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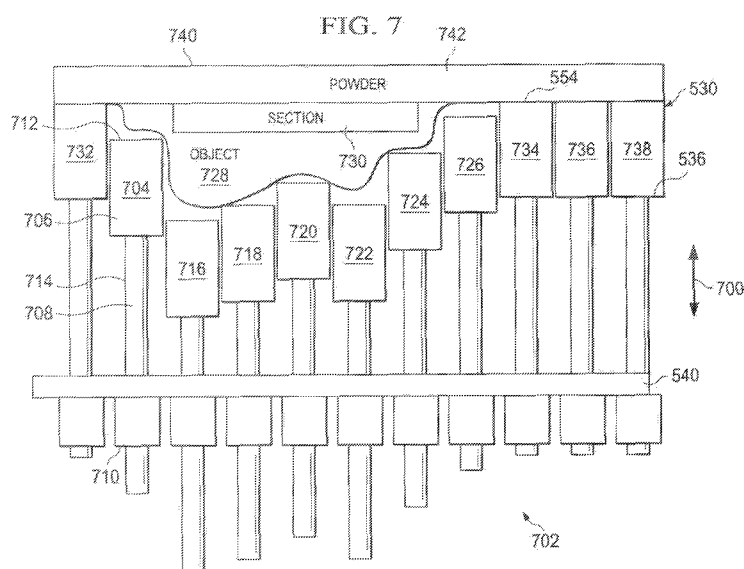
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(57) Abstract: An apparatus comprises a deformable platform (530) and a laser delivery system. The deformable platform (530) has a surface capable of changing to conform to a shape of an object as the object is being manufactured during a sintering process. The laser delivery system is capable of sintering powder on the deformable platform to manufacture the object.

GEOMETRY ADAPTIVE LASER SINTERING SYSTEM AND PROCESS USING THE SAME

BACKGROUND INFORMATION

The present disclosure relates generally to manufacturing and in particular, to a method and apparatus for manufacturing
5 objects using laser sintering.

Sintering is a process that may be used to make objects from powder. These objects include ceramic and/or metal objects. Sintering involves heating a material until the particles adhere to each other. With sintering, the material
10 may be heated to a temperature that is below the melting point to provide for solid state sintering.

Laser sintering is a type of sintering in which a high power laser is used to fuse particles into a mass representing a three-dimensional object. With this type of manufacturing
15 process, the laser selectively fuses powdered material by scanning cross-sections of powder in a bed. These cross-sections are scanned based on a three-dimensional description of the object or part. This description may be obtained from various sources such as, for example, a computer aided design
20 file, scan data, or some other source.

After each cross-section is scanned, the bed is lowered and a new layer of material is applied on top of the scanned layer. The process is then repeated until the part is completed. Laser sintering may be useful for manufacturing prototype parts and/or
25 limited or small numbers of parts. With currently used laser sintering machines, the powder used to create parts is often wasted during the build process. When a layer is scanned with the laser, the entire build layer is recoated with powder. At the end of the build job, some of this powder can be reclaimed
30 and reused. However, a large amount of the powder is unusable and disposed of.

Further, with currently available laser sintering machines, scaling to create parts of larger sizes may be a function of the

amount of powder. With a larger amount of powder, the amount of time needed to wait for the powder to cool down increases.

Thus, with currently available machines, larger parts cannot be manufactured as quickly. Even further, with larger amounts of

5 powder, differences in temperatures at different layers may result in parts that are warped or that do not meet tolerances.

Therefore, it would be advantageous to have a method and apparatus that overcome the problems as described above, as well as possibly other problems.

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SUMMARY

In one advantageous embodiment, an apparatus comprises a deformable platform and a laser delivery system. The deformable platform has a surface capable of changing to conform to a shape of an object as the object is being manufactured during a

15 sintering process. The laser delivery system is capable of sintering powder on the deformable platform to manufacture the object.

In another advantageous embodiment, a laser sintering apparatus comprises a build chamber, a deformable platform, a powder delivery system, a heating system, and a laser delivery system. The deformable platform is located inside the build chamber and has a surface capable of changing to conform to a shape of an object being manufactured while manufacturing of the object occurs within the build chamber. The powder delivery

25 system is capable of delivering powder to the deformable platform. The heating system is capable of heating the powder and the deformable platform with a heated gas. The laser delivery system is capable of sintering the powder to manufacture the object.

30 In yet another advantageous embodiment, a method is present for manufacturing an object. A powder is deployed onto a deformable platform to form a current layer of powder. Laser energy is applied in a pattern on the current layer of powder to

form a processed layer of powder. A portion of the deformable platform is then lowered. The deploying, applying, and lowering steps are repeated until the object is complete.

The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the advantageous embodiments are set forth in the appended claims. The advantageous embodiments, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an advantageous embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a diagram illustrating an aircraft manufacturing and service method in accordance with an advantageous embodiment;

Figure 2 is a diagram of an aircraft in which an advantageous embodiment may be implemented;

Figure 3 is a diagram of a laser sintering environment in accordance with an advantageous embodiment;

Figure 4 is a diagram of a laser sintering apparatus in accordance with an advantageous embodiment;

Figure 5 is a diagram of a laser sintering apparatus in accordance with an advantageous embodiment;

Figure 6 is a diagram of a top view of a deformable platform in accordance with an advantageous embodiment;

Figure 7 is a side view of a deformable platform in accordance with an advantageous embodiment;

Figure 8 is a portion of a laser sintering apparatus in accordance with an advantageous embodiment;

Figure 9 is another view of a portion of a laser sintering apparatus in accordance with an advantageous embodiment; and

5 **Figure 10** is a flowchart of a process for manufacturing an object is depicted in accordance with an advantageous embodiment.

DETAILED DESCRIPTION

Referring more particularly to the drawings, embodiments of
10 the disclosure may be described in the context of the aircraft manufacturing and service method **100** as shown in **Figure 1** and aircraft **200** as shown in **Figure 2**. Turning first to **Figure 1**, a diagram illustrating an aircraft manufacturing and service method is depicted in accordance with an advantageous
15 embodiment. During pre-production, exemplary aircraft manufacturing and service method **100** may include specification and design **102** of aircraft **200** in **Figure 2** and material procurement **104**.

During production, component and subassembly manufacturing
20 **106** and system integration **108** of aircraft **200** in **Figure 2** takes place. Thereafter, aircraft **200** in **Figure 2** may go through certification and delivery **110** in order to be placed in service **112**. While in service by a customer, aircraft **200** in **Figure 2** is scheduled for routine maintenance and service **114**, which may
25 include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **100** may be performed or carried out by a system integrator, a third party, and/or an operator. In these
30 examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without

limitation, any number of venders, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

With reference now to **Figure 2**, a diagram of an aircraft is depicted in which an advantageous embodiment may be implemented. In this example, aircraft **200** is produced by aircraft manufacturing and service method **100** in **Figure 1** and may include airframe **202** with a plurality of systems **204** and interior **206**. Examples of systems **204** include one or more of propulsion system **208**, electrical system **210**, hydraulic system **212**, and environmental system **214**. Any number of other systems may be included. Although an aerospace example is shown, different advantageous embodiments may be applied to other industries, such as the automotive industry.

Apparatus and methods embodied herein may be employed during any one or more of the stages of aircraft manufacturing and service method **100** in **Figure 1**. For example, components or subassemblies produced in component and subassembly manufacturing **106** in **Figure 1** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **200** is in service **112** in **Figure 1**.

Also, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing **106** and system integration **108** in **Figure 1**, for example, without limitation, by substantially expediting the assembly of or reducing the cost of aircraft **200**. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft **200** is in service **112** or during maintenance and service **114** in **Figure 1**. As one illustrative example, the different advantageous embodiments may be used to manufacture parts during component and subassembly manufacturing **106** and during maintenance and service **114**.

The advantageous embodiments recognize that currently designed laser sintering systems have a build area that results in a waste of powder. Further, the different advantageous embodiments recognize that with larger parts, lower layers in the Z direction may recrystallize or resolidify while upper layers are sintering or in liquid form. This difference in the states of the powder may result in parts that are warped or do not meet tolerances. As a result, a part may have to be remade.

The different advantageous embodiments also recognize that the manufacturing process for parts is currently limited in speed by a number of factors. For example, the build cake formed from the different layers of powder and the sintering of that powder to form a number of parts is currently removed from the machine. These parts are dug out of the build cake at a separate station. This type of process increases the time needed to manufacture parts because of the transport time.

Thus, the different advantageous embodiments provide a method and apparatus for manufacturing parts using laser sintering. In these examples, an apparatus may include a deformable platform and a laser delivery system. The deformable platform is capable of incrementally changing shape to conform to a shape of an object as the object is being manufactured during its sintering process. The laser delivery system is capable of sintering powder on the deformable platform to manufacture the object.

In another advantageous embodiment, the laser sintering apparatus comprises a build chamber, a deformable platform, a powder delivery system, a heating system, and a laser delivery system. The powdered delivery system delivers powder to the deformable platform. The heating system is capable of heating the powder and the deformable platform with a heated gas. By conforming to the shape of the object, powder is only needed for portions of the deformable platform on which laser sintering is to be performed. Other areas in which laser sintering is not to

be performed do not require additional layers of powder in one or more of these advantageous embodiments.

With reference now to **Figure 3**, a diagram of a laser sintering environment is depicted in accordance with an advantageous embodiment. In this example, laser sintering environment **300** includes laser sintering apparatus **302**, laser system **304**, and controller **306**. In these illustrative examples, powder **308** may be placed into laser sintering apparatus **302** to create object **310** using laser energy **312** generated by laser system **304**. Object **310** may take various forms. In these particular illustrative examples, object **310** may take the form of an aircraft part for aircraft **200** in **Figure 2**.

Controller **306** may send control signals **314** to laser system **304** and control signals **316** to laser sintering apparatus **302** to control the sintering of powder **308** to form object **310**. These control signals may be generated using design data **318**.

In these illustrative examples, laser system **304** may be a Gaussian style sealed tube CO₂ laser. Thus, laser system **304** may implement a CO₂ laser. Powder **308** may take various forms. For example, without limitation, powder **308** may be a polymer, steel, titanium, an alloy mixture, composite, sand, or some other suitable material or combination of materials. Design data **318** also may take various forms. For example, design data **318** may be a computer aided design file or scan data.

In these advantageous embodiments, laser sintering apparatus **302** is capable of heating powder **308** prior to powder **308** being processed using heated gas **320**. With this type of heating, problems with different temperatures in different portions of powder **308** within laser sintering apparatus **302** may be reduced. By heating powder **308** and/or laser centering apparatus **302**, recrystallization and/or resolidification of lower levels may not occur at a rate that causes object **310** to warp and/or not meet tolerances. Additionally, heated gas **320** also may heat other components within laser centering apparatus

302 in a manner that may help maintain temperatures of already processed layers of powder 308 closer to the temperature of layers being sintered.

Another advantage that may be provided using heated gas 320 is a capability to reduce the amount of laser energy 312 that may be needed to perform sintering. By reducing laser energy 312, processing of powder 308 using higher temperature materials to manufacture a part may be more easily performed.

The illustration of laser sintering environment 300 in **Figure 3** is not meant to imply physical and/or architectural limitations to the manner in which different laser sintering environments may be implemented. For example, in other advantageous embodiments, laser system 304 may be implemented as part of laser sintering apparatus 302 rather than as a separate component. The different components are illustrated as functional components, which may be combined or further separated into additional blocks depending on the particular implementation. In yet another example, controller 306 may be implemented within laser sintering apparatus 302.

Although in these illustrative examples, object 310 has been described with respect to an aircraft part, other advantageous embodiments may be applied to other types of structures. For example, without limitation, other advantageous embodiments may be applied to a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, and/or some other suitable object or structure.

More specifically, the different advantageous embodiments may be applied to, for example, without limitation, a submarine, a bus, a personnel carrier, a tank, a train, an automobile, a spacecraft, a space station, a satellite, a surface ship, a power plant, a dam, a manufacturing facility, a building, and/or some other suitable structure.

With reference now to **Figure 4**, a diagram of a laser sintering apparatus is depicted in accordance with an advantageous embodiment. In this illustrative example, laser sintering apparatus **400** is an example of one manner in which laser sintering apparatus **302** in **Figure 3** may be implemented. As illustrated, laser sintering apparatus **400** includes frame **402**, build chamber **404**, heating system **406**, powder delivery system **408**, and laser delivery system **410**.

Frame **402** forms a structure in which different components of laser sintering apparatus **400** may be attached and/or placed. In this illustrative example, build chamber **404** includes enclosure **412** with deformable platform **414**, recoater **416**, and actuator system **420** located inside of enclosure **412**. Enclosure **412** has transparent top **413** in these examples.

Deformable platform **414** has movable stages **418** that form surface **422** for deformable platform **414**. Movable stage **424** is an example of a movable stage within movable stages **418**. As depicted, movable stage **424** has planar member **426** with surface **428**. Surface **428** is a portion of surface **422** for deformable platform **414**. Additionally, rod **430** is attached to planar member **426**. Planar member **426** may have various shapes for surface **428**.

For example, the shape of planar member **426** may be a rectangle, a triangle, a square, a hexagon, or some other shape that may be combined with other shapes to form surface **422** for deformable platform **414**. Further, different movable stages within movable stages **418** may have shapes different from other movable stages within movable stages **418** depending on the particular implementation.

Movable stage **424** may be moved by actuator **432** of actuator system **420**. Actuator **432** may engage threads **434** on rod **430** to move movable stage **424** in a linear fashion. Deformable platform **414** also includes base **436**, which contains holes **438** to receive movable stages **418**. For example, rod **430** may be received within

a hole in holes **438**. Base **436** may provide a base and/or platform for movable stages **418**.

During operation, each of movable stages **418** may be independently moved through actuator system **420** to cause surface **422** to be capable of changing to conform to a shape of an object that is being manufactured during the sintering process.

In other words, the different stages in movable stages **418** may be lowered as powder is deposited as a layer on deformable platform **414**. The layer of powder may have a substantially smooth or planar surface. Portions of surface **422** may lower, while other portions of surface **422** may stay at a constant level each time a new layer of powder is deposited onto deformable platform **414** on top of another previous layer. With this type of deformability or configuration of surface **422**, less powder may be required to create a part.

In this example, powder delivery system **408** includes chamber **440**, which may hold powder **442**. Further, channels **444** may connect chamber **440** to enclosure **412** in build chamber **404**. Powder **442** may be introduced into build chamber **404** through channels **444**.

In these illustrative examples, channels **444** may lead to recoater **416**, located within enclosure **412**. Recoater **416** may receive powder **442** from channels **444** and move within enclosure **412** to deposit layers **446** of powder **442** onto deformable platform **414**. When first layer **448** is deposited, the layer is deposited in contact with surface **422** on deformable platform **414**. As additional layers **450** in layers **446** are deposited onto deformable platform **414** during the sintering process, these layers are deposited on top of other layers on deformable platform **414**.

Heating system **406** includes heater **450**, circulation unit **452**, and gas **454**. In these examples, gas **454** is an inert gas. Gas **454** may take various forms. For example, without limitation, gas **454** may be nitrogen, carbon dioxide, argon,

xenon, or some other inert gas. In these examples, gas 454 is an inert gas because inert gases are ones that do not react with elements.

Heater 450 is capable of heating gas 454. Circulation unit 452 is capable of circulating the heated form of gas 454 through various components within laser sintering apparatus 400. Heater 450 and circulation unit 452 may be implemented using any type of heater and/or circulation system. In these examples, heater 450 may be implemented in a number of different ways. For example, heater 450 may be a tube with heaters. The gas may be run through the tube and heated by the heaters. The temperature of the gas with this type of implementation may be a function of the flow rate through heater 450.

For example, circulation unit 452 may circulate heated gas 454 through build chamber 404 and powder delivery system 408. Gas 454 heats powder 442 and deformable platform 414 in these illustrative examples. Further, gas 454 may heat other components that may contact powder 442 in build chamber 404. In this manner, less laser energy or power may be required to perform sintering operations since powder 442 may be heated using gas 454 and heat applied to deformable platform 414 through gas 454.

Additionally, in some advantageous embodiments, heater 450 also may directly heat deformable platform 414. With these types of heating, higher temperature materials may be used with less waste.

In these examples, enclosure 412 is sealed and may have a connection to heating system 406 and powder delivery system 408. In this manner, gas 454 may circulate within laser sintering apparatus 400 to heat powder 442 and other components such as, for example, deformable platform 414.

In this illustrative example, laser delivery system 410 includes frame 456, mirror 458, servos 460, fiber optic connector 462, and fiber optic cable 464. Frame 456 is movable

along the top of enclosure **412**, which has transparent top **413**. Transparent top **413** may be made of any material that is capable of allowing laser energy to pass through transparent top **413** to sinter powder **442** located within enclosure **412**. For example,
5 transparent top **413** may be made up of glass.

Mirrors **458** may be moved and/or positioned to direct laser energy in a pattern onto layers **446** within build chamber **404**. Servos **460** may move frame **456** and mirrors **458** in these examples. Fiber optic connector **462** provides a connection to fiber optic
10 cables **464** to receive laser energy, which may be directed by mirrors **458**.

Another feature provided by laser sintering apparatus **400** is the capability to remove the part from the powder in build chamber **404** without having to move the entire build cake to a
15 separate location or station as is currently done. This capability is provided because less powder is left over due to the manner in which an object may be constructed using deformable platform **414**.

The illustration of laser sintering apparatus **400** in **Figure**
20 **4** is not meant to imply physical and/or architectural limitations to the manner in which different advantageous embodiments may be implemented. For example, in some advantageous embodiments, other components in addition to or in place of the ones illustrated may be used. As one example,
25 instead of having multiple mirrors for mirror **456**, a single mirror may be used in some advantageous embodiments. In yet other advantageous embodiments, laser delivery system **410** also may include the laser unit itself.

With reference now to **Figure 5**, a diagram of a laser
30 sintering apparatus is depicted in accordance with an advantageous embodiment. Laser sintering apparatus **500** is an example of one implementation of laser sintering apparatus **400** in **Figure 4**. In this depicted example, laser sintering apparatus **500** has frame **502** to which various components of laser

sintering apparatus **500** may be attached. For example, frame **502** forms part of build chamber **504**. Laser sintering apparatus **500** also has powder delivery system **506**, heating system **508**, laser delivery system **510**, and recoater **512**.

5 As illustrated, enclosure **514** contains both powder delivery system **506** and heating system **508**. In some advantageous embodiments, heating system **508** may not be present within laser sintering apparatus **500**. In these depicted examples, enclosure **514** is connected to build chamber **504**. Further, enclosure **514**
10 also has gas port **516** located on top side **518** of enclosure **514**.

Enclosure **514** may be formed using a number of different types of materials. Enclosure **514** may be comprised of various metals such as, for example, without limitation, aluminum, steel, or some other suitable material. For example, enclosure
15 **514** may be formed using an industrial grade welded sheet metal.

Enclosure **514** has transparent top **520**. Transparent top **520** allows laser energy to be delivered into build chamber **504** from laser delivery system **510**, which is located on the exterior of build chamber **504**. Transparent top **520** has channels **522** and
20 **524**, which may be coupled to channels **526** and **528** to allow for the delivery of powder from powder delivery system **506** into build chamber **504**.

Build chamber **504** also contains the deformable platform **530** and door **532**. Build chamber **504** may have various dimensions
25 depending on the particular implementation. For example, build chamber **504** may be 6 feet long, 4 feet wide, and 4 feet tall. Of course, the dimensions may change depending on the particular implementation. Deformable platform **530** is a platform on which powder may be deposited to manufacture an object. Door **532**
30 provides access to the object after the manufacturing process has been completed. As seen in this example, door **532** may be moved along the direction of arrow **534**.

As can be seen in this example, deformable platform **530** includes movable stages **536**, in which each of the movable stages

may be moved linearly along the direction of arrow **538**. In this example, movable stages **536** are supported by base **540** inside of build chamber **504**.

Recoater **512** is located within build chamber **504** and is capable of receiving powder from powder delivery system **506** through channels **522** and **526** or through channels **524** and **528**, depending on the location of recoater **512**. Recoater **512** may be moved along the direction of arrow **534** to deposit powder in a layer on deformable platform **530**.

Laser delivery system **510** has frame **542**. Section **544** and section **546** in frame **542** contain one or more mirrors capable of directing laser energy in a pattern on the powder that may be deposited on deformable platform **530**. Frame **542** also has fiber optic connector **548**, which may couple laser energy from a laser to mirrors within sections **544** and **546** for redirection into build chamber **504**.

Enclosure **514** in build chamber **504** forms a sealed volume or manufacturing area. The term sealed as used herein does not mean that the area must be gas-tight. The area may be sealed such that gas cannot enter or leave these areas. In other advantageous embodiments, the areas may be sealed such that the introduction of gas through gas port **416** may provide heating as desired for the powder and/or movable stages **536** of deformable platform **530**.

In other advantageous embodiments, the sealed volume may not be airtight. With this type of implementation, a positive pressure is maintained in build chamber **504**. The pressure may be maintained by a pressure and/or temperature regulator. In these examples, the temperature of the gas may depend on the type of material being processed. As a non-limiting example, the temperature of the gas may be from around 100 degrees Celsius to around 400 degrees Celsius.

In operation, gas may be introduced into powder delivery system **506** and build chamber **504** through gas port **516**. Heating

system **508** within enclosure **514** heats the gas. Depending on the particular implementation, the gas may be preheated prior to being introduced through gas port **516**. The heated gas is circulated and heats powder located within enclosure **514** and
5 build chamber **504**.

Further, the heated gas also may heat deformable platform **530**. Heating deformable platform **530** may provide indirect heating of the powder located on deformable platform **530**. The use of an inert gas to heat the powder and deformable platform
10 **530** is in contrast to currently used mechanisms in which quartz, rod heaters, or carbon fiber heating elements are employed to directly heat build chamber **504**.

The heating of these components may produce the amount of laser energy needed to sinter the powder into the shape of a
15 part. This type of capability is useful when higher temperature materials are used for the powder.

Further, by providing a heated gas, processed portions of the powder may not cool off as quickly as with current laser sintering systems. As a result, warping that may occur with
20 temperature gradients or differences between different portions of a part may be reduced or eliminated.

After the powder has been heated to a desired temperature, the powder may be introduced into build chamber **504** in layers. In these examples, servo delivery unit **550** and servo delivery
25 unit **552** are part of powder delivery system **506** and operate to introduce an amount of powder from enclosure **514** into build chamber **504** to be deposited as a layer onto surface **554** of movable stages **536** of deformable platform **530**. In these examples, servo delivery units **550** and **552** may comprise a servo
30 motor with a wheel that allows powder to be deposited into recoater **512**.

Recoater **512** moves along the direction of arrow **534** to deposit a layer of powder onto surface **554** of movable stages **536** of deformable platform **530**. After a layer of powder has been

deposited onto deformable platform **530**, laser delivery system **510** may also move along the direction of arrow **534** to deliver laser energy in a pattern to form a shape for the object.

After the layer of powder has been processed, at least a
5 portion of deformable platform **530** may be lowered. Thereafter, additional powder may be sent to recoater **512** to deposit another layer of powder onto surface **554** of deformable platform **530**. This powder is deposited onto deformable platform **530** on top of previous layers. This new layer of powder may then be processed
10 using laser energy delivered through laser delivery system **510**. Each time a layer of powder is deposited, recoater **512** may smooth out the layer such that the top portion of the layer has a substantially planar surface.

With this type of movement of deformable platform **530**, less
15 powder may be used. Specifically, less powder is deposited onto areas in which movable stages **536** have not moved downwards or have moved downwards less than other portions.

Laser sintering apparatus **500** may be constructed by modifying currently available laser sintering systems. The
20 different advantageous embodiments may use a currently available laser sintering system and modify build chamber **504** to include deformable platform **530**. Further, laser sintering apparatus **500** may be modified to include heated gas and laser delivery system **510**. Also, in other advantageous embodiments, door **532** may be
25 included in a manner that allows for removing the part from the build chamber.

With reference now to **Figure 6**, a diagram of a top view of a deformable platform is depicted in accordance with an advantageous embodiment. In this example, deformable platform
30 **530** contains movable stages **536**, in which each movable stage has a triangular shape. These triangular shapes interlock or fit together to form surface **554** for deformable platform **530**.

Each movable stage within movable stages **536** is independently movable in a linear direction. This type of

independent movement of movable stages **536** allows deformable platform **530** to conform to the shape of an object being manufactured.

With reference now to **Figure 7**, a side view of a deformable platform is depicted in accordance with an advantageous embodiment. In this example, a portion of deformable platform **530** is shown from a side view. Movable stages **536** may be moved along the direction of arrow **700** using actuator system **702**.

Movable stage **704** is an example of one movable stage within movable stages **536**. Movable stage **704** has planar member **706**, rod **708**, and actuator **710**. Planar member **706** has surface **712**. Rod **708** has threads **714**, which may be engaged by actuator **710** to move planar member **706** along the direction of arrow **700**. Rod **708** is supported by base **540** and actuator **710** in these examples.

In this example, movable stages **704**, **716**, **718**, **720**, **722**, **724**, and **726** have been moved downward to conform to the shape of object **728**. Section **730** may be in a molten form after the processing of powder by laser energy. In this example, movable stages **732**, **734**, **736**, and **738** also have moved downwards, and layer **740** of powder **742** has been deposited onto deformable platform **530**. As can be seen, movable stages **732**, **734**, **736**, and **738** may require less of powder **742** due to being moved less further downwards than movable stages **704**, **716**, **718**, **720**, **722**, **724**, and **726**.

A recoater may redistribute excess powder onto other areas such as those when movable stages **704**, **716**, **718**, **720**, **722**, **724**, and **726** are lowered. In this manner, less of powder **742** is required to create object **728** as compared to creating the same object with conventional laser sintering devices that are currently available.

With reference now to **Figure 8**, a portion of a laser sintering apparatus is depicted in accordance with an advantageous embodiment. In this example, a portion of laser

sintering apparatus **500** is depicted to illustrate mechanisms for laser delivery system **510** and recoater **512**.

In these examples, recoater **512** may move in the direction of arrow **534** along ball screw rod **800** and ball screw rod **802**.

5 Frame **542** of laser delivery system **510** may move along the direction of arrow **534** using ball screw rod **804** and ball screw rod **806**. These ball screw rods may be turned by actuators (not shown) to move recoater **512** and frame **542**.

10 With reference now to **Figure 9**, another view of a portion of a laser sintering apparatus is depicted in accordance with an advantageous embodiment. In this example, a portion of laser sintering apparatus is depicted to show another view of recoater **512** and laser delivery system **510**.

The illustrations of laser sintering apparatus **500** in
15 **Figures 5-9** are not meant to imply physical and/or architectural limitations to the manner in which different advantageous embodiments are implemented. For example, in some advantageous embodiments, a laser may be part of laser delivery system **510** located in frame **502**. In other advantageous embodiments, other
20 types of actuators may be used to move movable stages **536** other than actuators that engage threads on rods.

Further, in the different advantageous embodiments, connections for the actuators and other components are present to provide communication to a controller to control the movement
25 and operation of the different components within laser sintering apparatus **500**. Also, although build chamber **504** has a rectangular shape, other shapes may be employed.

For example, build chamber **504** may be square or have some other suitable shape at which laser delivery system **510** may
30 direct energy to perform sintering to create an object. As yet another example, in some advantageous embodiments, other types of mechanisms may be used to move the different components. For example, frame **542** of laser delivery system **510** may be moved

using a rail with teeth, a servo with a cable, or some other suitable mechanism.

Other advantageous embodiments may have other components in addition to or in place of the ones depicted for laser sintering apparatus **500**. In yet other advantageous embodiments, fewer components may be used. For example, in some embodiments, door **532** may swing open instead of slide. Door **532** may be manually opened or motorized. In still other embodiments, laser delivery system **510** may include a laser unit or device.

With reference now to **Figure 10**, a flowchart of a process for manufacturing an object is depicted in accordance with an advantageous embodiment. The process illustrated in **Figure 10** may be implemented using a laser sintering environment such as, for example, laser sintering environment **300** in **Figure 3**. The laser sintering apparatus employed may be, for example, laser sintering apparatus **400** in **Figure 4**.

The process begins by heating inert gas (operation **1000**). The inert gas is nitrogen in this depicted example. The heating may take place inside of the laser sintering apparatus or externally depending on the particular implementation. The heated inert gas is circulated inside the laser sintering apparatus (operation **1002**). Operation **1002** is performed to heat the powder and the deformable platform in the laser sintering apparatus. The process then waits for a period of time while the inert gas is circulated within the laser sintering apparatus (**1004**).

Operation **1004** is performed to allow the powder and the deformable platform to heat up to some desired temperature. In these examples, the temperature to which the powder and/or platform may be heated varies depending on the particular material used for the powder. The temperature may be, for example, without limitation, from around 100 degrees Celsius to around 400 degrees Celsius.

The process then deposits powder onto the deformable platform to form a current layer of powder (operation **1006**). Next, the process applies laser energy in a pattern on the current layer of powder to form a processed layer of powder (operation **1008**). This processed layer of powder has sections that have become sintered and/or molten to begin forming the object. The pattern is generated based on design data for the object. A determination is then made as to whether the object is complete (operation **1010**).

If the object is not complete, a portion of the deformable platform is lowered (operation **1012**). Lowering a portion of the deformable platform may be accomplished by moving a number of movable stages downward with respect to the build of the object. The lowering of the portion of the deformable platform is performed to cause the deformable platform to conform to a shape of the object as it is being created. The process then returns to operation **1006** to deposit another layer of powder onto the deformable platform on top of the current layer of powder. In depositing another layer of powder, less powder may be required because only a portion of the deformable platform is lowered to change the shape of the deformable platform to conform to the shape of the object.

As a result, powder may be needed only on the portions in which movable stages have been lowered. Other portions may not require powder when additional powder is deposited onto the deformable platform. In these examples, the powder is deposited to form a layer that is substantially planar.

Thus, for portions of the deformable platform that do not move downward, additional powder may not be necessary to form the current layer. In other words, the current layer may contain powder that has been deposited from a previous deposition of powder in those sections in which the movable stages have not moved downward.

With reference again to operation **1010**, when the object is complete, the part is removed (operation **1014**), with the process terminating thereafter. In these examples, a part may be removed from the build chamber without having to move the part and powder to another station. This additional feature may be provided because the deformable platform reduces the amount of powder that is leftover. As a result, the part may be more easily removed from the build chamber without having to move the entire build cake as is currently performed.

The flowchart and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus, methods and computer program products. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of computer usable or readable program code, which comprises one or more executable instructions for implementing the specified function or functions.

In some alternative implementations, the function or functions noted in the block may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

Thus, the different advantageous embodiments provide a method and apparatus for manufacturing objects. In one or more of the advantageous embodiments, a deformable platform has a surface capable of changing to conform to a shape of an object as the object is being manufactured during a sintering process. A laser delivery system is present that is capable of sintering powder on the deformable platform to manufacture the object.

Further, in one or more of the different advantageous embodiments, heated gas may be introduced into the build chamber. With the different advantageous embodiments, powder may be deposited only on the areas on which sintering has

occurred. As a result, the amount of powder needed and processing energy consumed may be reduced.

The description of the different advantageous embodiments has been presented for purposes of illustration and description,
5 and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different advantages as compared to other advantageous
10 embodiments.

The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for
15 various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS

What is claimed is:

1. An apparatus comprising:

a deformable platform having a surface capable of changing
5 to conform to a shape of an object as the object is being
manufactured during a sintering process; and

a laser delivery system capable of sintering powder on the
deformable platform to manufacture the object.

2. The apparatus of claim 1 further comprising:

10 a heating system capable of heating the powder prior to the
laser delivery system heating the powder.

3. The apparatus of claim 1 further comprising:

a powder delivery system capable of delivering the powder
to the deformable platform.

15 4. The apparatus of claim 1, wherein the deformable platform
comprises:

a plurality of movable stages forming the surface of the
deformable platform.

5. The apparatus of claim 4, wherein each movable stage in the
20 plurality of movable stages forming the surface comprises a
planar member forming a portion of the surface, a rod attached
to the planar member, and an actuator capable of moving the rod
in a linear direction.

6. The apparatus of claim 1 further comprising:

25 a build chamber, wherein the deformable platform is located
inside the build chamber.

7. The apparatus of claim 6, wherein the build chamber
comprises:

30 an enclosure, wherein the deformable platform is located
inside the enclosure; and

a recoater located inside the enclosure, wherein the recoater is capable of depositing a layer of powder on the deformable platform during manufacturing of the object.

8. The apparatus of claim 2, wherein the heating system

5 comprises:

a heater capable of heating a gas to form a heated gas; and
a circulation unit capable of circulating the heated gas.

9. The apparatus of claim 2, wherein the heating system
comprises:

10 a gas port capable of receiving a heated inert gas.

10. The apparatus of claim 7, wherein the enclosure has a
transparent top and wherein the laser delivery system comprises:

a frame;

a number of mirrors mounted to the frame, wherein the
15 number of mirrors is capable of directing laser energy onto
powder on the surface of the deformable platform;

a servo system mounted to the frame, wherein the servo
system is capable of positioning the number of mirrors and
moving the frame over the transparent top; and

20 a number of fiber optic connectors, wherein the fiber optic
connectors are capable of receiving the laser energy from a
number of fiber optic cables connected to the number of fiber
optic connectors and directing the laser energy to the number of
mirrors.

25 11. The apparatus of claim 1, wherein the object is a part for
a structure selected from one of a mobile platform, a stationary
platform, a land-based structure, an aquatic-based structure, a
space-based structure, an aircraft, a surface ship, a tank, a
personnel carrier, a train, a spacecraft, a space station, a
30 satellite, a submarine, an automobile, a power plant, a bridge,
a dam, a manufacturing facility, and a building.

12. The apparatus of claim 1, wherein the laser delivery system comprises:

a frame;

a number of mirrors mounted to the frame, wherein the
5 number of mirrors is capable of directing laser energy onto powder on the surface of the deformable platform;

a servo system mounted to the frame, wherein the servo system is capable of positioning the number of mirrors and moving the frame over the transparent top; and

10 a number of fiber optic connectors, wherein the fiber optic connectors are capable of receiving the laser energy from a number of fiber optic cables connected to the number of fiber optic connectors and directing the laser energy to the number of mirrors.

15 13. The apparatus of claim 1, wherein the object is a part for a structure selected from one of a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a
20 satellite, a submarine, an automobile, a power plant, a bridge, a dam, a manufacturing facility, and a building.

14. A method for manufacturing an object, the method comprising:

25 deploying a powder onto a deformable platform to form a current layer of powder;

applying laser energy in a pattern on the current layer of powder to form a processed layer of powder;

lowering a portion of the deformable platform; and

30 repeating the deploying, applying, and lowering steps until the object is complete.

15. The method of claim 14 further comprising:

circulating a heated inert gas using a heating system to heat the powder, wherein the powder is heated prior to applying the laser energy and wherein the heated inert gas further heats the deformable platform.

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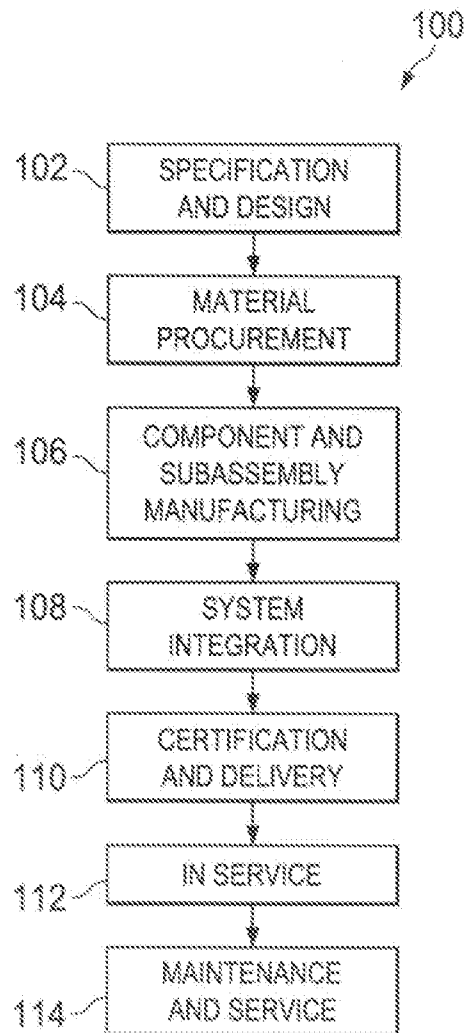


FIG. 1

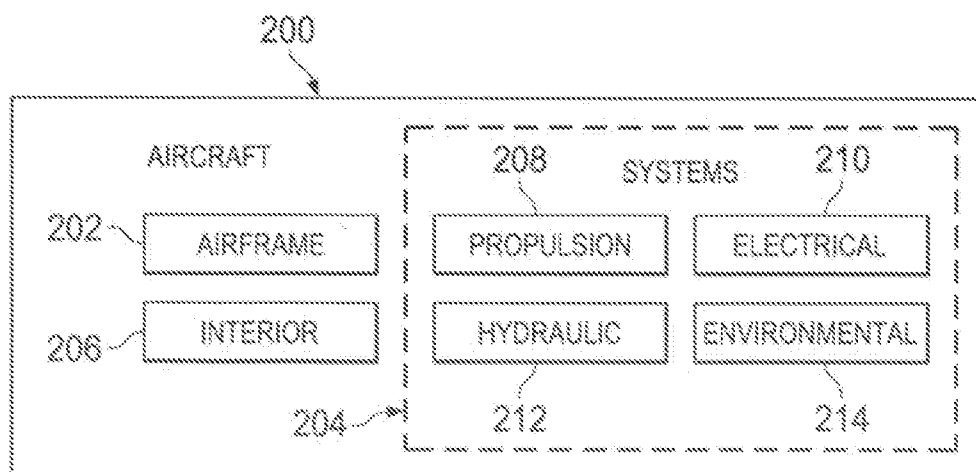


FIG. 2

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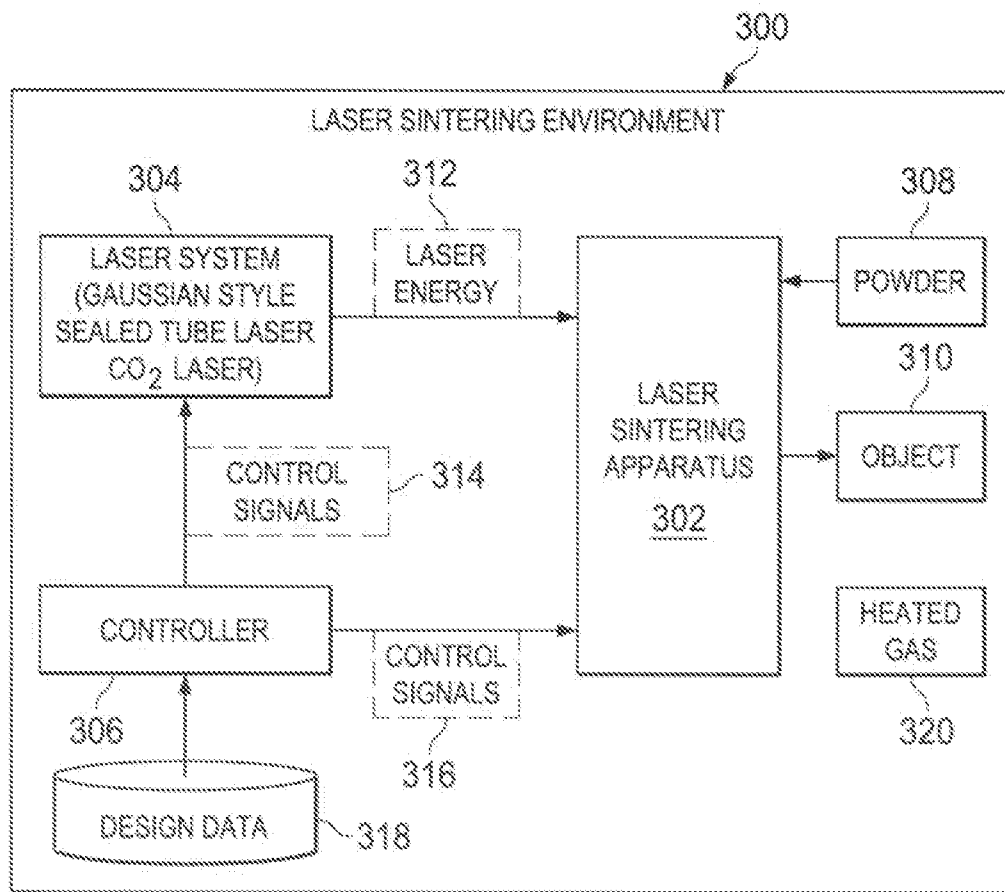
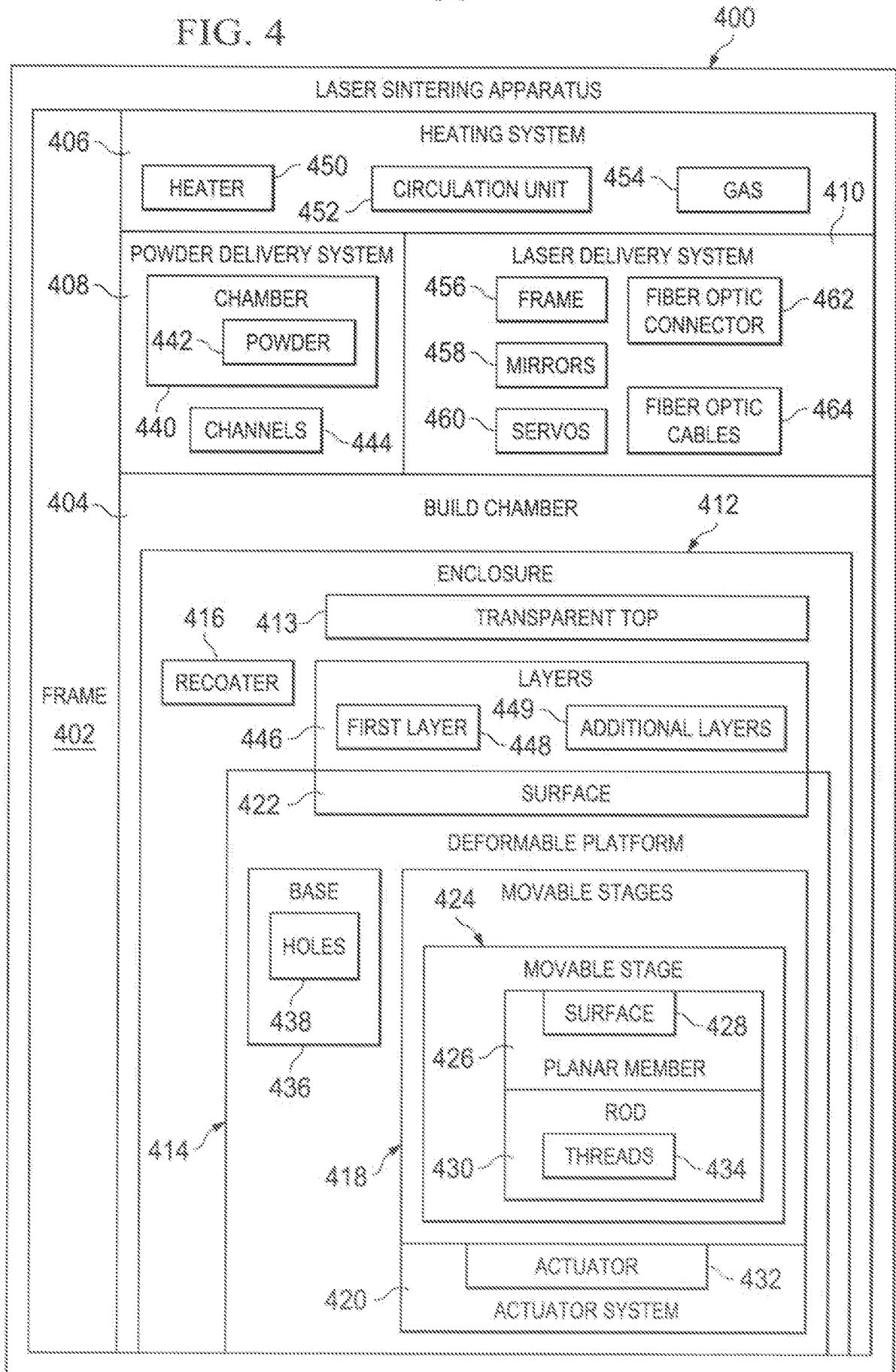


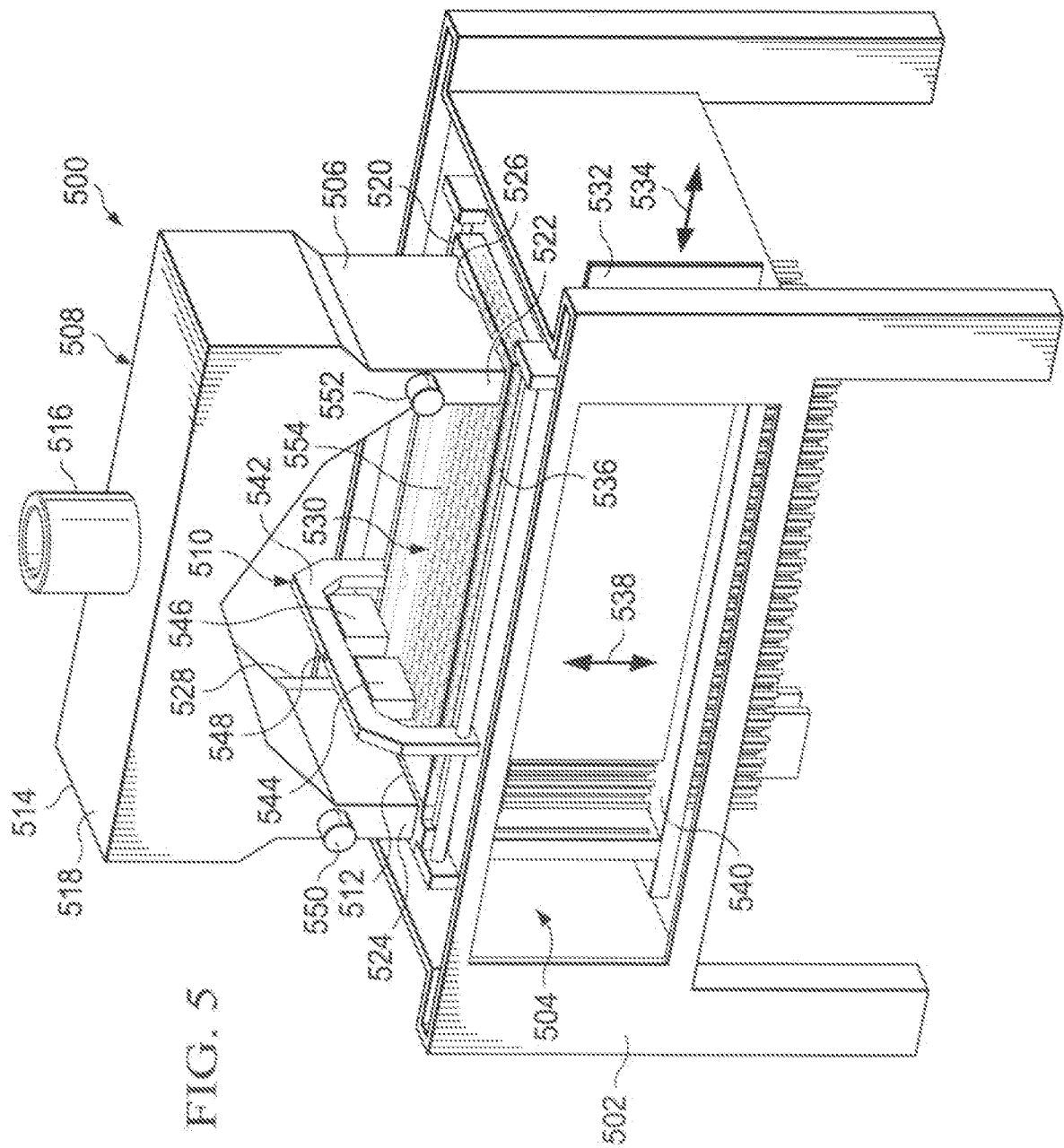
FIG. 3

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FIG. 4



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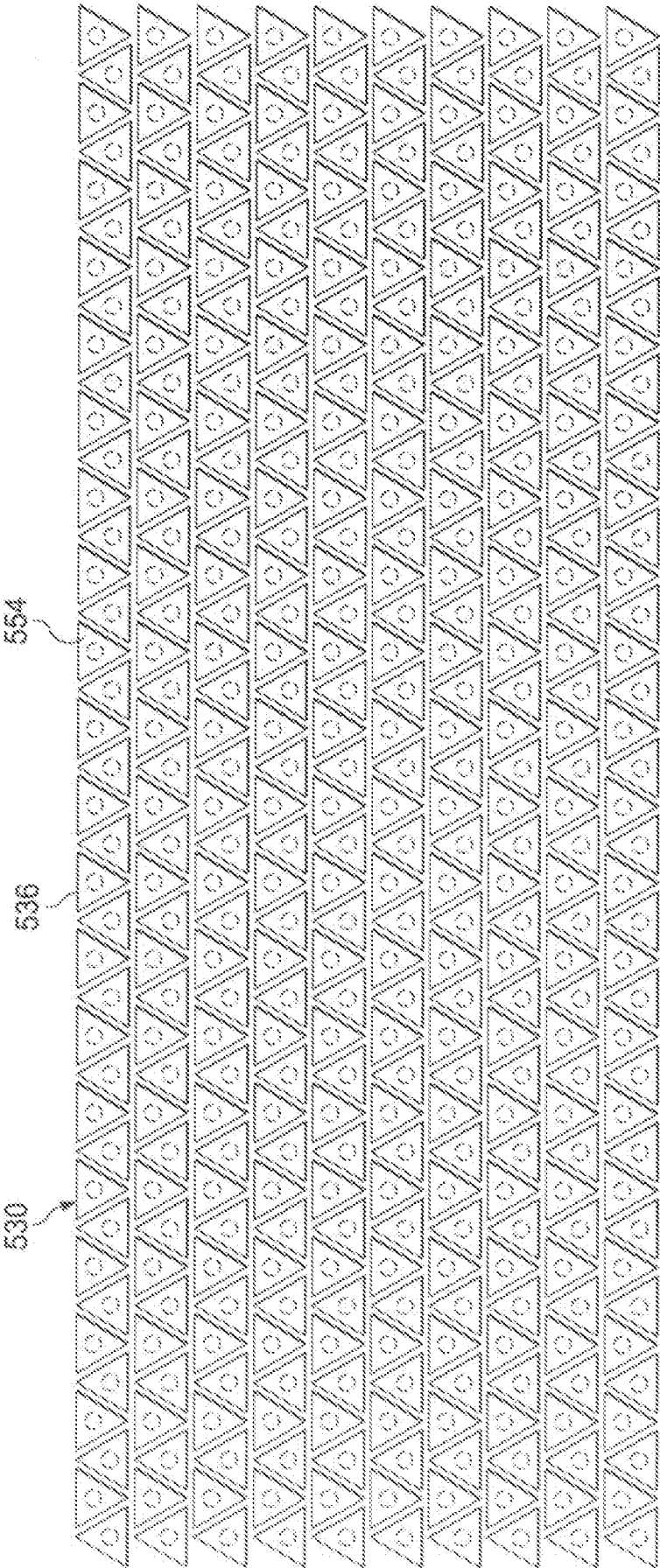
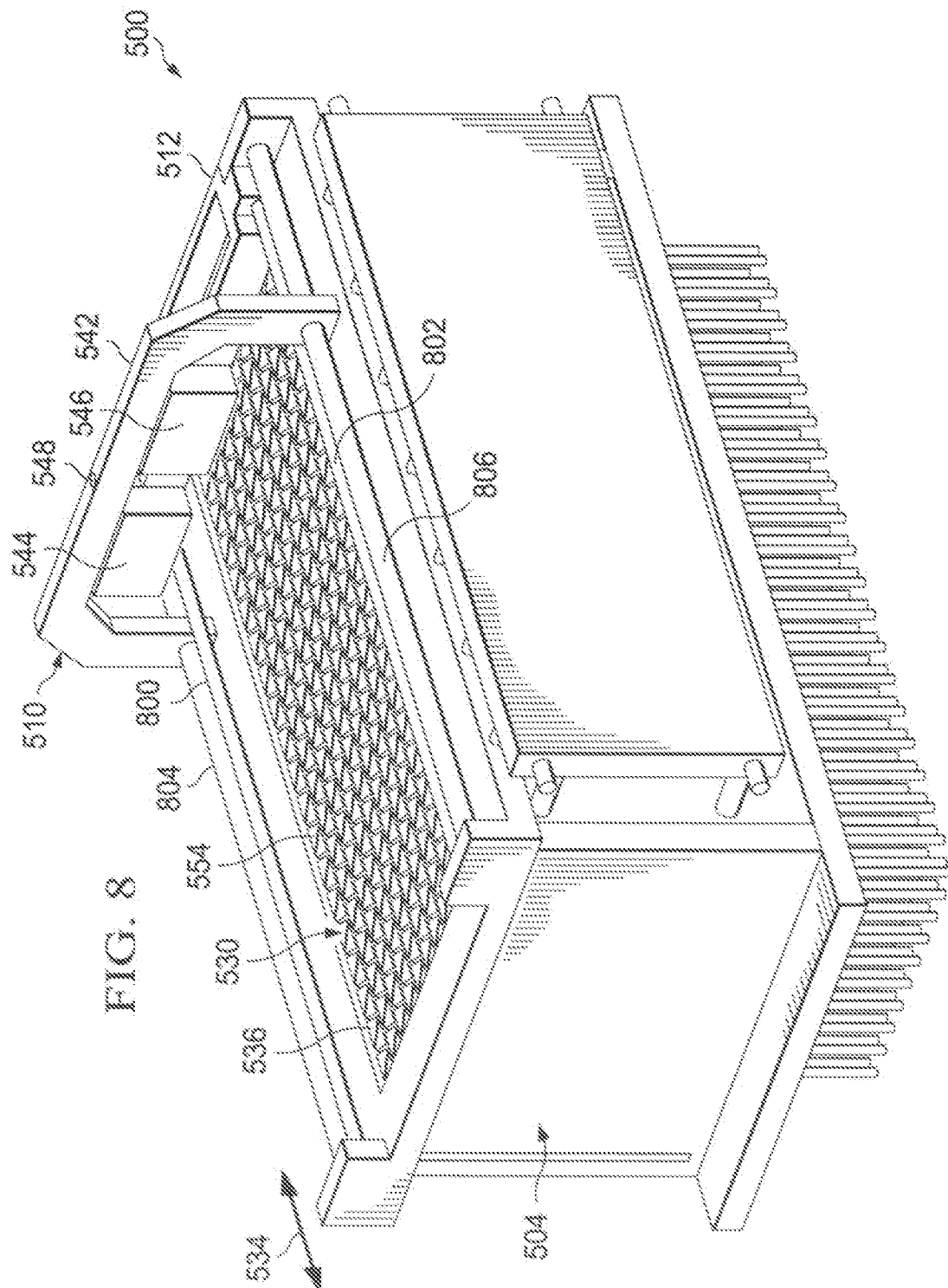


FIG. 6



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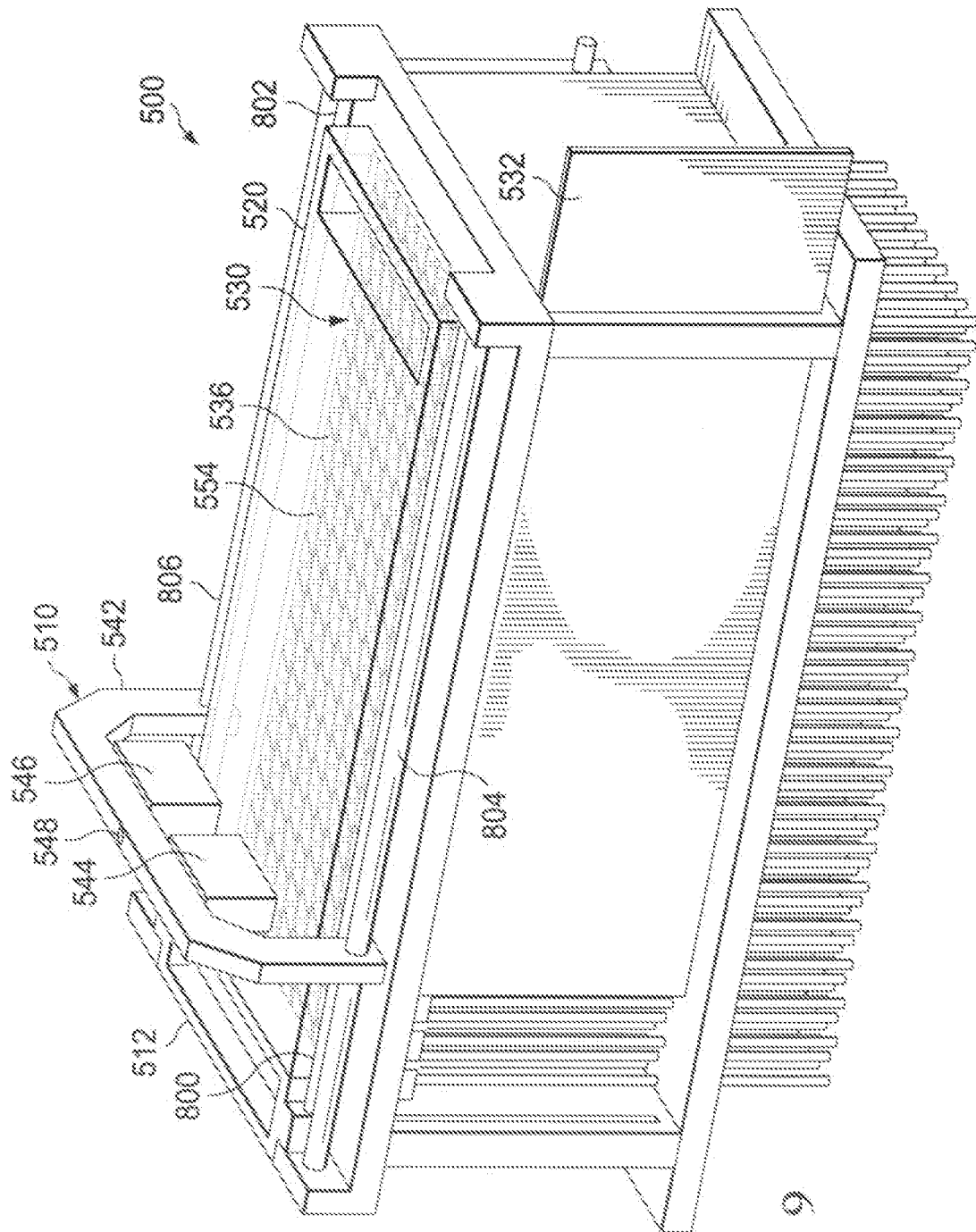


FIG. 9

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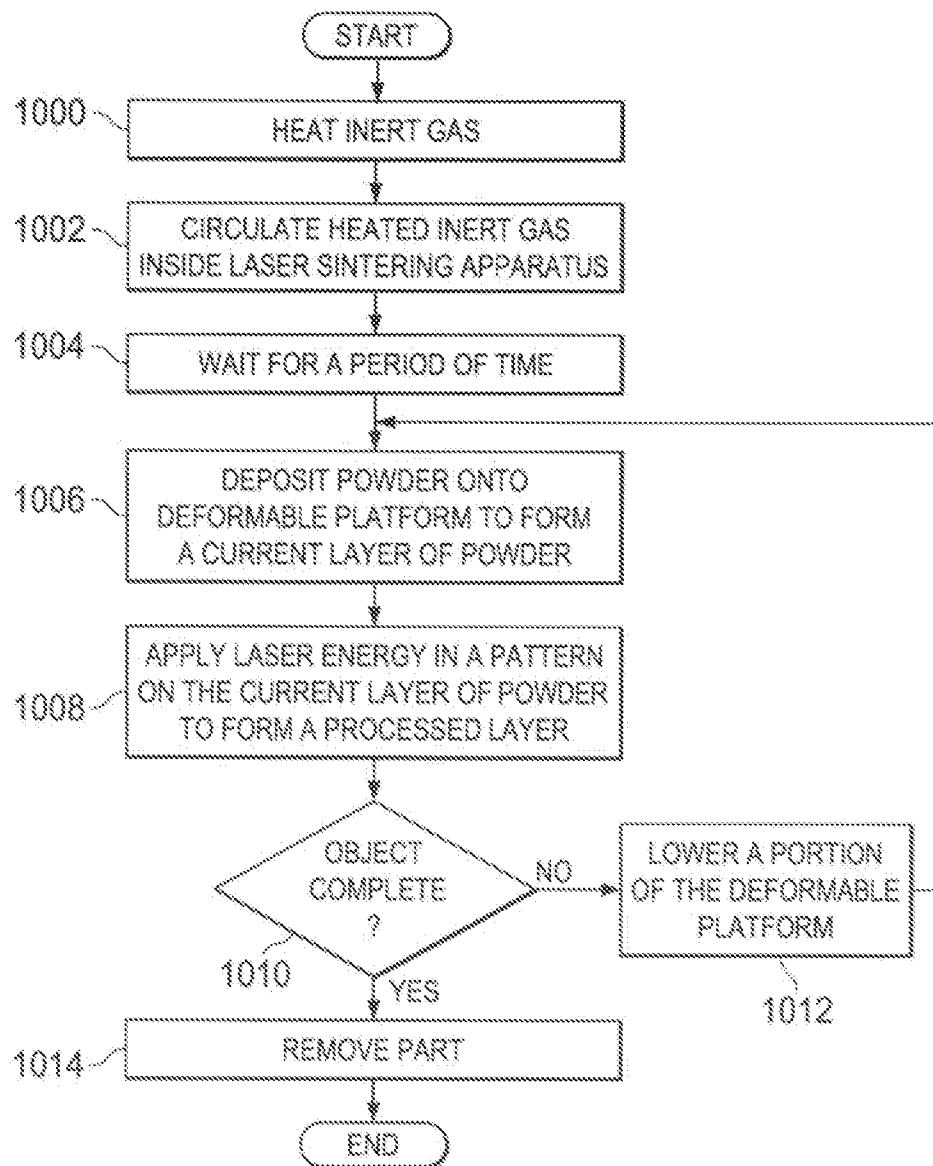


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/060709

A. CLASSIFICATION OF SUBJECT MATTER

INV. B22F3/105 B29C67/00 B29C35/04

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)

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 practical, search terms used)

EPO-Internal

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Y	figures 1,3	2-3,7-9, 11,13-15
Y	----- WO 2006/105827 A1 (EOS ELECTRO OPTICAL SYST [DE]; PHILIPPI JOCHEN [DE]; HALDER THOMAS [DE]) 12 October 2006 (2006-10-12) page 5, paragraph 2; figure 1	2-3,7,14
Y	----- WO 2006/121797 A2 (EX ONE COMPANY [US]; SEIBERT JAMES [US]; RYNERSON MICHAEL L [US]) 16 November 2006 (2006-11-16) page 10, line 10 - line 16	2,8-9,15
Y	----- EP 1 384 565 A1 (BOEING CO [US]) 28 January 2004 (2004-01-28) figure 1	11,13
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

24 February 2010

Date of mailing of the international search report

04/03/2010

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/060709

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Information on patent family members

International application No

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