the three-dimensional object forming apparatus.

[0785] The three-dimensional object forming apparatus 40010 is a material jetting apparatus, including a stage 40014, which is a forming stage on which object forming layers 30 are formed on top of each other to form a three-dimensional object, and a forming unit 40020, which forms a three-dimensional object by placing object forming layers 40030 on top of each other sequentially on the stage 40014.

[0786] The forming unit 40020 includes in a unit holder 40021 including a first head 40011 as a discharging unit for discharging the object forming material, UV irradiators 40013 for irradiating ultraviolet light as an active energy ray, and flattening rollers 40016 as flattening members for flattening an object forming layer 40030. In addition, second heads 40012 may be provided for discharging the supporting material supporting the shape of a three-dimensional object in addition to the object forming material as the modelling material for forming the shape of the three-dimensional object.

[0787] In the X-direction, the two second heads 40012 are disposed on both sides of the first head 40011, the UV irradiators 40013 are disposed on the outside of the two second heads 40012, and the flattening rollers 40016 are disposed on the outside of the UV irradiators 40013 as the flattening members.

[0788] The object forming material is supplied to the first head 40011 from a cartridge

40060 which is interchangeably loaded in a cartridge loading unit 40056 through a feed tube or the like. When color object forming materials having colors such as black, cyan, magenta, and yellow are used, a plurality of nozzle arrays for discharging droplets of these colors may be disposed in the first head 40011.

[0789] The UV irradiators 40013 cure the object forming material discharged from the first head 40011. The UV irradiators 40013, when the supporting material is used, cure an object forming layer 40030 made of the supporting material discharged from the second heads 40012.

[0790] When ultraviolet irradiation lamps are used, it is desirable to provide a mechanism to remove the ozone generated by the ultraviolet irradiation.

[0791] Examples of the ultraviolet irradiation lamp include, for example, a high-pressure mercury lamp, an ultrahigh-pressure mercury lamp, a metal halide lamp, and so forth. Although an ultrahigh-pressure mercury lamp is a light source, an ultraviolet ir-radiation lamp, for which the light utilization efficiency is improved by combination with an optical system, is capable of irradiating in a short wavelength range. A metal halide lamp is effective for curing colorants because of having a wide wavelength range. A metal halide, such as Pb, Sn, or Fe, may be used and can be selected to match the absorption spectrum of the polymerization initiator.

[0792] The flattening rollers 40016 flatten the surface of a cured object forming layer 40030 on the stage 40014 by a relative movement with respect to the stage 40014 while being rotated.

[0793] The term "on the stage 40014" means, unless otherwise specified, on the stage 30014 and on an object forming layer 40030 formed on the stage 40014.

[0794] The unit holder 40021 of the forming unit 40020 is movably held by guide members 40054 and 40055 disposed in the X-direction.

[0795] A maintenance mechanism 40061 for maintaining and recovering the first head 30011 is disposed on one side of the forming unit 40020 in the X direction.

[0796] Also, the guide members 40054 and 40055 holding the unit holder 40021 of the forming unit 40020 are held by side plates 40070. The side plates 40070 include a slider portion 40072 which is movably held by the guide member 40071 disposed on a base member 40007, and the forming unit 40020 is movable in forward and return ways along the Y direction perpendicular to the X direction.

[0797] The stage 40014 is lifted and lowered in the Z-direction by a lifting and lowering unit 40015. The lifting and lowering unit 40015 is movably disposed on the guide members 40075 and 40076 disposed in the X-direction on the base member 40007.

[0798] Next, an outline of object forming operation by the three-dimensional object forming device 40010 will be described with reference to Fig. 82.

[0799] First, the forming unit 40020 is moved in the Y direction to position above the stage

40014. Next, while the stage 40014 is moved relative to the forming unit 40020 which is stopped, the modelling material 40301 is discharged from the first head 40011 to an object forming section (the section where the three-dimensional object is formed). When the supporting material is used, the supporting material 40302 is discharged from the second heads 40012 to the supporting section (the section from where the supporting material is removed after object forming operation) other than the object forming section.

[0800] The UV irradiators 40013 then irradiate ultraviolet rays onto the modelling material 40301 and the supporting material 40302 to cure the materials to form a single object forming layer 40030 including the modelling section 40017 of the modelling material 40301 and the supporting section 40018 of the supporting material 40302.

[0801] An object forming layer 40030 is repeatedly formed and sequentially formed on top of each other to form a three-dimensional object formed of the modelling material 40301 while the modelling material 30301 is supported by the supporting material 40302. For example, in the example of Fig. 82, the five object forming layers 40030A-40030E are formed on top of each other.

[0802] For example, the flattening rollers 40016 are pressed against the surface of an object forming layer 40030 to flatten the object forming layer 40030 each time when some object forming layers 40030 (the actual number of the layers not necessarily having a fixed value) are formed on top of each other, for example, when every 10 layers are formed on top of each other. Thus, the thickness accuracy and flatness of the object forming layers 40030 are ensured.

[0803] When the flattering members have roller shapes, such as the flattening rollers 40016, the flattening rollers 40016 are rotated in a direction reversed to the moving direction in the X direction, so that the flattening effect can be improved.

[0804] In order to keep the gap between the forming unit 40020 and the top object forming layer 40030 constant, the stage 40014 is lowered by the lifting and lowering unit 40015 for each object forming layer 40030 being formed. The forming unit 40020 may be moved up and down instead.

[0805] The three-dimensional object forming apparatus may include a collection unit collecting the modelling material 40301 and the supporting material 40302, a recycling mechanism for the modelling material and the supporting material, and the like. The first head 40011 and the second heads 40012 may be provided with discharge condition detecting units detecting non-discharge nozzles. In addition, the ambient temperature in the three-dimensional object forming apparatus during object forming operation may be controlled.

<Object forming process>

[0806] In a basic object forming process, the stage is moved in a forward and return manner

in the main scanning direction. In this regard, depending on whether an object to be formed is larger or smaller than the length of the nozzle array of the head or for the purpose of using all of the nozzles evenly, two types of operations in the sub scanning direction are performed: "large pitch movement" and "small pitch movement".

<<Large pitch movement>>

[0807] In a case where an object to be formed is longer than the head sub-scanning direction length, a large pitch movement is performed for covering the object's sub-scanning direction length.

[0808] Between subsequent scanning operations, the stage is moved with a relatively large moving amount in the sub-scanning direction of the head, for example, 1/2 through 1 times the length of the head sub-scanning direction length.

<<Small pitch movement>>

[0809] Small pitch movement is performed for the purpose of causing nozzle clogging if any to occur evenly among all the nozzles, and for the purpose of reducing object forming material discharge amount variation.

[0810] Between subsequent scanning operations, the stage is moved with a moving amount that is relatively small in the sub-scanning direction of the head, for example, less than or equal to 1/8 times the length of the head sub-scanning direction length.

(Three-dimensional object forming program)

[0811] A three-dimensional object forming program of an embodiment of the present invention causes a computer to perform processes of moving a stage in a forward and return manner in opposite directions, discharging the modelling material from the head in first forward and return scanning operations to form modelling-section object forming layers, discharging the supporting material from the head in second forward and return scanning operations to form supporting-section object forming layers, and to perform control such that the positions of the head for discharging the materials to form the layers in the sub-scanning direction are different for at least some of the modelling-section object forming layers and the supporting-section object forming layers.

[0812] Processing according to the three-dimensional objecting program of an embodiment of the present invention can be implemented by using a computer having a control unit corresponding to a three-dimensional object forming apparatus.

[0813] An outline of the control unit will be described with reference to Fig. 85. Fig. 85 is a block diagram illustrating a control unit.

[0814] The control unit 40500 includes a main control unit 40500A including a CPU 40501 for controlling the entire apparatus, a ROM 40502 for storing the three-dimensional object forming program including instructions for controlling three-dimensional object forming operations of the CPU 40501 including control operations according to an em-

bodiment of the present invention as well as other fixed data, and a RAM 40503 for temporarily storing object forming data.

[0815] The control unit 40500 also includes a non-volatile memory (NVRAM) 40504 for storing data even after the power of the apparatus is cut off. The control unit 40500 includes an ASIC 40505 for processing image processing for performing various signal processing on image data or for processing input/output signals for controlling the entire apparatus.

[0816] The control unit 40500 further includes an I/F 40506 for transmitting and receiving data and signals used to receive object forming data from an external object forming data generating apparatus 40600.

[0817] The object forming data generating apparatus 40600 is an apparatus that produces object forming data (cross-sectional data) which is slice data obtained from slicing the final shape of a three-dimensional object on an object forming layer basis, and may be an information processing apparatus such as a personal computer.

[0818] The control unit 40500 includes an I/O 40507 for receiving sensing signals from various sensors.

[0819] The control unit 40500 includes a head driving control unit 40508 for driving and controlling the first head 40211 of an object forming unit and a head driving control unit 40509 for driving and controlling the second head 40212.

[0820] The control unit 40500 further includes a motor driving unit 40510 for driving a motor included in an X-direction moving mechanism 40550 for moving the object forming unit in the X-direction, and a motor driving unit 40511 for driving a motor included in a Y-direction scanning mechanism 40552 for moving the object forming unit in the Y-direction (a sub-scanning direction).

[0821] The control unit 40500 includes a motor driving unit 40513 for driving a motor included in a stage X-direction scanning mechanism 40553 that moves the forming stage 40214 in the X-direction together with the lifting and lowering unit 40215, and a motor driving unit 40514 for driving a motor included in the lifting and lowering unit 40215 that moves the forming stage 40214 in the Z-direction. The Z-direction movement may be implemented instead by lifting and lowering the object forming unit as described above.

[0822] The control unit 40500 includes a motor driving unit 40516 for driving a motor 30026 for rotating the flattening roller 40213, and a maintenance drive section 30518 for driving a maintenance mechanism 40061 for the first head 40211 and the second head 40212.

[0823] The control unit 40500 includes a curing control unit 40519 for controlling UV irradiation by the UV irradiator 40216.

[0824] The I/O 40507 of the control unit 40500 receives a sensing signal, such as a sensing

signal from a temperature and humidity sensor 40560, which detects the temperature and humidity as an environmental condition of the apparatus, and other sensing signals from other sensors.

[0825] An operation panel 40522 is connected to the control unit 40500 for inputting and displaying various information.

[0826] The control unit 40500 receives object forming data from the object forming data generating apparatus 40600 as described above. Object forming data is data (object forming section data) for determining a shape of each object forming layer as slice data of a desired three-dimensional object.

[0827] A main control unit 40500A generates data in which data of a supporting section to provide the supporting material is added to the object forming data (object forming section data) and provides the data to the head driving control units 40508 and 40509. The head driving control units 40508 and 40509 respectively discharge droplets of the modelling material from the first head 40011 to an object forming section and discharge droplets of the liquid supporting material 40302 from the second head 40012 to a supporting section.

[0828] A combination of the object forming data generating apparatus 40600 and the three-dimensional object forming apparatus may be referred to as a three-dimensional object forming apparatus.

[0829] Next, a processing procedure of the three-dimensional object forming program of an embodiment of the present invention will be described. FIG. 92 is a flowchart depicting a processing procedure of the three-dimensional object forming program in the control unit 40130 of the three-dimensional object forming apparatus 40100. The detailed description of the flowchart is described with reference to Examples 5-1 through 5-4.

<Examples>

[0830] Hereinafter, examples of the present invention will be described, but the present invention is not limited in any way to these examples.

(Comparison example 5-1)

[0831] Fig. 86A depicts a schematic diagram for illustrating a movement of the head in the sub-scanning direction of Comparison example 5-1. As depicted in FIG. 86B, the roller as the flattening member is not completely horizontal with respect to the stage, and there is a slight difference $\Delta 1$ in the gap between the roller and the stage front and rear the roller. As depicted in Fig. 86C, when using a head position as depicted in Fig. 86A in scanning operations when forming a supporting layer of an nth layer, the roller collides with the modelling material of the nth layer, causing distortion and/or scratches in the formed layer.

[0832] Figs. 86A-86C depict movements of the head in the sub-scanning direction. For

example, in the first scanning operation, the modelling material is discharged at the position a1 of the sub-scanning direction. The position of the head is depicted here, not the positions of nozzles used.

[0833] In Comparison example 5-1, the head position in the sub-scanning direction when the supporting layer is formed is not the same as the head position in the sub-scanning direction when the modelling layer is formed. Regardless of the object forming material (the modelling material or the supporting material), the head is moved in the sub-scanning direction for each layer. The first and second stroke may be performed as forward strokes or return strokes.

[0834] Fig. 90 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method of Comparison example 5-1. Hereinafter, the process flow of a three-dimensional object forming method of Comparison example 5-1 will be described with reference to Figs. 86A-86C.

[0835] In step S40001, when the modelling material is discharged at the sub-scanning position a1 in the first scanning operation (forward stroke) and cured, the process proceeds to step S40002.

[0836] In step S40002, the modelling material is discharged at the sub-scanning position a2 in the second scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40002.

[0837] In step S40003, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40004.

[0838] Here, the operation that "the stage moved in the sub-scanning direction with a large pitch" is for the purpose that, when an object to be formed is longer than the head sub-scanning direction length, the sub-scanning direction length of the object is covered as a result of the stage being moved between scanning operations with a moving amount relatively larger in the sub-scanning direction of the head, for example, 1/2 through 1 times the head sub-scanning direction length.

[0839] In step S40004, the modelling material is discharged at the sub-scanning position a3 in the third scanning operation (forward stroke) and cured, and the process proceeds to step S40005.

[0840] In step S40005, the modelling material is discharged at the sub-scanning position a4 in the fourth scanning operation (return stroke), and cured, and the process proceeds to step S40006.

[0841] In step S40006, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40007.

[0842] In step S40007, the supporting material is discharged at the sub-scanning position a6 in the fifth scanning operation (forward stroke) and cured, and the process proceeds to step S40008.

[0843] In step S40008, the supporting material is discharged at the sub-scanning position a7 in the sixth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40009.

[0844] In step S40009, steps S40001-S40008 are repeated a predetermined number of times so that the object forming is completed. Thus, the present process ends.

[0845] In Comparison example 5-1, the roller as the flattening member is not completely horizontal with respect to the stage, and there is a slight difference Δ1 in the gap between the roller and the stage front and rear the roller (see Fig. 86B). Therefore, as depicted in Fig. 86C, when the head position is set as depicted in Fig. 86A, when the supporting layer is formed of the nth layer, the roller collides with the modelling material of the nth layer, causing distortion and scratches in the formed layer.

(Example 5-1)

[0846] Figs. 87A and 87B depict movements of the head in the sub-scanning direction in Example 5-1. For example, in the first scanning operation, the modelling material is discharged at the position a1 of the sub-scanning direction. The position of the head is depicted here, not the positions of nozzles used.

[0847] In Example 1, the head is moved for each layer in the sub-scanning direction regardless of the object forming material (the modelling material or the supporting material). The first and second strokes may be performed as forward strokes or return strokes.

[0848] Fig. 91 depicts a flowchart for illustrating an example of a process flow of a three-dimensional object forming method according to Example 5-1. Hereinafter, the process flow of a three-dimensional object forming method according to Example 1 will be described with reference to Figs. 87A and 87B.

[0849] In step S40011, the modelling material is discharged at the sub-scanning position b1 in the first scanning operation (forward stroke) and cured, and the process proceeds to step S40012.

[0850] In step S40012, the modelling material is discharged at the sub-scanning position b2 in the second scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40013.

[0851] In step S40013, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40014.

[0852] In step S40014, the modelling material is discharged at the sub-scanning position b3 in the third scanning operation (forward stroke) and cured, and the process proceeds to step S40015.

[0853] In step S40015, the modelling material is discharged at the sub-scanning position b4 in the fourth scanning operation (return stroke) and cured, and the process proceeds to step S40016.

[0854] In step S40016, the stage is moved in the sub-scanning direction with a large pitch for scanning at the above-mentioned sub-scanning position b1 (b2). Then, the process proceeds to step S40017.

[0855] In step S40017, the supporting material is discharged at the sub-scanning position b5 in the fifth scanning operation (forward stroke) and cured, and the process proceeds to step S40018.

[0856] In step S40018, the supporting material is discharged at the sub-scanning position b6, flattened, and cured in the sixth scanning operation (return stroke), and the process proceeds to step S40019.

[0857] In step S40019, steps S40011-S40018 are repeated a predetermined number of times. Thus, the present process ends.

[0858] In Example 5-1, with respect to forming of the nth layer, the head position of the sub-scanning direction when the supporting layer is formed is made to be the same as the head position of the sub-scanning direction when the modelling layer of the nth layer is formed. As a result, an influence of roller collision to the modelling layer can be reduced during forming of the supporting layer.

[0859] However, in Example 5-1, the head positions in the sub-scanning direction are the same in the modelling layers 1 and 2. For this reason, there may be a problem that a groove is generated on the surface of the formed object when a nozzle is defective during the object forming process.

(Example 5-2)

[0860] Figs. 88A and 88B depict movements of the head in the sub-scanning direction. For example, in the first scanning operation, the modelling material is discharged at the position c1 of the sub-scanning direction. The position of the head is depicted here, not the positions of nozzles used. In this regard, special attention is needed for a case where a small pitch movement is performed, similarly with Example 5-2.

[0861] In Example 5-2, a small pitch movement is performed for the modelling layer. The sub-scanning direction head position for the nth-layer supporting layer is made to be the same as the sub-scanning direction head position for any layer included in the nth-layer modelling layer.

[0862] A "small pitch movement" is performed for the purpose of forming layers corresponding to the slice data resolution with respect to the sub-scanning direction, causing possible nozzle clogging to occur evenly among the nozzles, and reducing variations in the discharge amounts of the nozzles. In a "small pitch movement", the stage is moved between scanning operations with a relatively small moving amount with respect to the head sub-scanning direction, for example, 1/8 times or less of the length of the head sub-scanning direction length.

[0863] Fig. 92 depicts a flowchart illustrating an example of a process flow of a three-

dimensional object forming method according to Example 5-2. Hereinafter, the process flow of a three-dimensional object forming method according to Example 5-2 will be described with reference to Figs. 88A and 88B.

[0864] In step S40021, the modelling material is discharged at the sub-scanning position c1 in the first scanning operation (forward stroke) and cured, and the process proceeds to step S40022.

[0865] In step S40022, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40023.

[0866] In step S40023, the modelling material is discharged at the sub-scanning position c2 in the second scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40024.

[0867] At this time, it should be noted that the area in which the modelling material can be discharged is at least the sub-scanning area scanned at the sub-scanning position c1.

[0868] In step S40024, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40025.

[0869] In step S40025, the modelling material is discharged at the sub-scanning position c3 in the third scanning operation (forward stroke) and cured, and the process proceeds to step S40026.

[0870] In step S40026, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40027.

[0871] In step S40027, the modelling material is discharged at the sub-scanning position c4 in the fourth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40028.

[0872] In step S40028, the stage is moved in the sub-scanning direction with a large pitch for scanning at the sub-scanning position c1 or c2. Then, the process proceeds to step S40029.

[0873] In step S40029, the supporting material is discharged at the sub-scanning position c5 in the fifth scanning operation (forward stroke) and cured, and the process proceeds to step S40030.

[0874] In step S40030, the stage is moved in the sub-scanning direction with a small pitch for scanning at the sub-scanning position c2. Then, the process proceeds to step S40031.

[0875] In step S40031, the supporting material is discharged at the sub-scanning position c6 in the sixth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40032. In this regard, the sub-scanning positions of c5 and c6 may be the same as each other. It is also possible that the sub-scanning positions c5 and c6 may be the same as the sub-scanning position c2.

[0876] In step S40032, steps S40021-S40031 are repeated a predetermined number of times

so that the object forming process is completed. Thus, the present process ends.

[0877] In Example 5-2, with respect to forming of the nth layer, when the position of the head in the sub-scanning direction is shifted with a small pitch among a plurality of scanning operations, the head position in the sub-scanning direction when the supporting layer is formed is made to be the same as the head position in the sub-scanning direction at any one of the scanning operations to form the modelling layer.

[0878] In the method of Example 5-1 described above, upon forming of the modelling layers 1 and 2, the head positions in the sub-scanning direction are the same. In contrast, in Example 5-2, it is possible to solve the possible problem that a groove is formed on the surface of the formed object due to a presence of a defective nozzle during an object forming process.

[0879] However, in Example 5-2, the supporting layer 1 is formed for the modelling layer 1 for forming one object forming layer. Therefore, in order to form one object forming layer, a plurality of scanning operations are performed for each of the modelling layer and the supporting layer, resulting in a long object forming time.

(Example 5-3)

[0880] Figs. 89A and 89B depict movements of the head in the sub-scanning direction. For example, in the first scanning operation, the modelling material is discharged at the position d1 of the sub-scanning direction. The position of the head is depicted here, not the positions of nozzles used. In this regard, special attention is needed for a case where there is a small pitch movement, similarly with Example 5-3.

[0881] In Example 5-3, for example, the modelling layer 2 and the supporting layer 1 are regarded as one set referred to as a slice layer. The head position in the sub-scanning direction for forming a supporting layer of an nth slice layer is made to be the same as the head position in the sub-scanning direction for forming any one of the top modelling layers of the nth slice layer. The combination of the slice layer is not limited. For example, the modelling layer 3 and the supporting layer 1 may be included in a set as a slice layer.

[0882] Fig. 93 depicts a flowchart illustrating an example of a process flow of a three-dimensional object forming method of Example 5-3. Hereinafter, the process flow of a three-dimensional object forming method of Example 5-3 will be described with reference to Figs. 89A and 89B.

[0883] In step S40041, the modelling material is discharged at the sub-scanning position d1 in the first scanning operation (forward stroke) and cured, and the process proceeds to step S40042.

[0884] In step S40042, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40043.

[0885] In step S40043, the modelling material is discharged at the sub-scanning position d2

in the second scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40044.

[0886] In step S40044, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40045.

[0887] In step S40045, the modelling material is discharged at the sub-scanning position d3 in the third scanning operation (forward stroke) and cured, and the process proceeds to step S40046.

[0888] In step S40046, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40047.

[0889] In step S40047, the modelling material is discharged at the sub-scanning position d4 in the fourth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40048.

[0890] In step S40048, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40049.

[0891] In step S40049, in a way similar to the way with respect to the modelling layer 2, steps S40041-S40048 are performed (the sub-scanning positions are depicted in Fig. 89A), and the process proceeds to step S40050.

[0892] In step S40050, the supporting material is discharged at the sub-scanning position d9 in the ninth scanning operation (forward stroke) and cured, and the process proceeds to step S40051.

[0893] In step S40051, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40052.

[0894] In step S40052, the supporting material is discharged at the sub-scanning position d10 in the tenth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40053.

[0895] In step S40053, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40054.

[0896] In step S40054, at the eleventh scanning operation (forward stroke), the supporting material is discharged at the sub-scanning position d11, and cured, and the process proceeds to step S40055.

[0897] In step S40055, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40056.

[0898] In step S40056, the supporting material is discharged at the sub-scanning position d12 in the twelfth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40057.

[0899] In step S40057, the stage is moved in the sub-scanning direction with a large pitch, and the process proceeds to step S40057.

[0900] In step S40058, similarly, in a similar way also for the slice layer 2 and further

subsequent layers, steps S40041-S40057 are performed (the sub-scanning positions are depicted in Figs. 89A and 89B), and the process proceeds to step S40059.

[0901] It should be noted that the above-described detailed procedure is merely an example, and the scanning operations in a forward and return manner to form the layers are not limited to the above-described detailed procedure. For example, discharging may be performed only by using return strokes without using forward strokes (no discharging is performed at the sub-scanning positions d1, d3, d5, d7, d9, d11,... by using forward strokes).

[0902] In step S40059, steps S40051-S40058 are repeated a predetermined number of times and the object forming process is completed. Thus, the present process ends.

[0903] In Example 5-3, the modelling layer 2 and the supporting layer 1 is regarded as one layer unit (defined as a "slice layer"), and as a result, it is possible to shorten the object forming time. In this case, with respect to forming of the nth slice layer, the head position in the sub-scanning direction when the supporting layer is formed is made to be the same as the head position in the sub-scanning direction at any scanning operation for forming the modeling layers.

[0904] In Example 5-3, the supporting layer 1 is formed for the modelling layer 1. Thus, in order to form one slice layer, each of the modelling layer and the supporting layer is formed through a plurality of scanning operations. Notwithstanding such a situation, it is possible to solve the problem of a long object forming time, similarly with the above-described Example 5-2 by regarding the modelling layer 2 and the supporting layer 1 as one layer unit (defined as a "slice layer").

(Example 5-4)

[0905] Fig. 94 depicts a flow chart for illustrating an example of a process flow of a three-dimensional object forming method according to Example 5-4. Hereinafter, the process flow of a three-dimensional object forming method according to Example 5-4 will be described with reference to Figs. 89A and 89B.

[0906] Since Example 5-4 is basically the same as Example 5-3, only different points will now be described.

[0907] In step S40061, the supporting material is discharged at the sub-scanning position d11 in the ninth scanning operation (forward stroke) and cured, and the process proceeds to step S40062.

[0908] In step S40062, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40063.

[0909] In step S40063, the supporting material is discharged at the sub-scanning position d12 in the tenth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40064.

[0910] In step S40064, the stage is moved with a large pitch in the sub-scanning direction,

and the process proceeds to step S40065.

[0911] In step S40065, the supporting material is discharged at the sub-scanning position d9 at the eleventh scanning operation (forward stroke) and cured, and the process proceeds to step S40066.

[0912] In step S40066, the stage is moved in the sub-scanning direction with a small pitch, and the process proceeds to step S40067.

[0913] In step S40067, the supporting material is discharged at the sub-scanning position d10 at the twelfth scanning operation (return stroke), flattened, and cured, and the process proceeds to step S40068.

[0914] In step S40068, the stage is moved with a large pitch in the sub-scanning direction, and the process proceeds to step S40069.

[0915] In step S40069, in a similar way also for the slice layer 2 and further layers, steps S40061-S40068 are performed (the sub-scanning positions are depicted in Figs. 89A and 89B), and the process proceeds to step S40070.

[0916] In step S40070, steps S40041-S40049 of Example 5-3 the above-described steps S40061-S40069 are repeated a predetermined number of times, and the present process ends.

[0917] In Example 5-4, the three-dimensional object forming method further shortens the object forming time compared to the three-dimensional object forming method of according to Example 5-3. In Example 5-4, when the head is at the sub-scanning position d8 at the completion of forming the modelling layer 2, the supporting layer 1 can be formed from the sub-scanning position d11 (on the opposite side to the sub-scanning direction position of the first scanning operation of the immediately preceding modelling layer forming process), and thus, the object forming time can be further reduced.

[0918] Examples of the above-described mode V for carrying out the invention of the present invention are as follows:

[0919] <1> A three-dimensional object forming apparatus includes a layer forming unit that discharges a modelling material from a head at forward and return scanning operations to form a plurality of modelling layers and subsequently discharges a supporting material from the head in at forward and return scanning operations to form a plurality of supporting layers. In this regard, upon forming of at least some of the plurality of modelling layers and the plurality of supporting layers, positions of the head with respect to a sub-scanning direction are different.

[0920] <2> In the three-dimensional object forming apparatus of the above-described item <1>, the position of the head with respect to the sub-scanning direction upon discharging the supporting material for forming an nth layer among the plurality of supporting layers is made to be the same as the position of the head with respect to the

sub-scanning direction upon discharging the modelling material upon at least any one of scanning operations for forming an nth layer among the plurality of modelling layers.

[0921] <3> In the three-dimensional object forming apparatus of the above-described item <1>, the position of the head with respect to the sub-scanning direction upon a scanning operation for discharging the supporting material for a nth slice layer of a plurality of slice layers including the plurality of modelling layers and the plurality of supporting layers is made to be the same as the position of the head with respect to the sub-scanning direction for forming the highest modelling layer included the nth slice layer of the plurality of slice layers.

[0922] <4> In the three-dimensional object forming apparatus of the above-described item <2> or <3>, with respect to forming of any supporting layer included in a layer or a slice layer, a position with respect to the sub-scanning direction to start a first scanning operation for forming the supporting layer is made to be opposite to a position with respect to the sub-scanning direction to start an immediately preceding scanning operation for forming a modeling layer.

[0923] <5> The three-dimensional object forming apparatus of any one of the above-described items <1> through <4> includes a flattening member configured to flatten at least one of a modelling layer and a supporting layer. In this regard, upon a scanning operation of the flattening member, at least one of the modelling material and the supporting material is discharged.

[0924] <6> A three-dimensional object forming method includes a layer forming step of discharging a modelling material from a head at forward and return scanning operations to form a plurality of modelling layers and subsequently discharging a supporting material from the head at forward and return scanning operations to form a plurality of supporting layers. In this regard, upon forming of at least some of the plurality of modelling layers and the plurality of supporting layers, positions of the head in the sub-scanning direction are different.

[0925] <7> In the three-dimensional object forming method of the above-described item <6>, the position of the head with respect to the sub-scanning direction upon discharging the supporting material for forming an nth layer among the plurality of supporting layers is made to be the same as the position of the head with respect to the sub-scanning direction upon discharging the modelling material upon at least any one of scanning operations for forming an nth layer among the plurality of supporting layers.

[0926] <8> In the three-dimensional object forming method of the above-described item <6>, the position of the head with respect to the sub-scanning direction upon a scanning operation for discharging the supporting material in a nth slice layer of a

plurality of slice layers including the plurality of modelling layers and the plurality of supporting layers is made to be the same as the position of the head with respect to the sub-scanning direction for forming the highest modelling layer included the nth slice layer of the plurality of slice layers.

[0927] <9> In the three-dimensional object forming method of the above-described item <7> or <8>, a position with respect to the sub-scanning direction to start a first scanning operation for forming a supporting layer is made to be opposite to a position with respect to the sub-scanning direction to start an immediately preceding scanning operation for forming a modeling layer.

[0928] <10> The three-dimensional object forming method of any one of the above-described items <6> through <9> includes a flattening member configured to flatten at least one of a modelling layer and a supporting layer. In this regard, upon a scanning operation of the flattening member, at least one of the modelling material and the supporting material is discharged.

[0929] <11> A program causes a computer to discharge a modelling material from a head at forward and return scanning operations to form a plurality of modelling layers and subsequently discharge a supporting material from the head at forward and return scanning operations to form a plurality of supporting layers. In this regard, upon forming of at least some of the plurality of modelling layers and the plurality of supporting layers, positions of the head with respect to the sub-scanning direction are different.

[0930] According to the three-dimensional object forming apparatus of any one of items <1> through <5>, the three-dimensional object forming method according to any one of items <6> through <10>, and the three-dimensional object forming program of item <11>, the above-described problems can be solved and the object of the mode V for carrying out the invention of the present invention can be achieved.

<Mode VI for carrying out the invention>

[0931] Hereinafter, a mode VI for carrying out the invention of the present invention will be described.

[0932] The mode VI for carrying out the invention of the present invention relates to an three-dimensional object forming apparatus, a three-dimensional object forming method, and a program.

[0933] A material jetting method is known in which a three-dimensional object is obtained by forming using a modelling material that is used to form the three-dimensional object and a supporting material that supports the shape of the modelling material; repeatedly discharging, flattening, and curing the modelling material and the supporting material; and finally removing the supporting material.

[0934] An apparatus is known that has a head unit that scans in first and second scanning directions relative to a forming stage, a first discharge head that is disposed on the head

unit and discharges a photo-setting modelling material toward the forming stage, a second discharge head that is disposed on the head unit and discharges a photo-setting supporting material toward the forming stage, a light source disposed between the first and second discharge heads in the first and second scanning directions and cures the modelling material discharged by the first discharge head and the supporting material discharged by the second discharging unit by irradiating the modelling material and the supporting material (see PTL 7).

[0935] When an object forming material is discharged by a discharging unit, there may be a problem that the object forming quality may be degraded because streaky irregularities may be generated due to variation in the quantity of object forming material droplets.

[0936] The mode VI for carrying out the invention of the present invention has been developed in view of the above problem and an object is to improve the object forming quality of a three-dimensional object to be formed.

[0937] In order to solve the above-described problem, a three-dimensional object forming apparatus according to the mode VI for carrying out the invention of the present invention, which discharges an object forming material from a discharging unit to form object forming layers and forms the object forming layers on top of each other into a laminate to obtain a three-dimensional object, and controls discharging of the object forming material in such a manner of making a resolution of discharging the object forming material in a X or Y direction different between a nth layer and a (n+1)th layer.

[0938] According to the mode VI for carrying out the invention of the present invention, the object forming quality of a three-dimensional object can be improved.

[0939] Hereinafter, embodiments of the mode VI for carrying out the invention of the present invention will be described with reference to the accompanying drawings. An example of a three-dimensional object forming apparatus according to an embodiment of the mode VI for carrying out the invention of the present invention will be described with reference to Fig. 95. Fig. 95 depicts a schematic diagram for illustrating the three-dimensional object forming apparatus.

[0940] The three-dimensional object forming apparatus 50100 for forming a three-dimensional object includes a forming stage 50011 on which a modelling layer 10 is formed and a forming unit 50020 that forms the object forming layer 50010 and forms modelling layers on top of each other into a laminate on the forming stage 11.

[0941] The forming stage 11 is movable in a Z direction. The forming unit 50020 is movable in an X direction and a Y direction. The forming stage 50011 may be movable in any of the directions of X, Y, and Z; or the forming unit 50020 or the forming stage 50011 may be movable only in the X direction by configuring of the forming unit as being able to form a sufficient length of an object in the Y direction at a time.

[0942] This allows the forming stage 11 and the forming unit 50020 to be moved relative to each other and perform an object forming operation by at least one of forward and return strokes.

[0943] The forming unit 50020 includes, as a plurality of discharging units, a first head 50021 that is a discharging unit discharging the modelling material 50201 and a second head 50022 that is a discharging unit discharging the supporting material 50202.

[0944] The forming unit 50020 includes one flattening roller 50023, which is a flattening unit for flattening (smoothing) each of discharged modelling material 201 and supporting material 50202, and two curing units for curing the discharged modelling material 50201 and supporting material 50202 by irradiating these layers with ultraviolet rays as active energy radiation.

[0945] The flattening roller 50023 is on the upstream side of the first head 50021 and the curing unit 50024A is on the upstream side of the flattening roller 50023 when the forming unit 50020 moves in the relatively forward direction in the X direction. Similarly, the second head 50022 is on the downstream side of the first head 50021 and the curing unit 50024B is on the downstream side of the second head 50022.

[0946] Next, an outline of the portions related to control of a forming operation of the three-dimensional object forming apparatus will be described with reference to Fig. 96. Fig. 96 depicts a block diagram of the portions related to the control.

[0947] A forming control unit 50501 controls the object forming operation. For example, the forming control unit 50501 includes a CPU, a program causing the CPU to execute control of the object forming operation, a ROM storing other fixed data, and a RAM temporarily storing three-dimensional object forming data and so forth. This configuration of the forming control unit 50501 may be the same as the configuration of the above-described forming control unit 501 including the CPU 501-1, the ROM 501-2, and the 501-3 described above with reference to Fig. 2B.

[0948] The forming control unit 50501 receives three-dimensional object forming data from an external object forming data generating apparatus 50600. The object forming data generating apparatus 50600 generates three-dimensional object forming data (cross-section data) which is slice data of slices of respective layers of a desired shape of a three-dimensional object and is an information processing apparatus such as a personal computer.

[0949] The forming control unit 50501 transmits the three-dimensional object forming data to a head driving control unit 50508 which drives and controls the first head 50021 discharging the modelling material 50201, and the head driving control unit 50508 discharges the modelling material 50201 from the first head 50021 in accordance with the three-dimensional object forming data.

[0950] The forming control unit 50501 transmits the three-dimensional object forming data

to the head driving control unit 50509 which drives and controls the second head 50022 discharging the supporting material 50202, and the head driving control unit 50509 discharges the supporting material 50202 from the second head 50022 in accordance with the three-dimensional object forming data.

[0951] The forming control unit 50501 drives a motor included in a X-direction scanning mechanism 50550 which moves the forming unit 50020 in the X-direction through a motor driving unit 50510 and moves the forming unit 50020 in forward and return directions along the X direction relative to the forming stage 50011.

[0952] The forming control unit 50501 drives a motor included in a Y-direction scanning mechanism 50551 that moves the forming unit 50020 in the Y-direction through a motor driving unit 50511 and moves the forming unit 50020 in forward and return directions along the X direction relative to the forming stage 50011.

[0953] The forming control unit 50501 drives a motor included in a Z-direction scanning mechanism 50552 for moving (lifting and lowering) the forming stage 50011 in the Z-direction through a motor driving unit 50512.

[0954] The forming control unit 50501 rotates a motor 50556 that rotates the flattening roller 50023 through a motor driving unit 50516 to flatten a modelling layer made of the modelling material 50201 and a supporting layer made of the supporting material 50202 as a result of the modelling material 50201 and the supporting material 50202 being discharged onto the forming stage 50011.

[0955] The forming control unit 50501 controls curing of the modelling layer made of the discharged modelling material 50201 and the supporting layer made of the supporting material 50202 by controlling irradiation of ultraviolet light from the curing units 50024A and 50024B through a curing control unit 50519.

[0956] According to the program according to an embodiment of the present invention, the forming control unit 50501 controls operation such that the first head 50021 and the second head 50022 are moved relative to the forming stage 50011, and the resolution of discharging an object forming material in the X direction or the Y direction is made different between an nth layer and an (n+1)th layer when discharging the object forming material (the modelling material or the supporting material).

[0957] Next, an object forming operation according to an embodiment will be described with reference to Fig. 97. Fig. 97 is a cross-sectional view for illustrating the object forming operation.

[0958] When the size of a droplet of an object forming material fired from the first head 50021 or the second head 50022 varies, as depicted in Fig. 97, a recess 50090 may be formed so that there may be a streaky defect along the X direction.

[0959] That is, when, for example, an object forming layer 50010 is formed at a resolution A, a recess 50090 is formed at a zone where droplets having smaller sizes are used to

form the layer. The recess 50090 may be amplified as a result of a laminate of the thus formed object forming layers 50010 being produced and the depth of the recess 90 increases accordingly.

[0960] According to the mode VI for carrying out the invention of the present invention, the object forming layers 50010 are formed on top of each other into a laminate while the resolution of discharging the object forming material is changed from A to B. Accordingly, the distribution of the sizes of droplets of the object forming material on the XY plane varies from when the resolution A has been applied, so that the recess 50090 can be reduced or avoided.

[0961] As a result, the defect due to the recess 50090 is alleviated (to have a shallower depth) and the surface of the formed layers 50010 is smoothed.

[0962] In one aspect of the invention, an nth layer is a raft layer and an (n+1)th layer is an object layer. A "raft layer" means a layer whose top surface is formed of the supporting material, and an "object layer" means a layer formed of the modelling material. In one desirable embodiment, the raft layer (i.e., an nth layer) has a higher resolution than the resolution of the object layer (i.e., an (n+1)th).

[0963] In another aspect of the invention, an object forming material is discharged (i.e., a forming operation is performed) at both forward and return strokes of a head in a main scanning operation. In such an embodiment, it is desirable that the landing positions of the modelling material differ between the forward and return strokes upon forming of an nth layer, whereas, upon forming an (n+1)th layer, it is desirable that the landing positions of the modelling material be the same between the forward and return strokes.

[0964] In another aspect of the invention, both an nth layer and an (n+1)th layer are object layers. In this regard, it is desirable that the resolution of the nth layer be higher than the resolution of the (n+1)th layer. Also in such a case, upon forming of the nth layer, it is desirable that the landing positions of the modelling material be different between the forward and return strokes, whereas, upon forming of the (n+1)th layer, it is desirable that the landing positions of the modelling material be the same between the forward and return strokes.

[0965] Embodiments of the mode VI for carrying out the invention of the present invention include not only a three-dimensional object forming apparatus but also a three-dimensional object forming method using the three-dimensional object forming apparatus, i.e., a three-dimensional object forming method in which an object forming material is discharged at resolutions different in the X or Y direction between an nth object forming layer and an (n+1)th object forming layer; and a program for controlling the three-dimensional object forming apparatus in this manner.

[0966] Next, an embodiment 6-1 of the present invention and a comparison example 6-1 will

be described.

<Example 6-1>

(1) Forming of raft layer:

[0967] A raft layer was first formed on the forming table 50011. The raft layer was made by forming an object forming layer (a supporting layer) of 0.5 mm thick made of the supporting material 20202 on an object forming layer 50010 (a modelling layer) of 0.5 mm thick made of the modelling material 20201.

[0968] At this time, in both the modelling layer and the supporting layer, the modelling material is discharged at a resolution in the X direction of 1200 dpi and a resolution in the Y direction of 300 dpi. The pitch in the Z-direction in the lamination direction was 20 μm.

(2) Forming of object layer:

[0969] An object layer was formed on the top of the raft layer formed as described above to form a rectangular parallelepiped three-dimensional object having the dimensions of X: 60 mm, Y: 60 mm, and Z: 10 mm. At this time, the resolution in the X direction was 1200 dpi and the resolution in the Y direction was 150 dpi. The Z-direction pitch was 20 μm.

[0970] In other words, the raft layer was the nth layer and the object layer was the (n+1)th layer. The resolutions in the Y direction were thus made different between the nth layer (300 dpi) and the (n+1)th layer (150 dpi).

<Comparison example 6-1>

(1) Forming of raft layer:

[0971] A raft layer was formed in the same manner as Example 6-1.

(2) Forming of object layer:

[0972] An object layer made of a modelling material was formed on the top of the thus formed raft layer to form a rectangular parallelepiped three-dimensional object having the dimensions of X: 60 mm, Y: 60 mm, and Z: 10 mm. At this time, the resolution in the X direction was 1200 dpi and the resolution in the Y direction was 300 dpi. The Z-direction pitch was 20 μm.

[0973] That is, the raft layer was the nth layer and the object layer was the (n+1)th layer. The resolutions in the Y direction were made to be the same between the nth layer (300 dpi) and the nth layer (300 dpi).

<Evaluation>

[0974] The surface roughness of the top sides of the three-dimensional objects of Example 6-1 and Comparison example 6-1 were measured. As the measuring instrument, Surfcom 1400D made of Tokyo Seimitsu was used. The needle diameter was 2 μm, the cutoff wavelength λc was 2.5 mm, the scanning speed was 0.6 mm/sec, the evaluation length was 12.5 mm, and the measurement length was 15 mm. The scanning direction

was in the direction parallel to the Y direction, and measurement was performed at five points to calculate the surface roughness Ra. The worst value of the values of the five points was used as the Ra value.

[0975] As a result, Example 6-1 had the value 1.8 μm, and Comparison example 6-1 had the value 5.2 μm, and it was confirmed that the object forming quality of Example 6-1 was higher than the object forming quality of Comparison example 6-1.

[0976] Thus, the three-dimensional object forming apparatuses, the three-dimensional object forming methods, and the programs have been described with reference to the embodiments. However, the present invention is not limited to the specific embodiments, and various modifications, substitutions, and so forth, may be made without departing from the scope of the claimed invention.

[0977] The present application is based on and claims priority to Japanese patent application No. 2019-050403, filed on March 18, 2019, Japanese patent application No. 2019-051152, filed on March 19, 2019, Japanese patent application No. 2019-052422, filed on March 20, 2019, Japanese patent application No. 2019-052583, filed on March 20, 2019, Japanese patent application No. 2019-052079, filed on March 20, 2019, and Japanese patent application No. 2019-052141, filed on March 20, 2019. The entire contents of Japanese patent application No. 2019-050403, Japanese patent application No. 2019-051152, Japanese patent application No. 2019-052422, Japanese patent application No. 2019-052583, Japanese patent application No. 2019-052079, and Japanese patent application No. 2019-052141 are hereby incorporated herein by reference.

[0978]

Citation List

Patent Literature

[0979] [PTL 1] Japanese Laid-Open Patent Application No. 2012-096430

[PTL 2] Japanese Patent No. 5737905

[PTL 3] Japanese Laid-Open Patent Application No. 2017-105141

[PTL 4] Japanese Laid-Open Patent Application No. 2013-67118

[PTL 5] Japanese Patent No. 5759850

[PTL 6] Japanese Laid-Open Patent Application No. 2018-144236

[PTL 7] Japanese Laid-Open Patent Application No. 2015-208904

Claims

[Claim 1] A three-dimensional object forming apparatus comprising:

a plurality of discharging units configured to discharge a modelling material and a supporting material, respectively;

a forming stage on which a three-dimensional object is formed;

one or more flattening members configured to flatten a surface of each of the discharged modelling material and supporting material;

one or more curing units configured to cure each of the discharged modelling material and supporting material; and

at least one controlling unit configured to control an object forming operation,

wherein

the at least one controlling unit is configured to

move the forming stage and the plurality of discharging units relative to each other,

perform a modelling material layer forming operation of causing a corresponding discharging unit of the plurality of discharging units to discharge the modelling material at each of forward and return strokes, and causing the one or more flattening units and the one or more curing units to flatten and cure the modelling material immediately after the discharging of the modelling material at the return stroke, and

perform a supporting material layer forming operation of causing a corresponding discharging unit of the plurality of discharging units to discharge the supporting material at each of forward and return strokes, and causing the one or more flattening units and the one or more curing units to flatten and cure the supporting material immediately after the discharging of the supporting material at the return stroke.

[Claim 2] The three-dimensional object forming apparatus according to claim 1, wherein

the supporting material layer forming operation is performed after performing of the modelling material layer forming operation.

[Claim 3] The three-dimensional object forming apparatus according to claim 2, wherein

after performing of the modelling material layer forming operation a number of times, the supporting material layer forming operation is performed a number of times smaller than the number of times of performing of the modelling material layer forming operations, to

obtain a thickness of the supporting material layer approximately the same thickness of the modelling material layer obtained by the number of times of the performing of the modelling material layer forming operations.

[Claim 4] The three-dimensional object forming apparatus according to claim 3, wherein

a thickness of the supporting material discharged at the forward stroke of the supporting material layer forming operation is greater than a thickness of the modelling material discharged by the modelling material layer forming operation.

[Claim 5] The three-dimensional object forming apparatus according to any one of claims 1-4, wherein

a thickness of the modelling material discharged at the return stroke of the modelling material layer forming operation is greater than a thickness of the modelling material discharged at the forward stroke of the modelling material layer forming operation.

[Claim 6] The three-dimensional object forming apparatus according to any one of claims 1-5,

wherein, when a modelling material layer or a supporting material layer is not formed, the modelling material layer forming operation or the supporting material layer forming operation is omitted.

[Claim 7] A three-dimensional object forming apparatus that repeats a scanning operation to form a laminate of a plurality of modelling layers and a plurality of supporting layers, the three-dimensional object forming apparatus comprising:

a discharge control unit configured to cause a modelling layer to be formed at a first scanning operation and cause a supporting layer to be formed at a second scanning operation;

a flattening control unit configured to cause a layer from among the modelling layer and the supporting layer whichever higher to be flattened; and

a curing control unit configured to cause the layer from among the modelling layer and the supporting layer having been flattened by the flattering unit to be cured.

[Claim 8] The three-dimensional object forming apparatus according to claim 7, wherein

the discharge control unit is configured to cause modelling layers to be formed at a forward stroke and a return stroke of the first

scanning operation and cause supporting layers to be formed at a forward stroke and a return stroke of the second scanning operation, wherein

the flattening control unit is configured to cause the modelling layer to be flattened at the return stroke of the first scanning operation and cause the supporting layer to be flattened at the return stroke of the second scanning operation.

[Claim 9] The three-dimensional object forming apparatus according to claim 8, wherein

when forming the modelling layer at the return stroke of the first scanning operation, the discharge control unit controls a voltage for discharging the modelling material so as to be higher than a voltage for discharging the modelling material when forming the modelling layer at the forward stroke of the first scanning operation.

[Claim 10] The three-dimensional object forming apparatus according to claim 8, wherein

when forming the modelling layer at the return stroke of the first scanning operation, the discharge control unit controls the number of pulses for discharging the modelling material so as to be greater than the number of pulses for discharging the modelling material when forming the modelling layer at the forward stroke of the first scanning operation.

[Claim 11] The three-dimensional object forming apparatus according to any one of claims 8-10, wherein

the curing control unit is configured to cause the modelling layers to be cured at each of the forward stroke and the return stroke of the first scanning operation and cause the supporting layers to be cured at each of the forward stroke and the return stroke of the second scanning operation.

[Claim 12] The three-dimensional object forming apparatus according to any one of claims 7-11, wherein

the supporting layers are water soluble.

[Claim 13] A three-dimensional object forming apparatus, comprising:

a forward stroke layer forming unit configured to discharge an object forming material at a forward stroke to form an object forming layer;

a return stroke layer forming unit configured to discharge an object forming material at a return stroke to form an object forming

layer; and

a flattening unit configured to touch the object forming layer formed at the return stroke,

wherein

in the same object forming layer, the discharging position of the object forming material at the return stroke is adjacent to the discharging position of the object forming material at the forward stroke.

[Claim 14] A three-dimensional object forming apparatus comprising:

a layer forming unit configured to discharge an object forming material to form an object forming layer during a main scanning operation,

wherein

with respect to forming one object forming layer, when a main scanning area of a head overlaps, an object forming material discharge amount at a previous scanning operation at an overlapping portion is less than an object forming material discharge amount at a final scanning operation.

[Claim 15] A three-dimensional object forming apparatus comprising:

a layer forming unit configured to discharge a modelling material from a head at forward and return scanning operations to form a plurality of modelling layers and subsequently discharge a supporting material from the head at forward and return scanning operations to form a plurality of supporting layers,

wherein, upon forming of at least some of the plurality of modelling layers and the plurality of supporting layers, positions of the head with respect to a sub-scanning direction are different.

[Claim 16] The three-dimensional object forming apparatus according to claim 15,

wherein the position of the head with respect to the sub-scanning direction upon discharging the supporting material for forming an nth layer among the plurality of supporting layers is made to be the same as the position of the head with respect to the sub-scanning direction upon discharging the modelling material upon at least any one of scanning operations for forming an nth layer among the plurality of supporting layers.

[Claim 17] The three-dimensional object forming apparatus according to claim 15,

wherein the position of the head with respect to the sub-scanning

direction upon a scanning operation for discharging the supporting material in a nth slice layer of a plurality of slice layers including the plurality of modelling layers and the plurality of supporting layers is made to be the same as the position of the head with respect to the sub-scanning direction for forming the highest modelling layer included the nth slice layer of the plurality of slice layers.

[Claim 18] The three-dimensional object forming apparatus according to claim 16 or 17,

wherein a position with respect to the sub-scanning direction to start a first scanning operation for forming a supporting layer is made to be opposite to a position with respect to the sub-scanning direction to start an immediately preceding scanning operation for forming a modeling layer.

[Claim 19] The three-dimensional object forming apparatus according to any one of claims 15-18, comprising

a flattening unit configured to flatten at least one of a modelling layer and a supporting layer,

wherein

upon a scanning operation of the flattening unit, at least one of the modelling material and the supporting material is discharged.

[Claim 20] A three-dimensional object forming apparatus, discharging an object forming material from a discharging unit to form object forming layers and forming the object forming layers on top of each other into a laminate to obtain a three-dimensional object, the three-dimensional object forming apparatus comprising:

one or more controlling units configured to control discharging of an object forming material in such a manner of making a resolution of discharging an object forming material in a X or Y direction different between a nth layer and a (n+1)th layer of the three-dimensional object.

[Claim 21] The three-dimensional object forming apparatus according to claim 20, wherein

the nth layer of the three-dimensional object is a raft layer and the (n+1)th layer of the three-dimensional object is an object layer.

[Claim 22] The three-dimensional object forming apparatus according to claim 21, wherein

the resolution of the raft layer is higher than the resolution of the object layer.

[Claim 23] The three-dimensional object forming apparatus according to

claim 21 or 22, wherein

the raft layer is formed by discharging of an object forming material in both of forward and return directions in such a manner that the object forming material is caused to land at positions different between the forward and return directions; and

the object layer is formed by discharging of an object forming material in both of forward and return directions in such a manner that the object forming material is caused to land at the same positions between the forward and return directions.

[Claim 24] The three-dimensional object forming apparatus according to claim 20, wherein

both of the nth layer and the (n+1)th layer of the three-dimensional object are included in the three-dimensional object.

[Claim 25] The three-dimensional object forming apparatus according to claim 24, wherein

the resolution of the nth layer of the three-dimensional object is higher than the resolution of the (n+1)th layer of the three-dimensional object.

[Claim 26] The three-dimensional object forming apparatus according to claim 24 or 25, wherein

the nth layer is formed by discharging of an object forming material in both of forward and return directions in such a manner that the object forming material is caused to land at positions different between the forward and return directions; and

the (n+1)th layer is formed by discharging of an object forming material in both of forward and return directions in such a manner that the object forming material is caused to land at the same positions between the forward and return directions.

[Claim 27] A three-dimensional object forming method for forming a three-dimensional object made of a modelling material using a supporting material for supporting the modelling material, the three-dimensional object forming method comprising:

moving, relative to each other, a plurality of discharging units discharging the modelling material and the supporting material respectively and a forming stage on which the three-dimensional object is formed;

discharging the modelling material at each of forward and return strokes, and flattening and curing the modelling material immediately

after the discharging of the modelling material at the return stroke; and

discharging the supporting material at each of forward and return strokes, and flattening and curing the supporting material immediately after the discharging of the supporting material at the return stroke.

[Claim 28] A three-dimensional object forming method for repeating a scanning operation to form a laminate of a plurality of modelling layers and a plurality of supporting layers, the three-dimensional object forming method comprising:

forming a modelling layer at a first scanning operation;

forming a supporting layer at a second scanning operation;

flattening a layer from among the modelling layer and the supporting layer whichever is higher; and

curing the layer having been flattened from among the modelling layer and the supporting layer.

[Claim 29] A three-dimensional object forming method, comprising:

discharging an object forming material at a forward stroke to form an object forming layer;

discharging an object forming material at a return stroke to form an object forming layer; and

causing a flattening member to touch a surface of the object forming layer formed at the return stroke,

wherein

in the same object forming layer, the discharging position of the object forming material at the return stroke is adjacent to the discharging position of the object forming material at the forward stroke.

[Claim 30] The three-dimensional object forming method according to claim 29, wherein

the object forming material is discharged at the return stroke in such a manner as to overlap at least partially with the object forming material discharged at the forward stroke.

[Claim 31] The three-dimensional object forming method according to claim 29 or 30, wherein

at least two sides of the object forming material discharged at the forward stroke are in contact with the object forming material discharged at the return stroke.

[Claim 32] The three-dimensional object forming method according to any one of claims 29-31, wherein

coordinates of the forward and return strokes are switched from

each other in an object forming layer of a different height.

[Claim 33] The three-dimensional object forming method according to any one of claims 29-32, wherein

a total discharge amount of the object forming material discharged at the return stroke is greater than a total discharge amount of the object forming material discharged at the forward stroke.

[Claim 34] The three-dimensional object forming method according to any one of claims 29-33, wherein

in the same object forming layer, a first object forming material is discharged and cured, and then a second object forming material is discharged and cured.

[Claim 35] The three-dimensional object forming method according to claim 34, wherein

the second object forming material is a water soluble material.

[Claim 36] A three-dimensional object forming method comprising:

discharging an object forming material to form an object forming layer during a main scanning operation,

wherein

with respect to forming one object forming layer, when a main scanning area of a head overlaps, an object forming material discharge amount at a previous scanning operation at an overlapping portion is less than an object forming material discharge amount at a final scanning operation.

[Claim 37] The three-dimensional object forming method according to claim 36,

wherein

at the overlapping portion, the object forming material is not discharged at the previous scanning operation.

[Claim 38] The three-dimensional object forming method according to claim 36 or 37,

wherein

the head is moved in a sub-scanning direction relatively for forming one object forming layer.

[Claim 39] The three-dimensional object forming method according to claim 38,

wherein

the discharging the object forming material includes discharging the object forming material at both a forward stroke and a return stroke

in the main scanning direction, and

moving the head in the sub-scanning direction with respect to discharging the object forming material at both the forward stroke and the return stroke in the main scanning direction.

[Claim 40] The three-dimensional object forming method according to claim 38 or 39, wherein the head is moved in the sub-scanning direction during acceleration or deceleration of the head in the main scanning direction, after discharging the object forming material at the forward stroke.

[Claim 41] The three-dimensional object forming method according to any one of claims 38-40, wherein movement of the head in the sub-scanning direction corresponds to rendering.

[Claim 42] The three-dimensional object forming method according to any one of claims 36-41, comprising:

flattening a surface of the object forming layer formed at the return stroke.

[Claim 43] The three-dimensional object forming method according to any one of claims 36-42,

wherein

the total object forming material discharge amount at the return stroke is greater than the total object forming material discharge amount at the forward stroke.

[Claim 44] The three-dimensional object forming method according to any one of claims 36-43,

wherein

for forming one object forming layer, the first forming material is discharged and cured, and then, the second forming material is discharged and cured.

[Claim 45] The three-dimensional object forming method according to claim 44,

wherein

the first forming material is discharged and cured for an nth object forming layer and the second forming material is discharged and cured for an (n+m)th object forming layer, wherein n denotes a natural number and m denotes an integer which is positive or negative.

[Claim 46] The three-dimensional object forming method according to claim 44,

wherein

the first forming material is discharged and cured for an nth object forming layer and the second forming material is discharged and cured for an (n+2)th object forming layer, wherein n denotes a natural number.

[Claim 47] A three-dimensional object forming method comprising discharging a modelling material from a head at forward and return scanning operations to form a plurality of modelling layers and subsequently discharging a supporting material from the head at forward and return scanning operations to form a plurality of supporting layers, wherein

upon forming of at least some of the plurality of modelling layers and the plurality of supporting layers, positions of the head with respect to the sub-scanning direction are different.

[Claim 48] A three-dimensional object forming method, comprising:

discharging an object forming material from a discharging unit to form object forming layers and forming the object forming layers on top of each other into a laminate to obtain a three-dimensional object; and

controlling discharging of an object forming material in such a manner of making a resolution of discharging an object forming material in a X or Y direction different between a nth layer and a (n+1)th layer of the three-dimensional object.

[Claim 49] A program for causing a computer to execute control of forming a three-dimensional object made of a modelling material using a supporting material for supporting the modelling material, the program causing the computer to

move, relative to each other, a plurality of discharging units discharging the modelling material and the supporting material respectively and a forming stage on which the three-dimensional object is formed;

execute control of discharging the modelling material at each of forward and return strokes, and flattening and curing the modelling material immediately after the discharging of the modelling material at the return stroke; and

execute control of discharging the supporting material at each of forward and return strokes, and flattening and curing the supporting material immediately after the discharging of the supporting material at the return stroke.

[Claim 50] A program for repeating a scanning operation to form a laminate of a plurality of modelling layers and a plurality of supporting layers, the program causing a computer to:

cause a modelling layer to be formed at a first scanning operation;

cause a supporting layer to be formed at a second scanning operation;

cause a layer from among the modelling layer and the supporting layer whichever is higher to be flattened; and

cause the layer having been flattened from among the modelling layer and the supporting layer to be cured.

[Claim 51] A program causing a computer to

discharge an object forming material at a forward stroke to form an object forming layer;

discharge an object forming material at a return stroke to form an object forming layer;

cause a flattening member to touch the object forming layer formed at the return stroke; and

perform control in such a manner that, in the same object forming layer, the discharging position of the object forming material at the return stroke is adjacent to the discharging position of the object forming material at the forward stroke.

[Claim 52] A program for causing a computer to discharge an object forming material to form an object forming layer during a main scanning operation,

wherein

with respect to forming one object forming layer, when a main scanning area of a head overlaps, an object forming material discharge amount at a previous scanning operation at an overlapping portion is less than an object forming material discharge amount at a final scanning operation.

[Claim 53] A program causing a computer to

discharge a modelling material from a head at forward and return scanning operations to form a plurality of modelling layers and sub-sequently discharge a supporting material from the head at forward and return scanning operations to form a plurality of supporting layers,

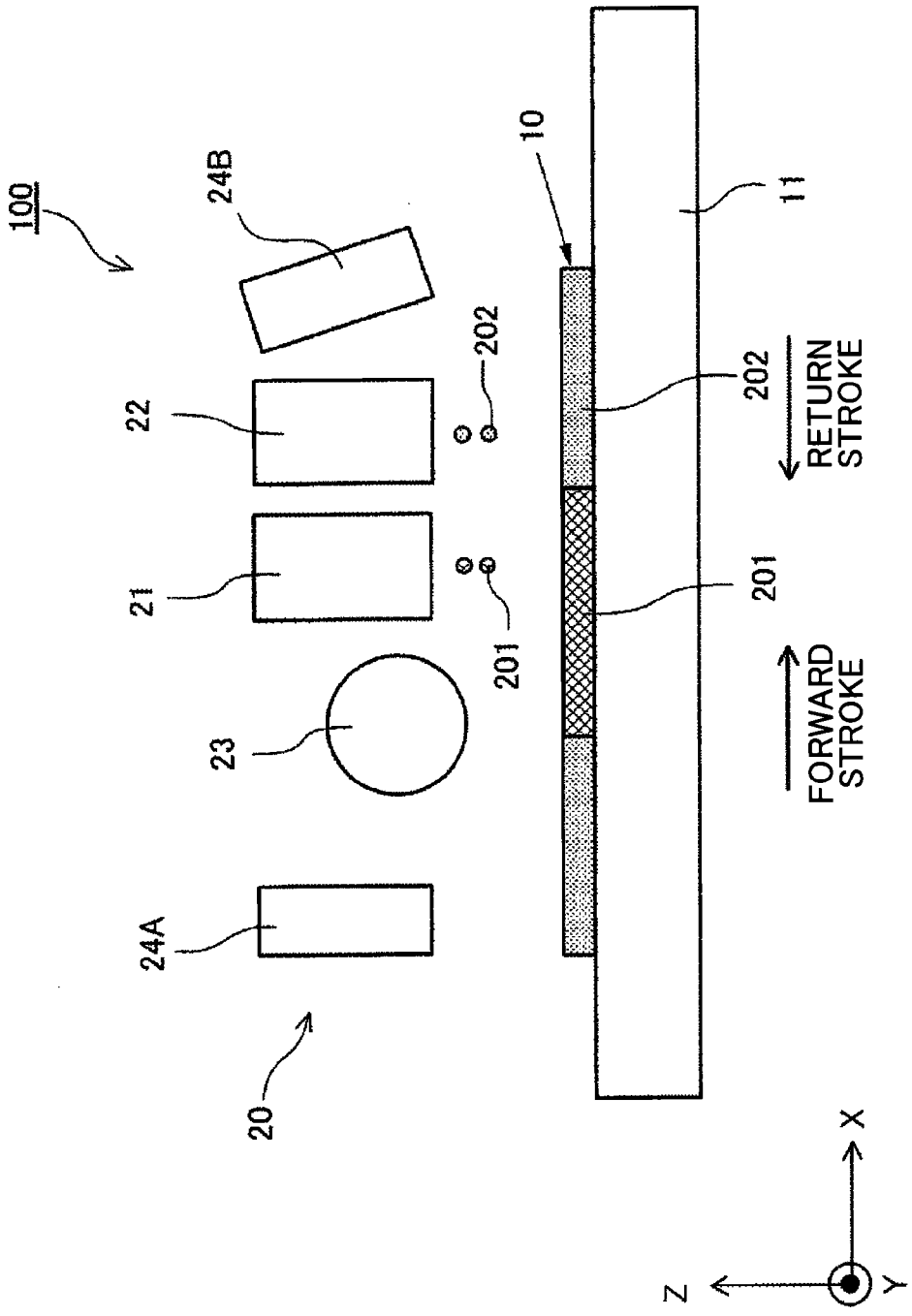
wherein, upon forming of at least some of the plurality of modelling layers and the plurality of supporting layers, positions of the head with respect to the sub-scanning direction are different.

[Claim 54] A program for causing a computer to perform

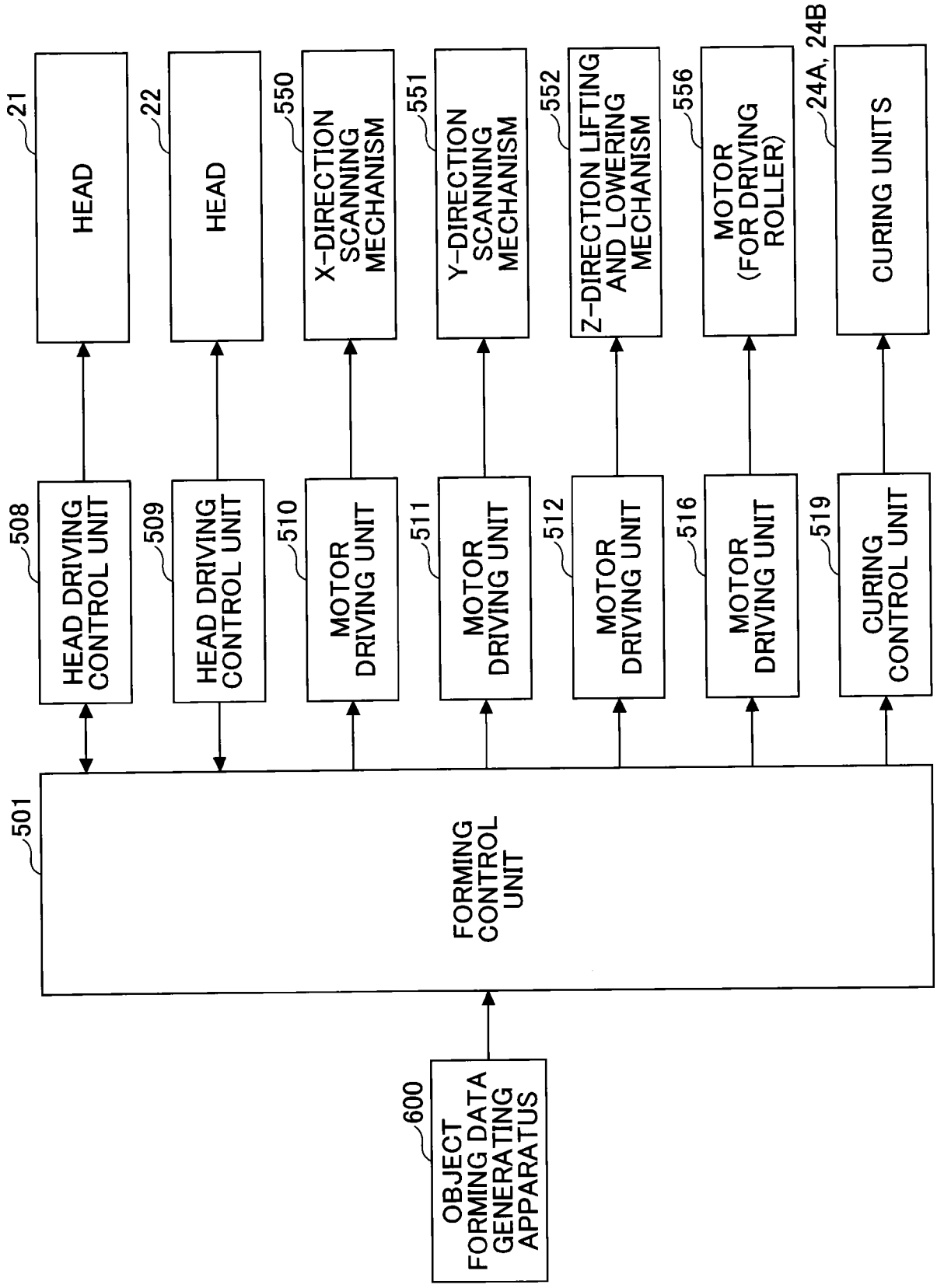
control of discharging an object forming material from a discharging unit to form object forming layers and forming the object forming layers on top of each other into a laminate to obtain a three-dimensional object; and

control of discharging of an object forming material in such a manner of making a resolution of discharging an object forming material in a X or Y direction different between a nth layer and a (n+1)th layer of the three-dimensional object.

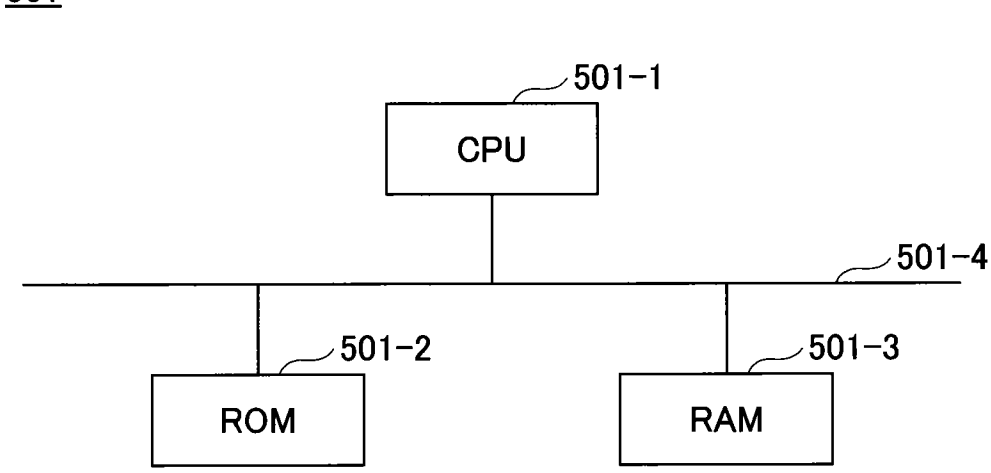
[Fig. 1]


100
24B
22
21
23
24A
20
202
201
10
11
202
RETURN STROKE
201
FORWARD STROKE
X
Y
Z

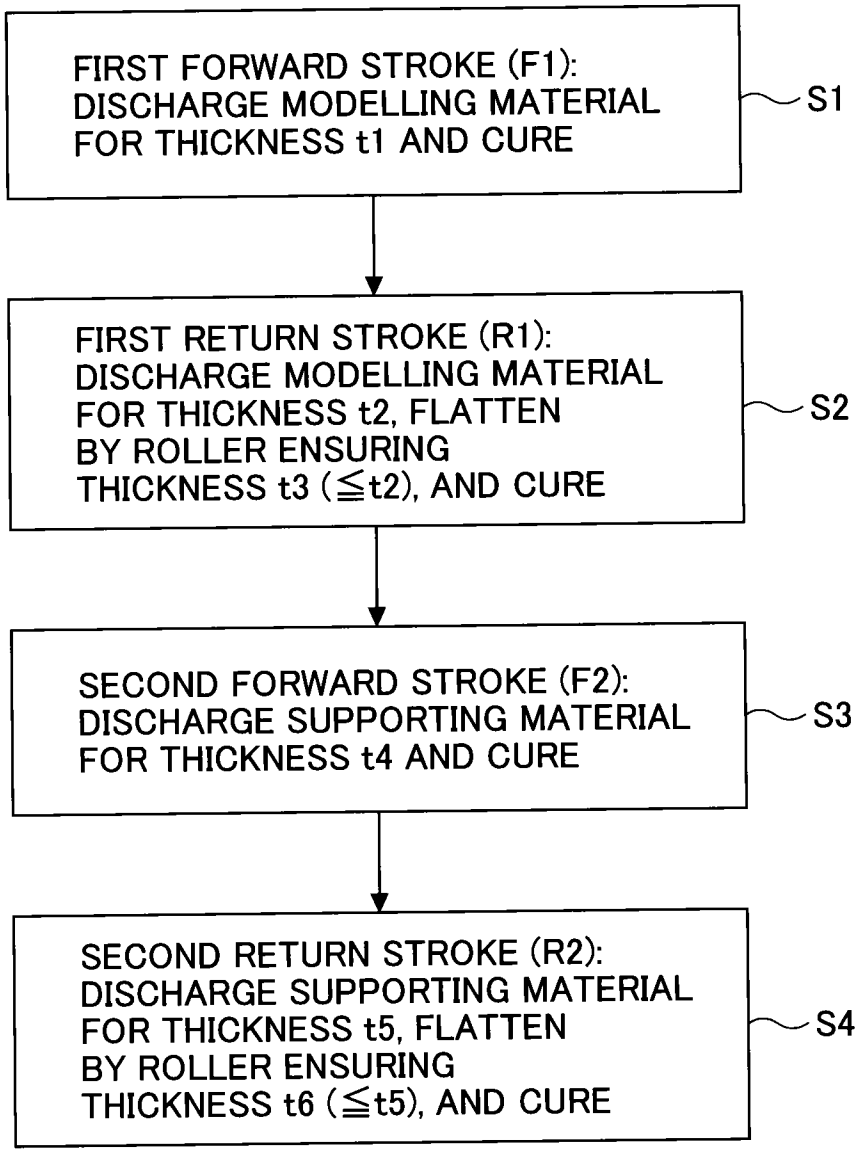
[Fig. 2A]


21
HEAD
22
HEAD
550
X-DIRECTION SCANNING MECHANISM
551
Y-DIRECTION SCANNING MECHANISM
552
Z-DIRECTION LIFTING AND LOWERING MECHANISM
556
MOTOR (FOR DRIVING ROLLER)
24A, 24B
CURING UNITS
508
HEAD DRIVING CONTROL UNIT
509
HEAD DRIVING CONTROL UNIT
510
MOTOR DRIVING UNIT
511
MOTOR DRIVING UNIT
512
MOTOR DRIVING UNIT
516
MOTOR DRIVING UNIT
519
CURING CONTROL UNIT
501
FORMING CONTROL UNIT
600
OBJECT FORMING DATA GENERATING APPARATUS

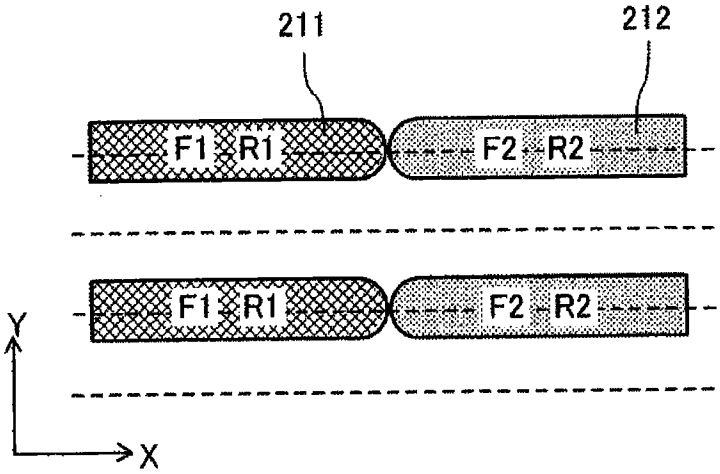
[Fig. 2B]



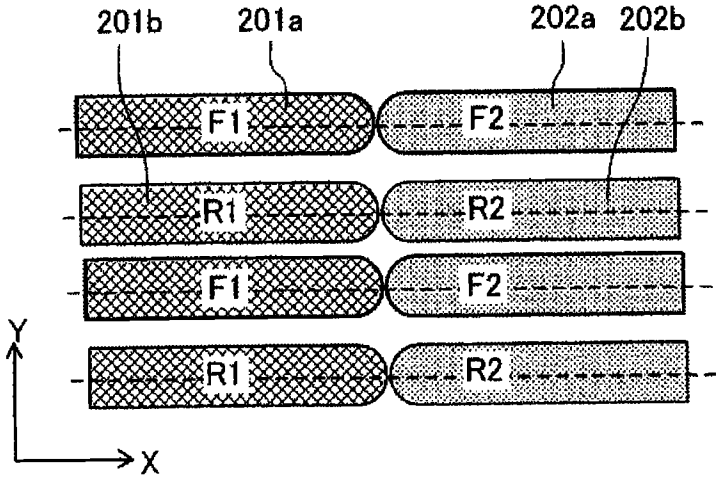
[Fig. 3]


FIRST FORWARD STROKE (F1): DISCHARGE MODELLING MATERIAL FOR THICKNESS t1 AND CURE
S1
FIRST RETURN STROKE (R1): DISCHARGE MODELLING MATERIAL FOR THICKNESS t2, FLATTEN BY ROLLER ENSURING THICKNESS t3 (≦t2), AND CURE
S2
SECOND FORWARD STROKE (F2): DISCHARGE SUPPORTING MATERIAL FOR THICKNESS t4 AND CURE
S3
SECOND RETURN STROKE (R2): DISCHARGE SUPPORTING MATERIAL FOR THICKNESS t5, FLATTEN BY ROLLER ENSURING THICKNESS t6 (≦t5), AND CURE
S4

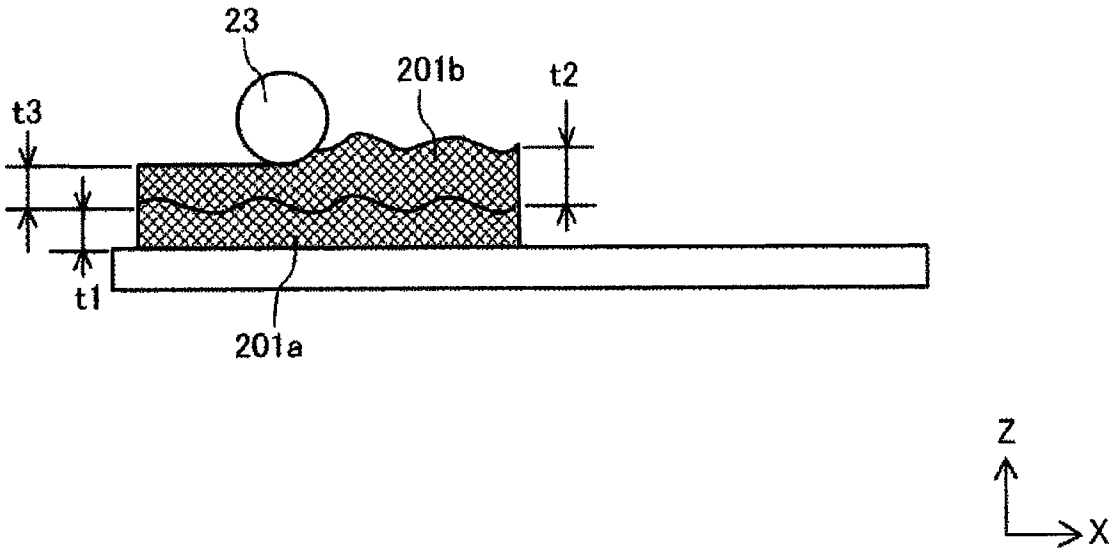
[Fig. 4A]


211
212
F1
R1
F2
R2
F1
R1
F2
R2
Y
X

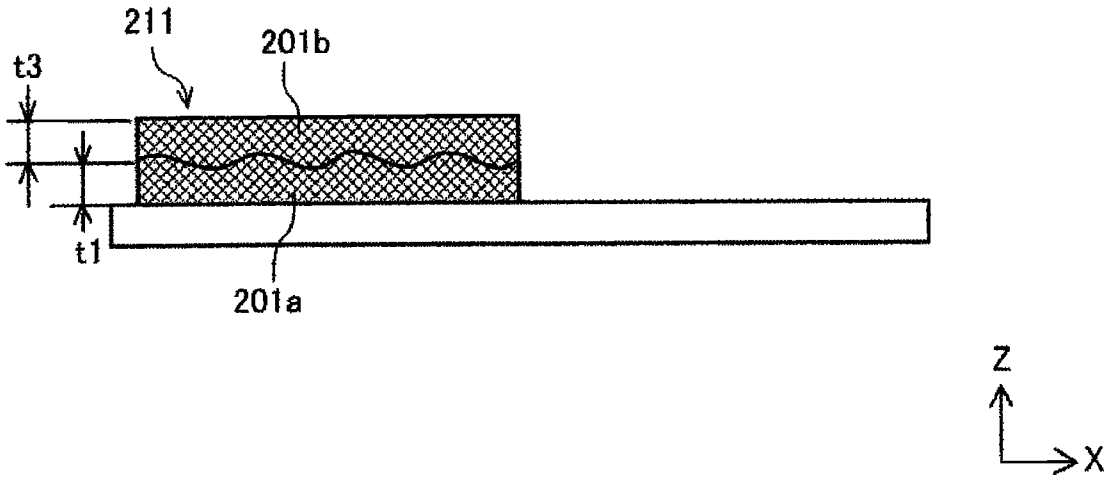
[Fig. 4B]


201b
201a
202a
202b
F1
F2
R1
R2
F1
F2
R1
R2
Y
X

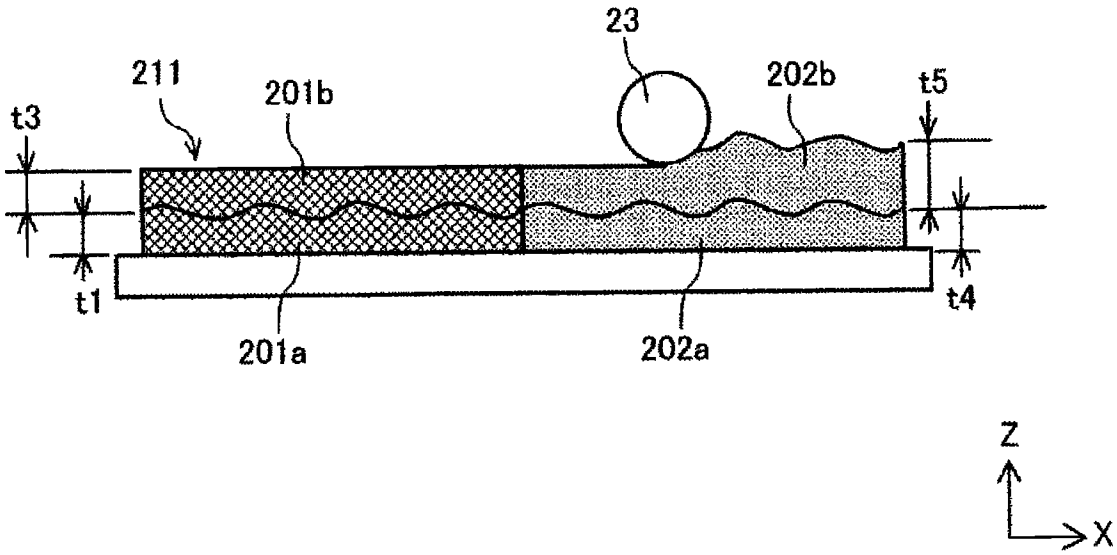
[Fig. 5A]



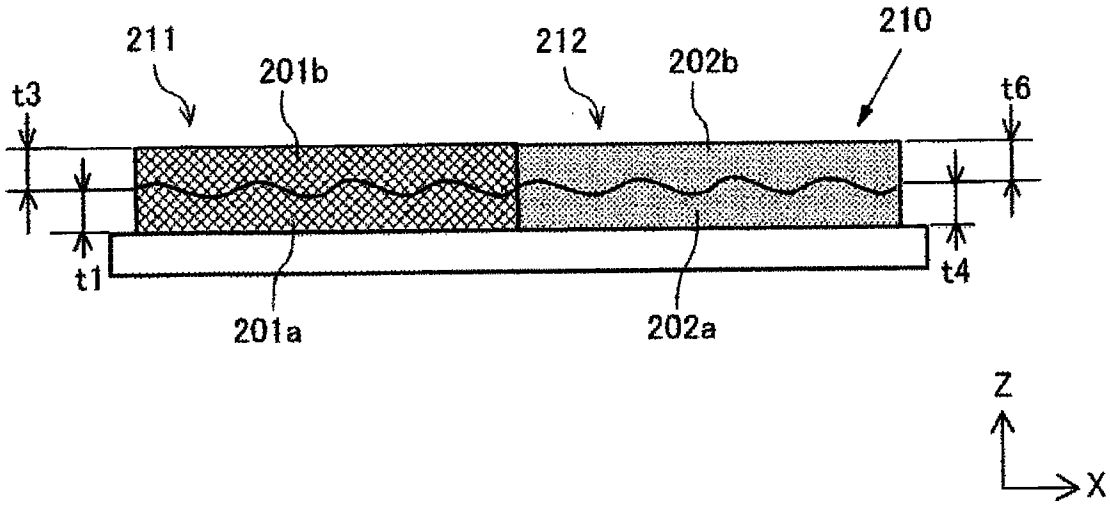
[Fig. 5B]



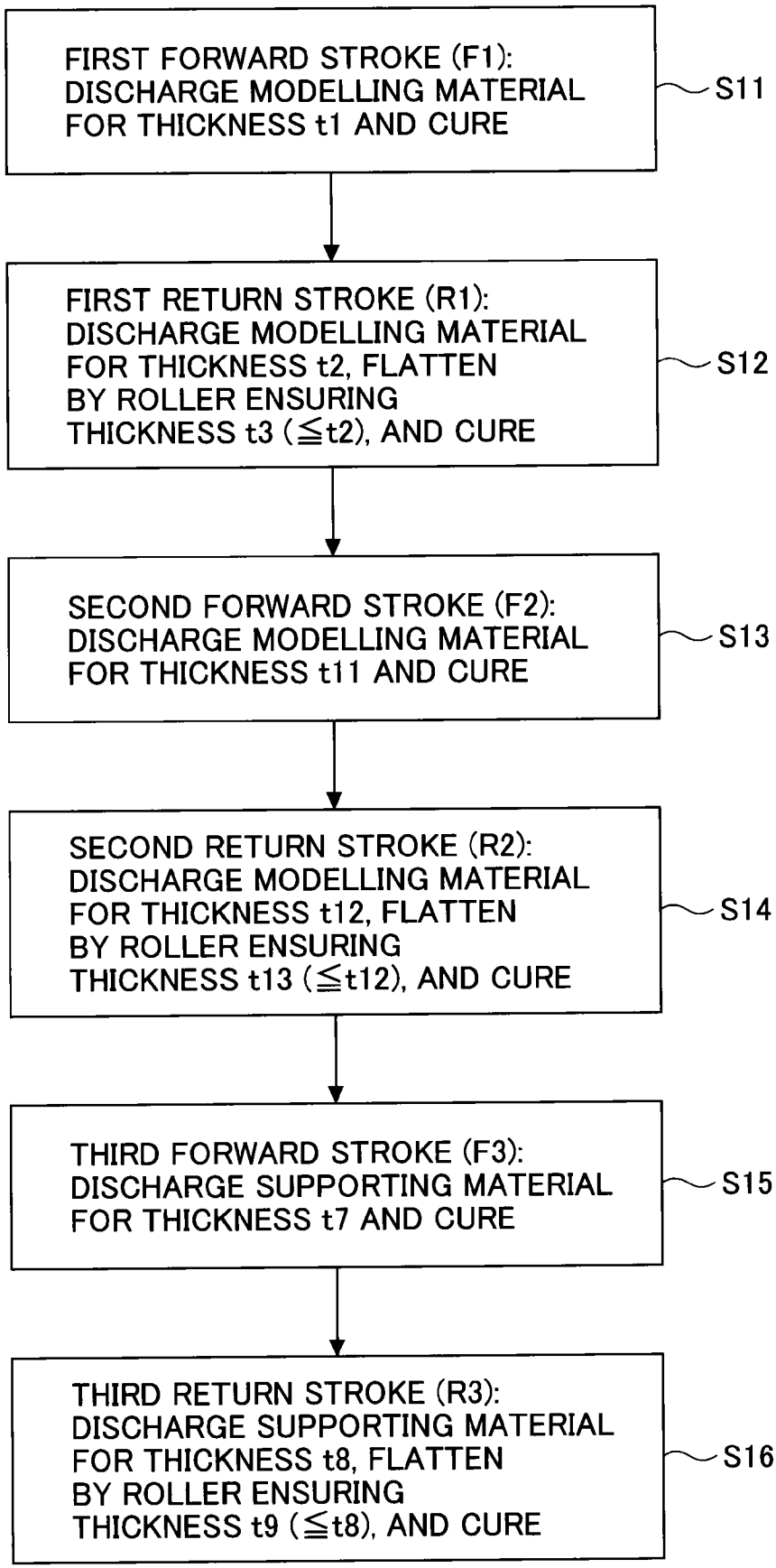
[Fig. 5C]


23
211
201b
202b
t5
t3
t1
t4
201a
202a
Z
X

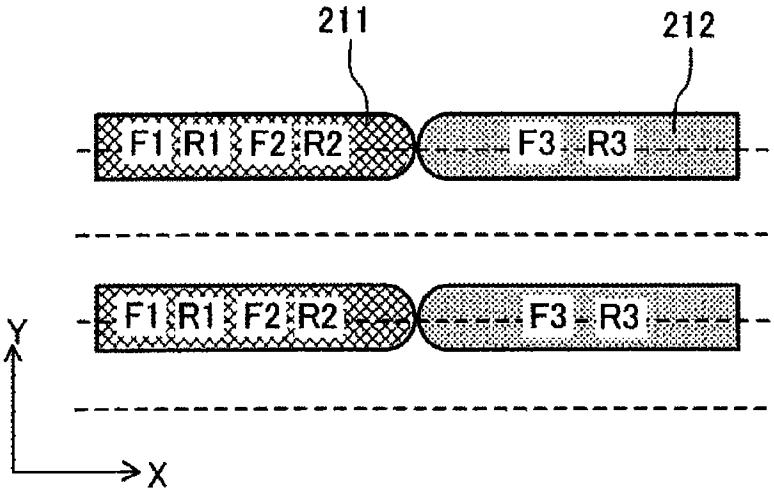
[Fig. 5D]


211
212
210
201b
202b
t6
t3
t1
t4
201a
202a
Z
X

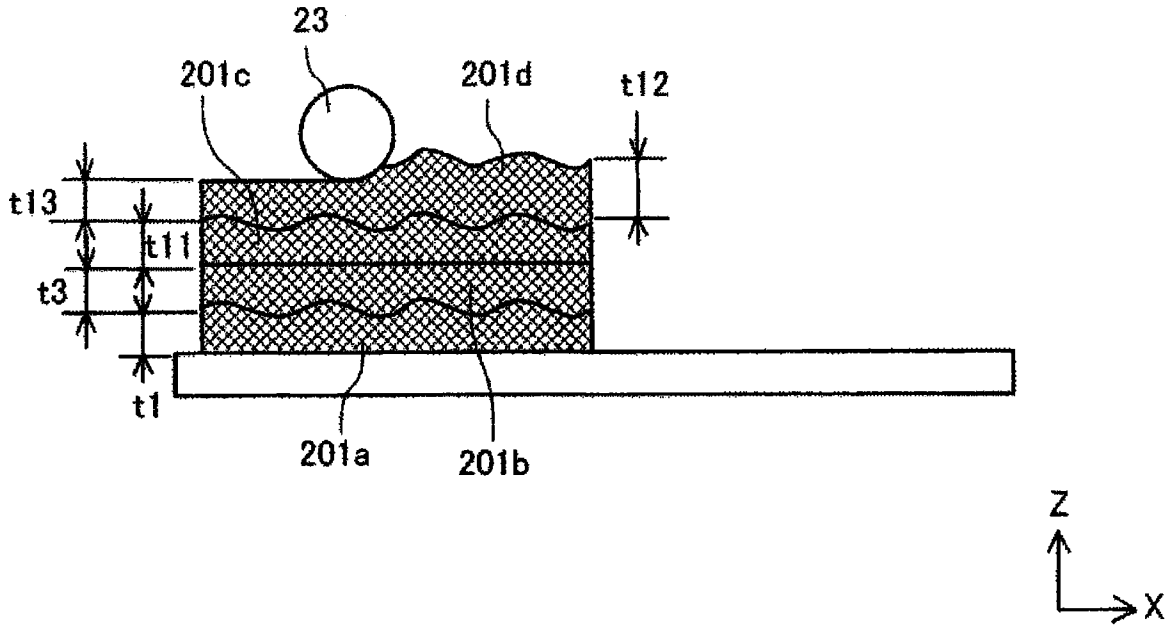
[Fig. 6]


FIRST FORWARD STROKE (F1): DISCHARGE MODELLING MATERIAL FOR THICKNESS t1 AND CURE
S11
FIRST RETURN STROKE (R1): DISCHARGE MODELLING MATERIAL FOR THICKNESS t2, FLATTEN BY ROLLER ENSURING THICKNESS t3 (≦t2), AND CURE
S12
SECOND FORWARD STROKE (F2): DISCHARGE MODELLING MATERIAL FOR THICKNESS t11 AND CURE
S13
SECOND RETURN STROKE (R2): DISCHARGE MODELLING MATERIAL FOR THICKNESS t12, FLATTEN BY ROLLER ENSURING THICKNESS t13 (≦t12), AND CURE
S14
THIRD FORWARD STROKE (F3): DISCHARGE SUPPORTING MATERIAL FOR THICKNESS t7 AND CURE
S15
THIRD RETURN STROKE (R3): DISCHARGE SUPPORTING MATERIAL FOR THICKNESS t8, FLATTEN BY ROLLER ENSURING THICKNESS t9 (≦t8), AND CURE
S16

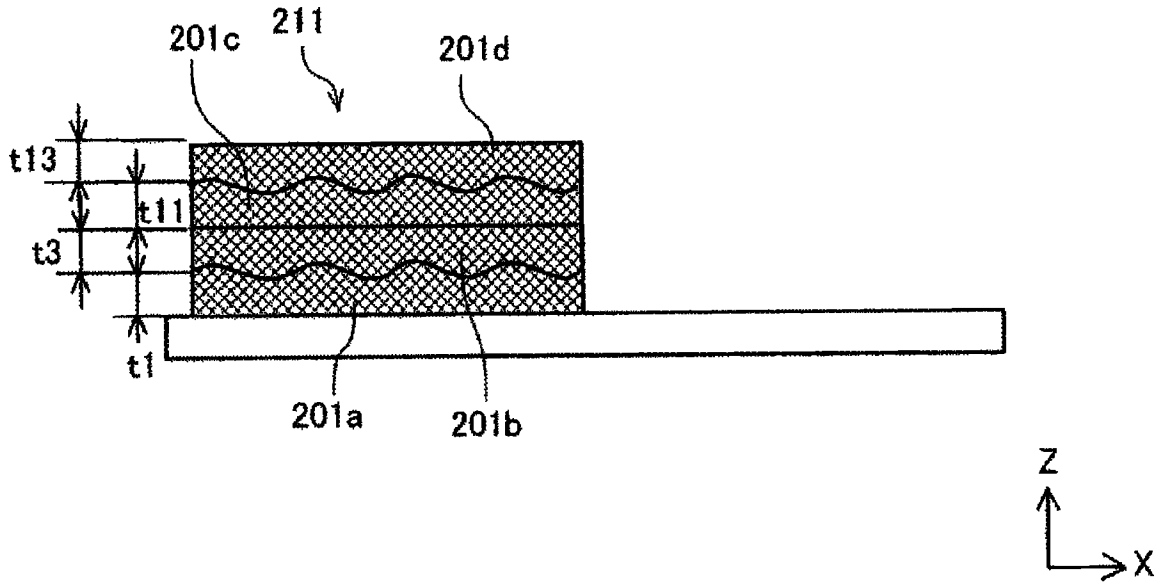
[Fig. 7]


211
212
F1
R1
F2
R2
F3
R3
F1
R1
F2
R2
F3
R3
Y
X

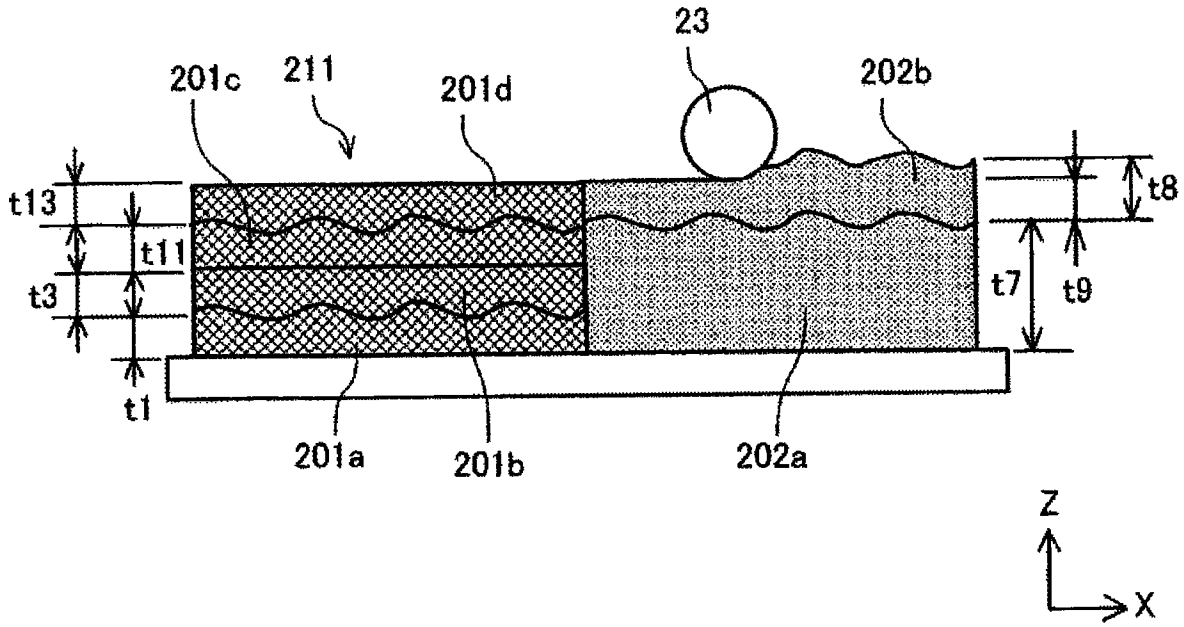
[Fig. 8A]


23
201c
201d
t12
t13
t11
t3
t1
201a
201b
Z
X

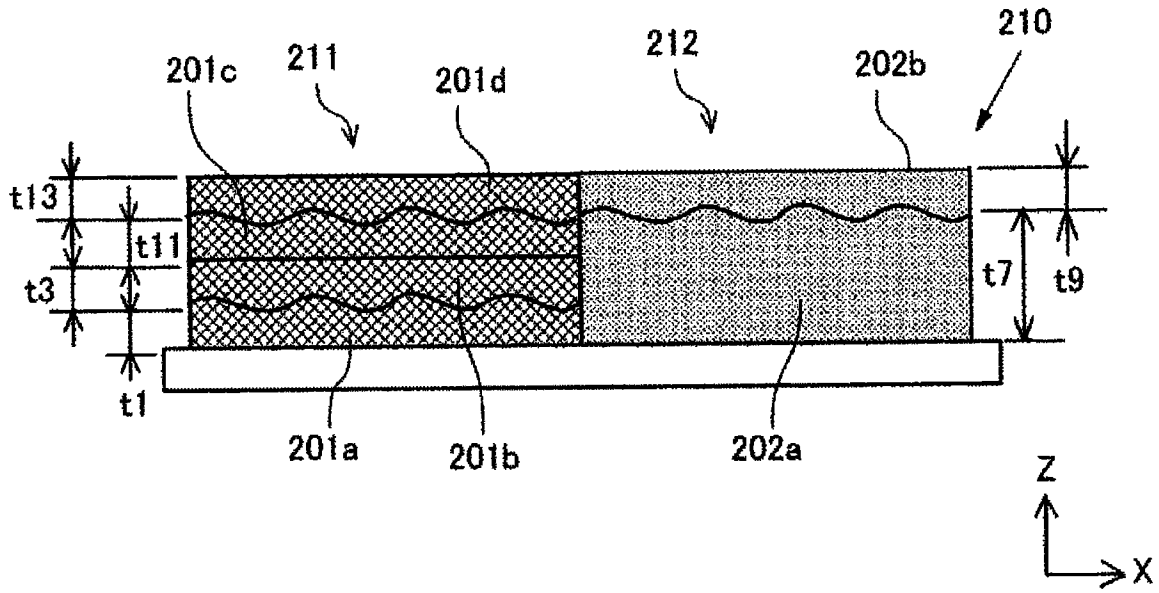
[Fig. 8B]


201c
211
201d
t13
t11
t3
t1
201a
201b
Z
X

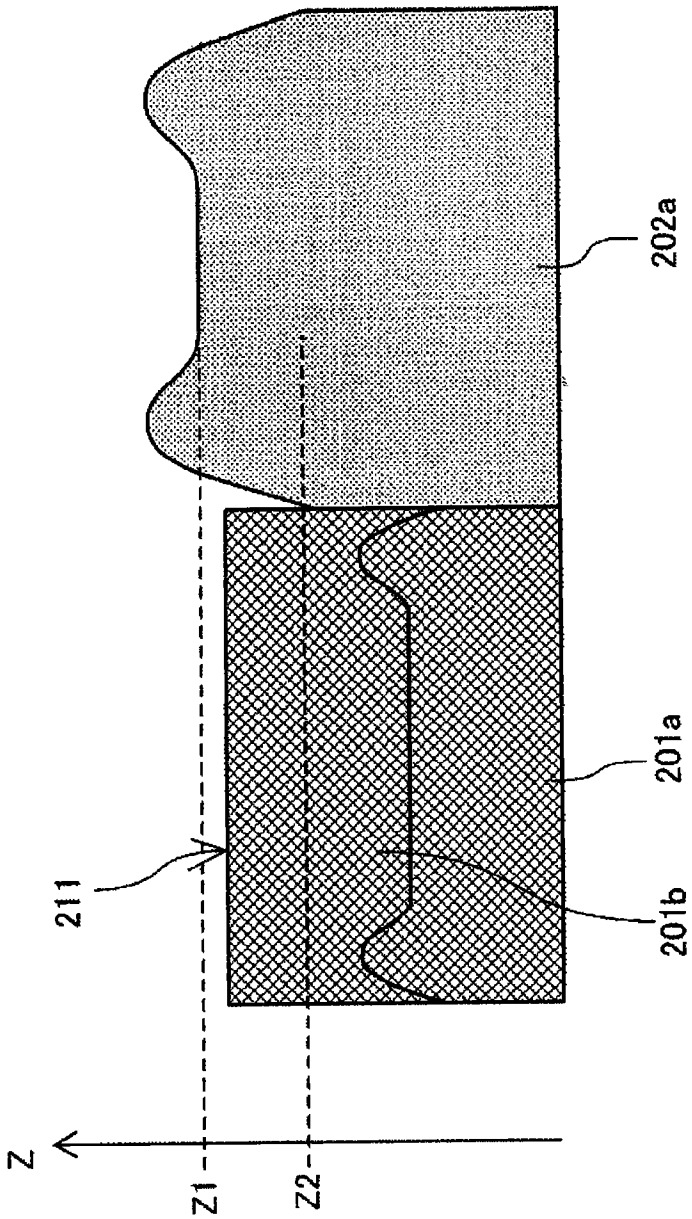
[Fig. 8C]


23
201c
211
201d
202b
t13
t11
t3
t1
t8
t7
t9
201a
201b
202a
Z
X

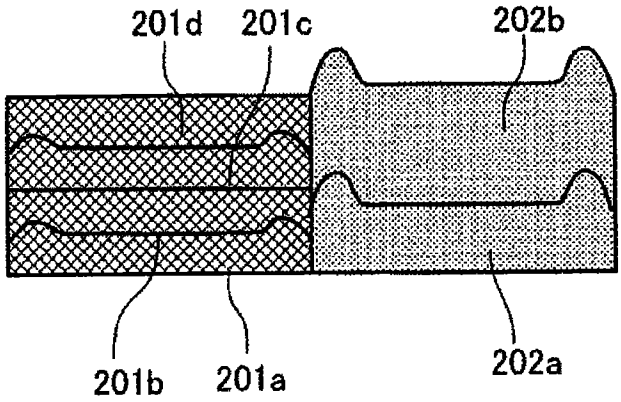
[Fig. 8D]



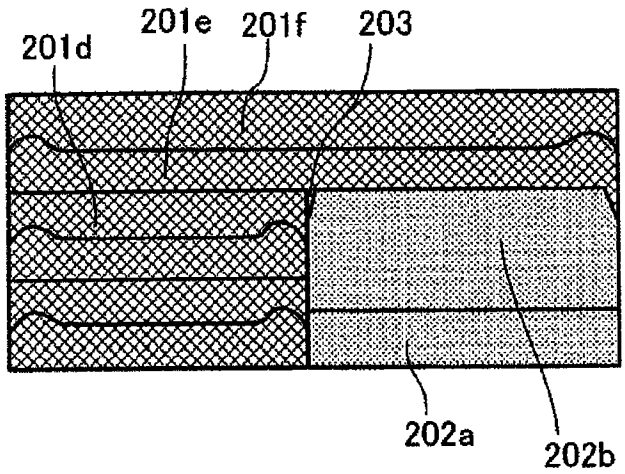
[Fig. 9]



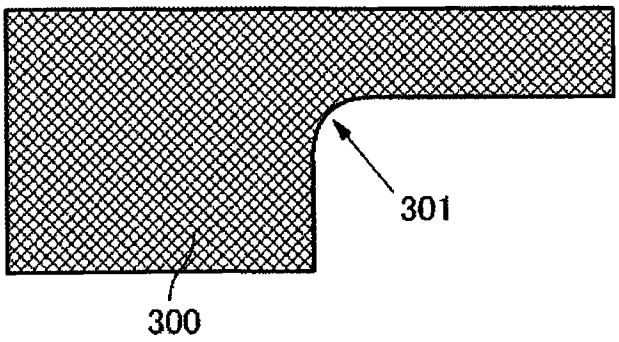
[Fig. 10A]



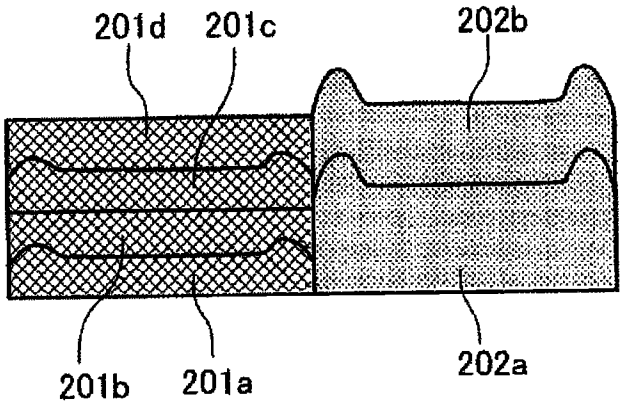
[Fig. 10B]



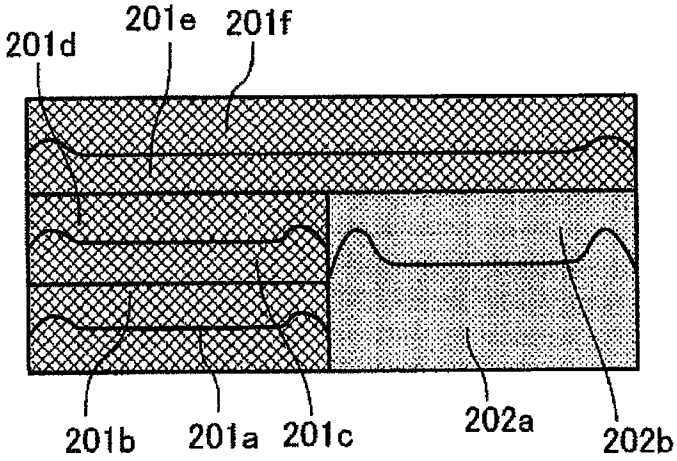
[Fig. 10C]



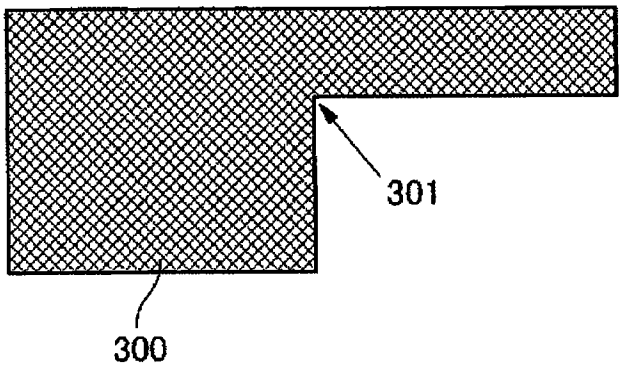
[Fig. 11A]



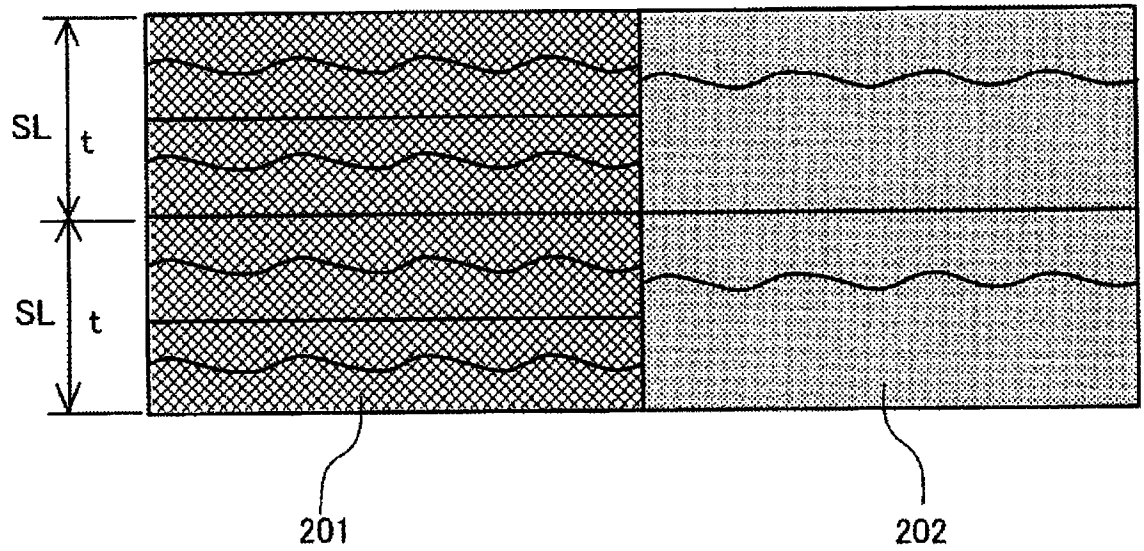
[Fig. 11B]



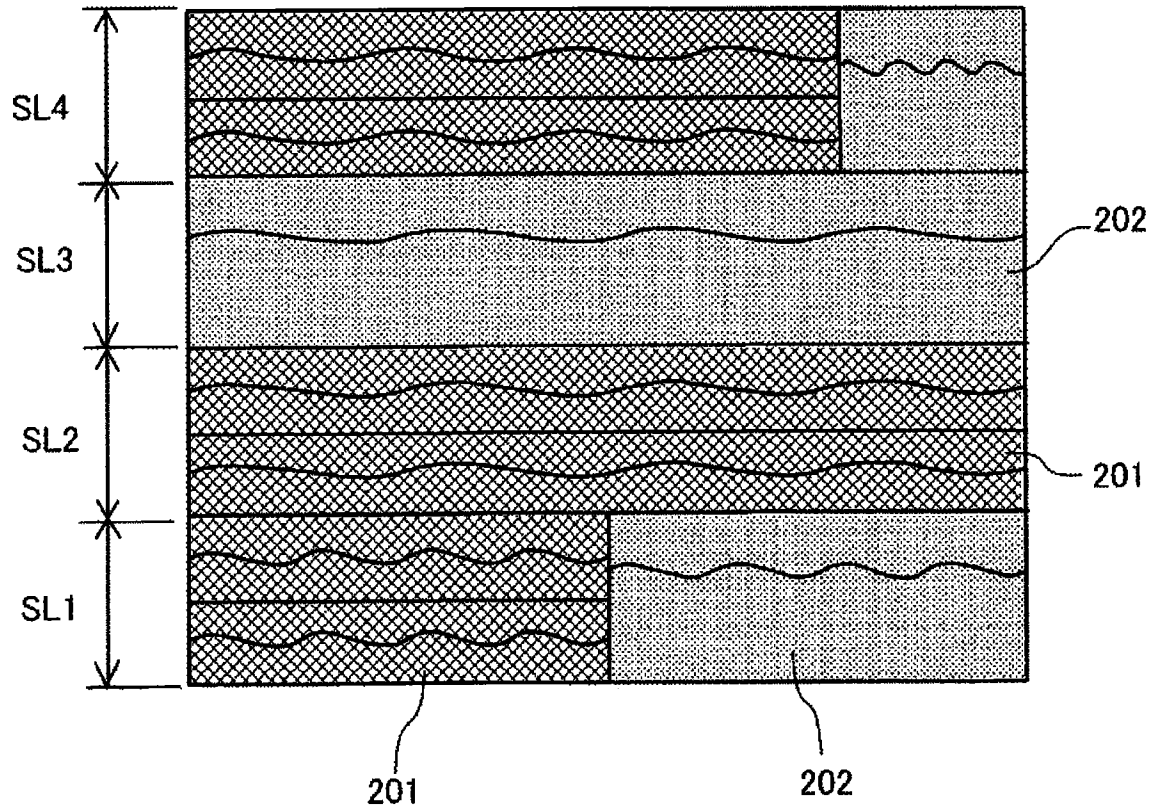
[Fig. 11C]



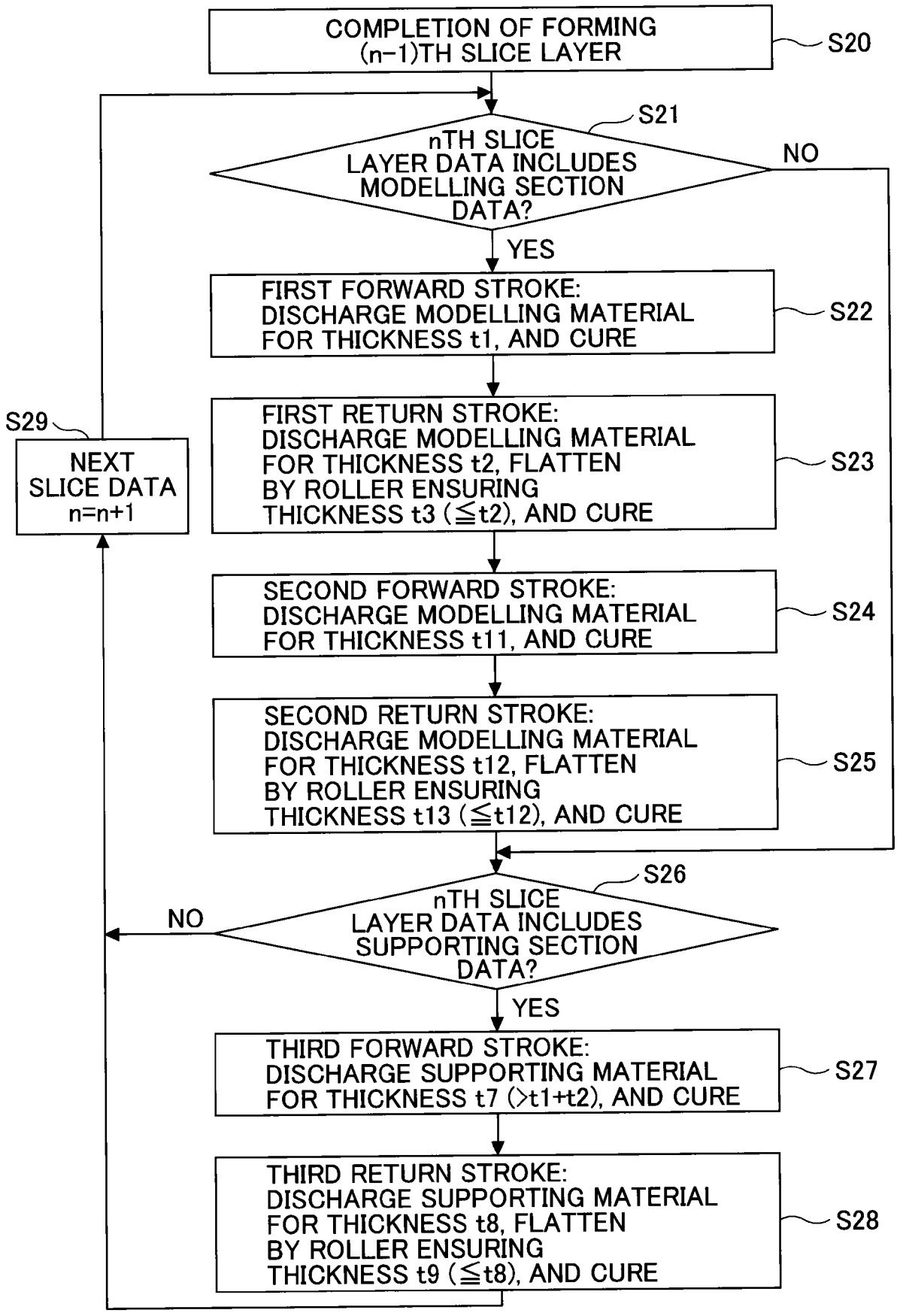
[Fig. 12]



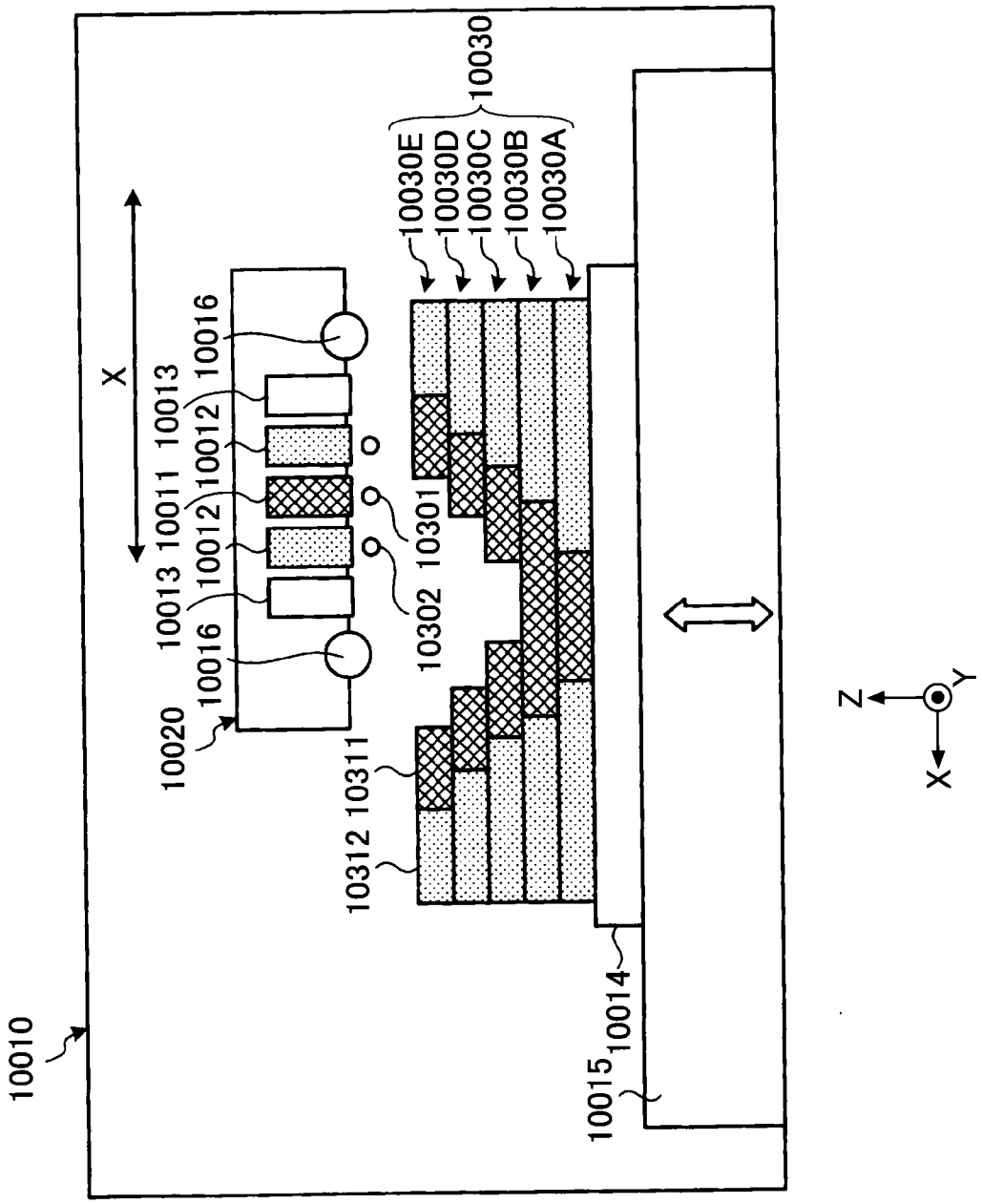
[Fig. 13]



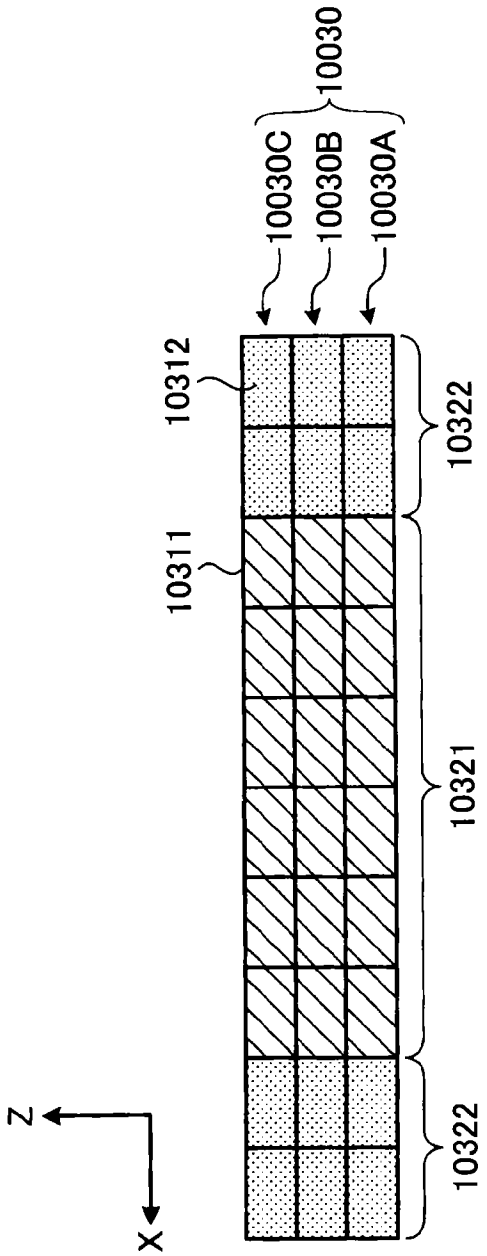
[Fig. 14]


COMPLETION OF FORMING (n-1)TH SLICE LAYER
S20
S21
nTH SLICE LAYER DATA INCLUDES MODELLING SECTION DATA?
NO
YES
FIRST FORWARD STROKE: DISCHARGE MODELLING MATERIAL FOR THICKNESS t1, AND CURE
S22
FIRST RETURN STROKE: DISCHARGE MODELLING MATERIAL FOR THICKNESS t2, FLATTEN BY ROLLER ENSURING THICKNESS t3 (≦t2), AND CURE
S23
SECOND FORWARD STROKE: DISCHARGE MODELLING MATERIAL FOR THICKNESS t11, AND CURE
S24
SECOND RETURN STROKE: DISCHARGE MODELLING MATERIAL FOR THICKNESS t12, FLATTEN BY ROLLER ENSURING THICKNESS t13 (≦t12), AND CURE
S25
S29
NEXT SLICE DATA n=n+1
S26
nTH SLICE LAYER DATA INCLUDES SUPPORTING SECTION DATA?
NO
YES
THIRD FORWARD STROKE: DISCHARGE SUPPORTING MATERIAL FOR THICKNESS t7 (>t1+t2), AND CURE
S27
THIRD RETURN STROKE: DISCHARGE SUPPORTING MATERIAL FOR THICKNESS t8, FLATTEN BY ROLLER ENSURING THICKNESS t9 (≦t8), AND CURE
S28

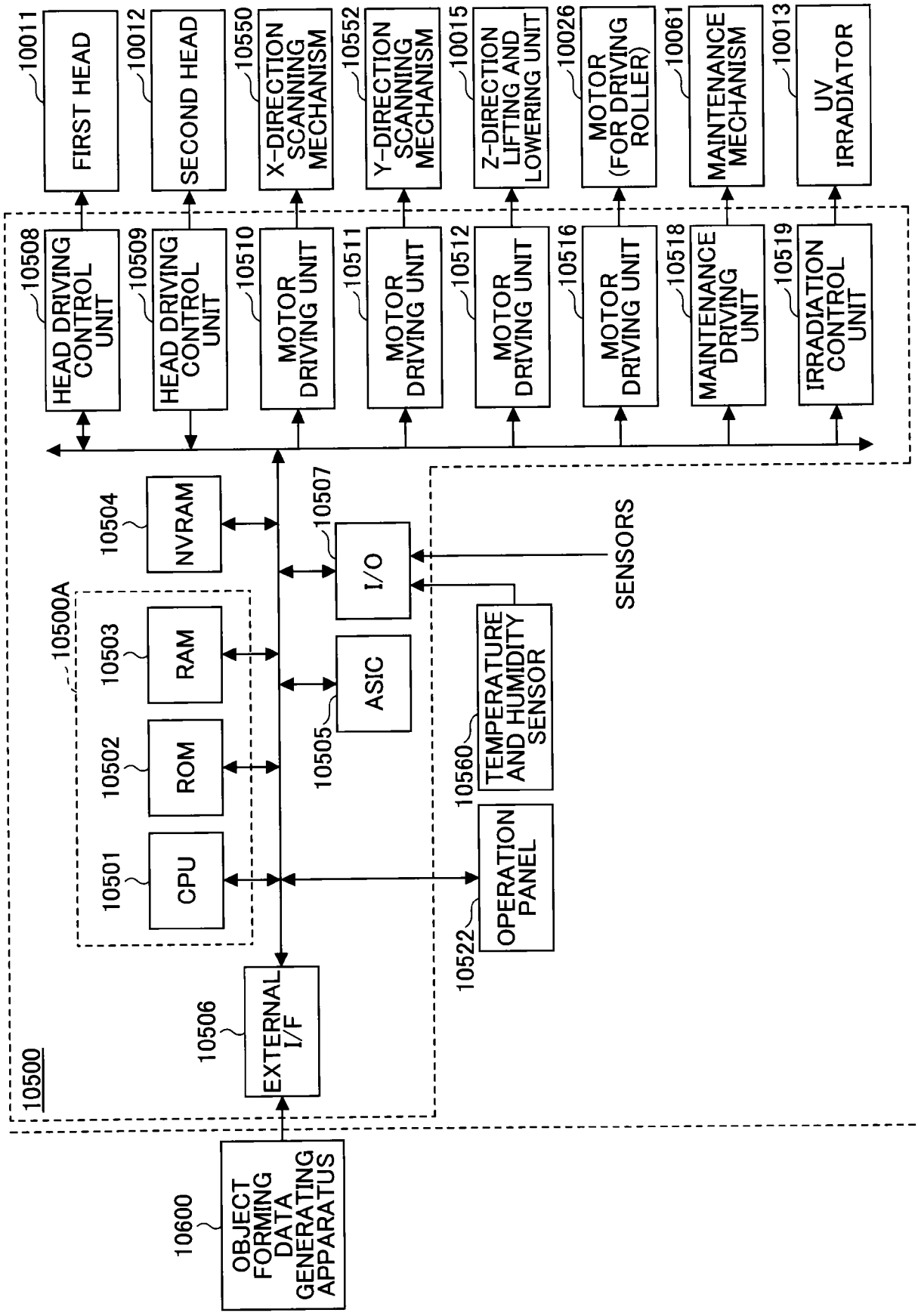
[Fig. 15]


10010
10020
10016
10013
10012
10011
10012
10013
10016
X
10030
10030E
10030D
10030C
10030B
10030A
10301
10302
10311
10312
10014
10015
Z
Y
X

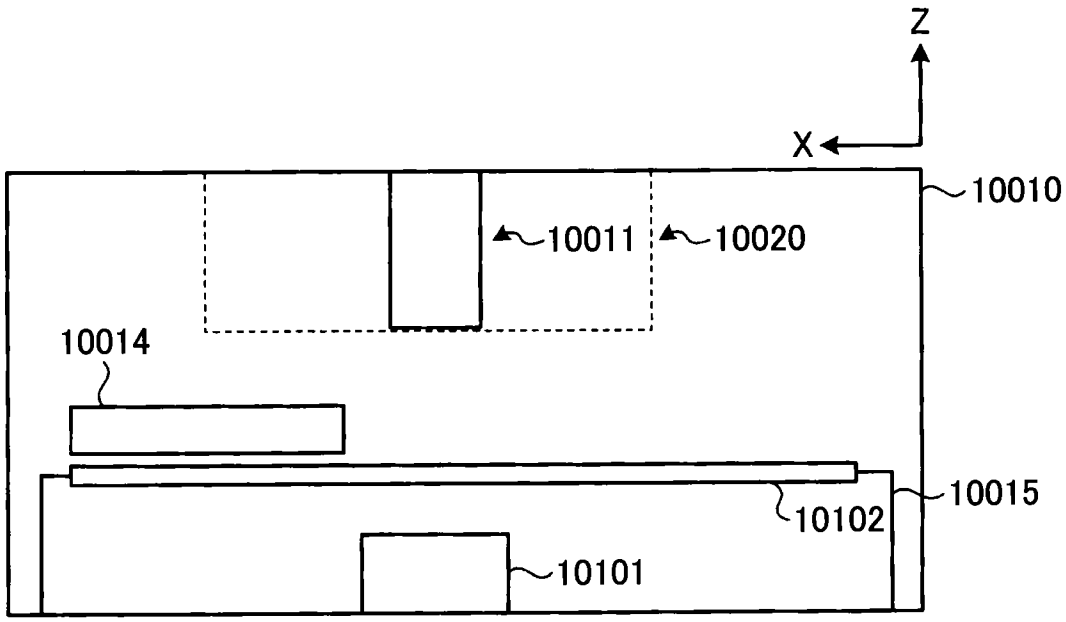
[Fig. 16]


10030
10030C
10030B
10030A
10312
10322
10311
10321
10322
Z
X

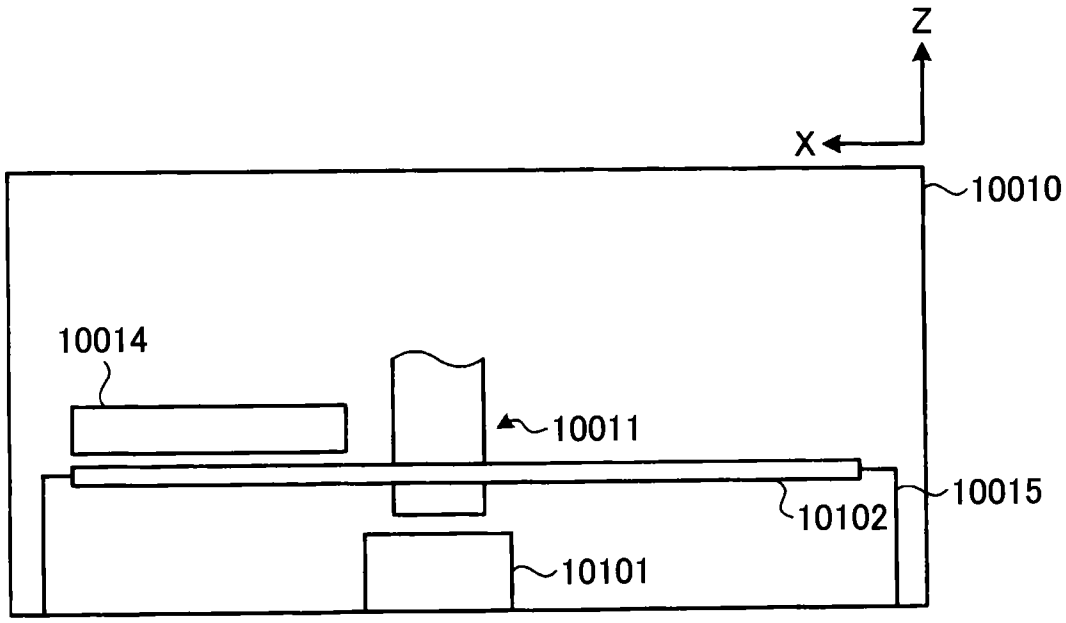
[Fig. 17]


10011
FIRST HEAD
10012
SECOND HEAD
10550
X-DIRECTION SCANNING MECHANISM
10552
Y-DIRECTION SCANNING MECHANISM
10015
Z-DIRECTION LIFTING AND LOWERING UNIT
10026
MOTOR (FOR DRIVING ROLLER)
10061
MAINTENANCE MECHANISM
10013
UV IRRADIATOR
10508
HEAD DRIVING CONTROL UNIT
10509
HEAD DRIVING CONTROL UNIT
10510
MOTOR DRIVING UNIT
10511
MOTOR DRIVING UNIT
10512
MOTOR DRIVING UNIT
10516
MOTOR DRIVING UNIT
10518
MAINTENANCE DRIVING UNIT
10519
IRRADIATION CONTROL UNIT
10504
NVRAM
10507
I/O
SENSORS
10500A
10503
RAM
10502
ROM
10501
CPU
10505
ASIC
10560
TEMPERATURE AND HUMIDITY SENSOR
10522
OPERATION PANEL
10506
EXTERNAL I/F
10500
10600
OBJECT FORMING DATA GENERATING APPARATUS

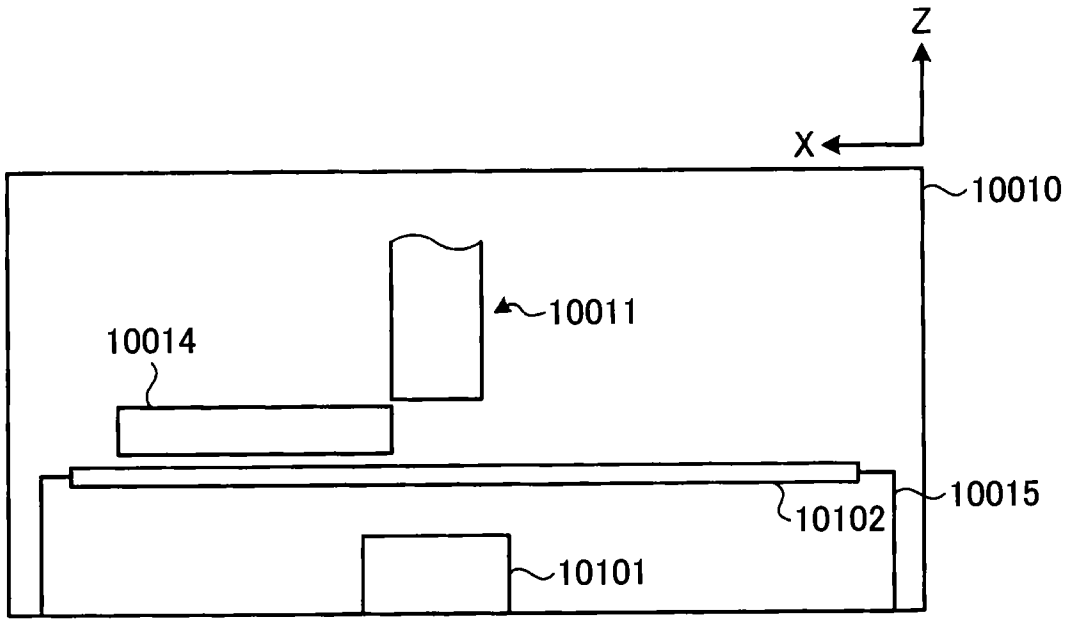
[Fig. 18]


Z
X
10010
10011
10020
10014
10015
10102
10101

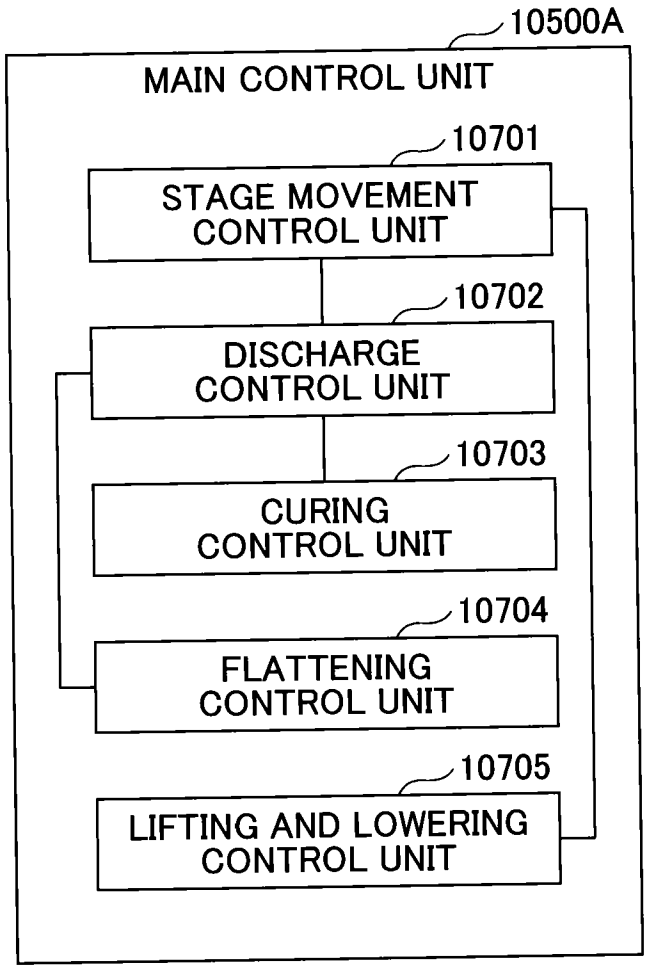
[Fig. 19]


Z
X
10010
10014
10011
10015
10102
10101

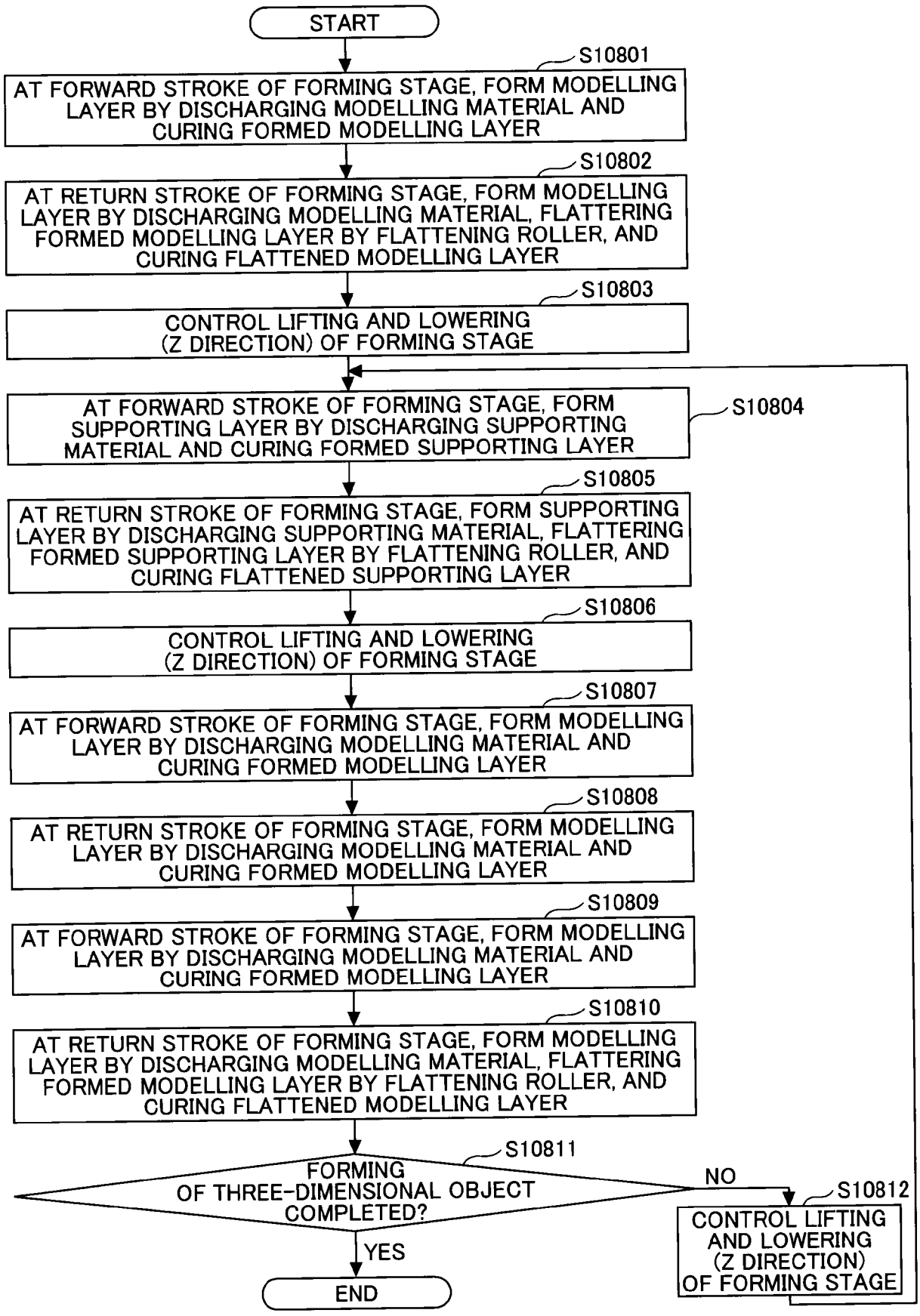
[Fig. 20]



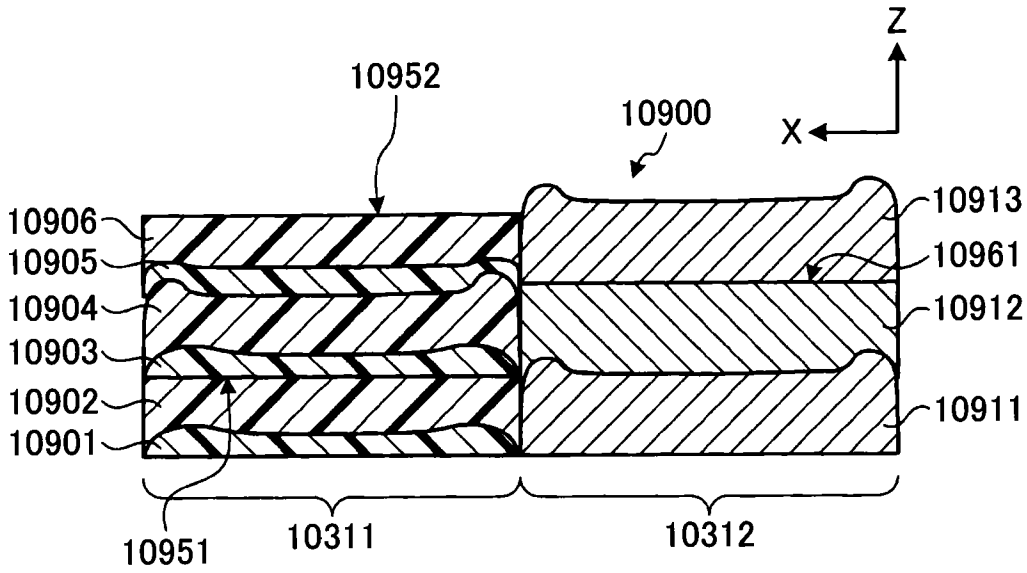
[Fig. 21]


10500A
MAIN CONTROL UNIT
10701
STAGE MOVEMENT CONTROL UNIT
10702
DISCHARGE CONTROL UNIT
10703
CURING CONTROL UNIT
10704
FLATTENING CONTROL UNIT
10705
LIFTING AND LOWERING CONTROL UNIT

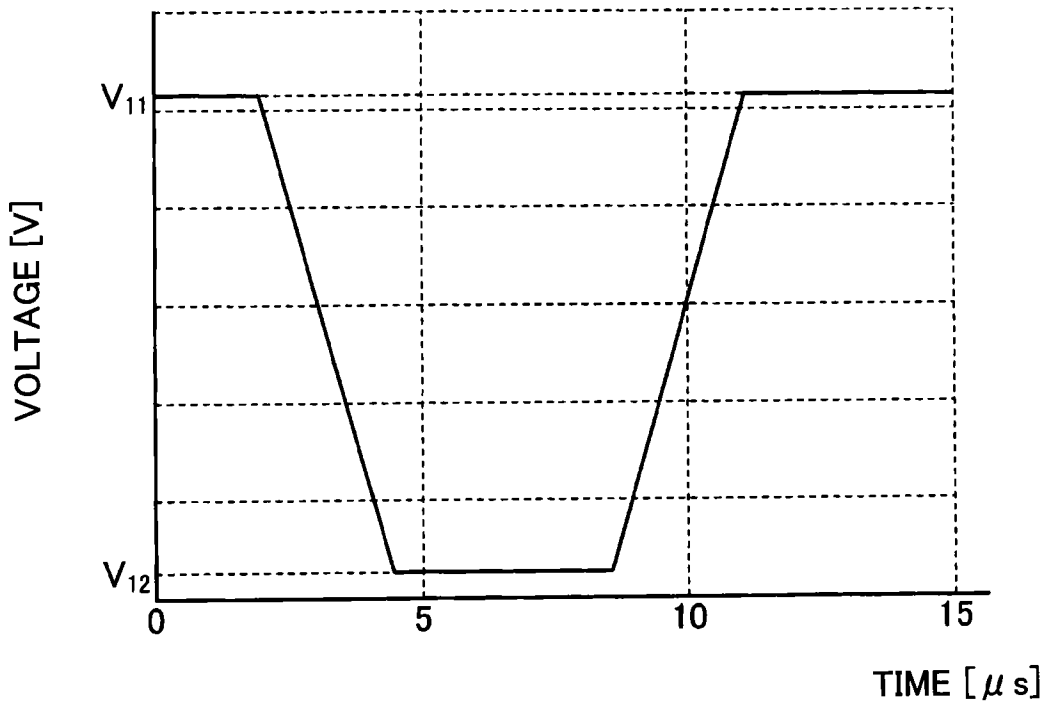
[Fig. 22]


START
S10801
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10802
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL, FLATTERING FORMED MODELLING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED MODELLING LAYER
S10803
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
AT FORWARD STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL AND CURING FORMED SUPPORTING LAYER
S10804
S10805
AT RETURN STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL, FLATTERING FORMED SUPPORTING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED SUPPORTING LAYER
S10806
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
S10807
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10808
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10809
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10810
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL, FLATTERING FORMED MODELLING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED MODELLING LAYER
S10811
FORMING OF THREE-DIMENSIONAL OBJECT COMPLETED?
NO
S10812
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
YES
END

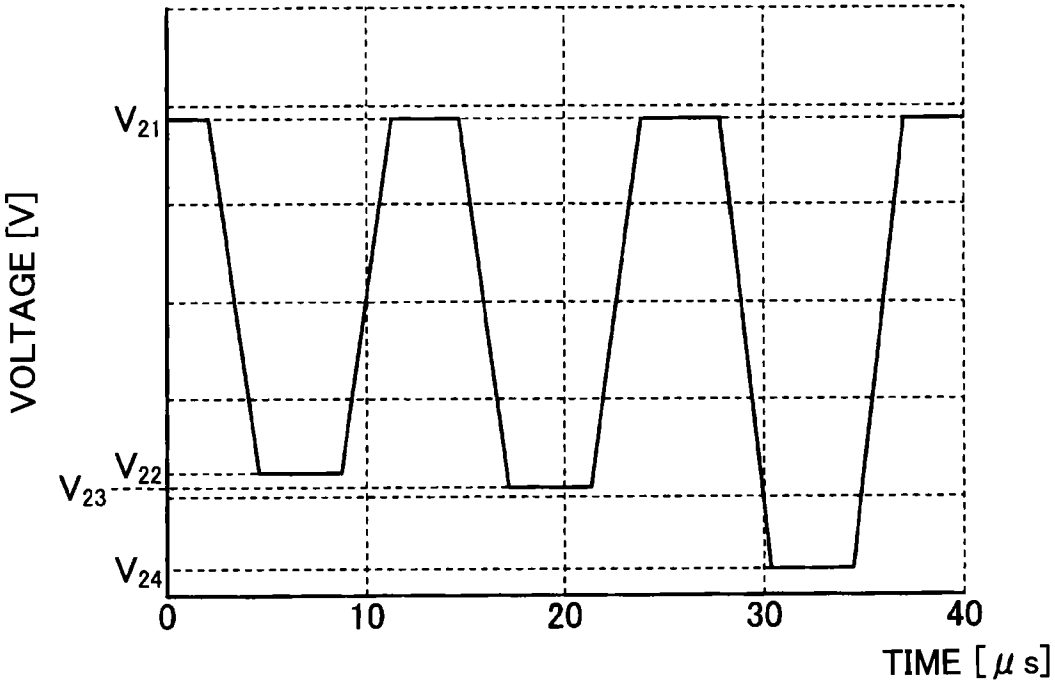
[Fig. 23]


Z
X
10952
10900
10906
10905
10904
10903
10902
10901
10913
10961
10912
10911
10951
10311
10312

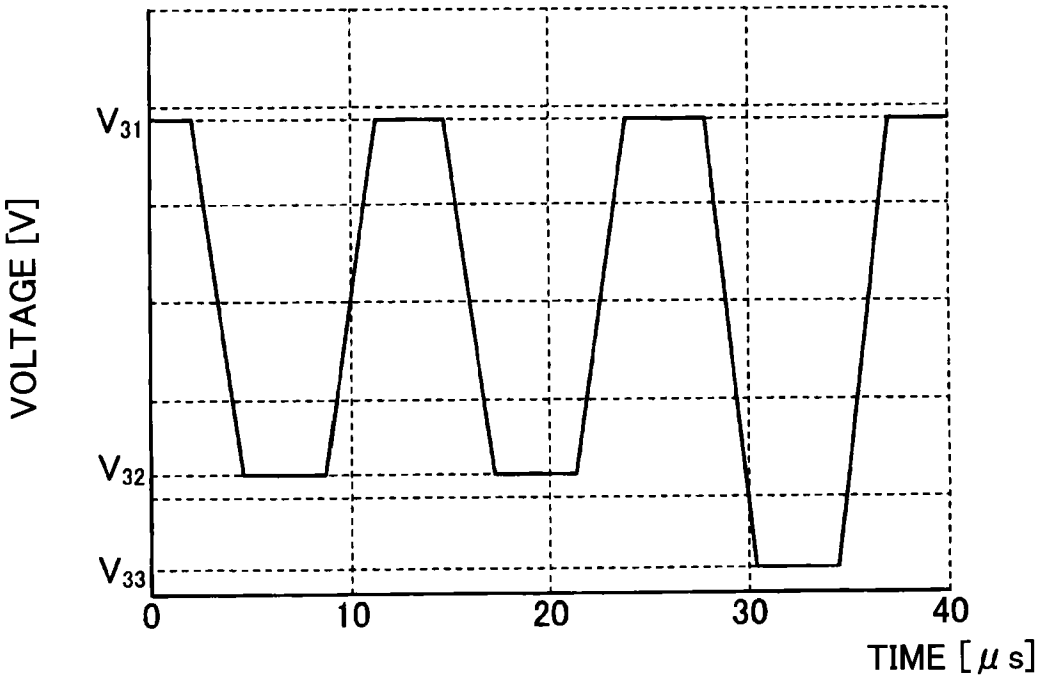
[Fig. 24]


V11
V12
VOLTAGE [V]
0
5
10
15
TIME [μs]

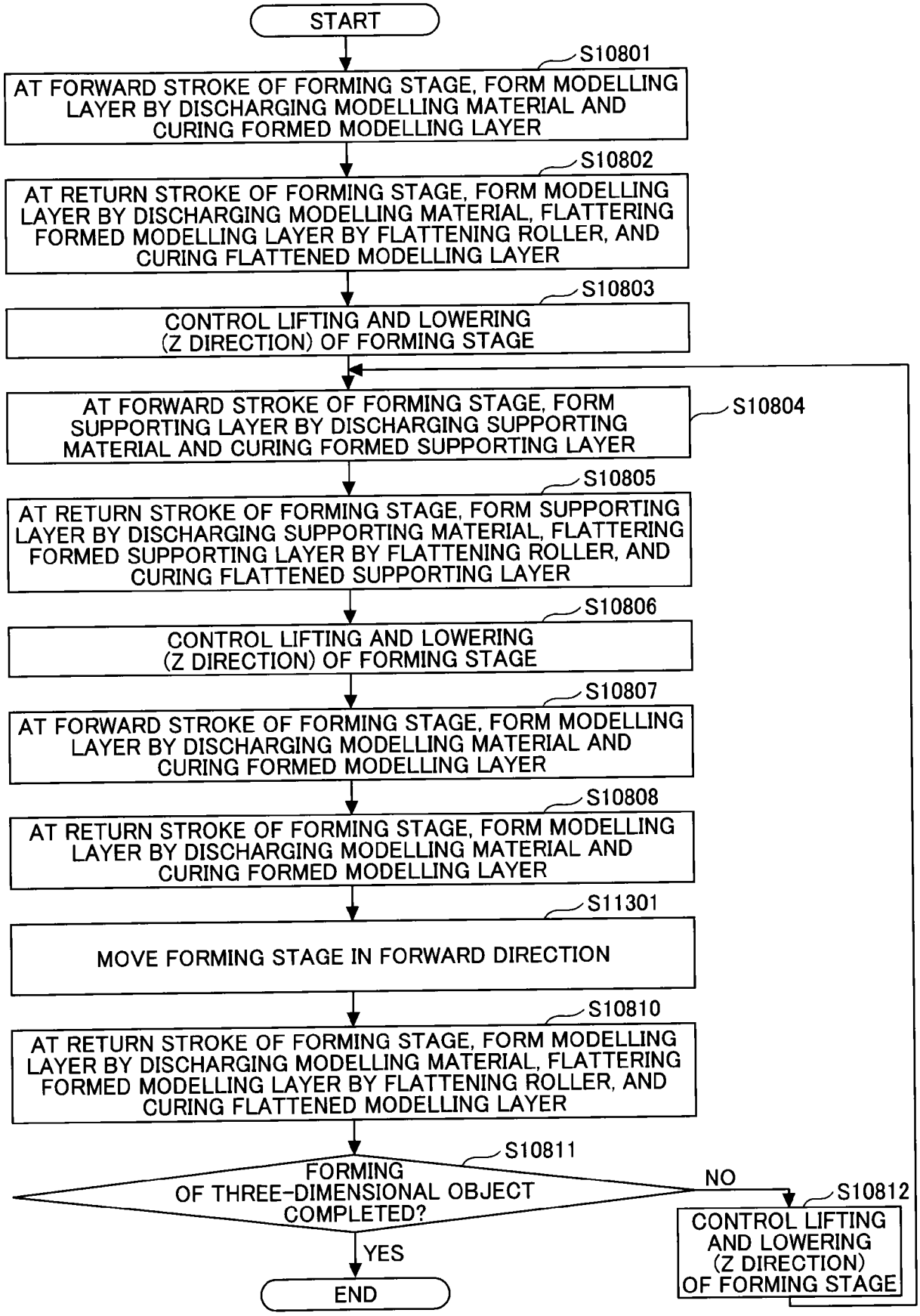
[Fig. 25]


VOLTAGE [V]
V21
V22
V23
V24
0
10
20
30
40
TIME [μs]

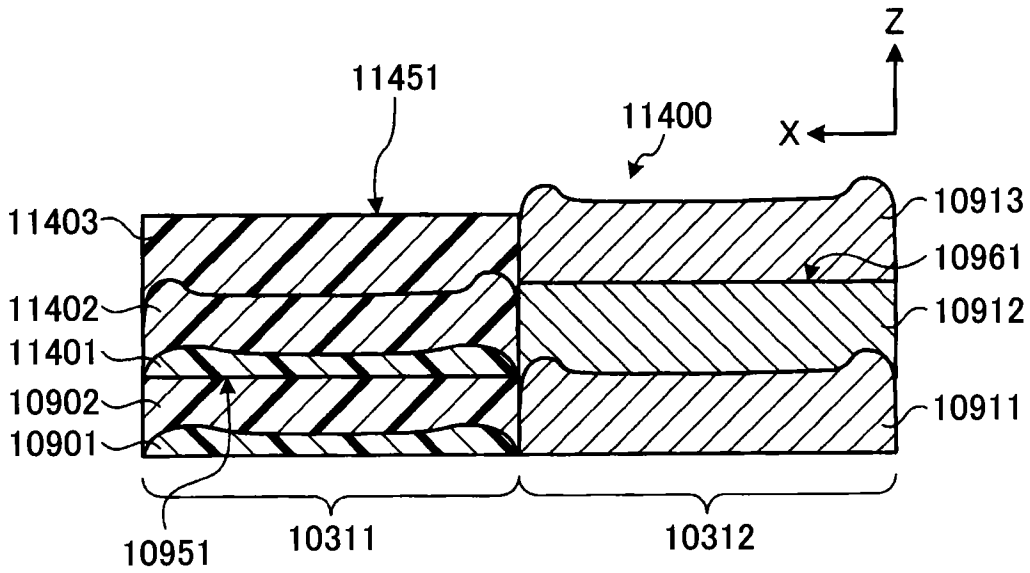
[Fig. 26]


VOLTAGE [V]
V31
V32
V33
0
10
20
30
40
TIME [μs]

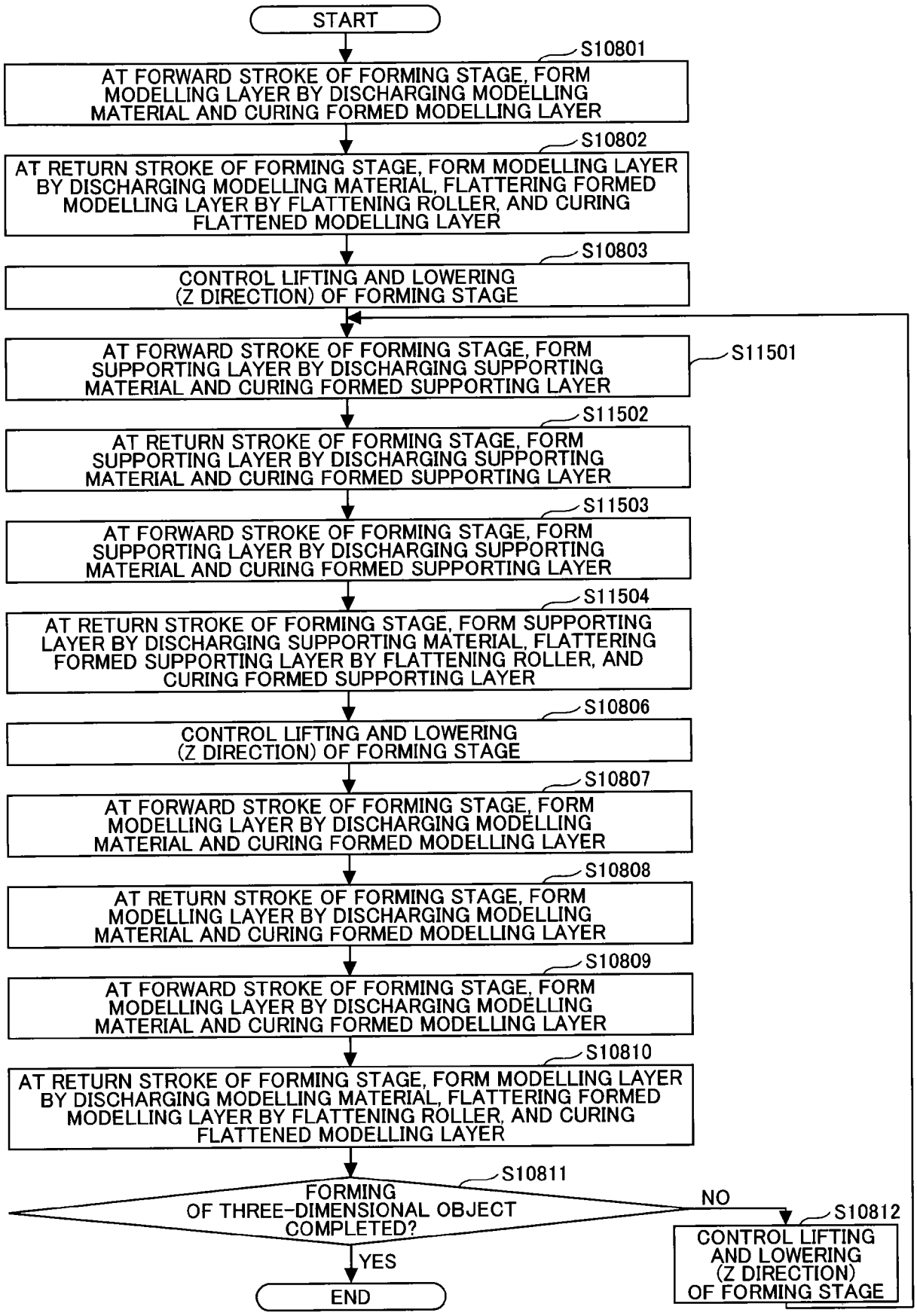
[Fig. 27]


START
S10801
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10802
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL, FLATTERING FORMED MODELLING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED MODELLING LAYER
S10803
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
AT FORWARD STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL AND CURING FORMED SUPPORTING LAYER
S10804
S10805
AT RETURN STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL, FLATTERING FORMED SUPPORTING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED SUPPORTING LAYER
S10806
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
S10807
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10808
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S11301
MOVE FORMING STAGE IN FORWARD DIRECTION
S10810
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL, FLATTERING FORMED MODELLING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED MODELLING LAYER
S10811
FORMING OF THREE-DIMENSIONAL OBJECT COMPLETED?
NO
S10812
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
YES
END

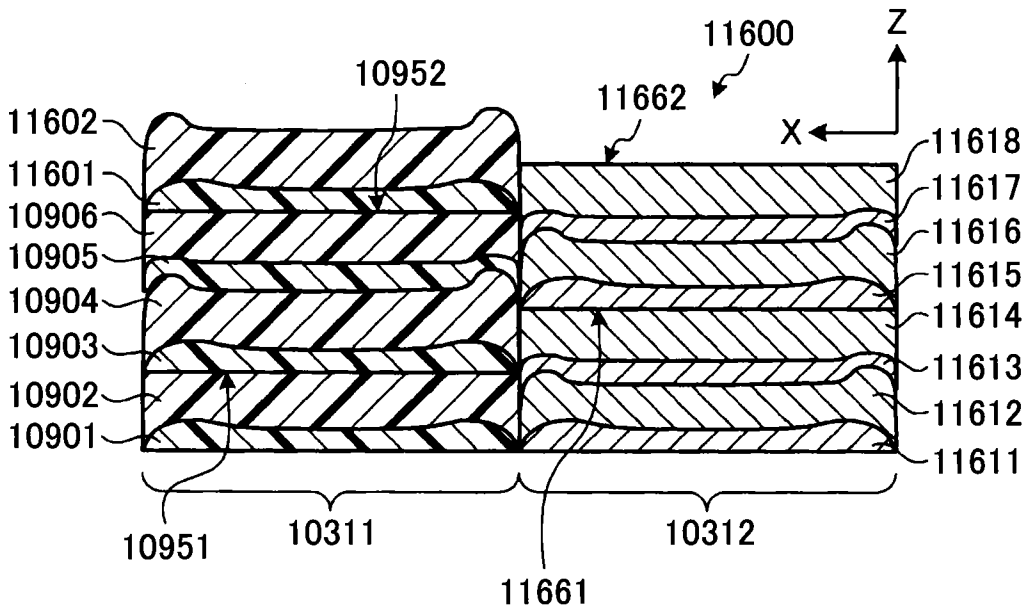
[Fig. 28]


Z
X
11451
11400
11403
11402
11401
10902
10901
10913
10961
10912
10911
10951
10311
10312

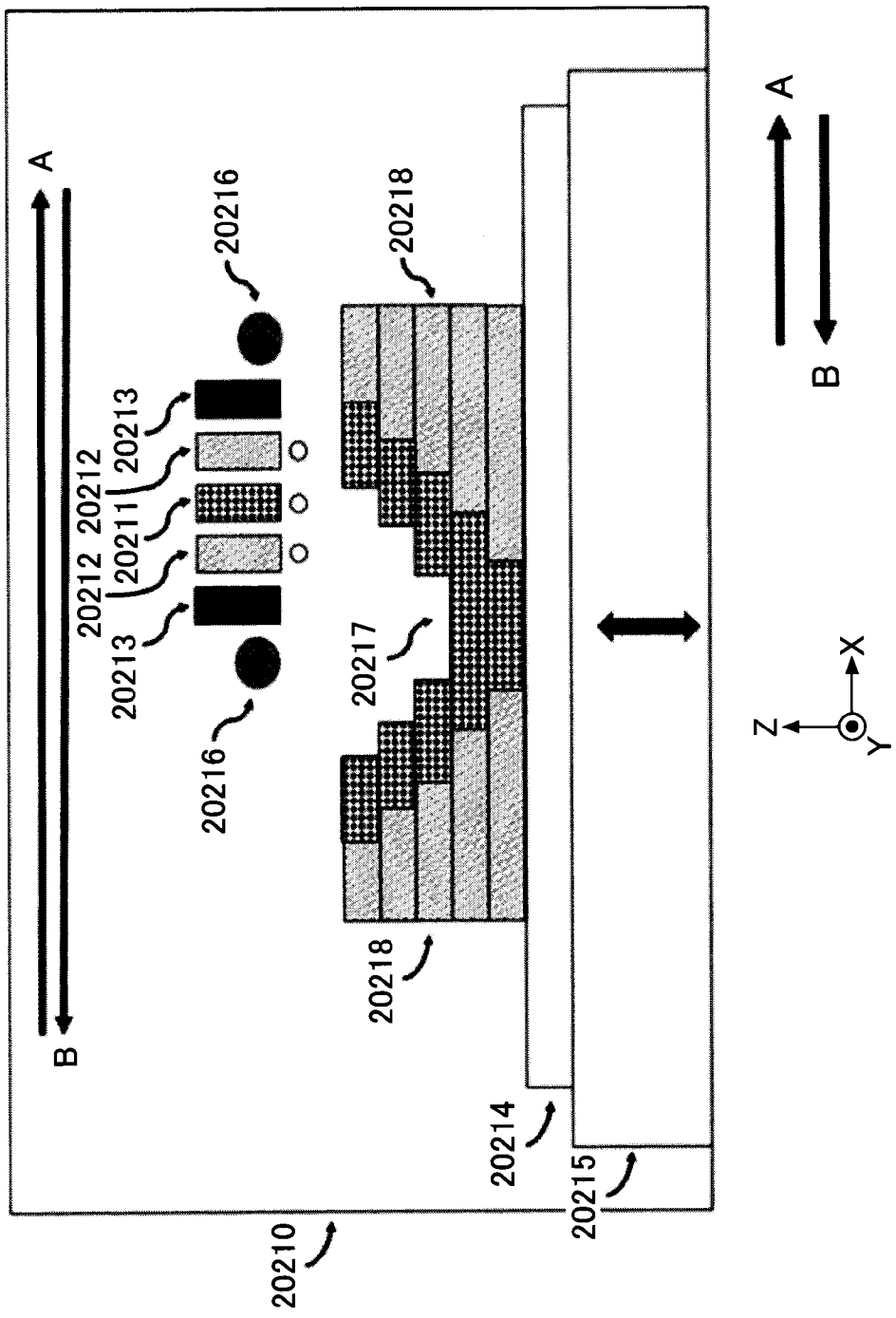
[Fig. 29]


START
S10801
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10802
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL, FLATTERING FORMED MODELLING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED MODELLING LAYER
S10803
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
S11501
AT FORWARD STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL AND CURING FORMED SUPPORTING LAYER
S11502
AT RETURN STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL AND CURING FORMED SUPPORTING LAYER
S11503
AT FORWARD STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL AND CURING FORMED SUPPORTING LAYER
S11504
AT RETURN STROKE OF FORMING STAGE, FORM SUPPORTING LAYER BY DISCHARGING SUPPORTING MATERIAL, FLATTERING FORMED SUPPORTING LAYER BY FLATTENING ROLLER, AND CURING FORMED SUPPORTING LAYER
S10806
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
S10807
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10808
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10809
AT FORWARD STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL AND CURING FORMED MODELLING LAYER
S10810
AT RETURN STROKE OF FORMING STAGE, FORM MODELLING LAYER BY DISCHARGING MODELLING MATERIAL, FLATTERING FORMED MODELLING LAYER BY FLATTENING ROLLER, AND CURING FLATTENED MODELLING LAYER
S10811
FORMING OF THREE-DIMENSIONAL OBJECT COMPLETED?
NO
S10812
CONTROL LIFTING AND LOWERING (Z DIRECTION) OF FORMING STAGE
YES
END

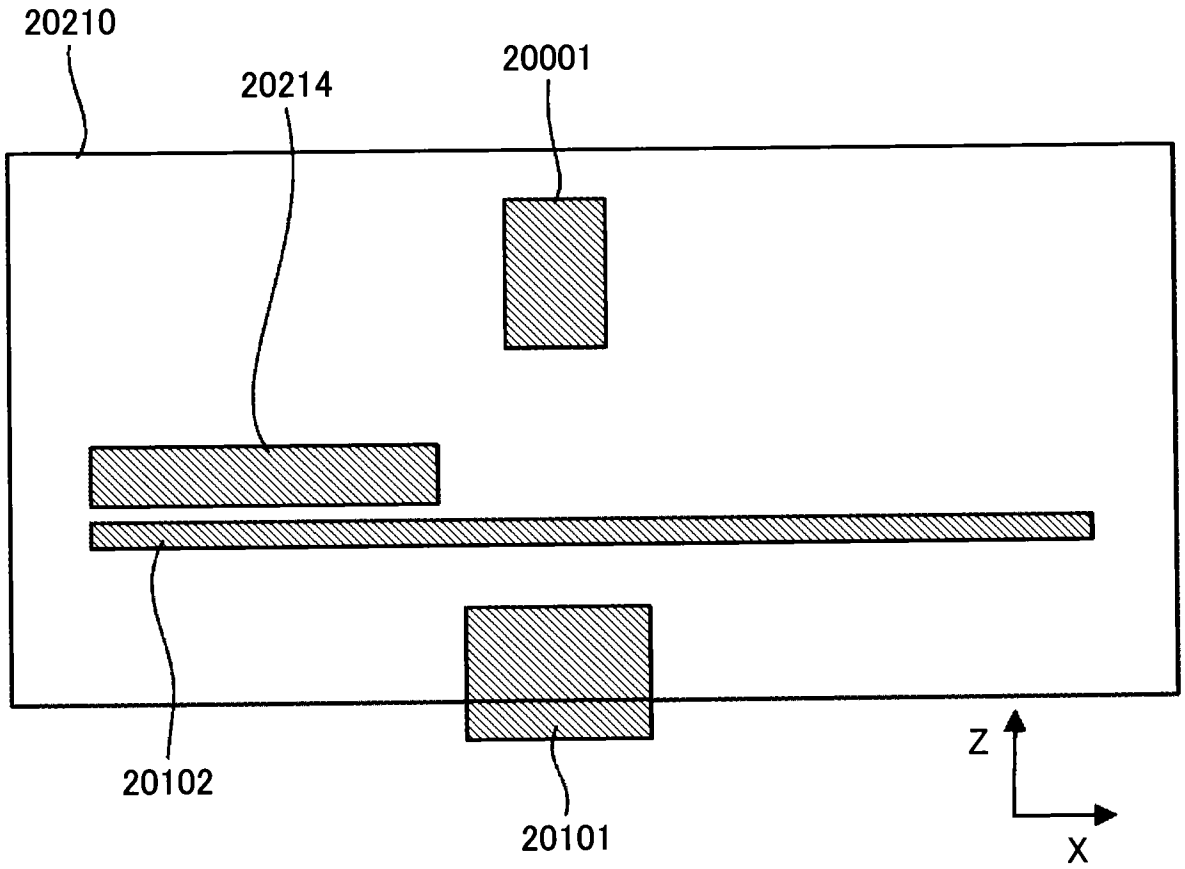
[Fig. 30]


11600
Z
X
10952
11662
11602
11601
10906
10905
10904
10903
10902
10901
11618
11617
11616
11615
11614
11613
11612
11611
10951
10311
10312
11661

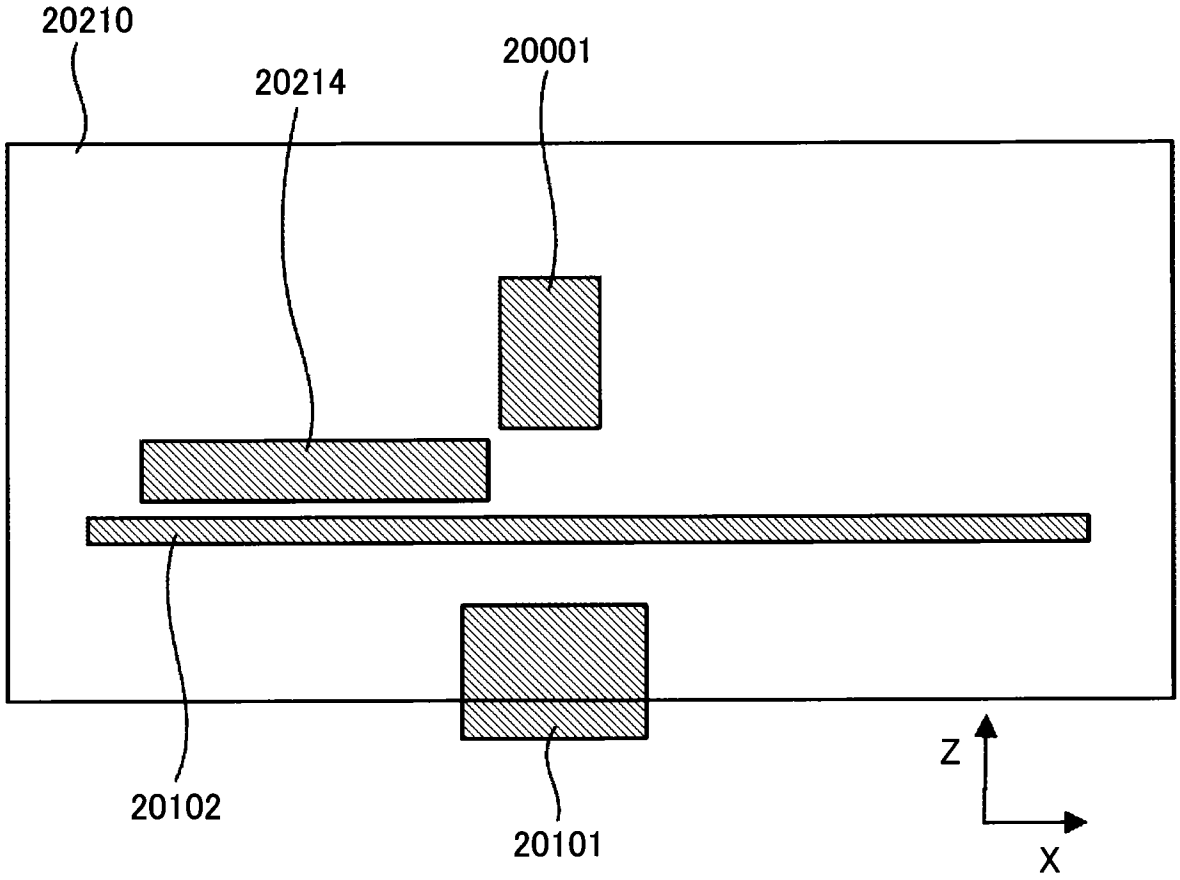
[Fig. 31]


A
B
20216
20213
20212
20211
20212
20213
20216
20218
20217
20218
20214
20215
20210
A
B
X
Z
Y

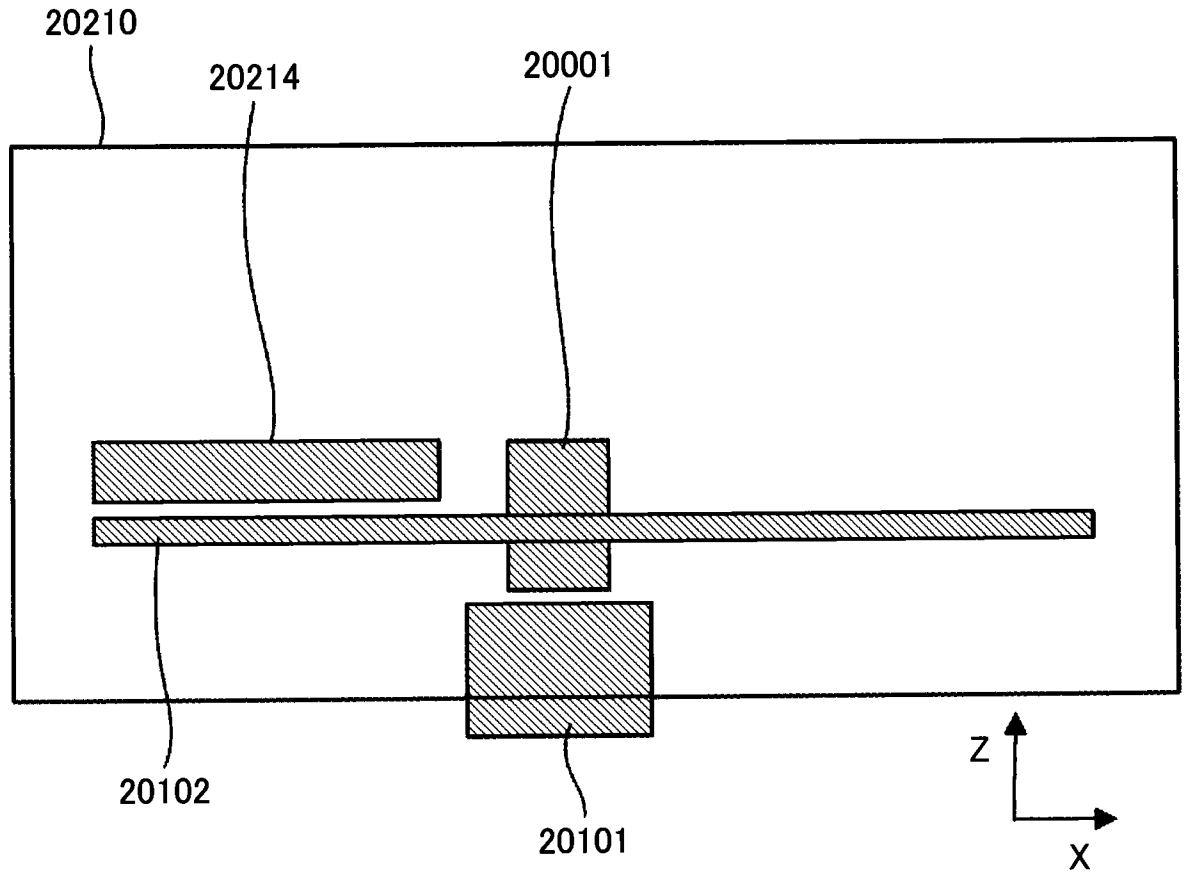
[Fig. 32]



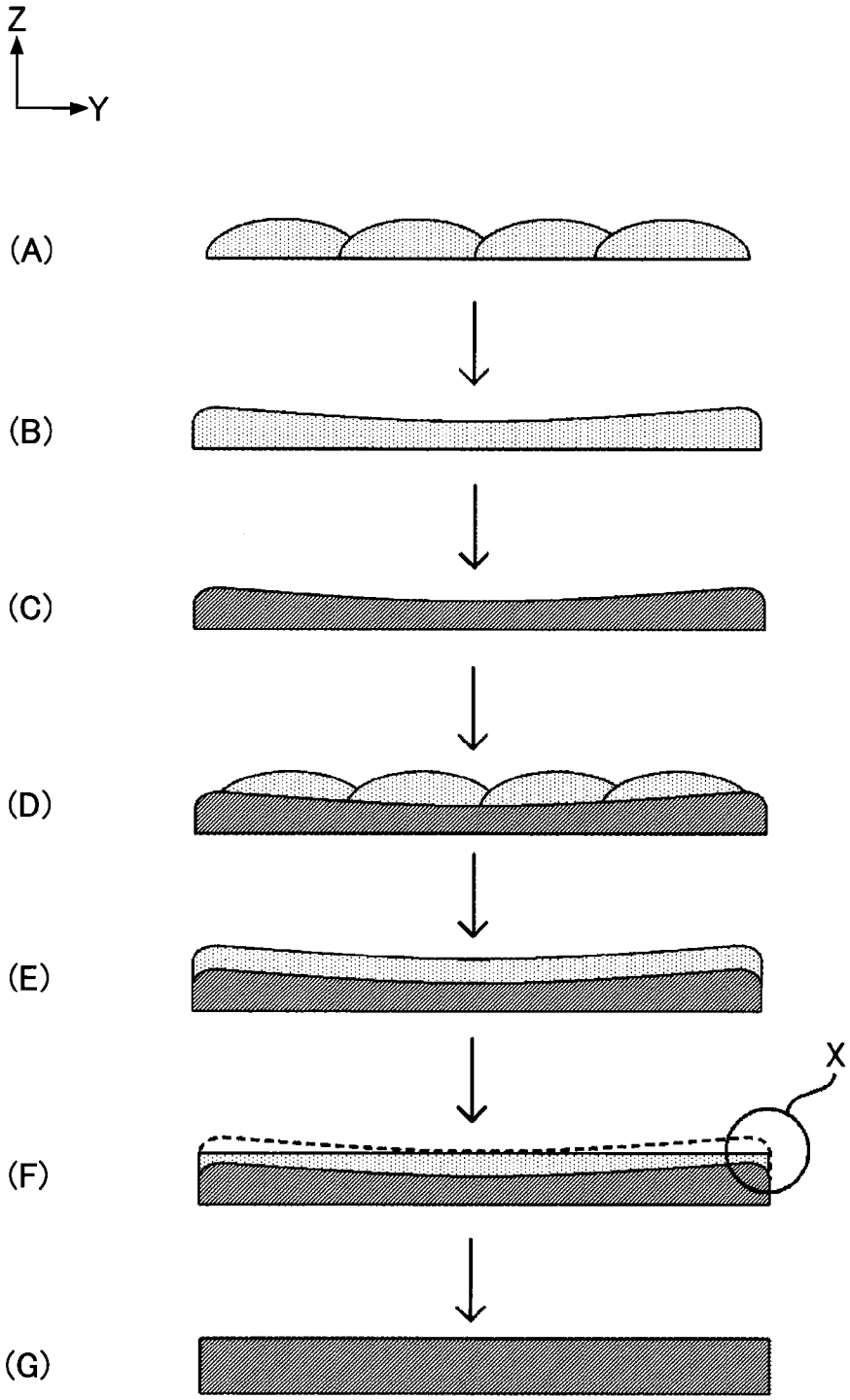
[Fig. 33]



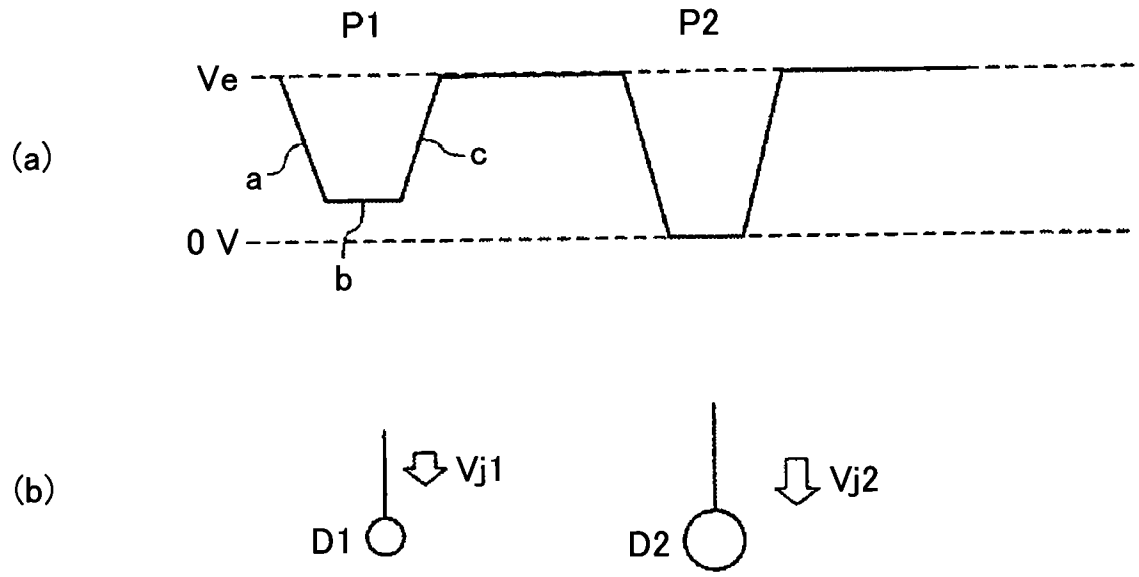
[Fig. 34]



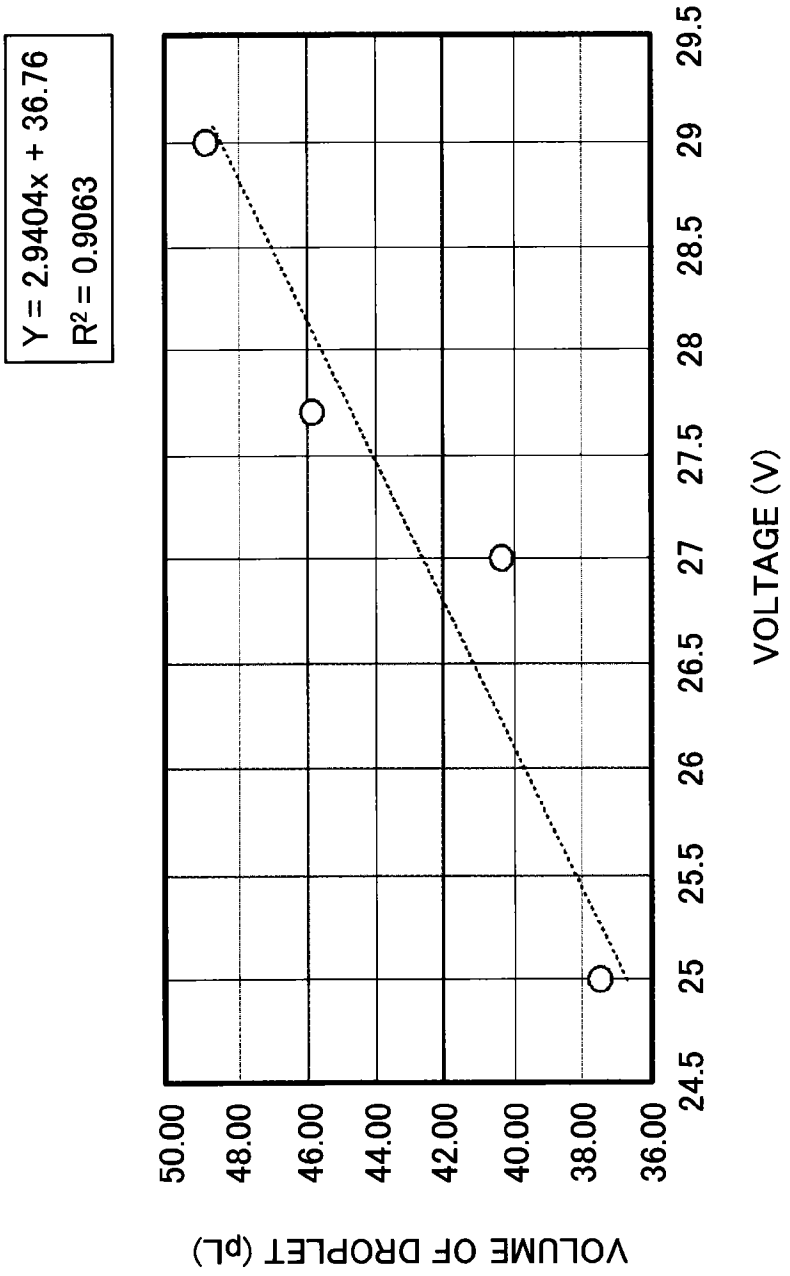
[Fig. 35]



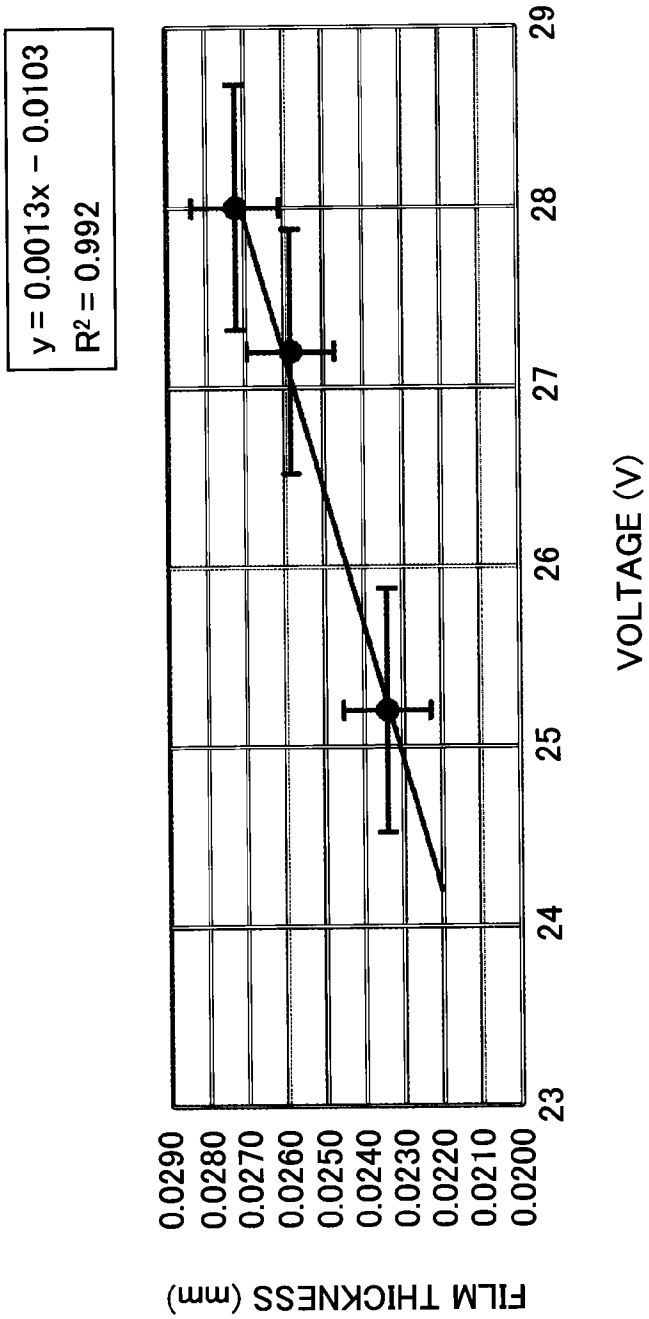
[Fig. 36]



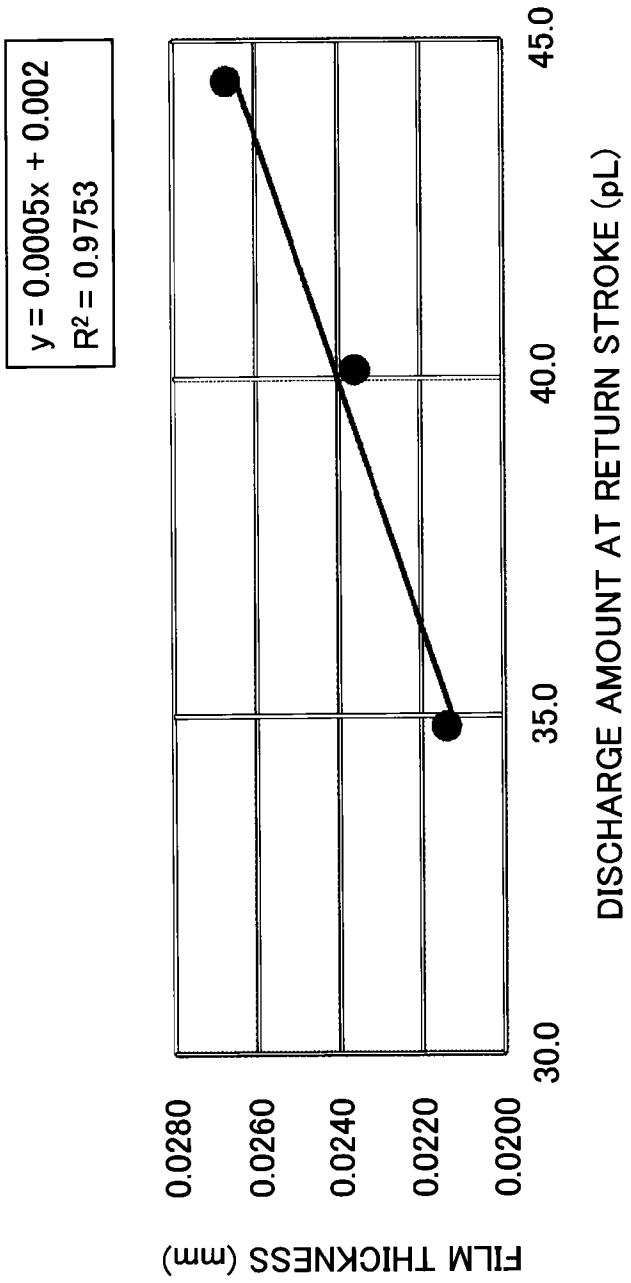
[Fig. 37]


Y = 2.9404x + 36.76
R² = 0.9063
VOLUME OF DROPLET (pL)
50.00
48.00
46.00
44.00
42.00
40.00
38.00
36.00
VOLTAGE (V)
24.5
25
25.5
26
26.5
27
27.5
28
28.5
29
29.5

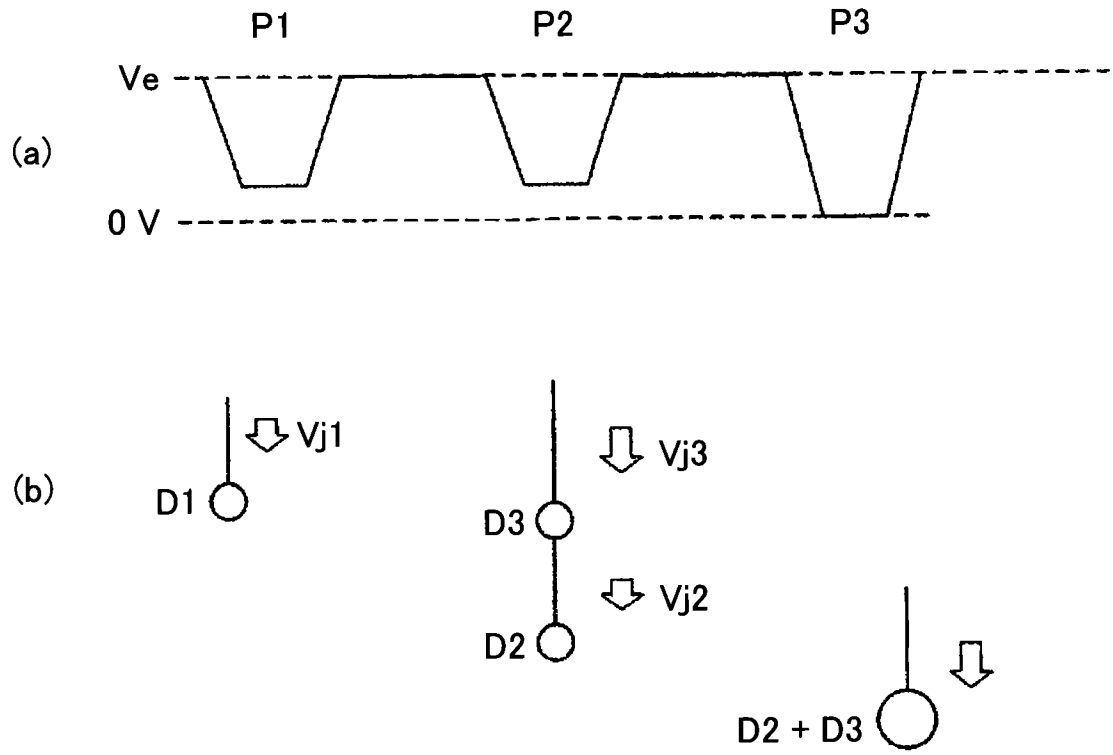
[Fig. 38]


y = 0.0013x − 0.0103
R² = 0.992
FILM THICKNESS (mm)
0.0290
0.0280
0.0270
0.0260
0.0250
0.0240
0.0230
0.0220
0.0210
0.0200
VOLTAGE (V)
23
24
25
26
27
28
29

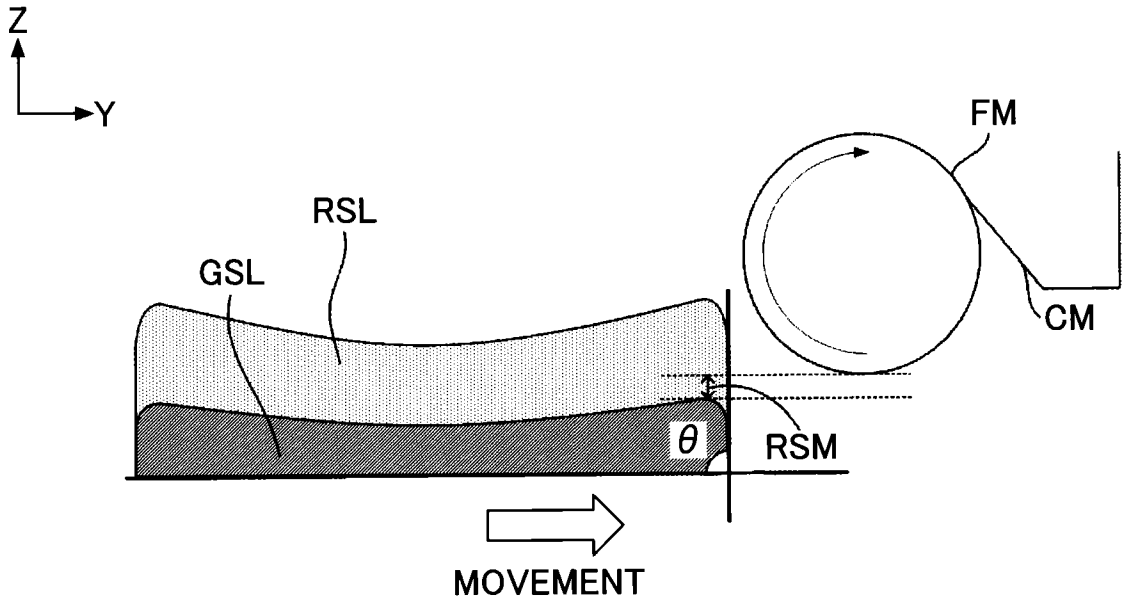
[Fig. 39]


y = 0.0005x + 0.002
R² = 0.9753
FILM THICKNESS (mm)
0.0280
0.0260
0.0240
0.0220
0.0200
DISCHARGE AMOUNT AT RETURN STROKE (pL)
30.0
35.0
40.0
45.0

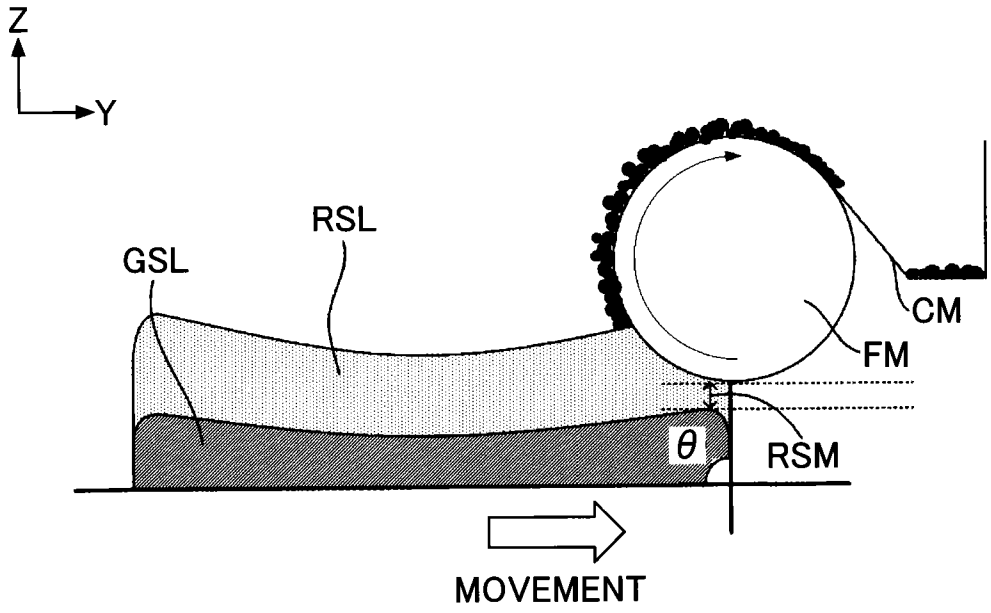
[Fig. 40]



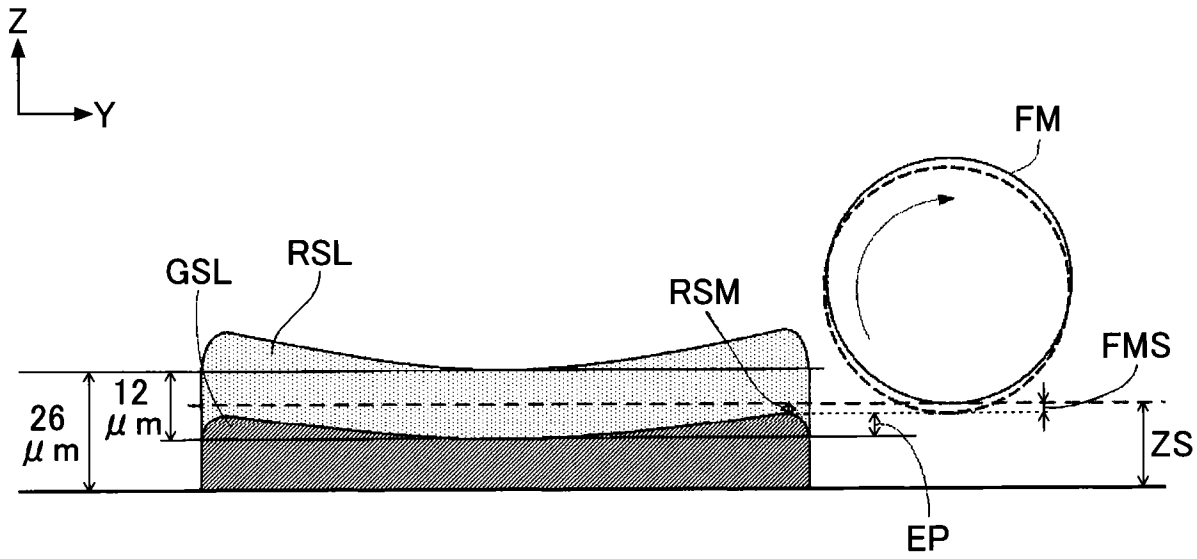
[Fig. 41]



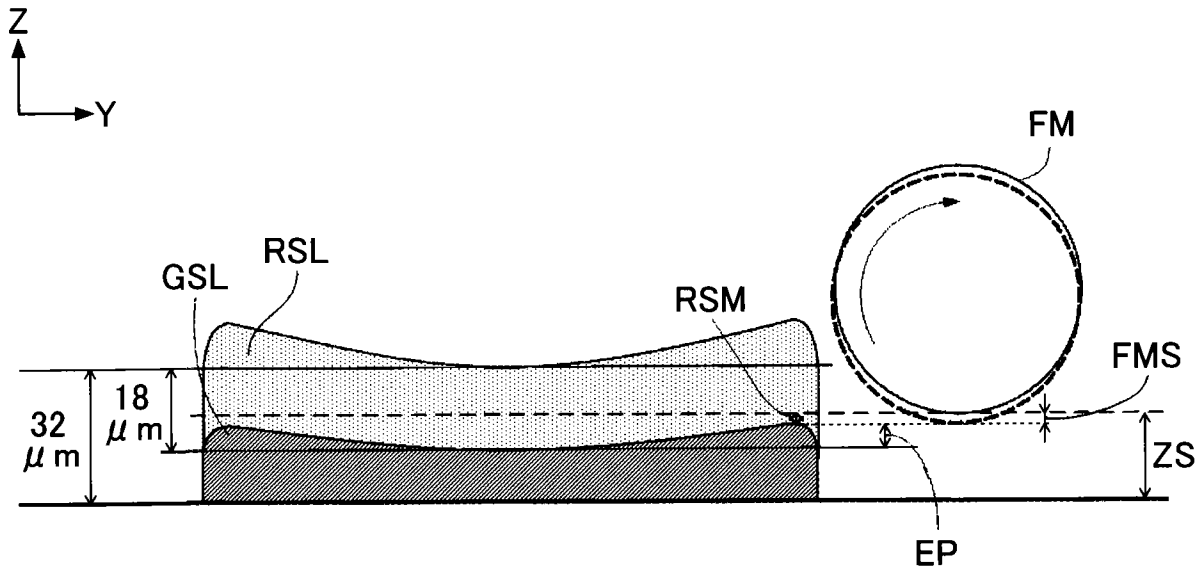
[Fig. 42]



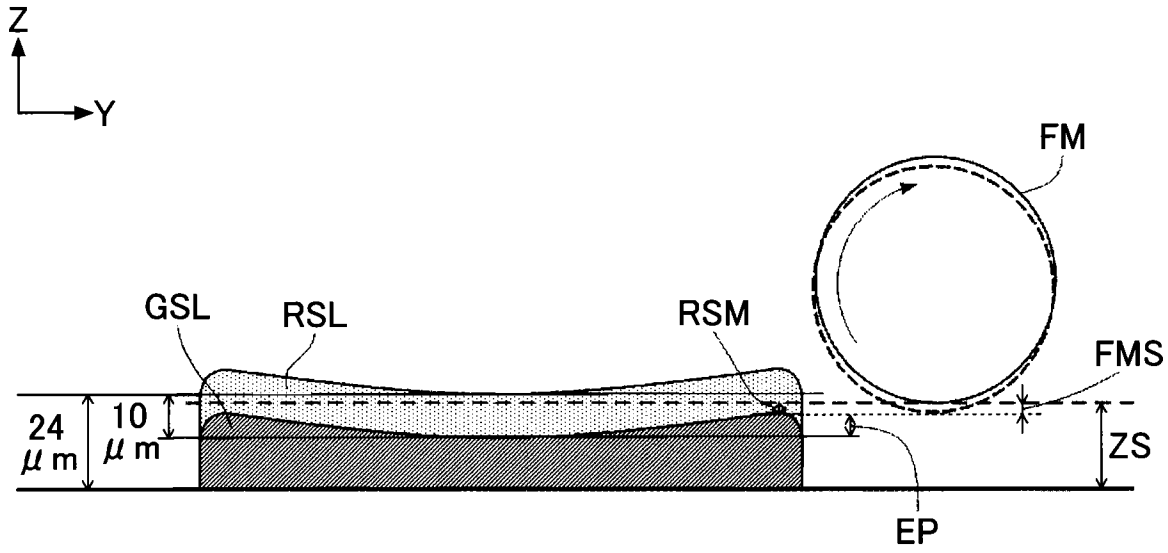
[Fig. 43]


Z
Y
FM
GSL
RSL
RSM
FMS
12 μm
26 μm
ZS
EP

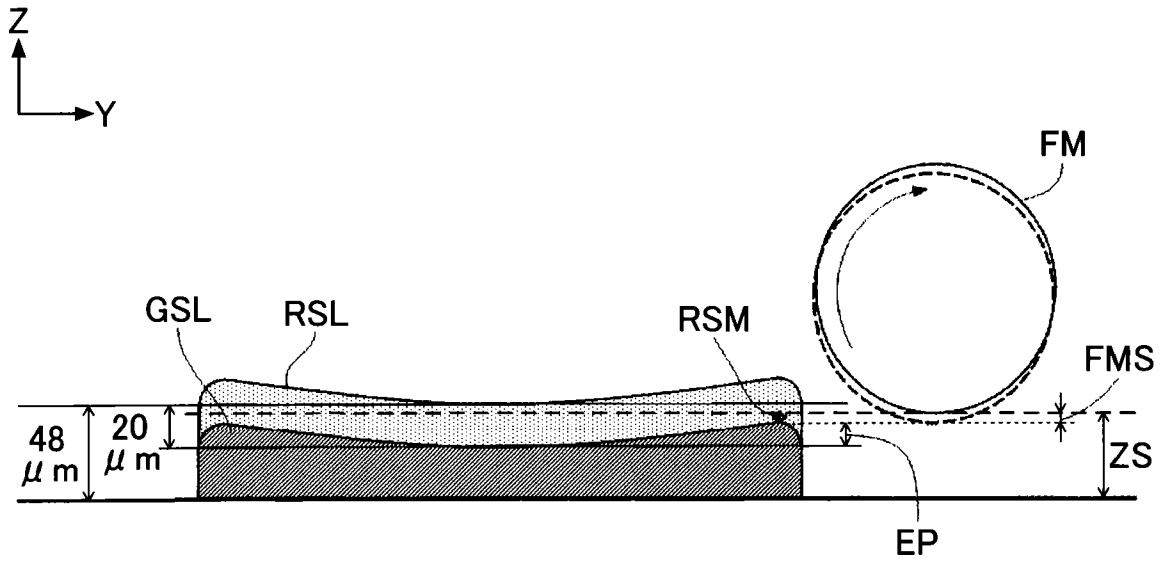
[Fig. 44]


Z
Y
FM
GSL
RSL
RSM
FMS
18 μm
32 μm
ZS
EP

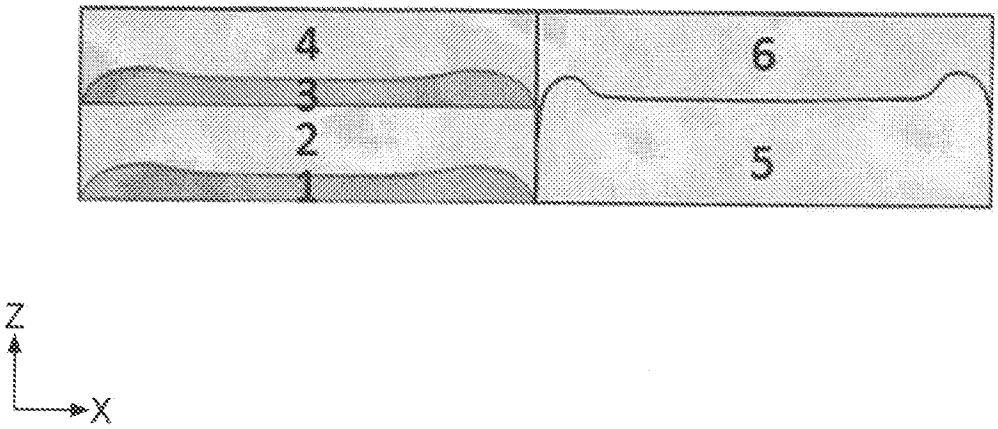
[Fig. 45]


Z
Y
FM
GSL
RSL
RSM
FMS
24 μm
10 μm
ZS
EP

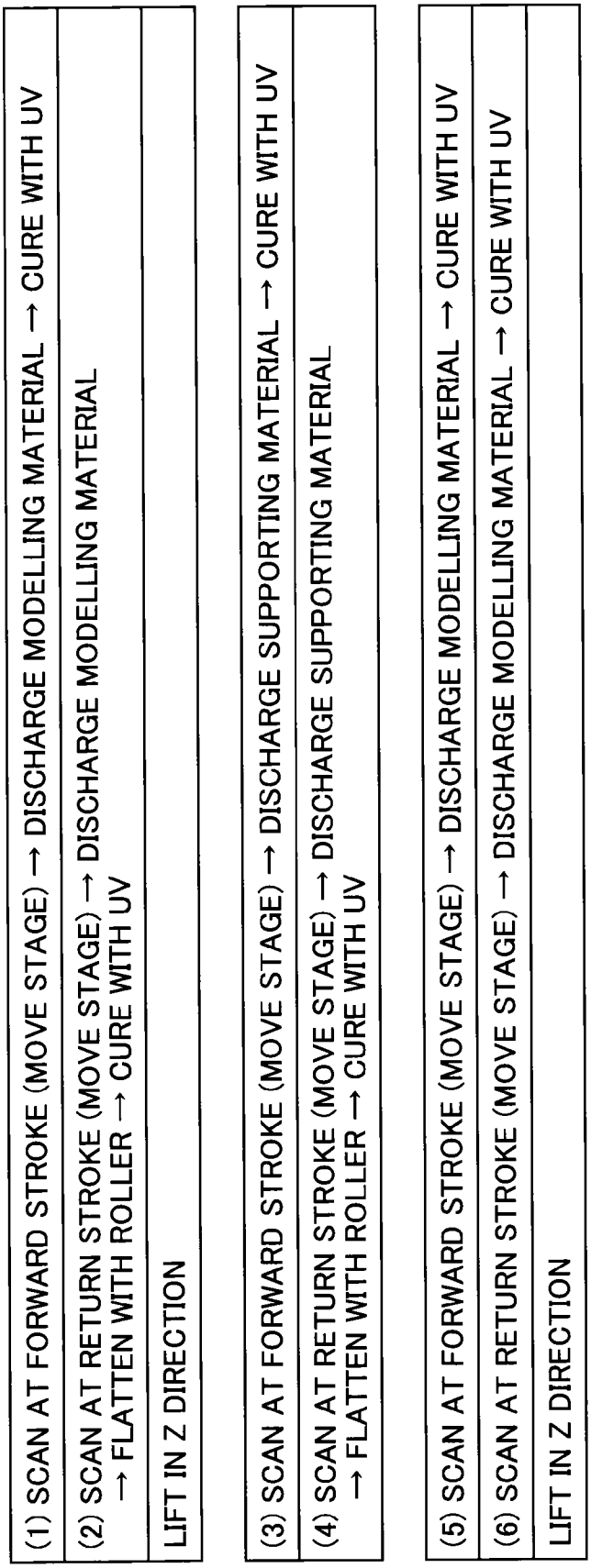
[Fig. 46]


Z
Y
FM
GSL
RSL
RSM
FMS
48 μm
20 μm
ZS
EP

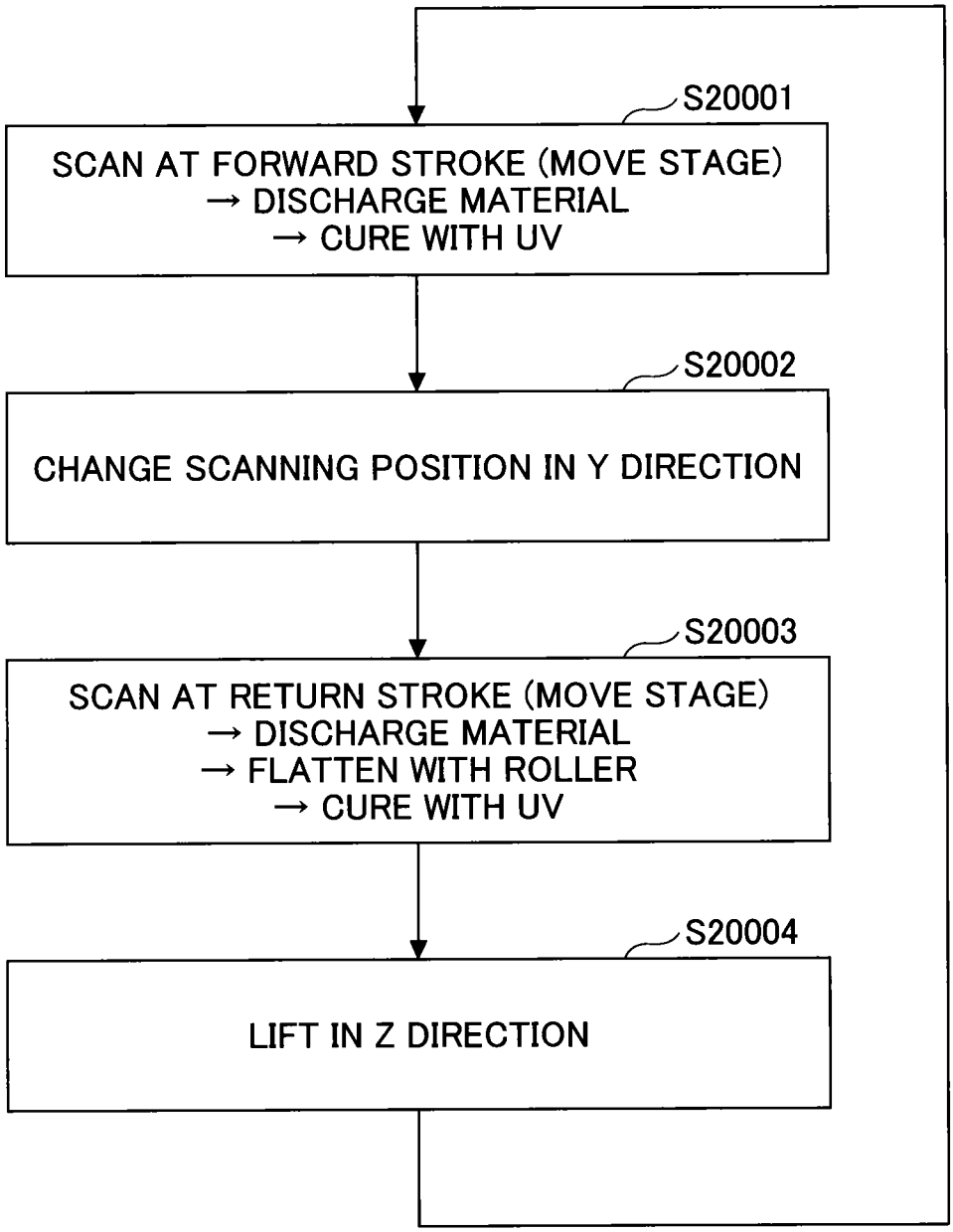
[Fig. 47]



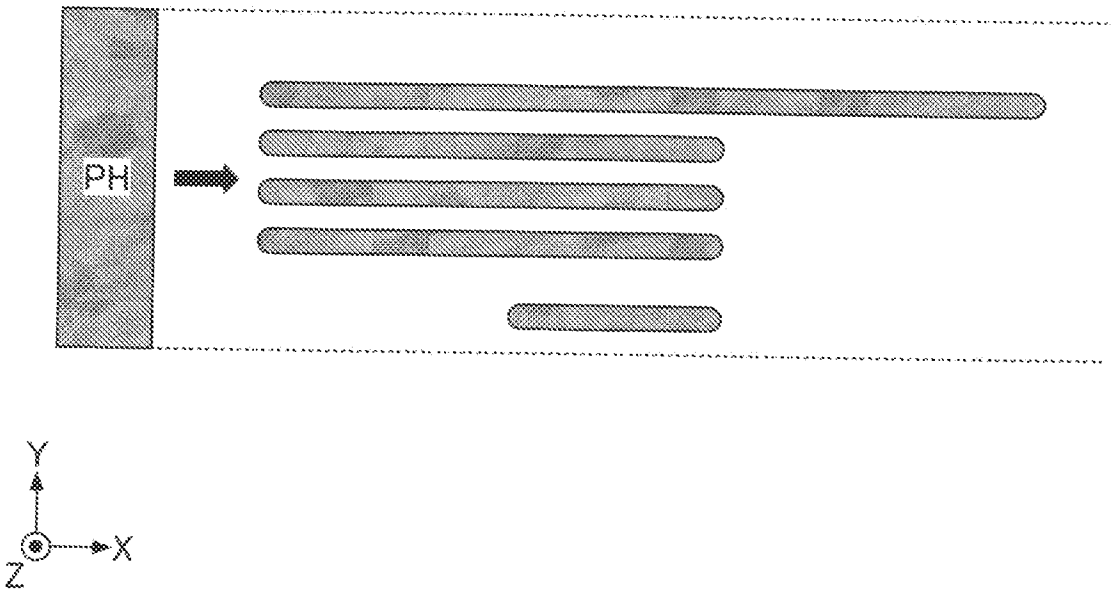
[Fig. 48]


(1) SCAN AT FORWARD STROKE (MOVE STAGE) → DISCHARGE MODELLING MATERIAL → CURE WITH UV
(2) SCAN AT RETURN STROKE (MOVE STAGE) → DISCHARGE MODELLING MATERIAL → FLATTEN WITH ROLLER → CURE WITH UV
LIFT IN Z DIRECTION
(3) SCAN AT FORWARD STROKE (MOVE STAGE) → DISCHARGE SUPPORTING MATERIAL → CURE WITH UV
(4) SCAN AT RETURN STROKE (MOVE STAGE) → DISCHARGE SUPPORTING MATERIAL → FLATTEN WITH ROLLER → CURE WITH UV
(5) SCAN AT FORWARD STROKE (MOVE STAGE) → DISCHARGE MODELLING MATERIAL → CURE WITH UV
(6) SCAN AT RETURN STROKE (MOVE STAGE) → DISCHARGE MODELLING MATERIAL → CURE WITH UV
LIFT IN Z DIRECTION

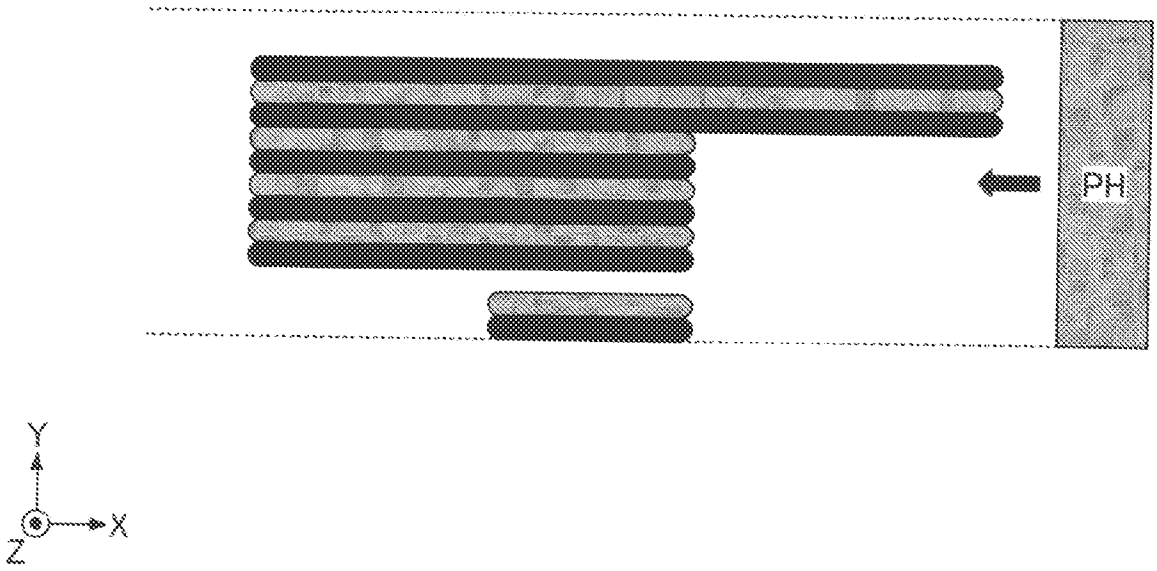
[Fig. 49A]


S20001
SCAN AT FORWARD STROKE (MOVE STAGE)
→ DISCHARGE MATERIAL
→ CURE WITH UV
S20002
CHANGE SCANNING POSITION IN Y DIRECTION
S20003
SCAN AT RETURN STROKE (MOVE STAGE)
→ DISCHARGE MATERIAL
→ FLATTEN WITH ROLLER
→ CURE WITH UV
S20004
LIFT IN Z DIRECTION

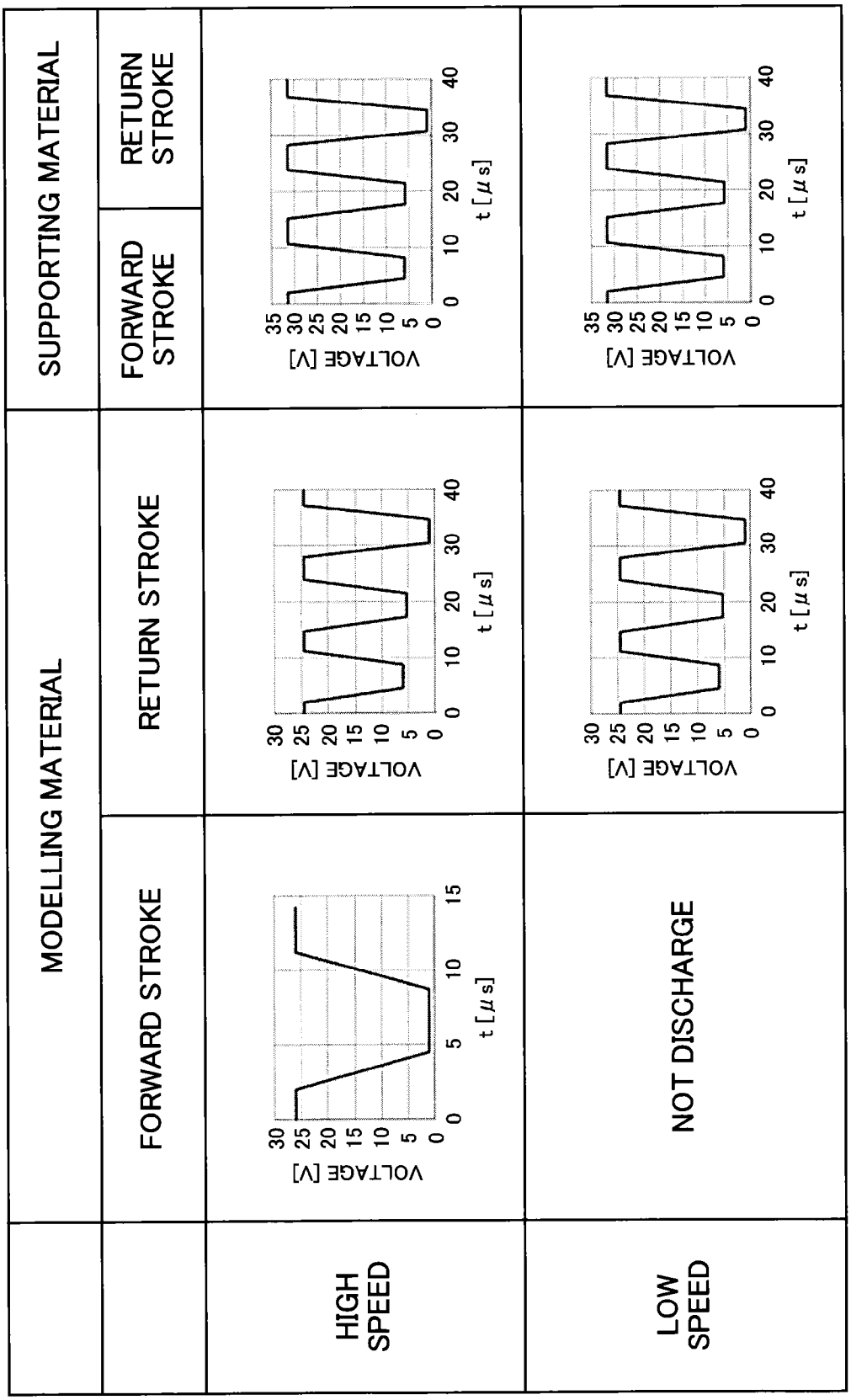
[Fig. 49B]



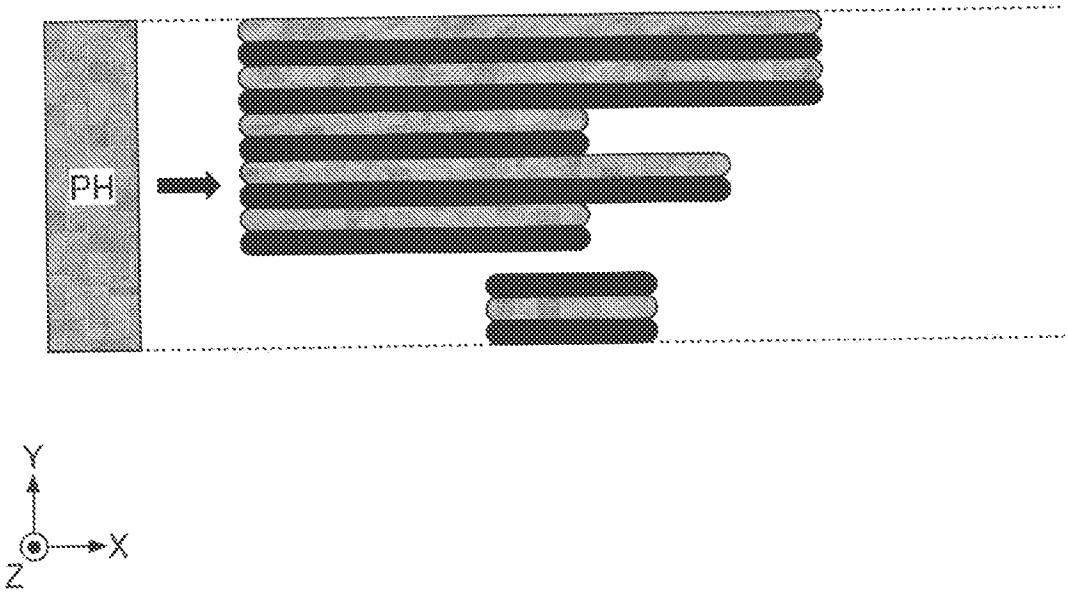
[Fig. 49C]



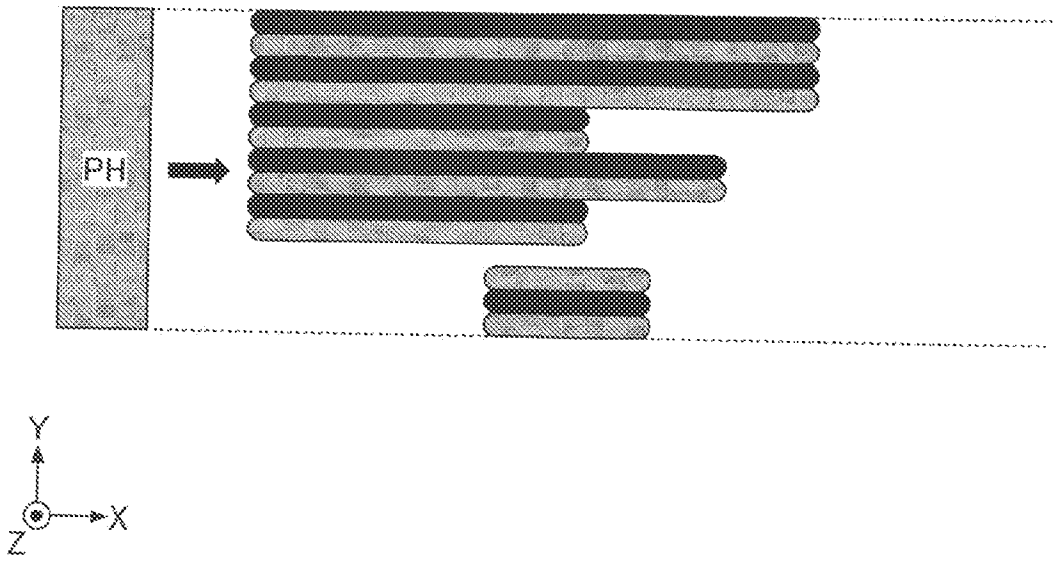
[Fig. 50]


MODELLING MATERIAL
SUPPORTING MATERIAL
FORWARD STROKE
RETURN STROKE
FORWARD STROKE
RETURN STROKE
HIGH SPEED
LOW SPEED
NOT DISCHARGE
VOLTAGE [V]
t [μs]

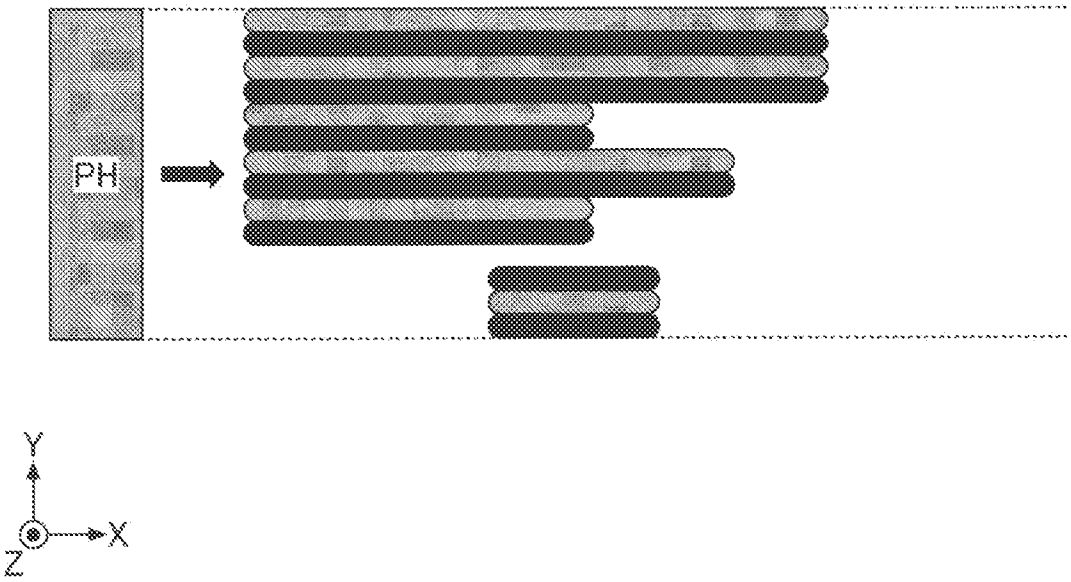
[Fig. 51A]



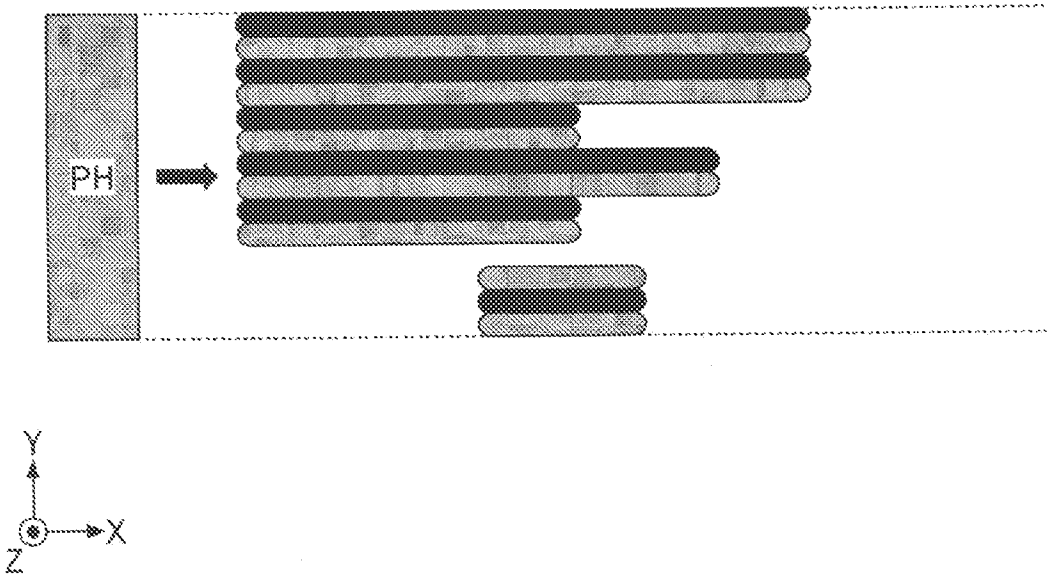
[Fig. 51B]



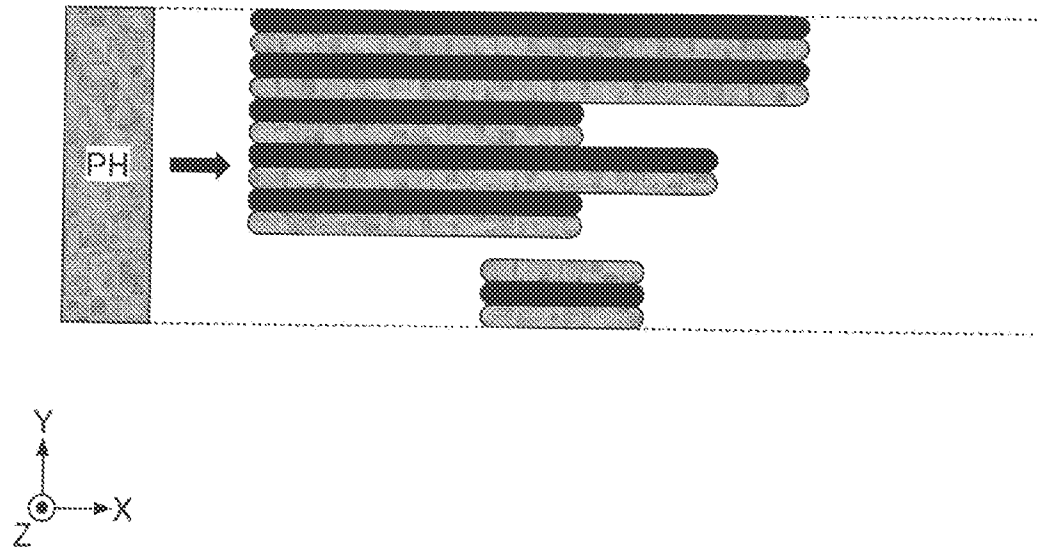
[Fig. 52A]



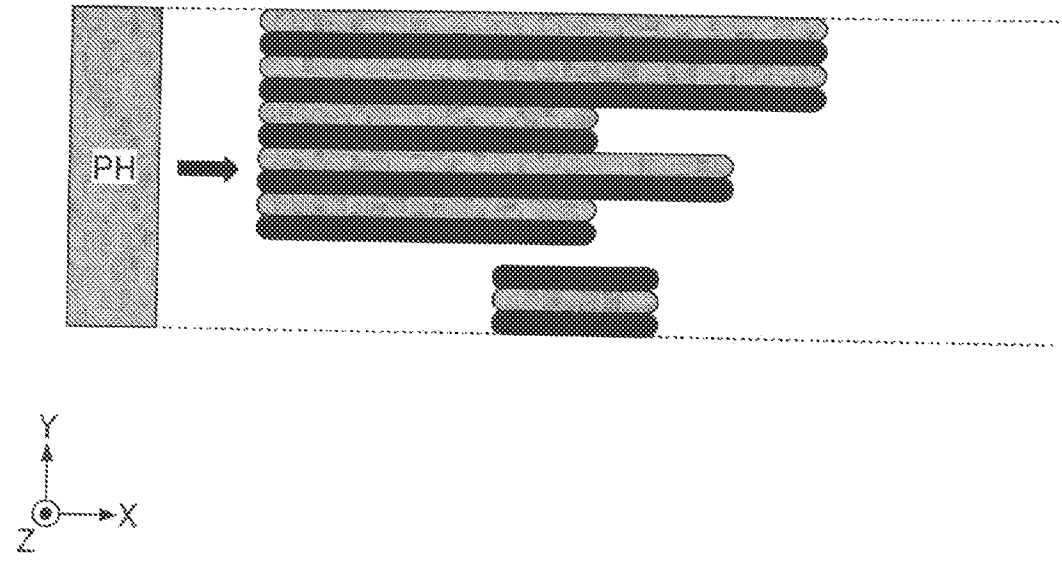
[Fig. 52B]



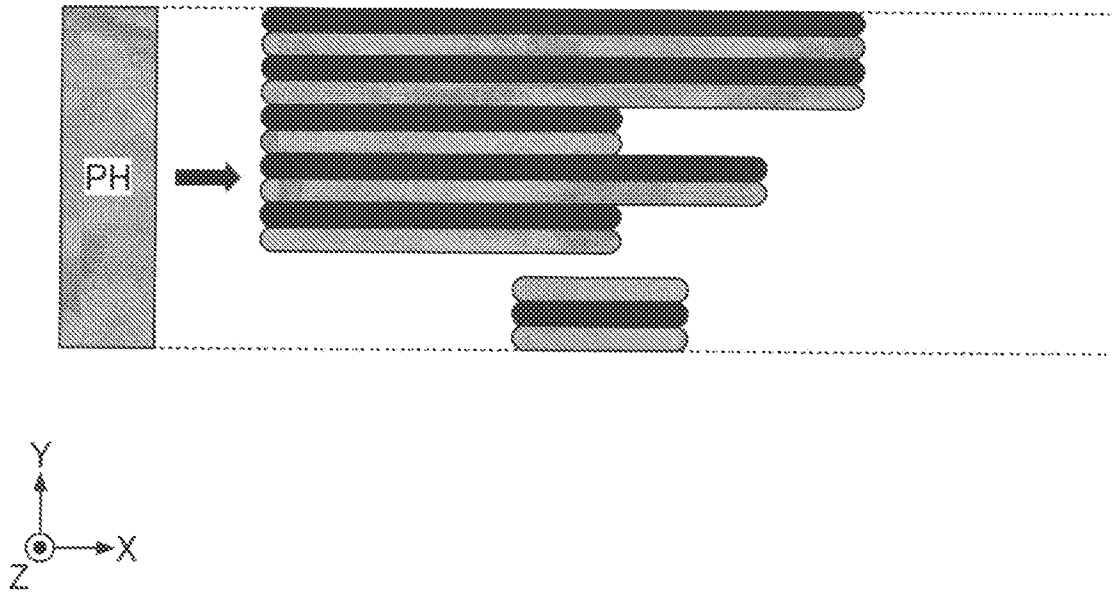
[Fig. 52C]



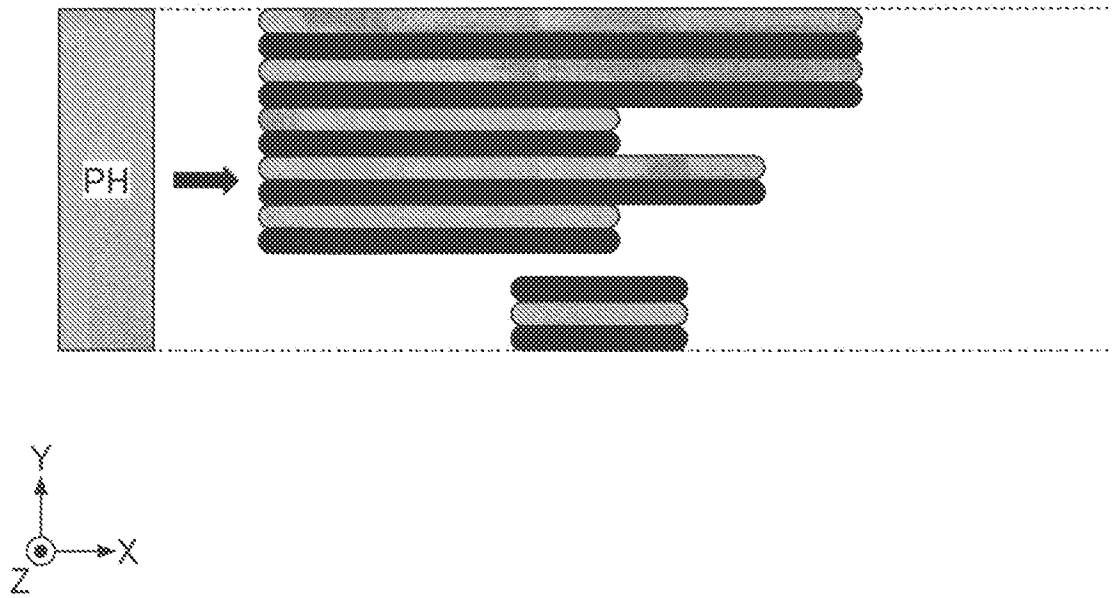
[Fig. 53A]



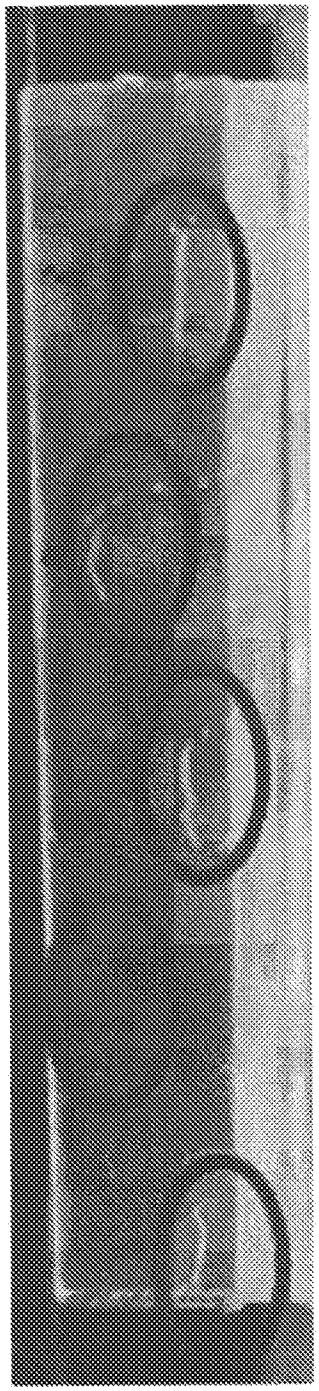
[Fig. 53B]



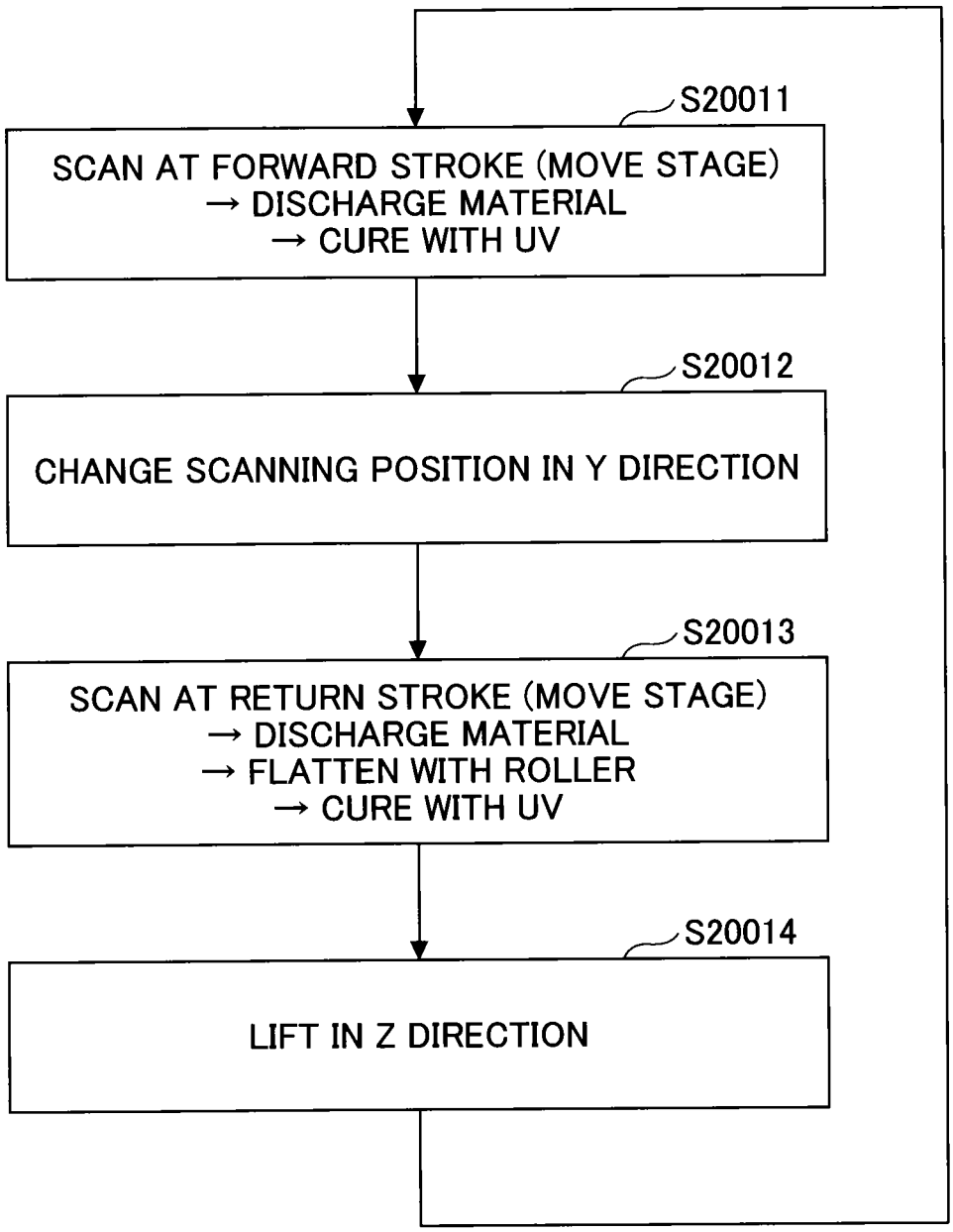
[Fig. 53C]



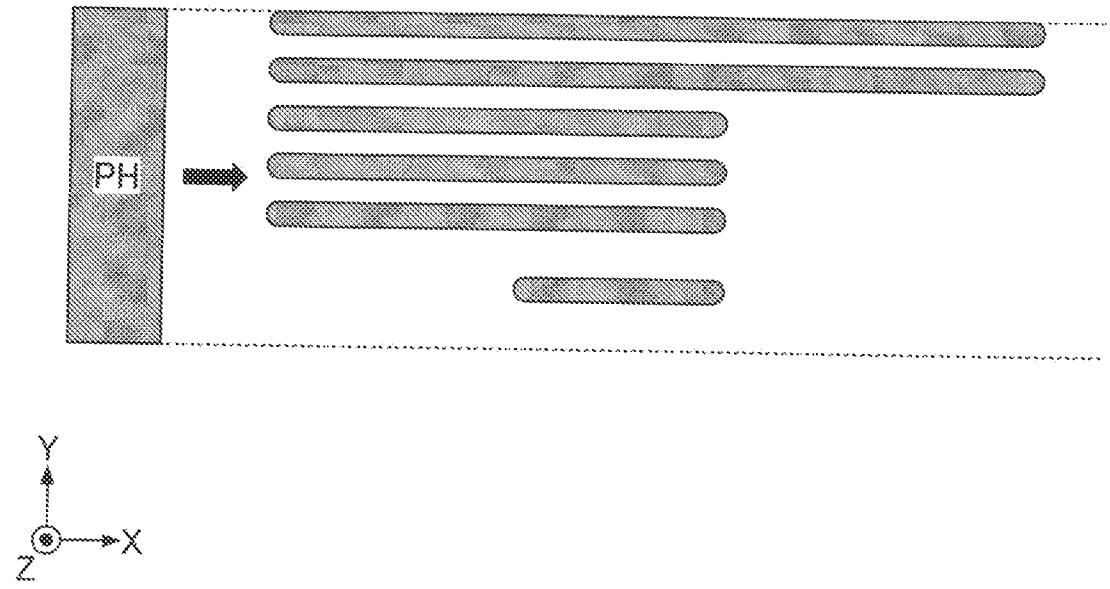
[Fig. 54]



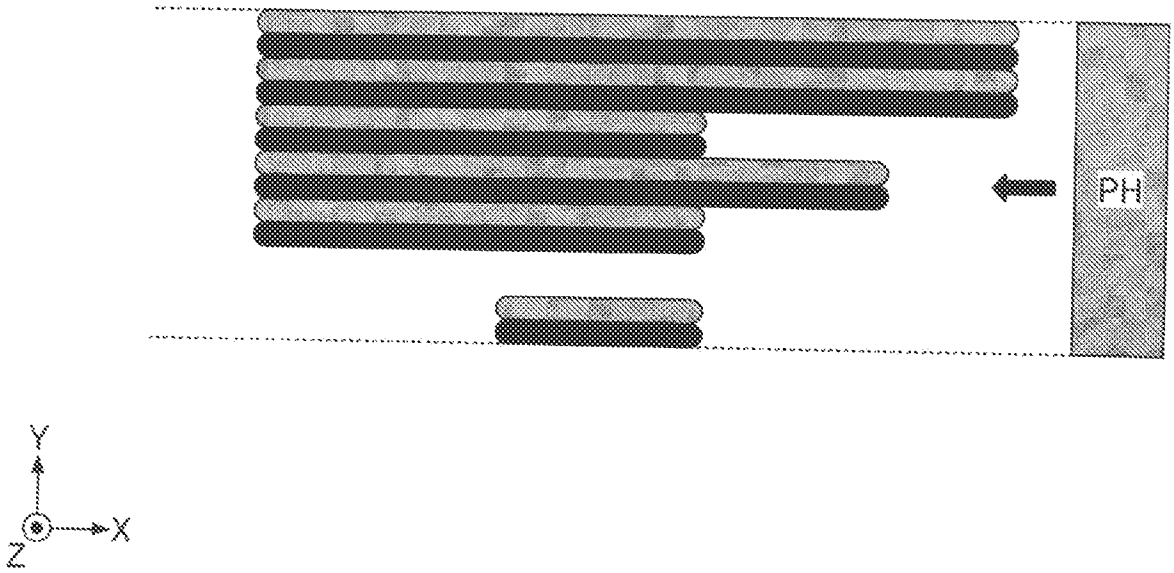
[Fig. 55A]


S20011
SCAN AT FORWARD STROKE (MOVE STAGE)
→ DISCHARGE MATERIAL
→ CURE WITH UV
S20012
CHANGE SCANNING POSITION IN Y DIRECTION
S20013
SCAN AT RETURN STROKE (MOVE STAGE)
→ DISCHARGE MATERIAL
→ FLATTEN WITH ROLLER
→ CURE WITH UV
S20014
LIFT IN Z DIRECTION

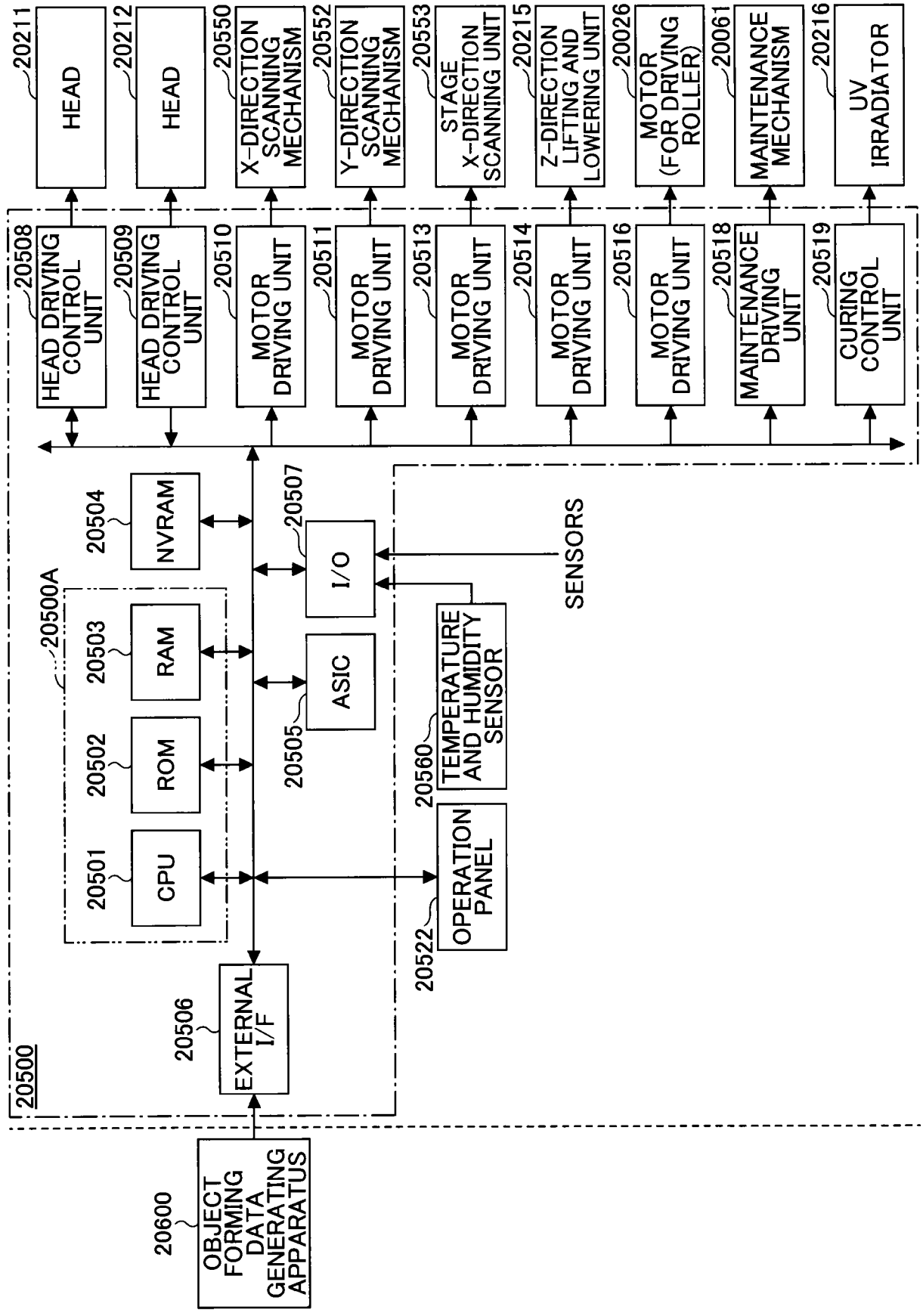
[Fig. 55B]



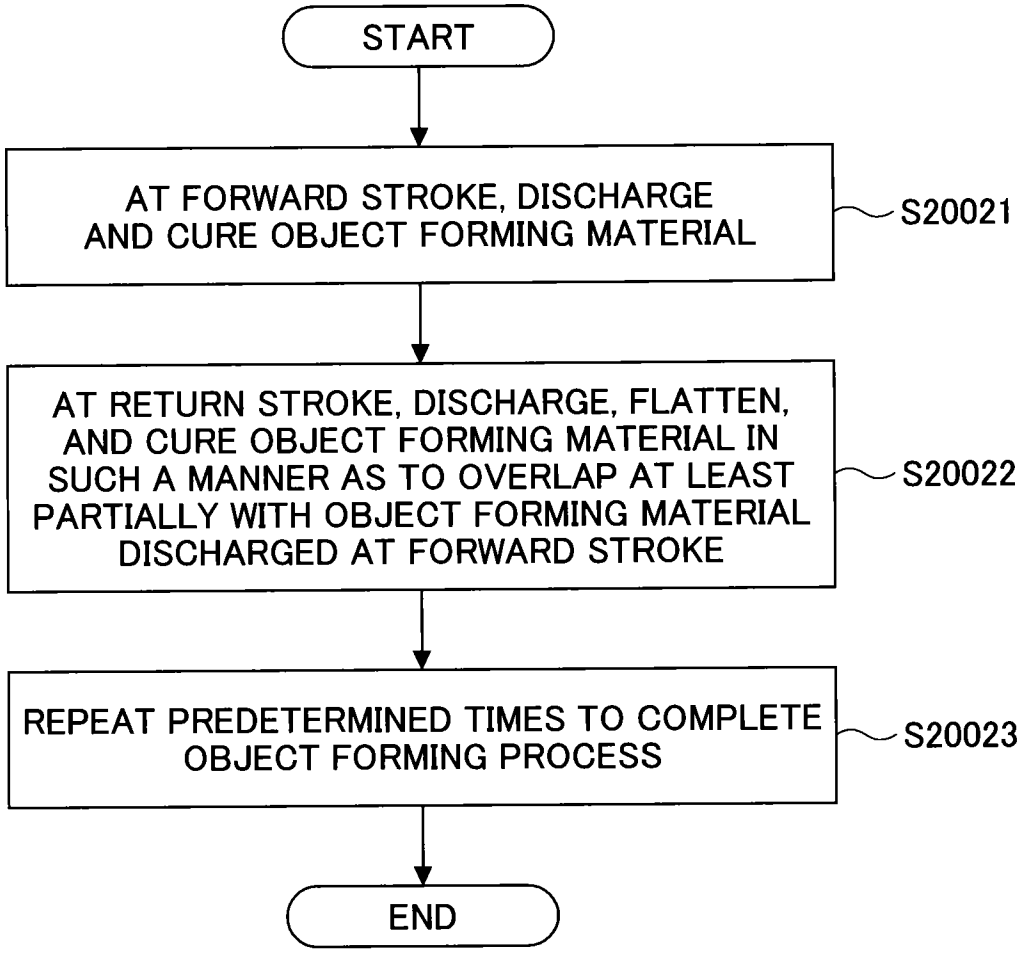
[Fig. 55C]



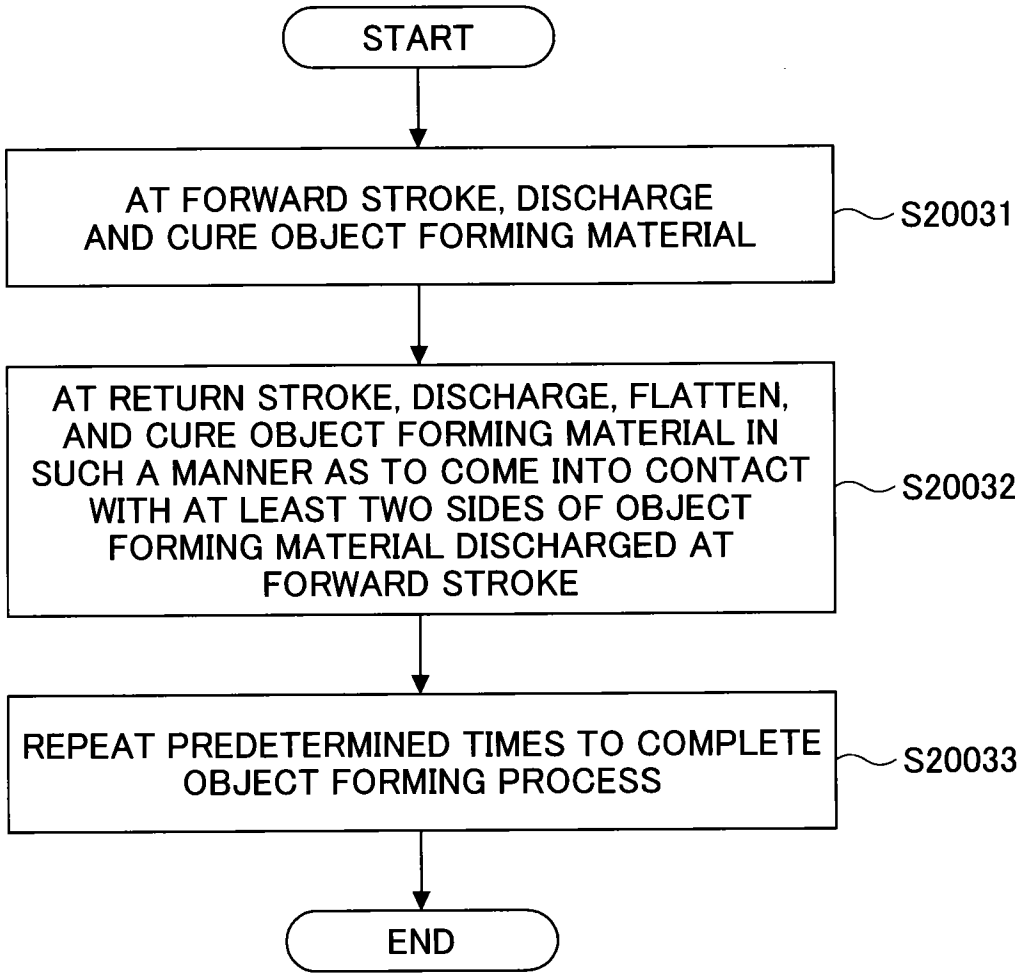
[Fig. 56]


20211 HEAD
20212 HEAD
20550 X-DIRECTION SCANNING MECHANISM
20552 Y-DIRECTION SCANNING MECHANISM
20553 STAGE X-DIRECTION SCANNING UNIT
20215 Z-DIRECTION LIFTING AND LOWERING UNIT
20026 MOTOR (FOR DRIVING ROLLER)
20061 MAINTENANCE MECHANISM
20216 UV IRRADIATOR
20508 HEAD DRIVING CONTROL UNIT
20509 HEAD DRIVING CONTROL UNIT
20510 MOTOR DRIVING UNIT
20511 MOTOR DRIVING UNIT
20513 MOTOR DRIVING UNIT
20514 MOTOR DRIVING UNIT
20516 MOTOR DRIVING UNIT
20518 MAINTENANCE DRIVING UNIT
20519 CURING CONTROL UNIT
20504 NVRAM
20507 I/O
SENSORS
20500A
20503 RAM
20502 ROM
20501 CPU
ASIC
20505
20560 TEMPERATURE AND HUMIDITY SENSOR
20522 OPERATION PANEL
20506 EXTERNAL I/F
20500
20600 OBJECT FORMING DATA GENERATING APPARATUS

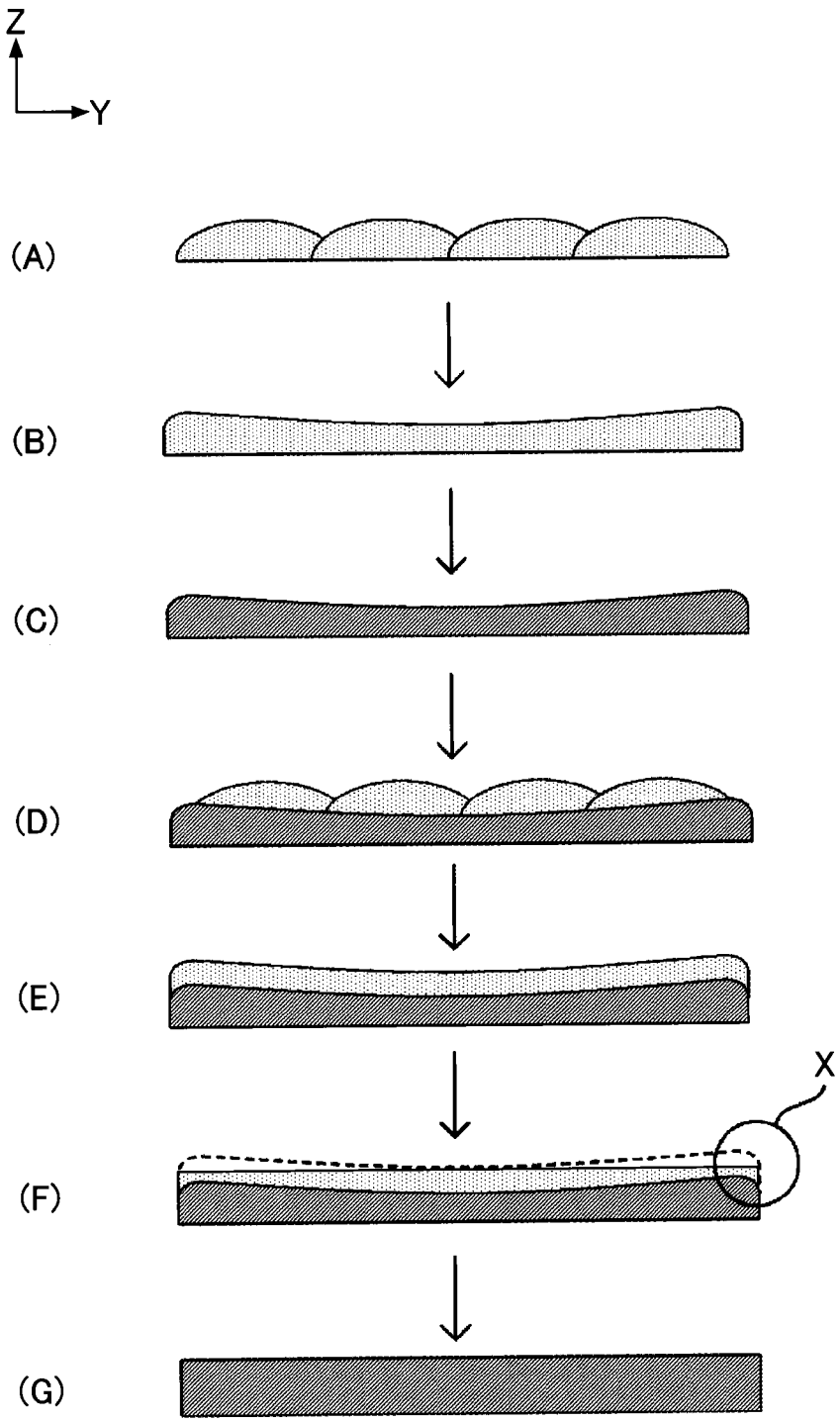
[Fig. 57]


START
AT FORWARD STROKE, DISCHARGE AND CURE OBJECT FORMING MATERIAL
S20021
AT RETURN STROKE, DISCHARGE, FLATTEN, AND CURE OBJECT FORMING MATERIAL IN SUCH A MANNER AS TO OVERLAP AT LEAST PARTIALLY WITH OBJECT FORMING MATERIAL DISCHARGED AT FORWARD STROKE
S20022
REPEAT PREDETERMINED TIMES TO COMPLETE OBJECT FORMING PROCESS
S20023
END

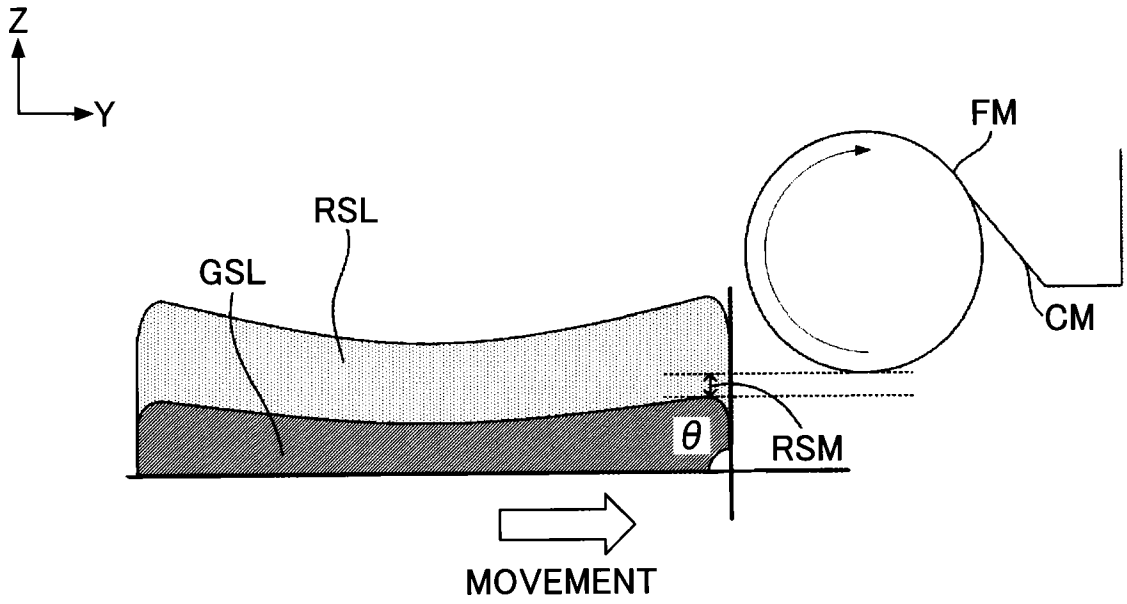
[Fig. 58]


START
AT FORWARD STROKE, DISCHARGE AND CURE OBJECT FORMING MATERIAL
S20031
AT RETURN STROKE, DISCHARGE, FLATTEN, AND CURE OBJECT FORMING MATERIAL IN SUCH A MANNER AS TO COME INTO CONTACT WITH AT LEAST TWO SIDES OF OBJECT FORMING MATERIAL DISCHARGED AT FORWARD STROKE
S20032
REPEAT PREDETERMINED TIMES TO COMPLETE OBJECT FORMING PROCESS
S20033
END

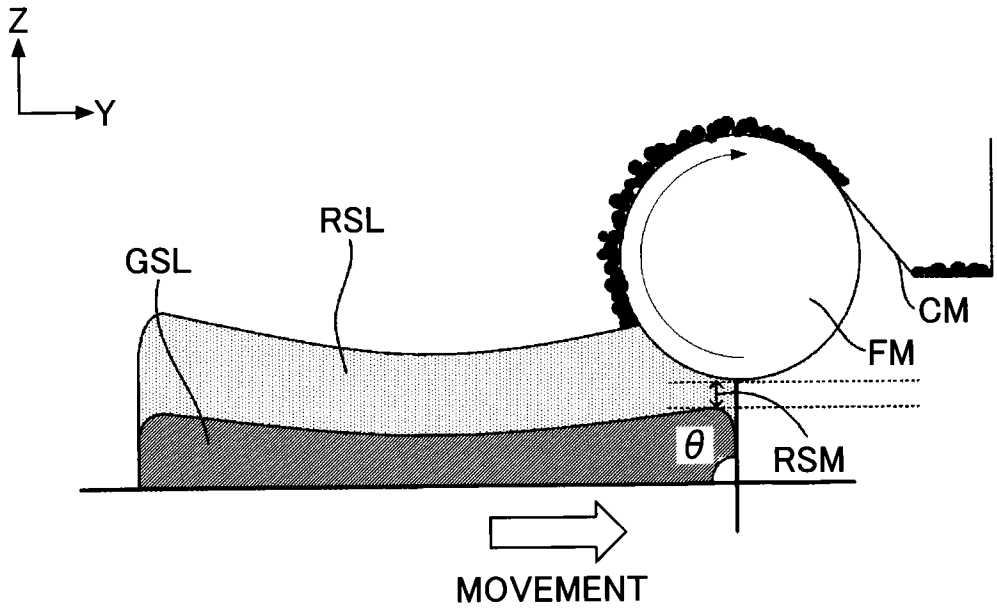
[Fig. 59]



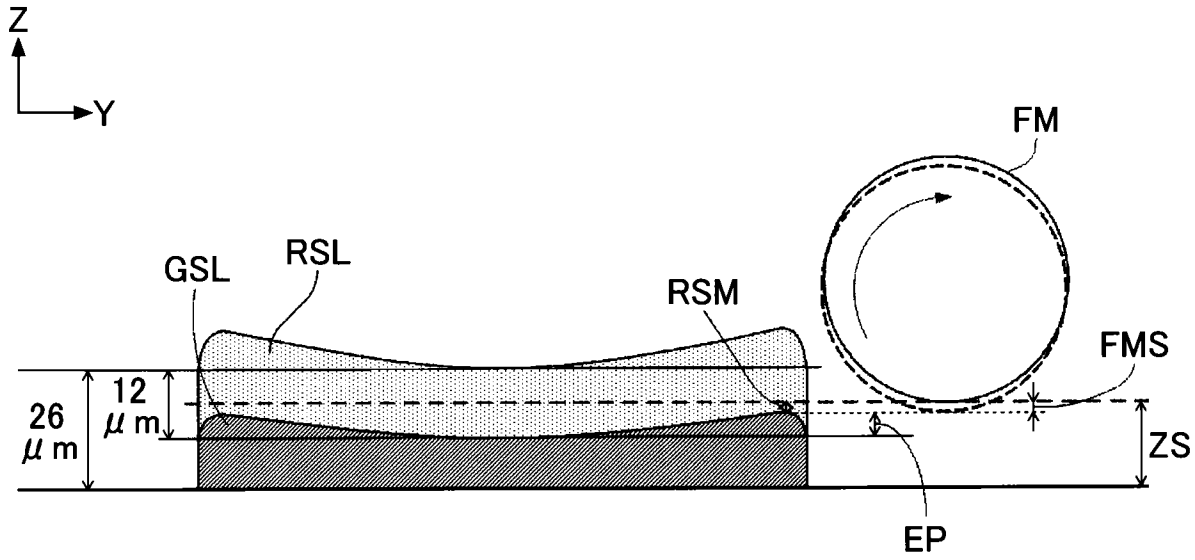
[Fig. 60]



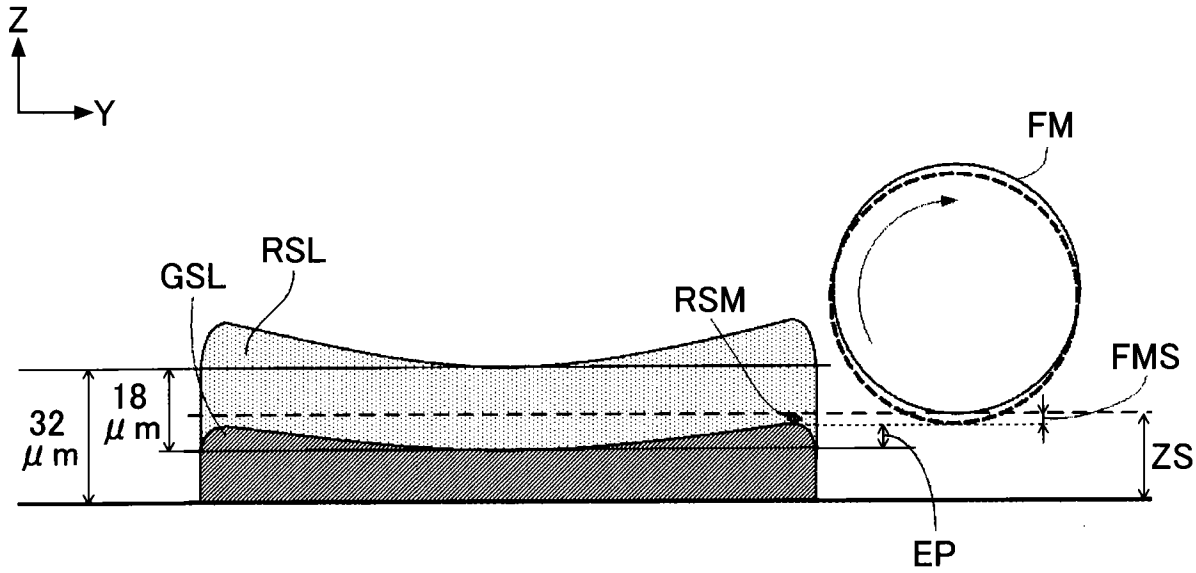
[Fig. 61]



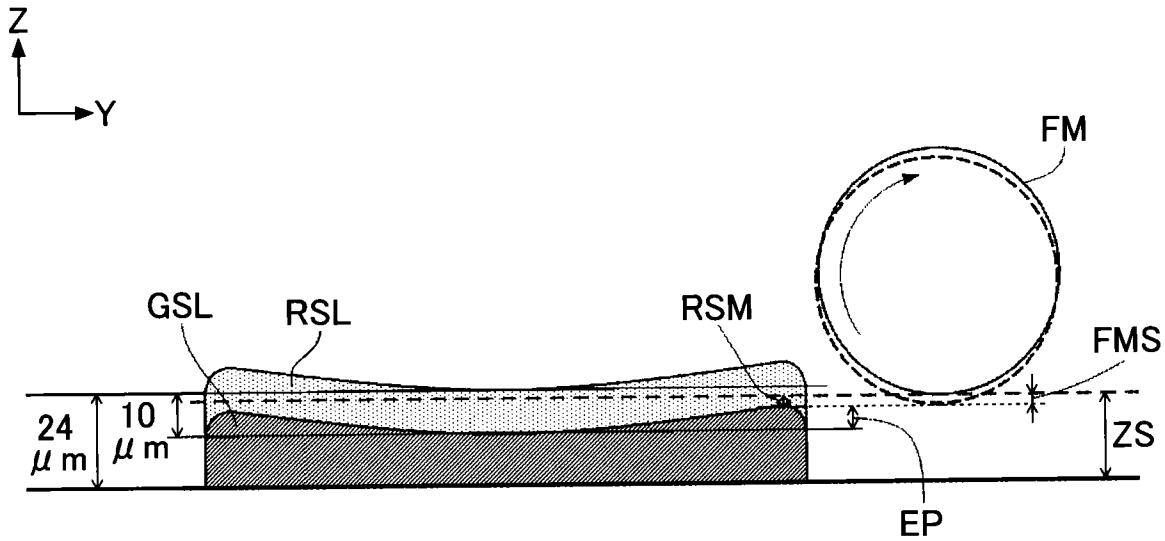
[Fig. 62]


Z
Y
FM
GSL
RSL
RSM
FMS
12 μm
26 μm
ZS
EP

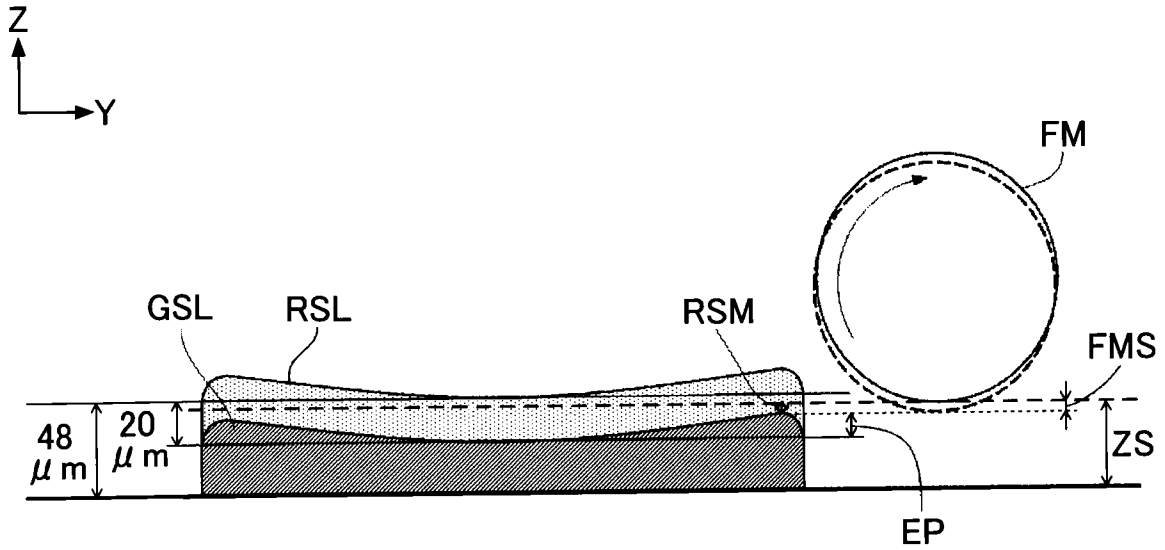
[Fig. 63]


Z
Y
FM
RSL
GSL
RSM
FMS
18 μm
32 μm
ZS
EP

[Fig. 64]


Z
Y
FM
GSL
RSL
RSM
FMS
24 μm
10 μm
ZS
EP

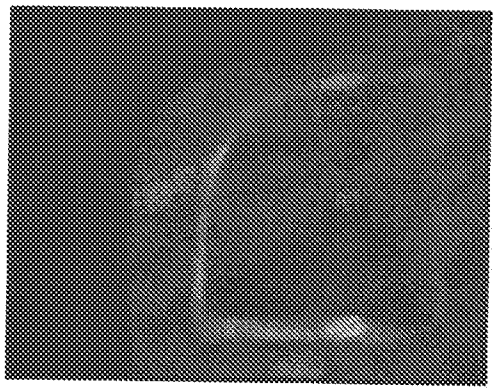
[Fig. 65]


Z
Y
FM
GSL
RSL
RSM
FMS
48 μm
20 μm
ZS
EP

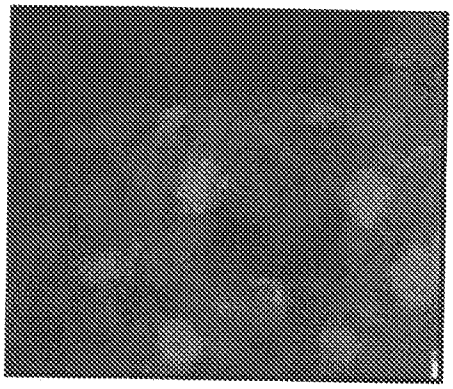
[Fig. 66A]



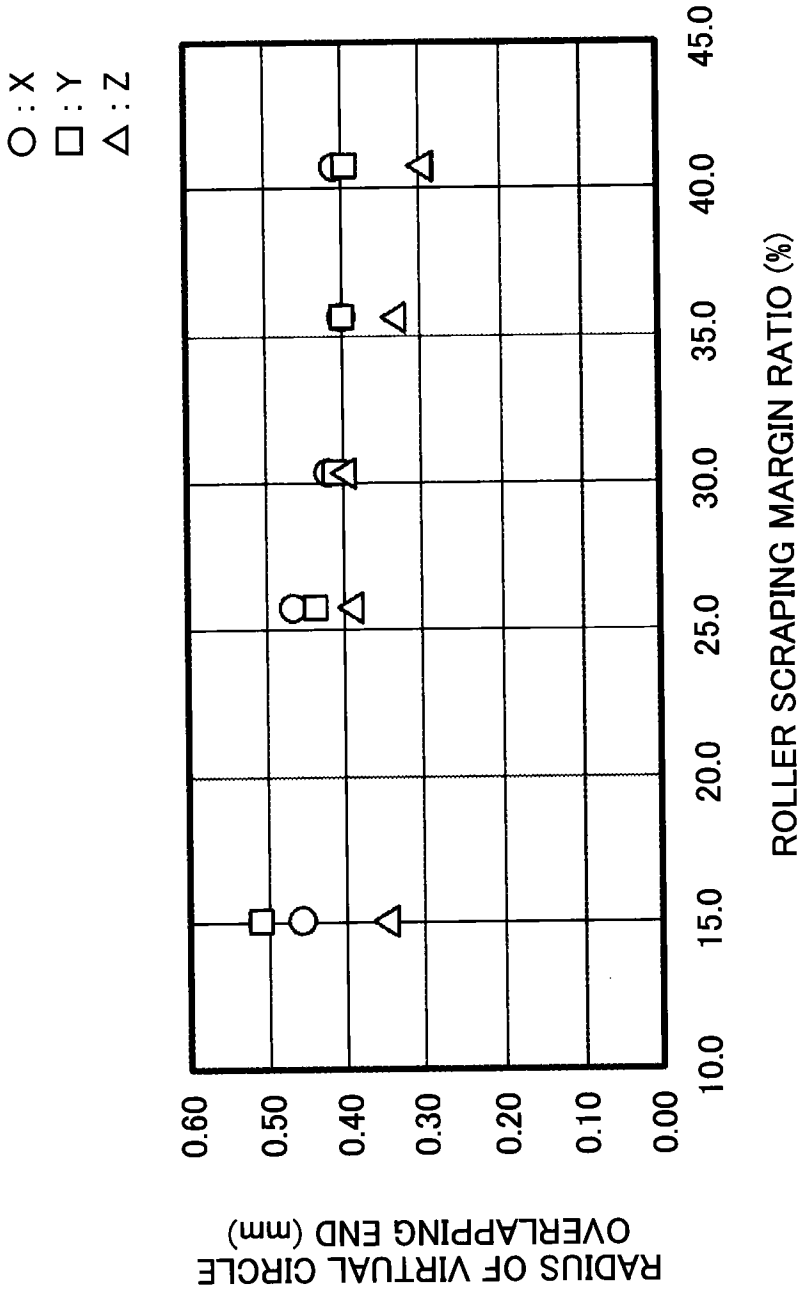
[Fig. 66B]



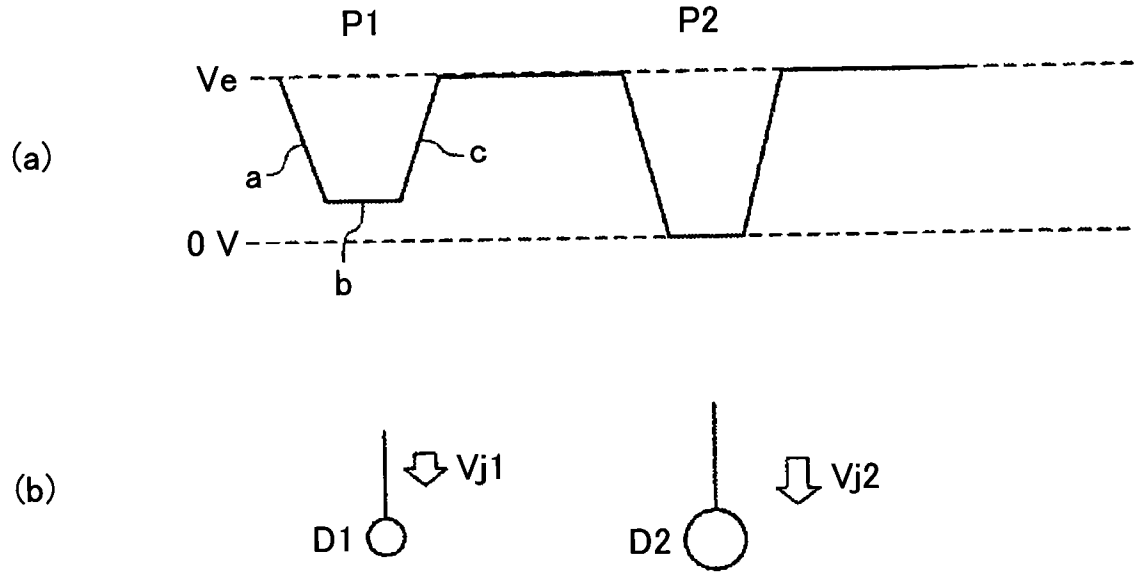
[Fig. 66C]



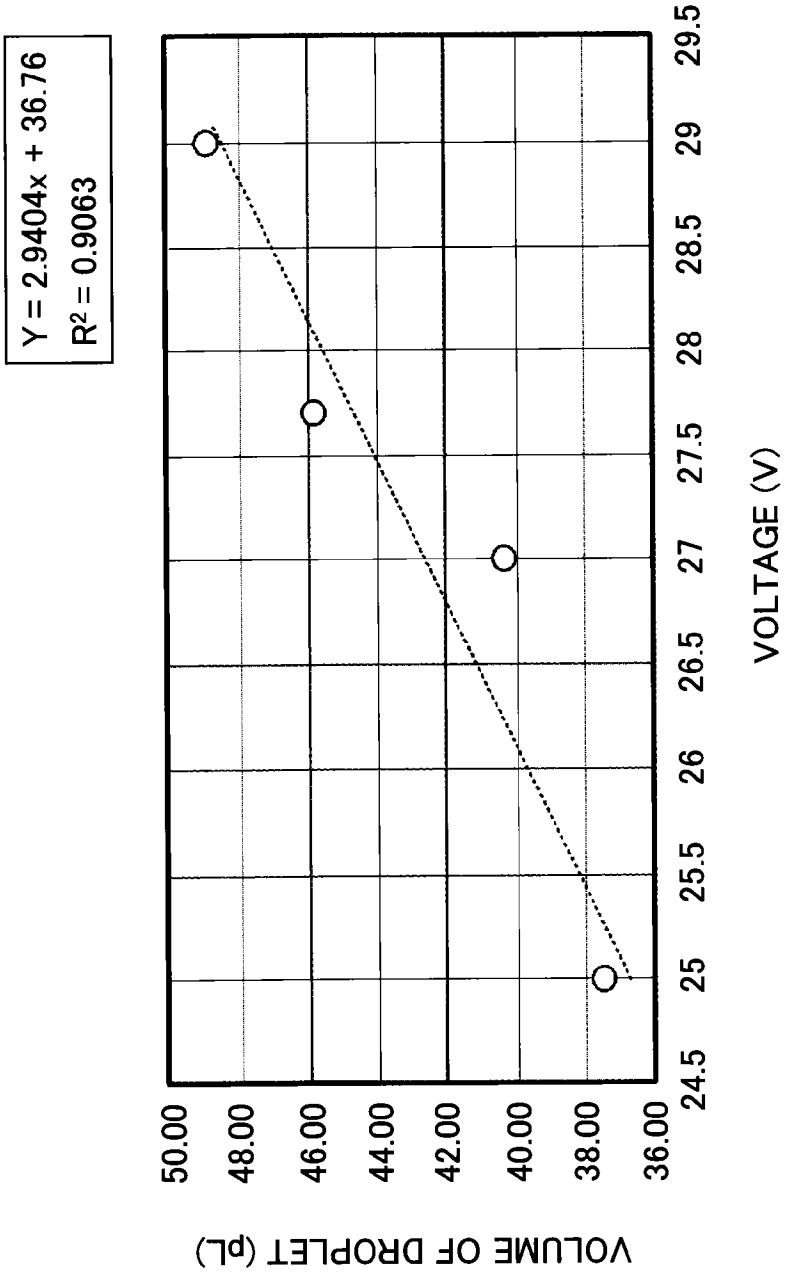
[Fig. 67]


○ : X
□ : Y
△ : Z
RADIUS OF VIRTUAL CIRCLE OVERLAPPING END (mm)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
ROLLER SCRAPING MARGIN RATIO (%)

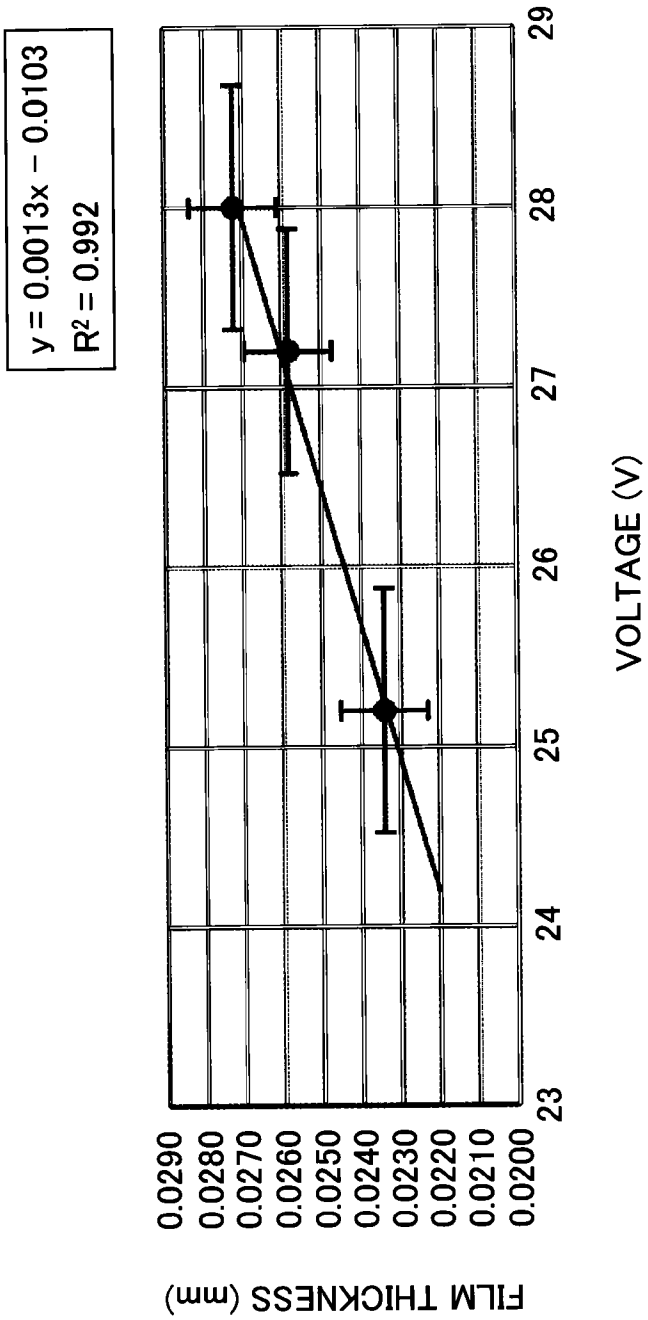
[Fig. 68]



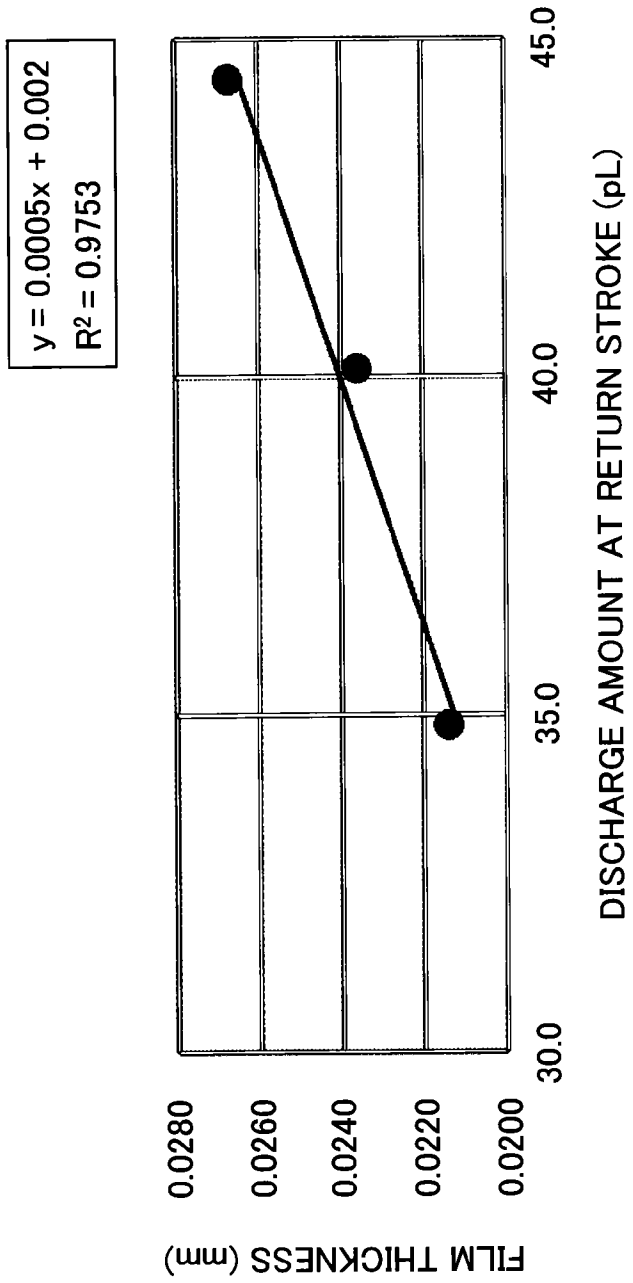
[Fig. 69]


Y = 2.9404x + 36.76
R² = 0.9063
VOLUME OF DROPLET (pL)
50.00
48.00
46.00
44.00
42.00
40.00
38.00
36.00
VOLTAGE (V)
24.5
25
25.5
26
26.5
27
27.5
28
28.5
29
29.5

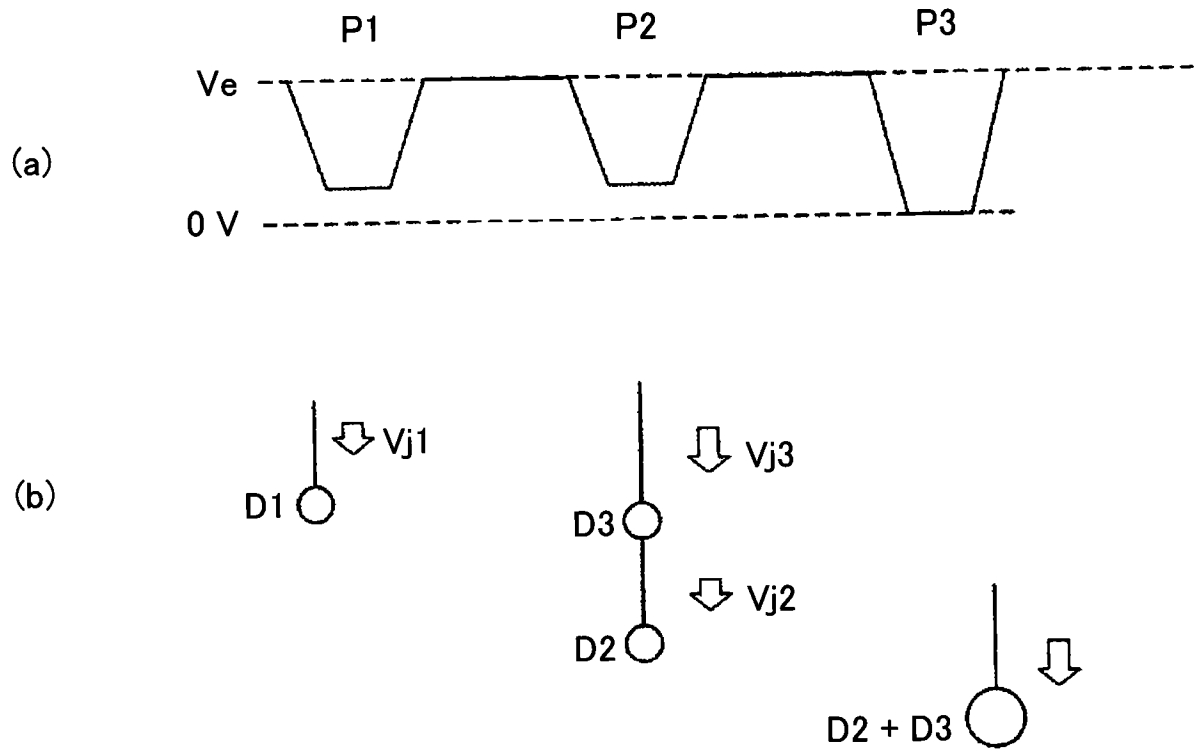
[Fig. 70]


y = 0.0013x – 0.0103
R² = 0.992
FILM THICKNESS (mm)
0.0290
0.0280
0.0270
0.0260
0.0250
0.0240
0.0230
0.0220
0.0210
0.0200
VOLTAGE (V)
23
24
25
26
27
28
29

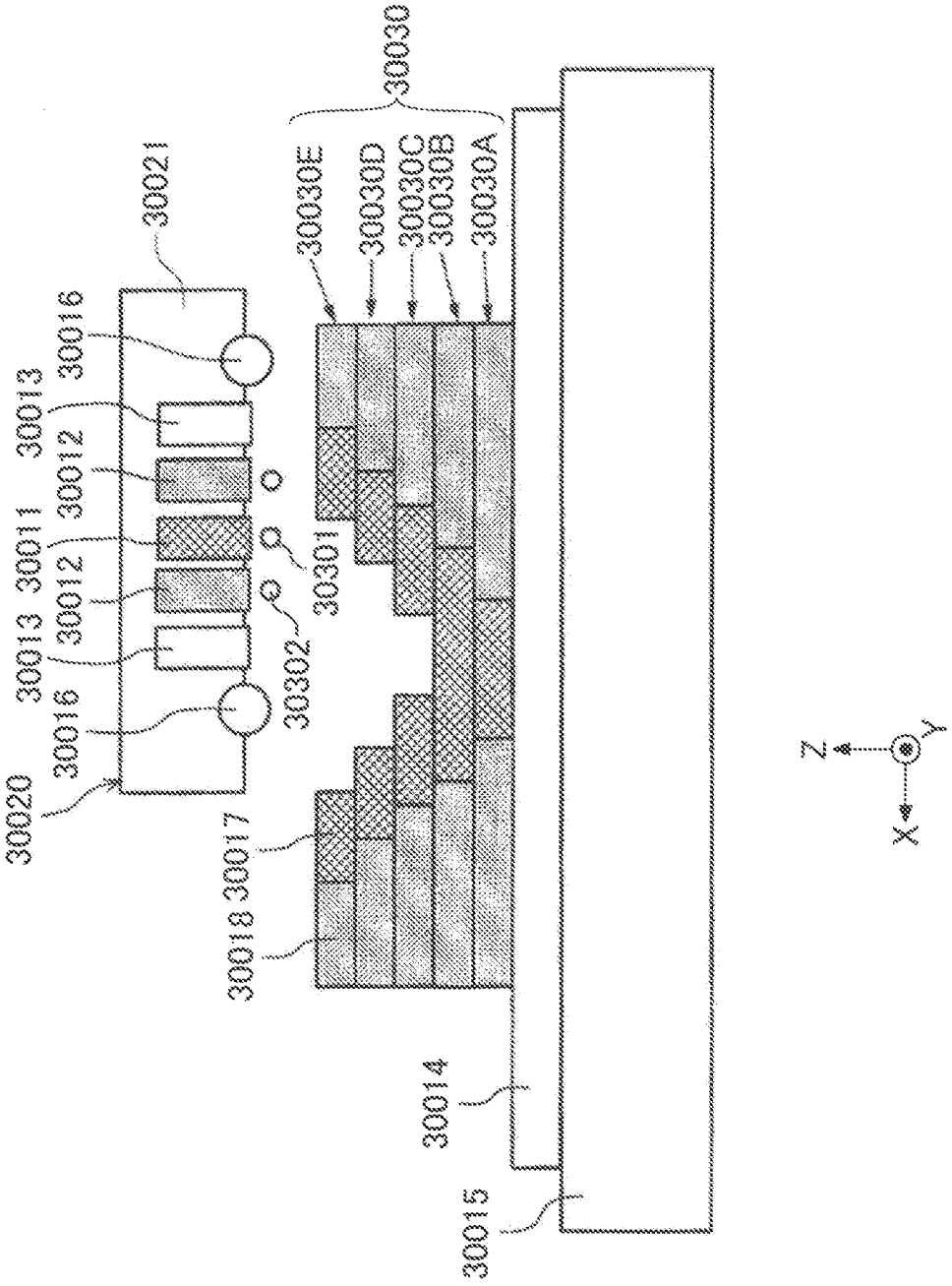
[Fig. 71]


y = 0.0005x + 0.002
R² = 0.9753
FILM THICKNESS (mm)
0.0280
0.0260
0.0240
0.0220
0.0200
DISCHARGE AMOUNT AT RETURN STROKE (pL)
30.0
35.0
40.0
45.0

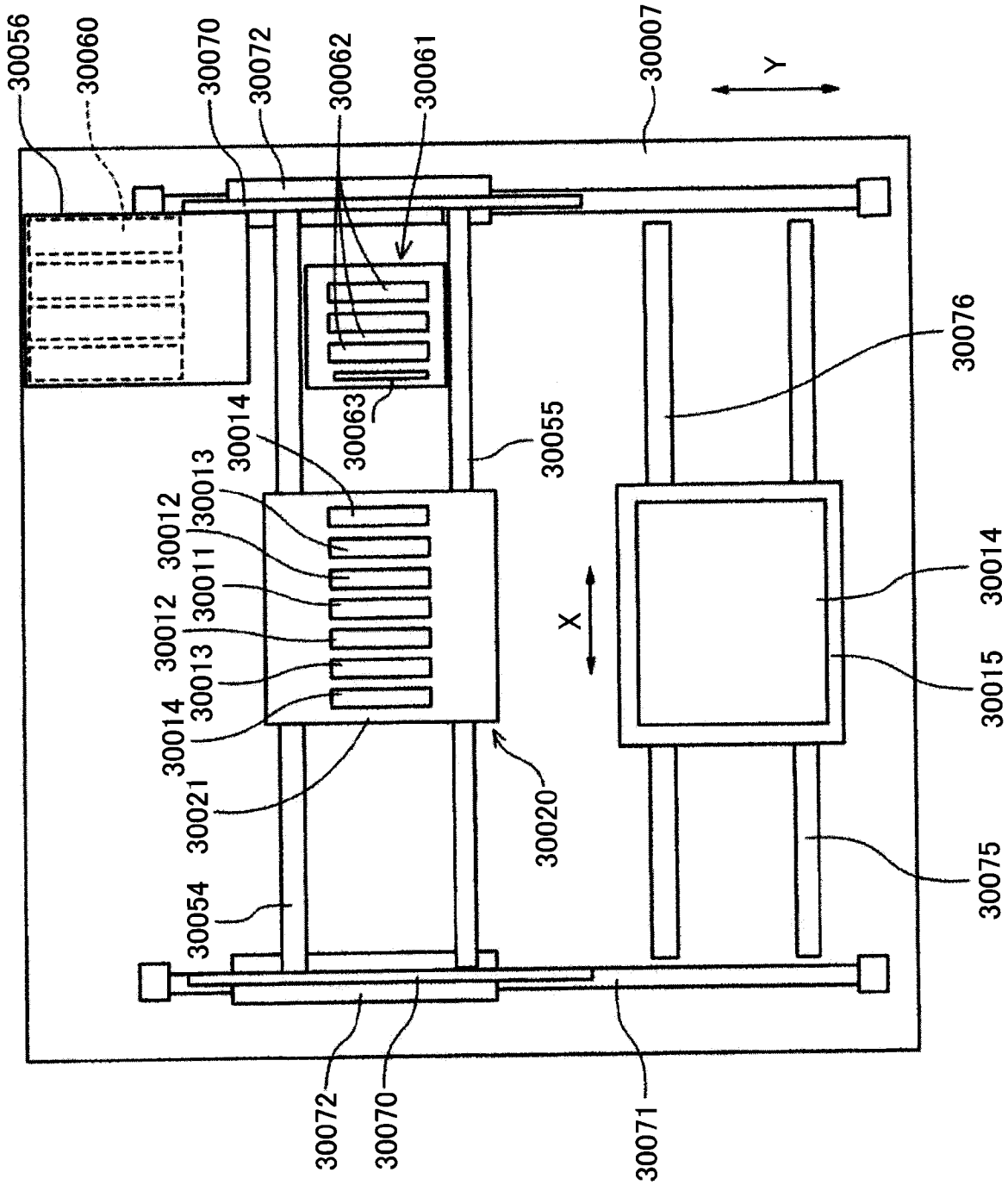
[Fig. 72]



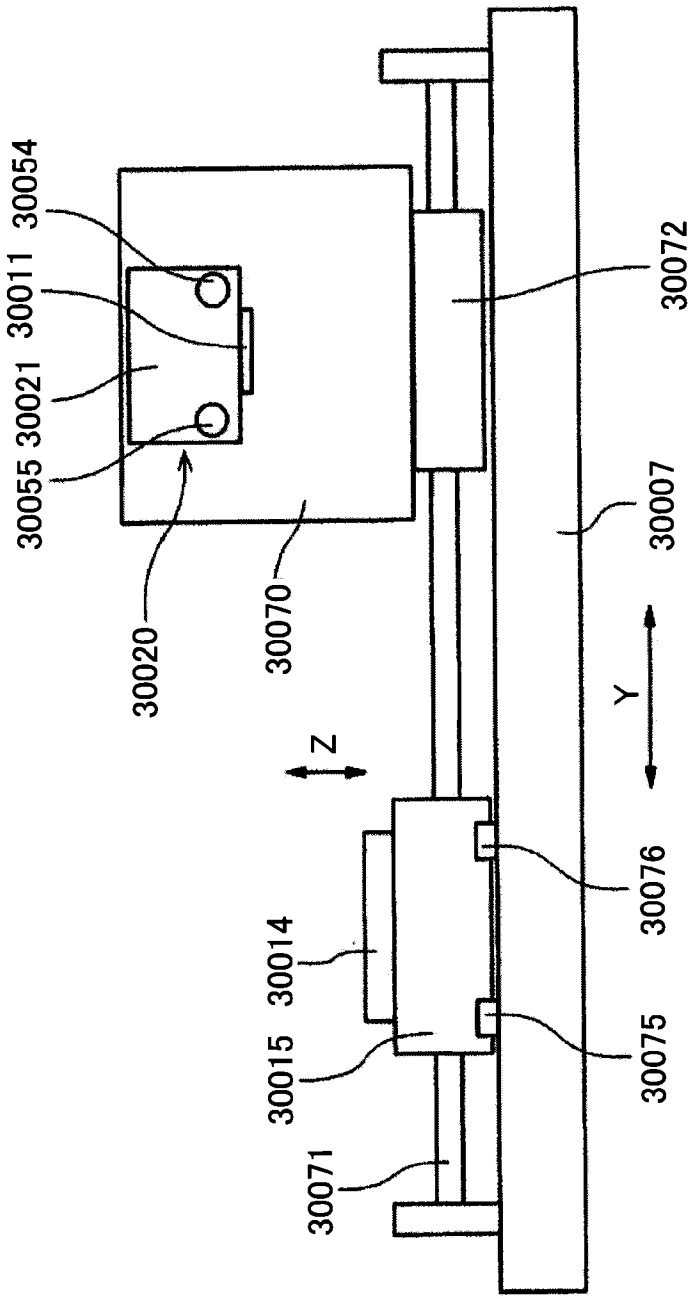
[Fig. 73]


30030
30030E
30030D
30030C
30030B
30030A
30021
30016
30013
30012
30011
30012
30013
30016
30020
30018
30017
30301
30302
30014
30015
Z
Y
X

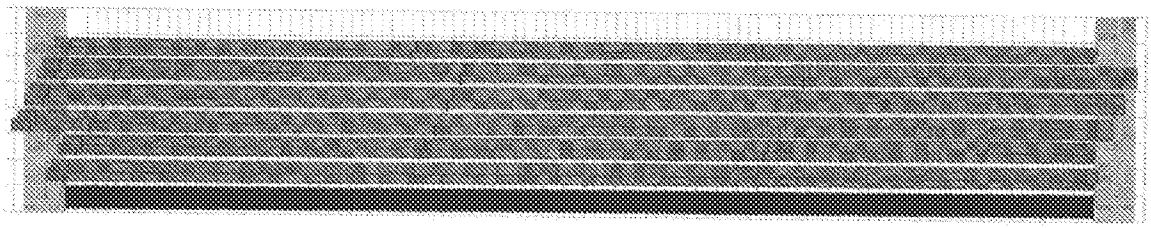
[Fig. 74]


30056
30060
30070
30072
30062
30061
30007
Y
30076
30063
30014
30055
30013
30012
30011
30012
30013
30014
X
30014
30015
30021
30020
30075
30054
30072
30070
30071

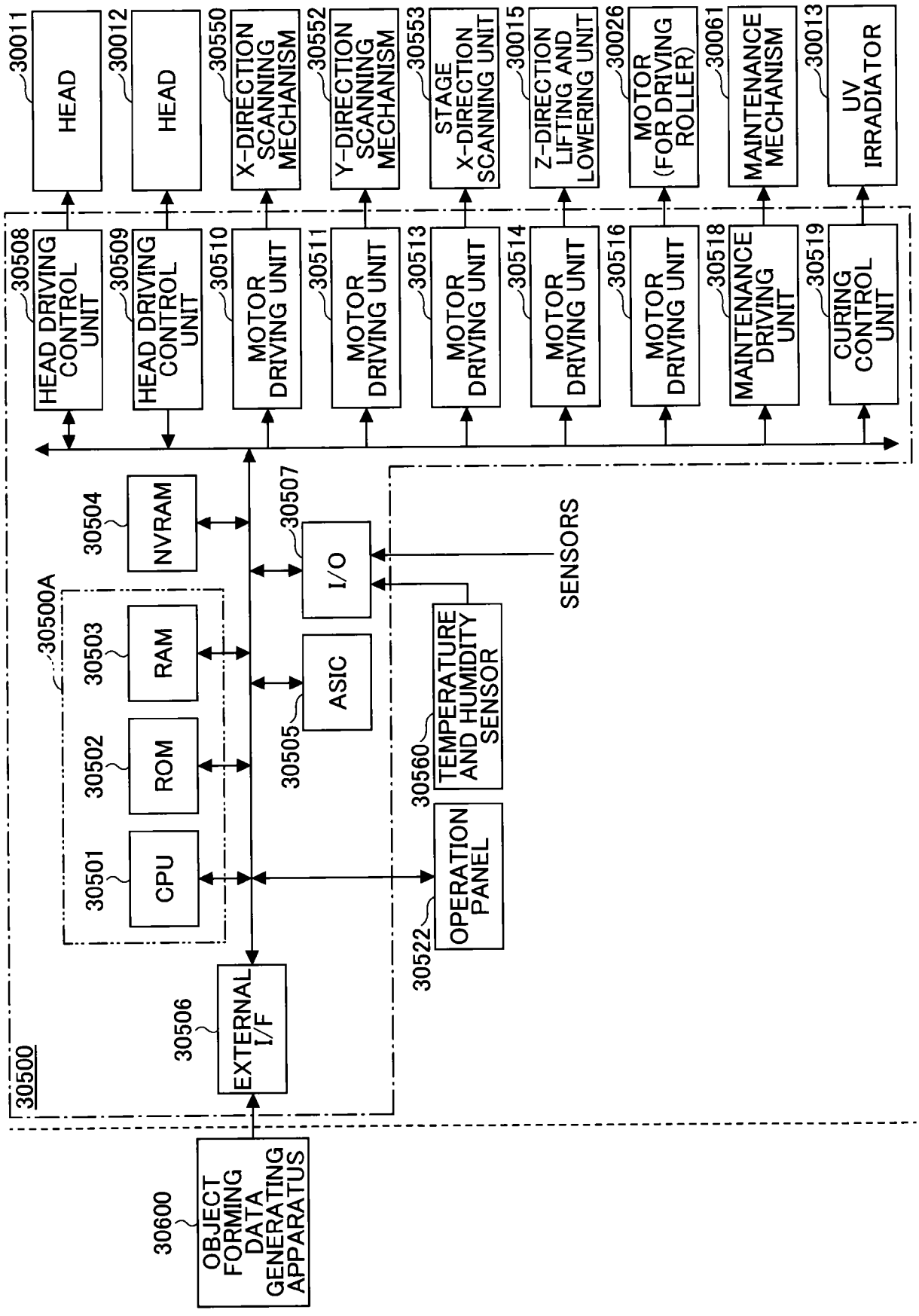
[Fig. 75]


30054
30011
30021
30055
30020
30070
30072
30007
Y
Z
30076
30014
30015
30075
30071

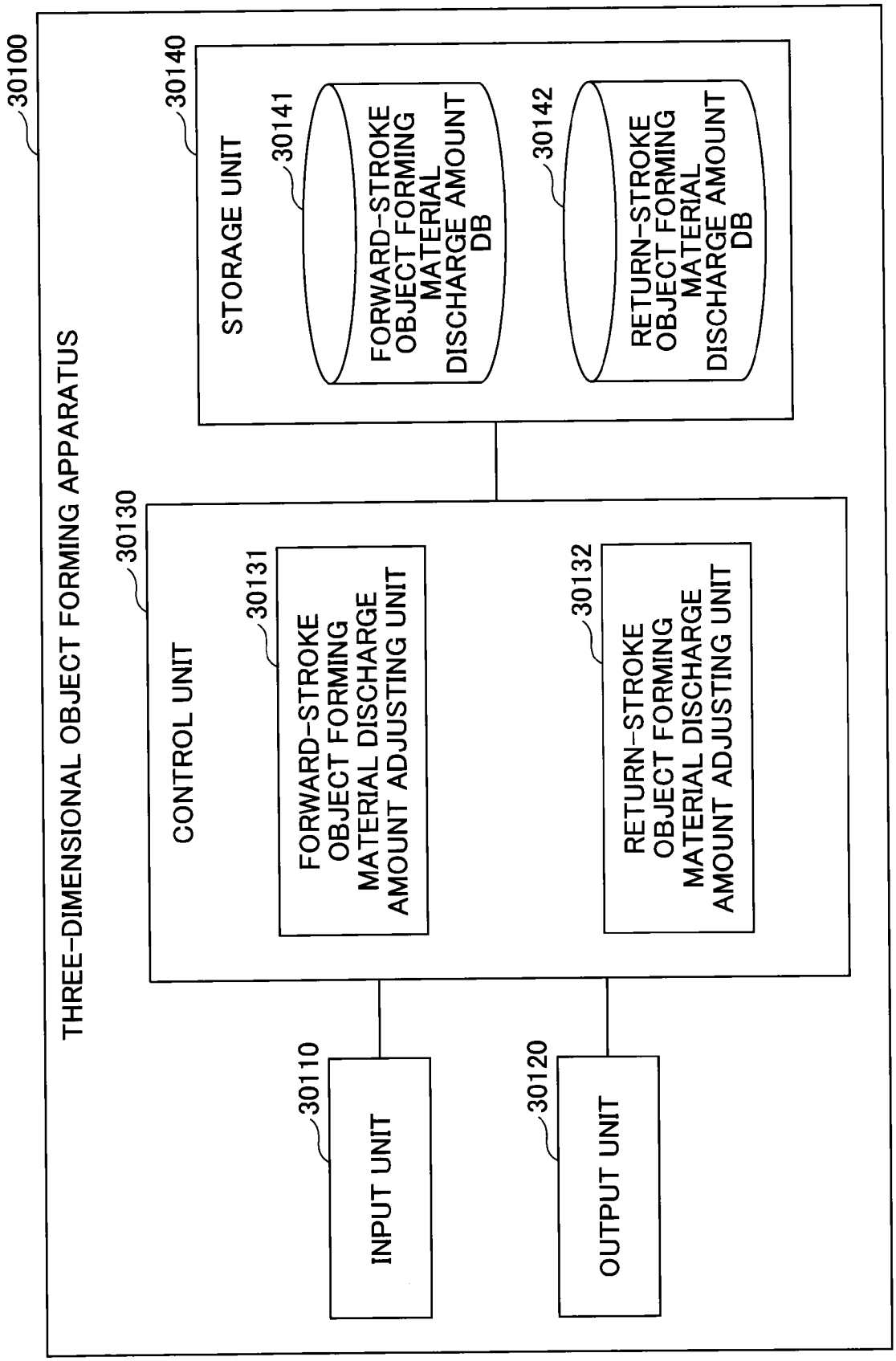
[Fig. 76]



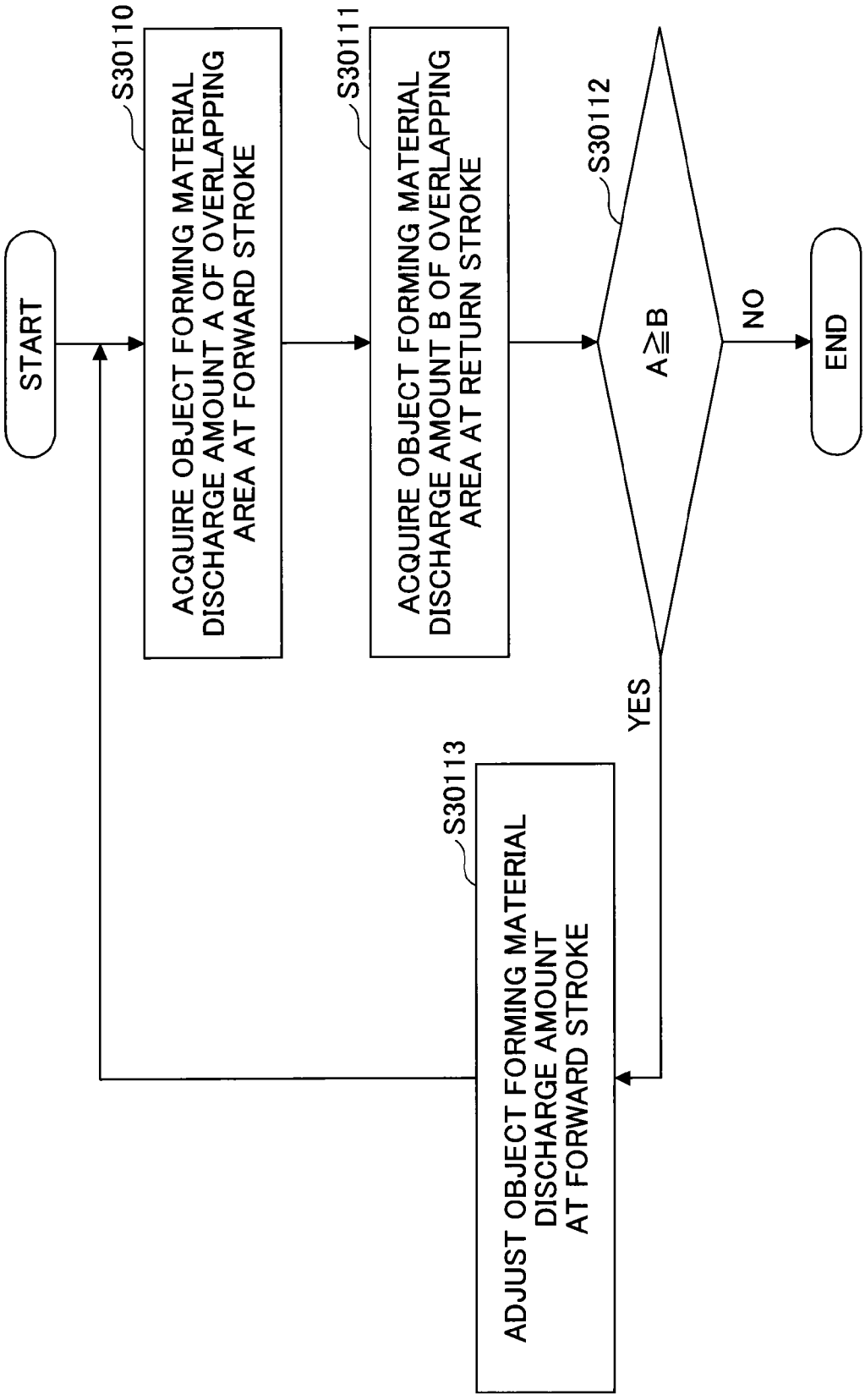
[Fig. 77]


30011
HEAD
30012
HEAD
30550
X-DIRECTION SCANNING MECHANISM
30552
Y-DIRECTION SCANNING MECHANISM
30553
STAGE X-DIRECTION SCANNING UNIT
30015
Z-DIRECTION LIFTING AND LOWERING UNIT
30026
MOTOR (FOR DRIVING ROLLER)
30061
MAINTENANCE MECHANISM
30013
UV IRRADIATOR
30508
HEAD DRIVING CONTROL UNIT
30509
HEAD DRIVING CONTROL UNIT
30510
MOTOR DRIVING UNIT
30511
MOTOR DRIVING UNIT
30513
MOTOR DRIVING UNIT
30514
MOTOR DRIVING UNIT
30516
MOTOR DRIVING UNIT
30518
MAINTENANCE DRIVING UNIT
30519
CURING CONTROL UNIT
30504
NVRAM
30507
I/O
SENSORS
30500A
30503
RAM
30502
ROM
30501
CPU
30505
ASIC
30560
TEMPERATURE AND HUMIDITY SENSOR
30522
OPERATION PANEL
30506
EXTERNAL I/F
30500
30600
OBJECT FORMING DATA GENERATING APPARATUS

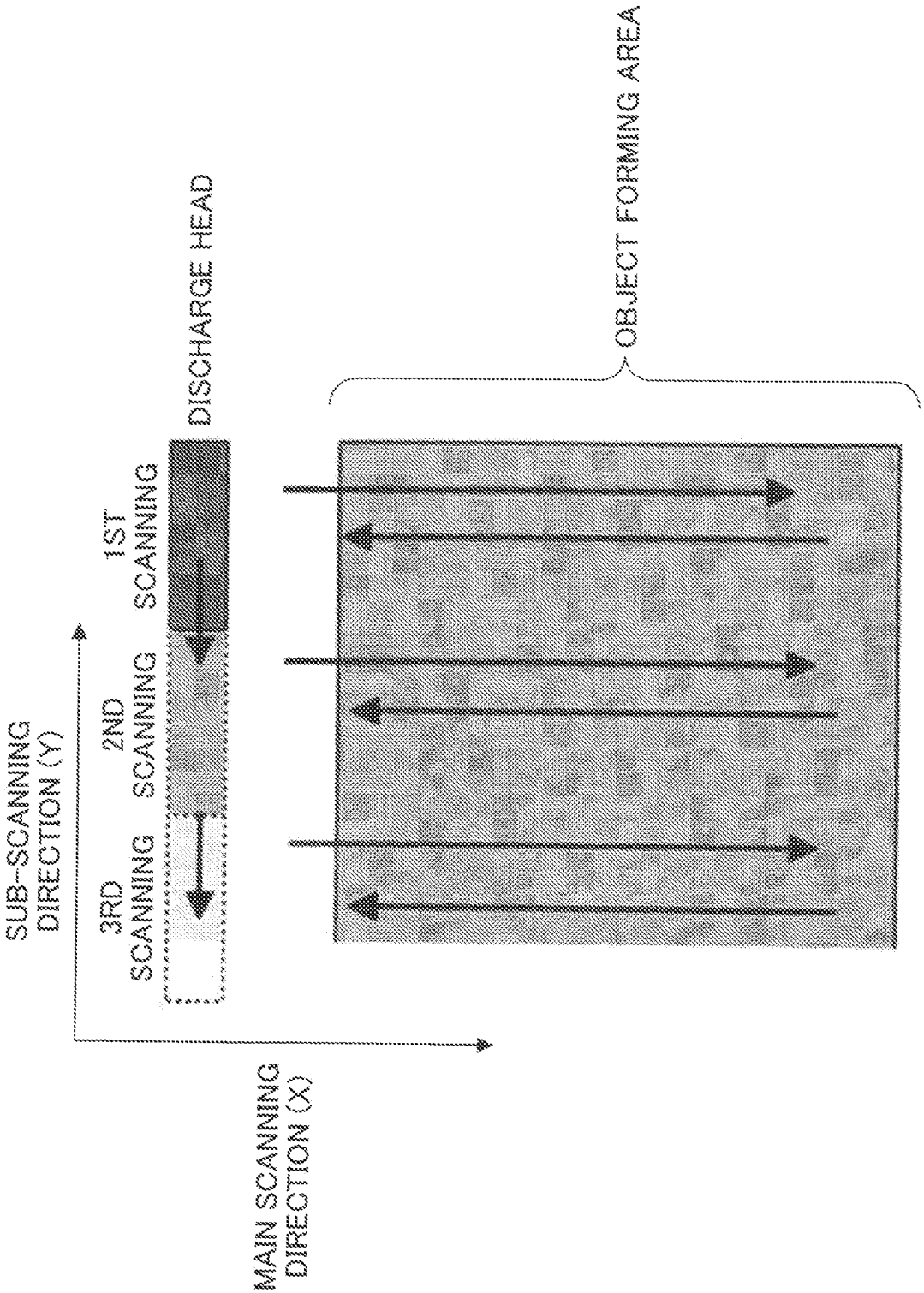
[Fig. 78]


30100
THREE-DIMENSIONAL OBJECT FORMING APPARATUS
30140
STORAGE UNIT
30141
FORWARD-STROKE OBJECT FORMING MATERIAL DISCHARGE AMOUNT DB
30142
RETURN-STROKE OBJECT FORMING MATERIAL DISCHARGE AMOUNT DB
30130
CONTROL UNIT
30131
FORWARD-STROKE OBJECT FORMING MATERIAL DISCHARGE AMOUNT ADJUSTING UNIT
30132
RETURN-STROKE OBJECT FORMING MATERIAL DISCHARGE AMOUNT ADJUSTING UNIT
30110
INPUT UNIT
30120
OUTPUT UNIT

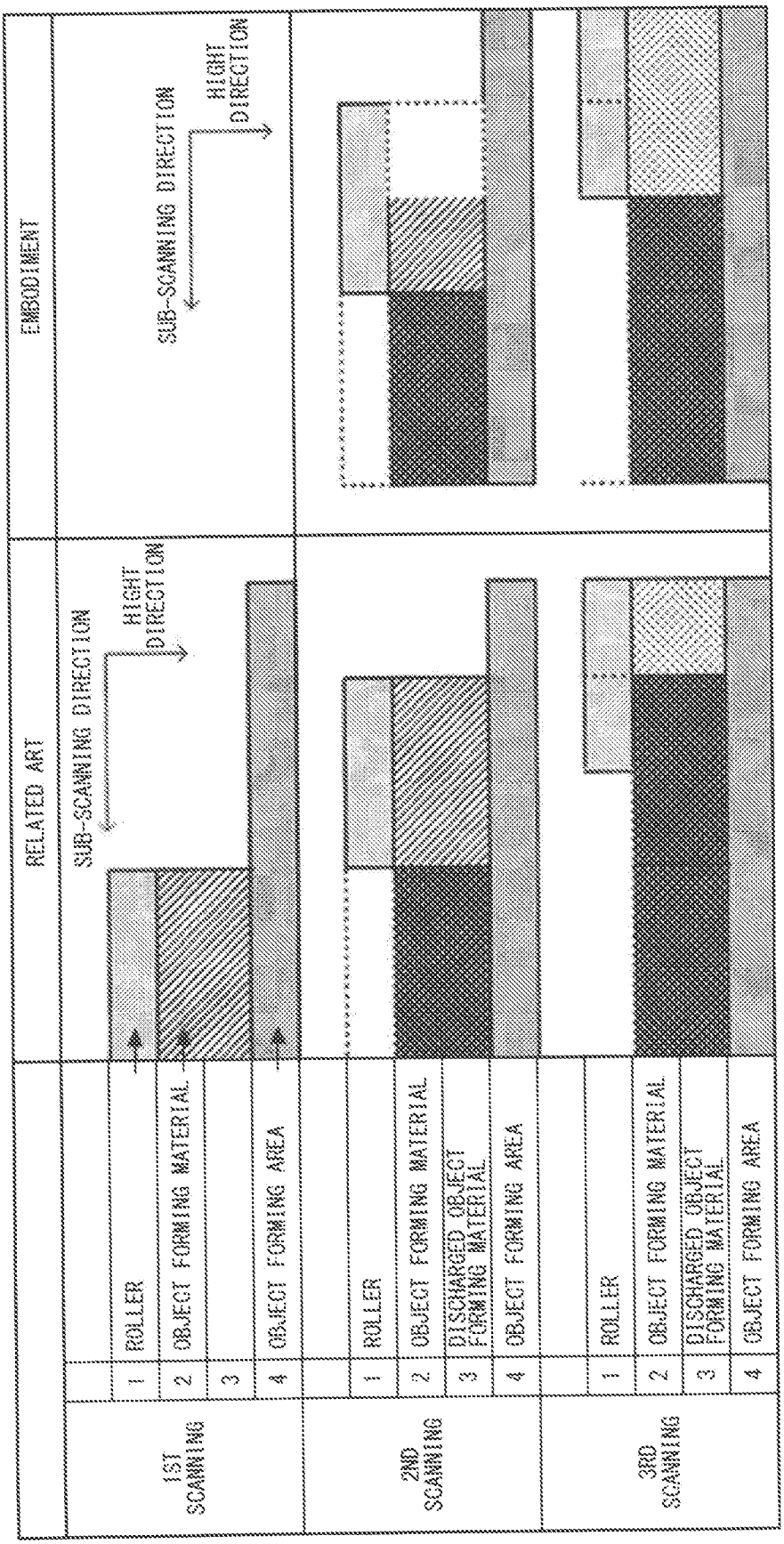
[Fig. 79]


START
S30110
ACQUIRE OBJECT FORMING MATERIAL DISCHARGE AMOUNT A OF OVERLAPPING AREA AT FORWARD STROKE
S30111
ACQUIRE OBJECT FORMING MATERIAL DISCHARGE AMOUNT B OF OVERLAPPING AREA AT RETURN STROKE
S30112
A≧B
NO
END
YES
S30113
ADJUST OBJECT FORMING MATERIAL DISCHARGE AMOUNT AT FORWARD STROKE

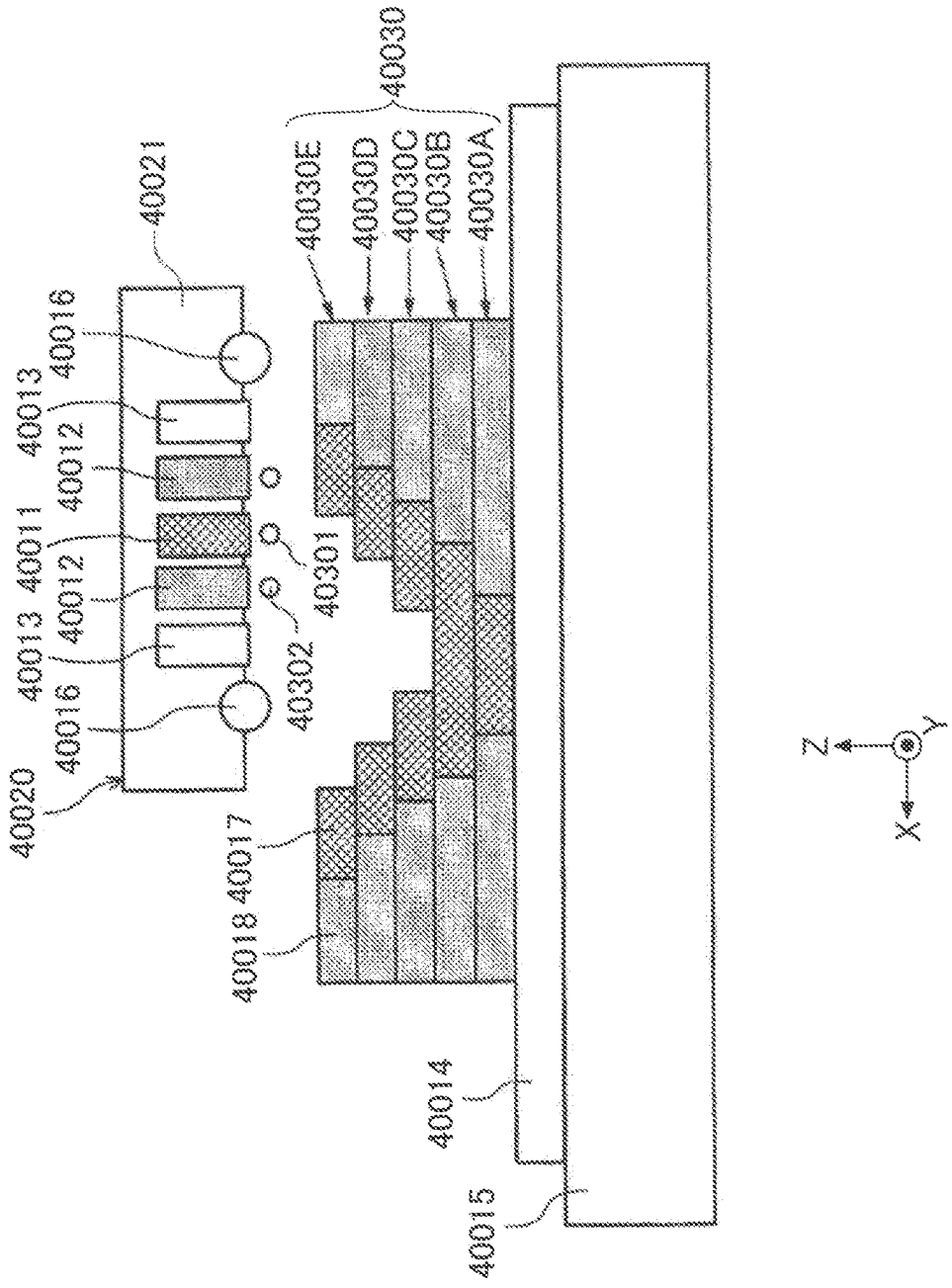
[Fig. 80]


OBJECT FORMING AREA
DISCHARGE HEAD
1ST SCANNING
2ND SCANNING
3RD SCANNING
SUB-SCANNING DIRECTION (Y)
MAIN SCANNING DIRECTION (X)

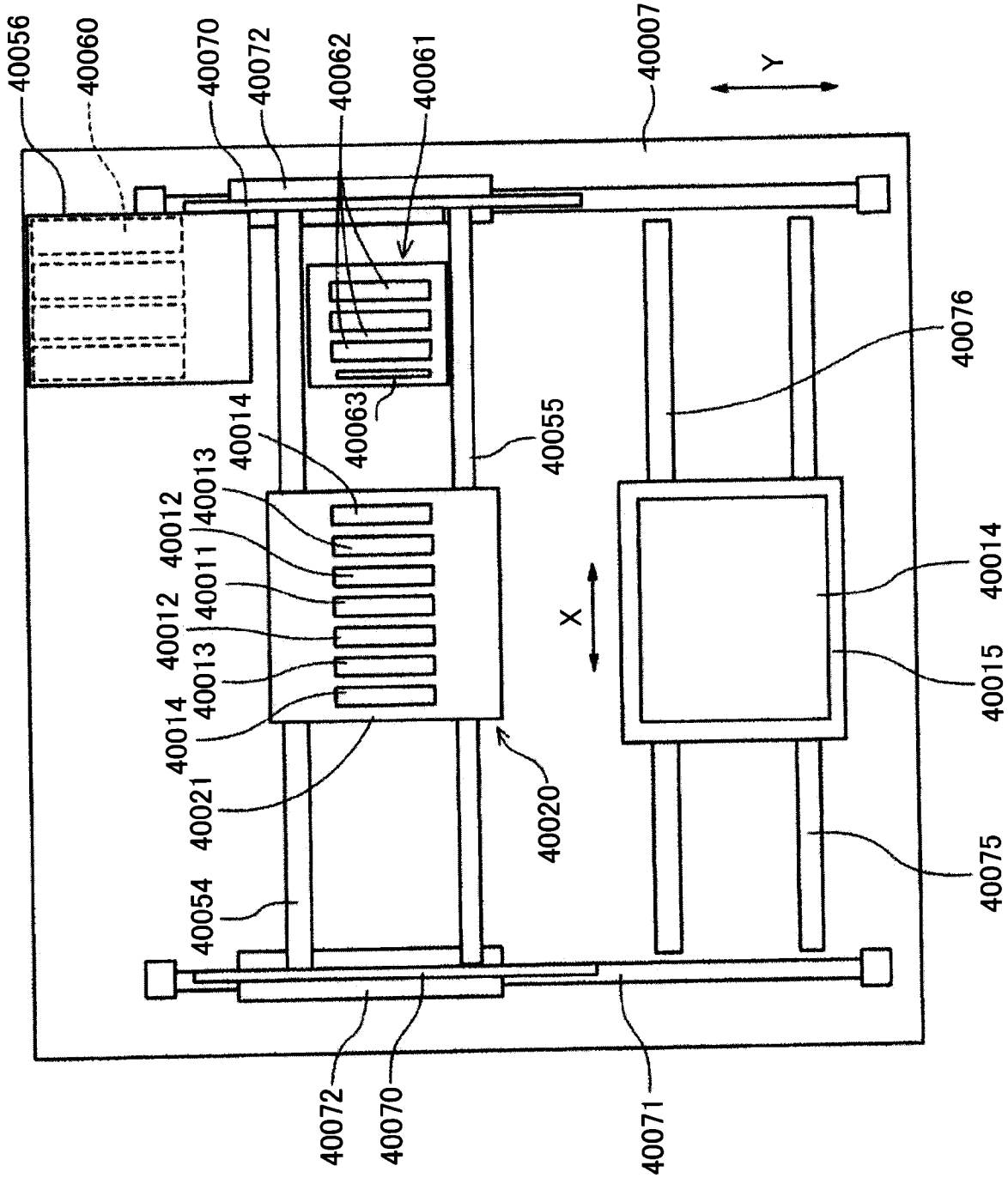
[Fig. 81]


RELATED ART
EMBODIMENT
SUB-SCANNING DIRECTION
RIGHT DIRECTION
SUB-SCANNING DIRECTION
RIGHT DIRECTION
1ST SCANNING
2ND SCANNING
3RD SCANNING
1 ROLLER
2 OBJECT FORMING MATERIAL
3
4 OBJECT FORMING AREA
1 ROLLER
2 OBJECT FORMING MATERIAL
3 DISCHARGED OBJECT FORMING MATERIAL
4 OBJECT FORMING AREA
1 ROLLER
2 OBJECT FORMING MATERIAL
3 DISCHARGED OBJECT FORMING MATERIAL
4 OBJECT FORMING AREA

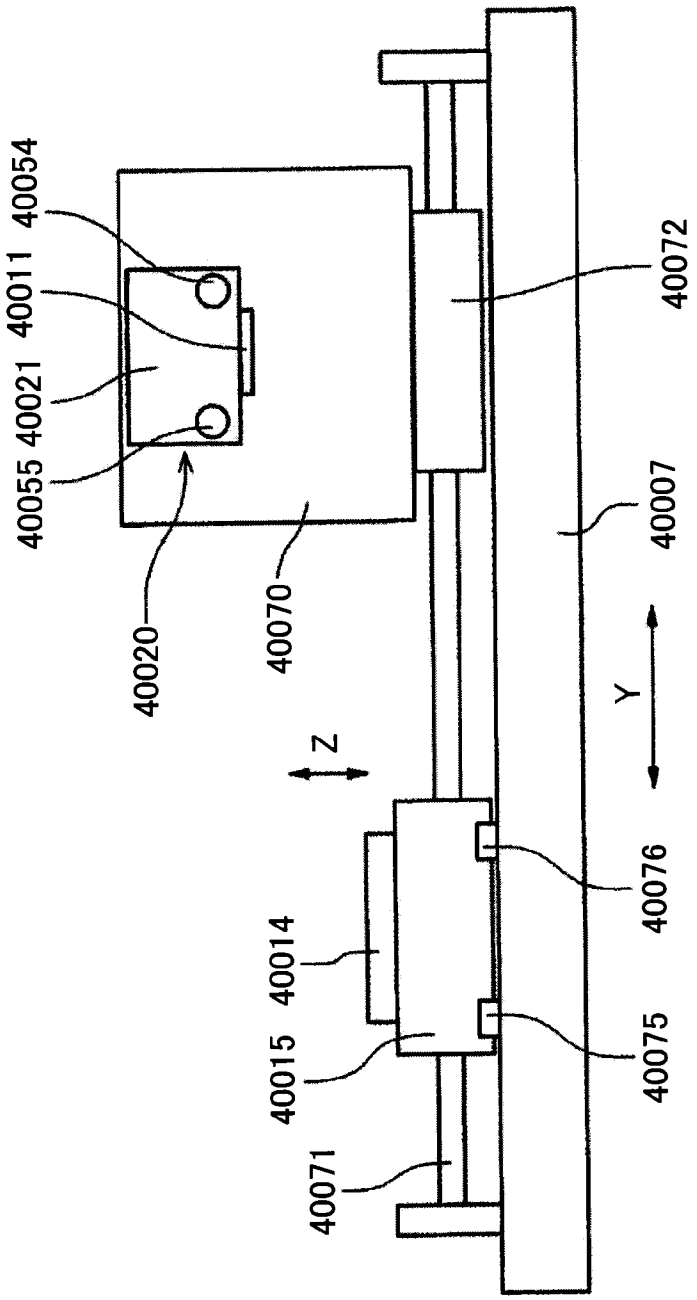
[Fig. 82]


40030
40030E
40030D
40030C
40030B
40030A
40021
40016
40013
40012
40011
40012
40013
40016
40020
40017
40018
40301
40302
40014
40015
Z
Y
X

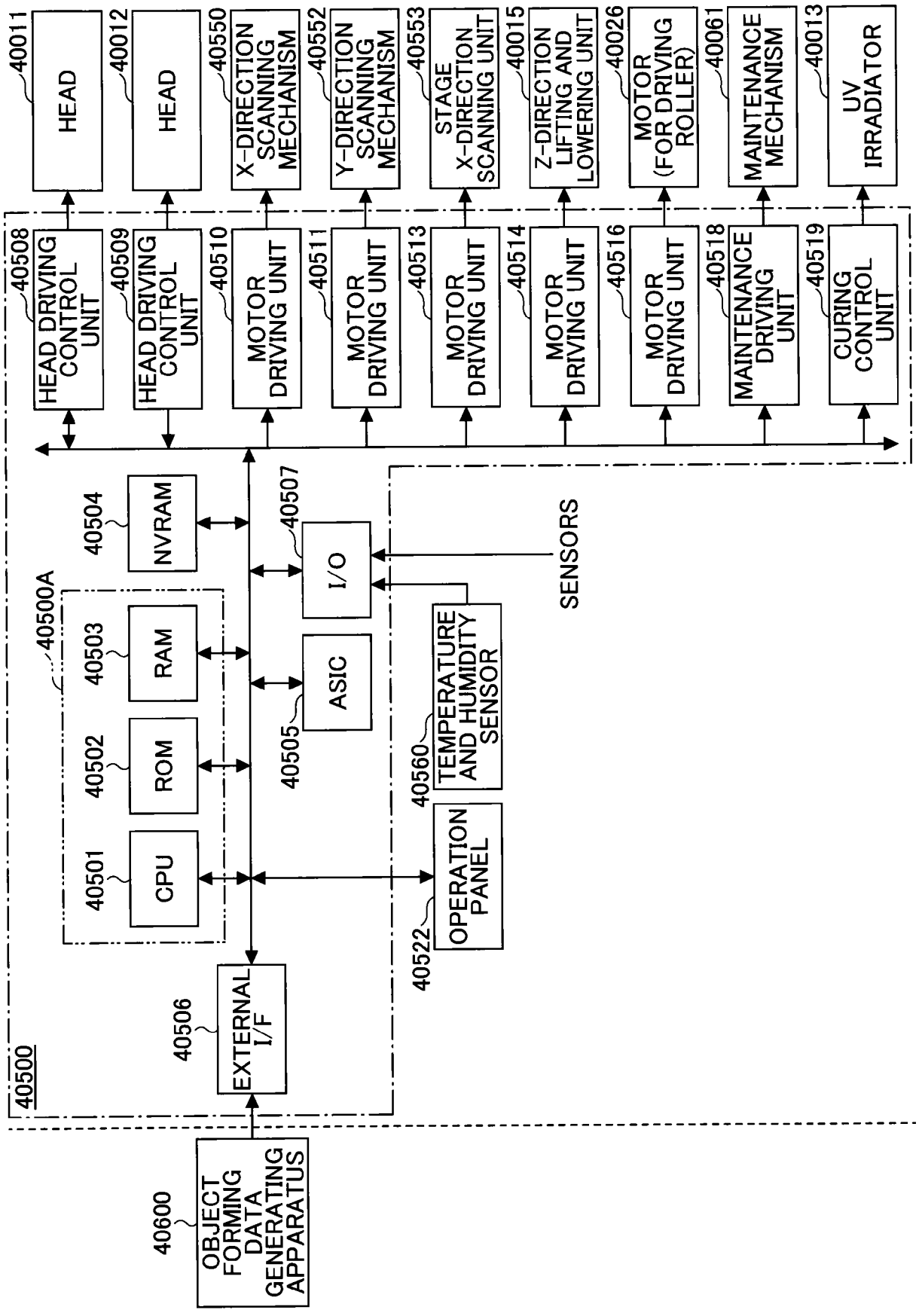
[Fig. 83]


40056
40060
40070
40072
40062
40061
40007
Y
40076
40063
40014
40055
40013
40012
40011
40012
40013
40014
40021
X
40014
40015
40020
40075
40054
40072
40070
40071

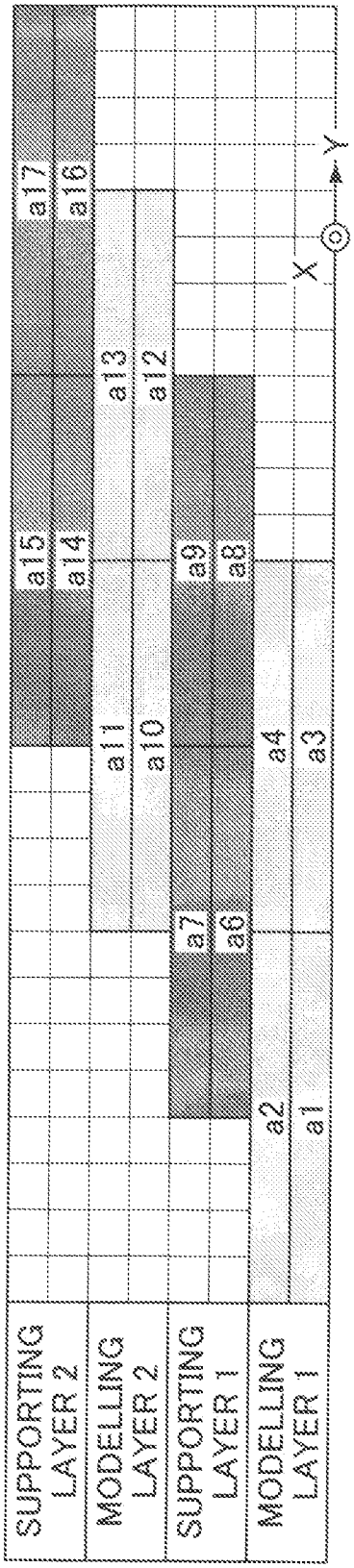
[Fig. 84]


40054
40011
40021
40055
40020
40070
40072
40007
Y
Z
40076
40014
40015
40075
40071

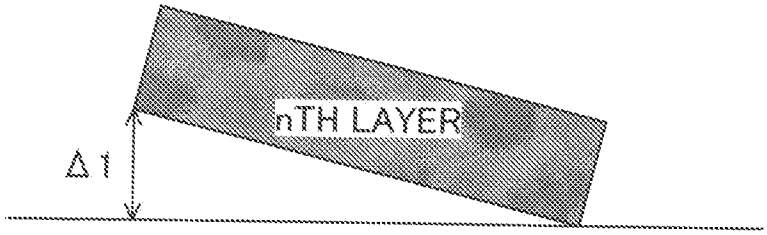
[Fig. 85]


40011
HEAD
40012
HEAD
40550
X-DIRECTION SCANNING MECHANISM
40552
Y-DIRECTION SCANNING MECHANISM
40553
STAGE X-DIRECTION SCANNING UNIT
40015
Z-DIRECTION LIFTING AND LOWERING UNIT
40026
MOTOR (FOR DRIVING ROLLER)
40061
MAINTENANCE MECHANISM
40013
UV IRRADIATOR
40508
HEAD DRIVING CONTROL UNIT
40509
HEAD DRIVING CONTROL UNIT
40510
MOTOR DRIVING UNIT
40511
MOTOR DRIVING UNIT
40513
MOTOR DRIVING UNIT
40514
MOTOR DRIVING UNIT
40516
MOTOR DRIVING UNIT
40518
MAINTENANCE DRIVING UNIT
40519
CURING CONTROL UNIT
40504
NVRAM
40507
I/O
SENSORS
40500A
40503
RAM
ASIC
40502
ROM
40505
40501
CPU
40560
TEMPERATURE AND HUMIDITY SENSOR
OPERATION PANEL
40522
40506
EXTERNAL I/F
40500
40600
OBJECT FORMING DATA GENERATING APPARATUS

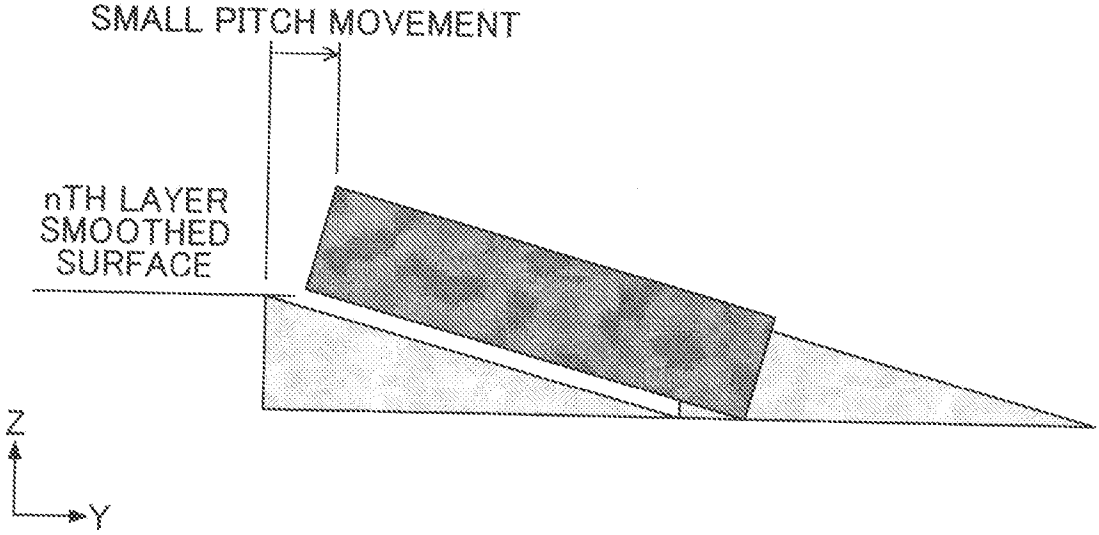
[Fig. 86A]


SUPPORTING LAYER 2
MODELLING LAYER 2
SUPPORTING LAYER 1
MODELLING LAYER 1
a1
a2
a3
a4
a6
a7
a8
a9
a10
a11
a12
a13
a14
a15
a16
a17
X
Y

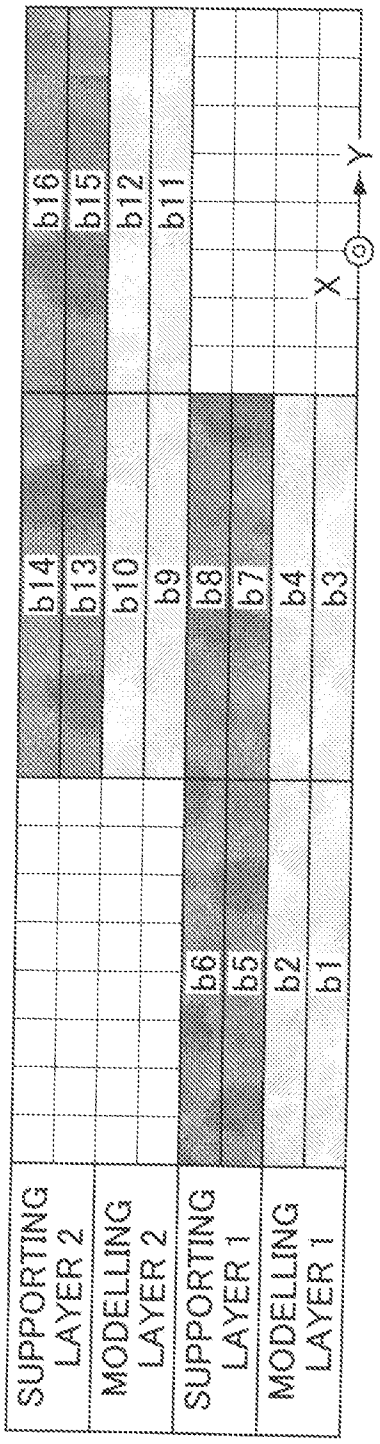
[Fig. 86B]



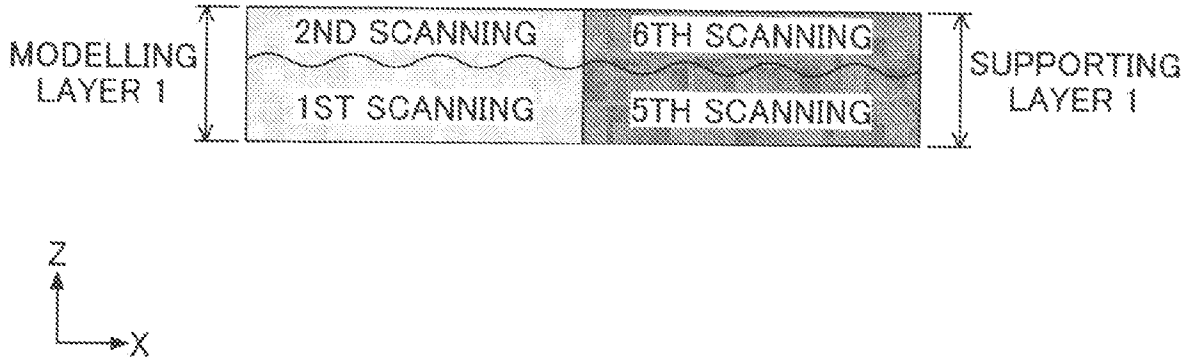
[Fig. 86C]



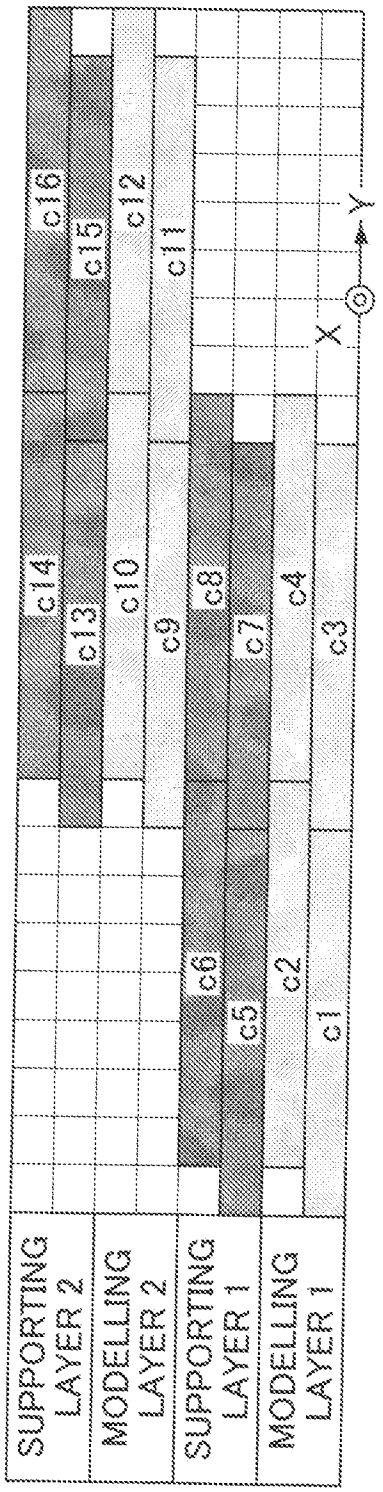
[Fig. 87A]


SUPPORTING LAYER 2
MODELLING LAYER 2
SUPPORTING LAYER 1
MODELLING LAYER 1
b16
b15
b12
b11
b14
b13
b10
b9
b8
b7
b4
b3
b6
b5
b2
b1
X
Y

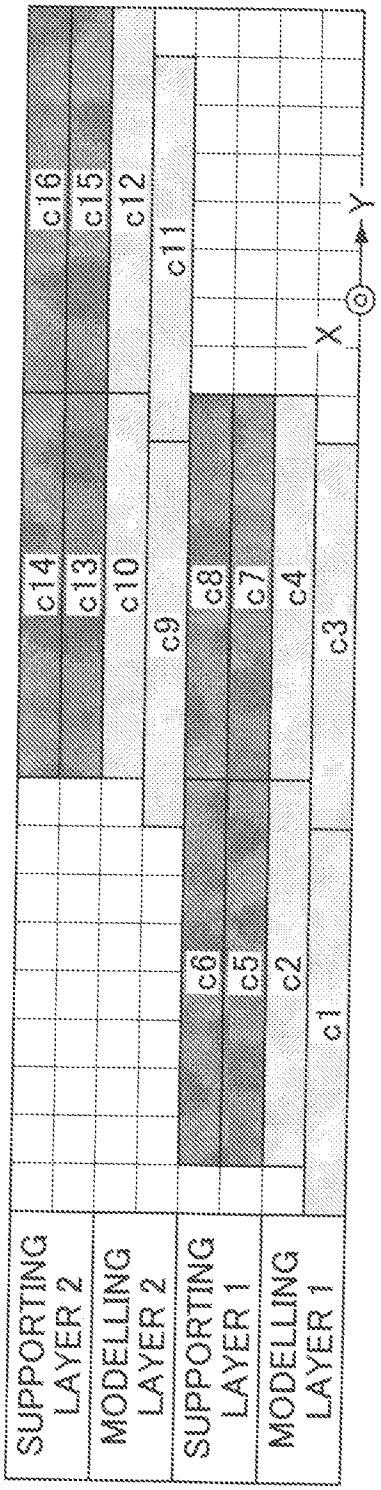
[Fig. 87B]


MODELLING LAYER 1
2ND SCANNING
1ST SCANNING
6TH SCANNING
5TH SCANNING
SUPPORTING LAYER 1
Z
X

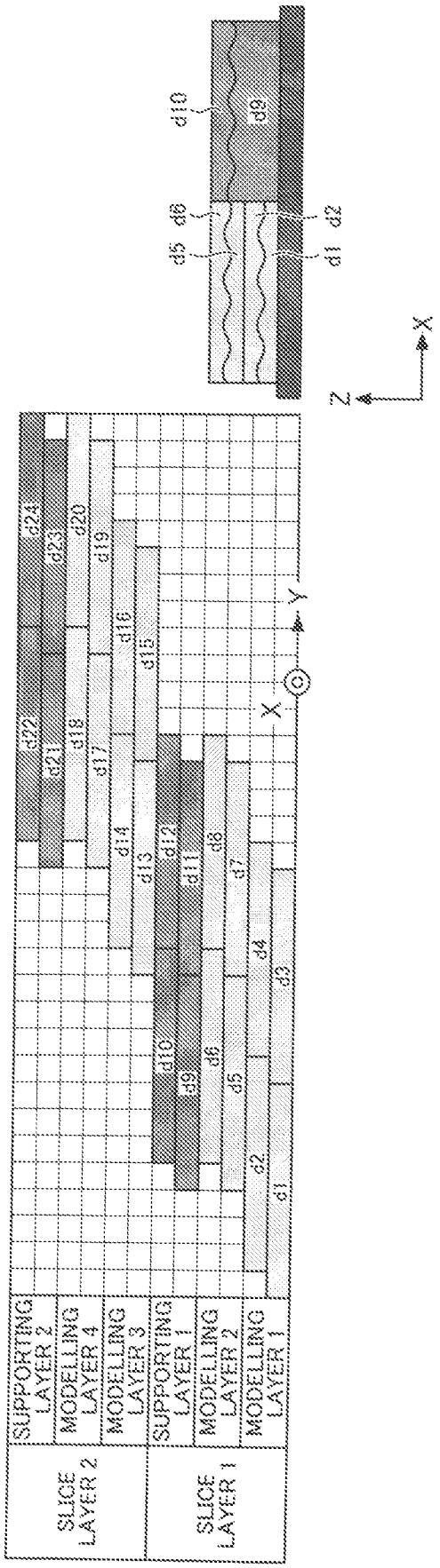
[Fig. 88A]


SUPPORTING LAYER 2
MODELLING LAYER 2
SUPPORTING LAYER 1
MODELLING LAYER 1
c1
c2
c3
c4
c5
c6
c7
c8
c9
c10
c11
c12
c13
c14
c15
c16
X
Y
O

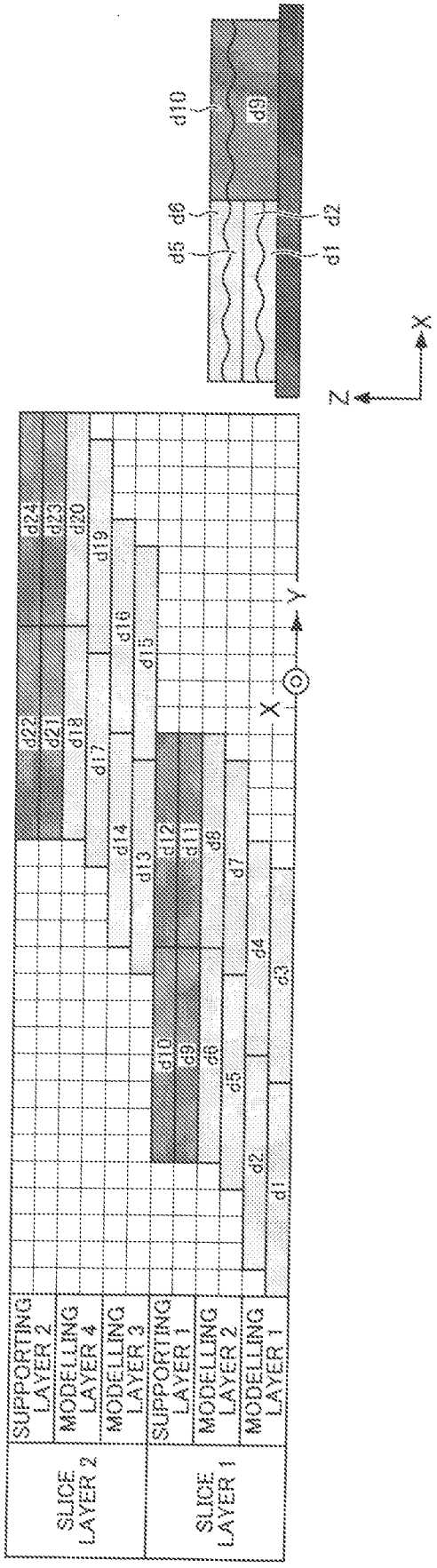
[Fig. 88B]


SUPPORTING LAYER 2
MODELLING LAYER 2
SUPPORTING LAYER 1
MODELLING LAYER 1
c1
c2
c3
c4
c5
c6
c7
c8
c9
c10
c11
c12
c13
c14
c15
c16
X
Y

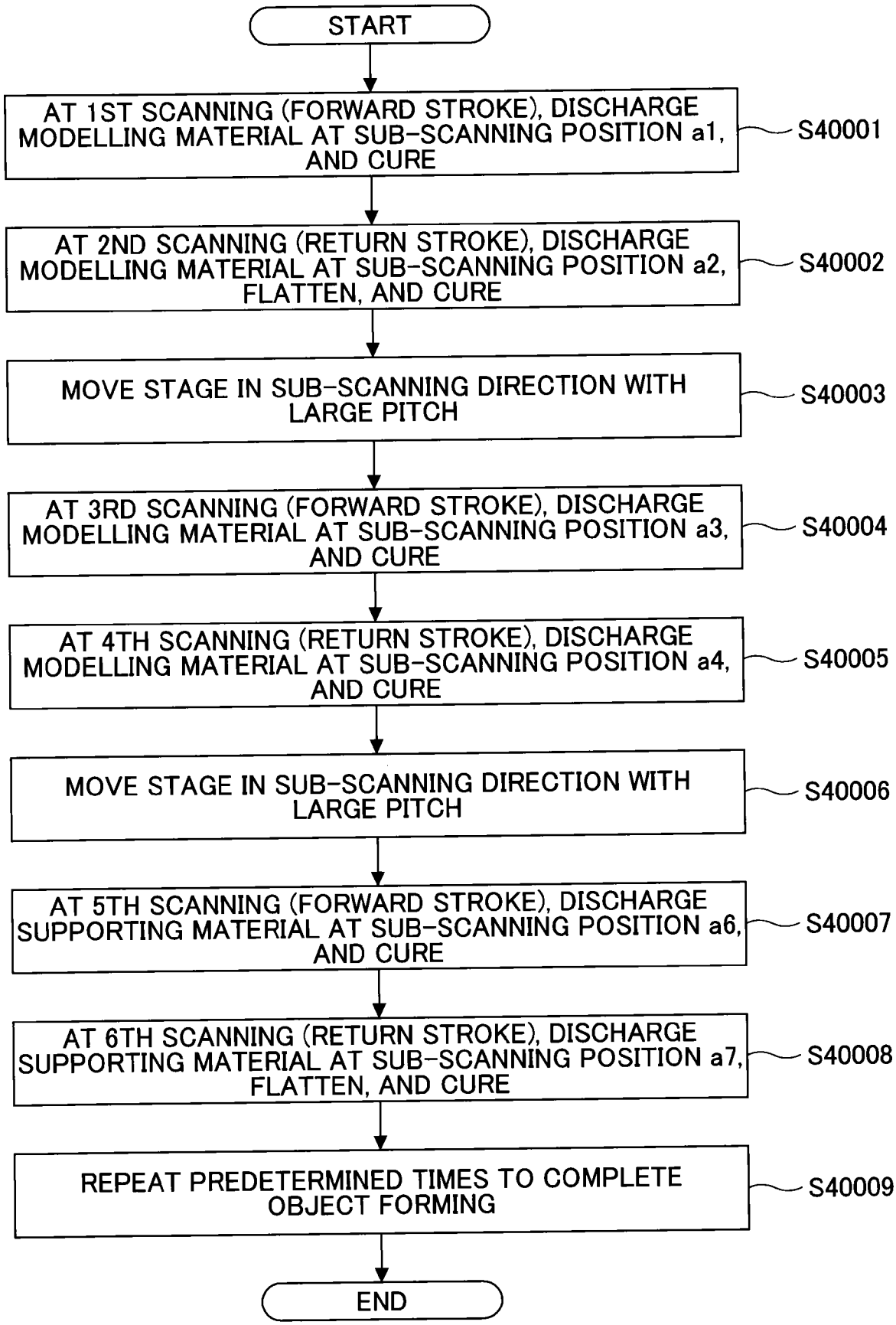
[Fig. 89A]


SLICE LAYER 2
SLICE LAYER 1
SUPPORTING LAYER 2
MODELLING LAYER 4
MODELLING LAYER 3
SUPPORTING LAYER 1
MODELLING LAYER 2
MODELLING LAYER 1
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
d20
d21
d22
d23
d24
X
Y
Z

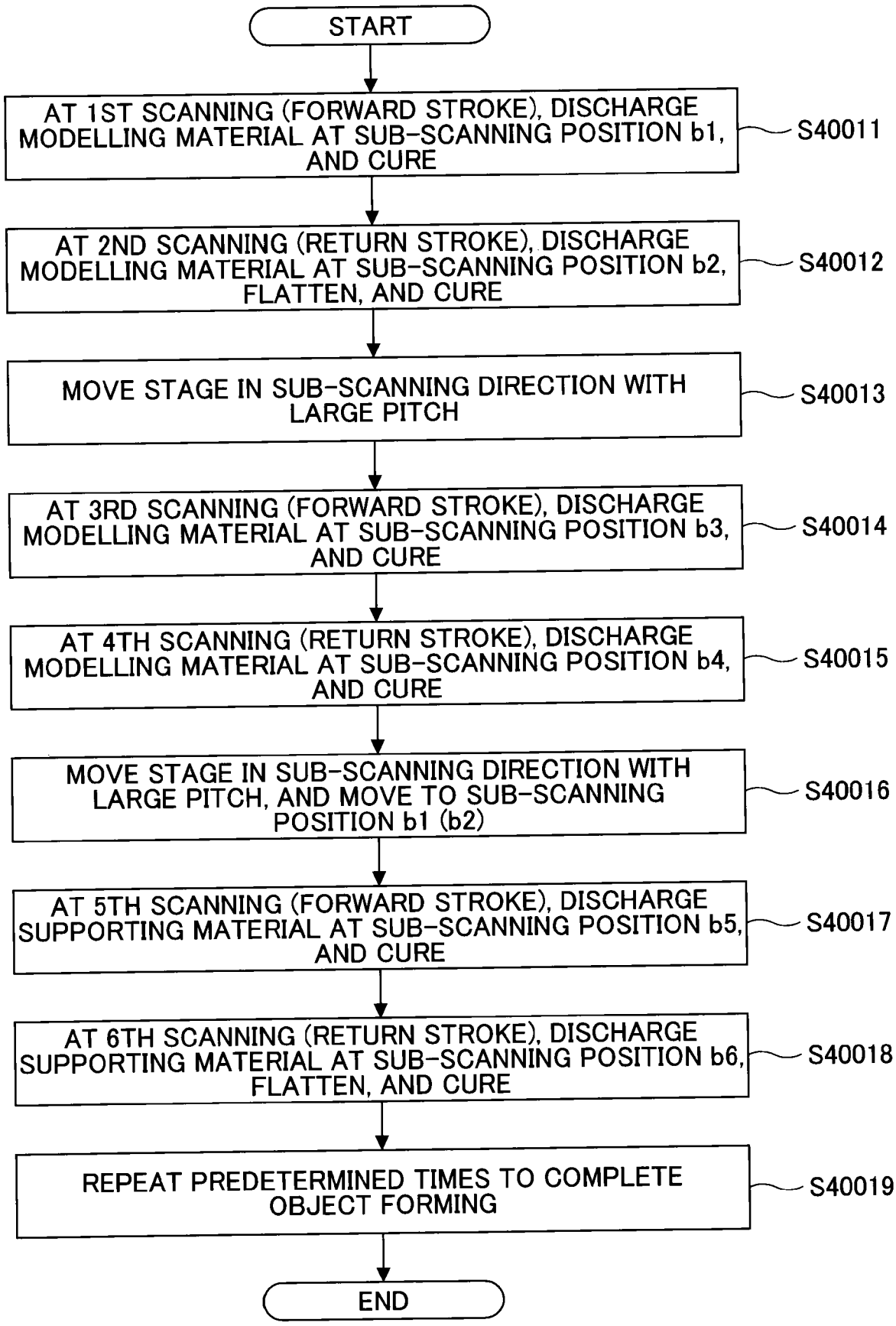
[Fig. 89B]


SLICE LAYER 2
SLICE LAYER 1
SUPPORTING LAYER 2
MODELLING LAYER 4
MODELLING LAYER 3
SUPPORTING LAYER 1
MODELLING LAYER 2
MODELLING LAYER 1
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
d20
d21
d22
d23
d24
X
Y
Z

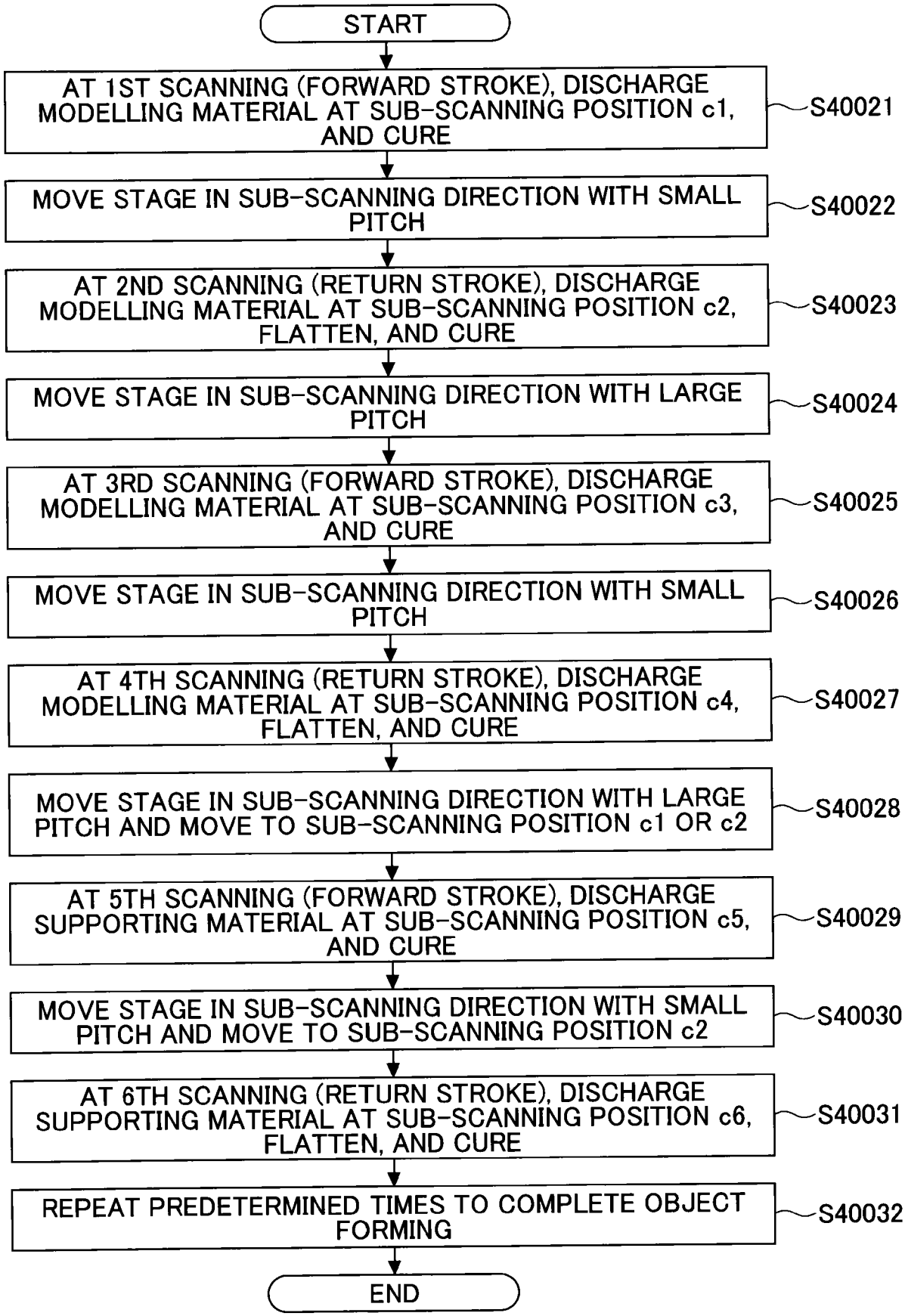
[Fig. 90]


START
AT 1ST SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION a1, AND CURE
S40001
AT 2ND SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION a2, FLATTEN, AND CURE
S40002
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40003
AT 3RD SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION a3, AND CURE
S40004
AT 4TH SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION a4, AND CURE
S40005
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40006
AT 5TH SCANNING (FORWARD STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION a6, AND CURE
S40007
AT 6TH SCANNING (RETURN STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION a7, FLATTEN, AND CURE
S40008
REPEAT PREDETERMINED TIMES TO COMPLETE OBJECT FORMING
S40009
END

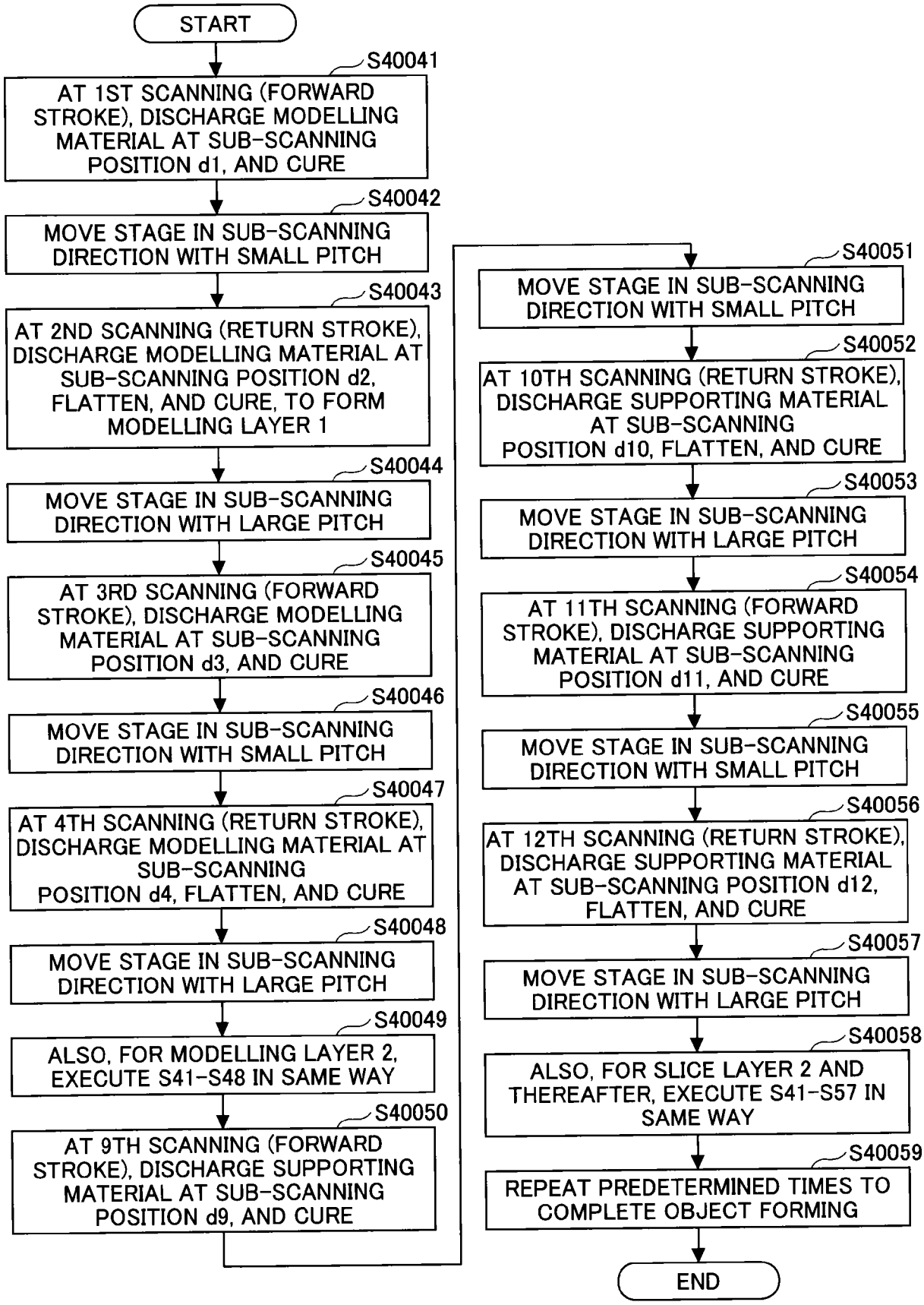
[Fig. 91]


START
AT 1ST SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION b1, AND CURE
S40011
AT 2ND SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION b2, FLATTEN, AND CURE
S40012
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40013
AT 3RD SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION b3, AND CURE
S40014
AT 4TH SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION b4, AND CURE
S40015
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH, AND MOVE TO SUB-SCANNING POSITION b1 (b2)
S40016
AT 5TH SCANNING (FORWARD STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION b5, AND CURE
S40017
AT 6TH SCANNING (RETURN STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION b6, FLATTEN, AND CURE
S40018
REPEAT PREDETERMINED TIMES TO COMPLETE OBJECT FORMING
S40019
END

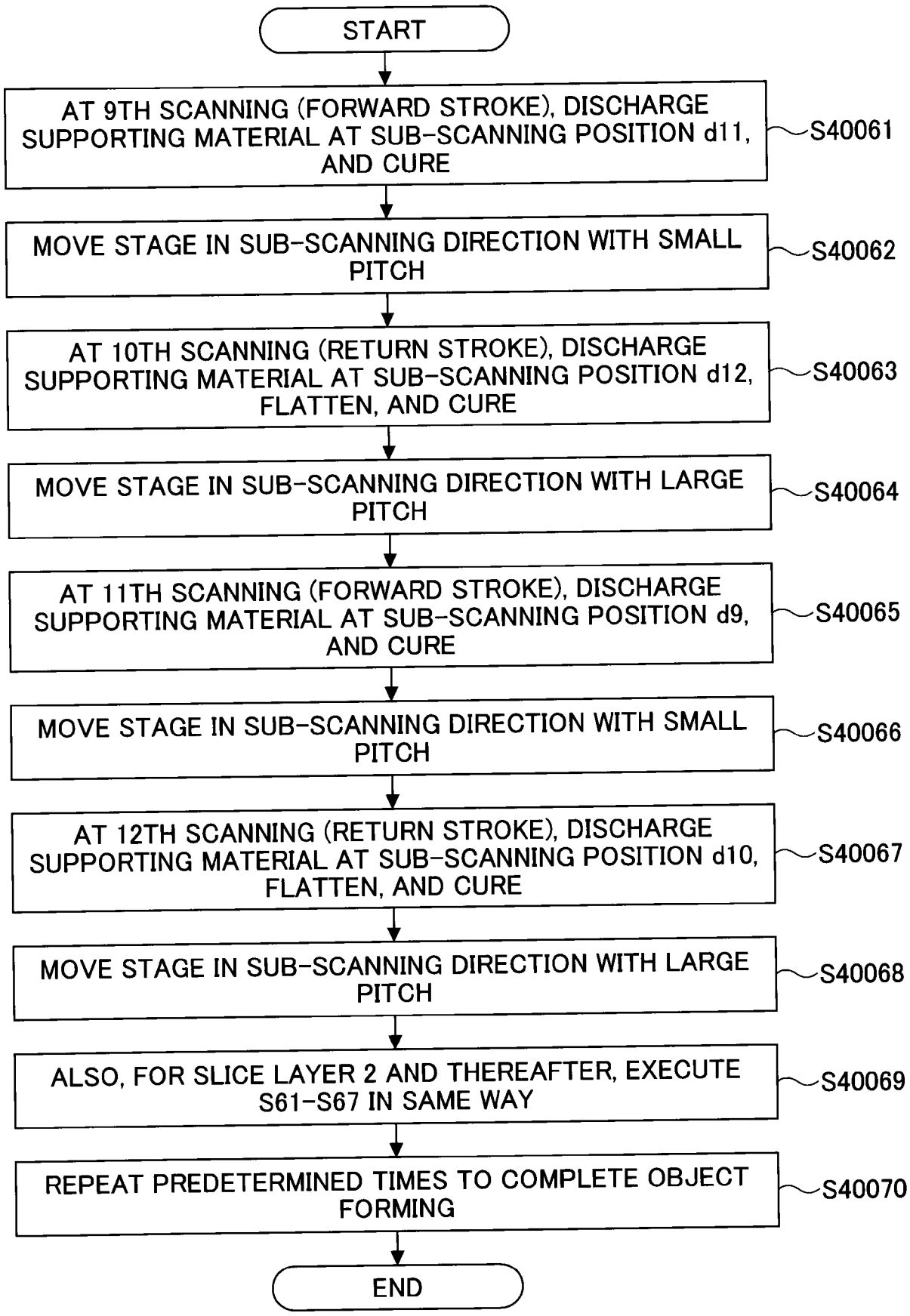
[Fig. 92]


START
AT 1ST SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION c1, AND CURE
S40021
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40022
AT 2ND SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION c2, FLATTEN, AND CURE
S40023
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40024
AT 3RD SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION c3, AND CURE
S40025
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40026
AT 4TH SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION c4, FLATTEN, AND CURE
S40027
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH AND MOVE TO SUB-SCANNING POSITION c1 OR c2
S40028
AT 5TH SCANNING (FORWARD STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION c5, AND CURE
S40029
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH AND MOVE TO SUB-SCANNING POSITION c2
S40030
AT 6TH SCANNING (RETURN STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION c6, FLATTEN, AND CURE
S40031
REPEAT PREDETERMINED TIMES TO COMPLETE OBJECT FORMING
S40032
END

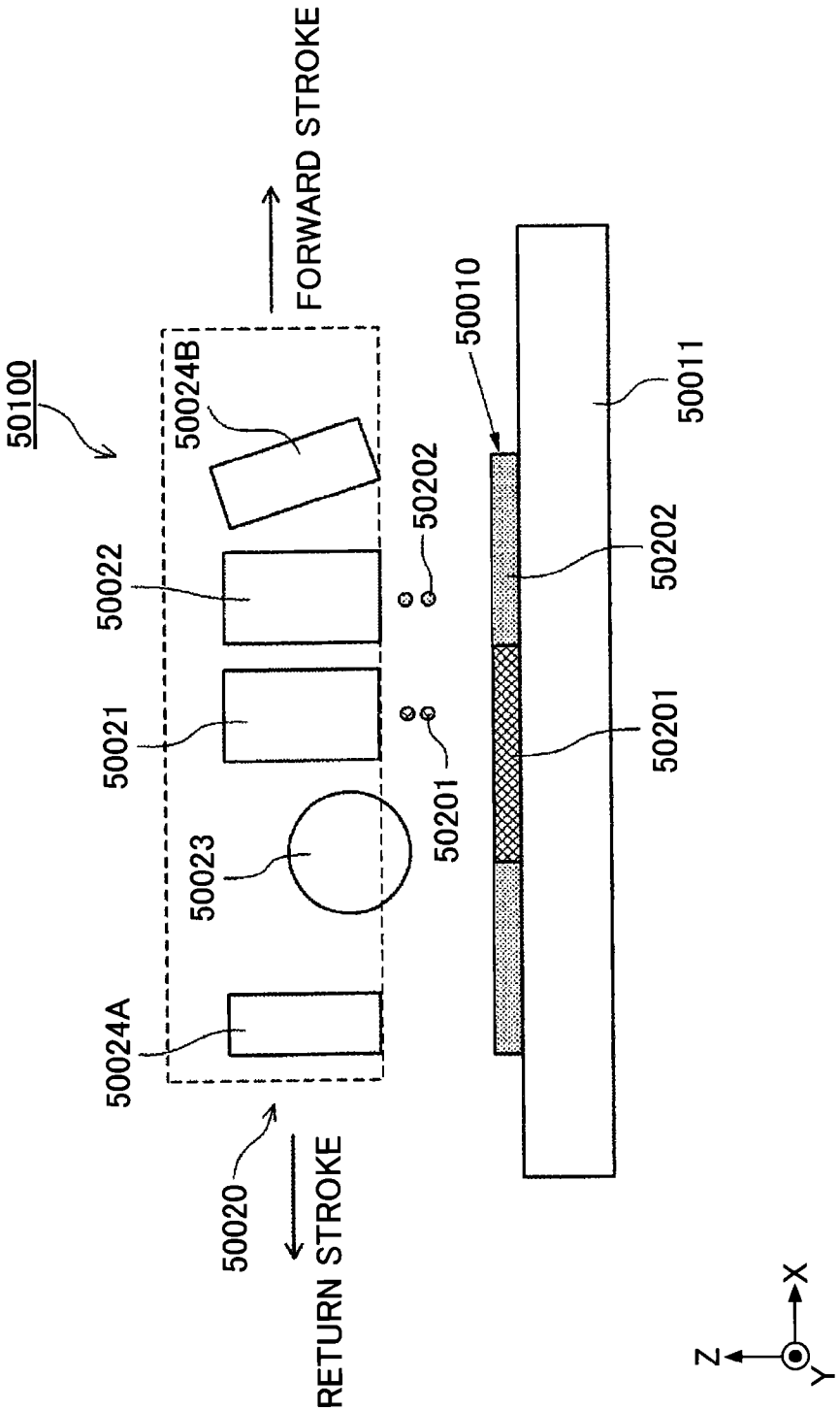
[Fig. 93]


START
S40041
AT 1ST SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION d1, AND CURE
S40042
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40043
AT 2ND SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION d2, FLATTEN, AND CURE, TO FORM MODELLING LAYER 1
S40044
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40045
AT 3RD SCANNING (FORWARD STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION d3, AND CURE
S40046
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40047
AT 4TH SCANNING (RETURN STROKE), DISCHARGE MODELLING MATERIAL AT SUB-SCANNING POSITION d4, FLATTEN, AND CURE
S40048
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40049
ALSO, FOR MODELLING LAYER 2, EXECUTE S41-S48 IN SAME WAY
S40050
AT 9TH SCANNING (FORWARD STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d9, AND CURE
S40051
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40052
AT 10TH SCANNING (RETURN STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d10, FLATTEN, AND CURE
S40053
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40054
AT 11TH SCANNING (FORWARD STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d11, AND CURE
S40055
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40056
AT 12TH SCANNING (RETURN STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d12, FLATTEN, AND CURE
S40057
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40058
ALSO, FOR SLICE LAYER 2 AND THEREAFTER, EXECUTE S41-S57 IN SAME WAY
S40059
REPEAT PREDETERMINED TIMES TO COMPLETE OBJECT FORMING
END

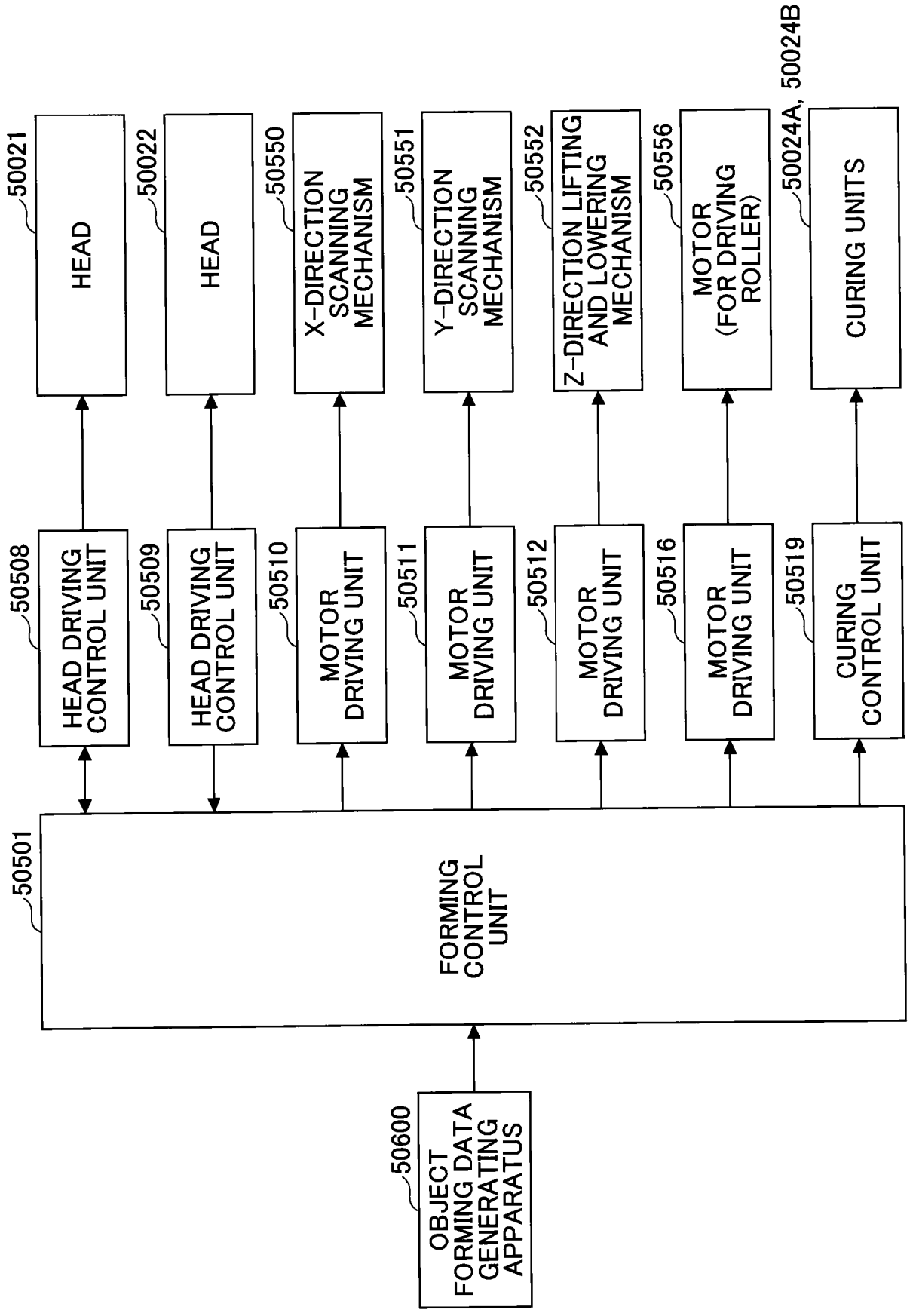
[Fig. 94]


START
AT 9TH SCANNING (FORWARD STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d11, AND CURE
S40061
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40062
AT 10TH SCANNING (RETURN STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d12, FLATTEN, AND CURE
S40063
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40064
AT 11TH SCANNING (FORWARD STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d9, AND CURE
S40065
MOVE STAGE IN SUB-SCANNING DIRECTION WITH SMALL PITCH
S40066
AT 12TH SCANNING (RETURN STROKE), DISCHARGE SUPPORTING MATERIAL AT SUB-SCANNING POSITION d10, FLATTEN, AND CURE
S40067
MOVE STAGE IN SUB-SCANNING DIRECTION WITH LARGE PITCH
S40068
ALSO, FOR SLICE LAYER 2 AND THEREAFTER, EXECUTE S61-S67 IN SAME WAY
S40069
REPEAT PREDETERMINED TIMES TO COMPLETE OBJECT FORMING
S40070
END

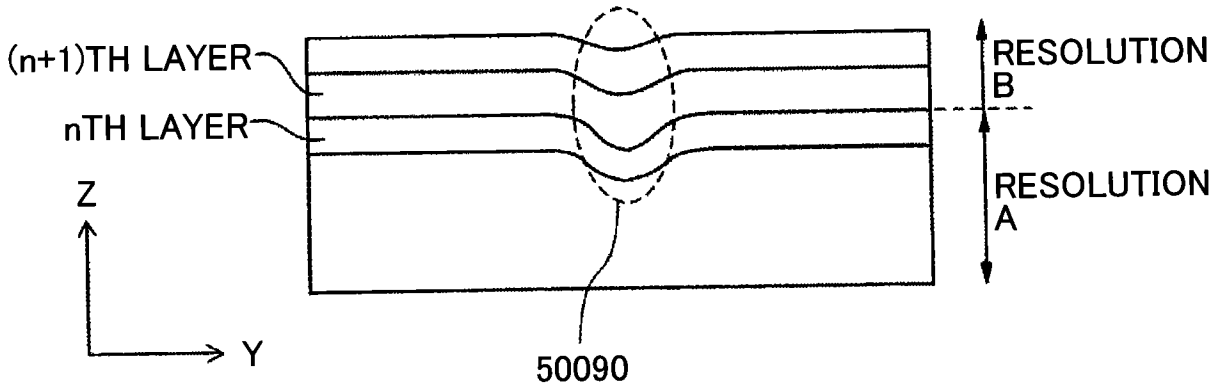
[Fig. 95]


50100
FORWARD STROKE
50024B
50022
50021
50023
50024A
50020
RETURN STROKE
50202
50201
50010
50011
50202
50201
X
Z
Y

[Fig. 96]


50600
OBJECT FORMING DATA GENERATING APPARATUS
50501
FORMING CONTROL UNIT
50508
HEAD DRIVING CONTROL UNIT
50509
HEAD DRIVING CONTROL UNIT
50510
MOTOR DRIVING UNIT
50511
MOTOR DRIVING UNIT
50512
MOTOR DRIVING UNIT
50516
MOTOR DRIVING UNIT
50519
CURING CONTROL UNIT
50021
HEAD
50022
HEAD
50550
X-DIRECTION SCANNING MECHANISM
50551
Y-DIRECTION SCANNING MECHANISM
50552
Z-DIRECTION LIFTING AND LOWERING MECHANISM
50556
MOTOR (FOR DRIVING ROLLER)
50024A, 50024B
CURING UNITS

[Fig. 97]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2020/011591

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C64/112 B29C64/336 B33Y10/00 B33Y30/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B29C B33Y

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2018 144370 A (RICOH CO LTD) 20 September 2018 (2018-09-20) figures 5-14 paragraph [0044] - paragraph [0052] paragraph [0099] - paragraph [0114] -----	1,2,5,6, 27,49 3,4
Y	EP 2 636 510 A1 (KEYENCE CO LTD [JP]) 11 September 2013 (2013-09-11) figures 1, 11-15 paragraph [0053] - paragraph [0071] -----	3,4
A	US 2016/263826 A1 (SUZUKI HIDEYUKI [JP] ET AL) 15 September 2016 (2016-09-15) the whole document -----	1-6

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 June 2020	28/08/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Sacepe, Nicolas

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/011591

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-6, 27, 49

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 27, 49

   A three dimensional apparatus, method and program to form a three dimensional object having a modeling material and support material.

   ---

2. claims: 7-12, 28, 50

   A three dimensional apparatus, method and program to flat the last layer.

   ---

3. claims: 13, 29-35, 51

   A three dimensional apparatus, method and program to flat a three dimensional oject.

   ---

4. claims: 14, 36-46, 52

   A three dimensional apparatus, method and program to form a three dimensional object having a overlapping of a main scanning area of a head.

   ---

5. claims: 15-19, 47, 53

   A three dimensional apparatus, method and program to form a three dimensional object wherein the positions of the head with respect to a sub-scanning direction are different.

   ---

6. claims: 20-26, 48, 54

   A three dimensional apparatus, method and program to form a three dimensional object having different resolution.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2020/011591

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