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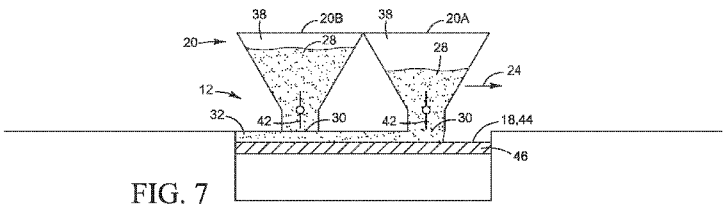


FIG. 7

(57) Abstract: In one example, a powdered build material layering system for additive manufacturing includes a work area and a group of build material dispensers. One or both of the group of dispensers and the work area are movable with respect to the other of the group of dispensers and/or the work area to layer a powdered build material on to the work area in a thickness corresponding to a gap between the dispensers and the work area. The gap is small enough to choke a flow of powdered build material from a corresponding one of the dispensers in the group to the work area when there is no relative motion between the dispenser and the work area.

WO 2017/127114 A1

LAYERING POWDERED BUILD MATERIAL FOR ADDITIVE MANUFACTURING

BACKGROUND

[0001] Additive manufacturing machines produce 3D (three-dimensional) objects by building up layers of material. Some additive manufacturing machines are commonly referred to as "3D printers." 3D printers and other additive manufacturing machines make it possible to convert a CAD (computer aided design) model or other digital representation of an object into the physical object. The model data may be processed into slices each defining that part of a layer or layers of build material to be formed into the object.

DRAWINGS

[0002] Fig. 1 is a block diagram illustrating an additive manufacturing machine implementing one example of a powdered build material layering system.

[0003] Fig. 2 is an isometric illustrating one example of a layering system, such as might be used in the machine shown in Fig. 1, layering powdered build material on to a work area.

[0004] Figs. 3-5 are sections illustrating one example of a powdered build material layering system.

[0005] Figs. 6-13 present a sequence of sections illustrating another example of a powdered build material layering system, layering powdered build material on to a work area.

[0006] Figs. 14-22 present a sequence of sections illustrating one example for manufacturing a multi-slice object using the layering system shown in Figs. 6-13.

[0007] Fig. 23 is a section illustrating one example of a powdered build material layering system.

[0008] Fig. 24 is a section illustrating one example of a powdered build material layering system.

[0009] Fig. 25 is a flow diagram illustrating one example of an additive manufacturing process.

[0010] Fig. 26 is a block diagram illustrating one example of a processor readable medium with instructions to layer powdered build material on to a work area.

[0011] Fig. 27 is a block diagram illustrating one example of an additive manufacturing machine implementing a controller with instructions to layer powdered build material on to a work area.

[0012] The same part numbers designate the same or similar parts throughout the figures. The figures are not necessarily to scale.

DESCRIPTION

[0013] In some additive manufacturing processes, heat is used to fuse together the particles in a powdered build material to form a solid object. Heat to fuse the build material may be generated, for example, by applying a liquid fusing agent to a thin layer of powdered build material(s) in the pattern of the object slice and then exposing the patterned area to light. Light or other energy absorbing components in the fusing agent absorb energy to help sinter, melt or otherwise fuse the build material. The process is repeated layer by layer, slice by slice to complete the object.

[0014] A new technique has been developed for dispensing powdered build material on to the work area in an additive manufacturing machine to help more effectively deliver consistent layering. In one example, the new technique is implemented in a system in which one or both of the build material dispenser and the work area is movable to layer powdered build material on to the work area in a thickness corresponding to the gap between the dispenser and the work area. The gap is small enough to choke the flow of powdered build material from the dispenser to the work area when the dispenser is stationary with respect to the work area.

[0015] A group of dispensers may be used with choked flow layering, for example, to automatically switch passively between dispensers. Automatic passive switching between choked flow dispensers may be used to change from an empty dispenser to a not empty dispenser “on the fly” without interrupting the flow of build material to the work area, thus increasing the supply capacity of the layering system. Also, the passive nature of choked flow layering helps reduce cost by lowering the number and complexity of the components of the dispensing system. A group of dispensers may also be used with choked flow layering, for another example, to simultaneously dispense multiple thin layers of different build materials including, for example, binders and fillers that together may act as a single layer of composite build material for subsequent fusing.

[0016] These and other examples enable the use of a mass flow hopper or a group of mass flow hoppers to both dispense and layer powdered build material. The build material can be dispensed and layered simultaneously, directly on to the work area, for uniform coverage even across areas of varying fill without dispensing excess material. Choked flow, usually an undesirable characteristic in powdered material supply systems, is exploited to help control and meter the delivery of powdered build material on to the work area in an additive manufacturing machine.

[0017] The examples described herein and shown in the figures illustrate but do not limit the scope of the patent, which is defined in the Claims following this Description.

[0018] As used in this document: “and/or” means one or more of the connected things; a "detailing agent" means a substance that inhibits or prevents or enhances fusing a build material, for example by modifying the effect of a fusing agent; “energy” means electromagnetic radiation of any wavelength; a “fusing agent” means a substance that causes or helps cause a powdered build material to sinter, melt or otherwise fuse; and “work area” means any suitable structure to support or contain build material for fusing, including underlying layers of build material and in-process slice and other object structures.

[0019] Fig. 1 is a block diagram illustrating an additive manufacturing machine 10 implementing one example of a powdered build material layering system 12. The block diagram of Fig. 1 shows one example for the layout of a machine 10 implementing system 12. Other layouts are possible. Referring to Fig. 1, machine 10 includes layering system 12, energy bars 14, and a fusing agent dispenser 16 located near a work area 18. Work area 18 in the figures represents any suitable structure to support or contain build material for fusing, including underlying layers of build material and in-process slices and other object structures.

[0020] Layering system 12 includes a group 20 of movable dispensers and a surface 18 to block the flow of powdered build material from each dispenser in group 20 when the dispenser is stationary over surface 18, and to not block the flow of powdered build material from each dispenser in the group when the dispenser is moving over surface 18. For example, each dispenser is separated from surface 18 by a gap that is small enough to choke the flow of powder from a stationary dispenser and big enough to allow powder flow when the dispenser is moving over surface 18. In the example shown in Fig. 1, work area 18 forms the blocking surface

in layering system 12. Thus, a work area blocking surface 18 may include underlying layers of build material and in-process object slices as an object is manufactured layer by layer and slice by slice.

[0021] Also in the example shown in Fig. 1, dispenser group 20 is mounted together with a pair of energy bars 14 on a movable carriage 22. Carriage 22 carries the dispensers and the energy bars 14 back and forth over work area 18, as indicated by direction arrows 24. Fusing agent dispenser 16 is also movable back and forth over work area 18, as indicated by direction arrows 26. Alternate "parking" positions for fusing agent dispenser 16 and carriage 22 across work area 18 are depicted by phantom lines in Fig. 1.

[0022] Fig. 2 is an isometric showing a group 20 of powdered build material dispensers 20A, 20B and energy bars 14 over a work area blocking surface 18. Carriage 22 with dispensers 20A, 20B and energy bars 14 is exploded away from work area 18 in Fig. 2 to more clearly show layering powder 28 on to work area 18. Also, while group 20 includes two dispensers 20A, 20B in the example shown in Fig. 2, group 20 may include more than two dispensers. Referring now also to Fig. 2, in operation powdered build material 28 is dispensed on to work area 18 from one or both dispensers 20A, 20B through an elongated opening 30 as carriage 22 moves across work area 18. A moving dispenser 20A, 20B forms a layer 32 of powdered build material 28 on the stationary work area 18. As described in detail below, dispensers 20A, 20B may be configured to dispense single layers of build material (for example as shown in Figs. 6-13) or to simultaneously dispense a double layer of build material (for example as shown in Fig. 23).

[0023] A liquid fusing agent is selectively applied to layered build material 32 on work area 18 in a pattern corresponding to an object slice, as fusing agent dispenser 16 is scanned across work area 18 (Fig. 1). One or both energy bars 14 are energized to expose the patterned area to light or other electromagnetic radiation to fuse build material where fusing agent is applied as carriage 22 (carrying bars 14) is scanned over work area 18. In the example shown in Fig. 2, each energy bar 14 is configured as an array of LEDs, laser diodes or other light sources 34 that span work area 18. The process of layering and fusing is repeated to form a multi-slice object.

[0024] In Figs. 3-5, a single dispenser 20A from group 20 is used to illustrate one example for choked flow layering in a layering system 12 such as the dual dispenser system 12 shown in Figs. 1 and 2. Referring to Figs. 3-5, dispenser 20A is spaced

apart from a work area or other horizontal blocking surface 18 across a gap 36. Dispenser 20A is configured as a hopper that includes a receptacle 38 to hold build material 28 and an elongated opening 30 oriented horizontally along a bottom part 40 of receptacle 38. Powdered build material 28 may be dispensed from receptacle 38 through opening 30 on to surface 18. Opening 30 extends lengthwise in a direction perpendicular to the direction of relative motion between surface 18 and dispenser 20A. The direction of relative motion is indicated by arrows 24 in Fig. 4.

[0025] Gap 36 is small enough to choke the flow of powder 28 from hopper 20A when hopper 20A and surface 18 are stationary relative to one another, and big enough to allow powder flow when hopper 20A is moving over surface 18 and/or surface 18 is moving under hopper 20A. In Fig. 3, hopper 20A and surface 18 are stationary relative to one another to choke (and thus block) the flow of powder 28 through opening 30 across gap 36. When hopper 20A and surface 18 are stationary as shown in Fig. 3, powder 28 will flow out of hopper 20A until the angle of repose or other internal characteristic of the powder accumulating in gap 36 meets the top of opening 30, at which point the flow is choked off. This choking condition will block the flow of powder 28 until there is relative motion between hopper 20A and surface 18.

[0026] In Fig. 4, one or both of hopper 20A and surface 18 are moving, as indicated by arrows 24, to layer powder 28 on to surface 18. When there is motion between hopper 20A and surface 18 as shown in Fig. 4, powder 28 is dragged from opening 30 and more powder flows into gap 36 until the relative motion stops. So long as the speed of hopper 20A relative to surface 18 does not exceed the flow capacity of hopper 20A, the thickness of powder layer 32 is determined by the size of gap 36. Accordingly, gap 36 can be set to the desired thickness for each layer 32 of powdered build material 28, for example by moving hopper 20A and/or surface 18 vertically with respect to other.

[0027] A PA 12 (polyamide 12) powdered build material 28 may be uniformly layered to a thickness in the range of 100μm-2mm using a choked flow technique implemented with a dispenser such as hopper 20A shown in Figs. 3-5, with vertical sidewalls defining an elongated opening 30 that is 30mm-40mm wide. The thickness of any particular powder layer that can be dispensed uniformly on to a work area will depend on several parameters including, for example, the angle of repose and compressibility of the powder, friction between the powder and the hopper, particle

size and shape, internal powder friction, and the size and shape of the opening. However, for a given set of parameters, the thickness of the layer may be controlled by the size of the gap between the dispenser and the work area.

[0028] The top surface of each layer of powdered build material is delineated with a line in the figures for clarity, and does necessarily suggest a smooth flat surface.

[0029] Figs. 6-13 present a sequence of sections illustrating one example for layering powdered build material 28 on to a work area blocking surface 18 using a group dispenser layering system 12. Again, while group 20 includes two hoppers 20A, 20B in this example, group 20 may include more than two hoppers. In the example shown in Figs. 6-13, each hopper 20A, 20B includes a valve 42 to control the flow of powder 28 from receptacle 38 to opening 30.

[0030] In Fig. 6, surface 44 of a vertically movable platform 46 forms an initial work area 18 and hoppers 20A, 20B are parked to the side of work area 18 with valves 42 closed. In Fig. 7, valves 42 are open and hoppers 20A, 20B are moving over platform 46. Leading hopper 20A layers build material 28 on to work area 18 across a gap 36 corresponding to the desired thickness of layer 32. The flow of powder from trailing hopper 20B is blocked by layer 32. Thus, the supply of build material 28 in leading hopper 20A is being depleted while the supply of build material 28 in trailing hopper 20B remains unchanged, as best seen by comparing the powder levels in each hopper in Figs. 6 and 7.

[0031] In Fig. 8, hoppers 20A, 20B are parked on the other side of work area 18 with valves 42 closed. In Fig. 9, platform 46 is lowered for the next layer of build material, as indicated by direction arrow 48. Work area 18 is now formed by the first, underlying layer 32 of build material 28. Valves 42 are open and hoppers 20A, 20B are moving back over platform 46, as indicated by direction arrow 24. The now leading hopper 20B layers build material 28 on to work area 18 across a gap 36 corresponding to the desired thickness of a second layer 50. The flow of powder from trailing hopper 20A is blocked by layer 50. Thus, the supply of build material 28 in leading hopper 20B is being depleted while the supply of build material 28 in trailing hopper 20A remains unchanged, as best seen by comparing the powder levels in each hopper in Figs. 8 and 9.

[0032] In Fig. 10, hoppers 20A, 20B are again parked to the left side of work area 18 with valves 42 closed. In Fig. 11, platform 46 is lowered for a third layer of build material, as indicated by direction arrow 48. Work area 18 is now formed by the

second, underlying layer 50 of build material 28. In Figs. 11 and 12, valves 42 are open and hoppers 20A, 20B are moving over platform 46, as indicated by direction arrow 24. Leading hopper 20A layers build material 28 on to work area 18 across gap 36 until it runs out of powdered build material 28. At the position shown in Fig. 11, leading hopper 20A is empty and is no longer layering build material, trailing hopper 20B has not yet reached the open gap, and the flow of powder from trailing hopper 20B is still blocked by third layer 52 in Fig. 11. At the position shown in Fig. 12, trailing hopper 20B has reached the open gap and is layering build material 28 on to work area 18, continuing to form third layer 52. In Fig. 13, the now empty hoppers 20A, 20B are again parked to the right of platform 46 where they may be refilled for more layering.

[0033] The use of a group of hoppers in a choked flow layering system such as system 12 shown in Figs. 6-13, in which the hoppers are arranged successively in the direction of relative motion, increases overall supply capacity and enables automatically and passively switching supplies from an empty, leading hopper to a not empty, trailing hopper "on the fly" to avoid any layering discontinuities and significant switching delays.

[0034] One example for manufacturing a multi-slice object will now be described with reference to the sequence of sections presented in Figs. 14-22, using a layering system 12 such as the one shown in Figs. 6-13. Powdered build material 28 is depicted by larger dots in Figs. 14-22 and the thickness of powder layers 32 and 50 greatly exaggerated to help more clearly illustrate the manufacturing process.

[0035] In Fig. 14, a first layer 32 of powdered build material 28 is dispensed from a leading hopper 20B on to work area 18 on platform 46. In Fig. 15, a fusing agent 54 is dispensed on to build material 28 in layer 32 in a pattern 56 corresponding to a first object slice, for example with an inkjet type dispenser 16. Pattern 56 for fusing agent 54 is depicted by an area of dense stippling in the figures. In some examples, a detailing agent 58 may be dispensed on to build material 28 in layer 32, for example with an inkjet type dispenser 60, as shown in Fig. 16. Detailing agent 58 may be applied before or after fusing agent 54 to inhibit or prevent or enhance fusing targeted areas of build material 28 for improved dimensional accuracy and overall quality of the manufactured object. In the example shown in Fig. 16, detailing agent 58 is dispensed on to an area 62 covering the area where a second object slice will overhang the first slice. Area 62 treated with detailing agent 58 is depicted by light

stippling in the figures. Detailing agent 58 may be dispensed on to other areas of build material layer 32 to help define other aspects of the object slice, including interspersed with the pattern of fusing agent, for example, to change the material characteristics of the slice.

[0036] Although two dispensers 16 and 60 are shown, agents 54 and 58 could be dispensed from dispensers integrated into a single device, for example using different printheads (or groups of printheads) in a single inkjet printhead assembly. In this example, fusing agent 54 includes a light absorbing component to absorb light to generate heat that sinters, melts or otherwise fuses patterned build material. Thus, in Fig. 17 the area of layer 32 patterned with fusing agent 54 is exposed to light 64 from a light bar 14 to fuse build material and form first object slice 66.

[0037] In Fig. 18, a second layer 50 of build material 28 is dispensed from a leading hopper 20A on to work area 18 on the underlying in-process structure 68, which includes untreated powdered build material 28, first slice 68 (fused build material), and treated build material in area 62. In Fig. 19, fusing agent 54 is dispensed on to powdered build material 28 in second layer 50 in a pattern 70 corresponding to a second object slice. In Fig. 20, detailing agent 58 is dispensed on to powdered build material 28 in layer 50 in area 72 to help prevent unwanted fusing of build material along the edge of the second slice. In Fig. 21, the area 70 of second layer 50 patterned with fusing agent 54 is exposed to light 64 to fuse build material and form second object slice 74. While distinct first and second slices 66, 74 are shown in Fig. 23, the two slices actually fuse together into a single part. The now fused slices 66, 74 may be removed from platform 46 as a finished object 75 shown in Fig. 22. Although a simple two-slice object 75 is shown, the same processes may be used to form more complex, multi-slice objects.

[0038] Another example of choked flow layering for additive manufacturing will now be described with reference to Fig. 23. Referring to Fig. 23, two different build materials 28A, 28B are layered simultaneously with a group 20 of two dispensers 20A, 20B in layering system 12. Dispenser 20A layers build material 28A on to a work area 18A across a gap 36A to form layer 32A. Dispenser 20B simultaneously layers build material 28B on to a work area 18B, formed by layer 32A, across a gap 36B to form layer 32B. Gaps 36A, 36B may be adjusted for each layer during the additive manufacturing process by moving a platform or other structure supporting the work areas, by moving dispensers 20A, 20B together as a group 20 (for example

where constant gapping between dispensers is desired), and/or by moving each dispenser 20A, 20B individually (for example if variable gapping between dispensers is desired).

[0039] In other implementations for the dual choked flow layering system 12, shown in Figs. 23 and 24, two different materials 28A, 28B are layered through gaps 36A, 36B. In the implementation shown in Fig. 23, dispensers 20A and 20B are moving over stationary surfaces 18A, 18B across gaps 36A and 36B that are sufficiently small to form layers 32A, 32B thin enough to act as a single layer 32 of composite build material for subsequent fusing. If the individual layers 32A, 32B are sufficiently thin, such that the particles in each layer mix with one another, a blended composite layer 28 is possible. In the implementation shown in Fig. 24, surface 18A is configured as an endless loop belt moving past stationary dispensers 20A and 20B, for example to carry the two layers 32A, 32B of material 28A, 28B into a mixing flow 77. While two layers 32A, 32B of equal thickness 36A, 36B are shown in Figs. 23 and 24, it may be possible and desirable in some implementations to use more than two layers and/or with unequal layer thickness.

[0040] Fig. 25 illustrates one example of an additive manufacturing process 100 that uses a group dispensing system, such as a system 12 shown in Figs. 6-13. Referring to Fig. 25, a first dispenser layers powdered build material on to a work area (block 102), for example as shown in Figs. 7 and 9. When the first dispenser stops layering, the layering switches automatically but passively to a second dispenser trailing the first dispenser (block 104) and the second dispenser layers powdered build material on to the work area (block 105), for example as shown in Figs. 11 and 12.

[0041] Fig. 26 is a block diagram illustrating a processor readable medium 76 with instructions 78 to use a choked flow group dispenser configuration to layer powdered build material on to a work area, for example by relative motion between dispensers 20A, 20B and a work area 18 across a gap 36 as shown in Figs. 6-13 or across gaps 36A and 36B as shown in Figs. 23 and 24. Choked flow layering instructions 78 may also include instruction to fuse powdered build material layered on to a work area, for example as described above with reference to Figs. 15-17. A processor readable medium 76 in Fig. 26 is any non-transitory tangible medium that can embody, contain, store, or maintain instructions for use by a processor, and may include for example a hard drive, a random access memory (RAM), a read-only

memory (ROM), memory cards and sticks and other portable storage devices. Processor readable medium 76 with choked flow layering instructions 78 may be implemented, for example, in a CAD computer program product, in an object model processor, or in a controller for an additive manufacturing machine.

[0042] Fig. 27 is a block diagram illustrating one example of an additive manufacturing machine 10 implementing a controller 80 with choked flow layering instructions 78. Referring to Fig. 27, machine 10 includes controller 80, a work area 18, a build material layering system 12, a fusing agent dispenser 16, a detailing agent dispenser 60, and an energy source 14. Controller 80 represents the processor (or multiple processors), the associated memory (or multiple memories) and instructions, and the electronic circuitry and components needed to control the operative elements of machine 10. In particular, controller 80 includes a memory 82 having a processor readable medium 76 with layering instructions 78, and a processor 84 to read and execute instructions 78. For example, controller 80 would receive control data and other instructions generated by a CAD program to make an object and execute layering instructions 78 as part of the process of making the object.

[0043] Any suitable powdered build material may be used, including for example metals, composites, ceramics, glass and polymers, and processed to make the desired solid object which may be hard or soft, rigid or flexible, elastic or inelastic. Suitable build materials for an additive manufacturing process such as that shown in Figs. 14-22 may include, for example, polyamides and other thermoplastics. A build material may also include a charging agent to suppress or otherwise modify charge characteristics or a flow aid to improve flowability.

[0044] Energy source 14 supplies energy to help fuse build material patterned with a fusing agent. Energy source 14 may be implemented, for example, as an infra-red (IR) or near infra-red light source, a halogen light source, or a light emitting diode. A light source 14 may be a single light source or an array of multiple light sources configured to apply light energy in a substantially uniform manner simultaneously to the whole area of a layer of build material or to apply light energy to just select areas of a layer of build material.

[0045] Suitable fusing agents may include pigments, dyes, polymers and other substances that have significant light or other energy absorption. Carbon black ink and light absorbing color inks commercially known as CM997A, CE039A and

CE042A available from HP Inc. may be suitable fusing agents with the appropriate light source.

[0046] Suitable detailing agents may separate individual particles of the build material to prevent the particles from fusing. Examples of this type of detailing agent include colloidal, dye-based, and polymer-based inks, as well as solid particles that have an average size less than the average size of particles of the build material. In one example, a salt solution may be used as a detailing agent. In other examples, inks commercially known as CM996A and CN673A available from HP Inc. may be used as a detailing agent. Suitable detailing agents may act to modify the effects of a fusing agent by preventing build material from reaching temperatures above its fusing point. A liquid that exhibits a suitable cooling effect may be used as this type of detailing agent. For example, when build material is treated with a cooling liquid, energy applied to the build material may be absorbed evaporating the liquid to help prevent build material from reaching its fusing point. Thus, for example, a fluid with a high water content may be a suitable detailing agent. Other types of detailing agent may be used. Examples of a detailing agent to enhance fusing may include plasticizers and surface tension modifiers (that increase the wettability of particles of build material).

[0047] "A", "an" and “the” used in the claims means one or more. For example, “a work area” means one or more work areas and “the work area” means the one or more work areas.

[0048] The examples shown in the figures and described above illustrate but do not limit the patent, which is defined in the following Claims.

CLAIMS

1. A powdered build material layering system for additive manufacturing, the layering system comprising:

a work area; and

a group of build material dispensers; where:

one or both of the group of dispensers and the work area being movable with respect to the other of the group of dispensers and/or the work area to layer a powdered build material on to the work area in a thickness corresponding to a gap between the dispensers and the work area; and

the gap is small enough to choke a flow of powdered build material from a corresponding one of the dispensers in the group to the work area when there is no relative motion between the dispenser and the work area.

2. The layering system of Claim 1, where the gap is the same for all of the dispensers in the group.

3. The layering system of Claim 2, where:

the group includes a lead dispenser and a trail dispenser;

the lead dispenser to layer powdered build material on to the work area in front of the trail dispenser such that powdered build material layered by the lead dispenser blocks a flow of powdered build material from the trail dispenser; and

the trail dispenser is to layer powdered build material on to the work area when the lead dispenser is no longer layering powdered build material on to the work area.

4. The layering system of Claim 1, where the gap includes:

a first gap between a lead dispenser and the work area; and

a second gap larger than the first gap between a trail dispenser and the work area.

5. The layering system of Claim 4, where:

the lead dispenser is to layer powdered build material on to the work area in front of the trail dispenser in a first thickness corresponding to the first gap; and

the trail dispenser is to layer powdered build material on to the powdered build material layered by the lead dispenser in a second thickness corresponding to the second gap.

6. The layering system of Claim 5, where the lead dispenser is to layer a first powdered build material on to the work area and the trail dispenser is to layer a second powdered build material different from the first powdered build material on to the first powdered build material layered by the lead dispenser.

7. The layering system of Claim 6, where the second gap is twice the size of the first gap and the second thickness is equal to the first thickness.

8. The layering system of Claim 1, comprising powdered build material in the dispensers.

9. A powdered build material layering system for additive manufacturing, the layering system comprising:

a first movable hopper including a receptacle to hold a powdered build material and an elongated opening along a bottom part of the receptacle through which powdered build material may be dispensed from the hopper;

a second movable hopper including a receptacle to hold a powdered build material and an elongated opening along a bottom part of the receptacle through which powdered build material may be dispensed from the second hopper;

a surface to cover the openings simultaneously and block a flow of powdered build material from each receptacle on to the surface through the opening when the hoppers are stationary over the surface and to not block the flow of powdered build material on to the surface from the receptacle through the opening when the hoppers are moving over the surface;

a first gap between the first hopper opening and the surface; and

a second gap between the second hopper opening.

10. The layering system of Claim 9, where:

the gap is the same for both dispensers;

a lead one of the dispensers is to layer powdered build material on to the surface in front of a trail one of the dispensers such that powdered build material layered by the lead dispenser blocks a flow of powdered build material from the trail dispenser; and

the trail dispenser is to layer powdered build material on to the work area when the lead dispenser is not layering powdered build material on to the surface.

11. The layering system of Claim 9, where:

the gap includes a first gap between a lead one of the dispensers and the surface and a second gap larger than the first gap between a trail one of the dispensers and the surface;

the lead dispenser is to layer powdered build material on to the surface in front of the trail dispenser in a first thickness corresponding to the first gap; and

the trail dispenser is to layer powdered build material on to the powdered build material layered by the lead dispenser in a second thickness corresponding to the second gap.

12. An additive manufacturing process, comprising:

layering powdered build material on to a work area with a first dispenser;

when the first dispenser stops layering, passively and automatically switching layering to a second dispenser trailing the first dispenser; and

layering powdered build material on to the work area with the second dispenser after the first dispenser stops layering.

13. The process of Claim 12, comprising moving the first dispenser and the second dispenser together simultaneously while layering with the first dispenser and while layering with the second dispenser, and where the switching and the layering with the second dispenser occur simultaneously as the second dispenser is moving through a location where the first dispenser stops layering.

14. The process of Claim 12, where the first dispenser stops layering when it runs out of powdered build material.

15. The process of Claim 12, comprising fusing powdered build material layered on to the work area to form a slice.

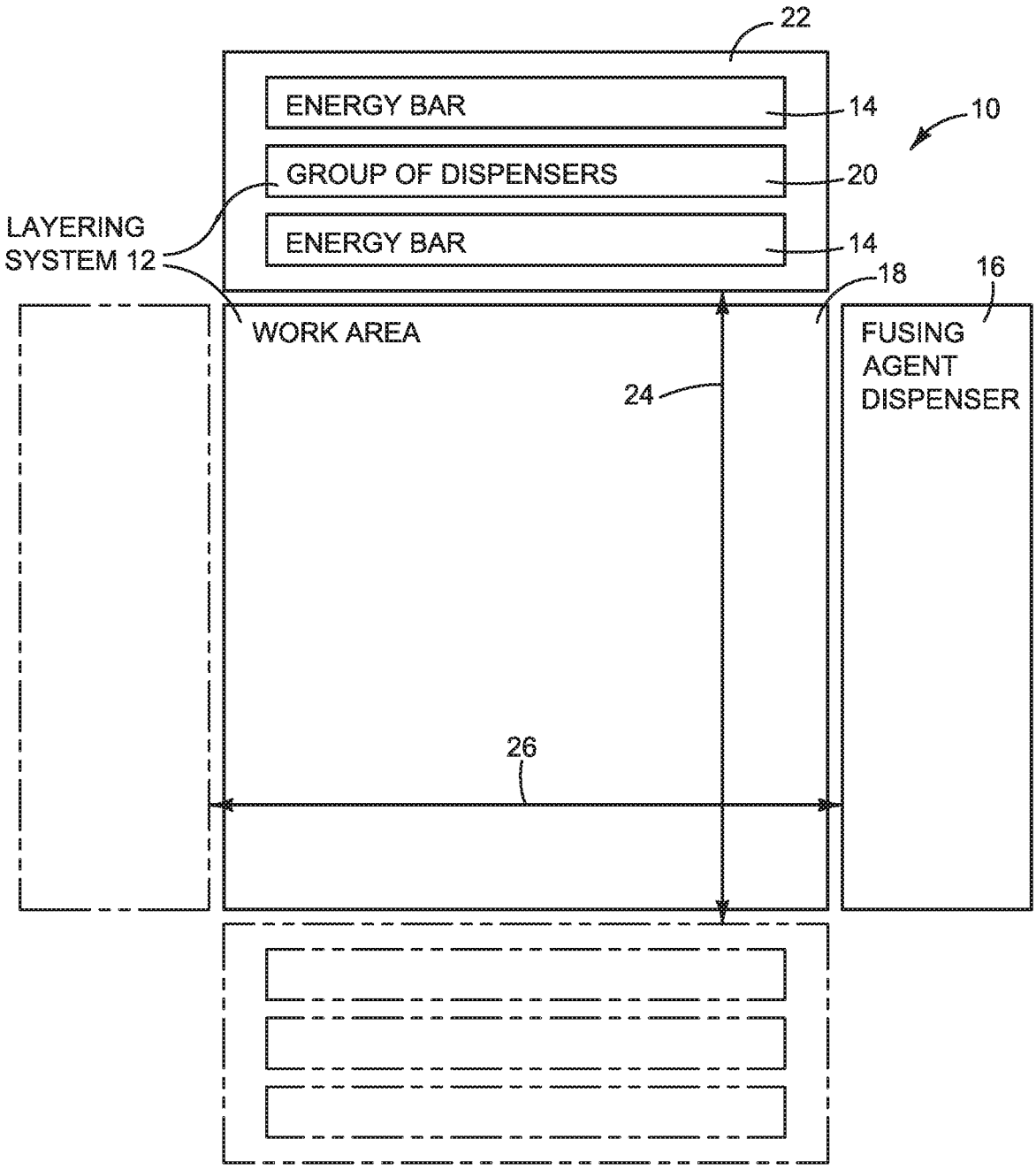

22
ENERGY BAR
14
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GROUP OF DISPENSERS
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LAYERING SYSTEM 12
ENERGY BAR
14
18
16
WORK AREA
FUSING AGENT DISPENSER
24
26

FIG. 1

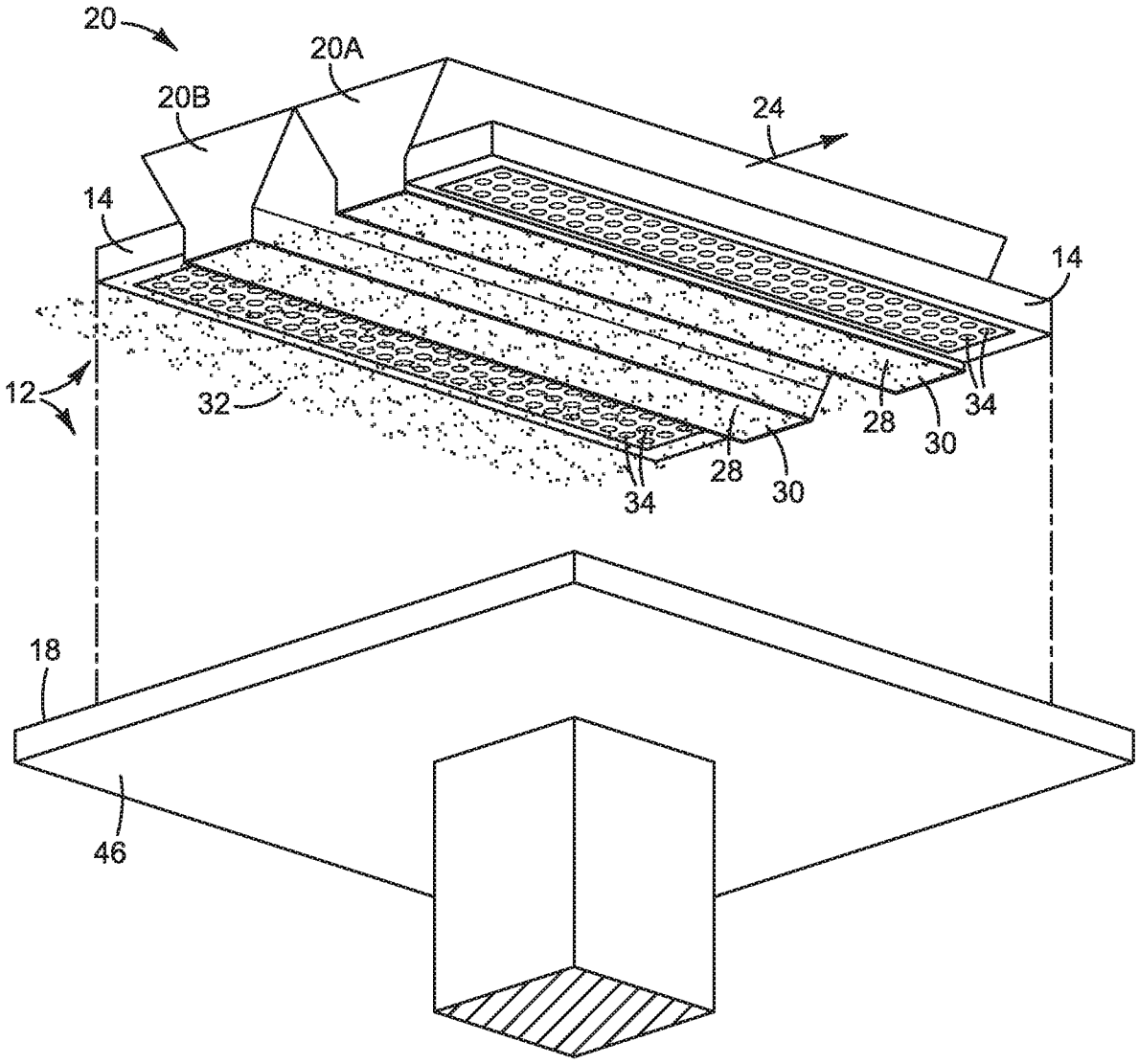


FIG. 2

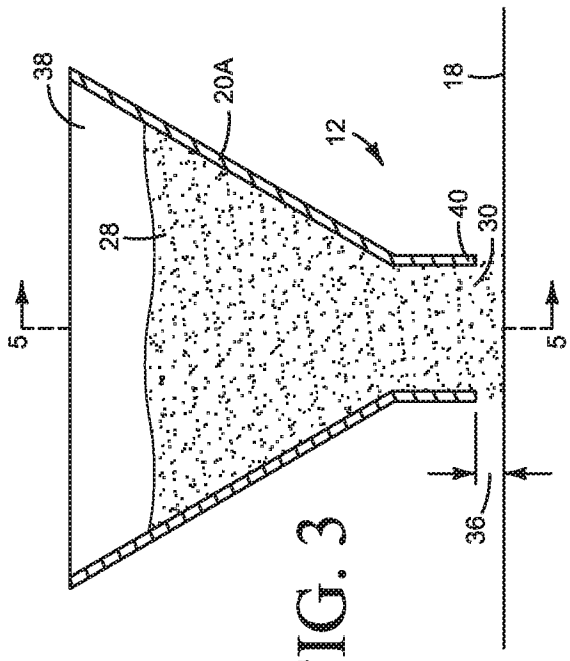


FIG. 3

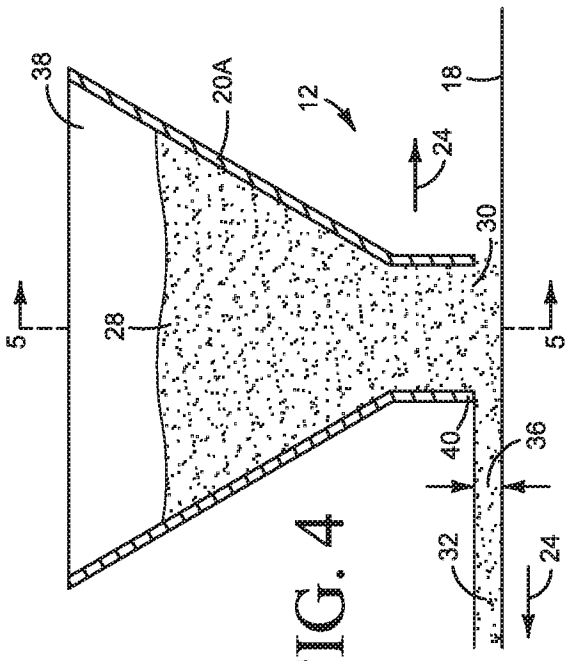


FIG. 4

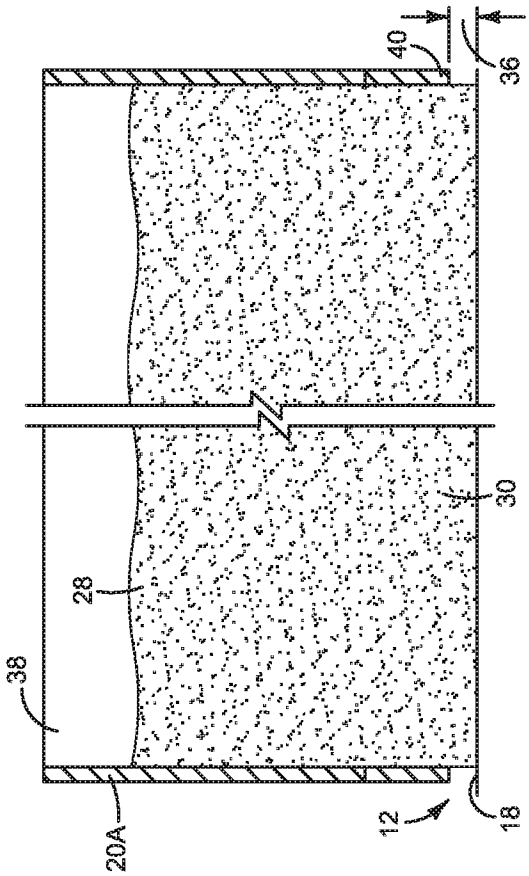


FIG. 5

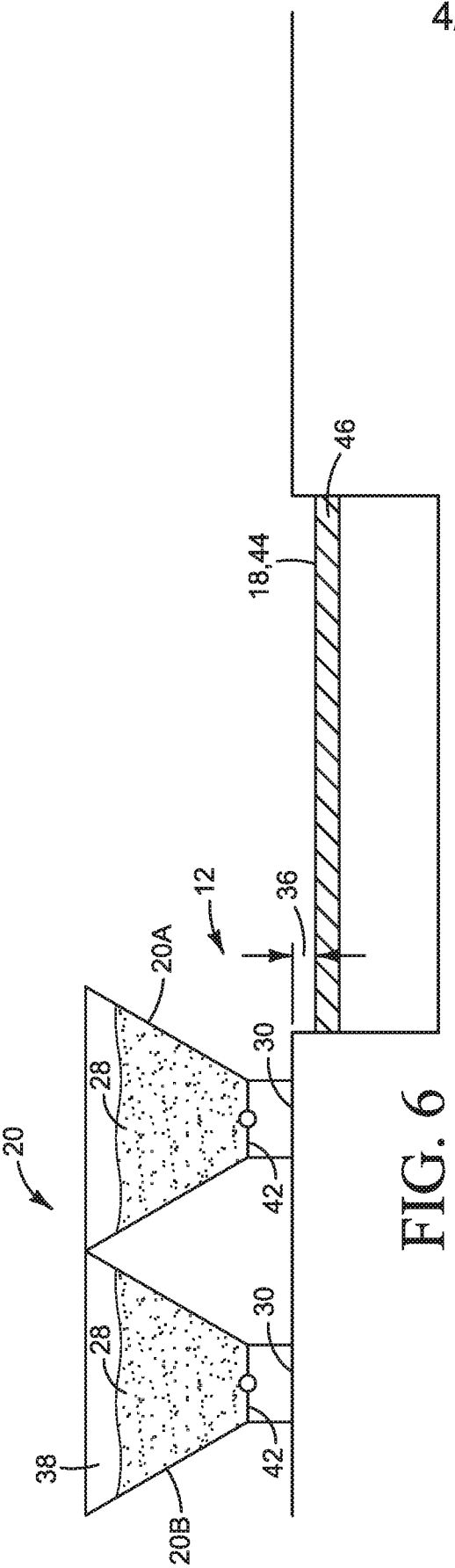

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FIG. 6

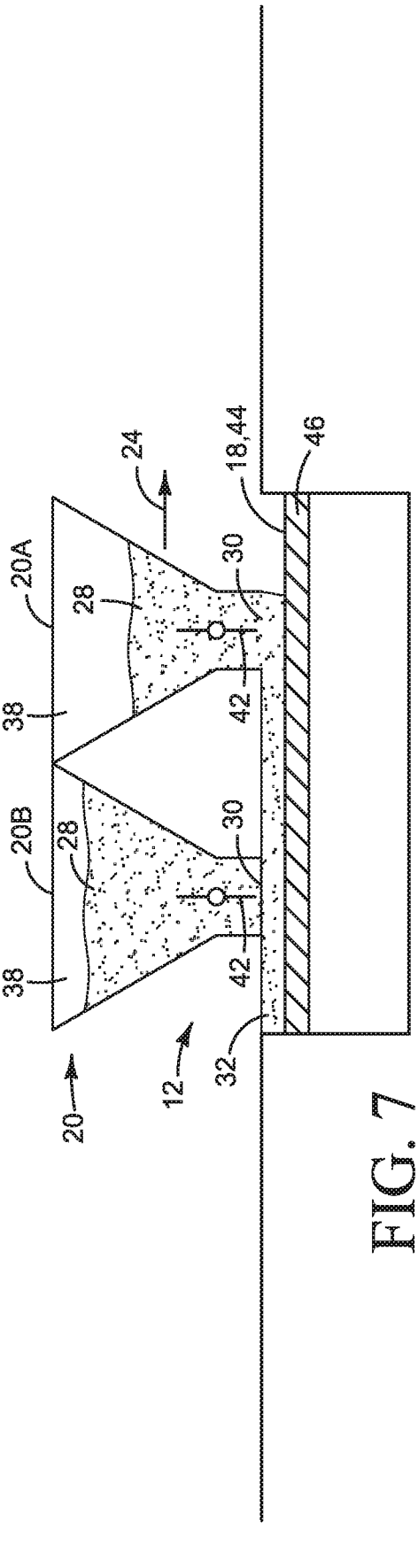

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FIG. 7

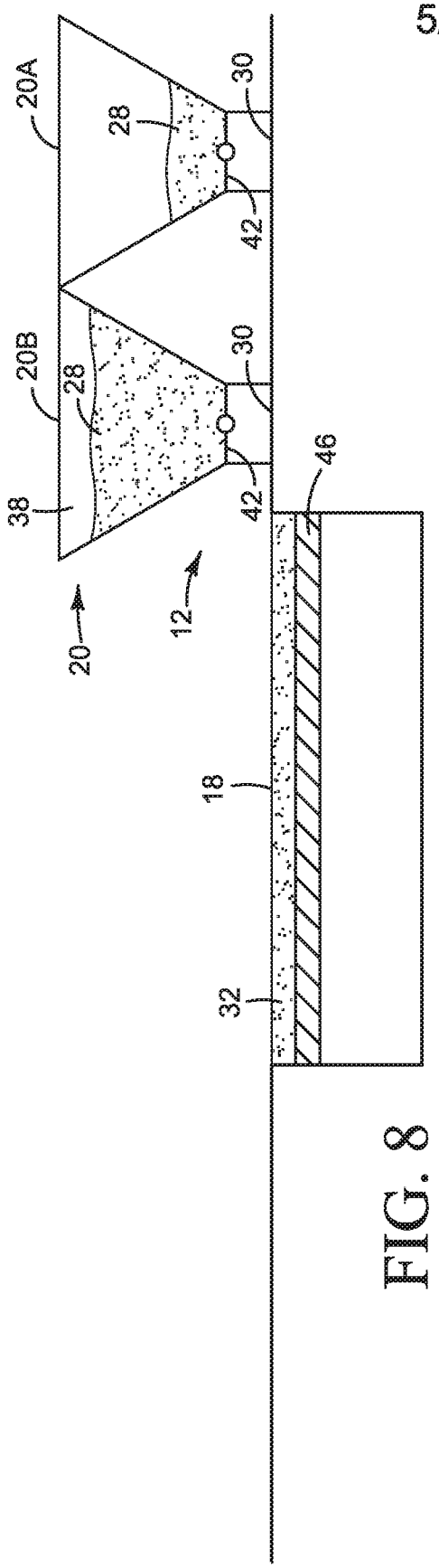

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FIG. 8

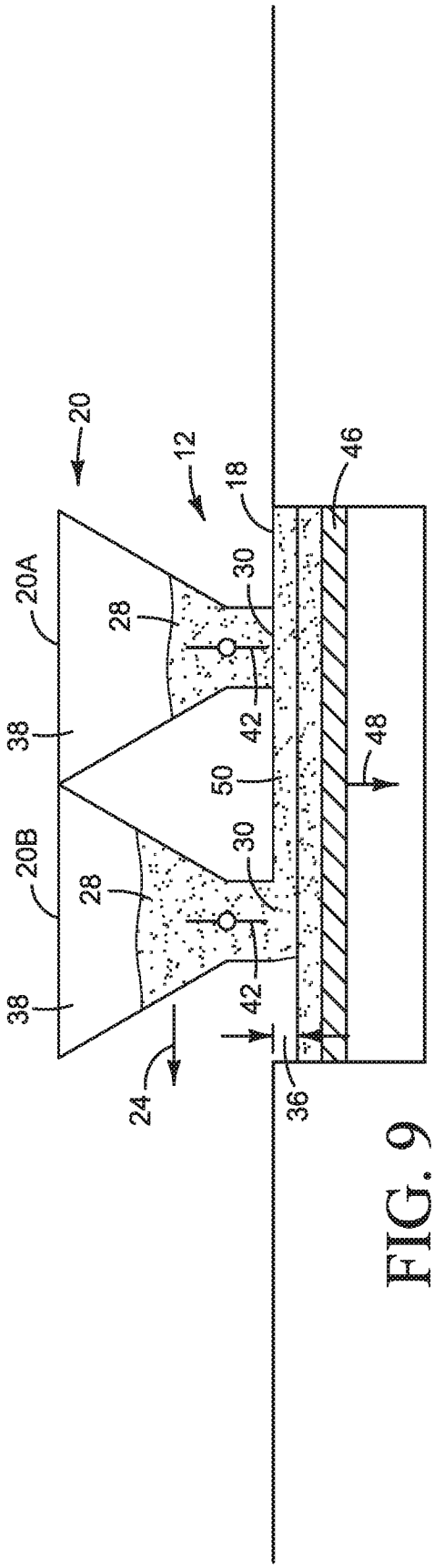

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FIG. 9

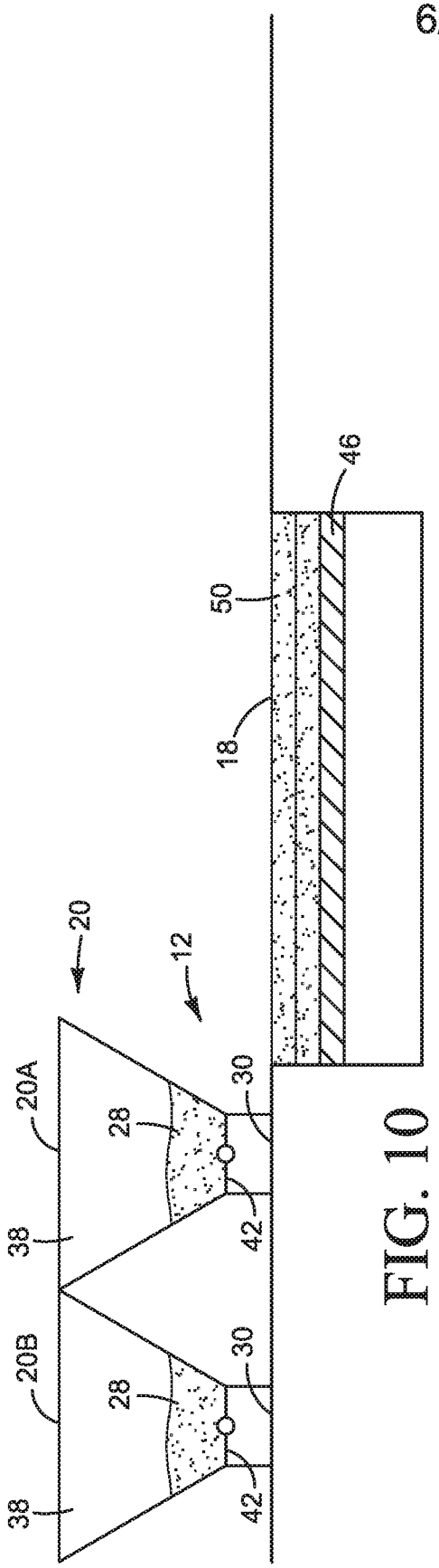

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FIG. 10

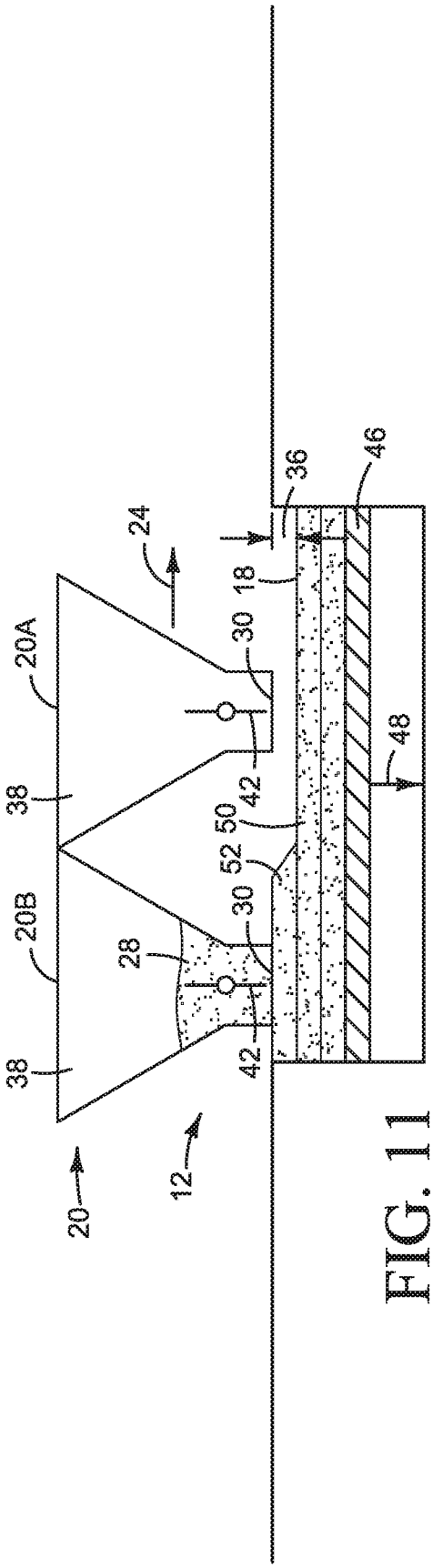

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FIG. 11

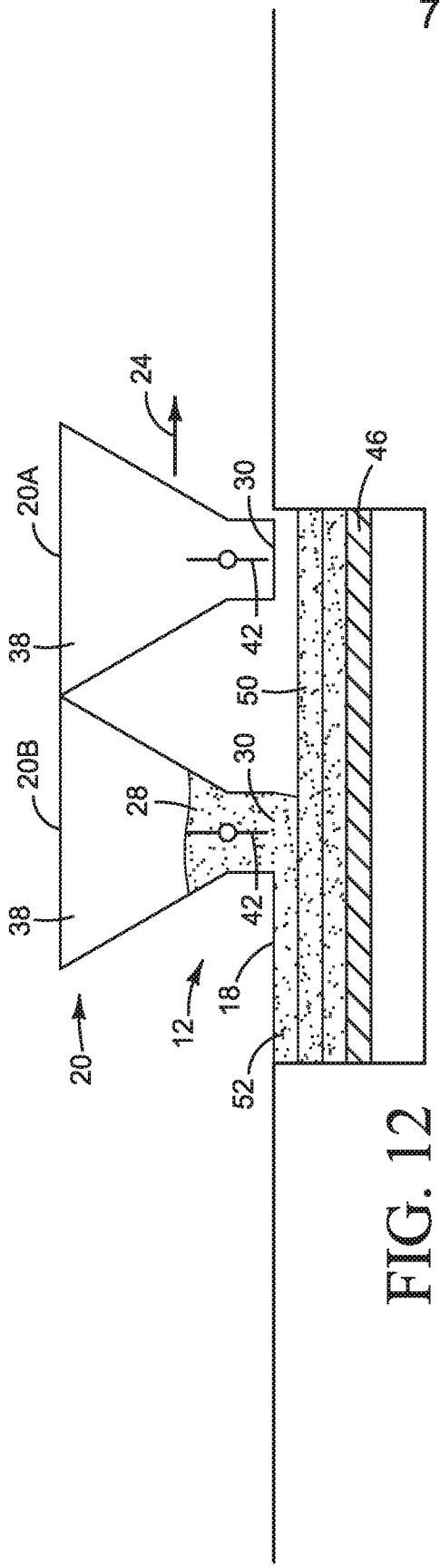

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FIG. 12

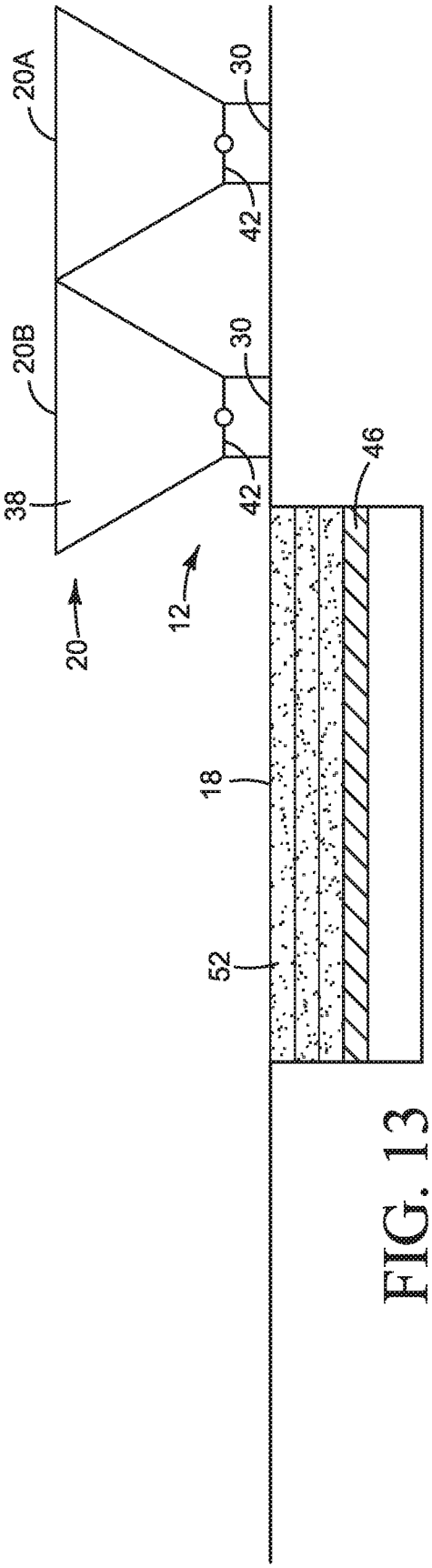

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FIG. 13

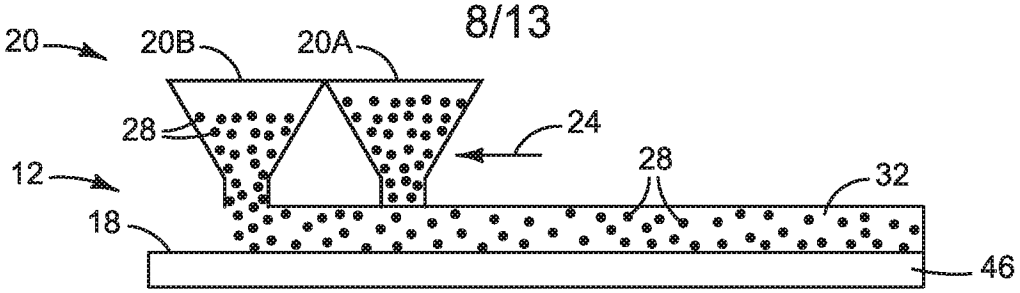


FIG. 14

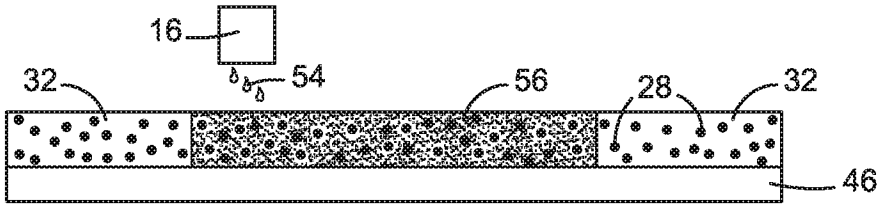


FIG. 15

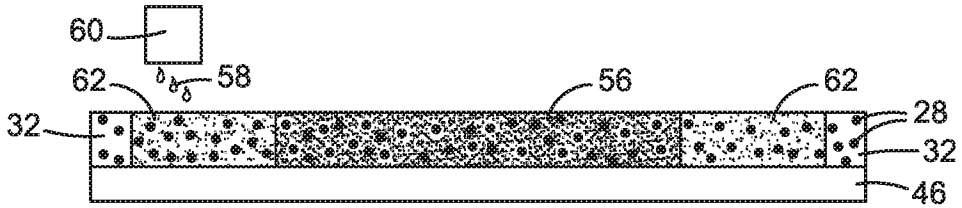


FIG. 16

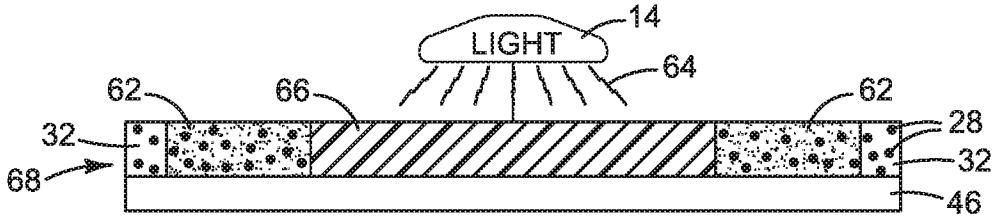


FIG. 17

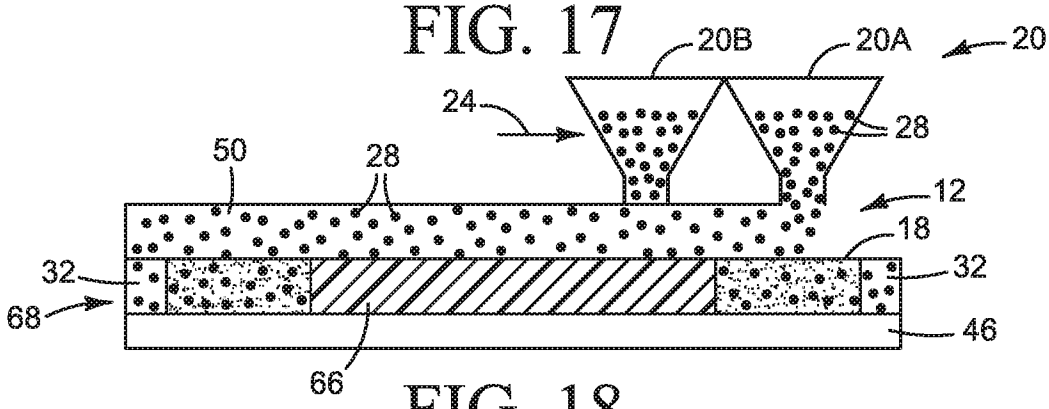


FIG. 18

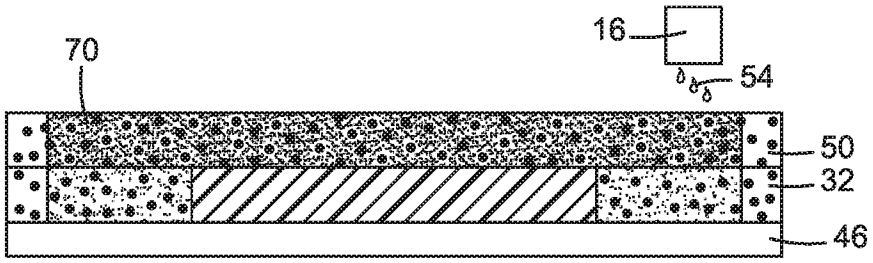


FIG. 19

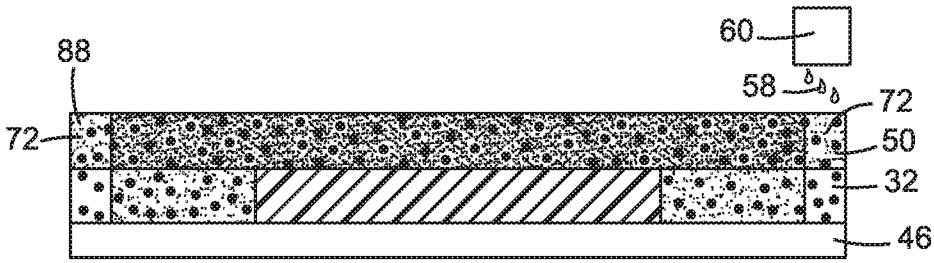


FIG. 20

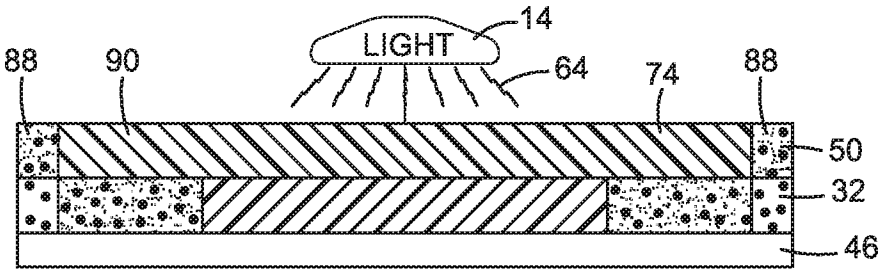


FIG. 21

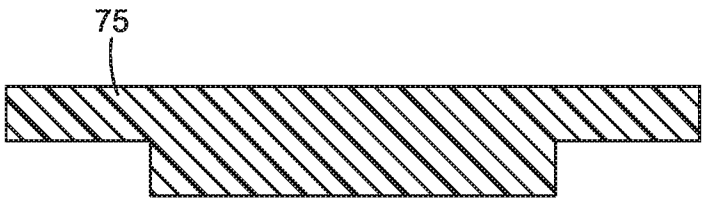


FIG. 22

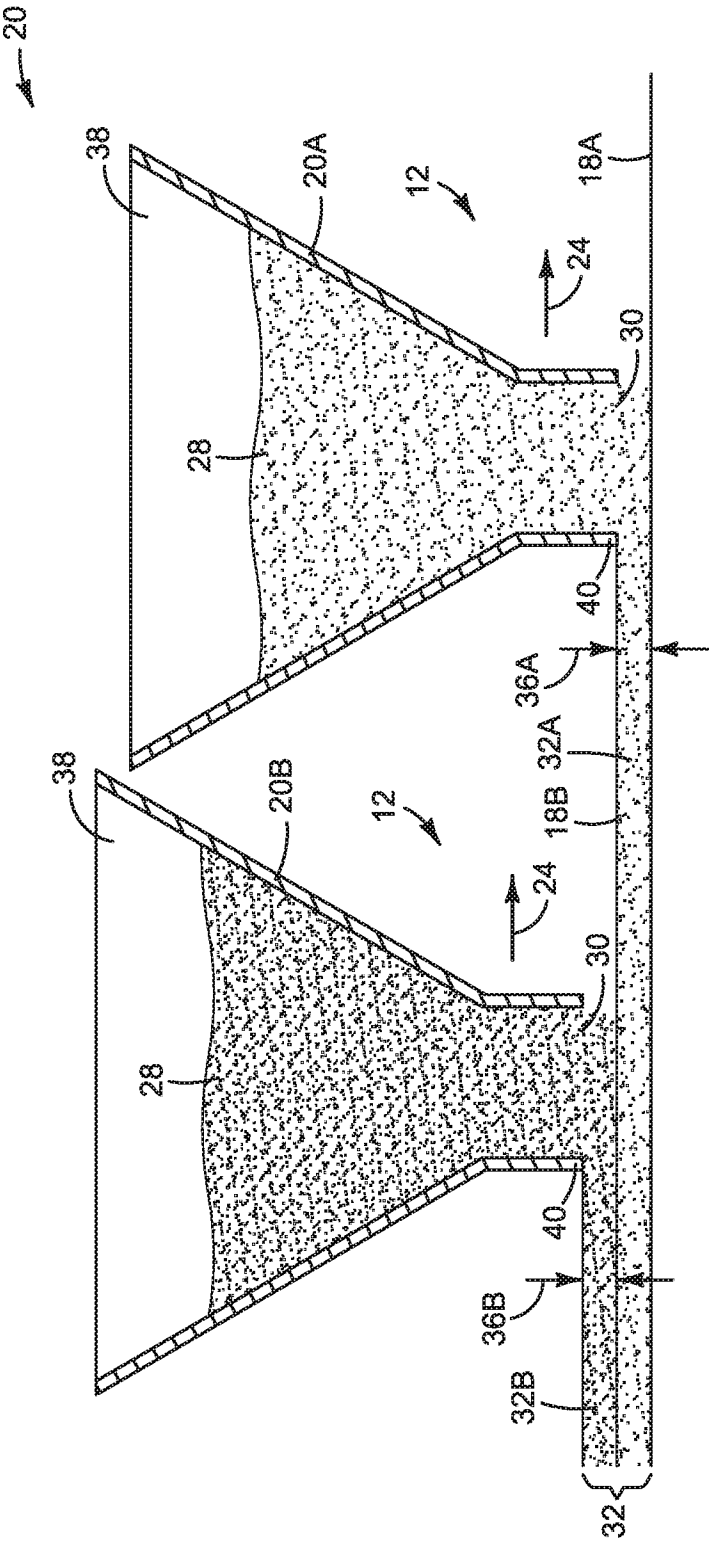

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FIG. 23

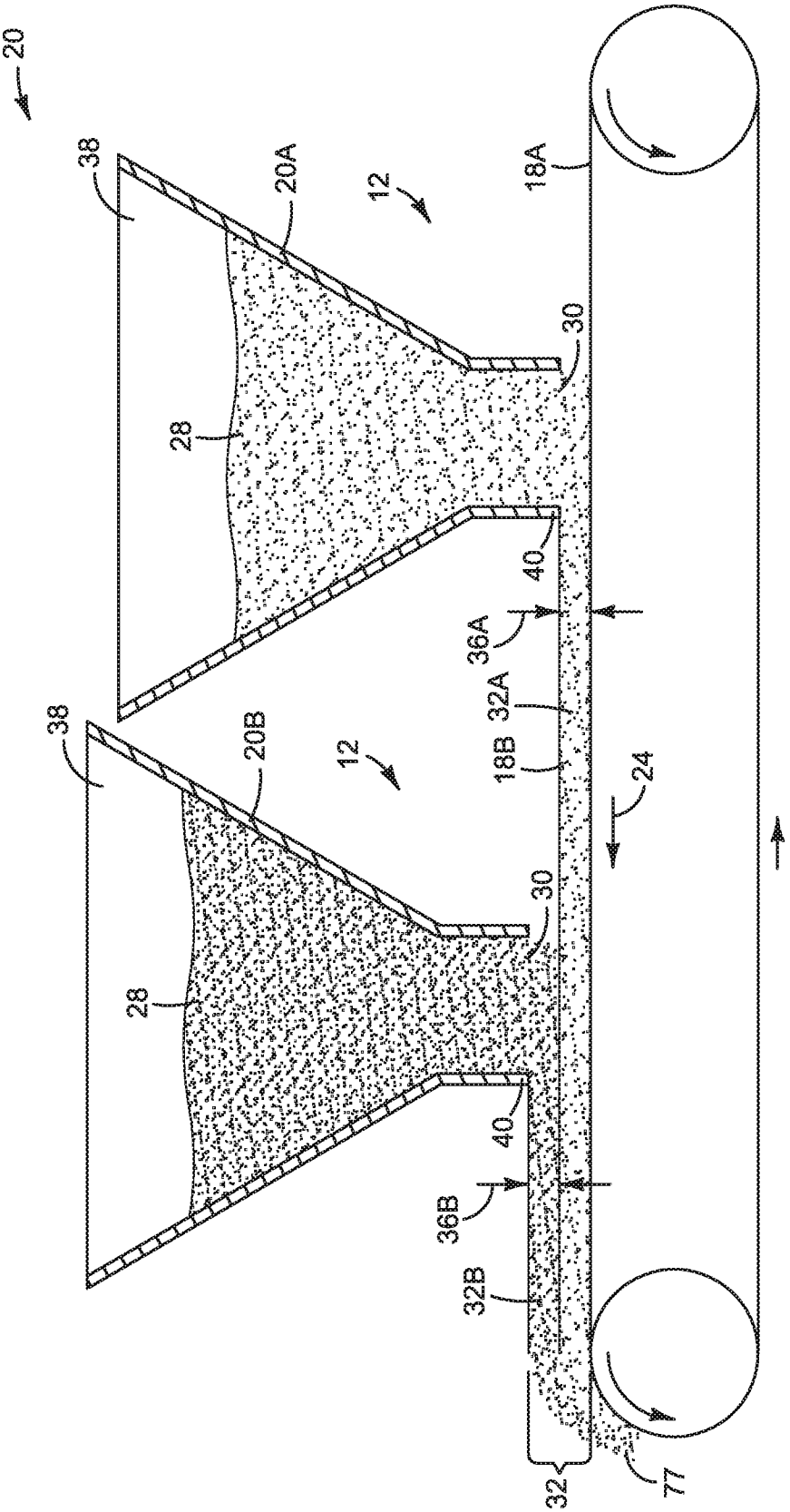

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FIG. 24

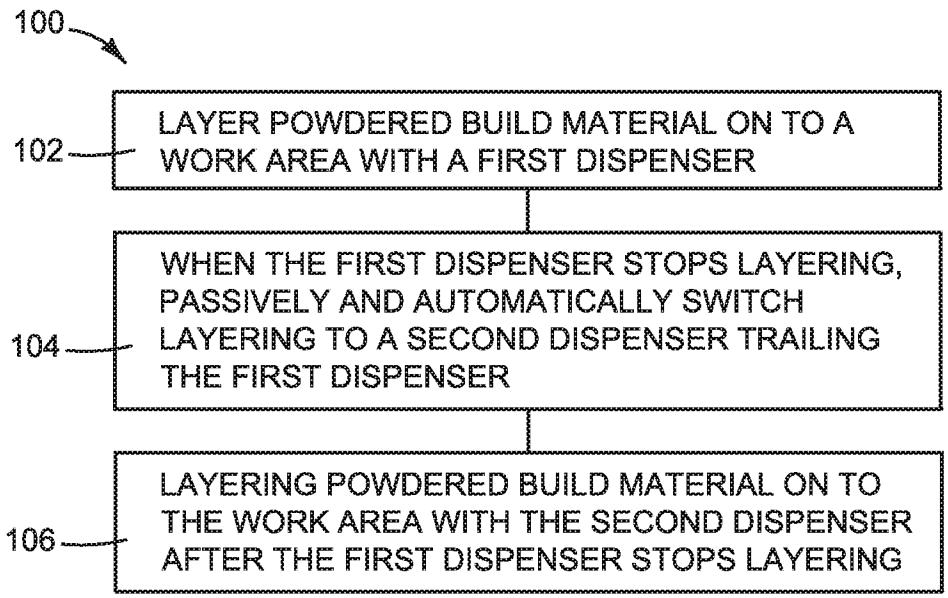

100
LAYER POWDERED BUILD MATERIAL ON TO A WORK AREA WITH A FIRST DISPENSER
102
WHEN THE FIRST DISPENSER STOPS LAYERING, PASSIVELY AND AUTOMATICALLY SWITCH LAYERING TO A SECOND DISPENSER TRAILING THE FIRST DISPENSER
104
LAYERING POWDERED BUILD MATERIAL ON TO THE WORK AREA WITH THE SECOND DISPENSER AFTER THE FIRST DISPENSER STOPS LAYERING
106

FIG. 25

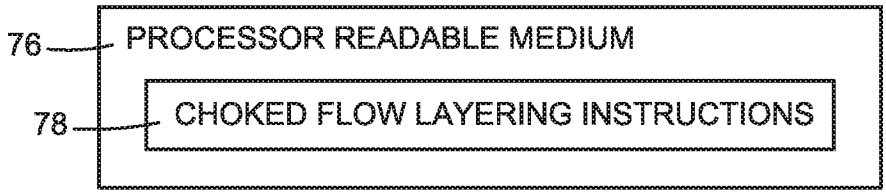

76
PROCESSOR READABLE MEDIUM
78
CHOKED FLOW LAYERING INSTRUCTIONS

FIG. 26

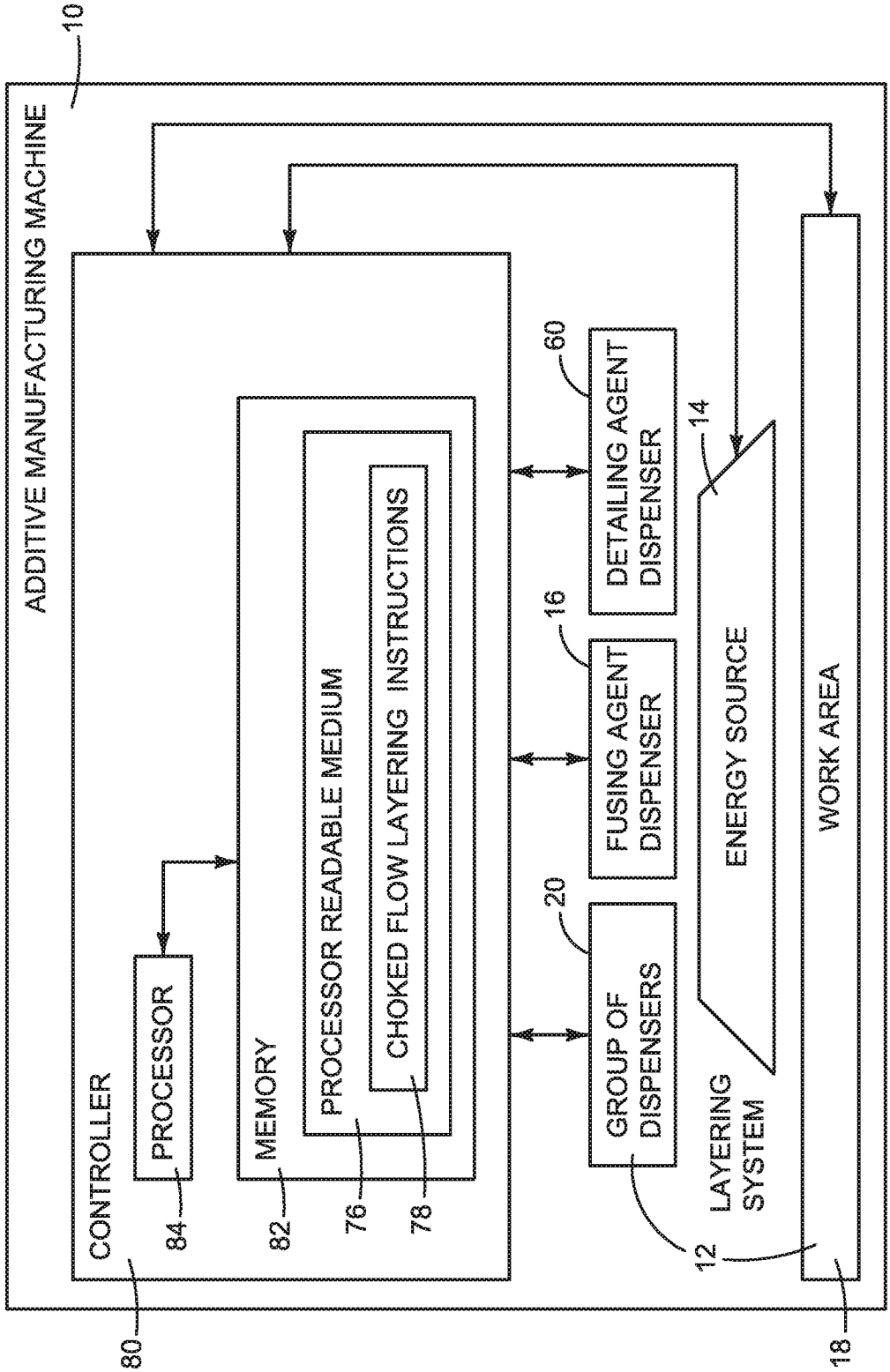

ADDITIVE MANUFACTURING MACHINE
10
CONTROLLER
PROCESSOR
84
MEMORY
82
PROCESSOR READABLE MEDIUM
76
CHOKED FLOW LAYERING INSTRUCTIONS
78
80
GROUP OF DISPENSERS
20
FUSING AGENT DISPENSER
16
DETAILING AGENT DISPENSER
60
ENERGY SOURCE
14
LAYERING SYSTEM
12
WORK AREA
18

FIG. 27

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/014570

A. CLASSIFICATION OF SUBJECT MATTER

B29C 67/00(2006.01)i, B22F 3/105(2006.01)i, B33Y 30/00(2015.01)i, B33Y 50/02(2015.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B29C 67/00; B22F 7/02; B29C 41/02; B22F 3/105; B33Y 30/00; B33Y 50/02

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords:additive manufacturing, dispenser, gap, movable, switch

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014-208741 A1 (CMET INC.) 31 December 2014 See abstract; paragraphs [0024],[0025]; claims 1, 3, 5, 9, 16, 17; and figures 1-4.	1-15
Y	JP 2006-205456 A (TOYOTA MOTOR CORP.) 10 August 2006 See abstract; paragraphs [0014]-[0018],[0021],[0022]; and figures 1-4.	1-15
A	US 6998087 B1 (HANSON, JEFFERY J. et al.) 14 February 2006 See abstract.	1-15
A	WO 2015-106832 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.) 23 July 2015 See abstract; and figure 1.	1-15
A	WO 2015-196149 A1 (VELO3D, INC.) 23 December 2015 See abstract; and figure 24.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 October 2016 (20.10.2016)	**20 October 2016 (20.10.2016)**

Name and mailing address of the ISA/KR
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Facsimile No. +82-42-481-8578

Authorized officer
KANG, Min Jeong
Telephone No. +82-42-481-8131

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2016/014570

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		JP 2015-009509 A	19/01/2015
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JP 2006-205456 A	10/08/2006	None	
US 6998087 B1	14/02/2006	US 6749414 B1	15/06/2004
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		US 2015-0367447 A1	24/12/2015
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		US 9254535 B2	09/02/2016
		US 9346127 B2	24/05/2016