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(54) **SYSTEM AND METHOD TO CONTROL A THREE-DIMENSIONAL (3D) PRINTER**

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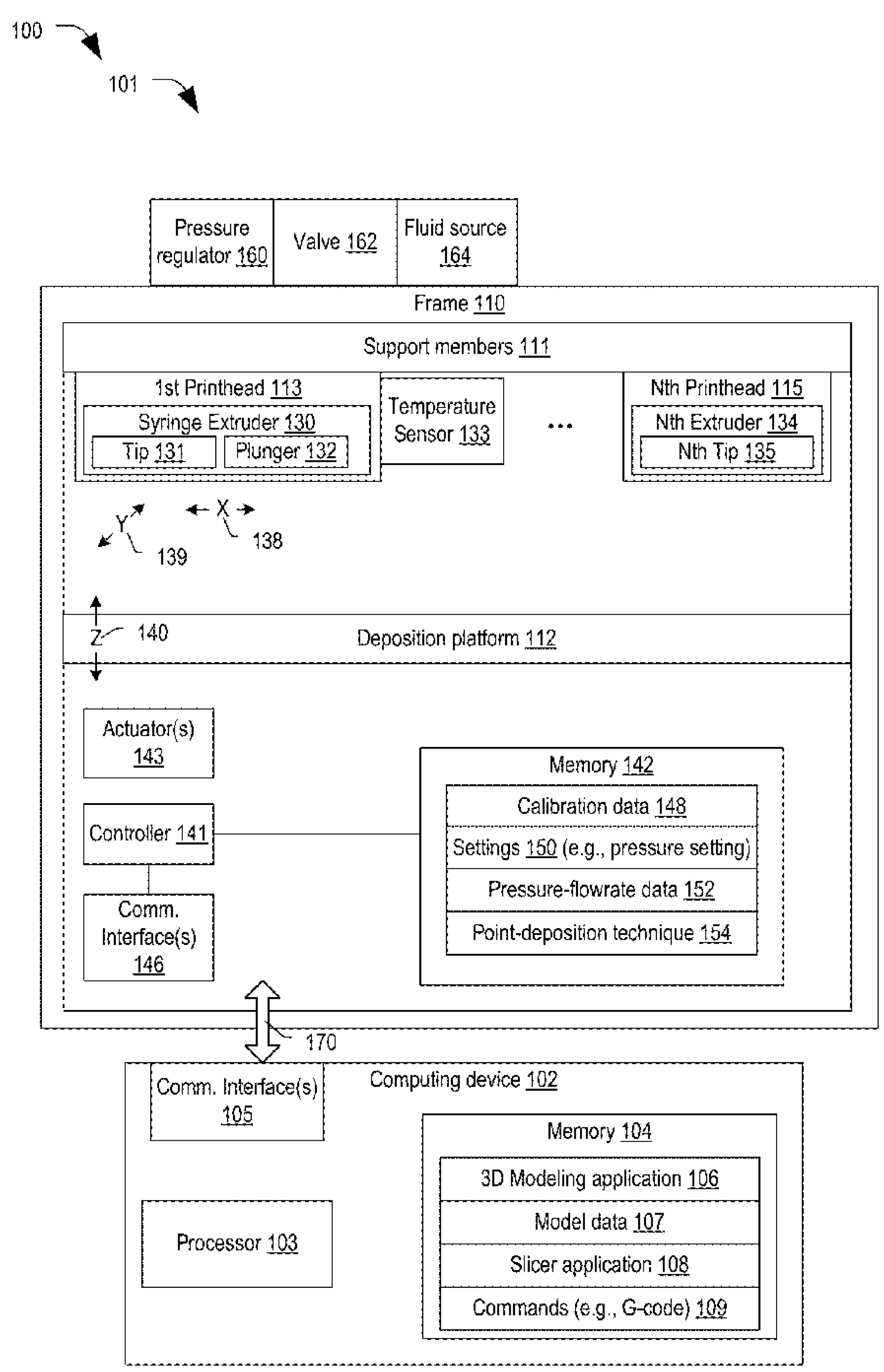
(57) **ABSTRACT**

A method include obtaining model data specifying a three-dimensional (3D) model of an object. The method also includes generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder. The first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a pressure to be applied to the syringe extruder. The method also includes generating second machine instructions executable by a 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder. The second machine instructions indicate a second value of the pressure setting, the second value different from the first value.



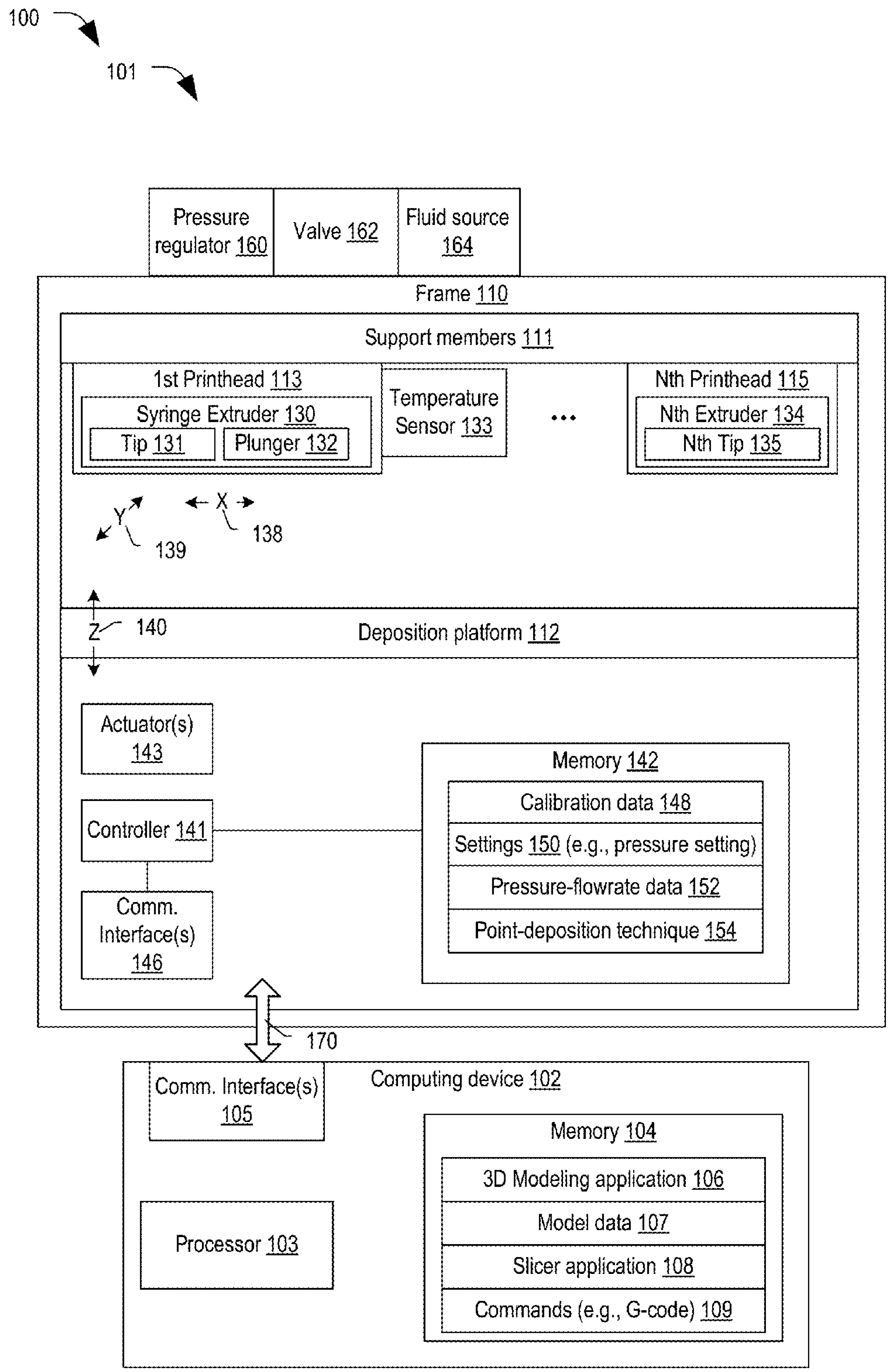

100
101
Pressure regulator 160
Valve 162
Fluid source 164
Frame 110
Support members 111
1st Printhead 113
Syringe Extruder 130
Tip 131
Plunger 132
Temperature Sensor 133
Nth Printhead 115
Nth Extruder 134
Nth Tip 135
Y
139
X
138
Z
140
Deposition platform 112
Actuator(s) 143
Controller 141
Comm. Interface(s) 146
Memory 142
Calibration data 148
Settings 150 (e.g., pressure setting)
Pressure-flowrate data 152
Point-deposition technique 154
170
Comm. Interface(s) 105
Computing device 102
Processor 103
Memory 104
3D Modeling application 106
Model data 107
Slicer application 108
Commands (e.g., G-code) 109

FIG. 1

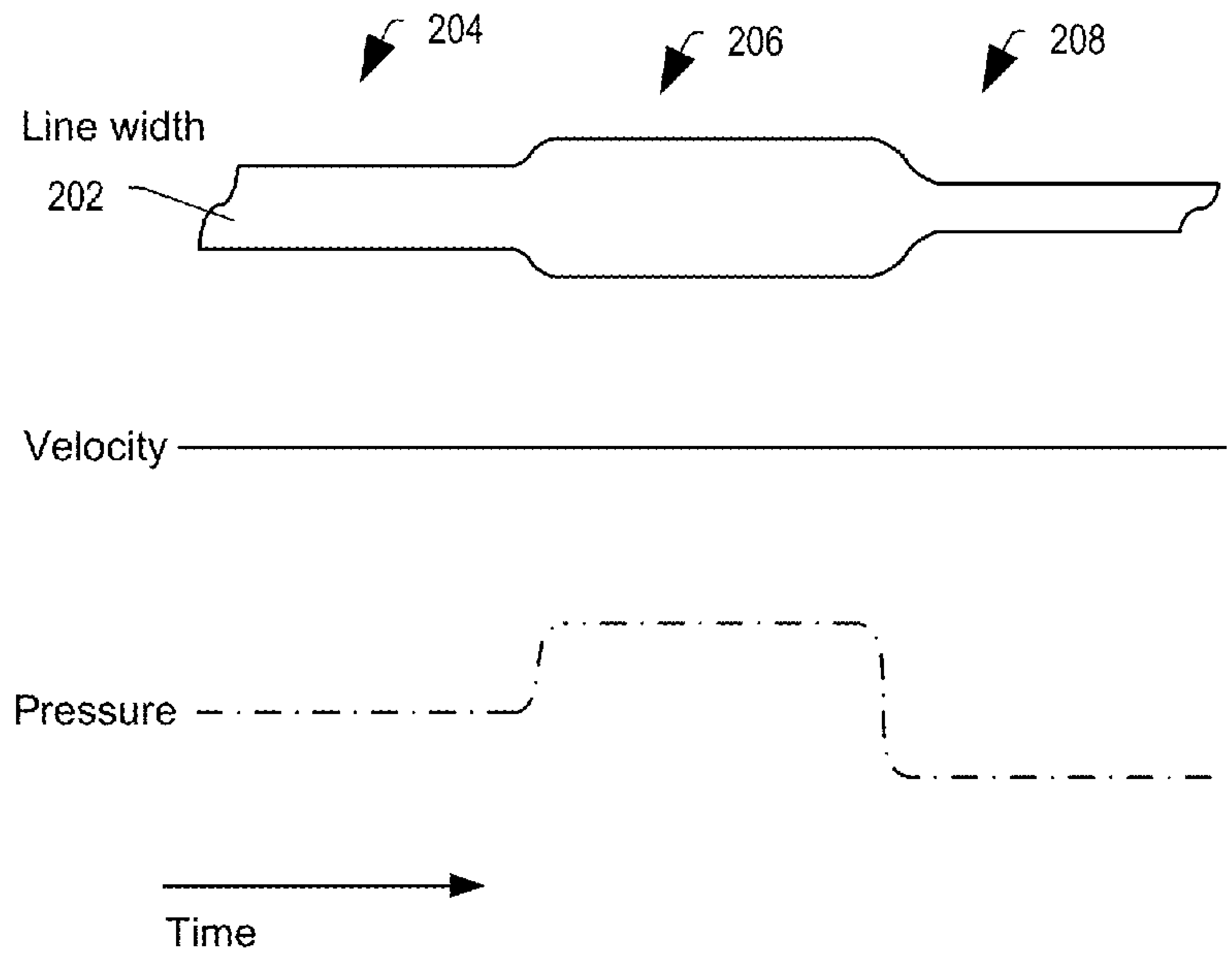

204
206
208
Line width
202
Velocity
Pressure
Time

FIG. 2A

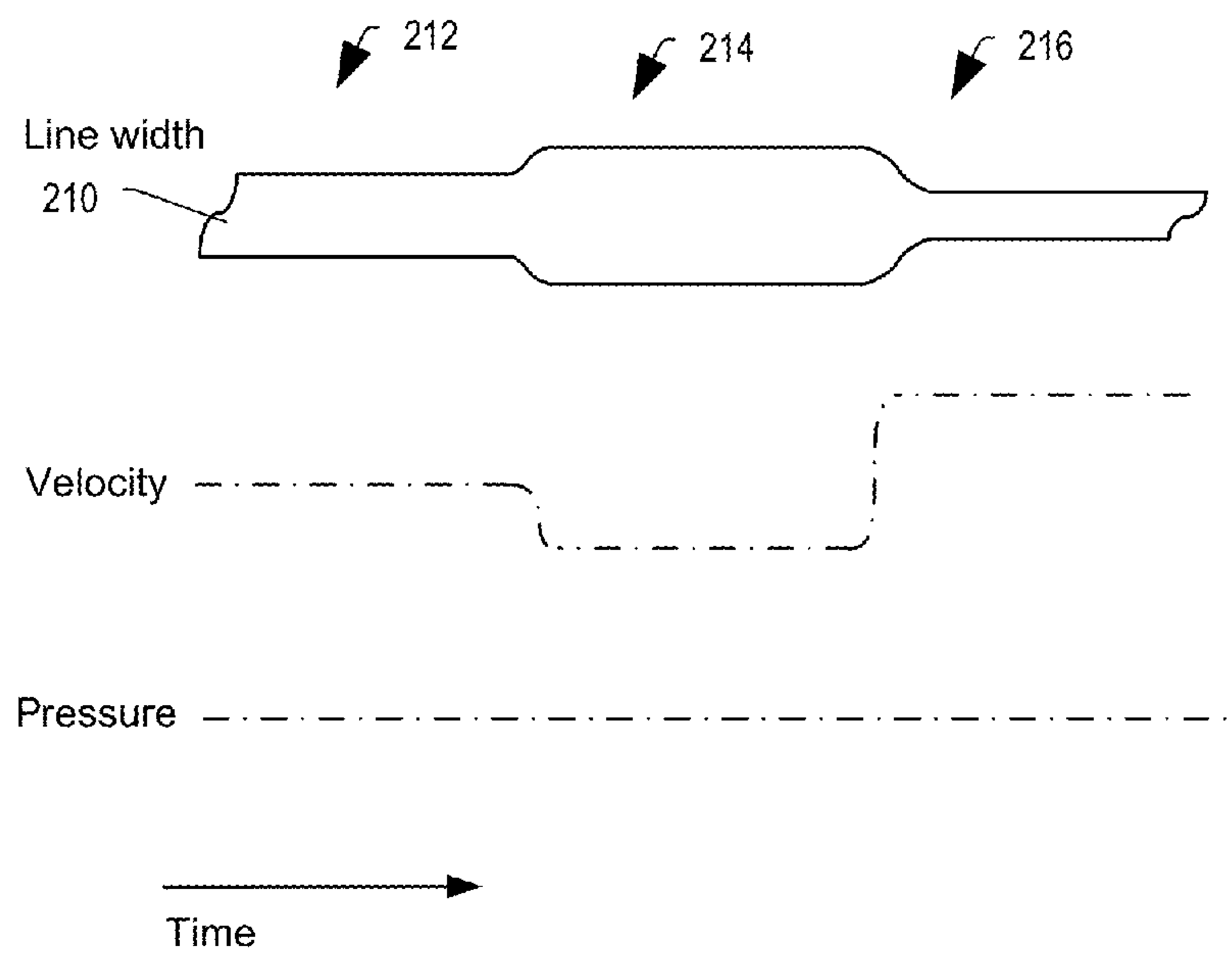

212
214
216
Line width
210
Velocity
Pressure
Time

FIG. 2B

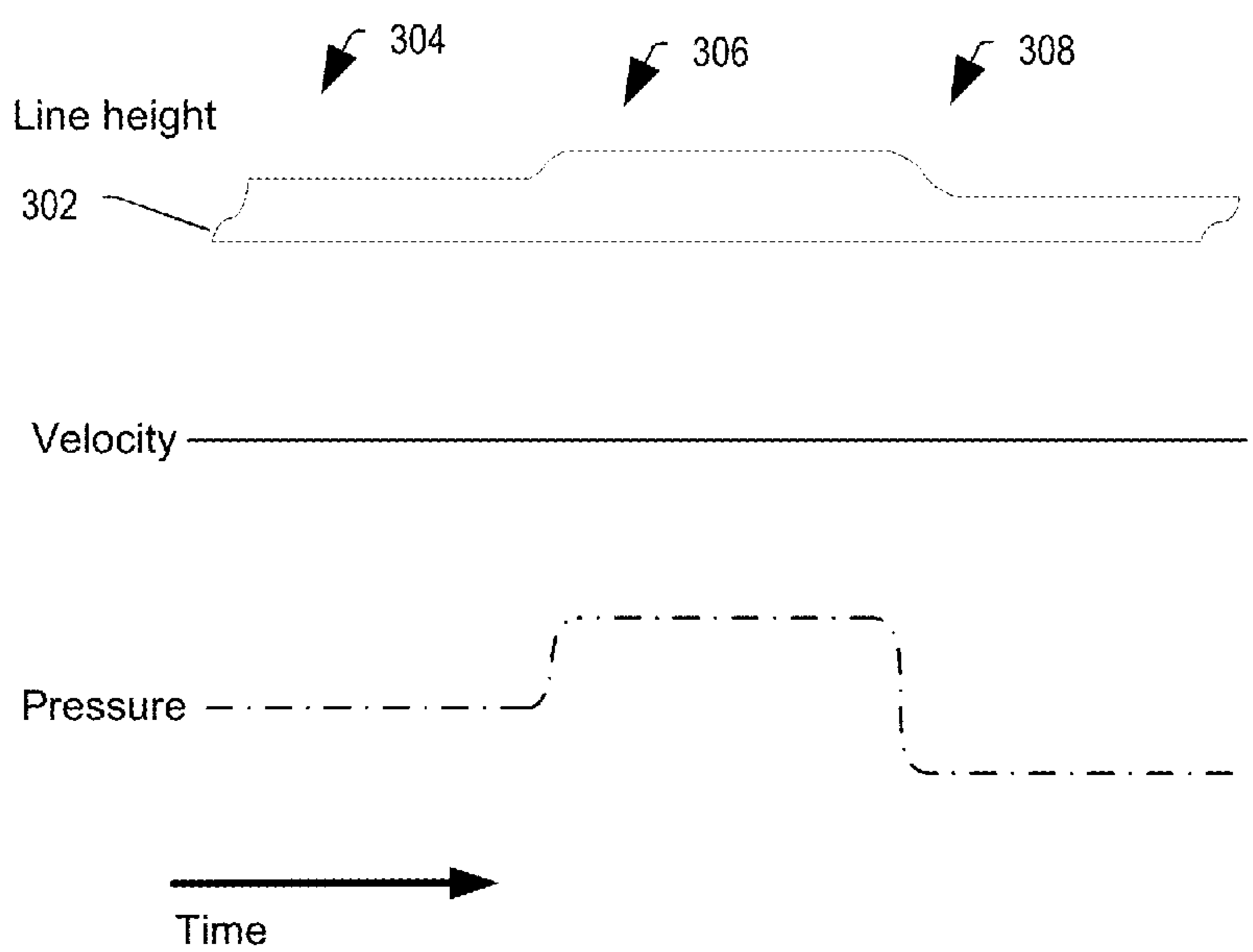

304
306
308
Line height
302
Velocity
Pressure
Time

FIG. 3A

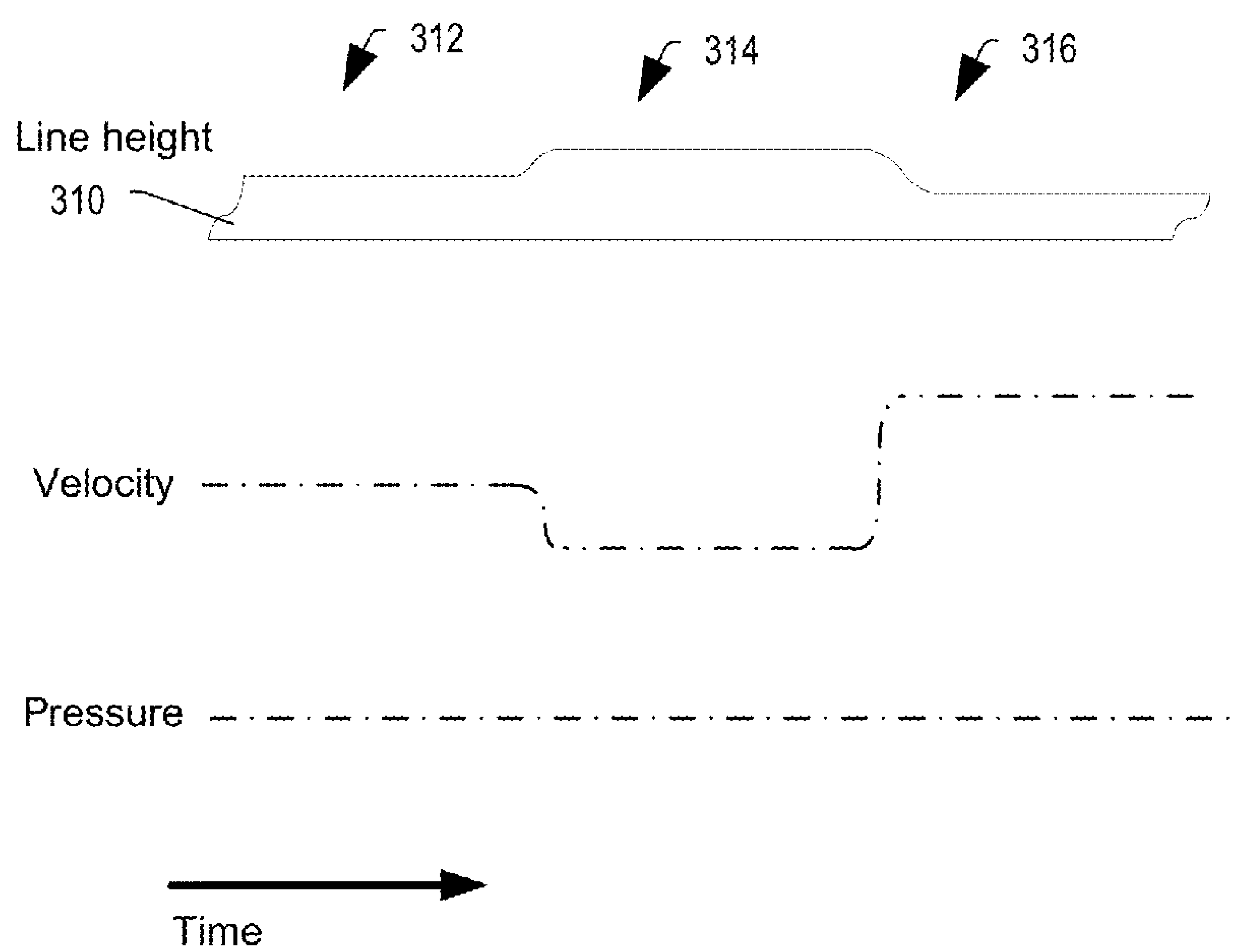
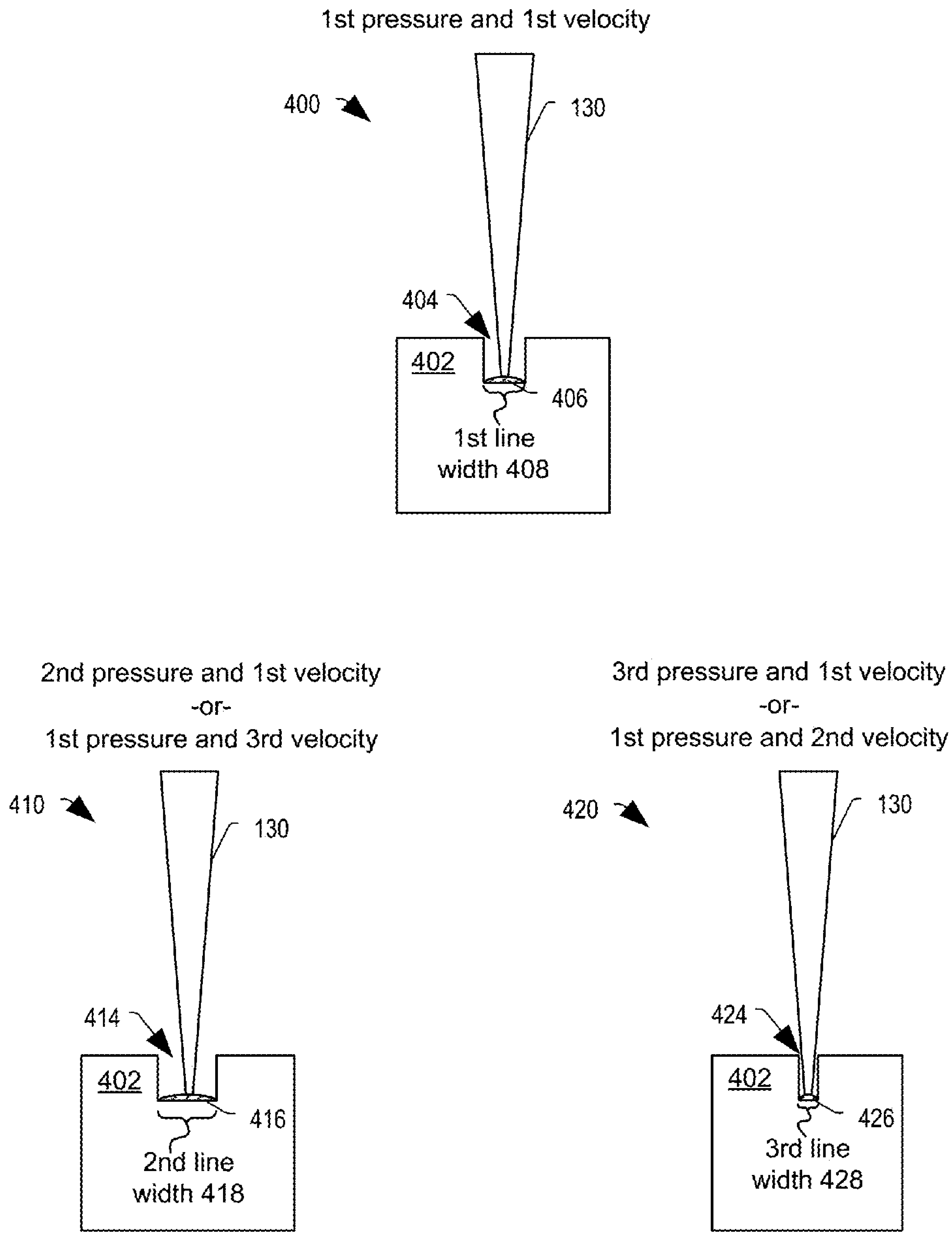

312
314
316
Line height
310
Velocity
Pressure
Time

FIG. 3B



3rd pressure < 1st pressure < 2nd pressure

3rd velocity < 1st velocity < 2nd velocity

3rd line width < 1st line width < 2nd line width

FIG. 4

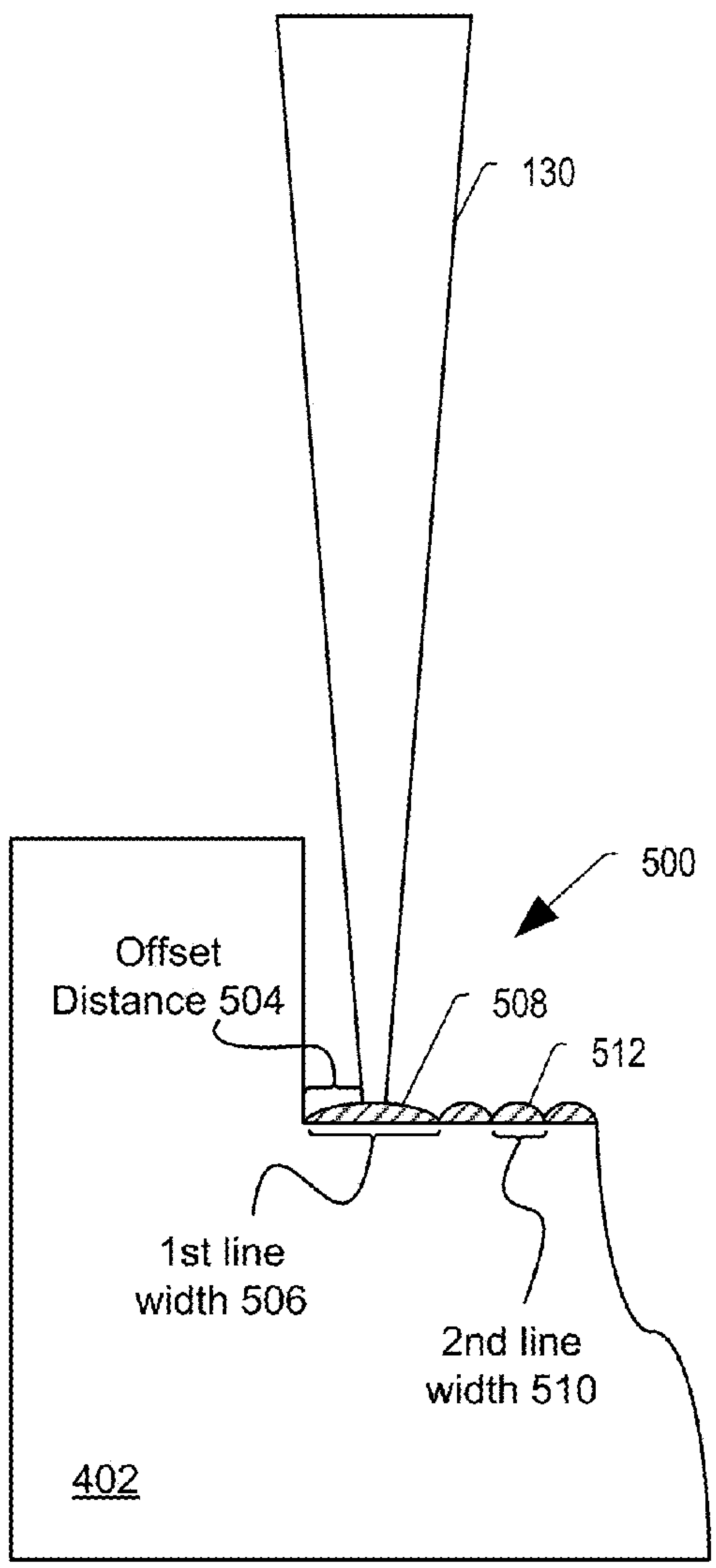

130
500
Offset
Distance 504
508
512
1st line
width 506
2nd line
width 510
402

FIG. 5

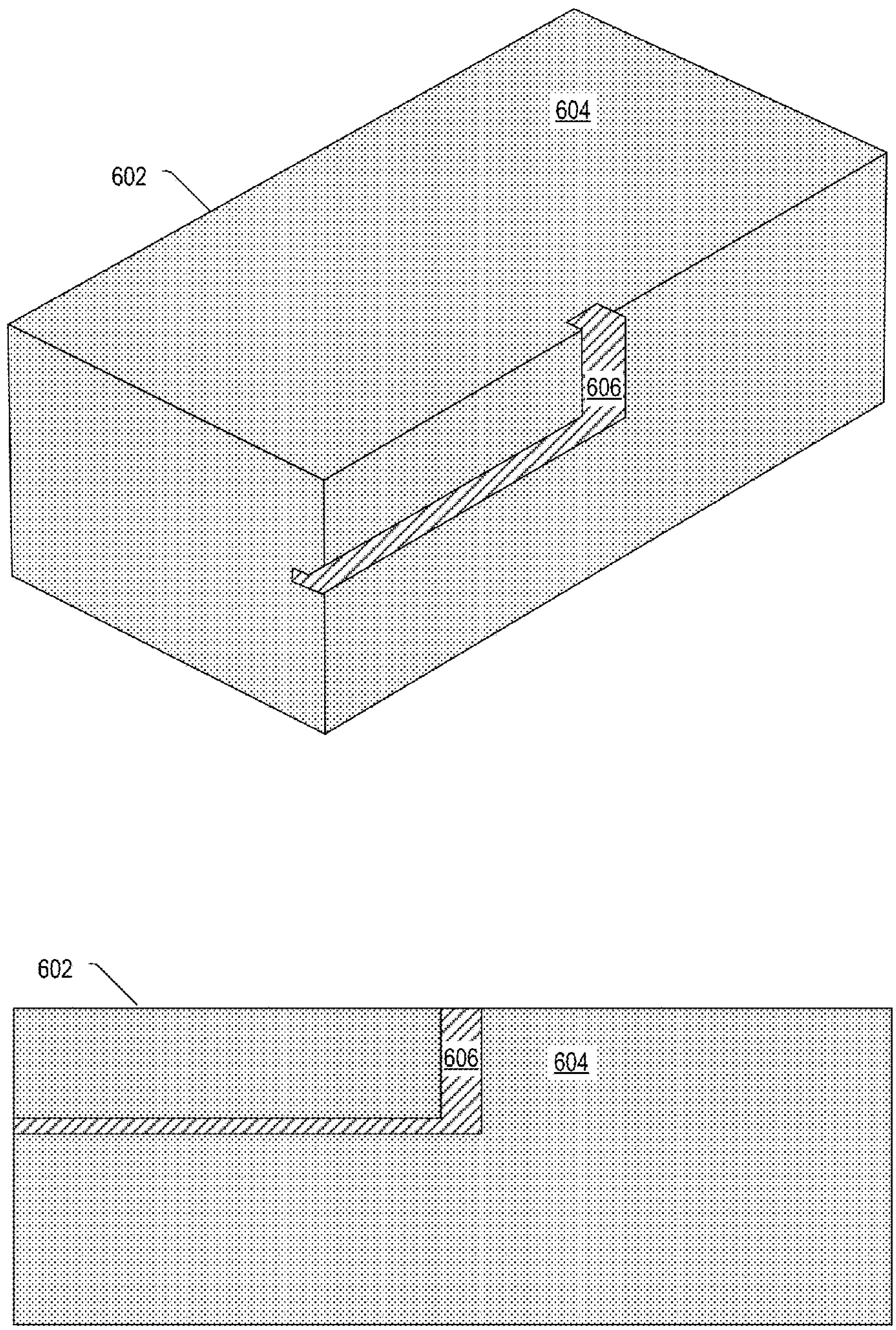


FIG. 6

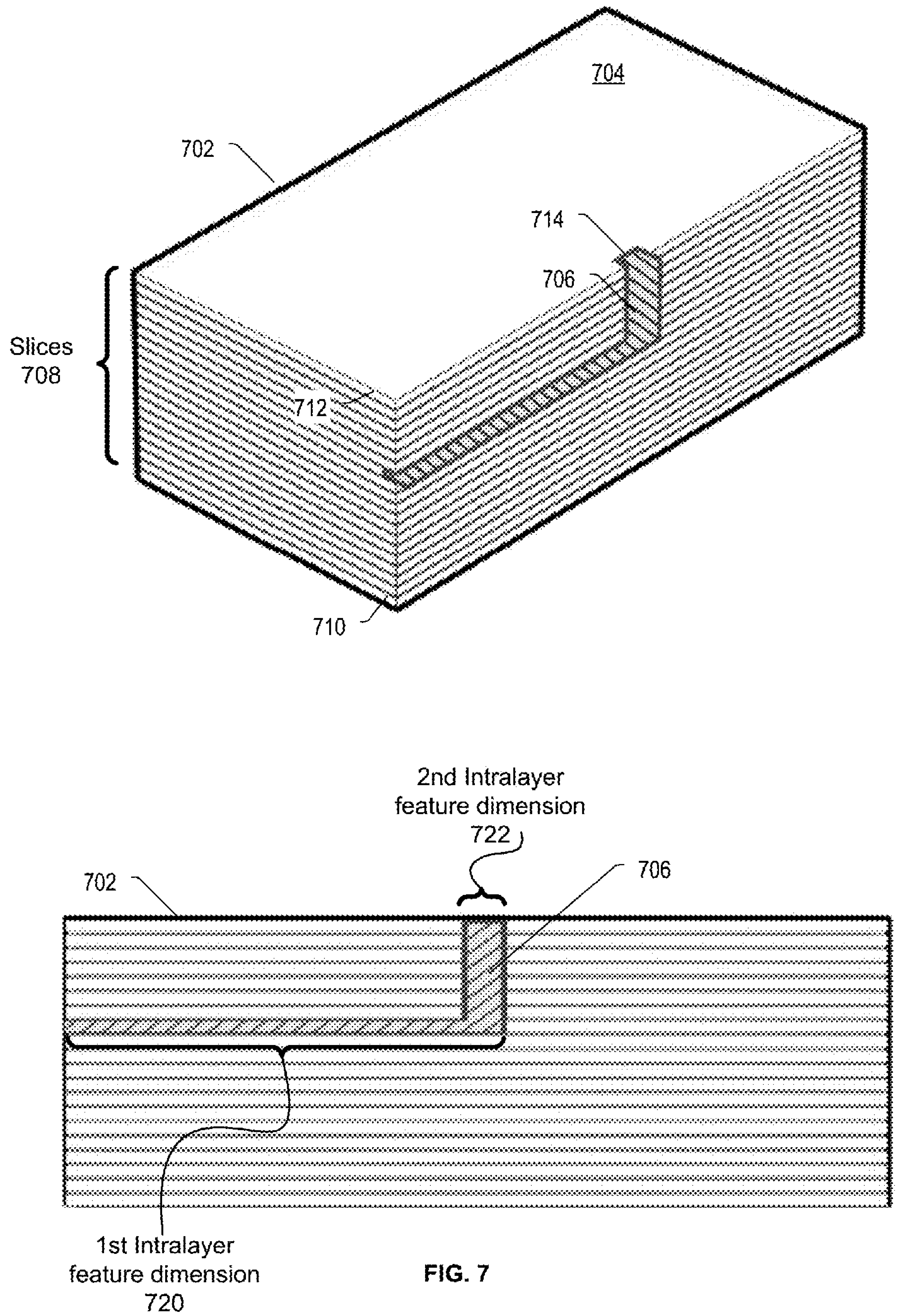

704
702
714
706
Slices
708
712
710
2nd Intralayer
feature dimension
722
702
706
1st Intralayer
feature dimension
720

FIG. 7

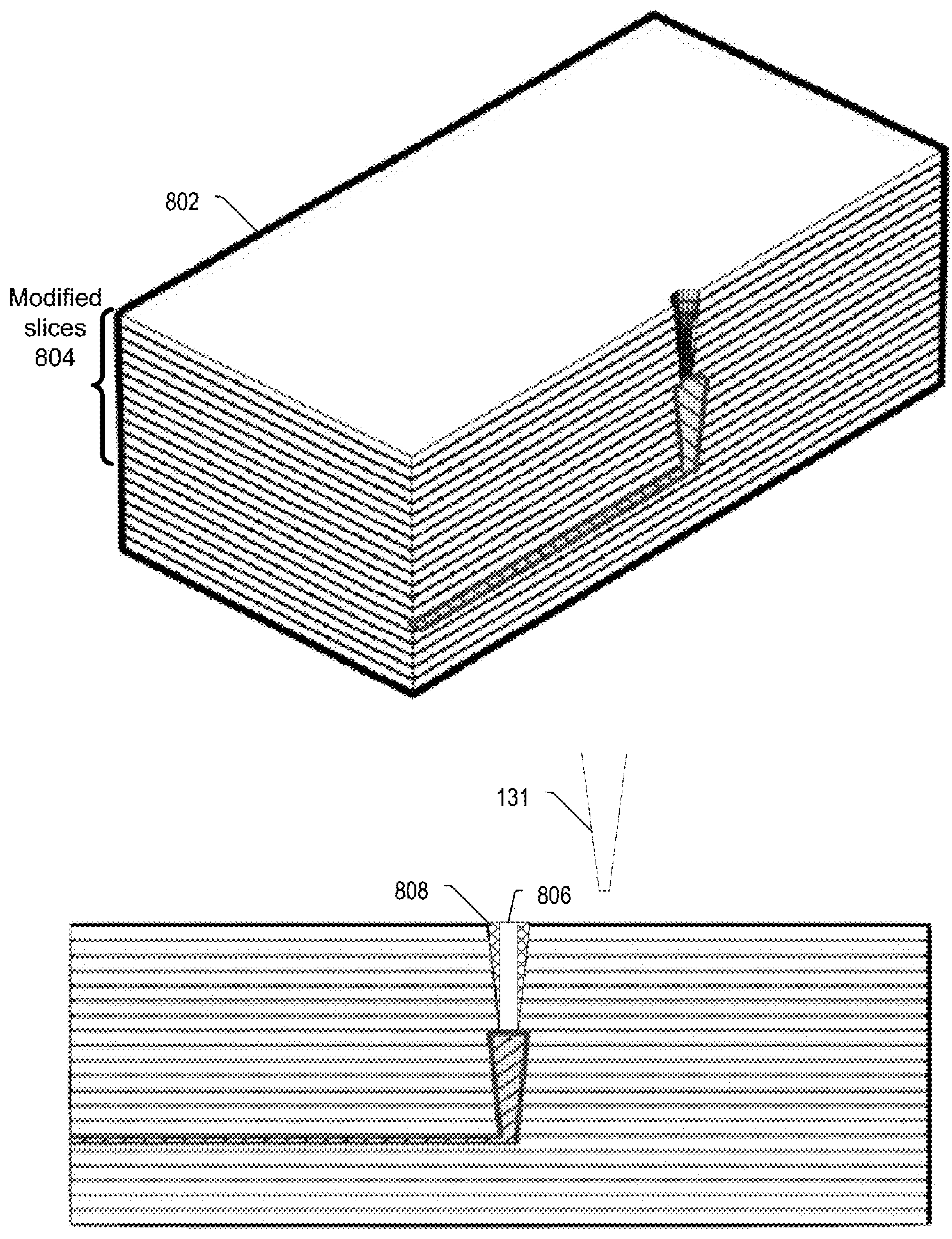


FIG. 8

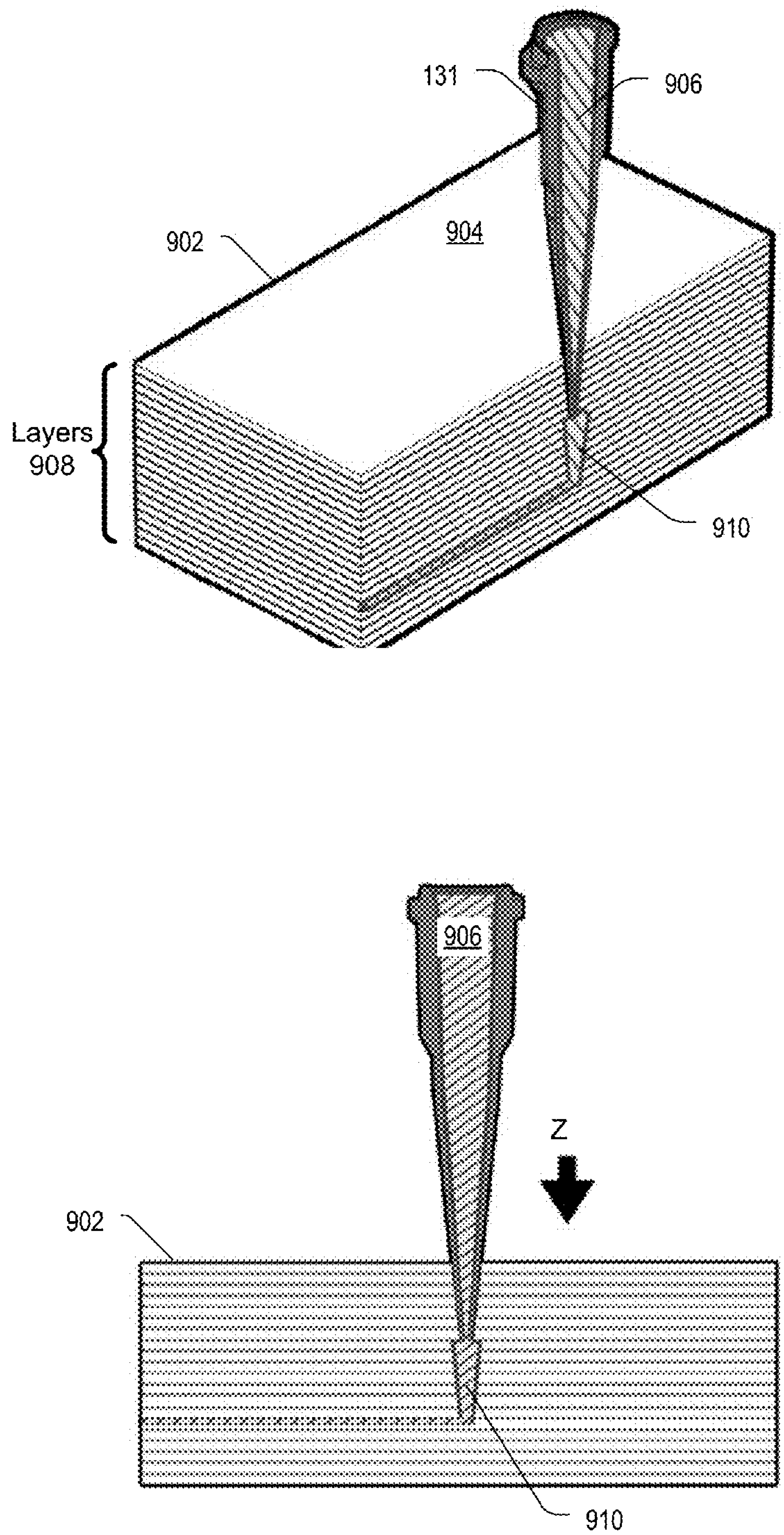


FIG. 9

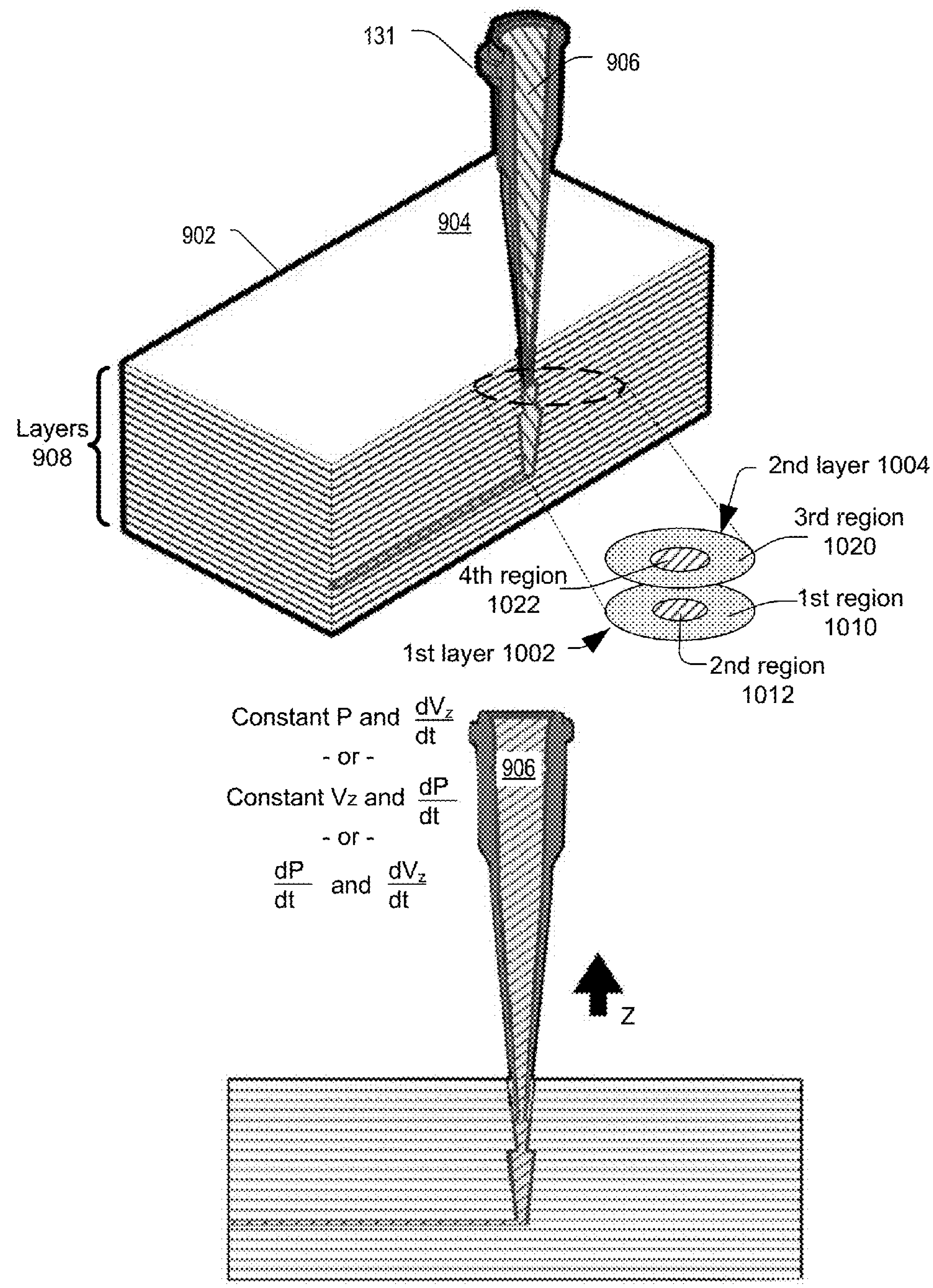

131
906
902
904
Layers 908
2nd layer 1004
3rd region 1020
4th region 1022
1st region 1010
1st layer 1002
2nd region 1012
Constant P and $\frac{dV_z}{dt}$
- or -
Constant Vz and $\frac{dP}{dt}$
- or -
$\frac{dP}{dt}$ and $\frac{dV_z}{dt}$
906
Z

FIG. 10

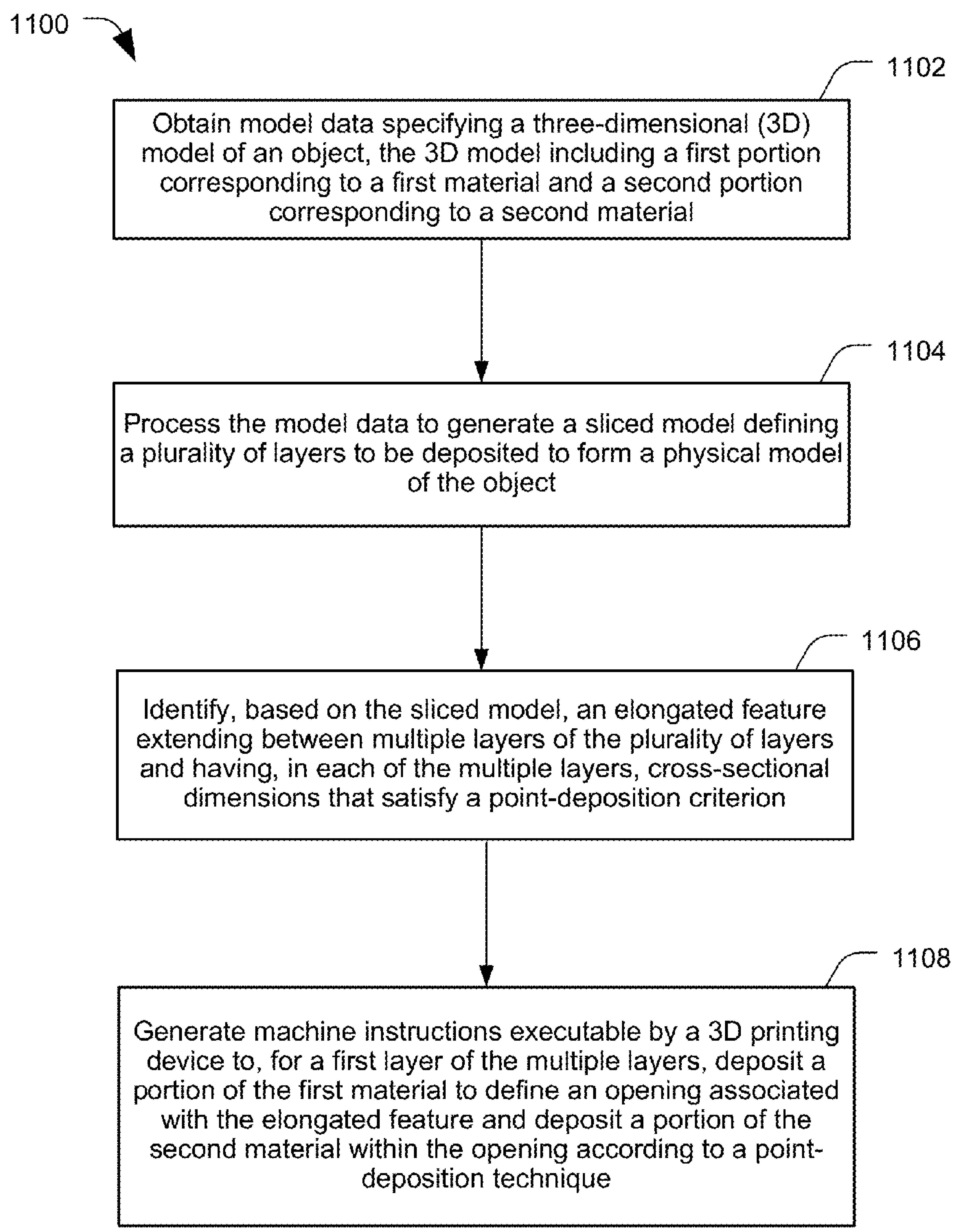

1100
1102
Obtain model data specifying a three-dimensional (3D) model of an object, the 3D model including a first portion corresponding to a first material and a second portion corresponding to a second material
1104
Process the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object
1106
Identify, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion
1108
Generate machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique

FIG. 11

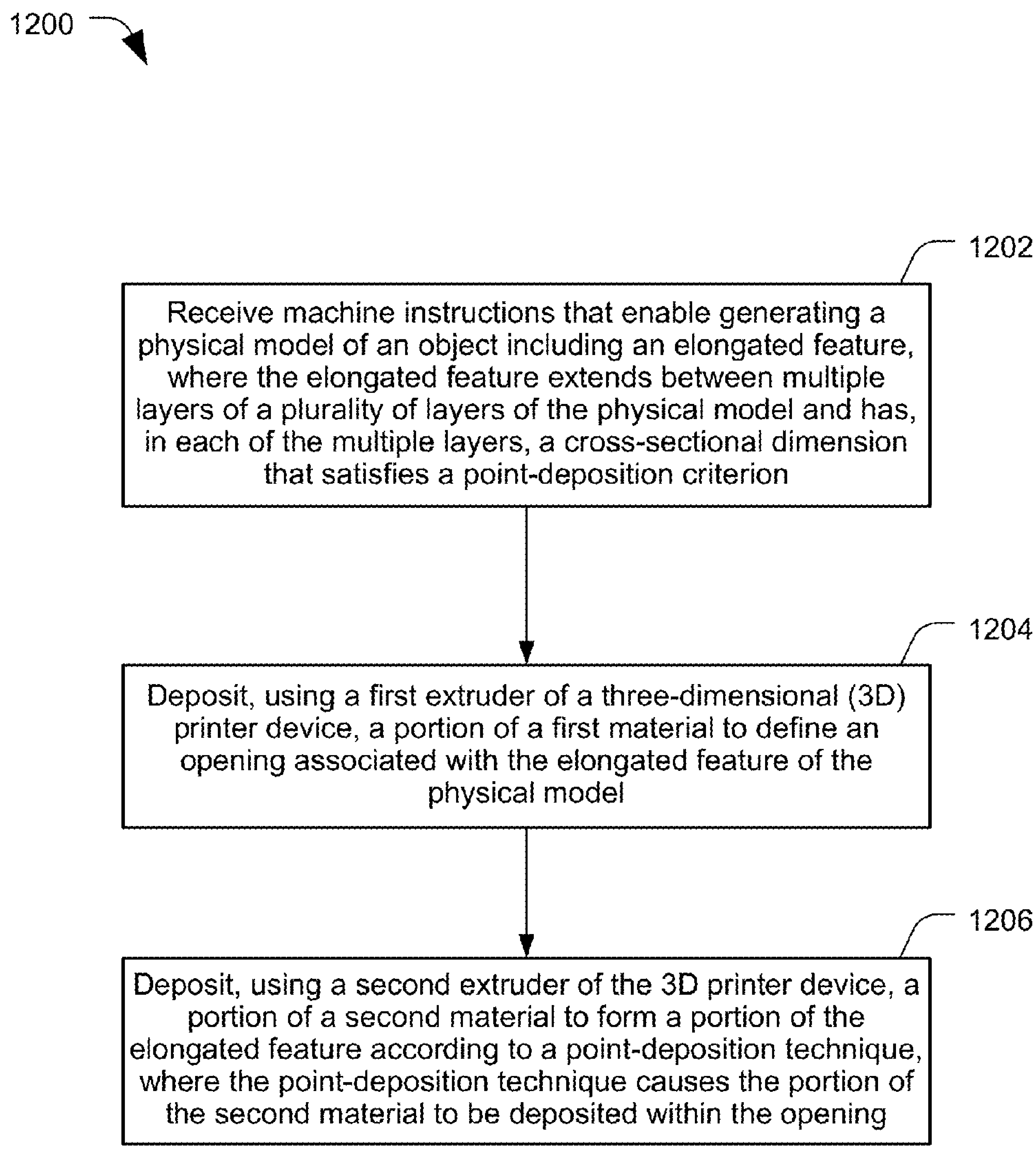

1200
1202
Receive machine instructions that enable generating a physical model of an object including an elongated feature, where the elongated feature extends between multiple layers of a plurality of layers of the physical model and has, in each of the multiple layers, a cross-sectional dimension that satisfies a point-deposition criterion
1204
Deposit, using a first extruder of a three-dimensional (3D) printer device, a portion of a first material to define an opening associated with the elongated feature of the physical model
1206
Deposit, using a second extruder of the 3D printer device, a portion of a second material to form a portion of the elongated feature according to a point-deposition technique, where the point-deposition technique causes the portion of the second material to be deposited within the opening

FIG. 12

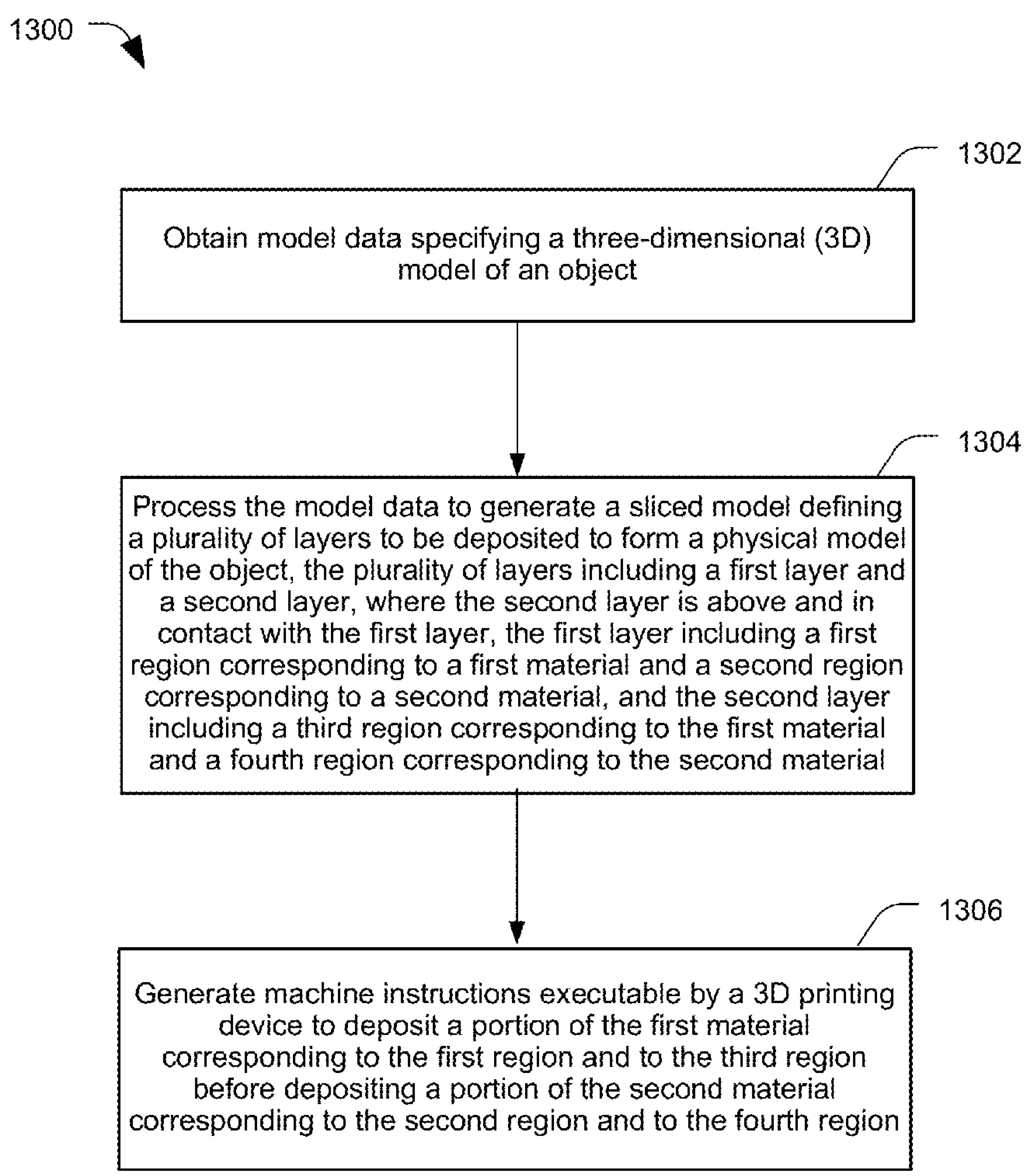

1300
1302
Obtain model data specifying a three-dimensional (3D) model of an object
1304
Process the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object, the plurality of layers including a first layer and a second layer, where the second layer is above and in contact with the first layer, the first layer including a first region corresponding to a first material and a second region corresponding to a second material, and the second layer including a third region corresponding to the first material and a fourth region corresponding to the second material
1306
Generate machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region

FIG. 13

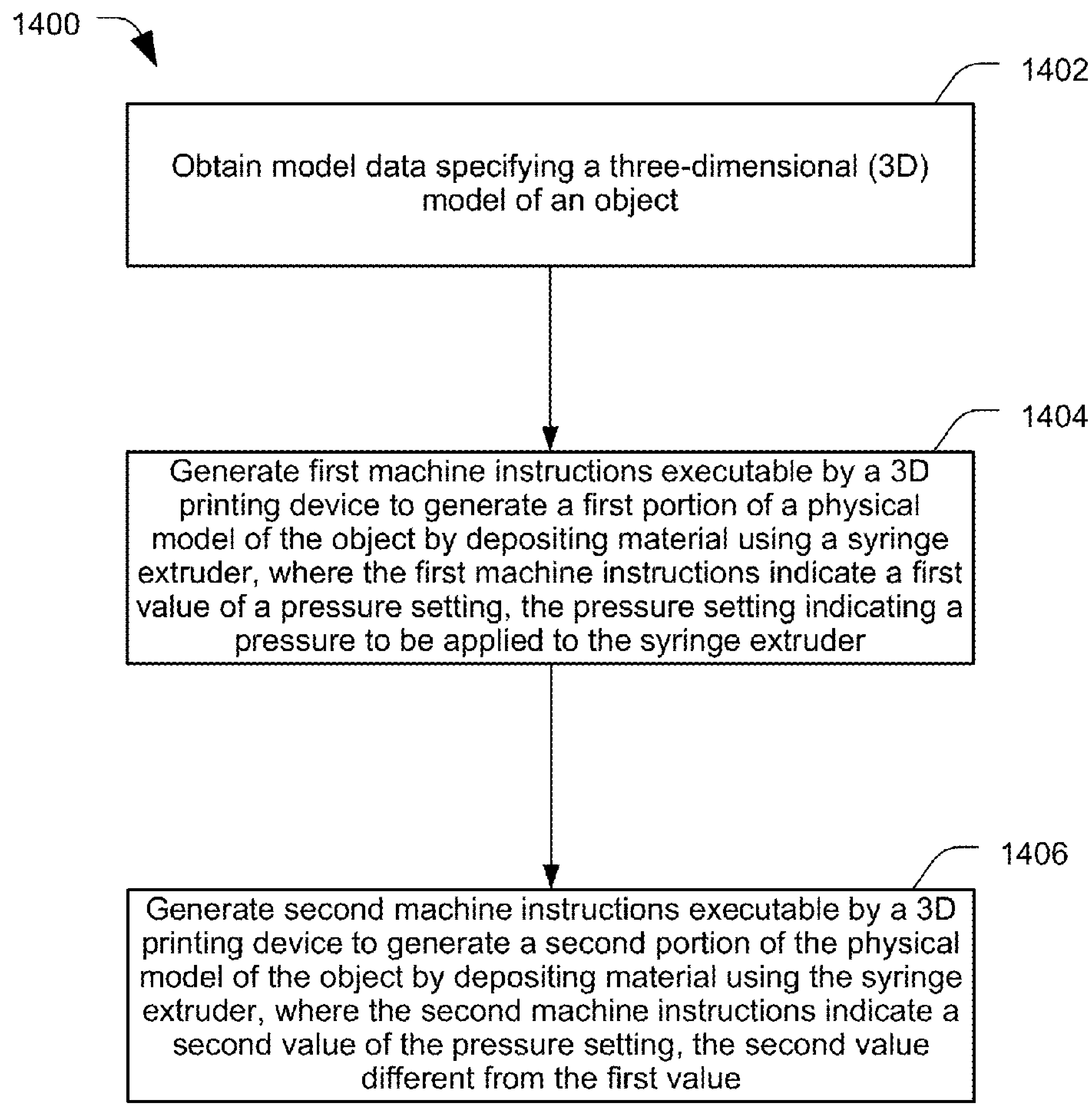

1400
1402
Obtain model data specifying a three-dimensional (3D) model of an object
1404
Generate first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder, where the first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a pressure to be applied to the syringe extruder
1406
Generate second machine instructions executable by a 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder, where the second machine instructions indicate a second value of the pressure setting, the second value different from the first value

FIG. 14

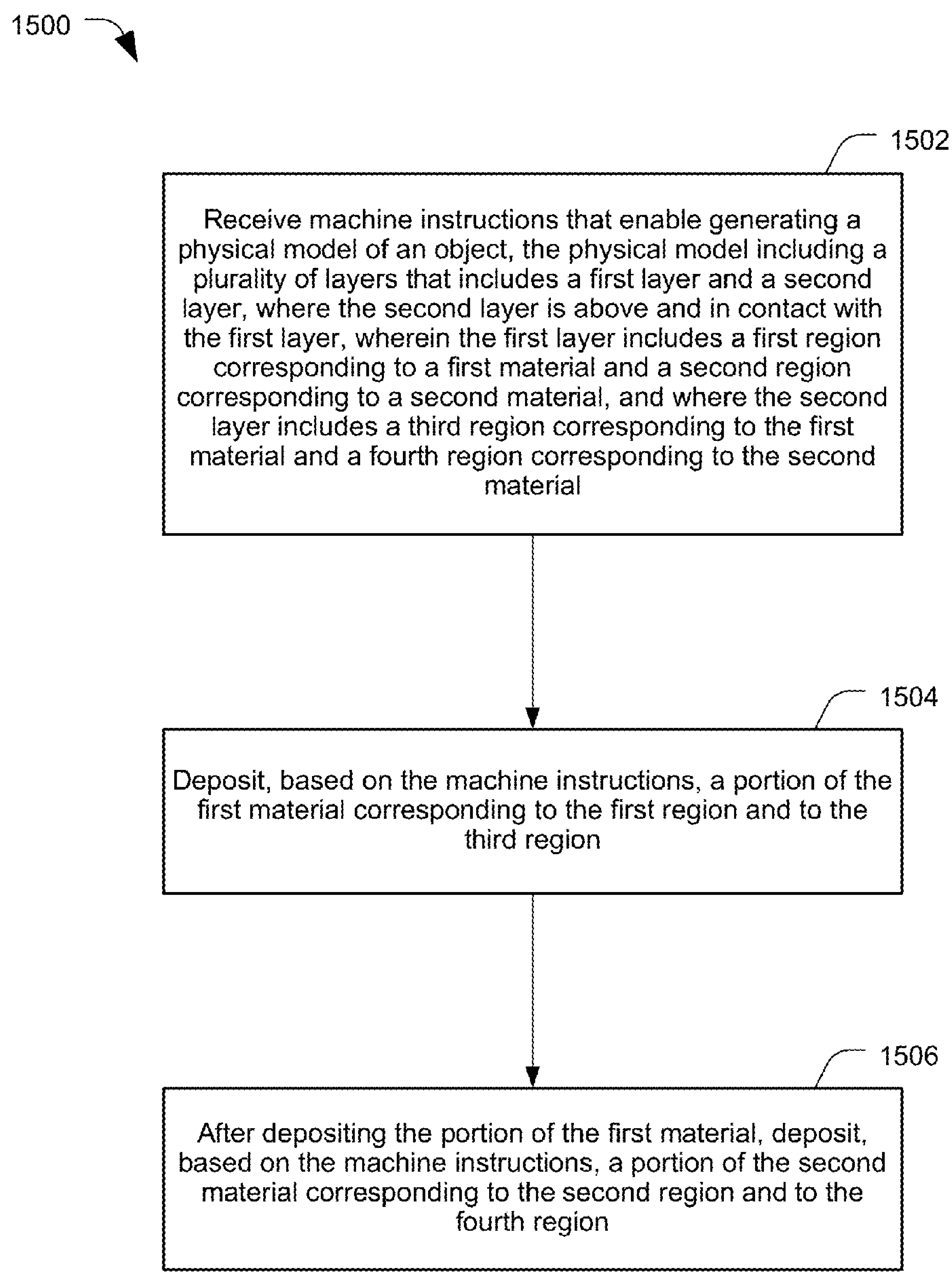

1500
1502
Receive machine instructions that enable generating a physical model of an object, the physical model including a plurality of layers that includes a first layer and a second layer, where the second layer is above and in contact with the first layer, wherein the first layer includes a first region corresponding to a first material and a second region corresponding to a second material, and where the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material
1504
Deposit, based on the machine instructions, a portion of the first material corresponding to the first region and to the third region
1506
After depositing the portion of the first material, deposit, based on the machine instructions, a portion of the second material corresponding to the second region and to the fourth region

FIG. 15

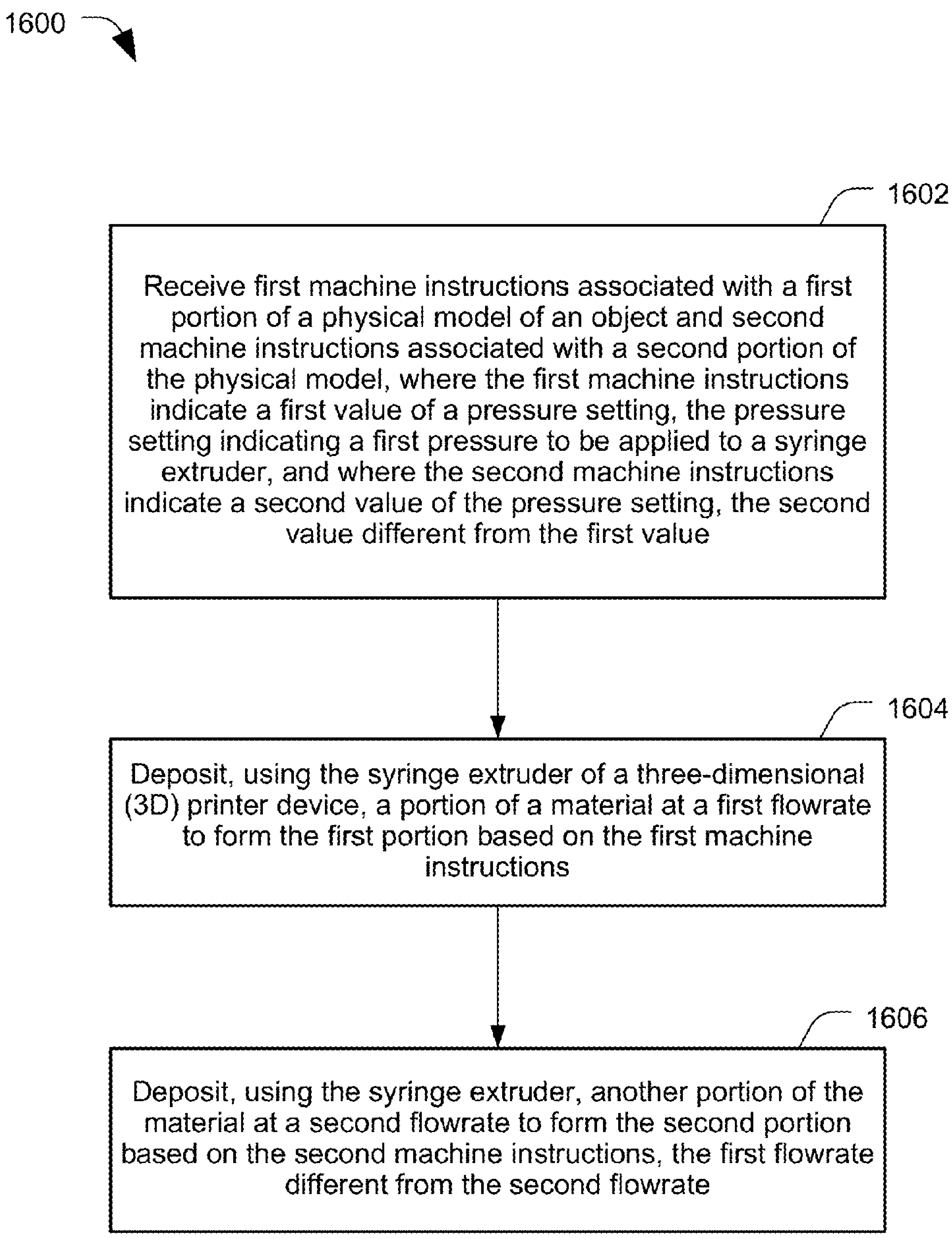

1600
1602
Receive first machine instructions associated with a first portion of a physical model of an object and second machine instructions associated with a second portion of the physical model, where the first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a first pressure to be applied to a syringe extruder, and where the second machine instructions indicate a second value of the pressure setting, the second value different from the first value
1604
Deposit, using the syringe extruder of a three-dimensional (3D) printer device, a portion of a material at a first flowrate to form the first portion based on the first machine instructions
1606
Deposit, using the syringe extruder, another portion of the material at a second flowrate to form the second portion based on the second machine instructions, the first flowrate different from the second flowrate

FIG. 16

SYSTEM AND METHOD TO CONTROL A THREE-DIMENSIONAL (3D) PRINTER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/208,222, filed Aug. 21, 2015 and entitled "Closed-Loop 3D Printing Incorporating Sensor Feedback," U.S. Provisional Patent Application No. 62/340,389, filed May 23, 2016 and entitled "SYSTEM AND METHOD TO CONTROL A THREE-DIMENSIONAL (3D) PRINTER," U.S. Provisional Patent Application No. 62/340,421, filed May 23, 2016 and entitled "SYSTEM AND METHOD TO CONTROL A THREE-DIMENSIONAL (3D) PRINTER," U.S. Provisional Patent Application No. 62/340,453, filed May 23, 2016 and entitled "SYSTEM AND METHOD TO CONTROL A THREE-DIMENSIONAL (3D) PRINTING DEVICE," U.S. Provisional Patent Application No. 62/340,436, filed May 23, 2016 and entitled "SYSTEM AND METHOD TO CONTROL A THREE-DIMENSIONAL (3D) PRINTER," and U.S. Provisional Patent Application No. 62/340,432, filed May 23, 2016 and entitled "3D PRINTER CALIBRATION AND CONTROL," the contents of each of the aforementioned applications are expressly incorporated herein by reference in their entirety.

FIELD OF THE DISCLOSURE

[0002] The present disclosure is generally related to control of a three-dimensional (3D) printer device.

BACKGROUND

[0003] Improvements in computing technologies and material processing technologies have led to an increased interest in computer-driven additive manufacturing techniques, such as three-dimensional (3D) printing. Generally, 3D printing is performed using a 3D printer device that includes an extruder, one or more actuators, and a controller coupled to some form of structural alignment system, such as a frame. The controller is configured to control the extruder and the actuators to deposit material, such as a polymer-based material, in a controlled arrangement to form a physical object.

SUMMARY

[0004] In a particular implementation, a method includes obtaining model data specifying a three-dimensional (3D) model of an object. The method further includes processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object. The plurality of layers include a first layer and a second layer, where the second layer is above and in contact with the first layer. The first layer includes a first region corresponding to a first material and a second region corresponding to a second material, and the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material. The method further includes generating machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region.

[0005] In another particular implementation, a method includes obtaining model data specifying a three-dimensional (3D) model of an object and generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder. The first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a pressure to be applied to the syringe extruder. The method also includes generating second machine instructions executable by the 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder. The second machine instructions indicate a second value of the pressure setting.

[0006] In a particular embodiment, a computer-readable storage device stores instructions that are executable by a processor to cause the processor to perform operations including obtaining model data specifying a three-dimensional (3D) model of an object. The operations also include processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object, the plurality of layers including a first layer and a second layer. The second layer is above and in contact with the first layer. The first layer includes a first region corresponding to a first material and a second region corresponding to a second material. The second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material. The operations also include generating machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region.

[0007] In a particular embodiment, a computer-readable storage device stores instructions that are executable by a processor to cause the processor to perform operations including obtaining model data specifying a three-dimensional (3D) model of an object. The operations also include generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder. The first machine instructions indicate a first value of a pressure setting. The pressure setting indicating a pressure to be applied to the syringe extruder. The operations also include generating second machine instructions executable by the 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder. The second machine instructions indicate a second value of the pressure setting.

[0008] In a particular embodiment, a computing device includes a processor and a memory accessible to the processor. The memory stores instructions that are executable by the processor to cause the processor to perform operations including obtaining model data specifying a three-dimensional (3D) model of an object. The operations also include processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object. The plurality of layers include a first layer and a second layer, where the second layer is above and in contact with the first layer. The first layer includes a first region corresponding to a first material and a second region corresponding to a second material, and the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material. The operations also include generating machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region.

[0009] In a particular embodiment, a computing device includes a processor and a memory accessible to the processor. The memory stores instructions that are executable by the processor to cause the processor to perform operations including obtaining model data specifying a three-dimensional (3D) model of an object. The operations also include generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder. The first machine instructions indicate a first value of a pressure setting, where the pressure setting indicates a pressure to be applied to the syringe extruder. The operations also include generating second machine instructions executable by the 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder. The second machine instructions indicate a second value of the pressure setting.

[0010] In a particular embodiment, a three-dimensional (3D) printer device includes one or more extruders configured to deposit a first material and a second material on a deposition platform to generate a physical model of an object. The physical model includes a plurality of layers including a first layer and a second layer, where the second layer is above and in contact with the first layer. The first layer includes a first region corresponding to the first material and a second region corresponding to the second material, and the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material. The 3D printer device also includes an actuator coupled to the one or more extruders, the deposition platform, or a combination thereof. The 3D printer device also includes a controller coupled to the actuator. The controller is configured to cause the one or more extruders to deposit a portion of the first material corresponding to the first region and to the third region, after depositing the portion of the first material, to cause the one or more extruders to deposit a portion of the second material corresponding to the second region and to the fourth region.

[0011] In a particular embodiment, a three-dimensional (3D) printer device includes a syringe extruder configured to deposit a material on a deposition platform at a flowrate based on a pressure regulator setting. The 3D printer device also includes an actuator coupled to the syringe extruder, to the pressure regulator, to the deposition platform, or to a combination thereof. The 3D printer device further includes a controller coupled to the actuator. The controller is configured to cause the syringe extruder to deposit, based on a first value of the pressure regulator setting, a first portion of the material at a first flowrate to form a first portion of a physical model and to cause the syringe extruder to deposit, based on a second value of the pressure regulator setting, a second portion of the material at a second flowrate to form a second portion of the physical model.

[0012] In a particular embodiment, a method includes receiving machine instructions that enable a 3D printer to generate a physical model of an object. The physical model includes a plurality of layers that includes a first layer and a second layer, where the second layer is above and in contact with the first layer. The first layer includes a first region corresponding to a first material and a second region corresponding to a second material, and the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material. The method also includes depositing, based on the machine instructions, a portion of the first material corresponding to the first region and to the third region. The method further includes, after depositing the portion of the first material, depositing, based on the machine instructions, a portion of the second material corresponding to the second region and to the fourth region.

[0013] In a particular embodiment, a method includes receiving first machine instructions associated with a first portion of a physical model of an object and second machine instructions associated with a second portion of the physical model. The first machine instructions indicate a first value of a pressure setting, where the pressure setting indicates a first pressure to be applied to a syringe extruder. The second machine instructions indicate a second value of the pressure setting, where the second value different from the first value. The method also includes depositing, using the syringe extruder of a three-dimensional (3D) printer device, a portion of a material at a first flowrate to form the first portion based on the first machine instructions. The method further includes depositing, using the syringe extruder, another portion of the material at a second flowrate to form the second portion based on the second machine instructions. The first flowrate is different from the second flowrate.

[0014] In another particular implementation, a method includes obtaining model data specifying a three-dimensional (3D) model of an object. The 3D model includes a first portion corresponding to a first material and a second portion corresponding to a second material. The method also includes processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object. The method further includes identifying, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion. The method also includes generating machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique.

[0015] In a particular implementation, a computer-readable storage device stores instructions that are executable by a processor to cause the processor to perform operations including obtaining model data specifying a three-dimensional (3D) model of an object. The 3D model includes a first portion corresponding to a first material and a second portion corresponding to a second material. The operations also include processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object. The operations further include identifying, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion. The operations also include generating machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique.

[0016] In a particular embodiment, a computing device includes a processor and a memory accessible to the processor. The memory stores instructions that are executable by the processor to cause the processor to perform operations including obtaining model data specifying a three-dimensional (3D) model of an object. The 3D model includes a first portion corresponding to a first material and a second portion corresponding to a second material. The operations also include processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object. The operations further include identifying, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion. The operations also include generating machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique.

[0017] In a particular embodiment, a three-dimensional (3D) printer device includes a first extruder configured to deposit a first material on a deposition platform and a second extruder configured to deposit a second material on the deposition platform. The 3D printer device also includes an actuator coupled to the first extruder, to the second extruder, to the deposition platform, or to a combination thereof. The 3D printer device also includes a controller coupled to the actuator. The controller is configured to cause the first extruder to deposit a portion of the first material to define an opening associated with an elongated feature of a physical model of an object. The elongated feature extends between multiple layers of a plurality of layers of the physical model and has, in each of the multiple layers, a cross-sectional dimension that satisfies a point-deposition criterion. The controller is further configured to cause the second extruder to deposit a portion of the second material to form a portion of the elongated feature according to a point-deposition technique.

[0018] In an embodiment, a method includes receiving machine instructions that enable generating a physical model of an object including an elongated feature, where the elongated feature extends between multiple layers of a plurality of layers of the physical model and has, in each of the multiple layers, a cross-sectional dimension that satisfies a point-deposition criterion. The method also includes depositing, using a first extruder of a three-dimensional (3D) printer device, a portion of a first material to define an opening associated with the elongated feature of the physical model. The method further includes depositing, using a second extruder of the 3D printer device, a portion of a second material to form a portion of the elongated feature according to a point-deposition technique, where the point-deposition technique causes the portion of the second material to be deposited within the opening.

[0019] Features, functions, and advantages described herein can be achieved independently in various implementations or may be combined in yet other implementations, further details of which are disclosed with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1** is a block diagram that illustrates a system that includes a three-dimensional (3D) printing device, according to a particular embodiment;

[0021] FIGS. **2**A and **2**B illustrate extruding material having particular line widths by a 3D printing device, according to particular embodiments;

[0022] FIGS. **3**A, and **3**B illustrate extruding material having particular line heights by a 3D printing device, according to particular embodiments;

[0023] FIG. **4** illustrate extruding material to fill an opening according to particular embodiments;

[0024] FIG. **5** illustrate extruding material to fill an offset distance according to particular embodiments;

[0025] FIGS. **6**, **7**, **8**, **9**, and **10** illustrate various stages during modeling, slicing and printing of a physical model;

[0026] FIG. **11** is a flow chart of an example of a method that may be performed by the system of FIG. **1**;

[0027] FIG. **12** is a flow chart of another example of a method that may be performed by the system of FIG. **1**;

[0028] FIG. **13** is a flow chart of another example of a method that may be performed by the system of FIG. **1**;

[0029] FIG. **14** is a flow chart of another example of a method that may be performed by the system of FIG. **1**;

[0030] FIG. **15** is a flow chart of another example of a method that may be performed by the system of FIG. **1**; and

[0031] FIG. **16** is a flow chart of another example of a method that may be performed by the system of FIG. **1**.

DETAILED DESCRIPTION

[0032] A 3D printer may be a peripheral device that includes an interface to a computing device. For example, the computing device may be used to generate or access a 3D model of an object. In this example, a computer-aided design (CAD) program may be used to generate the 3D model. A slicer application may process the 3D model to generate commands that are executable by the 3D printer to form a physical model of the object. For example, the slicer application may generate G-code (or other machine instructions) that instructs the controller of the 3D printer when and where to move the extruder and provides information regarding 3D printer settings, such as extruder temperature, material feed rate, extruder movement direction, extruder movement speed, among others.

[0033] The slicer application may generate the G-code or machine instructions by dividing the 3D model into layers (also referred to as "slices"). The slicer application determines a pattern of material to be deposited to form a physical model of each slice. Generally, the physical model of each slice is formed as a series or set of lines of extruded material. The G-code (or other machine instructions), when executed by the controller of the 3D printer, causes the extruder to deposit a set of lines of the material in a pattern to form each layer, and one layer is stacked upon another to form the physical model. Layer stacking arrangements or support members can also be used to form lines of the material that are partially unsupported (e.g., arches).

[0034] There are many ways that the slicer application can arrange the pattern of materials to be deposited to form each layer. Characteristics of a 3D print job may vary depending on how the slicer application arranges the pattern lines that make up each of the layers. For example, two different patterns of lines may have different printing characteristics, such as an amount of time used to print the physical model, an amount of material used to print the physical model, etc. As another example, two different patterns of lines may result in physical models that have different characteristics, such as interlayer adhesion, weight, durability, etc. Accordingly, different slicer applications or different settings or configurations of the slicer application can affect the outcome of a particular 3D print job.

[0035] In a particular embodiment, a 3D printer may include more than one print head or more than one extruder. Different types of extruders may be used to deposit different types of materials (e.g., physically or chemically distinct materials). For example, a filament-fed extruder may be used to deposit thermoplastic polymers, such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS) polymers, and polyamide, among others. Paste extruders, such as pneumatic or syringe extruders, may be used to deposit materials that are flowable at room temperature (or at a temperature controlled by the 3D printer). Examples of materials that may be deposited using syringe extruders include silicone polymers, polyurethane, epoxy polymers. syringe extruders may be especially useful to deposit materials that undergo curing upon exposure to air or when mixed together (such as multi-component epoxies).

[0036] Some 3D printers include multiple extruders to improve print speed or to enable printing with multiple different materials. For example, a first extruder may be used to deposit a first material, and a second extruder may be used to deposit second material. In this example, the first and second materials may have different visual, physical, electrical, chemical, mechanical, and/or other properties. To illustrate, the first material may have a first color, and the second material may have a second color. As another illustrative example, the first material may have first chemical characteristics (e.g., may be a thermoplastic polymer), and the second material may have a second chemical characteristics (e.g., may be a thermoset polymer). As yet another illustrative example, the first material may be substantially non-conductive, and the second material may be conductive. In this example, the first material may be used to form a structure or matrix, and the second material may be used to form conductive lines or electrical components (e.g., capacitors, resistors, inductors) of a circuit.

[0037] When a 3D printer uses multiple extruders to deposit multiple materials, determining when to switch between extruders can be challenging. For example, if an object being printed is formed of two different materials (e.g., a first material deposited by a first extruder and a second material deposited by a second extruder), a single layer of the object may include a region of the first material and a region of the second material. Switching extruders multiple times to print a single layer is time consuming and inefficient. Accordingly, the slicer application may be configured to reduce a number of tool swaps (i.e., changing from using the first extruder to using the second extruder, or vice versa). To illustrate, the region of the first material may be deposited before the region of the second material.

[0038] Further, in some implementations, regions of multiple layers of the first material may be deposited before the second material is deposited in regions of the multiple layers. For example, a first layer may include a first region associated with the first material and a second region associated with the second material. In this example, a second layer that is immediately adjacent to the first layer may include a third region associated with the first material and a fourth region associated with the second material. In this example, portions of the first material may be deposited to form the first region and the third regions. Subsequently, portions of the second material may be deposited to form the second region and the fourth region. Thus, some of the second material may be deposited on a layer below a highest layer of the first material that has been previously deposited.

[0039] In some instances, a 3D model may include a feature associated with one material that extends through multiple layers of the other material. For example, the feature may include a conductive feature (e.g. a wire formed of a conductive material) that is positioned such that it extends between multiple layers of a non-conductive material (e.g., a matrix material). In this example, the wire may have a relatively small cross-section in each layer. Conventional deposition techniques move an extruder laterally (e.g., in an X-Y plane) as material is extruded; however, due to the small cross-section of wires, and other extended features, lateral motion of the extruder may be inconvenient. In a particular embodiment, such extended features may be formed according to a point-deposition technique. To use the point-deposition technique, one or more layers of the matrix material may be deposited to form an opening (or hole). A second material (e.g., the conductive material) may be deposited in the opening according to the point-deposition technique. The point-deposition technique may control a flow rate and dwell time of the extruder such that enough of the second material is deposited to substantially fill the opening. If multiple layers of the matrix material are deposited before the second material is deposited, an end of the extruder may be positioned with the opening (e.g., below an upper layer of the matrix material). The extruder may begin extruding the second material, and the extruder may move vertically (e.g., along a Z-axis) relative to the physical model being formed. For example, a deposition platform may be moved away from the extruder. As another example, the extruder may be moved away from the deposition platform. Thus, multiple layers of the second material may be deposited together according to the point-deposition technique. Depositing multiple layers of the second material together may improve interlayer adhesion. Additionally, if the second material is conductive, depositing multiple layers of the second material together may improve electrical properties of a wire formed using the second material.

[0040] FIG. **1** illustrates a particular embodiment of a system **100** that includes a 3D printer device **101** and a computing device **102**. A communication interface **146** of the 3D printer device **101** may be coupled, via a communications bus **170**, to a communication interface **105** of the computing device **102**. The bus **170** may include a wired or wireless communications interface. The 3D printer device **101** is configured to generate physical models of objects based on a 3D model or commands based on model data.

[0041] In a particular embodiment, the computing device **102** includes a processor **103** and a memory **104**. The memory **104** may include a computer readable storage device (e.g., a physical, hardware device, which is not merely a signal), such as a volatile or non-volatile memory device. The computing device **102** may include a 3D modeling application **106**. The 3D modeling application **106** may enable generation of 3D models, which can be used to generate model data **107** descriptive of the 3D models. For example, the 3D modeling application **106** may include a computer-aided design application.

[0042] The computing device **102** or the 3D printer device **101** includes a slicer application **108**. The slicer application **108** may be configured to process the model data **107** to generate commands **109** that the 3D printer device **101** (or portions thereof) uses during generation of a physical model of an object represented by the model data **107**. In the particular embodiment illustrated in FIG. **1**, the commands **109** may include G-code commands or other machine instructions that are executable by the 3D printer device **101** (or a portion thereof). The computing device **102** may also include a communications interface **105** that may be coupled via the communication bus **170** to the 3D printer device **101**. For example, the 3D printer device **101** may be a peripheral device that is coupled via a communication port to the computing device **102**.

[0043] The 3D printer device **101** includes a frame **110** and support members **111** arranged to support various components at the 3D printer device **101**. In particular embodiments, the 3D printer device **101** may include a deposition platform **112**. In other embodiments, the 3D printer device **101** does not include a deposition platform **112** and another substrate or surface may be used for deposition. The 3D printer device **101** also includes one or more printheads. For example, in the embodiment illustrated in FIG. **1**, the 3D printer device **101** includes a first printhead **113** and an Nth printhead **115**.

[0044] Although two particular printheads are illustrated in FIG. **1**, in other embodiments, the 3D printer device **101** may include more than two printheads or fewer than two printheads. Each printhead **113**,**115** includes a corresponding extruder with an extruder tip. For example, the first printhead **113** includes a syringe extruder **130** having a tip **131**, and the Nth printhead **115** includes an Nth extruder **134** including a tip **135**. The Nth extruder **134** may include another syringe extruder or another type of extruder, such as a filament-fed extruder.

[0045] The controller **141** may control one or more actuators **143** to move the deposition platform **112** relative to the printheads **113**, **115**, to move the printheads **113**, **115** relative to the deposition platform **112**, or both. For example, in a particular configuration, the deposition platform **112** may be configured to move in a Z direction **140**. In this example, the printheads **113**, **115** may be configured to move in an X direction **138** and a Y direction **139** relative to the deposition platform **112**. Thus, movement of one or more printheads **113**, **115** relative to the deposition platform **112** may involve movement of the deposition platform **112**, movement of one or more of the printheads **113**, **115**, or movement of both the deposition platform **112** and the printheads **113**, **115**. In other examples, the deposition platform **112** may be stationary, and one or more of the printheads **113**, **115** may be moved. In yet other examples, the one or more printheads **113**, **115** may be stationary, and the deposition platform **112** may be moved.

[0046] The controller **141** may also be coupled to a control system associated with the syringe extruder **130**. For example, the syringe extruder **130** may include a plunger **132** that is movable to force material through the tip **131**. The plunger **132** may be pneumatically, hydraulically, or mechanically controlled. For example, in the implementation illustrated in FIG. **1**, the plunger **132** is coupled to a pressurized fluid source **164** via a pressure regulator **160** and a valve **162**. In this example, a position of the valve **162** (e.g., open or closed) is controlled by the controller **141** to control when the syringe extruder **130** extrudes material. To illustrate, to begin deposition of the material, the controller **141** causes the valve **162** to be moved to an open position, and to stop deposition of the material, the controller **141** causes the valve **162** to be moved to a closed position. A pressure setting of the pressure regulator **160** may be controlled by the controller **141** to control an extrusion rate (e.g., a material flowrate) of the syringe extruder **130**. To illustrate, to increase the flowrate, the pressure setting of the pressure regulator **160** may be increased to apply more pressure to the plunger **132**. Conversely, to decrease the flowrate, the pressure setting of the pressure regulator **160** may be decreased to apply less pressure to the plunger **132**. Although the valve **162** is illustrated between the pressurized fluid source **164** and the pressure regulator **160** in FIG. **1**, in other implementations, the pressure regulator **160** may be positioned between the valve **162** and the pressurized fluid source **164**.

[0047] The 3D printer device **101** may also include a memory **142** accessible to the controller **141**. The memory **142** may include a computer readable storage device (e.g., a physical, hardware device, which is not merely a signal), such as a volatile or non-volatile memory device. In a particular embodiment, the memory **142** includes calibration data **148**. The calibration data **148** may include information that indicates relative positions of the printheads **113**, **115**. In the particular example illustrated in FIG. **1**, the printheads **113**, **115** may be independently movable by corresponding actuators **143** or may be movable together by one or more actuators **143**. The calibration data **148** may indicate distances between printheads **113-115**, extruder tips **131**, **135**, or both. The calibration data **148** may include extrusion rates or deposition rates associated with one or more of the printheads **113**, **115** based on particular control parameters, such as temperature of the extruder or extruder tip, pressure applied to the extruder or extruder tip, a type of material being deposited, a material feed rate, or a combination thereof. For example, the calibration data **148** may include rheology data based on temperature associated with one or more materials deposited by the extruders **130**, **134**.

[0048] The memory **142** may also include settings **150**. The settings **150** may include control parameters or other values used by the controller **141** to control components of the 3D printer device **101**. For example, the settings **150** may indicate a value of the pressure setting for the pressure regulator **160**. In other examples, the settings **150** may indicate a target or actual deposition platform temperature, extruder or extruder tip temperature, filament feed rate, or other information. The settings **150** may be updated of modified by a user (e.g., via a user interface, not shown), by the computing device **102** (e.g., via the commands **109**), or via feedback or control input from one or more sensors of the 3D printer device **101** (such as a temperature sensor **133** associated with the first printhead **113**).

[0049] In a particular embodiment, the memory **142** may also include pressure-flowrate data **152** that indicates a relationship between pressure applied to the plunger **132** and a flowrate of the syringe extruder **130**. The pressure-flowrate data **152** may be temperature dependent. To illustrate, the pressure-flowrate data **152** may specify a first relationship between the pressure and the flowrate associated with first temperature or temperature range, and may specify a second relationship between the pressure and the flowrate associated with second temperature or temperature range. In this embodiment, the controller **141** may update the settings **150** occasionally or periodically based on a temperature indicated by the temperature sensor **133**. For example, the pressure setting of the settings **150** may be updated when the temperature changes from the first temperature to the second temperature.

[0050] The memory **142** may also include point-deposition technique instructions **154**. The point-deposition technique instruction **154** include instructions that enable formation features that have a cross-section within a particular layer (or multiple layers) that satisfy a point-deposition criterion (such as being too small to extruder while moving the printheads **113**, **115** in the X direction **138**, in the Y direction **139**, or both. Examples of point-deposition techniques are described further with reference to FIGS. **6-10**. The point-deposition technique instructions **154** may be applied to commands provided by an external computing device, such as the computing device **102**, in order to improve interlayer adhesion or other properties (e.g., electrical properties) of small, low aspect ratio features within a layer or extending between layers.

[0051] Accordingly, the 3D printer device **101** enables use of multiple printheads **113**, **115** with multiple distinct materials. Further, the 3D printer device **101** includes data, settings and instructions that improve printing using a syringe type extruder, such as the syringe extruder **130**. For example, the pressure-flowrate data **152** may be used to determine a pressure setting for the pressure regulator **160** based on, for example, a target line width, a target line height, a temperature associated with the first printhead **113**, other information, or a combination thereof. As another example, the point-deposition technique instruction **154** may be used to control deposition by the syringe extruder **130** of material to form small, low aspect ratio features within a layer or extending between layers.

[0052] FIGS. **2A-2B** illustrate use pressure (e.g. a pressure setting of the pressure regulator **160**) and velocity (e.g., a rate of motion in the X direction **138**, in the Y direction **139**, in the Z direction **140**, or in a combination thereof, such as during conformal printing with concurrent motion in the X, Y and Z directions **138-140**) to control line width of material deposited by the syringe extruder **130** of FIG. **1**. In particular, FIG. **2A** illustrates line width of a line **202** deposited at a constant velocity while changing the pressure setting. FIG. **2B** illustrates line width of a line **210** deposited at a constant pressure setting while changing the velocity of motion of the syringe extruder **130**.

[0053] In FIG. **2A**, the pressure setting has a first value during a first time **204** and has a second value during a second time **206**. The second value is greater than the first value; thus, the plunger **132** of the syringe extruder **130** is subject to higher pressure during the second time **206** than during the first time **204**. Due to the pressure difference, the line **202** has a first line width during the first time **204** and has a second line width during the second time **206**. The first line width is less than the second line width because, although the velocity of the syringe extruder **130** is constant, the flowrate of material deposited by the syringe extruder **130** during the second time **206** is greater than the flowrate of material during the first time **204** as a result of the increased pressure. The increased flowrate (with the same extruder velocity) causes the material deposited during the second time **206** to spread out more than the material deposited during the first time **204**.

[0054] Further, the pressure setting has a third value during a third time **208**. The third value is less than the first value; thus, the syringe extruder **130** is subject to less pressure during the third time **208** than during the first time **204**. Accordingly, during the third time **208**, the line **202** has a third line width that is less than the first line width. In a particular embodiment, the pressure-flowrate data **152** may include a table, a set of tables, an algorithm, a set of algorithms, or other information that enables the controller **141** to determine a value of the pressure setting based on a target line width (e.g., a desired line width at a particular time), a velocity of the syringe extruder **130**, a temperature associated with the syringe extruder **130**, or a combination thereof.

[0055] In FIG. **2B**, the pressure is constant; however, the velocity has a first value during a first time **212** and has a second value during a second time **214**. The second value is less than the first value; thus, the syringe extruder **130** has a constant flowrate, but a reduced velocity during the second time **214**. Due to the velocity difference, the line **210** has a first line width during the first time **212** and has a second line width during the second time **214**. The first line width is less than the second line width. The decreased velocity causes the material deposited during the second time **214** to spread out more than the material deposited during the first time **212**.

[0056] Further, the velocity has a third value during a third time **216**. The third value is greater than the first value. Accordingly, during the third time **216**, the line **210** has a third line width that is less than the first line width. In a particular embodiment, the pressure-flowrate data **152** may include information that enables the controller **141** to determine a value of the velocity of the syringe extruder **130** based on a target line width (e.g., a desired line width at a particular time), a pressure setting of the pressure regulator **160**, a temperature associated with the syringe extruder **130**, or a combination thereof.

[0057] FIGS. **3A-3B** illustrate use pressure (e.g. a pressure setting of the pressure regulator **160**) and velocity (e.g., a rate of motion in the X direction **138**, in the Y direction **139**, or a combination thereof) to control line height of material deposited by the syringe extruder **130** of FIG. **1**. In particular, FIG. **3A** illustrates line height of a line **302** deposited at a constant velocity while changing the pressure setting. FIG. **2B** illustrates line width of a line **310** deposited at a constant pressure setting while changing the velocity of motion of the syringe extruder **130**.

[0058] In FIG. **3A**, the pressure setting has a first value during a first time **304** and has a second value during a second time **306**. The second value is greater than the first value; thus, the plunger **132** of the syringe extruder **130** is subject to higher pressure during the second time **306** than during the first time **304**. Due to the pressure difference, the line **302** has a first line height during the first time **304** and has a second line height during the second time **306**. The first line height is less than the second line height because, although the velocity of the syringe extruder **130** is constant, the flowrate of material deposited by the syringe extruder **130** during the second time **306** is greater than the flowrate of material during the first time **304** as a result of the increased pressure. The increased flowrate (with the same extruder velocity) causes the material deposited during the second time **306** to pile up more than the material deposited during the first time **304**

[0059] Further, the pressure setting has a third value during a third time **308**. The third value is less than the first value; thus, the syringe extruder **130** is subject to less pressure during the third time **308** than during the first time **304**. Accordingly, during the third time **308**, the line **302** has a third line height that is less than the first line height. In a particular embodiment, the pressure-flowrate data **152** may include a table, a set of tables, an algorithm, a set of algorithms, or other information that enables the controller **141** to determine a value of the pressure setting based on a target line height (e.g., a desired line height at a particular time), a velocity of the syringe extruder **130**, a temperature associated with the syringe extruder **130**, or a combination thereof.

[0060] In FIG. 3B, the pressure is constant; however, the velocity has a first value during a first time **312** and has a second value during a second time **314**. The second value is less than the first value; thus, the syringe extruder **130** has a constant flowrate, but a reduced velocity during the second time **314**. Due to the velocity difference, the line **310** has a first line height during the first time **312** and has a second line height during the second time **314**. The first line height is less than the second line height. The decreased velocity causes the material deposited during the second time **314** to pile up more than the material deposited during the first time **312**.

[0061] Further, the velocity has a third value during a third time **316**. The third value is greater than the first value. Accordingly, during the third time **316**, the line **310** has a third line height that is less than the first line height. In a particular embodiment, the pressure-flowrate data **152** may include information that enables the controller **141** to determine a value of the velocity of the syringe extruder **130** based on a target line height (e.g., a desired line height at a particular time), a pressure setting of the pressure regulator **160**, a temperature associated with the syringe extruder **130**, or a combination thereof.

[0062] FIG. **4** illustrates several examples of using pressure, velocity, or both, to control a quantity of material deposited at a particular location (e.g., a line width, a line height, or both). FIG. **4** illustrates the syringe extruder **130** depositing lines of material within openings **404**, **414**, **424** formed in another material. For example, the Nth extruder **134** of FIG. **1** may be used to deposit a matrix material **402** to form a portion of an object corresponding to a 3D model. The matrix material **402** may define the openings **404**, **414**, **424**.

[0063] In a first example **400**, the first opening **404** has a first width. In the first example **400**, the controller **141** of FIG. **1** may set the pressure setting associated with the pressure regulator **160** to a first pressure value, and may control the actuators **143** to achieve movement of the syringe extruder **130** at a first velocity (e.g., in the X direction **138**, in the Y direction **139**, or a combination thereof). The first pressure value and the first velocity are selected to enable the syringe extruder **130** to deposit at least a sufficient quantity of material to form a line **406** that extends to each edge of the opening **404**. For example, the first line **406** may have a first line width **408** that is substantially equal to a width of the opening **404**.

[0064] In a second example **410**, the second opening **414** has a second width. The second width of the second opening **414** is greater than the first width of the first opening **404**. To deposit at least a sufficient quantity of material to form a line **416** that extends to each edge of the opening **414**, the velocity, the flowrate, or both, of the syringe extruder **130** may be controlled. For example, the controller **141** of FIG. **1** may set the pressure setting associated with the pressure regulator **160** to a second pressure value and may control the actuators **143** to achieve movement of the syringe extruder **130** at the first velocity. In this example, the second pressure value is greater than the first pressure value used in the first example **400**.

[0065] Alternatively, the controller **141** of FIG. **1** may set the pressure setting associated with the pressure regulator **160** to the first pressure value and may control the actuators **143** to achieve movement of the syringe extruder **130** at the third velocity. In this example, the third velocity is less than the first velocity used in the first example **400**.

[0066] In a third example **420**, the third opening **424** has a third width. The third width of the third opening **424** is less than the first width of the first opening **404**. To deposit at least a sufficient quantity of material to form a line **426** that extends to each edge of the opening **424**, the velocity, the flowrate, or both, of the syringe extruder **130** may be controlled. For example, the controller **141** of FIG. **1** may set the pressure setting associated with the pressure regulator **160** to a third pressure value and may control the actuators **143** to achieve movement of the syringe extruder **130** at the first velocity. In this example, the third pressure value is less than the first pressure value used in the first example **400**.

[0067] Alternatively, the controller **141** of FIG. **1** may set the pressure setting associated with the pressure regulator **160** to the first pressure value and may control the actuators **143** to achieve movement of the syringe extruder **130** at the second velocity. In this example, the second velocity is less than the first velocity used in the first example **400**.

[0068] Although three examples **400**, **410**, and **420** are illustrated in FIG. **4**, other examples are possible. To illustrate, both the pressure and the velocity may be controlled to achieve a target line width. Further, during formation of a single physical model, different pressure values, different velocities, or both, may be used to achieve different target line widths.

[0069] FIG. **5** illustrates another example of using pressure, velocity, or both, to control a quantity of material deposited at a particular location (e.g., a line width, a line height, or both). FIG. **5** illustrates the syringe extruder **130** depositing lines of material within an opening **500** formed in another material. For example, the Nth extruder **134** of FIG. **1** may be used to deposit the matrix material **402** to form a portion of an object corresponding to a 3D model. The matrix material **402** may define the opening **500** (only a portion of which is illustrated in FIG. **5**).

[0070] The tip of the syringe extruder **130** had an orifice through which material is extruded. The orifice has a first dimension (e.g., an inner diameter) that is different from a second dimension (e.g., an outer diameter) of an outer surface of the tip of the syringe extruder **130**. Further, in some embodiments, the tip of the syringe extruder **130** is tapered (as illustrated in FIG. **5**). Accordingly, the tip of the syringe extruder **130** may be positioned at an offset distance **504** from a wall of the opening **500** when the syringe extruder **130** is depositing material. Depositing material at the offset distance **504** from the wall of the opening **500** may lead to issues with the physical model. For example, if a line **508** deposited closest to the wall does not contact the wall, the physical model material deposited by the syringe extruder **130** may not adhere sufficiently to the material **402**.

[0071] In the example illustrated in FIG. **5**, the line **508** deposited closest to the wall has a first line width **506**, and other lines **512** deposited further from the wall have a second line width **510**. The first line width **506** and the second line width are controlled based on pressure applied to the plunger **132** of the syringe extruder **130**, velocity of motion of the syringe extruder **130**, or both. For example, when forming the line **508** closest to the wall a higher value of the pressure setting may be used than when forming the other lines **512**. Alternatively, or in addition, when forming the line **508** closest to the wall a lower velocity of motion of the syringe extruder **130** may be used than when forming the other lines **512**. Thus, different pressure settings may be used to form a single physical model or portions of a single layer of the single physical model.

[0072] FIGS. **6-10** illustrate several aspects of forming a physical model of an object corresponding to a 3D model using a syringe extruder. Each of FIGS. **6-10** includes a perspective view and a front view.

[0073] FIG. **6** illustrates 3D model **602** of an object. For example, the 3D model **602** may be represented by the model data **107** of FIG. **1**. In this example, the 3D model **602** may include one or more solid body models formed using a 3D computer-aided design (CAD) application, such as the 3D modeling application **106** of FIG. **1**. The 3D model includes a first portion (a body **604**) corresponding to a first material and a second portion (e.g., a feature **606**) corresponding to a second material. For example the body **604** may correspond to a matrix material (e.g., a non-conductive structural polymer), and the feature **606** may correspond to a filler material (e.g., a conductive polymer forming at least part of an electrical interconnect).

[0074] FIG. **7** illustrates a sliced model **702** formed based on the 3D model **602**. For example, the sliced model **702** may include a plurality of slices **708**. The sliced model **702** may be formed by the slicer application **108** based on the model data **107** representing the 3D model **602**.

[0075] In FIG. **7**, each slice corresponds to a layer to be printed by a 3D printing device (such as the 3D printer device **101** of FIG. **1**) to form a physical model of the object. Each of the slices may include one or more regions, with each region corresponding to a single material. For example, a first slice **710** (e.g., the bottom slice in FIG. **7**) may include only a single region, indicating that a layer corresponding to the first slice **710** is to be printed entirely of a first material. However, a second slice **712** (e.g., a top slice in FIG. **7**) may include two regions, i.e., a first region **704** corresponding to the first material and a second region **714** corresponding to a second material. Thus, printing the second slice **712** includes depositing a portion of the first material to form the first region **704** and depositing a portion of the second material to form the second region **714**.

[0076] The second region **712** is a portion of a feature (e.g., the electrical interconnect described with reference to FIG. **6**) that extends through multiple slices of the sliced model **702** (and accordingly, when formed will extend through multiple layers of the physical model of the object). The slicer application **108** may analyze the feature to determine whether the feature satisfies a point-deposition criterion. For example, if the feature has a cross-sectional dimension (e.g., a length, a width, a diameter, an aspect ratio, or a combination thereof) within one or more slices, the feature may satisfy the point-deposition criterion. To illustrate, the point-deposition criterion may be satisfied if the feature has an aspect ratio that is less than an aspect ratio threshold, has a diameter (or length) that is less than a length threshold, has a cross-sectional area that is less than a cross-sectional area threshold, or has a combination thereof (e.g., has an aspect ratio that is less than an aspect ratio threshold and has a cross-sectional area that is less than a cross-sectional area threshold). The point-deposition criterion may be determined based on characteristics of the 3D printing device that will be used to form a physical model of the sliced model **702**. For example, for a particular 3D printing device, such as the 3D printer device **101** of FIG. **1**, thresholds for the point-deposition criterion may be selected based on a minimum reliable line length of the 3D printer device **101**. The minimum reliable line length refers to a length of a smallest length of a line that can be deposited by the 3D printing device while maintaining desired characteristics, such as interlayer adhesion, electrical characteristics (e.g., if the material being deposited in conductive), etc.

[0077] For example, a first part of the feature may extend along a single slice and may have a first interlayer feature dimension **720**. In this example, a second part of the feature may extend more or less vertically through several slices and may have a second interlayer feature dimension **722**. The first interlayer feature dimension **720** may not satisfy the point-deposition criterion since the first part has a large aspect ratio and a large length within the single slice. However, the second interlayer feature dimension **722** may satisfy the point-deposition criterion in multiple slices since the second part has a small aspect ratio and a small length in each of the multiple slices.

[0078] FIG. **8** illustrates a modified sliced model **802** based on the sliced model **702** of FIG. **7**. The modified sliced model **802** may include one or more modified slices **804**, which are modified relative to slices of the sliced model **702**. In the example illustrated in FIG. **8**, the modified slices **804** are modified to enable forming the second region **712** of FIG. **7** according to a point deposition techniques.

[0079] For example, the tip **131** of the syringe extruder **130** may have a tapering shape, as illustrated in FIG. **8**. The second region **712** of the feature that extends through multiple slices in the sliced model **702** of FIG. **7** has a shape **806** illustrated in FIG. **8**. The shape **806** of the second region **712** satisfies the point-deposition criterion in each slice that is modified in FIG. **8**. For example, the shape **806** is only slightly larger than an outer dimension of the tip **131** of the syringe extruder.

[0080] In the example of FIG. **8**, multiple slices have been modified to accommodate the tip **131**. For example, in the top seven slices of FIG. **8**, the shape **806** has been modified to provide an opening sufficiently large for the tip **131** to extend within layers corresponding to the slices (as illustrated in FIG. **9**). Thus, the modified slices **804** enable use of a point deposition technique in which the tip **131** is positioned below an upper surface of a physical model, and the tip **131** is used to extrude material while moving vertically (e.g., in a Z direction **140**, as illustrated in FIGS. **9** and **10**) rather than laterally (e.g. in the X direction **138**, the Y direction **139**, or both).

[0081] FIG. **9** illustrates a first stage during formation of a physical model **902** corresponding to the modified sliced model **802**. For example, a plurality of layers **908** of a first material **904** have been deposited leaving an opening **910** in each layer that corresponds to one of the modified slices **804**. The opening **910** in each layer is to accommodate the tip **131** and to receive a second material **906** deposited according to a point-deposition technique. In FIG. **9**, the tip **131** is moved vertically (e.g., in the Z direction) to insert the tip **131** into openings **910** within layers of the first material **904**.

[0082] FIG. **10** illustrates a second stage during formation of the physical model **902** corresponding to the modified sliced model **802**. The second stage may be subsequent to the first stage illustrated in FIG. **9**. In the second stage, the tip **131** is moved vertically (e.g., in the Z direction) while depositing the second material **906** to fill the opening in the layers of the first material.

[0083] For example, as illustrated in the callout of the perspective view, the layers **908** may include a first layer **1002** and a second layer **1004**. The second layer **1004** may be positioned above and in contact with the first layer **1002**. The first layer **1002** includes a first region **1010** corresponding to a portion of the first material **904** and a second region **1012** corresponding to a portion of the second material **906**. The second layer **1004** includes a third region **1020** corresponding to a portion of the first material **904** and a fourth region **1022** corresponding to a portion of the second material **906**. In the example illustrated in FIG. **10**, multiple layers of the first material **904** are deposited before the second material **906** is deposited. To illustrate, the first region **1010** and the third region **1020** may be formed before the second region **1012** and the fourth region **1022** are formed.

[0084] The openings in the layers of the first material **904** to accommodate the tip **131** for a tapered shape. Accordingly, a quantity of the second material **906** deposited in adjacent layers (such as the first layer **1002** and the second layer **1004**) may be different. To illustrate, as the tip **131** moves in the Z direction, the tip **131** deposits more of the second material **906** in each layer than in a previous layer. Pressure applied to a plunger of the syringe extruder or velocity of motion of the tip **131** may be used to vary the quantity of the second material deposited in each layer. For example, as the tip **131** is moved in the Z direction, the pressure setting of the pressure regulator **160** may remain constant and the rate of motion in the Z direction may change (e.g., decrease) over time. As another example, as the tip **131** is moved in the Z direction, the pressure setting of the pressure regulator **160** may be changed (e.g., increased) and the rate of motion in the Z direction may remain constant. As yet another example, as the tip **131** is moved in the Z direction, the pressure setting of the pressure regulator **160** may be changed (e.g., increased) and the rate of motion in the Z direction may be changed.

[0085] FIG. **11** is a flowchart of a particular embodiment of a method **1100** that may be performed by one or more devices or components of the system **100** of FIG. **1**. For example, the method **1100** may be performed by the controller **141** of the 3D printer device **101** executing instructions from the memory **142**. As another example, the method **1100** may be performed by the processor **103** of the computing device **102** executing instructions from the memory **104**.

[0086] The method **1100** includes, at **1102**, obtaining model data specifying a three-dimensional (3D) model of an object. The 3D model includes a first portion corresponding to a first material and a second portion corresponding to a second material. For example, the 3D model may correspond to the model data **107** of FIG. **1**. As another example, the 3D model may include or correspond to the 3D model **602** of and the feature corresponding to the second portion may correspond to the feature **606**. In some implementations, the first material may include a matrix material (e.g., a non-conductive material, such as a polymer), and the second material may include a filler material (e.g., a conductive material, such as a conductive polymer). Thus, the 3D model may include a conductive features, such as a wire, formed of the second material extending though portions of the first material.

[0087] The method **1100** includes, at **1104**, processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object. For example, the sliced model may include or correspond to the sliced model **702** of FIG. **7**. In this example, the sliced model may include a plurality of slices **708**.

[0088] The method **1100** includes, at **1106**, identifying, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion. For example, the elongated feature may correspond to or include the feature **706** that has the second intralayer feature dimension **722**. In some implementations, the point-deposition criterion is satisfied when an aspect ratio determined based on the cross-sectional dimensions is less than an aspect ratio threshold.

[0089] In some implementations, after identifying the elongated feature, the sliced model may be modified. For example, the slice model may be modified to increase a cross-sectional area of the elongated feature in at least one layer of the multiple layers. To illustrate, the cross-sectional area of the elongated feature may be increased based on a dimension associated with an extruder of the 3D printing device, where the extruder is associated with the second material. For example, in the sliced model **702** of FIG. **7**, the feature **706** has a first cross-section, which is modified to generate the modified sliced model **802** of FIG. **8**. The modified sliced model **802** is used to form the layers **908** of FIG. **9**, which include openings to receive a portion of the second material to form a physical model of the elongated features. In this example, the cross-section of the elongated feature in the first layer of the physical model **902** corresponds to a cross-section of the opening in the first layer. Also, the cross-sectional area of the feature **606** in the 3D model **602** is less than a cross-sectional area of the opening **910** in the at least some of the layers **908**. Thus, in some layers, the sliced model **702** is modified to increase a cross-sectional dimension associated with the feature.

[0090] The method **1100** includes, at **1108**, generating machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique. The machine instructions may include or correspond to the commands **109** of FIG. **1**. The machine instructions may enable depositing a portion of the first material (e.g., corresponding to the first region **704** of FIG. **7**) to define an opening corresponding the opening **808** of FIG. **8**. The machine instructions may also enable depositing a portion of the second material within the opening as illustrated in FIG. **10**.

[0091] In some implementations, the machine instructions include instructions to translate a first extruder associated with the first material along a first axis, along a second axis, or both, to deposit the portion of the first material. For example, the machine instruction may cause the one or more of the extruders **130**, **134** of FIG. **1** to move in the X direction **138**, in the Y direction **139**, or both, while depositing the first material. In some such implementations, the portion of the second material is deposited according to a point-deposition technique without translating a second extruder along the first axis and without translating the second extruder along the second axis. To illustrate, the syringe extruder **130** may deposit the second material according to the point-deposition technique by extruding the second material while stationary in the X direction **138** and in the Y direction **139**; however, the syringe extruder **130** may move relative to the deposition platform **112** in the Z direction **140**.

[0092] In some implementations, the point-deposition technique causes a quantity of the second material sufficient to fill the opening to be deposited. The quantity of the second material deposited may be determined based on a flowrate of the second material. To illustrate, the second material may dep be deposited using the syringe extruder **130**. In this illustrative example, generating the machine instructions may include determining a pressure setting and an extrusion time (or values of others of the settings **150**) to cause the syringe extruder **130** to deposit the quantity of the second material. For example, as illustrated in FIG. **10**, the pressure setting, the velocity of motion of the tip **131** of the syringe extruder **130**, or both, may be controlled to substantially fill the opening **910** of FIG. **9** with the second material **906**.

[0093] In a particular implementation, the machine instructions may cause the 3D printing device to deposit at least a second layer of the multiple layers before depositing the portion of the second material within the opening. To illustrate, in FIG. **9**, regions **1010** and **1020** of the first and second layers **1002** and **1004**, respectively, are formed of the first material **904** before the second material **906** is deposited in an opening **910** formed in the first and second layers **1002** and **1004**. Thus, the opening **910** extends between multiple layers, including the first layer and the second layer. The syringe extruder **130** is used to deposit a portion of the second material **906** in the opening **910** sufficient to fill the opening **910**. For example, as illustrated in FIGS. **9** and **10**, the machine instructions may cause the tip **131** of the syringe extruder **130** to be positioned below a surface of the layers of the first material **904** during at least a portion of the point-deposition technique. In this example, the tip **131** of the syringe extruder **130** may be translated in a direction perpendicular to a surface of the layers of the first material **904** (e.g., in the Z direction) during at least a portion of the point-deposition technique.

[0094] FIG. **12** is a flowchart of a particular embodiment of a method **1200** that may be performed by one or more devices or components of the system **100** of FIG. **1**. For example, the method **1200** may be performed by the 3D printer device **101** (or a one or more components thereof).

[0095] The method **1200** includes, at **1202**, receiving machine instructions that enable generating a physical model of an object including an elongated feature. The elongated feature extends between multiple layers of a plurality of layers of the physical model and has, in each of the multiple layers, a cross-sectional dimension that satisfies a point-deposition criterion. For example, the object may correspond to the sliced model **702** of FIG. **7**, which includes the feature **706**, a portion of which extends through multiple slices of the sliced model **702**.

[0096] The method **1200** includes, at **1204**, depositing, using a first extruder of a three-dimensional (3D) printer device, a portion of a first material to define an opening associated with the elongated feature of the physical model. For example, the 3D printer device **101** of FIG. **1** may be used to deposit a portion of the first material **904** of FIG. **9** in a manner that defines the opening **910** associate with at least a portion of the feature **706**.

[0097] The method **1200** includes, at **1206**, depositing, using a second extruder of the 3D printer device, a portion of a second material to form a portion of the elongated feature according to a point-deposition technique. The point-deposition technique causes the portion of the second material to be deposited within the opening. For example, the tip **131** of the syringe extruder **130** may be inserted into at least a portion of the opening **910** in the first material **904** of FIG. **9**. In this example, the syringe extruder **130** may deposit a portion of the second material **906** in the opening as the syringe extruder **130** is moved in the Z direction (as illustrated in FIG. **10**).

[0098] FIG. **13** is a flowchart of a particular embodiment of a method **1300** that may be performed by one or more devices or components of the system **100** of FIG. **1**. For example, the method **1300** may be performed by the controller **141** of the 3D printer device **101** executing instructions from the memory **142**. As another example, the method **1300** may be performed by the processor **103** of the computing device **102** executing instructions from the memory **104**.

[0099] The method **1300** includes, at **1302**, obtaining model data specifying a three-dimensional (3D) model of an object. For example, the computing device **102** of the 3D printer device **101** of FIG. **1** may receive the model data **107**, which includes or corresponds to a 3D model of an object. To illustrate, the model data **107** may represent the 3D model **602** of FIG. **6**.

[0100] The method **1300** includes, at **1304**, processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object, the plurality of layers including a first layer and a second layer. The second layer is above and in contact with the first layer, the first layer including a first region corresponding to a first material and a second region corresponding to a second material, and the second layer including a third region corresponding to the first material and a fourth region corresponding to the second material. For example, model data representing the 3D model **602** of FIG. **6** may be processed to generate the sliced model **702** of FIG. **7**. As described with reference to FIG. **10**, the sliced model may include adjacent slices (e.g., a first slice and a second slice) corresponding to the first layer **1002** and the second layer **1004**, respectively. The first layer **1002** includes the first region **1010** corresponding to the first material and includes the second region **1012** corresponding to the second material. Further, the second layer **1004** includes the third region

1020 corresponding to the first material and includes the fourth region **1022** corresponding to the second material.

[0101] The method **1300** includes, at **1306**, generating machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region. For example, as described with reference to FIG. **10**, first material may be deposited to form the first region **1010** and the third region **1020** before second material is deposited to form the second region **1012** and the fourth region **1022**.

[0102] In some implementations, depositing the portion of the second material corresponding to the second region includes positioning a tip of an extruder associated with the second material below an upper surface of the first material. For example, as illustrated in FIG. **10**, the tip **131** of the syringe extruder **130** may be inserted in the opening defined by layers of the first material **904** to deposit the second material **906** below an upper surface of the first material **904**.

[0103] FIG. **14** is a flowchart of a particular embodiment of a method **1400** that may be performed by one or more devices or components of the system **100** of FIG. **1**. For example, the method **1400** may be performed by the controller **141** of the 3D printer device **101** executing instructions from the memory **142**. As another example, the method **1400** may be performed by the processor **103** of the computing device **102** executing instructions from the memory **104**.

[0104] The method **1400** includes, at **1402**, obtaining model data specifying a three-dimensional (3D) model of an object. For example, the computing device **102** of the 3D printer device **101** of FIG. **1** may receive the model data **107**, which includes or corresponds to a 3D model of an object. To illustrate, the model data **107** may represent the 3D model **602** of FIG. **6**.

[0105] The method **1400** includes, at **1404**, generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder. The first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a pressure to be applied to the syringe extruder. For example, the pressure setting may include a value stored in the settings **150** that indicates a setting of the pressure regulator **160** that controls fluid pressure applied to the plunger **132** of the syringe extruder **130** of FIG. **1**. The first machine instructions may include a data field indicating the first value of the pressure setting. Alternatively, the first machine instruction may include information (such as a target flowrate, a target line width, a target line height, etc.) that the controller **141** can use along with the pressure-flowrate data **152** to determine the first value of the pressure setting.

[0106] The method **1400** includes, at **1406**, generating second machine instructions executable by a 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder. The second machine instructions indicate a second value of the pressure setting, the second value different from the first value. As with the first value of the pressure setting, the second value of the pressure setting may indicate a setting of the pressure regulator **160** and may be included a data field of the second machine instruction or may be derived from information in the second machine instructions along with the pressure-flowrate data **152**.

[0107] In some implementations, the controller **141**, the computing device **102**, or another device may determine the pressure-to-flowrate data **152** by determining a flowrate-to-pressure relationship of the material. To illustrate, one or more test prints may be performed by the 3D printer device **101** to determine the flowrate-to-pressure relationship of the material. As another example, data specifying the flowrate-to-pressure relationship (e.g., rheology data) of the material may be provided to the computing device **102**, to the 3D printer device **101**, or to both, from an external source, such as a vendor of the material.

[0108] In some implementations, the flowrate-to-pressure relationship may be temperature dependent. For example, during operation, the 3D printer device **101** may determine a temperature associated with the first printhead **113** based on output of the temperature sensor **133**. The temperature associated with the first printhead **113** may correspond to or be correlated with the temperature of the material. The temperature of the material may be used to select (e.g., from a look up table) or calculate the flowrate-to-pressure relationship of the material. In such an implementation, the first value of the pressure setting may be determined based on a first temperature associated with the material, and the second value of the pressure setting may be determined based on a second temperature (e.g., at a later time) associated with the material.

[0109] In some implementations, the value of the pressure setting may be determined (e.g., by the controller **141**) based on target characteristics of a line that is to be deposited. For example, the first value of the pressure setting may be determined based on a first target line width (or a first target line height) of the material, and the second value of the pressure setting may be determined based on a second target line width (or a second target line height) of the material. The first target line width (or the first target line height) may be different from the second target line width (or the second target line height). For example, in some circumstances, a larger (e.g., wider or taller) than normal line may be deposited in a particular location (e.g., to fill a space (as illustrated in FIG. **4**) if the space is smaller than two normal-sized lines, but larger than one normal sized line. In this example, the second target line width (or the second target line height) may be greater than the first target line width (or the first target line height) but less than two times the first target line width (or the first target line height). To illustrate, the second target line width (or the second target line height) may be greater than the first target line width (or the first target line height) by a non-integer multiple. The pressure setting, velocity of the extruder, or both, may be controlled to deposit the larger than normal line.

[0110] In a particular embodiment, the syringe extruder **130** has a first flowrate when the pressure setting has the first value and has a second flowrate (different than the first flowrate) when the pressure setting has the second value. In addition to or instead of controlling the pressure setting, the velocity of motion of the extruder may be controller to control characteristics (e.g., line width or line height) of deposited material. For example, the first machine instructions may include first instructions to cause the syringe extruder **130** to move at a first speed while depositing the material, and the second machine instructions may include second instructions to cause the syringe extruder **130** to move at the first speed while depositing the material. The first speed may be the same as or different from the second speed.

[0111] In some implementations, the material deposited by the syringe extruder **130** may be deposited within an opening (or set of openings) formed in another material. For example, a third portion of the physical model may be associated with a second material and may define a first opening. In this example, the first value of the pressure setting may be selected to cause the syringe extruder to, during a single pass, substantially fill the first opening to form the first portion of the physical model. Likewise, in this example, a fourth portion of the physical model may be associated with the second material and may define a second opening. The second value of the pressure setting may be selected to cause the syringe extruder to, during a single pass, substantially fill the second opening to form the second portion of the physical model. The first opening may have a first width that is the same as or different from a second width of the second opening. To illustrate, as described with reference to FIGS. **2**A, **2**B, **3**A, **3**B and **4**, the pressure setting, the velocity of motion of the extruder, or both, may be varied to achieve various line widths (or line heights), e.g., to substantially fill an opening.

[0112] In another example, the third portion of the physical model (associated with the second material) may define an opening. During deposition of a portion of the material to form the first portion of the physical model, the syringe extruder may be offset from a wall of the first opening by an offset distance, as illustrated in FIG. **5**. In this example, the first value of the pressure setting may be selected to cause the syringe extruder to deposit a line of the material having a line width equal to or greater than the offset distance, such as the line width **506**. In this example, the second line width may correspond to the second line width **510**, which may be used to form other lines of the material in the opening.

[0113] FIG. **15** is a flowchart of a particular embodiment of a method **1500** that may be performed by one or more devices or components of the system **100** of FIG. **1**. For example, the method **1500** may be performed by the 3D printer device **101** (or one or more components thereof).

[0114] The method **1500** includes, at **1502**, receiving machine instructions that enable generating a physical model of an object, the physical model including a plurality of layers that includes a first layer and a second layer. The second layer is above and in contact with the first layer. The first layer includes a first region corresponding to a first material and a second region corresponding to a second material, and wherein the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material. For example, the machine instructions may include or correspond to the commands **109** of FIG. **1**. The machine instructions specify operations to form a physical model of an object. For example, the object may correspond to the 3D model **602** of FIG. **6**. In this example, the 3D model **602** may be sliced to form the sliced model **702** of FIG. **7**. The sliced model **702** may be modified to form the modified sliced model **802**, which may be used to form machine instructions. The 3D printer device **101** performing operations described by the machine instructions may deposit material corresponding to a plurality of layers **908**, which includes the first layer **1002** and the second layer **1004**.

[0115] The method **1500** includes, at **1504**, depositing, based on the machine instructions, a portion of the first material corresponding to the first region and to the third region. For example, the first material **904** of FIG. **10** may be deposited to form the first region **1010** and the third region **1020**.

[0116] The method **1500** includes, at **1502**, after depositing the portion of the first material, depositing, based on the machine instructions, a portion of the second material corresponding to the second region and to the fourth region. For example, the second material **906** of FIG. **10** may be deposited to form the second region **1012** and the fourth region **1022**.

[0117] FIG. **16** is a flowchart of a particular embodiment of a method **1600** that may be performed by one or more devices or components of the system **100** of FIG. **1**. For example, the method **1600** may be performed by the 3D printer device **101** (or one or more components thereof).

[0118] The method **1600** includes, at **1602**, receiving first machine instructions associated with a first portion of a physical model of an object and second machine instructions associated with a second portion of the physical model. The first machine instructions indicates a first value of a pressure setting, the pressure setting indicating a first pressure to be applied to a syringe extruder, and the second machine instructions indicates a second value of the pressure setting, the second value different from the first value. For example, the machine instruction may include or correspond to the commands **109** of FIG. **1**. The machine instructions may specify values of one or more of the settings **150**. Alternately, the machine instructions may include information that is used by the controller **141** to determine the values of the settings **150**. To illustrate, the machine instructions may include target line information, such as flowrate information, line height information, line width information, or other parameters related to flowrate. In this illustrative example, the controller **141** may determine values of various settings, such as a pressure setting, a temperature setting, a velocity setting, etc., to achieve line parameters specified by the target line information. The various settings may be determined, for example, based on the pressure-flowrate data **152**, based on the calibration data **148**, or based on other information.

[0119] The method **1600** includes, at **1604**, depositing, using the syringe extruder of a three-dimensional (3D) printer device, a portion of a material at a first flowrate to form the first portion based on the first machine instructions. For example, the syringe extruder **130** may be used to deposit a first portion of a line having a first line width as described with reference to FIGS. **2**A and **2**B by setting a flowrate of the syringe extruder **130** (based on a pressure setting of the pressure regulator **160**) and a velocity of motion of the syringe extruder **130**. As another example, the syringe extruder **130** may be used to deposit the first portion of the line having a first line height as described with reference to FIGS. **3**A and **3**B by setting a flowrate of the syringe extruder **130** (based on a pressure setting of the pressure regulator **160**) and a velocity of motion of the syringe extruder **130**.

[0120] The method **1600** includes, at **1606**, depositing, using the syringe extruder, another portion of the material at a second flowrate to form the second portion based on the second machine instructions, the first flowrate different from the second flowrate. For example, the syringe extruder **130**

may be used to deposit a second portion of the line having a second line width as described with reference to FIGS. **2**A and **2**B by setting a flowrate of the syringe extruder **130** (based on a pressure setting of the pressure regulator **160**) and a velocity of motion of the syringe extruder **130**. As another example, the syringe extruder **130** may be used to deposit the second portion of the line having a second line height as described with reference to FIGS. **3**A and **3**B by setting a flowrate of the syringe extruder **130** (based on a pressure setting of the pressure regulator **160**) and a velocity of motion of the syringe extruder **130**.

[0121] The illustrations of the examples described herein are intended to provide a general understanding of the structure of the various implementations. The illustrations are not intended to serve as a complete description of all of the elements and features of apparatus and systems that utilize the structures or methods described herein. Many other implementations may be apparent to those of skill in the art upon reviewing the disclosure. Other implementations may be utilized and derived from the disclosure, such that structural and logical substitutions and changes may be made without departing from the scope of the disclosure. For example, method operations may be performed in a different order than shown in the figures or one or more method operations may be omitted. Accordingly, the disclosure and the figures are to be regarded as illustrative rather than restrictive.

[0122] Moreover, although specific examples have been illustrated and described herein, it should be appreciated that any subsequent arrangement designed to achieve the same or similar results may be substituted for the specific implementations shown. This disclosure is intended to cover any and all subsequent adaptations or variations of various implementations. Combinations of the above implementations, and other implementations not specifically described herein, will be apparent to those of skill in the art upon reviewing the description.

[0123] The Abstract of the Disclosure is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, various features may be grouped together or described in a single implementation for the purpose of streamlining the disclosure. Examples described above illustrate but do not limit the disclosure. It should also be understood that numerous modifications and variations are possible in accordance with the principles of the present disclosure. As the following claims reflect, the claimed subject matter may be directed to less than all of the features of any of the disclosed examples. Accordingly, the scope of the disclosure is defined by the following claims and their equivalents.

What is claimed is:

1. A method comprising:

obtaining model data specifying a three-dimensional (3D) model of an object;

processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object, the plurality of layers including a first layer and a second layer, wherein the second layer is above and in contact with the first layer, the first layer including a first region corresponding to a first material and a second region corresponding to a second material, and the second layer including a third region corresponding to the first material and a fourth region corresponding to the second material; and

generating machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region.

2. The method of claim **1**, wherein depositing the portion of the second material corresponding to the second region includes positioning a tip of an extruder associated with the second material below an upper surface of the first material.

3. A method comprising:

obtaining model data specifying a three-dimensional (3D) model of an object;

generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder, wherein the first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a pressure to be applied to the syringe extruder; and

generating second machine instructions executable by a 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder, wherein the second machine instructions indicate a second value of the pressure setting, the second value different from the first value.

4. The method of claim **3**, wherein the pressure setting indicates a setting of a pressure regulator that controls fluid pressure applied to a plunger of the syringe extruder.

5. The method of claim **3**, wherein the syringe extruder has a first flowrate when the pressure setting has the first value and has a second flowrate when the pressure setting has the second value, and wherein the first flowrate is different from the second flowrate.

6. The method of claim **3**, wherein the first machine instructions further include first instructions to cause the syringe extruder to move at a first speed while depositing the material, and the second machine instructions further include second instructions to cause the syringe extruder to move at the first speed while depositing the material.

7. The method of claim **3**, wherein the first machine instructions further include first instructions to cause the syringe extruder to move at a first speed while depositing the material, and the second machine instructions further include second instructions to cause the syringe extruder to move at a second speed while depositing the material, wherein the first speed is different from the second speed.

8. The method of claim **3**, wherein the first value of the pressure setting is determined based on a first temperature associated with the material, wherein the second value of the pressure setting is determined based on a second temperature associated with the material.

9. The method of claim **3**, further comprising determining, based on characteristics of the material, a flowrate-to-pressure relationship of the material before generating the first machine instructions.

10. The method of claim **9**, wherein the flowrate-to-pressure relationship of the material is determined based on a temperature associated with the material.

11. The method of claim **3**, wherein the first value of the pressure setting is determined based on a first target line width of the material, wherein the second value of the pressure setting is determined based on a second target line width of the material, wherein the first target line width is different from the second target line width.

12. The method of claim **11**, wherein the second target line width is greater than the first target line width by a non-integer multiple.

13. The method of claim **11**, wherein the second target line width is greater than the first target line width and is less than two times the first target line width.

14. The method of claim **3**, wherein the first value of the pressure setting is determined based on a first target line height of the material, wherein the second value of the pressure setting is determined based on a second target line height of the material, wherein the first target line height is different from the second target line height.

15. The method of claim **14**, wherein the second target line height is greater than the first target line height by a non-integer multiple.

16. The method of claim **14**, wherein the second target line height is greater than the first target height and is less than two times the first target line height.

17. The method of claim **3**, wherein a third portion of the physical model is associated with a second material, wherein the third portion of the physical model defines a first opening, and wherein the first value of the pressure setting is selected to cause the syringe extruder to, during a single pass, substantially fill the first opening to form the first portion of the physical model.

18. The method of claim **17**, wherein a fourth portion of the physical model is associated with the second material, wherein the fourth portion of the physical model defines a second opening, and wherein the second value of the pressure setting is selected to cause the syringe extruder to, during a single pass, substantially fill the second opening to form the second portion of the physical model.

19. The method of claim **18**, wherein the first opening has a first width, the second opening has a second width, and the first width is different from the second width.

20. The method of claim **3**, wherein a third portion of the physical model is associated with a second material, wherein the third portion of the physical model defines a first opening, and wherein, during deposition of the first portion of the physical model, the syringe extruder is offset from a wall of the first opening by an offset distance, and the first value of the pressure setting is selected to cause the syringe extruder to deposit a line of the material having a line width equal to or greater than the offset distance.

21. A computer-readable storage device storing instructions that are executable by a processor to cause the processor to perform operations comprising:

obtaining model data specifying a three-dimensional (3D) model of an object;

processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object, the plurality of layers including a first layer and a second layer, wherein the second layer is above and in contact with the first layer, the first layer including a first region corresponding to a first material and a second region corresponding to a second material, and the second layer including a third region corresponding to the first material and a fourth region corresponding to the second material; and

generating machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region.

22. A computer-readable storage device storing instructions that are executable by a processor to cause the processor to perform operations comprising:

obtaining model data specifying a three-dimensional (3D) model of an object;

generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder, wherein the first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a pressure to be applied to the syringe extruder; and

generating second machine instructions executable by a 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder, wherein the second machine instructions indicate a second value of the pressure setting, the second value different from the first value.

23. A computing device comprising:

a processor; and

a memory accessible to the processor, the memory storing instructions that are executable by the processor to cause the processor to perform operations comprising:

obtaining model data specifying a three-dimensional (3D) model of an object;

processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object, the plurality of layers including a first layer and a second layer, wherein the second layer is above and in contact with the first layer, the first layer including a first region corresponding to a first material and a second region corresponding to a second material, and the second layer including a third region corresponding to the first material and a fourth region corresponding to the second material; and

generating machine instructions executable by a 3D printing device to deposit a portion of the first material corresponding to the first region and to the third region before depositing a portion of the second material corresponding to the second region and to the fourth region.

24. A computing device comprising:

a processor; and

a memory accessible to the processor, the memory storing instructions that are executable by the processor to cause the processor to perform operations comprising:

obtaining model data specifying a three-dimensional (3D) model of an object;

generating first machine instructions executable by a 3D printing device to generate a first portion of a physical model of the object by depositing material using a syringe extruder, wherein the first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a pressure to be applied to the syringe extruder; and

generating second machine instructions executable by a 3D printing device to generate a second portion of the physical model of the object by depositing material using the syringe extruder, wherein the second machine instructions indicate a second value of the pressure setting, the second value different from the first value.

25. A three-dimensional (3D) printer device comprising:

one or more extruders configured to deposit a first material and a second material on a deposition platform to generate a physical model of an object, the physical model including a plurality of layers that includes a first layer and a second layer, wherein the second layer is above and in contact with the first layer, wherein the first layer includes a first region corresponding to the first material and a second region corresponding to the second material, and wherein the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material;

an actuator coupled to the one or more extruders, the deposition platform, or a combination thereof; and

a controller coupled to the actuator, the controller configured to:

cause the one or more extruders to deposit a portion of the first material corresponding to the first region and to the third region; and

after depositing the portion of the first material, cause the one or more extruders to deposit a portion of the second material corresponding to the second region and to the fourth region.

26. A three-dimensional (3D) printer device comprising:

a syringe extruder configured to deposit a material on a deposition platform at a flowrate based on a pressure regulator setting;

an actuator coupled to the syringe extruder, to the pressure regulator, to the deposition platform, or to a combination thereof; and

a controller coupled to the actuator, the controller configured to cause the syringe extruder to deposit a first portion of the material at a first flowrate to form a first portion of a physical model of an object based on a first value of the pressure regulator setting and to cause the syringe extruder to deposit a second portion of the material at a second flowrate to form a second portion of the physical model based on a second value of the pressure regulator setting.

27. A method comprising:

receiving machine instructions that enable generating a physical model of an object, the physical model including a plurality of layers that includes a first layer and a second layer, wherein the second layer is above and in contact with the first layer, wherein the first layer includes a first region corresponding to a first material and a second region corresponding to a second material, and wherein the second layer includes a third region corresponding to the first material and a fourth region corresponding to the second material;

depositing, based on the machine instructions, a portion of the first material corresponding to the first region and to the third region; and

after depositing the portion of the first material, depositing, based on the machine instructions, a portion of the second material corresponding to the second region and to the fourth region.

28. A method comprising:

receiving first machine instructions associated with a first portion of a physical model of an object and second machine instructions associated with a second portion of the physical model, wherein the first machine instructions indicate a first value of a pressure setting, the pressure setting indicating a first pressure to be applied to a syringe extruder, and wherein the second machine instructions indicate a second value of the pressure setting, the second value different from the first value;

depositing, using the syringe extruder of a three-dimensional (3D) printer device, a portion of a material at a first flowrate to form the first portion based on the first machine instructions; and

depositing, using the syringe extruder, another portion of the material at a second flowrate to form the second portion based on the second machine instructions, the first flowrate different from the second flowrate.

29. A method comprising:

obtaining model data specifying a three-dimensional (3D) model of an object, the 3D model including a first portion corresponding to a first material and a second portion corresponding to a second material;

processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object;

identifying, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion; and

generating machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique.

30. The method of claim **29**, wherein the machine instructions include instructions to translate a first extruder associated with the first material along a first axis, along a second axis, or both, to deposit the portion of the first material.

31. The method of claim **30**, wherein the portion of the second material is deposited according to a point-deposition technique without translating a second extruder along the first axis and without translating the second extruder along the second axis.

32. The method of claim **29**, wherein the point-deposition technique causes a quantity of the second material sufficient to fill the opening to be deposited.

33. The method of claim **32**, wherein the quantity of the second material is determined based on a flowrate of the second material.

34. The method of claim **32**, wherein the second material is deposited using a syringe extruder, and wherein generating machine instructions to deposit the portion of the second material according to the point-deposition technique includes determining a pressure setting and an extrusion time to cause the syringe extruder to deposit the quantity of the second material.

35. The method of claim **29**, wherein a cross-section of the elongated feature in the first layer of the physical model corresponds to a cross-section of the opening in the first layer.

36. The method of claim **29**, wherein a cross-sectional area of the elongated feature in the 3D model is less than a cross-sectional area of the opening in the first layer.

37. The method of claim **29**, further comprising, after identifying the elongated feature, modifying the sliced model to increase a cross-sectional area of the elongated feature in at least one layer of the multiple layers.

38. The method of claim **37**, wherein the cross-sectional area of the elongated feature is increased based on a dimension associated with an extruder of the 3D printing device, wherein the extruder is associated with the second material.

39. The method of claim **29**, wherein the machine instructions are further executable by the 3D printing device to, before depositing the portion of the second material within the opening, deposit at least a second layer of the multiple layers, wherein the opening extends between the first layer and the second layer, and wherein the portion of the second material deposited within the opening is sufficient to fill the opening extending between the first layer and the second layer.

40. The method of claim **39**, wherein the machine instructions cause a tip of an extruder associated with the second material to be positioned below a surface of the second layer during at least a portion of the point-deposition technique.

41. The method of claim **39**, wherein the machine instructions cause a tip of an extruder associated with the second material to translate in a direction perpendicular to a surface of the second layer during at least a portion of the point-deposition technique.

42. The method of claim **29**, wherein the point-deposition criterion is satisfied when an aspect ratio determined based on the cross-sectional dimensions is less than an aspect ratio threshold.

43. A computer-readable storage device storing instructions that are executable by a processor to cause the processor to perform operations comprising:

obtaining model data specifying a three-dimensional (3D) model of an object, the 3D model including a first portion corresponding to a first material and a second portion corresponding to a second material;

processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object;

identifying, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion; and

generating machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique.

44. A computing device comprising:

a processor; and

a memory accessible to the processor, the memory storing instructions that are executable by the processor to cause the processor to perform operations comprising:

obtaining model data specifying a three-dimensional (3D) model of an object, the 3D model including a first portion corresponding to a first material and a second portion corresponding to a second material;

processing the model data to generate a sliced model defining a plurality of layers to be deposited to form a physical model of the object;

identifying, based on the sliced model, an elongated feature extending between multiple layers of the plurality of layers and having, in each of the multiple layers, cross-sectional dimensions that satisfy a point-deposition criterion; and

generating machine instructions executable by a 3D printing device to, for a first layer of the multiple layers, deposit a portion of the first material to define an opening associated with the elongated feature and deposit a portion of the second material within the opening according to a point-deposition technique.

45. A three-dimensional (3D) printer device comprising:

a first extruder configured to deposit a first material on a deposition platform;

a second extruder configured to deposit a second material on the deposition platform;

an actuator coupled to the first extruder, to the second extruder, to the deposition platform, or to a combination thereof; and

a controller coupled to the actuator, the controller configured to:

cause the first extruder to deposit a portion of the first material to define an opening associated with an elongated feature of a physical model of an object, wherein the elongated feature extends between multiple layers of a plurality of layers of the physical model and has, in each of the multiple layers, a cross-sectional dimension that satisfies a point-deposition criterion; and

cause the second extruder to deposit a portion of the second material to form a portion of the elongated feature using a point-deposition technique, wherein the point-deposition technique deposits the portion of the second material within the opening.

46. A method comprising:

receiving machine instructions that enable generating a physical model of an object including an elongated feature, wherein the elongated feature extends between multiple layers of a plurality of layers of the physical model and has, in each of the multiple layers, a cross-sectional dimension that satisfies a point-deposition criterion;

depositing, using a first extruder of a three-dimensional (3D) printer device, a portion of a first material to define an opening associated with the elongated feature of the physical model; and

depositing, using a second extruder of the 3D printer device, a portion of a second material to form a portion of the elongated feature according to a point-deposition technique, wherein the point-deposition technique causes the portion of the second material to be deposited within the opening.

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