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METHOD AND APPARATUS FOR 3D PRINTING BY SELECTIVE SINTERING

RELATED APPLICATION

5 This application claims the benefit of priority under 35 USC §119(e) of U.S. Provisional Patent Application No. 61/990,165 filed May 8, 2014, the contents of which are incorporated herein by reference in their entirety.

FIELD AND BACKGROUND OF THE INVENTION

10 The present invention, in some embodiments thereof, relates to three dimensional (3D) printing and, more particularly, but not exclusively, to 3D printing by selective sintering.

A number of different processes for fabricating solid objects by 3D printing with successive layers of powdered material are known. Some known 3D printing techniques
15 selectively apply a liquid binder material based on a 3D model of the object, binding the material together layer by layer to create a solid structure. In some processes, the object is heated and/or sintered to further strengthen bonding of the material at the end of the building process.

Selective Laser Sintering (SLS) uses a laser as the power source to sinter layers of
20 powdered material. The laser is controlled to aim at points in space defined by a 3D model, binding the material together layer by layer to create a solid structure. Selective laser melting (SLM) is comparable technique that applies full melting of the material instead of sintering. SLM is typically applied when the melting temperature of the powder is uniform, e.g. when pure metal powders are used as the building material.

25 US Patent No. 4,247,508 entitled "Molding process," the contents of which are incorporated herein by reference, describes a molding process for forming a 3D article in layers. In one embodiment, planar layers of material are sequentially deposited. In each layer, prior to the deposition of the next layer, a portion of its area is solidified to define that portion of the article in that layer. Selective solidification of each layer may
30 be accomplished by using heat and a selected mask or by using a controlled heat scanning process. Instead of using a laser to selectively fuse each layer, a separate mask for each layer and a heat source may be employed. The mask is placed over its associated layer and a heat source located above the mask. Heat passing through the

opening of the mask will fuse together the particles exposed through the opening of the mask. The particles not exposed to the direct heat will not be fused.

US Patent No. 5,076,869 entitled "Multiple material systems for selective beam sintering," the contents of which are incorporated herein by reference, describes a method and apparatus for selectively sintering a layer of powder to produce a part comprising a plurality of sintered layers. The apparatus includes a computer controlling a laser to direct the laser energy onto the powder to produce a sintered mass. For each cross-section, the aim of the laser beam is scanned over a layer of powder and the beam is switched on to sinter only the powder within the boundaries of the cross-section. Powder is applied and successive layers sintered until a completed part is formed. Preferably, the powder comprises a plurality of materials having different dissociation or bonding temperatures. The powder preferably comprises blended or coated materials.

SUMMARY OF THE INVENTION

According to an aspect of some embodiments of the present invention there is provided a system and method for 3D printing by selective sintering. According to some embodiments of the present invention, an object is formed by an additive manufacturing process that includes printing a mask on a powder layer, compacting the layer including the mask and then sintering the compacted layer. This process is typically repeated for each layer until the object is formed. The present inventor has found that adding the compacting step on a per layer basis can improve the efficiency of the manufacturing process and can also improve a quality of the end product.

According to an aspect of some embodiments of the present invention there is provided a system for building a three dimensional object including: a powder delivery station for applying a layer of powder material on a building tray; a digital printing station for printing a mask pattern on the layer, wherein the mask pattern defines a negative of a portion of the layer to be sintered, said portion exposed; a sintering station for selectively sintering the portion of the layer that is exposed; and a stage for repeatedly advancing the building tray to each of the powder delivery station, digital printing station and sintering station to build a plurality of layers that together form the three dimensional object.

Optionally, the system includes a die compaction station for compacting per layer of powder material, wherein the compaction station includes a die for receiving the layer.

Optionally, the die compacting station includes a heating element for warming a
5 surface of the die that interfaces with the layer.

Optionally, the die compacting station is operable to apply up to 100 MPa of pressure on the layer.

Optionally, the die compacting station includes a lifting system for lifting the building tray toward the die.

10 Optionally, the compacting station includes an anti-peeling mechanism, the anti-peeling mechanism including a foil positioned between the die, wherein the foil is supported by two opposite edges to allow bowing of the foil during separation between the building tray and the die.

Optionally, the system includes a controller for adjusting height of the building
15 tray in a subsequent layer responsive to a thickness of the layer after compaction.

Optionally, the system includes a cooling station for cooling the layer after sintering.

Optionally, the cooling station includes air knives for providing jet stream of gas to cool the layer.

20 Optionally, the digital printing system is operable to dispense ink including frit suspended in a liquid carrier.

Optionally, frit is formed from particles having a diameter of between 500 nm to 1 μ m.

Optionally, the sintering station includes a high thermal mass roller for sintering
25 the layer.

Optionally, the high thermal mass roller is heated to 0° - 80° C above a melting temperature of the powder.

Optionally, the high thermal mass roller applies a pressure in the order of magnitude of 20-180 N/cm of roller length.

30 Optionally, the sintering station includes an anti-peeling mechanism, the anti-peeling mechanism including a foil positioned between the high thermal mass roller and the layer.

Optionally, the sintering station includes an array of vertical-cavity surface-emitting lasers (VCSEL) that swept over the layer for pre-heating and/or sintering.

Optionally, the building tray includes at least one channel running substantially parallel to a surface of the tray on which the layer is positioned, through which fluid is introduced for cooling the building tray.

Optionally, the powder is metal powder.

Optionally, the powder is aluminum powder and/or aluminum alloy.

According to an aspect of some embodiments of the present invention there is provided a method for building a three dimensional object including: spreading a layer of powder on a building tray; printing a mask pattern on the layer, wherein the mask pattern defines a negative of portion of the layer to be sintered, said portion exposed, the mask pattern for the layer is defined by mask pattern data defining a shape of the three dimensional object; sintering the portion of the layer that is exposed; and repeating the spreading printing and sintering until the three dimensional object is completed.

Optionally, the mask pattern is printed with a digital printer that dispenses ink.

Optionally, the ink provides an insulating coating on a masked portion of the layer.

Optionally, the ink includes a liquid carrier selected to have an evaporation temperature that is lower than a melting temperature of the powder.

Optionally, the method includes performing die compaction per layer prior to the sintering.

Optionally, the method includes performing warm die compaction.

Optionally, the pressure applied on the layer during compaction is up to 100 MPa.

Optionally, the die compaction is performed per layer after the printing of the layer.

Optionally, the method includes cooling the building tray during the die compaction.

Optionally, the sintering is performed by passing a heat source over a length of the building tray, wherein the heat source provides heat along a narrow strip that extends over a width of the building tray.

Optionally, the sintering is performed with a high thermal mass roller rolling over the layer.

Optionally, the high thermal mass roller is heated to 0° - 30° C above a melting temperature of the powder during the sintering.

Optionally, the high thermal mass roller is pressed against the layer with a pressure in the order of magnitude of 10 N/cm of roller length.

5 Optionally, the method includes cooling the building tray during sintering.

Optionally, the method includes cooling the layer immediately after the sintering, wherein the cooling is performed with a jet stream of gas.

Optionally, the method includes adjusting height of the building tray responsive to a thickness of one or more previous layers of the object being built.

10 According to an aspect of some embodiments of the present invention there is provided a method for building a three dimensional object including: providing a layer of powder on a building tray; performing die compaction on the layer; sintering the layer that is die compacted by selective laser sintering or selective laser melting; and repeating the providing, the die compaction and the sintering per layer until the three
15 dimensional object is completed.

Optionally, the method includes performing warm die compaction.

Optionally, the pressure applied on the layer during compaction is up to 100 MPa.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which
20 the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

25 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard,
30 the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIG. 1 is a simplified schematic drawing of an exemplary 3D printing system in accordance with some embodiments of the present invention;

FIG. 2 is a simplified block diagram showing exemplary units of an exemplary 3D printing system in accordance with some embodiments of the present invention;

FIG. 3 is a simplified block diagram of powder dispensing station in accordance with some embodiments of the present invention;

FIG. 4 is a simplified block diagram of powder spreading station in accordance with some embodiments of the present invention;

FIG. 5 is a simplified block diagram of an exemplary printing system in accordance with some embodiments of the present invention;

FIG. 6 is a simplified schematic representation of an object layer including a printed mask in accordance with some embodiments of the present invention;

FIGs. 7A and 7B are simplified schematic drawings of an exemplary compacting system in a released and compressed state respectively in accordance with some embodiments of the present invention;

FIGs. 8A and 8B are simplified schematic drawings of an exemplary anti-peeling mechanism for a compacting system in a compacting state and a post compacting state respectively in accordance with some embodiments of the present invention;

FIG. 9 is a simplified schematic drawing of a cleaning mechanism for a compacting system in accordance with some embodiments of the present invention;

FIG. 10 is a simplified schematic drawing of exemplary sintering station and cooling station in accordance with some embodiments of the present invention;

FIG. 11 is a simplified schematic drawing of another exemplary sintering station in accordance with some embodiments of the present invention; and

FIG. 12 is a simplified flow chart of an exemplary method for constructing an object by 3D printing in accordance with some embodiments of the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to three dimensional (3D) printing and, more particularly, but not exclusively, to three dimensional printing by selective sintering.

According to some embodiments of the present invention, there is provided a 3D printing system and method for building an object from multiple layers of sintered powder. According to some embodiments of the present invention, the system includes a building tray on which a powder dispenser applies powdered material on a per layer basis and a roller spreads each layer of powder once applied. Optionally, powder dispensing and powder spreading is performed in a powder delivery station of the system. According to some embodiments of the present invention, a powdered metal is used as the building material. In some exemplary embodiments, aluminum powder is used. Optionally, a metal alloy is used, e.g. an aluminum alloy or a combination of powder metal is used. Optionally, a ceramic powder is used as the building material and/or a combination of metal and ceramic powder.

Building with aluminum is known to be advantageous due to its light weight, relatively low melting temperature and its resistance to corrosion. One of the challenges of building with aluminum powder is that the aluminum particles of the powder tend to form an aluminum oxide coating, e.g. alumina. The aluminum oxide coating introduces a barrier between the aluminum particles that interferes with bonding of the particles during sintering. The final result is typically an object with reduced strength due to poor bonding between the powdered elements.

Additional challenges come into play when applying an SLS and/or SLM process for building with aluminum. Molten aluminum is known to provide a poor wetting surface for receiving additional layers. It is known to add tin and other additives to provide an improved wetting surface. However, the addition of tin and other additives reduces the strength of the final product that is built. In addition, the molten layer suffers from coalescence between adjacent molten drops by the scanning laser beam, due to the poor previous layer wetting. The final result is again an object with reduced strength and inaccurate dimensions. It is known to add an exoskeleton to the object as it is built to provide additional stability, and to reduce internal stress, e.g. due to dimensional variations. This exoskeleton is later removed. Removing the exoskeleton is typically a cumbersome process.

According to an aspect of the present invention, there is provided an improved three dimensional (3D) printing system and method that can also be applied to building objects with pure metals such as aluminum. It is noted that the system and method is

not limited for use with pure aluminum and can also be used for building with metal alloys, ceramics and/or a combination of different materials.

According to some embodiments of the present invention, the system includes a digital printer that prints a mask on the powder bed on a per layer basis based on a stored digital mask pattern. Typically, the mask pattern is negative of the object at a particular cross section being printed. According to some embodiments of the present invention, the ink applied by the printer includes heat insulating material, e.g. glass or silicon frit suspended in a liquid carrier, e.g. oil and/or organic solvent. Typically, the ink provides for retarding sintering of the powder material during the sintering process and at the location on which the ink is applied.

According to some embodiments of the present invention, the system includes a die compacting station for compacting the layer of powder in a die prior to sintering. Typically, compaction is applied to increase the density of the powder layer and/or remove air. In some exemplary embodiments, the compaction strength applied is defined to provide permanent deformation of the powder layer, e.g. press the powder particles past its elastic state and into its plastic state. Optionally, heating is applied during compaction so that a state of permanent deformation can be achieved at lower compaction pressures. Typically, the density and thereby the mechanical strength of the object is improved by compaction. According to some embodiments of the present invention, the compaction promotes bonding during sintering by breaking up the alumina layer to expose the aluminum and allow direct engagement between aluminum particles of the powdered material. Optionally, compaction increases thermal conductivity of the powder layer and allows for more uniform sintering. Optionally, compaction improves the bonding between layers and prevents layer separation that may occur after sintering. According to some embodiments of the present invention, die compaction per layer is applied to known SLM and SLS processes for building a 3D object.

According to some embodiments of the present invention, the system includes a sintering station for sintering the compacted layer. According to some embodiments of the present invention sintering is performed with a sintering roller, e.g. a high thermal mass roller. In some exemplary embodiments, the roller is heated to a temperature that is slightly above a melting temperature of the powder material, e.g. 0° - 80° C above the

melting temperature and is pressed against the layer with a pressure of about 20-180 N/cm of roller length. Typically, the applied pressure ensures substantial to full contact between the roller surface and the layer. Typically, the pressure applied promotes adhesion between the layers. In some exemplary embodiments, the temperature of the roller together with the speed of rotation is defined so that adequate melting of the unmasked portion can be achieved prior to substantial evaporation of the liquid carrier in the masked portion. Typically, liquid carrier has a lower boiling temperature than the melting temperature of the powder material so that in the masked portion evaporation of the liquid carrier occurs prior to melting of the powder material. In the unmasked portion, there is no liquid carrier, so that substantially all the energy transfer is used for melting the powder material. This results in aluminum melting at the model trajectory prior to aluminum melting at the masked trajectory. If this time delay is properly used, the model trajectory will be solidified and bonded to the previous layer while the masked trajectory will not. In some alternative embodiments of the present invention, sintering is achieved with an array of vertical-cavity surface-emitting lasers (VCSEL) that sweep over the layer for sintering. In some additional alternative embodiments of the present invention, sintering is achieved with the roller and an array of vertical-cavity surface-emitting lasers (VCSEL) is used for layer preheating. This preheating can shorten the sintering period and can reduce potential contamination of the sintering roller.

According to some embodiments of the present invention, the system optionally includes an anti-peeling mechanism for reducing and/or preventing peeling of the powder layer on contact surface, e.g. the sintering roller and/or the die. In some exemplary embodiments, the anti-peeling mechanism includes a foil and/or film positioned between the powder layer and a contact surface that maintains contact with the powder layer after initial disengagement of the contact surface and then separated from the powder layer in a gradual manner. Typically, the presence of the foil prevents any peeling on the contact surface. In some exemplary embodiments, the gradual separation of the foil also prevents and/or reduces peeling of the powder layer on the foil.

According to some embodiments of the present invention, the system additionally includes a cooling station for cooling the layer. Typically, cooling is applied

immediately after the selective sintering so that the applied heat does not penetrate and/or leak into masked non-sintered areas over time. Typically, cooling is applied with one or more air-knives. Typically, nitrogen gas is used for cooling.

According to some embodiments of the present invention, a building tray is
5 advanced on a precision stage to each of the plurality of stations including the powder dispensing station, the powder spreading station, the printing station, the compacting station, the sintering station and the cooling station. In some exemplary embodiments, the tray reverses directions when leaving the printing station and compaction, heating
10 sintering and cooling is performed as the tray moves back in a direction toward the powder dispensing station. Typically, this back and forth motion is repeated for each layer printed.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the
15 following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

Referring now to the drawings, FIG. 1 shows a simplified schematic drawing and FIG. 2 shows a simplified block diagram of an exemplary 3D printing system in
20 accordance with some embodiments of the present invention. According to some embodiments of the present invention, a 3D printing system 100 is integrated on a working platform 500. According to some embodiments of the present invention, working platform 500 includes a precision stage 250 on which a building tray 200 is advanced through a plurality of stations for printing an object 15 one layer at a time.
25 Typically, precision stage 250 is a linear stage, e.g. an X-Z stage providing motion along a single axis, e.g. an X axis while building a layer and also providing motion in the vertical direction (Z-axis) for adjusting height of tray 200, e.g. lowering tray 200 as each new layer is added.

According to some embodiments of the present invention, working platform 500
30 includes a powder dispensing station 10 for dispensing a powder layer on tray 200, a powder spreading station 20 for spreading a layer of dispensed powder, a printing platform station 30, for printing a mask on the layer of powder according to a mask

pattern, a compacting station 40 for compacting the layer of powder prior to sintering, a sintering station 50, for sintering the compacted layer and a cooling station for cooling the sintered layer. Typically for each layer printed tray 20 advances to each of the stations and then repeats the process until all the layers have been printed. In some exemplary embodiments, tray 20 is advanced in one direction with stops at powder dispensing station 10, powder spreading station 20 and printing platform station 30 and then reverses direction back toward powder dispensing station 10 with stops at compacting station 40, sintering station 50 and cooling station 60 for completing a current layer. According to some embodiments of the present invention, a controller 300 controls operation of 3D printing system 100 and coordinates operation of each of the stations with positioning and/or movement of tray 200 on precision stage 250. Typically, controller 300 includes and/or is associated with memory and processing ability.

In some exemplary embodiments, one or more stations along a path of precision stage 250 are supported on rails extending along the path and/or by one or more bridges, e.g. bridge 47 positioned over working platform 500. In some exemplary embodiments, compacting station 40 includes a piston 42 positioned below working platform 500 that is operated to raise tray 200 toward a flattening surface positioned above tray 200 as is described in further detail herein below.

Typically, working platform 500 is covered with a hood 550. According to some embodiments of the present invention, a gas source 510 includes an inlet 520 through hood 550 and provides a positive flow of non-combusting gas to the working area under hood 550 for safety, e.g. to avoid possible combustion of the materials during the manufacturing process. Typically, gas source 510 is nitrogen.

Reference is now made to FIG. 3 showing a simplified block diagram of powder dispensing station in accordance with some embodiments of the present invention. Typically, powder dispensing station 10 includes a container 12 storing powder 55, a pump 14 for extracting a defined quantity and/or volume of powder 55 through a tube 16 and onto tray 200. In some exemplary embodiments, the defined volume is adjusted over the course of the building process based on feedback from system 100 and/or controller 300. In some exemplary embodiments, a thickness of a layer after compaction is monitored and the defined volume dispensed by powder dispensing station 10 is

adjusted responsive to a thickness of the compacted layer(s). Optionally, powder 55 is dispensed while tray 200 is in motion so that powder 55 is spread over a length of try 200. In some exemplary embodiments, powder dispensing station 10 is adapted to deliver powder aluminum. In other exemplary embodiments, other metals and/or alloys
5 are stored and delivered by powder dispensing station 10. Optionally, container 12 includes a plurality of components that are mixed. Optionally, container 12 includes a mechanism for mixing contents stored.

Reference is now made to FIG. 4 showing a simplified block diagram of powder spreading station in accordance with some embodiments of the present invention.
10 Typically, spreading station 20 includes a motorized roller 25 rotatably mounted on an axle 24. In some exemplary embodiments, a linear motor 22 engages axle 24 and moves back and forth for spreading an even layer of powder. In some exemplary embodiments, a height of table 200 is adjusted, e.g. moved up/down with a Z stage in order to obtain a defined layer thickness. In some exemplary embodiments, a powder
15 layer of about 150 μm thick, e.g. 100 μm to 200 μm thick is spread with roller 25. In some exemplary embodiments, a thickness of a layer after compaction is monitored and a height of table 200 is adjusted to alter a thickness of a current layer to compensate for drifts in layer thicknesses of one or more previous layers.

In some exemplary embodiments, roller 25 extends substantially over an entire
20 length of tray 200 and only one pass of the roller is required to spread the powder. Alternatively, roller 25 extends over less than the entire length of tray 200 and a plurality of passes is required. Optionally, roller 25 is operated while tray 200 is in motion. Optionally, roller 25 is held at a height above tray 200 and is lowered as required for spreading.

Reference is now made to FIG. 5 showing a simplified block diagram of an exemplary printing system in accordance with some embodiments of the present invention. According to some embodiments of the present invention, print platform station 30 includes a direct inkjet printing head 35 that deposits ink 32 based on a generated mask pattern data 39. In some exemplary embodiments, print head 35 is
30 stationary and printer controller 37 together with system controller 300 control timing for depositing ink as tray 200 advances under print head 35. Optionally, printing head 35 is mounted on a Y axis stage and moves in a direction perpendicular to tray 200.

Alternatively, tray 200 is stationary during printing and printing head 35 is supported by an X, Y or XY stage for moving print head 35 in one or more directions. Typically, print head 35 includes an array of nozzles through which ink is selectively deposited.

According to some embodiments of the present invention, print head 35 forms a mask and/or a negative of the object to be constructed. Typically, the mask pattern is defined by mask data 39 that is typically stored in memory. Typically, the mask data is generated by a computer aided design (CAD) software program or the like. Optionally, a pixel size of the printed pixel is in an order of magnitude of 50 μ m, e.g. between 50 μ m-300 μ m.

According to some embodiments of the present invention, ink 32 includes particles suspended in a liquid carrier. Typically, the liquid carrier is oil or oil based. According to some embodiments of the present invention, the glass and/or silicon particles and/or frit have an average diameter that is less than 1 μ m, e.g. 500-600nm. In some exemplary embodiments, the concentration of the glass frit in the ink solution is up to 50%. Typically, the particles are formed from an insulating material that provides insulating surfaces while the liquid carrier penetrates the powder layer. Typically, the insulation provided by ink 32 only retards a rise in temperature of the masked portion. Typically, the glass frit is significantly smaller than the powder particles, e.g. the powder particles have a diameter of about 40 μ m while the glass frit has a diameter of about 500-600nm.

Reference is now made to FIG. 6 showing a simplified schematic representation of an object layer including a printed mask in accordance with some embodiments of the present invention. According to some embodiments of the present invention, a powder layer 151 includes a mask portion 327 on which ink 32 is deposited and an unmasked portion 528 where no ink is deposited. Typically, unmasked portion only includes powder material and does not include additives. It is noted that although mask portion 327 is shown near the edges in FIG. 6, the mask portion can appear in other portions of layer 151.

Typically, ink 32 includes glass frit 322 that collects on the upper surface of the masked portion and oil 324 that penetrates through the powder layer 151. Typically, oil 324 has an evaporation temperature that is lower than a melting temperature of the powder in powder layer 151. According to some embodiments of the present invention,

both frit 322 and oil 324 provide for retarding sintering of masked portion 327. Optionally, frit 322 provides an insulating upper surface and oil 324 soaks the interior portion of powder layer 151 so that any heat penetrating through frit 322 is directed toward evaporating oil 324. In some exemplary embodiments, the duration and temperature of sintering is defined to provide for sintering unmasked portion 528 without sintering masked portion 327.

Reference is now made to FIGS. 7A and 7B showing a simplified schematic drawings of an exemplary die compaction station shown in a released and compressed state respectively in accordance with some embodiments of the present invention.

According to some embodiments of the present invention, a powder layer is compacted prior to sintering. According to some embodiments of the present invention, as the compaction process is performed per each layer, the compaction station generates a die per layer.

In some exemplary embodiments, die compaction is performed after printing a mask pattern on the powder layer. Alternatively, die compaction is performed prior to printing or performed both before and after printing. According to some embodiments of the present invention, the compaction station includes a piston 42 that is operative to provide the compaction pressure for compacting a powder layer 151. According to some embodiments of the present invention, during compaction, piston 42 is raised through a bore 49 in working platform 500 or precision stage 250 and lifts building tray 200 towards a die and/or surface 45 positioned above tray 200.

In some exemplary embodiments, tray 200 is secured to one or more linear guides 41 that ride along linear bearings 46 as piston 42 elevates and/or lowers tray 200. Optionally, tray 200 is lifted against one or more compression springs 47. In some exemplary embodiments, gravitational force as well as springs 47 provide for lowering piston 42 after compacting layer 151.

According to some embodiments of the present invention, a pressure of up to 100 MPa is applied to compact a powder layer. Typically, the applied pressure provides for removing air and bringing powder layer 151 past its elastic state so that permanent deformation of the layer is achieved. Optionally, the compaction provides for removing 95% to 99% of the air in layer 151. Optionally, compaction reduces the thickness of a layer by around 50%.

In some exemplary embodiments, warm die compaction is performed and upper surface 45 of die 43 and/or the entire die 43 is heated, e.g. pre-heated with a heating element 44 during compaction. Typically, when heating surface 45 and/or die 43, layer 151 can reach its plastic and/or permanent deformation state with less pressure applied on the layer. Optionally, upper surface 45 is heated to a temperature of 150° C, e.g. 150° - 300° C. Typically there is a tradeoff between compaction temperature and pressure. Increasing the temperature during compaction may provide for reaching plastic deformation at lower pressure but also may lead to undesired evaporation of ink deposited in the layer. On the other hand, reducing temperature of upper surface 45 may reduce the energy efficiency of the compaction since higher pressure may be required. Typically, the pressure and temperature applied is defined based on the material of the powder and the thickness of layer 151.

In some exemplary embodiments, table 200 is water cooled to provide stable temperature of layer 152. Optionally, table 200 includes a plurality of passages and/or channels 205 through which water and/or other coolant flow is introduced. Optionally, temperature and flow rate of the fluid through passages 205 is defined to maintain table 200 at a desired temperature, e.g. up to about 10° C above ambient temperature. Typically, this cooling mechanism is also applied during sintering.

In some exemplary embodiments, e.g. when aluminum powder is used, the compaction is operative to break up the oxide layer, e.g. the alumina on the powdered particles. Typically, exposing the aluminum promotes direct engagement between aluminum particles of the powdered material and improves bonding of the particles during sintering.

According to some embodiments of the present invention, height of the object, e.g. height of one or more layers of the object as it is being built, is detected, determined and/or sensed at the compaction station. Optionally, a height of tray 200 while pressed in die 43 and/or against surface 45 is detected. According to some embodiments of the present invention, controller 300 (FIG. 2) monitors the height and/or the change in height and provides input to powder dispensing station and/or Z stage of tray 200 when adjustments in layer thicknesses are required to compensate for a drift from a desired height and/or change in height. In some exemplary embodiments, controller 300 uses one or more lookup tables stored in memory to control adjustments in layer thicknesses.

Reference is now made to FIGS. 8A and 8B showing a simplified schematic drawings of an exemplary anti-peeling mechanism for a compacting system shown in a compacting state and a post compacting state respectively both in accordance with some embodiments of the present invention. According to some embodiments of the present invention, a foil and/or film 49 supported on rollers 47 is positioned between layer 151 and upper surface 45 during compaction. Optionally, the foil has a thickness between 0.1-0.3 mm, e.g. 0.2 mm. Optionally, the foil is a stainless steel 304L or 316L foil. Typically, foil 49 protects upper surface 45 from accumulating powder and ink particles and also prevents substantial peeling of layer 151 during separation of upper surface 45. In some exemplary embodiments, foil 49 is wound with rollers 47 to stretch foil 49 on surface 45 by prior to compaction and then foil 49 is partially unwound as tray 200 is lowered. The extra length of foil 49 due to unwinding allows foil 49 to gradually detach from layer 151 as layer 151 is lowered. Optionally, the separation provided by pulling one or two opposite edges of foil 49 provides for separation by line separation instead of full surface separation. The present inventor has found that this gradual detachment of the foil avoids peeling and/or loss of material from layer 151 on foil 49.

Reference is now made to FIG. 9 is a simplified schematic drawing of a cleaning mechanism for a compacting system in accordance with some embodiments of the present invention. According to some embodiments of the present invention, compacting station 40 includes a cleaning unit 411 for cleaning foil 49 (or surface 45 when foil 49 is not used). In some exemplary embodiments, cleaning unit 405 includes a rotation brush 414 that sweeps over foil 49. Optionally, brush 414 is partially covered by a collection hood 415 and powder is removed by brush 414 is removed with a suction port 416. In some exemplary embodiments, cleaning unit is driven along a rail 417 that mounted on working platform and/or frame 500.

Reference is now made to FIG. 10 is a simplified schematic drawing of exemplary sintering station in accordance with some embodiments of the present invention. According to some embodiments of the present invention, an object 15 is sintered one layer at a time with a sintering roller 519. According to some embodiments of the present invention, sintering roller 519 is a high thermal mass roller. Optionally, sintering roller 519 is formed from hard polished steel. In some exemplary embodiments, sintering roller 519 is heated to a temperature that is slightly above a

melting temperature of the powder material, e.g. 0° - 80° C above the melting temperature and is pressed against the layer with a pressure of about 20-180N/cm of roller length. Optionally, sintering roller 519 rolls over layer 151 as tray 200 advances with stage 250. According to some embodiments of the present invention, the mask
5 applied on layer 151 with ink 32 acts as a temporary insulator so that only a selected portion of layer 151 that does not include ink 32 is sintered as sintering roller 519 rolls over layer 151. Typically, the powder in the masked portions, e.g. portions 327 (FIG. 6) remains intact with optionally, the absorbed oil 324 evaporating as a result of sintering.

According to some embodiments of the present invention, a diameter of sintering
10 roller 519 is defined so that a circumference of sintering roller 519 is larger than a length of tray 200 and/or a length over which sintering roller 519 is required to roll on a layer 151. In some exemplary embodiments, roller is heated using an array of electric heaters 521, e.g. finger type electric heaters. Typically, sintering roller 519 provides uniform heating surface of between 600° - 800° C. Typically sintering roller 519 rolls
15 over layer 151 in much less than one rotation, so that potential local cooling of sintering roller 519 due to contact with layer 151 does not adversely affect the sintering process. In addition, any debris accumulated on sintering roller 519 is not reintroduced on layer 151. In addition, the electrical cables that support the heating fingers are not typically twisted. In some exemplary embodiments, sintering roller 519 is pressed down on layer
20 151 with a piston or pistons 520 that presses down on an arm 518 connected to an axle of roller 519.

Optionally, plurality of passages 205 provide for maintaining table 200 and layers close to table 200 at a desired temperature, e.g. up to about 10° C above ambient temperature during sintering. During the sintering process, heat that typically spreads
25 from the top surface (held at a high temp) toward table 200 (held at relatively low temp) and the fluid typically absorbs the heat. Typically, fluid flow through passages 205 is circulatory and passes a heat exchange unit that cools the fluid before reentering passages 205. According to some embodiments of the present invention, roller 519 is cleaned after sintering, e.g. after each layer is sintered. In some exemplary
30 embodiments, a brush 514 brushes against roller 519. Optionally, brush 514 is partially covered by a collection hood 515 and powder is removed by brush 514 is removed with

a suction port 516. Optionally, rotation of roller 519 during cleaning is initiated by a piston 25 that moves an arm 24 that contacts roller 519.

In some exemplary embodiments, for a post compaction layer thickness of 50 μm and post compaction mask thickness of 100 μm , the required time for full sintering may be around 0.2 msec. In such an exemplary case, a linear speed for roller 519 may be 1 m/sec and the roller rotation speed may be 20 rad/sec.

According to some embodiments of the present invention, layer 151 and/or object 15 is immediately cooled in cooling station 60 after sintering. Optionally, cooling station 60 is positioned substantially close to the sintering station so that cooling may be applied immediately after sintering. According to some embodiments of the present invention, a pattern of nitrogen air knives 65 are used to provide a jet stream of gas for cooling layer 151 and/or object 15.

Reference is now made to FIG. 11 is a simplified schematic drawing of another exemplary sintering station in accordance with some embodiments of the present invention. According to some embodiments of the present invention, a foil 59 provides an interface between roller 519 and layer 151. In some exemplary embodiments, secondary rollers 57 stretch foil 59 over a length while sintering roller 519 pushes down on layer 151 and rolls along layer 151. Typically, the touching point between foil 59 and the post compaction layer varies while the roller 519 advances. Typically, sintering roller 519 and secondary rollers 57 rotate together over foil 59. Optionally, the low lift of the foil due to secondary rollers 57, provides a smooth separation between layer 151 that may prevent peeling and/or sticking of particles from layer 151 on foil 59. Optionally, foil 59 is supported by a frame with spring mountings 53 allowing foil 59 to be held with tension.

According to some embodiments of the present invention, sintering station includes a cleaning unit 511 that operates in a manner that is similar to cleaning unit 411 described herein above. Typically, cleaning unit includes a brush 514 that is partially covered by a collection hood 515. Typically, debris collected by brush 414 is removed with suction via a suction port 416.

Typically, the mask generates a delay in the sintering process but does not prevent sintering under all circumstances. There is potential for spontaneous sintering in the masked areas of a current layer and/or previous layers. Masked areas provide support

for subsequent layers and the masked area in a lower layer may be subject to spontaneous sintering when covered by an unmasked area. According to some embodiments of the present invention, applying an insulation coating, e.g. frit above a threshold thickness can help prevent spontaneous sintering. The present inventor has
5 also found that maintaining a powder layer below a threshold thickness can also help prevent spontaneous sintering below the mask coating. In some exemplary embodiments, both the thickness of the frit layer and the thickness of the powder layer are controlled to avoid spontaneous sintering.

Reference is now made to FIG. 12 is a simplified flow chart of an exemplary
10 method for constructing an object by 3D printing in accordance with some embodiments of the present invention. According to some embodiments of the present invention, the method includes dispensing powder layer on a building tray (block 805) and spreading the powder layer to obtain and uniform layer of powder (block 810). According to some embodiments of the present invention, a mask that defines a
15 boundary of the object is printed over the powder layer (block 815). According to some embodiments of the present invention, the ink used in the printing process is formed from material that provides for excluding the printed area from sintering during a subsequent sintering process. According to some embodiments of the present invention, prior to sintering, the printed layer is compacted (block 820) to prepare the layer for
20 sintering. Typically, the compaction provides for remove air from the printed layer to improve heat conduction during sintering. Optionally, the compaction also provides for breaking an oxide crust that typically forms on particles of the metal powder, e.g. aluminum powder. Typically, heat conduction through the layer of powdered metal is more uniform after breaking up the oxide crust. According to some embodiments of the
25 present invention, sintering (block 825) is performed on a post compacted layer. Optionally, sintering is performed with a sintering roller. According to some embodiments of the present invention, the layer is immediately cooled after sintering (block 830). Typically, cooling prevents heat accumulated during sintering from spreading in masked areas of the layer. According to some embodiments of the present
30 invention, the method described in blocks 805-830 is repeated for each layer printed. Typically, after all the layers have been printed, the final object can be removed from the powder bed. Typically, no additional post finishing procedures are required.

The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to".

The term "consisting of" means "including and limited to".

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

WHAT IS CLAIMED IS:

1. A system for building a three dimensional object comprising:
 - a powder delivery station for applying a layer of powder material on a building tray;
 - a digital printing station for printing a mask pattern on the layer, wherein the mask pattern defines a negative of a portion of the layer to be sintered;
 - a sintering station for selectively sintering the portion of the layer that is defined by the mask to be sintered; and
 - a stage for repeatedly advancing the building tray to each of the powder delivery station, digital printing station and sintering station to build a plurality of layers that together form the three dimensional object.
2. The system according to claim 1 comprising a die compaction station for compacting per layer of powder material, wherein the compaction station includes a die for receiving the layer.
3. The system according to claim 2, wherein the die compacting station includes a heating element for warming a surface of the die that interfaces with the layer.
4. The system according to claim 2 or claim 3, wherein the die compacting station is operable to apply up to 100 MPa of pressure on the layer.
5. The system according to any one of claims 2-4, wherein the die compacting station includes a lifting system for lifting the building tray toward the die.
6. The system according to any one of claims 2-5, wherein the compacting station includes an anti-peeling mechanism, the anti-peeling mechanism including a foil positioned between the die, wherein the foil is supported by two opposite edges to allow bowing of the foil during separation between the building tray and the die.

7. The system according to any one of claims 2-6, comprising a controller for adjusting height of the building tray in a subsequent layer responsive to a thickness of the layer after compaction.
8. The system according to any one of claims 1-7 comprising a cooling station for cooling the layer after sintering.
9. The system according to claim 8, wherein the cooling station includes air knives for providing jet stream of gas.
10. The system according to any one of claims 1-9, wherein the digital printing system is operable to dispense ink including frit suspended in a liquid carrier.
11. The system according to claim 10, wherein frit is formed from particles having a diameter of between 500 nm to 1 μ m.
12. The system according to any one of claims 1-11, wherein the sintering station includes a high thermal mass roller for sintering the layer.
13. The system according to claim 12, wherein the high thermal mass roller is heated to 0° - 80° C above a melting temperature of the powder.
14. The system according to claim 12 or claim 13, wherein the high thermal mass roller applies a pressure in the order of magnitude of 20-180 N/cm of roller length.
15. The system according to any one of claims 12-14, wherein the sintering station includes an anti-peeling mechanism, the anti-peeling mechanism including a foil positioned between the high thermal mass roller and the layer.
16. The system according to any one of claims 1-11, wherein the sintering station includes an array of vertical-cavity surface-emitting lasers (VCSEL) that swept over the layer for pre-heating and/or sintering.

17. The system according to any one of claims 1-16, wherein the building tray includes at least one channel running substantially parallel to a surface of the tray on which the layer is positioned, through which fluid is introduced for cooling the building tray.
18. The system according to any one of claims 1-17, wherein the powder is metal powder.
19. The system according to claim 18 wherein the powder is aluminum and/or aluminum alloy powder.
20. A method for building a three dimensional object comprising:
spreading a layer of powder on a building tray;
printing a mask pattern on the layer, wherein the mask pattern defines a negative of a portion of the layer to be sintered, the mask pattern for the layer is defined by mask pattern data defining a shape of the three dimensional object;
sintering the portion of the layer that is defined by the mask to be sintered; and
repeating the spreading printing and sintering until the three dimensional object is completed.
21. The method according to claim 20, wherein the mask pattern is printed with a digital printer that dispenses ink.
22. The method according to claim 21, wherein the ink provides an insulating coating on a masked portion of the layer.
23. The method according to claim 21 or claim 22, wherein the ink includes a liquid carrier selected to have an evaporation temperature that is lower than a melting temperature of the powder.
24. The method according to any one of claims 20-23 comprising performing die compaction per layer prior to the sintering.

25. The method according to claim 24, comprising performing warm die compaction.
26. The method according to claim 24 or claim 25, wherein the pressure applied on the layer during compaction is up to 100 MPa.
27. The method according to any one of claims 24-26, wherein the die compaction is performed per layer after the printing of the layer.
28. The method according to any one of claims 24-27 comprising cooling the building tray during the die compaction.
29. The method according to any one of claims 20-28, wherein the sintering is performed by passing a heat source over a length of the building tray, wherein the heat source provides heat along a narrow strip that extends over a width of the building tray.
30. The method according to any one of claims 20-28, wherein the sintering is performed with a high thermal mass roller rolling over the layer.
31. The method according to claim 30, wherein the high thermal mass roller is heated to 0° - 30° C above a melting temperature of the powder during the sintering.
32. The method according to claim 30 or 31, wherein the high thermal mass roller is pressed against the layer with a pressure in the order of magnitude of 10 N/cm of roller length.
33. The method according to any one of claims 20-32, comprising cooling the building tray during sintering.
34. The method according to any one of claims 20-33, comprising cooling the layer immediately after the sintering, wherein the cooling is performed with a jet stream of gas.

35. The method according to any one of claims 20-34, comprising adjusting height of the building tray responsive to a thickness of one or more previous layers of the object being built.
36. A method for building a three dimensional object comprising:
providing a layer of powder on a building tray;
performing die compaction on the layer;
sintering the layer that is die compacted by selective laser sintering or selective laser melting; and
repeating the providing, the die compaction and the sintering per layer until the three dimensional object is completed.
37. The method according to claim 36, comprising performing warm die compaction.
38. The method according to claim 36 or claim 37, wherein the pressure applied on the layer during compaction is up to 100 MPa.

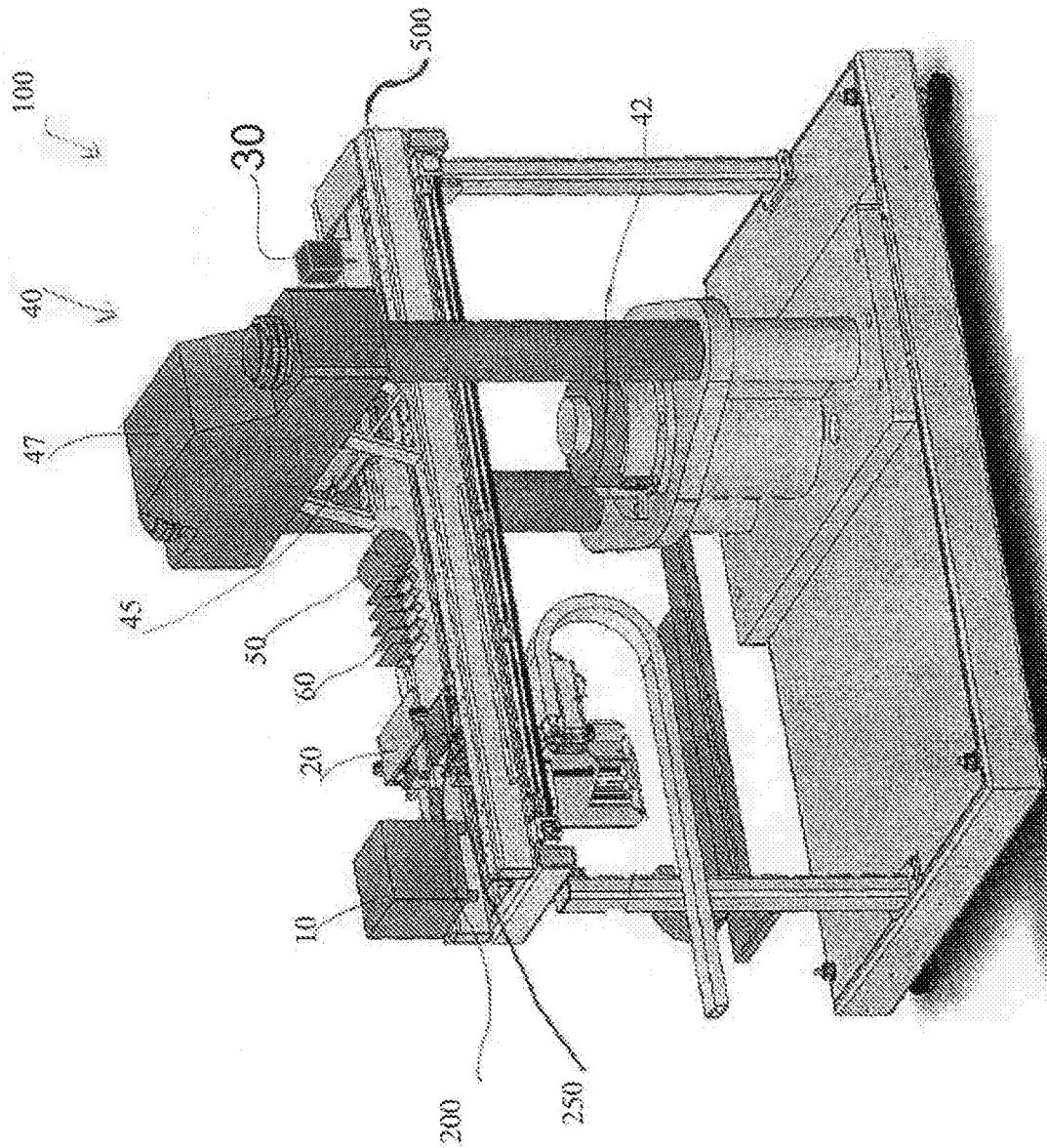
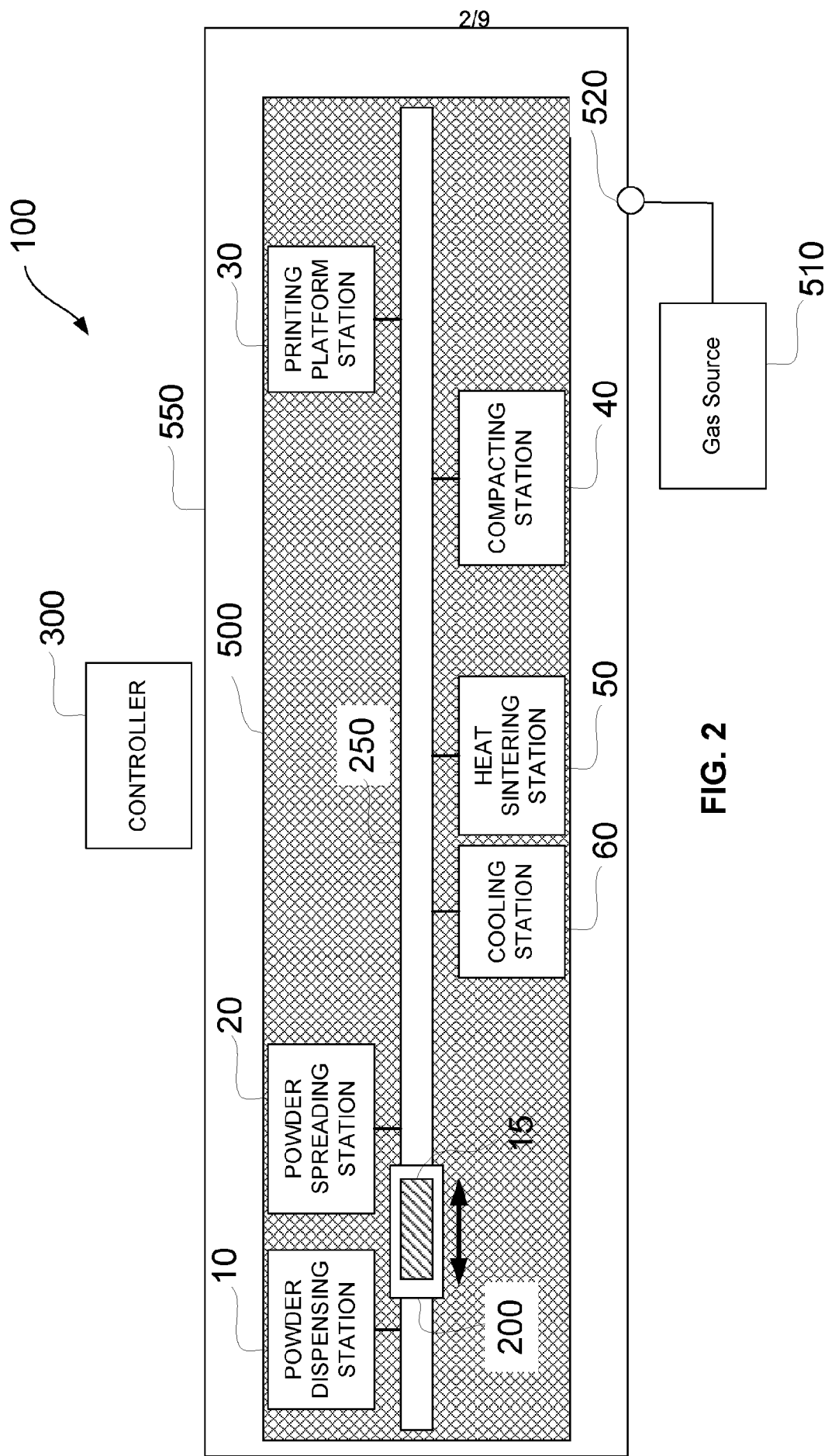


FIG. 1



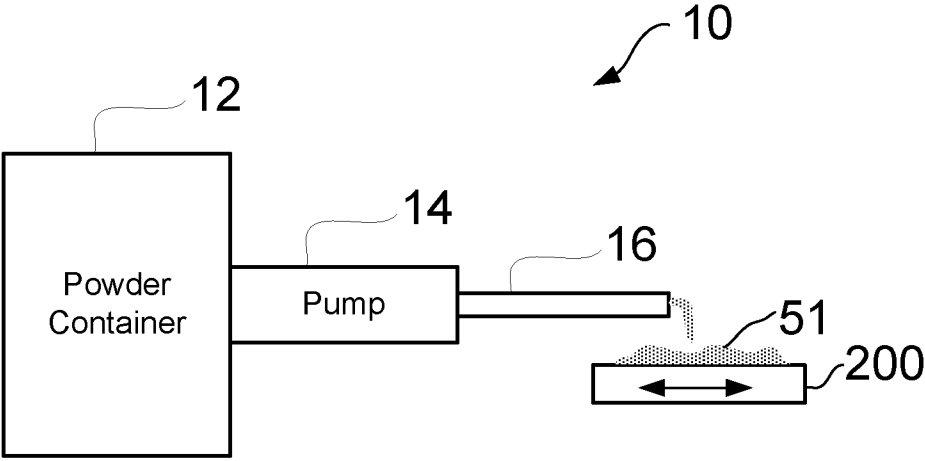


FIG. 3

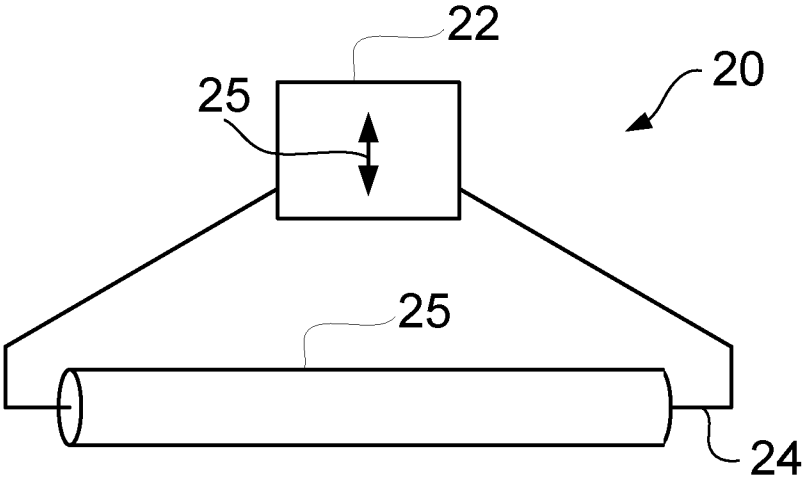


FIG. 4

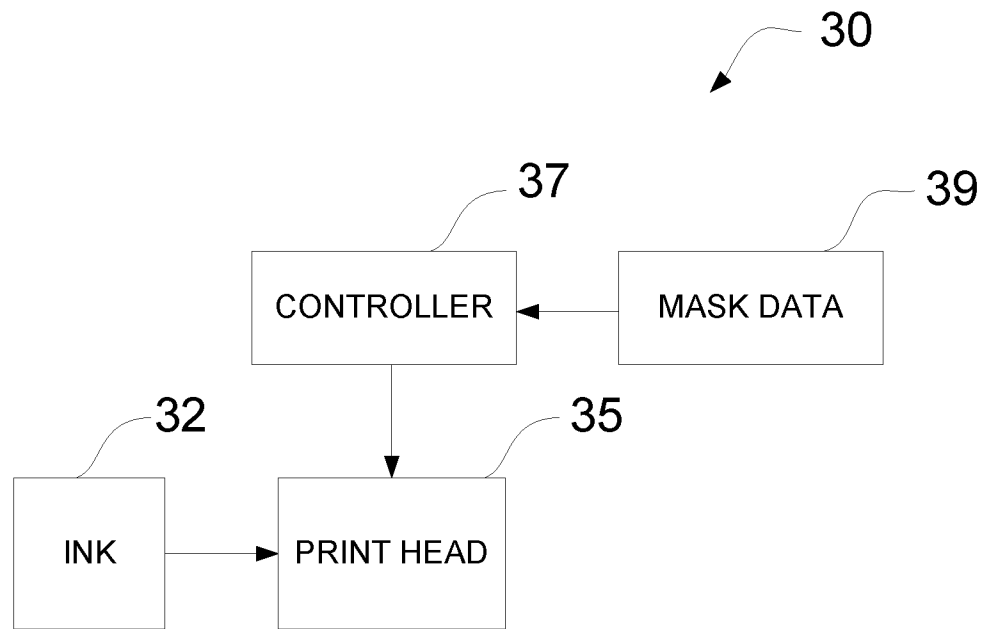


FIG. 5

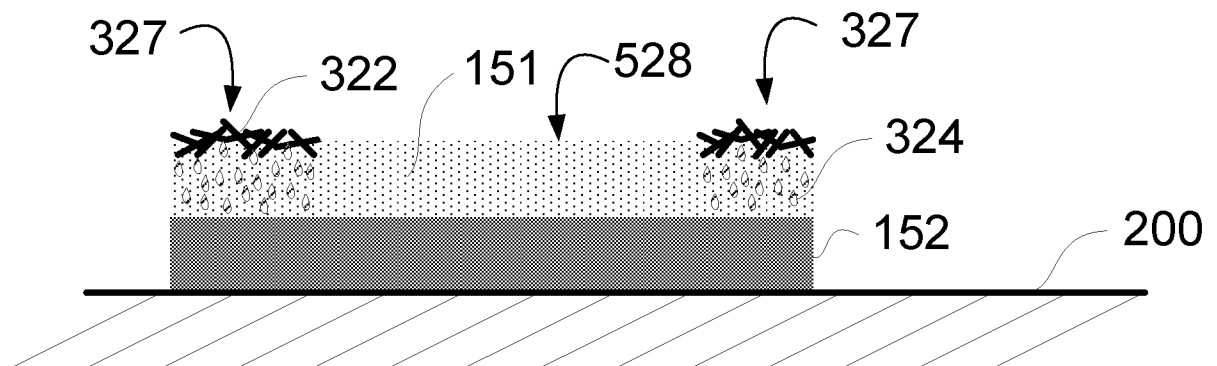


FIG. 6

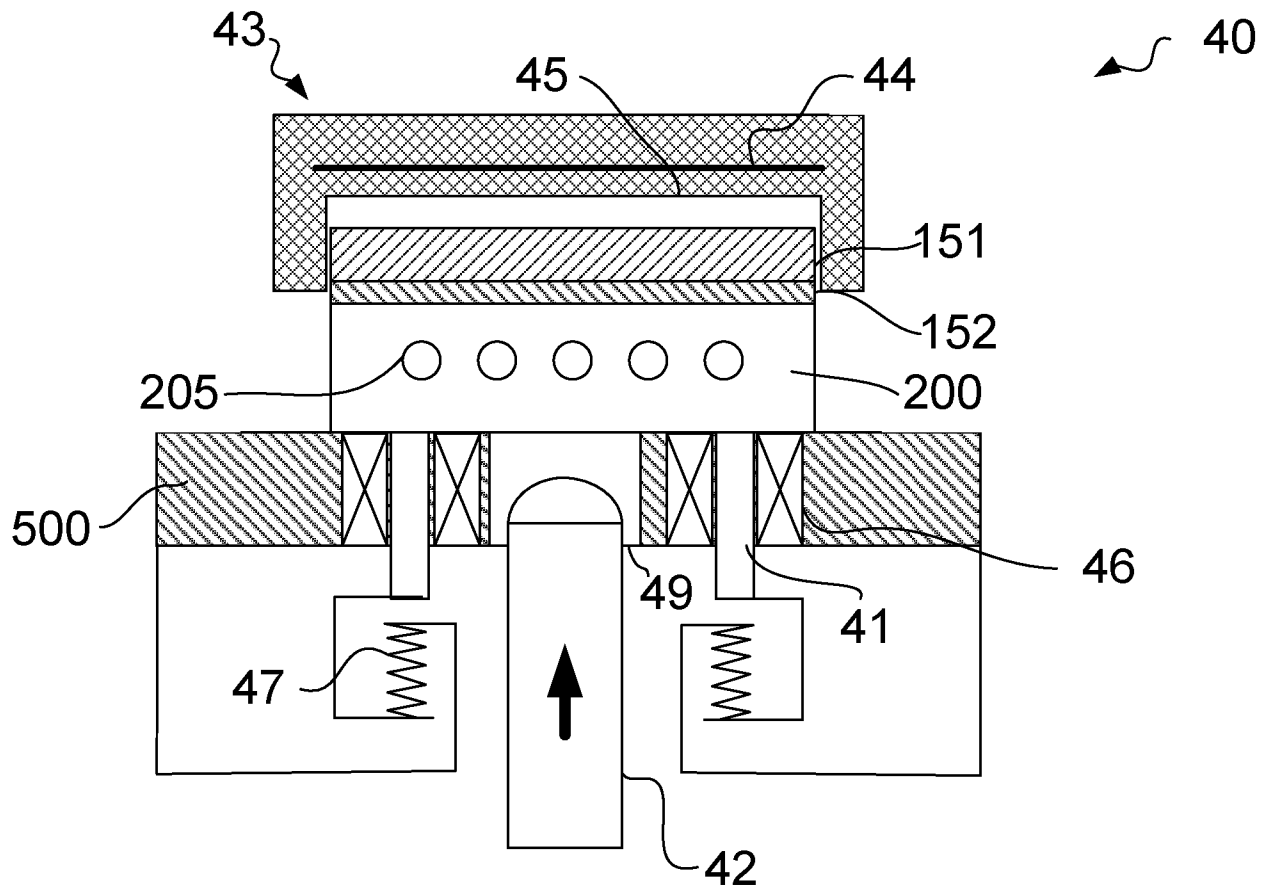


FIG. 7A

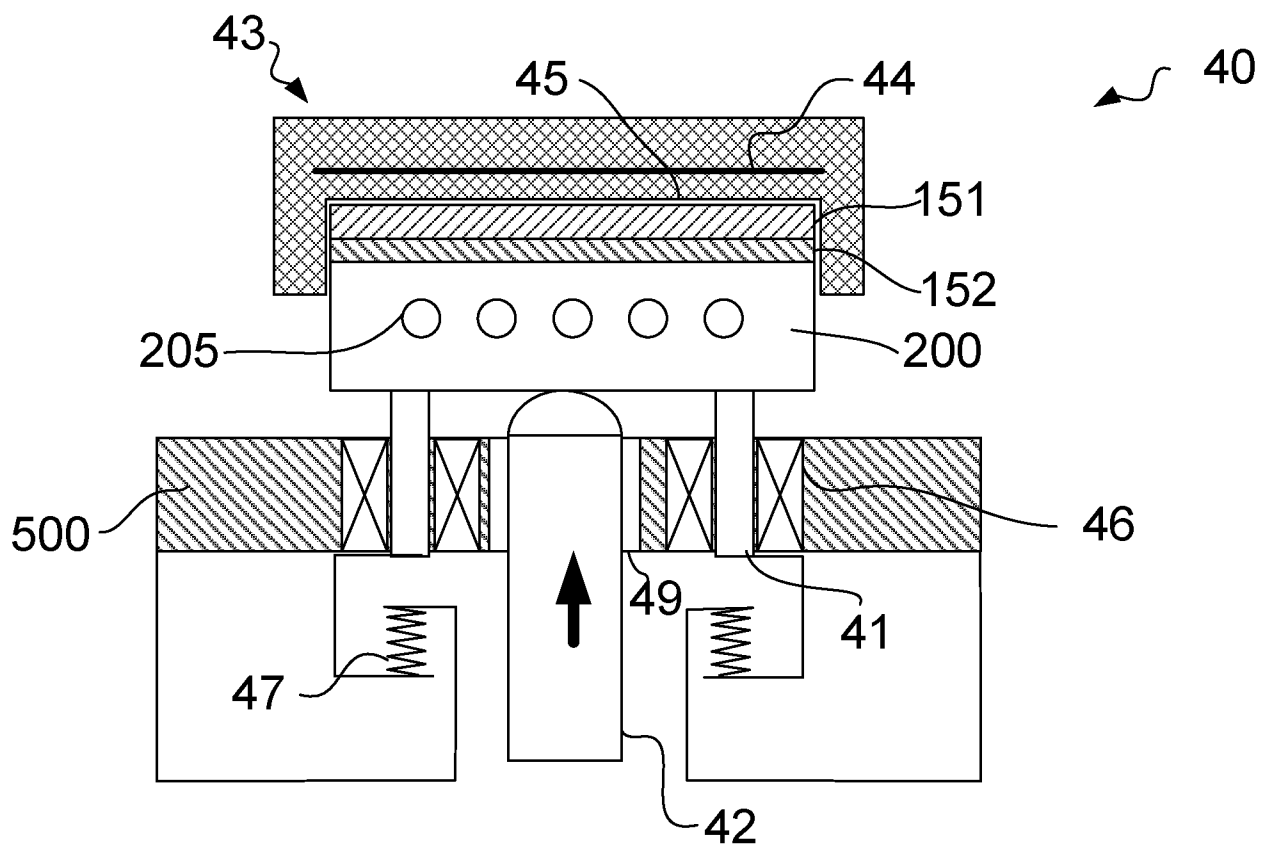


FIG. 7B

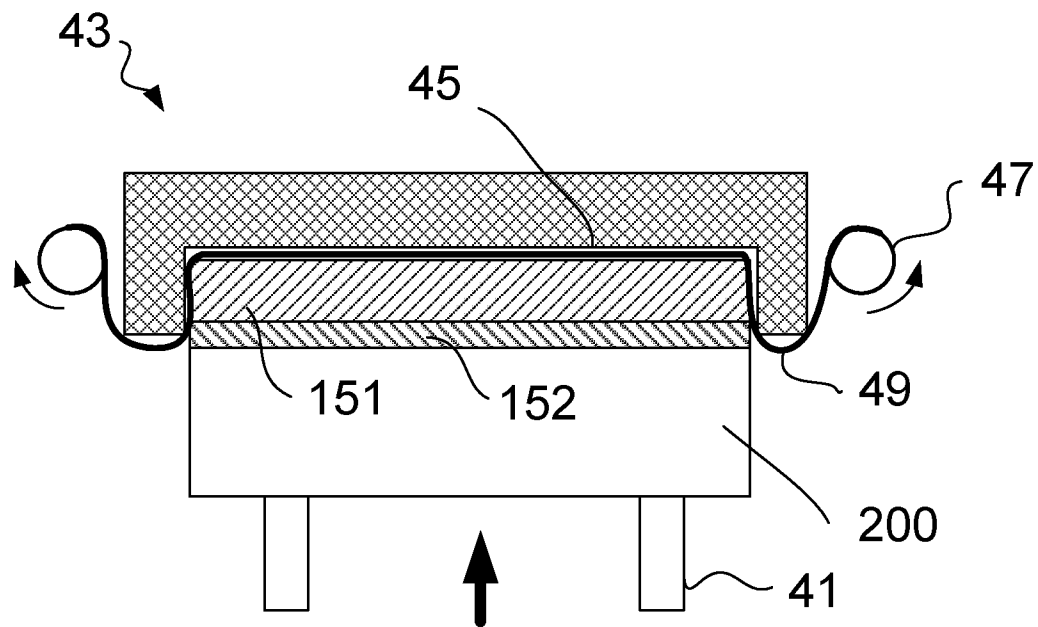


FIG. 8A

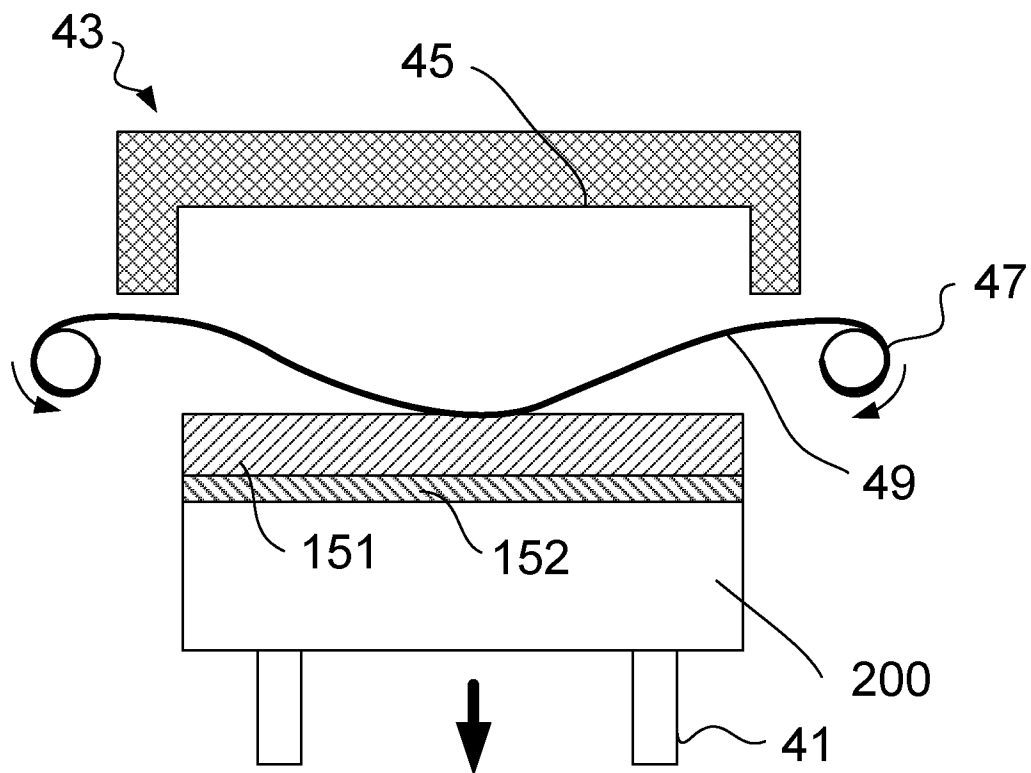
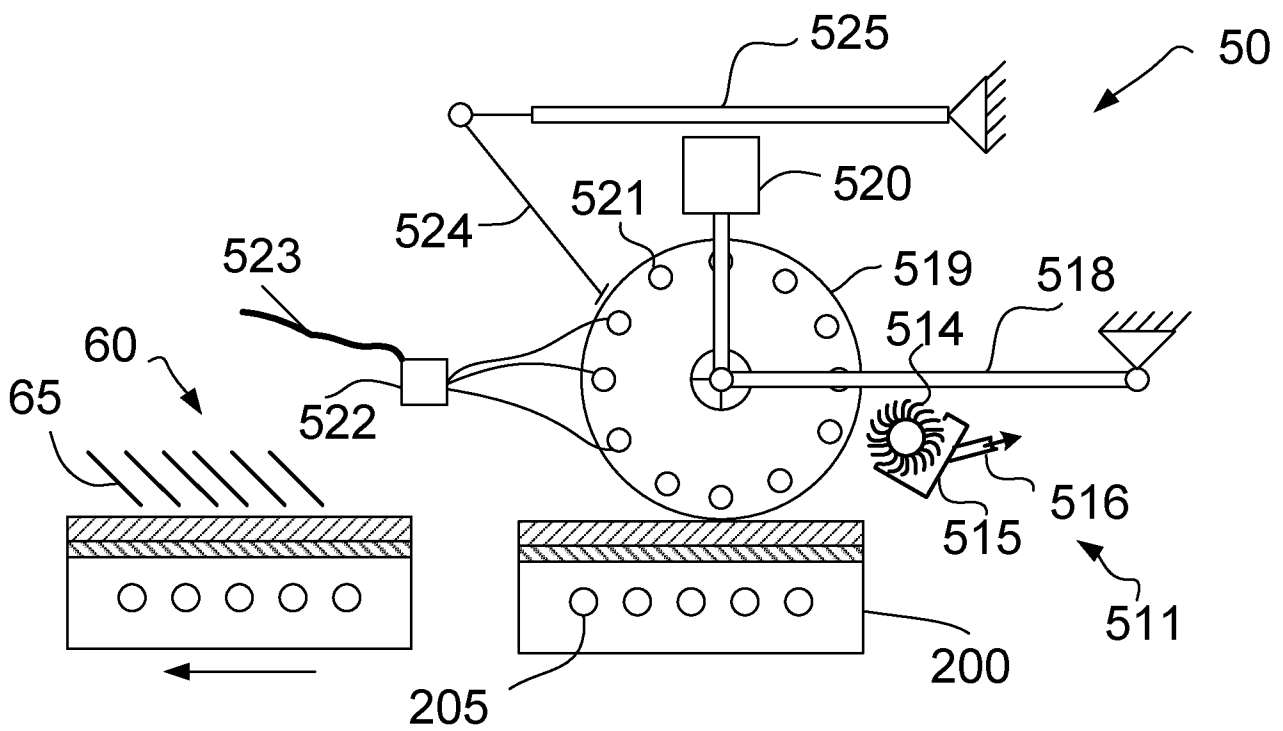
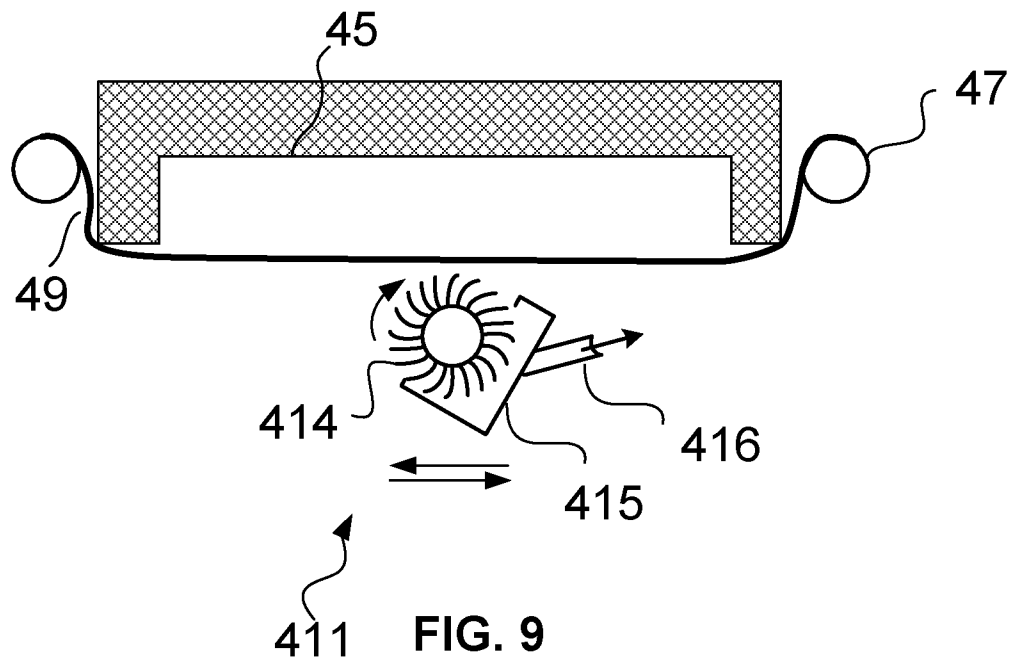


FIG. 8B



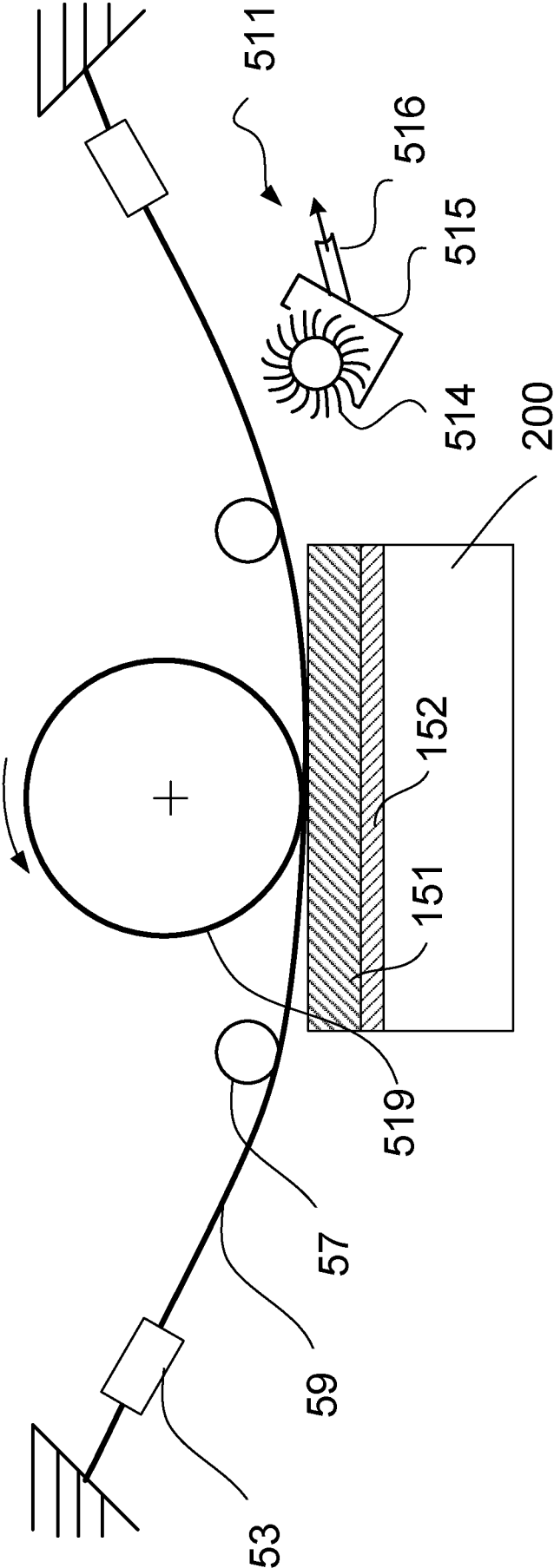
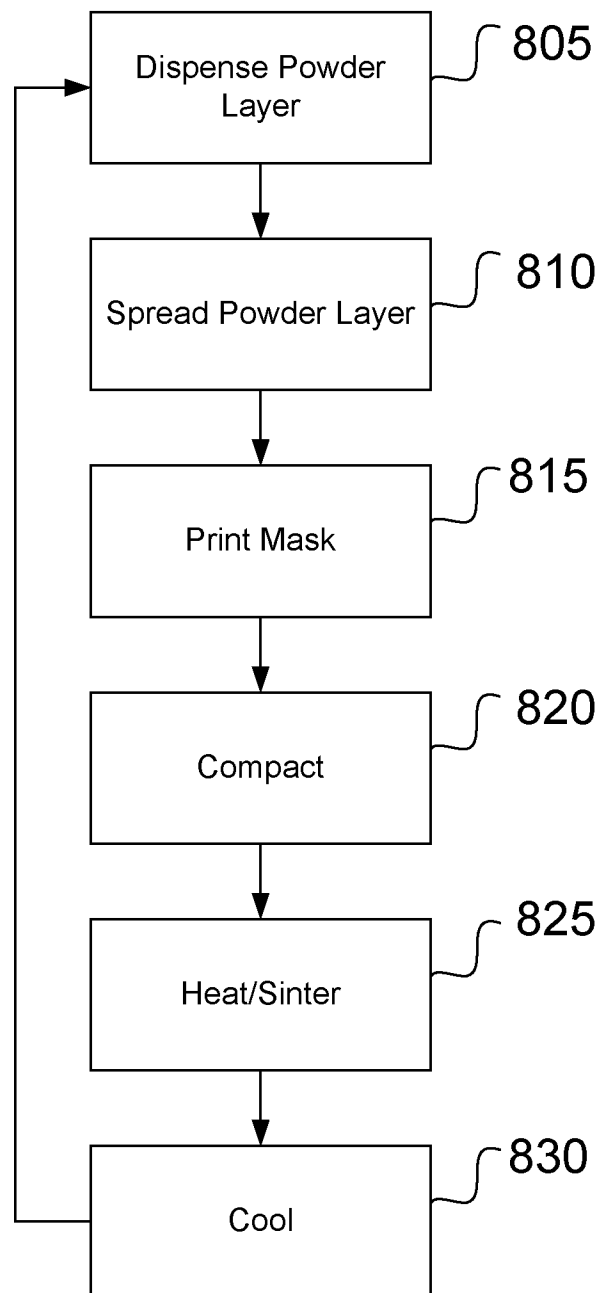


FIG. 11

**FIG. 12**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2015/050478

A. CLASSIFICATION OF SUBJECT MATTER IPC (2015.01) B22F 7/00, B22F 3/10, B22F 3/16, B22F 3/18, B29C 67/00, B33Y 10/00, B33Y 30/00 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) IPC (2015.01) B22F, B29C 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) Databases consulted: Google Patents, Google Scholar, FamPat database Search terms used: Rapid manufacturing , 3D printing , sintering , heated roller , inkjet , powder , mask , die press, compaction , stage		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6589471 B1 KHOSHNEVIS B. 08 Jul 2003 (2003/07/08) abstract ; Fig. 3 ; col. 1 lines 56-67 ; col. 3 lines 27-54 ; col. 4 lines 12-13 , 19-20 , 36-43	20-23,29
Y		1,8-11,16-19,34
X	US 2004018107 A1 KHOSHNEVIS B. 29 Jan 2004 (2004/01/29) Para. [0010],[0014]-[0015],[0017]-[0018],[0025]-[0026]	20-24,27
Y		1-5,7-11,16-19,25,26,28,33-35,37,38
X	US 2008111271 A1 KHOSHNEVIS B. 15 May 2008 (2008/05/15) Para. [0023],[0042],[0043],[0044],[0049] ; Fig . 1	20-23,29
Y		1,8,9,16-19,33,34
☒ 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 09 Aug 2015		Date of mailing of the international search report 13 Aug 2015
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616		Authorized officer GUTMAN Ariel Telephone No. 972-2-5657816

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2015/050478

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013021173 A1 LOUGHBOROUGH UNIVERSITY 14 Feb 2013 (2013/02/14) Fig. 3 ; page 18 lines 8-23	20
Y		1,8,9,16-19,33,34
X	US 6147138 A HOCHSMANN R. 14 Nov 2000 (2000/11/14) abstract ; col. 3 line 16 – col. 4 line 7 ; col. 4 line 48 – col. 5 line 7; claim 1	20-23
X	US 5354414 A FEYGIN F. 11 Oct 1994 (1994/10/11) fig. 1,2, 21 ; col. 5 line 52 –col. 6 line 15; col. 10 line 51 – col. 11 line 9 ; col. 20 lines 6- 44 ; col. 21 lines 59-66	36
Y		1-5,7-11,16-19,25, 26,28,33-35,37,38
Y	US 2007241482 A1 GILLER E. et al. 18 Oct 2007 (2007/10/18) Para. [0044],[0066],[0075],[0094],[0124],[0126]	8,9,17,33,34

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2015/050478

Patent document cited search report			Publication date	Patent family member(s)		Publication Date	
US	6589471	B1	08 Jul 2003	US	6589471	B1	08 Jul 2003
				AU	4301501	A	04 Jun 2001
				WO	0138061	A1	31 May 2001
US	2004018107	A1	29 Jan 2004	US	2004018107	A1	29 Jan 2004
				US	7241415	B2	10 Jul 2007
				AT	471222	T	15 Jul 2010
				AU	2003256355	A1	09 Feb 2004
				CA	2492605	A1	29 Jan 2004
				CA	2492605	C	24 Mar 2009
				CN	1671503	A	21 Sep 2005
				CN	100406169	C	30 Jul 2008
				DE	60333019	D1	29 Jul 2010
				EP	1534461	A1	01 Jun 2005
				EP	1534461	A4	27 Dec 2006
				EP	1534461	B1	16 Jun 2010
				JP	2005533927	A	10 Nov 2005
				JP	4351998	B2	28 Oct 2009
				KR	20050025651	A	14 Mar 2005
				KR	100659008	B1	21 Dec 2006
				RU	2005104942	A	20 Jul 2005
				RU	2288073	C2	27 Nov 2006
				WO	2004009281	A1	29 Jan 2004
US	2008111271	A1	15 May 2008	US	2008111271	A1	15 May 2008
				US	8047251	B2	01 Nov 2011
				AT	497874	T	15 Feb 2011
				AU	2003301196	A1	22 Jul 2004
				CA	2511001	A1	15 Jul 2004
				CN	1741895	A	01 Mar 2006
				CN	100336655	C	12 Sep 2007

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2015/050478

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		CN 1982039 A	20 Jun 2007
		DE 60336017 D1	24 Mar 2011
		EP 1583652 A1	12 Oct 2005
		EP 1583652 B1	09 Feb 2011
		JP 2006511365 A	06 Apr 2006
		JP 4220967 B2	04 Feb 2009
		KR 20050085854 A	29 Aug 2005
		KR 100702934 B1	06 Apr 2007
		RU 2005122938 A	20 Jan 2006
		RU 2302945 C2	20 Jul 2007
		US 2004173945 A1	09 Sep 2004
		US 7291242 B2	06 Nov 2007
		WO 2004058487 A1	15 Jul 2004
WO 2013021173 A1	14 Feb 2013	WO 2013021173 A1	14 Feb 2013
		AU 2012293491 A1	27 Feb 2014
		CA 2843188 A1	14 Feb 2013
		CN 103842157 A	04 Jun 2014
		EP 2739457 A1	11 Jun 2014
		GB 201113612 D0	21 Sep 2011
		GB 2493398 A	06 Feb 2013
		JP 2014527481 A	16 Oct 2014
		KR 20140050093 A	28 Apr 2014
		US 2014314613 A1	23 Oct 2014
US 6147138 A	14 Nov 2000	US 6147138 A	14 Nov 2000
		AT 234192 T	15 Mar 2003
		DE 19723892 C1	03 Sep 1998
		DE 59807431 D1	17 Apr 2003
		EP 0882568 A2	09 Dec 1998
		EP 0882568 A3	17 Nov 1999

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IL2015/050478

Patent document cited search report			Publication date	Patent family member(s)		Publication Date
				EP 0882568	B1	12 Mar 2003
				EP 0882568	B8	03 Sep 2003
				ES 2192289	T3	01 Oct 2003
US	5354414	A	11 Oct 1994	US 5354414	A	11 Oct 1994
				AU 4194696	A	02 May 1996
				AU 4504089	A	01 May 1990
				US 5637175	A	10 Jun 1997
				US 5876550	A	02 Mar 1999
				WO 9003893	A1	19 Apr 1990
				WO 9611117	A1	18 Apr 1996
US	2007241482	A1	18 Oct 2007	US 2007241482	A1	18 Oct 2007
				EP 2001656	A2	17 Dec 2008
				EP 2001656	B1	15 Oct 2014
				WO 2007114895	A2	11 Oct 2007
				WO 2007114895	A3	21 Feb 2008

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:

Invention/s 1	Refers to a system and method for building a 3D object by selective mask sintering.	Claim/s 1,10,11,17-23,29
Invention/s 2	Refers to a system and method for building a 3D object by selective mask sintering comprising die compaction.	Claim/s 2-7,24-28,35
Invention/s 3	Refers to a system and method for building a 3D object by selective mask sintering comprising cooling step/means.	Claim/s 8,9,33,34
Invention/s 4	Refers to a system and method for building a 3D object by selective mask sintering comprising high thermal mass roller to perform layer sintering.	Claim/s 12-15,30-32
Invention/s 5	Refers to a system and method for building 3D object by selective mask sintering comprising VCSEL to perform layer sintering	Claim/s 16
Invention/s 6	Refers to a method for building a 3D object by selective laser sintering comprising die compaction	Claim/s 36-38