(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 January 2016 (21.01.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/010536 A1

(51) International Patent Classification:
G06F 9/06 (2006.01) *B29C 47/08* (2006.01)

(21) International Application Number:
PCT/US2014/046892

(22) International Filing Date:
16 July 2014 (16.07.2014)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

[Continued on next page]

(54) **Title**: CONSOLIDATING A BUILD MATERIAL SUBSTRATE FOR ADDITIVE MANUFACTURING

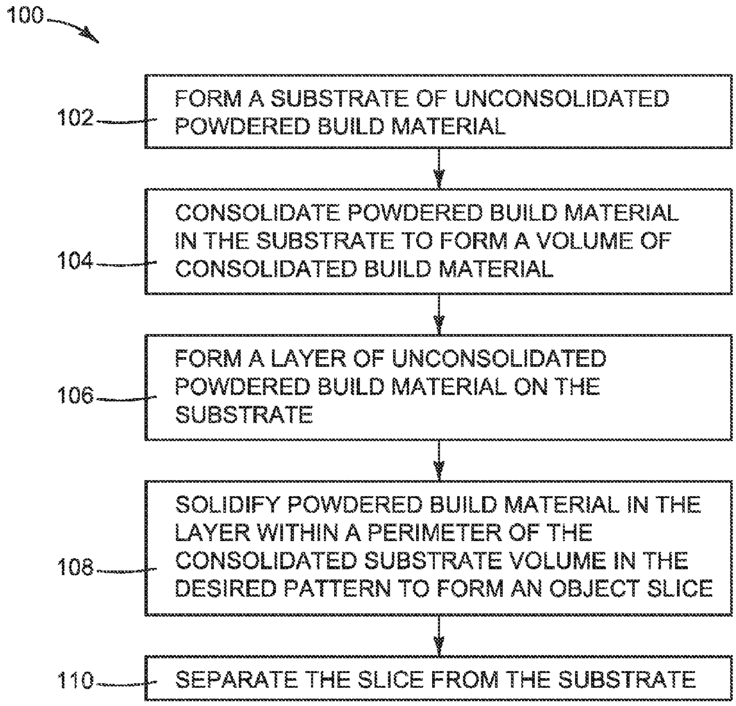


FIG.7

(57) **Abstract**: In one example, a non-transitory processor readable medium with instructions thereon that when executed cause an additive manufacturing machine to consolidate powdered build material in a volume of a substrate of powdered build material to form a consolidated volume of substrate.

WO 2016/010536 A1

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

CONSOLIDATING A BUILD MATERIAL SUBSTRATE FOR ADDITIVE MANUFACTURING

BACKGROUND

[0001] Additive manufacturing machines produce 3D (three-dimensional) objects by building up layers of material. Some additive manufacturing machines are commonly referred to as "3D printers" because they often use inkjet or other printing technology to apply some of the manufacturing materials. 3D printers and other additive manufacturing machines make it possible to convert a CAD (computer aided design) model or other digital representation of an object directly into the physical object.

DRAWINGS

[0002] Figs. 1 and 2 are plan and section views, respectively, illustrating an in-process structure for two objects being manufactured using one example of a build material substrate.

[0003] Figs. 3 and 4 show one example of the finished objects from the in-process structure illustrated in Figs. 1 and 2.

[0004] Figs. 5 and 6 are plan views illustrating in-process structures for two objects being manufactured using other examples of a build material substrate.

[0005] Fig. 7 is a flow diagram illustrating one example of an additive manufacturing process.

[0006] Figs. 8-12 are cross sections illustrating one example of an object being manufactured with the process of Fig. 7.

[0007] Fig. 13 is a flow diagram illustrating one example of consolidating substrate material in the process shown in Fig. 7.

[0008] Fig. 14 is a flow diagram illustrating another example of consolidating substrate build material in the process shown in in Fig. 7.

[0009] Fig. 15 is a flow diagram illustrating one example of solidifying build material in the process shown in Fig. 7.

[0010] Fig. 16 is a block diagram illustrating one example of a processor readable medium with instructions to form a build material substrate during the manufacture of a 3D object, using the process of Fig. 7 for example, such as might be used with the additive manufacturing machine of Fig. 17 or with the system of Fig. 18.

[0011] Fig. 17 is a block diagram illustrating one example of an additive manufacturing machine implementing a controller with instructions to form a build material substrate, such as the one shown in Figs. 1 and 2, during manufacture of a 3D object.

[0012] Fig. 18 is a block diagram illustrating one example of an additive manufacturing system implementing a CAD computer program product with instructions to form a build material substrate, such as the one shown in Figs. 1 and 2, during manufacture of a 3D object.

[0013] The same part numbers designate the same or similar parts throughout the figures.

DESCRIPTION

[0014] Additive manufacturing machines make a 3D object through the solidification of one or more layers of a build material. Additive manufacturing machines make objects based on data in a 3D model of an object created, for example, with a CAD computer program product. The model data is processed into slices each defining that part of a layer or layers of build material to be solidified.

[0015] In some additive manufacturing processes thermal bonding is used to solidify a powdered build material. The powdered build material substrate, commonly referred to as a "powder bed", may be held at an elevated temperature to limit differential shrinkage of the edge of the first slices (formed in the first layers of build material) so that each slice stays flat during solidification. Heating the substrate increases power consumption and cost, and can alter the characteristics of the powder sufficient to render otherwise unused powder unfit for recycling back into the manufacturing process. In a thermal bonding process that uses nylon 12 powder for the build material, for example, it may be necessary to heat the powder substrate to as high as 150°C to keep the edges of the object flat. Testing indicates that heating nylon 12 powder to temperatures above about 120° may make the powder unfit for reuse.

[0016] A new process has been developed to help stabilize the powdered build material substrate at a lower temperature. In one example of the new process, powdered build material in the substrate is consolidated before layering the object slices. The first layer of powdered build material is formed on the substrate. Build material in the first layer within a perimeter of the consolidated volume of substrate is solidified in the desired pattern to form the first slice of the object. The consolidated volume of substrate underlying the powder in the slice pattern during solidification provides a more stable base compared to an unconsolidated substrate.

[0017] Substrate may be consolidated, for example, by heating build material in the substrate to a temperature at least as high as the boiling point of a liquid binder but lower than a damaging temperature, and then applying the liquid binder to the heated volume of substrate. For example, a nylon 12 powdered build material heated to only about 100°C and treated with a latex ink for the binder generates sufficient consolidation of the treated powder for a more stable base compared to unconsolidated nylon 12 powder. While the precise stabilization mechanism in the powder is not known, the nylon 12 powder exhibits more adhesion after water evaporates from the ink compared to untreated powder. The treated powder is dry but not as fine grained as untreated powder. The untreated nylon 12 powder is not damaged by the lower temperature and, thus, may be recycled for reuse.

[0018] A processor readable medium with instructions for consolidating the powdered build material substrate during an additive manufacturing process may be implemented, for example, in a CAD computer program product, in an object model processor, or in the controller for the additive manufacturing machine.

[0019] As used in this document: a "binder" means a substance that consolidates or helps consolidate a powdered build material; a "liquid binder" means a binder in which the substance that consolidates or helps consolidate a powdered build material is liquid and/or the substance is carried in a liquid; a "coalescing agent" means a substance that causes or helps cause a build material to coalesce or solidify or to both coalesce and solidify; a "coalescence modifier agent" means a substance that modifies the effect of a coalescing agent; "consolidate" means to make stronger or more stable; "powder" means a dry substance made up of very small pieces of something; and a "slice" means one or more slices of a multi-slice object or the object itself for a single slice object.

[0020] Figs. 1 and 2 are plan and section views, respectively, illustrating a first object 10 and a second object 12 being manufactured using one example of a consolidated substrate volume 14. The finished objects 10 and 12 are shown in Figs. 3 and 4. In this example, first object 10 is a single slice star and second object 12 is a three slice disc. Referring to Figs. 1 and 2, an in-process structure 16 is supported on a platform or other support 18 in an additive manufacturing machine (not shown). Structure 16 includes a substrate 20 of build material on platform 18. Substrate 20 includes an unconsolidated volume 22 of powdered build material and a consolidated volume 14 of build material formed from unconsolidated powdered build material.

[0021] Star 10 is formed on substrate 20 in a first layer 24 of powdered build material that has been solidified in the shape of star 10. Disc 12 is formed on substrate 20 in first, second and thirds layers 24, 26, 28 of powder build material that have been successively solidified in the shape of disc 12. Any suitable powdered build material may be used, including for example metals, composites, ceramics, glass and polymers, and processed to make the desired solid object which may be hard or soft, rigid or flexible, elastic or inelastic. The finished parts 10, 12 shown in Figs. 3 and 4 are obtained by "uncaking" layers of in-process structure 16 to separate the two objects 10, 12 from substrate 20 and untreated build material in layers 24-28. While two very simple objects 10, 12 made with just a few layers of build material are shown to illustrate the use of a consolidated substrate volume 14, a consolidated substrate volume may be used for complex objects manufactured in a single layer or in multiple layers.

[0022] Consolidated volume 14 is formed in substrate 20 with a perimeter 29 that will surround the first few slices of the object or objects to be formed on substrate 20. Although a rectangular consolidated volume 14 with a single perimeter surrounding both objects 10 and 12 is shown, other configurations for consolidated volume 14 are possible. In the configuration shown in Fig. 5, for example, the perimeter 29 of each consolidated volume 14 corresponds to the shape of each object 10, 12. In the configuration shown in Fig. 6, for another example, the perimeter 29 of each consolidated volume 14 surrounds only the edge of each object 10, 12.

[0023] Fig. 7 is a flow diagram illustrating one example of an additive manufacturing process 100. Figs. 8-12 are cross sections illustrating one example of an object 30 (Fig. 10) being manufactured with process 100 of Fig. 7. Referring to Figs. 7-12, a substrate 20 of unconsolidated powdered build material is formed at block 102 in Fig. 7, as shown in Fig. 8. Substrate 20 may be formed on any suitable supporting structure such as a platform 18 shown in Fig. 1, or on an underlying slice or object formed previously. In this example, substrate 20 is formed with two layers of unconsolidated build material of equal thickness, such as might be formed with the same dispensing device used to form the subsequent slice layers. Other suitable configurations for substrate 20 are possible.

[0024] Powdered build material in substrate 20 is consolidated to form a consolidated volume 14 as shown in Fig. 9 (block 104 in Fig. 7). A layer 24 of unconsolidated powdered build material is formed on substrate 20 as shown in Fig. 10 (block 106 in Fig. 7) and then powdered build material in layer 24 within a perimeter of consolidated substrate volume 14 is solidified in the desired pattern to form an object slice 30, as shown in Fig. 11 (block 108 in Fig. 7). Slice 30 is separated from substrate 20, for example after the object is completed (block 110 in Fig. 7). A single slice object 30 separating from substrate 20 is shown in Fig. 12. While the exact stabilization mechanism is not known, testing suggests that consolidated substrate volume 14 under slice layer 24 provides a "restoring" force at the edge of the slice pattern to help hold slice 30 flat during solidification, compared to a slice formed on unconsolidated substrate.

[0025] Fig. 13 is a flow diagram illustrating one example of consolidating substrate build material at block 104 in Fig. 7. Referring to Fig. 13, unconsolidated powdered build material in substrate 20 is heated to a temperature at least as high as the boiling point of a liquid binder but lower than a temperature damaging to the build material (block 112). Then the liquid binder is applied to a heated volume of substrate 20 (block 114). In one implementation for the process steps illustrated in Fig. 13, a nylon 12 powdered build material is heated to about 100°C and treated with Hewlett-Packard Company's HP881 Latex Ink, for example by dispensing ink on to the build material in the desired pattern with an inkjet printhead. The treated nylon 12 powder exhibits more adhesion after water evaporates from the ink compared to untreated powder. The consolidated powder is dry but not as fine grained as unconsolidated powder, and may appear clumpy. The untreated nylon 12 powder is not damaged at temperatures below about 120°C and, thus, may be recycled for reuse.

[0026] Fig. 14 is a flow diagram illustrating another example of consolidating substrate build material at block 104 in Fig. 7. Referring to Fig. 14, a light-curable liquid binder is applied to an unheated, unconsolidated powdered build material in substrate 20 (block 116) and then exposed to light to consolidate a volume of the substrate where binder was applied to the build material (block 118). In one implementation for the process steps illustrated in Fig. 14, a polymer powdered build material at room temperature is treated with a UV (ultraviolet) curable ink such as Hewlett-Packard Company's HP HDR240 Scitex UV Curable Ink, for example by dispensing ink on to the build material in the desired pattern with an inkjet printhead, and then exposed to UV light to cure the ink and consolidate the polymer powder.

[0027] Other suitable combinations of powdered build material, binder, temperature and/or light are possible.

[0028] Fig. 15 is a flow diagram illustrating one example of solidifying build material to form the object slice at block 108 in Fig. 7. Referring to Fig. 15, a coalescing agent is selectively applied to powdered build material layer 26 in a pattern corresponding to slice 30 (block 120). A coalescence modifier agent is selectively applied to layer 26 to help define the desired shape and characteristics of slice 30 (block 122). A coalescence modifier agent modifies the effect of the coalescing agent and may be dispensed, for example, along the edge of the coalescence agent to help reduce the effects of lateral coalescence bleed and improve the definition of the edges of the slice. In another example, a modifier agent is dispensed interspersed with the pattern of the coalescing agent to change the material characteristics of the slice. The patterned parts of layer 26 are exposed to light to form slice 30 (block 124 in Fig. 15).

[0029] Suitable coalescing agents include pigments, dyes, polymers and other substances that have significant light absorption. Carbon black ink and light absorbing color inks commercially known as CM997A, CE039A and CE042A available from Hewlett-Packard Company are suitable coalescing agents with the appropriate light source.

[0030] Suitable coalescence modifier agents may separate individual particles of the build material to prevent the particles from joining together and solidifying as part of the slice. Examples of this type of coalescence modifier agent include colloidal, dye-based, and polymer-based inks, as well as solid particles that have an average size less than the average size of particles of the build material. The molecular mass of the coalescence modifier agent and its surface tension should be such that it enables the agent to penetrate sufficiently into the build material to achieve the desired mechanical separation. In one example, a salt solution may be used as a coalescence modifier agent. In other examples, inks commercially known as CM996A and CN673A available from Hewlett-Packard Company may be used as a coalescence modifier agent.

[0031] Suitable coalescence modifier agents may act to modify the effects of a coalescing agent by preventing build material from reaching temperatures above its melting point during heating. A fluid that exhibits a suitable cooling effect may be used as this type of coalescence modifier agent. For example, when build material is treated with a cooling fluid, energy applied to the build material may be absorbed evaporating the fluid to help prevent build material from reaching its melting point. Thus, for example, a fluid with a high water content may be a suitable coalescence modifier agent.

[0032] Other types of coalescence modifier agent may be used. An example of a coalescence modifier agent that may increase the degree of coalescence may include, for example, a plasticizer. Another example of a coalescence modifier agent that may increase the degree of coalescence may include a surface tension modifier to increase the wettability of particles of build material.

[0033] Fig. 16 is a block diagram illustrating a processor readable medium 32 with instructions 34 to consolidate build material in the substrate during the manufacture of a 3D object. A processor readable medium 32 is any non-transitory tangible medium that can embody, contain, store, or maintain instructions for use by a processor. Processor readable media include, for example, electronic, magnetic, optical, electromagnetic, or semiconductor media. More specific examples of suitable processor readable media include a hard drive, a random access memory (RAM), a read-only memory (ROM), memory cards and sticks and other portable storage devices.

[0034] Instructions 34 include instructions to consolidate powdered build material in the substrate, shown at block 104 in Fig. 7. Instructions 34 may also include other manufacturing instructions, for example instructions to form, solidify and separate shown at blocks 106, 108 and 110 in Fig. 7. Processor readable medium 32 with instructions 34 may be implemented, for example, in a CAD computer program product, in an object model processor, or in a controller for an additive manufacturing machine. Control data to consolidate powdered build material in the substrate can be generated, for example, by processor readable instructions on the source application, usually a CAD computer program product, in an object model processor, or by processor readable instructions on the additive manufacturing machine.

[0035] Fig. 17 is a block diagram illustrating one example of an additive manufacturing machine 36 implementing a controller 38 with instructions 34 to consolidate a substrate volume during the manufacture of a 3D object. Referring to Fig. 17, machine 36 includes controller 38, a support 18, a build material layering device 40, a binder dispenser 42, a coalescing agent dispenser 44, a heater 46 and a light source 48. The in-process object structure is supported on support 18 during manufacturing. In some machines 36, support 18 may support the in-process structure during uncaking. Also, in some machines 36, support 18 is movable at the urging of controller 38 to compensate for the changing thickness of the in-process structure, for example as layers of build material are added during manufacturing.

[0036] Build material layering device 40 layers build material on support 18 and on the in-process structures and may include, for example, a device to dispense the build material and a blade or roller to distribute the build material uniformly to the desired thickness for each layer. Binder dispenser 42 dispenses binder selectively at the direction of controller 38 on to substrate build material in a pattern that will surround the first slices of an object supported on the substrate during manufacturing. Coalescing agent dispenser 44 dispenses coalescing agent selectively at the direction of controller 38 on to build material, usually in a pattern corresponding to a slice. While any suitable dispenser may be used to dispense the binder and coalescing agent, inkjet printheads are often used in additive manufacturing machines because of the precision with which they can dispense agents and their flexibility to dispense different types and formulations of agents. Manufacturing machine 36 may include a heater 46 if it is desired to heat the substrate. Manufacturing machine 36 includes a light source 48 to apply light energy to solidify build material treated with coalescing agent.

[0037] Controller 38 represents the processor (or multiple processors), the associated memory (or multiple memories) and instructions, and the electronic circuitry and components needed to control the operative elements of machine 36. In particular, controller 38 includes a memory 50 having a processor readable medium 32 with instructions 34 and a processor 52 to read and execute instructions 34. For example, controller 38 would receive control data and other instructions from a CAD program to make an object (e.g., blocks 102, 106, 108 and 110 in Fig. 7) and execute local instructions 34 to consolidate part of the substrate (e.g., block 104 in Fig. 7) as part of the process of making the object.

[0038] Alternatively, consolidation instructions 34 may be embodied in a processor readable medium 32 separate from controller 38, for example as part of a CAD computer program product shown in Fig. 18. Referring to Fig. 18, an additive manufacturing system 54 includes an additive manufacturing machine 36 operatively connected to a CAD computer program product 56 with the instructions to consolidate parts of the substrate during manufacture of the object. In this example, CAD program 56 includes processor readable medium 32 with instructions 34. Any suitable connection between machine 36 and CAD program 56 may be used to communicate instructions and control data to machine 36 including, for example, a wired link, a wireless link, and a portable connection such as a flash drive or compact disk. Also, in this example, additive manufacturing machine 36 includes a coalescence modifier agent dispenser 58. Inkjet printheads or another suitable dispenser 58 dispenses coalescence modifier agent selectively on to build material at the direction of controller 38 executing instructions from CAD program 58.

[0039] Light source 48 applies light energy to build material formed on or over the substrate to cause the solidification of portions of the build material according to where coalescing agent has been delivered or has penetrated. In some examples, light source 48 is an infra-red (IR) or near infra-red light source, a halogen light source, or a light emitting diode. Light source 48 may be a single light source or an array of multiple light sources. In some examples, light source 48 is configured to apply light energy in a substantially uniform manner simultaneously to the whole surface of a layer of build material. In other examples, light source 48 is configured to apply energy to only a select areas of the whole surface of a layer of build material. In these examples light source 48 may be moved or scanned across the layer of build material such that a substantially equal amount of energy is applied to the selected areas or across the whole surface of a layer of build material.

[0040] The combination of build material, coalescing and coalescence modifier agents, and light energy may be selected for an object slice so that (1) build material with no coalescing agent does not coalesce when the energy is applied, (2) build material with only coalescing agent solidifies when energy is applied; or (3) build material with both agents undergo a modified degree of coalescence between no coalescence and solidification with or without the application of energy.

[0041] "A" and "an" used in the claims means one or more.

[0042] The examples shown in the figures and described above illustrate but do not limit the invention, which is defined in the following Claims.

CLAIMS

What is claimed is:

1. A non-transitory processor readable medium having instructions thereon that when executed cause an additive manufacturing machine to consolidate powdered build material in a volume of a substrate of powdered build material to form a consolidated volume of substrate.

2. The medium of Claim 1, wherein the instructions to form a consolidated volume of substrate include instructions to:

heat unconsolidated powdered build material in the substrate to a temperature at least as high as a boiling point of a liquid binder; and then

apply the liquid binder to a volume of heated substrate.

3. The medium of Claim 1, wherein the instructions to form a consolidated volume of substrate include instructions to:

apply a light-curable liquid binder to an unheated, unconsolidated powdered build material in the substrate; and then

expose the substrate to light where binder was applied to the build material.

4. The medium of Claim 1, wherein the instructions include instructions to:

form a layer of unconsolidated powdered build material on the substrate; and

solidify powdered build material in the layer within a perimeter of the consolidated volume of substrate to form a slice

5. The medium of Claim 4, wherein the instructions to solidify include instructions to:

dispense a coalescing agent on to powdered build material in the layer in a pattern to form patterned build material; and

expose the patterned build material to light.

6. A computer program product that includes the processor readable medium of Claim 1.

7. An additive manufacturing machine controller that includes the processor readable medium of Claim 1.

8. An additive manufacturing process, comprising:

forming a substrate of unconsolidated powdered build material;

consolidating powdered build material in a volume of the substrate to form a consolidated dry volume of substrate;

forming a layer of powdered build material on the consolidated volume of substrate; and

solidifying powdered build material in the layer to form a slice.

9. The process of Claim 8, wherein the consolidating includes:

heating dry powdered build material in the substrate including the volume of the substrate to a temperature at least as high as a boiling point of a liquid binder; and then

applying the liquid binder to the heated first volume of substrate.

10. The process of Claim 8, wherein the consolidating includes:

applying a light-curable liquid binder to an unheated, unconsolidated powdered build material in the substrate; and then

exposing the substrate to light where binder was applied to the build material.

11. The process of Claim 8, wherein the solidifying includes:

dispensing a coalescing agent on to powdered build material in the layer in a pattern to form patterned build material; and

applying light energy to the patterned build material.

12. The process of Claim 9, wherein the solidifying includes:

dispensing a coalescing agent on to powdered build material in the layer in a first pattern to form first patterned build material;

dispensing a coalescence modifier agent on to first patterned build material in a second pattern to form second patterned build material; and then

applying light energy to the first patterned build material and the second patterned build material.

13. The process of Claim 10, comprising separating the slice from the substrate.

14. The process of Claim 8, wherein the consolidating includes:

applying a liquid binder to the volume of substrate; and

evaporating liquid from the volume.

15. The process of Claim 14, wherein the evaporating includes applying the liquid binder to powdered build material in the substrate that has been heated to a temperature at or above the boiling point of liquid in the binder.

16. An additive manufacturing machine, comprising:

a first device to layer powdered build material;

a second device to dispense a binder on to build material;

a third device to dispense a coalescing agent on build material;

a heater to heat build material;

a light source to apply light energy to build material; and

a controller to execute instructions to:

cause the first device to layer a substrate of build material;

cause the heater to heat build material in the substrate;

cause the second device to dispense a binder on to heated build material in the substrate;

cause the first device to layer build material on the substrate where the binder has been dispensed;

cause the third device to dispense a coalescing agent on to the layer of build material; and cause the light source to apply light energy to the layer of build material where coalescing agent has been dispensed.

17. The machine of Claim 16, comprising a fourth device to dispense a coalescence agent modifier on to build material and wherein the controller is to execute instructions to cause the fourth device to dispense a coalescence modifier agent on to the layer of build material where coalescing agent has been dispensed before applying light energy to the layer.

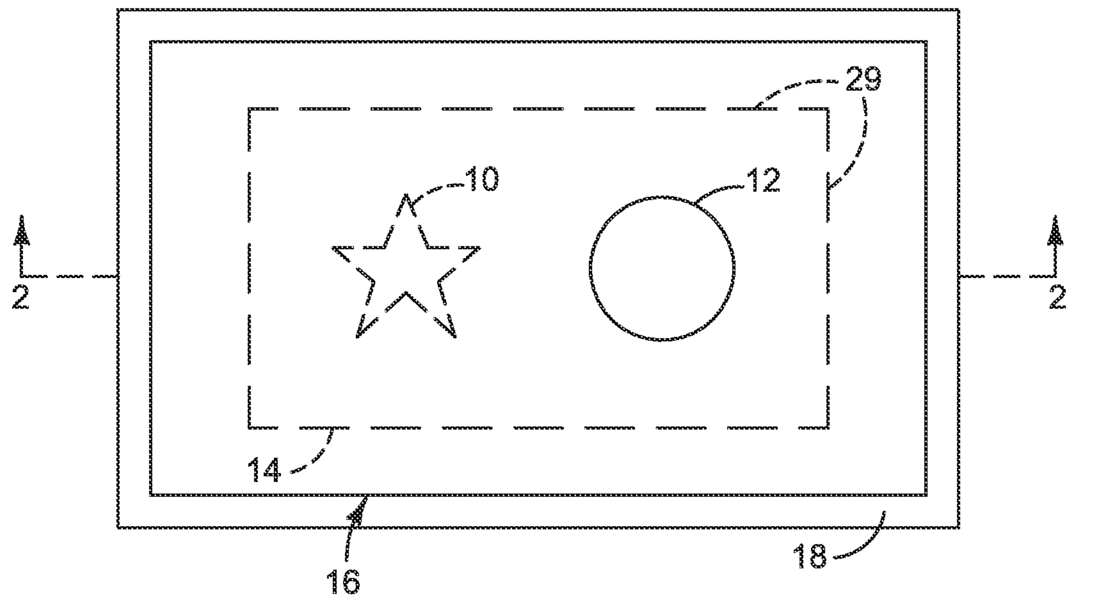


FIG. 1

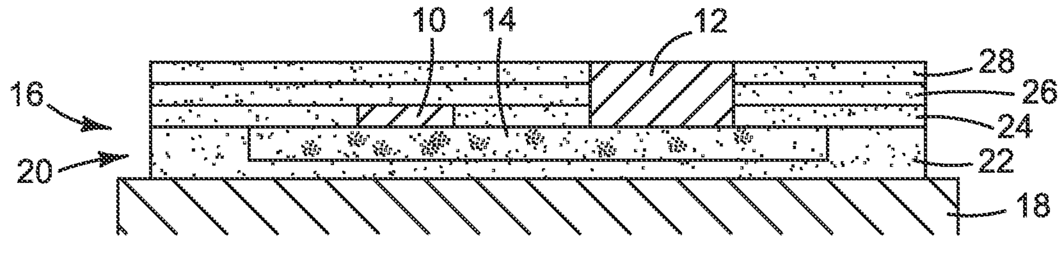


FIG. 2

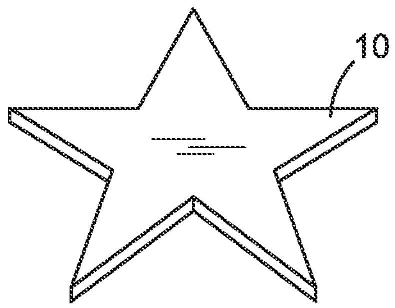


FIG. 3

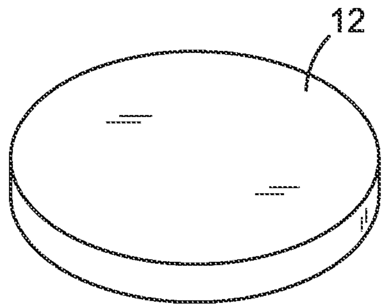


FIG. 4

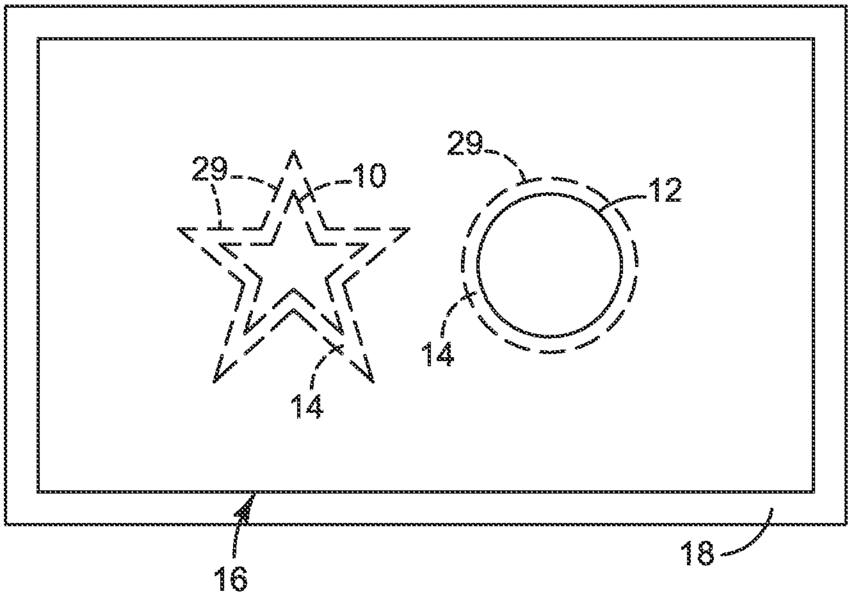


FIG. 5

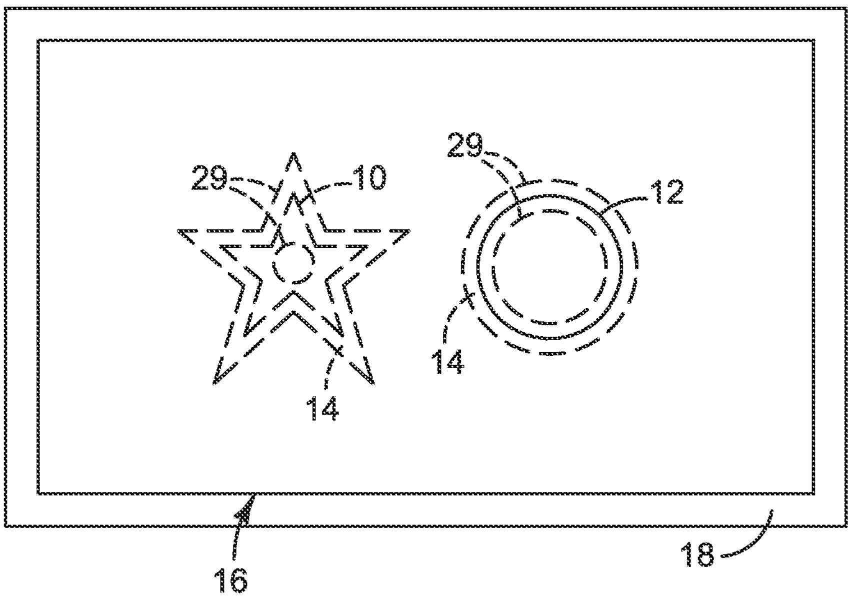


FIG. 6

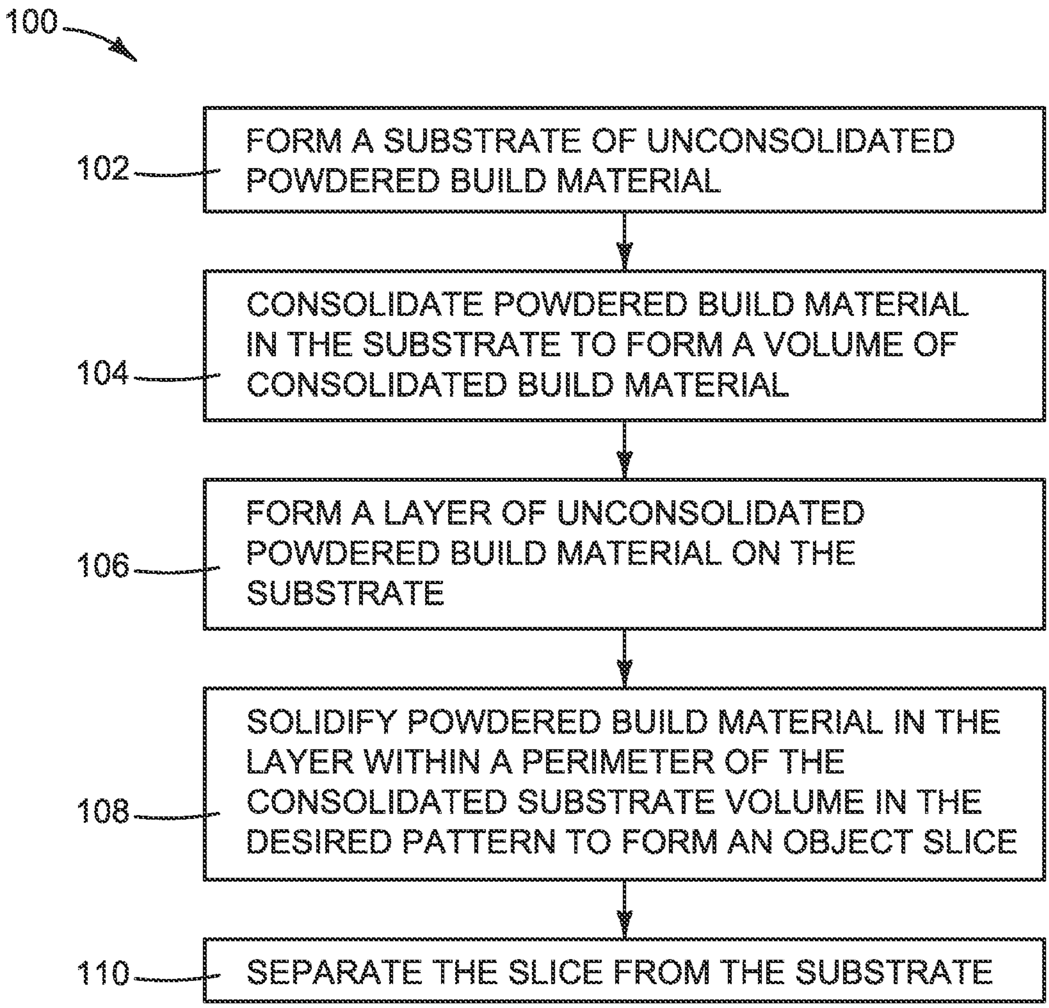

100
102
FORM A SUBSTRATE OF UNCONSOLIDATED POWDERED BUILD MATERIAL
104
CONSOLIDATE POWDERED BUILD MATERIAL IN THE SUBSTRATE TO FORM A VOLUME OF CONSOLIDATED BUILD MATERIAL
106
FORM A LAYER OF UNCONSOLIDATED POWDERED BUILD MATERIAL ON THE SUBSTRATE
108
SOLIDIFY POWDERED BUILD MATERIAL IN THE LAYER WITHIN A PERIMETER OF THE CONSOLIDATED SUBSTRATE VOLUME IN THE DESIRED PATTERN TO FORM AN OBJECT SLICE
110
SEPARATE THE SLICE FROM THE SUBSTRATE

FIG.7

FIG. 8

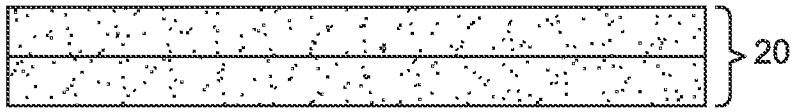


FIG. 9

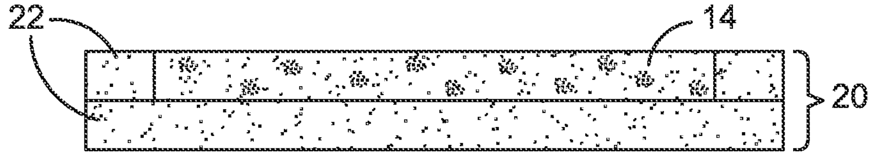


FIG. 10

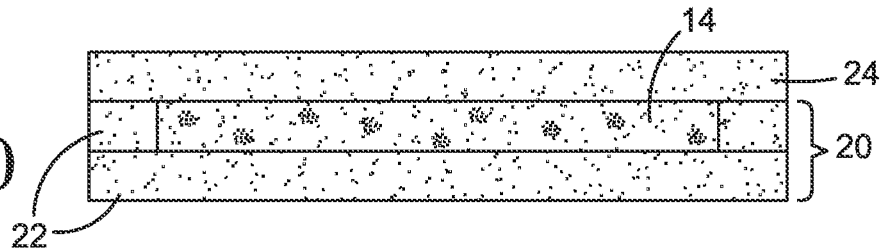


FIG. 11

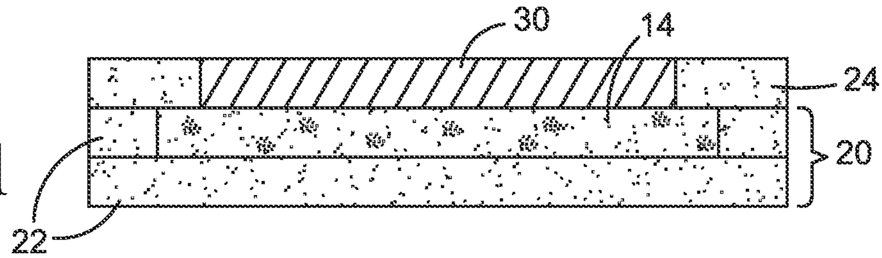
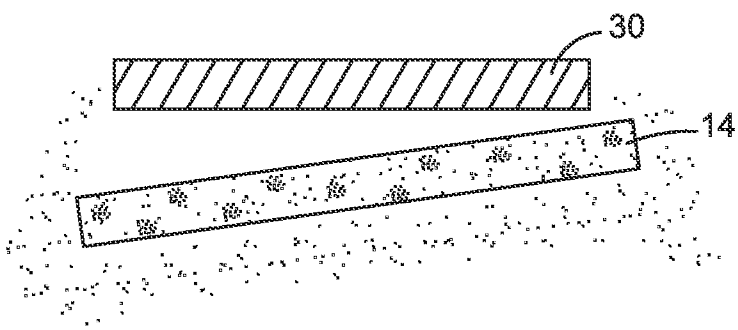


FIG. 12



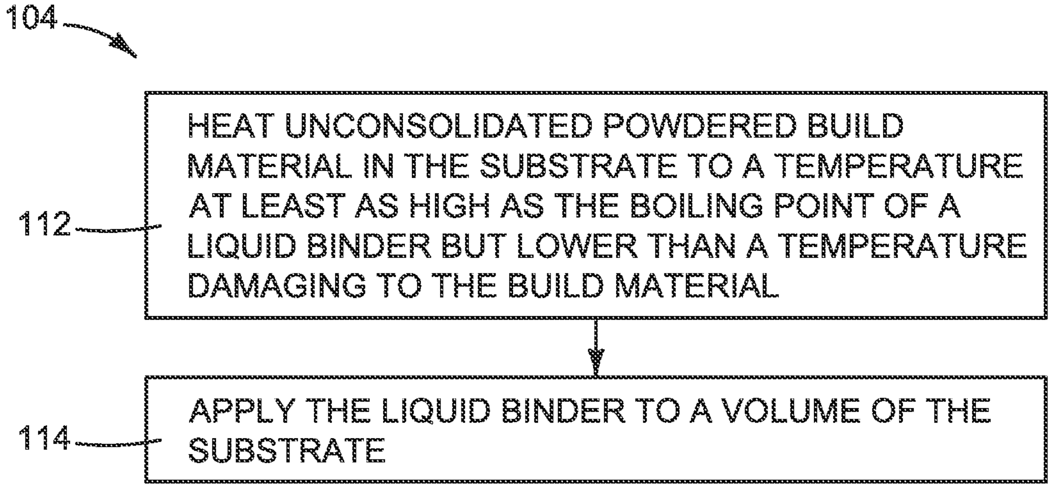

104
112
HEAT UNCONSOLIDATED POWDERED BUILD MATERIAL IN THE SUBSTRATE TO A TEMPERATURE AT LEAST AS HIGH AS THE BOILING POINT OF A LIQUID BINDER BUT LOWER THAN A TEMPERATURE DAMAGING TO THE BUILD MATERIAL
114
APPLY THE LIQUID BINDER TO A VOLUME OF THE SUBSTRATE

FIG. 13

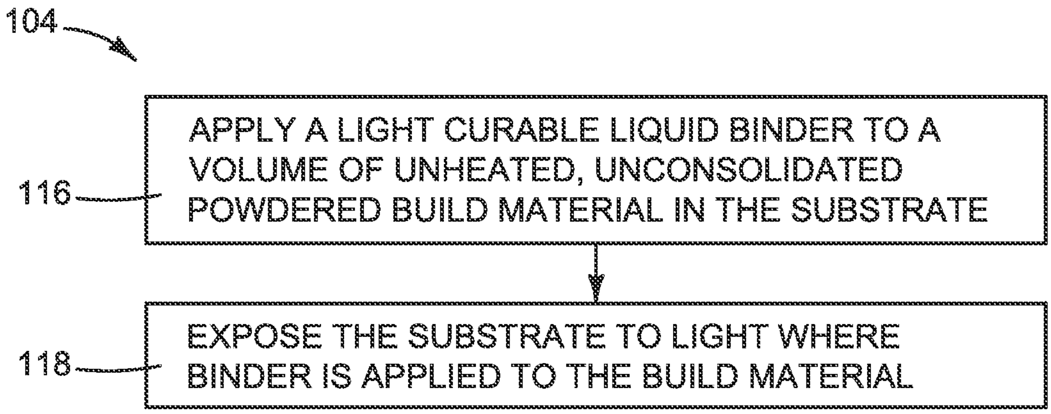

104
116
APPLY A LIGHT CURABLE LIQUID BINDER TO A VOLUME OF UNHEATED, UNCONSOLIDATED POWDERED BUILD MATERIAL IN THE SUBSTRATE
118
EXPOSE THE SUBSTRATE TO LIGHT WHERE BINDER IS APPLIED TO THE BUILD MATERIAL

FIG. 14

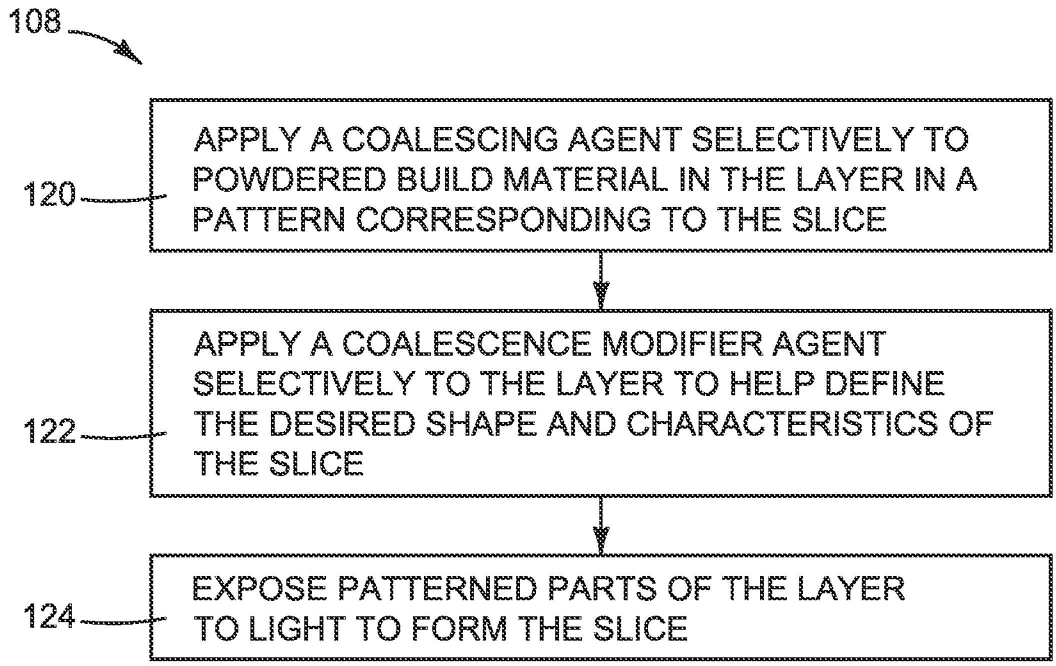

108
120
APPLY A COALESCING AGENT SELECTIVELY TO POWDERED BUILD MATERIAL IN THE LAYER IN A PATTERN CORRESPONDING TO THE SLICE
122
APPLY A COALESCENCE MODIFIER AGENT SELECTIVELY TO THE LAYER TO HELP DEFINE THE DESIRED SHAPE AND CHARACTERISTICS OF THE SLICE
124
EXPOSE PATTERNED PARTS OF THE LAYER TO LIGHT TO FORM THE SLICE

FIG. 15

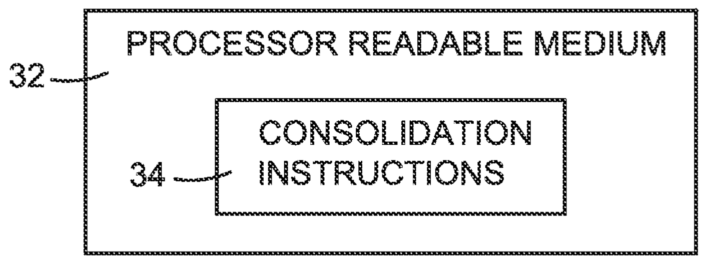

32
PROCESSOR READABLE MEDIUM
34
CONSOLIDATION INSTRUCTIONS

FIG. 16

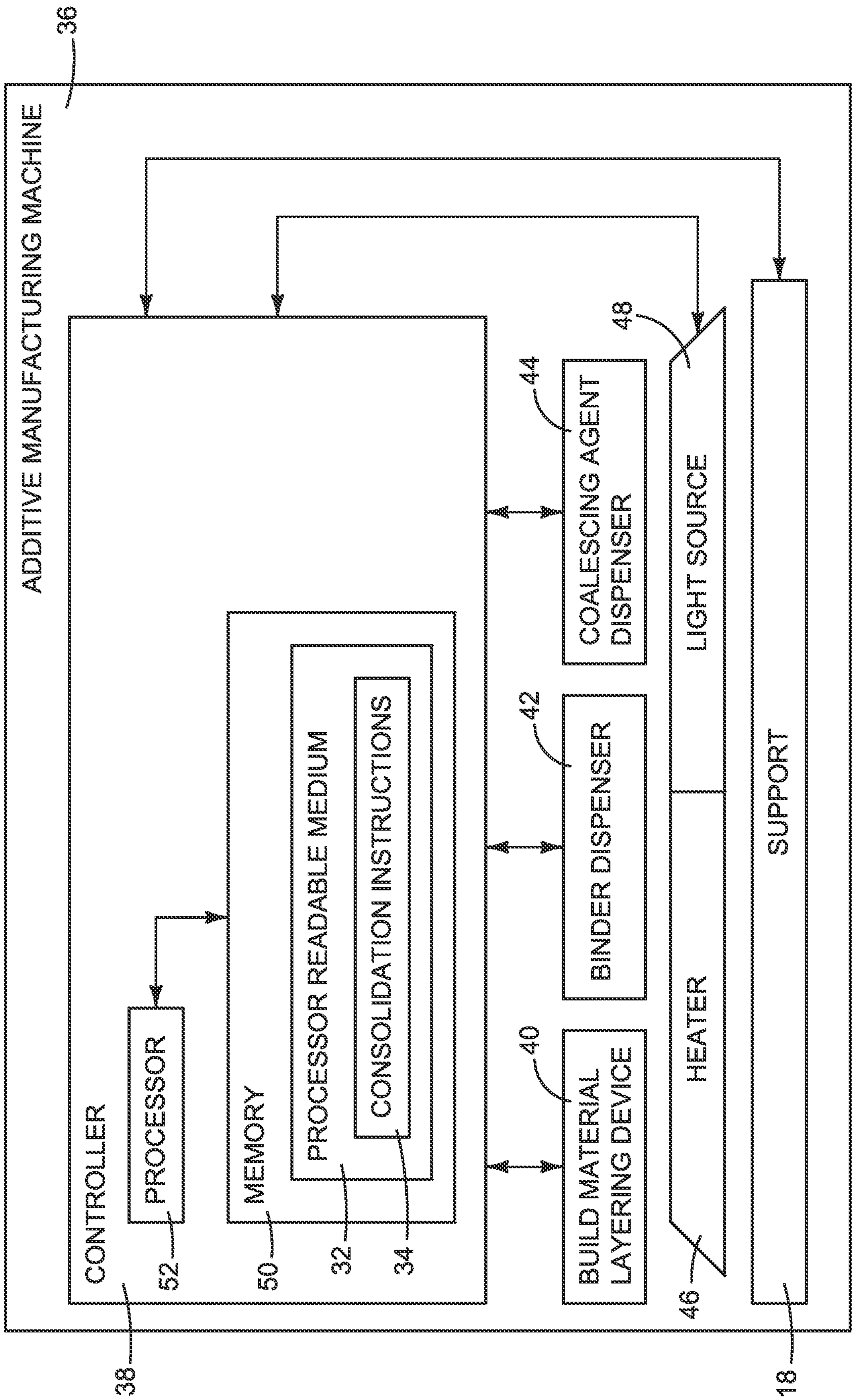

36
ADDITIVE MANUFACTURING MACHINE
CONTROLLER
PROCESSOR
MEMORY
PROCESSOR READABLE MEDIUM
CONSOLIDATION INSTRUCTIONS
52
50
32
34
38
BUILD MATERIAL LAYERING DEVICE
40
BINDER DISPENSER
42
COALESCING AGENT DISPENSER
44
HEATER
LIGHT SOURCE
46
48
SUPPORT
18

FIG. 17

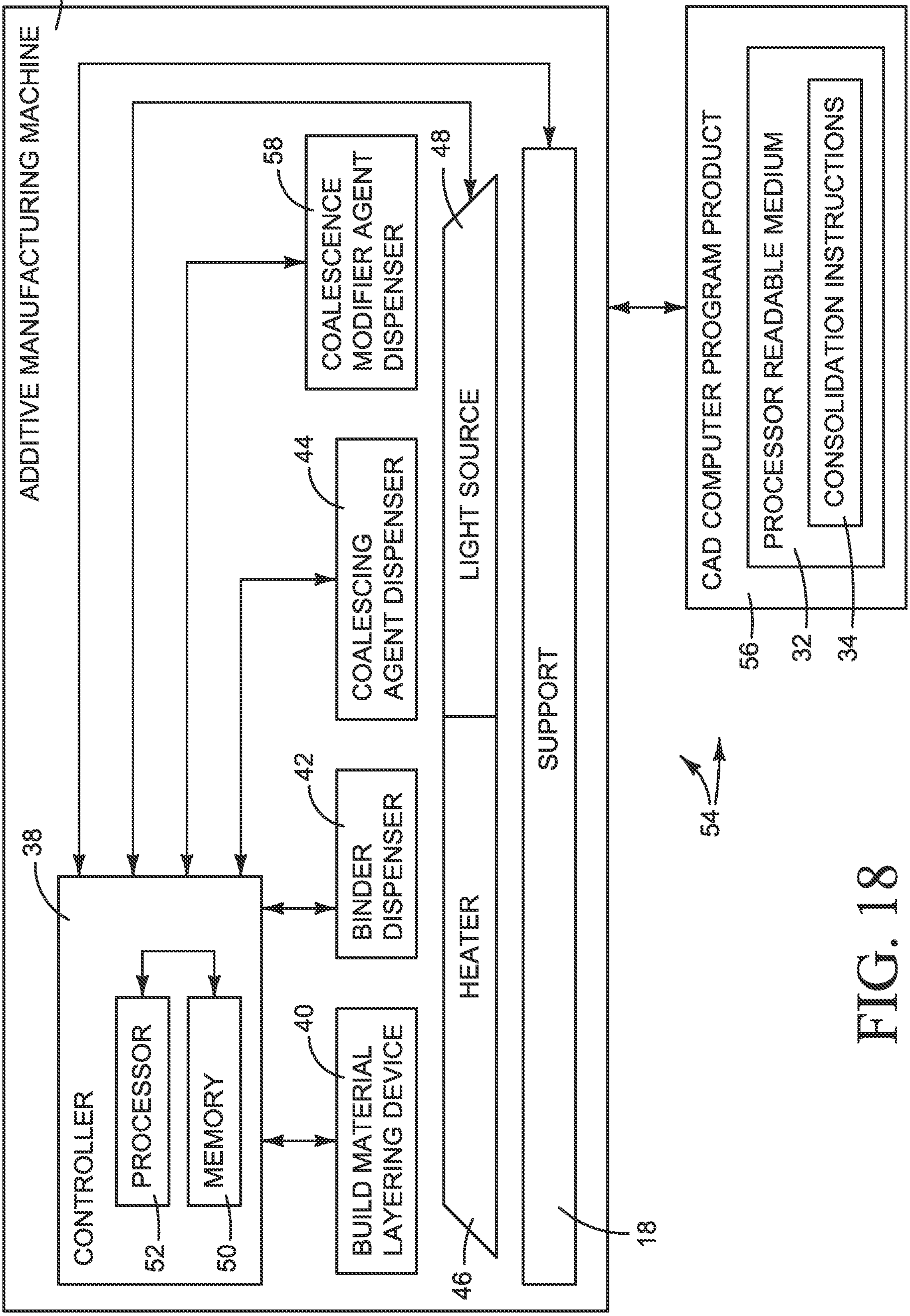

ADDITIVE MANUFACTURING MACHINE
36
CONTROLLER
38
PROCESSOR
52
MEMORY
50
BUILD MATERIAL LAYERING DEVICE
40
BINDER DISPENSER
42
COALESCING AGENT DISPENSER
44
COALESCENCE MODIFIER AGENT DISPENSER
58
HEATER
46
LIGHT SOURCE
48
SUPPORT
18
CAD COMPUTER PROGRAM PRODUCT
56
PROCESSOR READABLE MEDIUM
32
CONSOLIDATION INSTRUCTIONS
34
54

FIG. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/046892

A. CLASSIFICATION OF SUBJECT MATTER

G06F 9/06(2006.01)i, B29C 47/08(2006.01)i

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)
G06F 9/06; B29C 67/24; B32B 18/00; B29C 67/00; B05D 3/10; B05C 19/04; B29C 35/08; B29C 47/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: 3D, printer, powder, binder, dispense, substrate.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012-0308837 A1 (NADJA SCHLECHTRIEMEN et al.) 06 December 2012 See abstract, paragraphs [0031]-[0048], claim 1 and figures 1-3.	1-17
Y	US 2006-0208388 A1 (JAMES F. BREDT et al.) 21 September 2006 See abstract, paragraphs [0035]-[0044],[0117]-[0124], claim 120 and figures 1-3.	1-17
A	US 2014-0065194 A1 (JAEDEOK YOO et al.) 06 March 2014 See abstract, paragraphs [0088]-[0102], claim 1 and figure 1.	1-17
A	US 2008-0241404 A1 (ALLAMAN SANDRINE et al.) 02 October 2008 See abstract, paragraphs [0141]-[0147], claim 1 and figures 1-6.	1-17

☐ 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
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"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
15 April 2015 (15.04.2015)	**16 April 2015 (16.04.2015)**

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Facsimile No. ++82 42 472 7140	Telephone No. +82-42-481-5696

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