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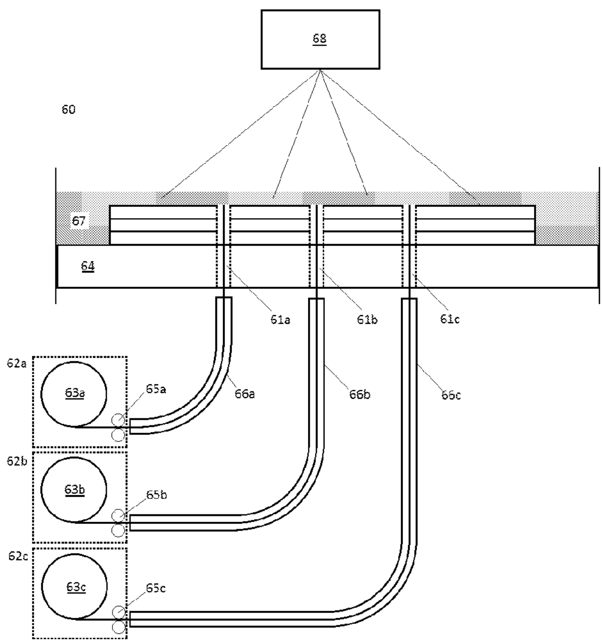

Fig. 6

(57) Abstract: A method and additive manufacturing system for producing a three dimensional object. The system comprising a build material arrangement unit to deposit predetermined arrangements of build material comprising apertures that form a conduit. A thread feed unit is arranged to move a thread though the conduit to form an object comprising a thread embedded within.

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METHODS AND SYSTEMS FOR PRODUCING THREE DIMENSIONAL OBJECTS

TECHNICAL FIELD

The present disclosure relates generally to methods and systems for producing three dimensional objects, and more specifically to methods and systems for the additive manufacturing of three dimensional objects comprising one or more threads.

BACKGROUND

Additive manufacturing is a term used to refer to a range of technologies whereby objects are formed by adding material. An exemplary subset of additive manufacturing includes 3D printing, whereby material is sequentially arranged to form a 3D object. There is a desire to improve the functionality of the objects that can be produced by additive manufacturing processes. In particular, for conductive pathways to be introduced into such objects to allow electronics or other objects to be integrated into the object. That way, functional objects can be achieved in a single manufacturing process.

An example of an additive manufacturing system capable of introducing conductive pathways is the Voxel8 system. The Voxel8 system uses fused deposition modelling to manufacture a 3D object. The Voxel8 system deposits silver ‘ink’ as a conductor into the manufactured 3D object. The Voxel8 system can deliver two materials; a thermoplastic build material and a conductive silver ‘ink’. The Voxel8 system is capable of depositing both materials within a single printed layer. However, to produce conductive paths in the Z-direction (i.e. parallel to the build direction), a large number of individual layers of ink need to be printed on top of each other. This results in a fragmented and inconsistent pathway, which causes increased resistance and hotspots that may lead to failure of the conductive path. This in turn limits the functionality of the objects that can be produced using the Voxel8 system. For example, use in electronic applications may be restricted to low powered electronic components only.

An alternative example of an additive manufacturing system that is capable of introducing conductive pathways comprises an ultrasonic roller mechanism that can be used to embed copper wire into the external face of fused deposition moulded (FDM) component. This process requires the user to remove a FDM 3D object from the 3D printer and mount the component in a precise configuration in a secondary machine. The secondary machine then presses a copper wire into an outer surface of the 3D object.

This technique can only press copper wire into an outwardly facing, even, and accessible component face. Thus, it is incompatible with small features, overhangs, or other shapes that would interfere with the application of the copper wire. The application of the copper wire requires the 3D print process to be stopped and the component removed from 3D printer. Application of the copper wires then takes place on a second machine. After this, the component is loaded back onto the FDM 3D printer and a second 3D printed object is printed onto the first 3D printed object. Thus this process is time consuming and requires multiple machines. Furthermore, this encapsulation technique can only apply copper wire in the X-Y plane (i.e. perpendicular to the build direction and parallel to the build plate), it cannot apply copper wire through the Z direction (i.e. parallel to the build direction).

In spite of the effort already invested in the development of methods and systems for improving the functionality of objects produced by additive manufacturing, further improvements are desirable.

SUMMARY

The present disclosure provides a method of producing a three dimensional object. The method comprises arranging build material in at least one predetermined arrangement onto a prior arrangement of build material or onto a build plate. The at least one predetermined arrangement comprises at least one aperture in the build material, the aperture cooperating with at least one aperture in the prior arrangement of build material and/or at least one aperture in the build plate, to form at least one conduit. The method also comprises moving at least one thread through the at least one conduit to at least partially occupy the aperture in the arranged predetermined arrangement of build material.

The present disclosure provides an additive manufacturing system comprising: at least one controller; at least one build plate; at least one build material arrangement unit, the build material arrangement unit controlled by the at least one controller to arrange build material into a predetermined arrangement onto the build plate or a prior arrangement of build material. The predetermined arrangement comprises an aperture to cooperate with at least one aperture in the prior arrangement of build material and/or at least one aperture in the build plate, to form at least one conduit. The at least one thread feed unit is controlled by the at least one controller and configured to move a thread through the conduit.

In embodiments, the build plate comprises at least one aperture which is comprised as part of the conduit, and the at least one thread feed unit is configured to move a thread through the aperture in the build plate and the aperture in a predetermined arrangement.

In embodiments, at least one conduit through which at least one thread may be moved may comprised only of apertures in predetermined arrangements of build material.

The present disclosure may provide an additive manufacturing system and method for embedding threads in an object made by additive manufacture. Embodiments of the present disclosure may work with a range of different additive manufacturing technologies and threads. Embodiments may also embed threads in X, Y and Z directions through the object without the need for stopping the process or using additional systems. Thus, embodiments of the present disclosure may also provide the ability to create objects with increased functionality without significantly increasing the production time.

Furthermore, in embodiments of the present disclosure, the thread may also extend in the Z direction (parallel to the build direction) as a single solid entity and not as a series of layers arranged to connect in the Z direction.

In embodiments, the method for producing a three dimensional object may be repeated to form the three dimensional object comprising at least one conduit and at least one thread within the at least one conduit. In embodiments, the predetermined arrangement of build material and build plate may comprise two or more apertures to form two or more conduits, and a thread may be moved through each conduit.

In embodiments build material may surround one or more apertures around the entire perimeter of the one or more apertures.

In embodiments, the at least one thread is moved through at least one conduit by moving the thread in its axial direction. The at least one thread may be moved in its axial direction by pushing the thread to slide it through the conduit, for example. In embodiments, the at least one thread may be moved through the at least one conduit after each arrangement of build material is arranged into a predetermined arrangement.

In embodiments, the at least one thread may be moved through the at least one conduit by a distance equal to the length the conduit increases with each arrangement of build material into a predetermined arrangement. This may further improve the ease of moving the thread by limiting the ingress of build materials into the conduit. In embodiments, the at least one thread may be moved through the at least one conduit at the same rate as the conduit increases in length.

In embodiments, arranging build material in a predetermined arrangement may comprise arranging build material in a planar layer, or depositing build material as part of a continuous process. In embodiments, build material may be arranged in a first predetermined arrangement onto a build plate, then further build material may be arranged in a second predetermined arrangement onto the first predetermined arrangement.

In embodiments, moving the at least one thread comprises determining the length of the conduit that is unoccupied by the thread and moving the thread by a distance that corresponds to the determined unoccupied length. This may further improve the movement of the thread through the conduit, in particular when the conduit extends in a direction that is not parallel to the build direction.

In embodiments, a method for producing a three dimensional object may comprise any of the following steps: determining at least one conduit path through a three dimensional shape that corresponds to a three dimensional object; creating instructions to arrange build material in a plurality of predetermined arrangements based on the three dimensional shape and the at least one determined conduit path, where apertures in the predetermined arrangements correspond to the at least one determined path conduit path; creating instructions to control the moving at least one thread into the conduit; wherein arranging build material and/or moving at least one thread in a predetermined arrangement comprises executing the instructions. In embodiments an additive manufacturing system may comprise or be associated with software executable to perform these steps.

In embodiments, moving the at least one thread may comprise pushing the thread through the conduit, and optionally, wherein the thread may be pushed by actuating a stepper motor.

In embodiments, moving the at least one thread may comprise one or more of the application of oscillatory movement to the at least one thread; vibration of the at least one thread; and/or flow of a fluid through the at least one conduit. In embodiments, a method may comprise forming a conduit that comprises an entrance portion where the cross sectional area of the entrance portion is greater than the cross sectional area of the rest of the conduit. An entrance portion may be considered to be the portion of conduit formed in the predetermined arrangements of build materials closest to the build plate.

In embodiments, one or more predetermined arrangements may comprise at least one component aperture sized to receive at least part of one component. In embodiments, a component may be placed within the at least one component aperture. In embodiments, at least one thread may be moved through at least one conduit, to make a connection with the at least one component placed within the at least one component aperture. In embodiments, the component may comprise a functional element. In embodiments, the component may comprise a receiving portion to engage with a thread.

In embodiments, a portion of the conduit may be surrounded by a sacrificial portion of arranged build material to be removed from the three dimensional object. In embodiments, a sacrificial portion may be a guide stem, comprising a conduit to guide a thread from an aperture in the build plate to an aperture in a surface of the object not facing the aperture of the build plate, or to guide a thread from an exit of a conduit in an object, to an entrance of another conduit in the same or an adjacent object.

In embodiments, the thread may have a circular cross section. In embodiments, the thread may be electrically conductive. In embodiments, the thread may be thermally conductive. In embodiments, the thread may comprise a shape memory alloy. In embodiments, the thread may comprise a data transmission element. In embodiments, the thread may comprise a structural element. In embodiments, the thread may comprise one or more functional elements. In embodiments, the thread may comprise a circuit, or part of a circuit.

In embodiments, the thread may comprise a metal or metal alloy, optionally wherein metal may comprise at least one of: copper; gold; silver; aluminium; or steel.

In embodiments, arranging build material may comprise using one of: fused deposition modelling; stereolithography; digital light processing; laminated object manufacturing; or powder deposition. In embodiments, at least one build material arrangement unit may comprise one of: fused deposition modelling apparatus; stereolithography apparatus; digital light processing apparatus; or powder fusing apparatus.

In embodiments, the three dimensional object may undergo a finishing process step, optionally the finishing processing step may comprise placement in a UV chamber.

In embodiments, one or more conduits may have a cross section having the same proportions as the cross section of the thread.

In embodiments, at least one thread feed unit may be arranged to move a thread through an aperture in the build plate. In embodiments, the thread feed unit may comprise a motor controlled by the controller, optionally the motor may be a stepper motor. In embodiments, the thread feed unit may feed thread from a spool.

In embodiments, the build plate may be configured to move upwards as build material is arranged, or alternatively, wherein the build plate may be configured to move downwards as build material is arranged.

In embodiments, the additive manufacturing system may comprise a thread feed assistance means. In embodiments, a method may comprise using a thread feed assistance means, when moving at least one thread through a conduit.

In embodiments, the thread feed assistance means may comprise any of: a conduit clearing device, a thread vibration means; a thread friction reducing means, a thread heating means or a thread cooling means.

In embodiments, a conduit clearing device may comprise apparatus (e.g. a pump) for the application of fluid pressure to the at least one conduit, to clear build material from the conduit.

In embodiments, thread vibration means may comprise an ultrasound emitter and/or an actuator for vibrating the thread. In embodiments, the thread friction reducing means may comprise any one of a lubricating substance, a thread end cap and/or a conduit insert.

The present disclosure provides a method for modifying a digital record of a three dimensional shape comprising: receiving a digital record of a three dimensional shape; receiving a start and an end point for at least one conduit in the three dimensional shape; and determining a conduit path for the at least one conduit in the three dimensional shape based on the start and end points and the digital record of the three dimensional shape; modifying the digital record to comprise the determined conduit path. The modified digital record may be used by systems and methods for producing three dimensional objects comprising a thread embedded within, as described herein.

In embodiments, a conduit path may be determined to avoid objects or voids in the three dimensional shape. In embodiments, a conduit path may be determined to minimise conduit length and/or to maximise the smallest radii of curvature of the conduit path.

In embodiments, a method for modifying a digital record may comprise any of: receiving information of the at least one thread to be inserted into the at least one conduit path; determining a minimum radius of the conduit path based on the received information of the at least one thread; and/or determining conduit path so that the radii of the conduit path are not smaller than the determined minimum radius. In embodiments, received information of the at least one thread may comprise any of: thread material data; thread cross section data; or thread stiffness data.

In embodiments, the conduit path may comprise an entrance portion that corresponds to an entrance portion of at least one conduit of the three dimensional object, where the cross sectional area of the entrance portion is larger than the cross sectional area of the rest of the at least one conduit.

In embodiments, the conduit path of the three dimensional record may comprise a guide stem portion that corresponds to a guide stem portion of the three dimensional object. The guide stem portion may connect to a surface of the object not facing the build plate aperture. The guide stem portion may be a sacrificial portion that can be removed once the object has been formed. In embodiments, the conduit path may comprise a conduit cross section that is proportional to the thread cross section.

In embodiments, a method for modifying a digital record of a three dimensional shape may comprise generating instructions for control of an additive manufacturing system for the arrangement of build material into a plurality of predetermined arrangements, to form a three dimensional shape comprising the at least one conduit. The generated instructions may be derived from the modified digital record.

In embodiments, a method for modifying a digital record of a three dimensional shape may comprise generating instructions for control of an additive manufacturing system for controlling movement of a thread into the at least one conduit. The generated instructions may be derived from the modified digital record.

In an aspect, there is a computer software which, when executed, is arranged to perform a method as described herein. In a further aspect, there is a storage medium comprising the computer software.

In an aspect, there is an additive manufacturing system configured to execute any method described herein.

In an aspect, there is a three dimensional product comprising a conduit with a thread embedded therein produced by any method described herein or with any additive manufacturing system described herein. In an aspect, there is a thread feed unit and built plate comprising at least one aperture that may be combined with an additive manufacturing unit to form an additive manufacturing system of the disclosure.

In an aspect, there is a three dimensional object printing kit comprising any additive manufacturing system as described herein with a thread and a build material.

In an aspect, there is the use of a method or an additive manufacturing system as described herein for producing a three dimensional object comprising a thread embedded within the object.

The preceding summary is provided for purposes of summarizing some embodiments to provide a basic understanding of aspects of the subject matter described herein. Accordingly, the above-described features are merely examples and should not be construed to narrow the scope or spirit of the subject matter described herein in any way. Moreover, the above and/or proceeding embodiments may be combined in any suitable combination to provide further embodiments. Other features, aspects, and advantages of the subject matter described herein will become apparent from the following Detailed Description, Figures, and Claims.

BRIEF DESCRIPTION OF THE FIGURES

Aspects, features and advantages of embodiments of the present disclosure will become apparent from the following description of embodiments in reference to the appended drawings in which like numerals denote like elements.

Figure 1 A-D show steps of an embodiment method for producing a three dimensional object.
Figure 2 is a diagram showing an embodiment of the present disclosure.
Figure 3 is a diagram showing an embodiment of the present disclosure.
Figure 4 is a diagram showing an embodiment of the present disclosure.
Figure 5 A and B are diagrams showing embodiment systems of the present disclosure.
Figure 6 is a diagram showing an embodiment system of the present disclosure.
Figure 7 is a diagram showing steps of an embodiment of the present disclosure.
Figure 8 is a flow chart showing steps of an embodiment method of the present disclosure.

DETAILED DESCRIPTION

Before describing several embodiments of the method and additive manufacturing system, it is to be understood that the apparatus and methods are not limited to the details of construction or process steps set forth in the following description. It will be apparent to those skilled in the art having the benefit of the present disclosure that the apparatus and methods are capable of other embodiments and of being practiced or being carried out in various ways.

As used herein, the term "**producing**" in reference to a three dimensional object may refer to the making, forming, manufacturing etc. of a three dimensional object. This may specifically refer to the producing of an object by additive manufacturing, including 3D printing.

As used herein, the term “**three dimensional object**” may comprise any object, component product or item. The object may be formed from a build material which may be arranged as a plurality of predetermined arrangements to form the three dimensional object. For example, a three dimensional object may be a product produced by an additive manufacturing process.

As used herein, the term “**build material**” may refer to the substance from which a three dimensional object is produced. The build material may be converted from a feedstock form of the build material into an arranged form of the build material as part of arranging the build material into the predetermined arrangements that form a three dimensional object. Non-limiting examples of conversion of a build material may comprise polymerisation, sintering, curing, binding with a binding agent, laminating, crystallising, placing, melting, freezing etc. or any combination thereof.

As used herein, the term “**predetermined arrangement**” may refer to an arrangement of build material that is arranged to form part of a three dimensional object. In a non-limiting example, where the three dimensional object is formed from a plurality of layers of arranged build material, a predetermined arrangement may comprise one or more a layers of build material that form part of a three dimensional object. The predetermined arrangement may, in a non-limiting example, be determined as a layer of, or section through a three dimensional shape corresponding to the three dimensional object to be formed.

As used herein, the term "**prior arrangement of build material**" may refer to one or more predetermined arrangements of build material that have been placed onto a build plate. Further predetermined arrangements may be deposited onto the prior arrangement(s) to build the three dimensional object. In a non-limiting example, where the three dimensional object comprises layers of arranged build material, the prior arrangement of build material may comprise the layers already placed. In a non-limiting example, where the three dimensional object is produced by a continuous deposition process, the prior arrangement of build material comprises the build material already arranged as part of producing a three dimensional object.

As used herein, the term "**build plate**" may refer to the stage, platform, surface or volume to which build material is arranged to form the three dimensional object.

As used herein, the term "**aperture**" in reference to a predetermined arrangement or build plate may refer to a hole, gap, channel or spacing in a predetermined arrangement or build plate. In particular, the aperture may be surrounded partially or along the entirety of its perimeter or circumference by build material of the predetermined arrangement, or by the material of the build plate. The aperture may be suitable sized for a thread to be moved through.

As used herein, the term "**conduit**" may refer to a channel, tube or passage in the arranged build material of a three dimensional object. A conduit may be comprised from a plurality of apertures. The plurality of apertures forming a conduit may be apertures in arrangements of build material. The conduit may additionally be comprised from an aperture in a build plate.

As used herein, the term "**thread**" may refer to any elongate material capable of being moved through a conduit. Non-limiting examples of thread include, any strand, fibrous or wire material, optical fibre/cable or structural fibre etc. The thread may also comprise a composite of different thread materials, e.g. a ribbon of wires, or a laminated wire.

As used herein, the term "**conduit path**" may refer to the path or route the conduit takes through a three dimensional object or shape.

As used herein, the term "**instructions**" may include, amongst others, numerical code, parameters or variables. The instructions may be executable by a controller for example. Non limiting examples include G-code or any other numerical code programming language.

As used herein, the term "**entrance portion**" may refer to a portion of a conduit in a three dimensional object, shape or arrangement of build material that is positioned towards the build material. The entrance portion may be part of a conduit that first receives a thread from the build plate aperture. In a non-limiting embodiment, the entrance portion may be a portion of conduit that guides the thread into the conduit.

As used herein, the term "**functional element**" may refer to elements for performing a complex function. A complex function may be considered to be any function of greater complexity than carrying a signal or current. For example, a complex function may comprise processing data, emitting light, converting detected phenomenon into a signal, or receiving a signal and generating an output, changing a signal or current. Examples of a functional element may include an LED, an actuator, a sensor, an antenna, a receiver or an electronic component such as a transistor, resistor, amplifier, transformer, inductor, capacitor etc.

As used herein, the term "**component**", in reference to a component aperture may refer to a component that can be inserted into a component aperture. This may include, amongst others, electronic components, e.g. circuit boards, LEDs, actuators or sensors.

As used herein, the term "**sacrificial portion**" may for example, refer to part of a three dimensional object that may be removed as part of a finishing step, for the three dimensional object to be ready for its final intended use.

As used herein, the term "**controller**" may refer to any apparatus that performs a control function. The controller may comprise processing means. The processing means may comprise a processor or other electrical circuitry.

As used herein, the term "**build material arrangement unit**" may refer to apparatus for forming or arranging build material into predetermined arrangements. Non-limiting examples include stereolithography apparatus; digital light processing apparatus; or powder fusing apparatus.

As used herein, the term "**feed mechanism**" or "**thread feed unit**" may refer to means for moving thread through an aperture.

As used herein, the term "**digital record**" may, in reference to a three dimensional shape, be electronically stored data or code that contains information for a shape, surface or volume. Non limiting examples include volume or surface files (e.g. STL, AMF, X3D, Wavefront OBJ and PLY file types), arrays of voxel data, stacks of image files (e.g. JPEG, RAW, DICOM) or any other data form suitable for use in additive manufacturing.

Referring to figure 1, A to D, an embodiment method for producing a three dimensional object is shown. The method comprises arranging a build material into a predetermined arrangement 2. Arranging the build material may, for example, comprise the positioning of build material by a computer controlled extrusion element into the predetermined arrangement. Similarly arranging the build material may be by deposition from a printer head, by polymerisation with a computer controlled radiation source or by any other known additive manufacturing technique. The predetermined arrangement may be arranged onto a build plate 8 as shown in figure 1A, or it may be arranged onto another prior predetermined arrangement 4 as shown in figure 1C. The predetermined arrangement 2, and prior predetermined arrangements 4 may comprise part of a three dimensional object, such that a three dimensional object may be formed from a plurality of predetermined arrangements. The shape and location of the arrangements may be determined based on a three dimensional shape which corresponds to the three dimensional object to be formed. The three dimensional shape may be a digital record of the three dimensional object formed therefrom.

The predetermined arrangement 2 comprises one or more apertures 10 within the build material of the predetermined arrangement 2. The aperture cooperates with an aperture in the build plate 11 (as shown in figure 1A) or with an aperture of another prior predetermined arrangement 13 (as shown in figure 1C). Cooperation of two or more apertures forms a conduit 12. The apertures may cooperate by being suitably sized, located and/or orientated to form the conduit 12 from two or more apertures 10, 11, 13, where a thread may be moved through the conduit. The apertures may be partially offset from each other or deposited at varying angles so that a conduit may take any path through the object.

The method comprises moving a thread 14 through the conduit 12 to at least partially occupy the portion of the conduit formed by aperture 10 of the predetermined arrangement 2, as shown in figures 1B and 1D. The thread may be moved to at least partially occupy the portion of the conduit formed by aperture 10 of the predetermined arrangement 2. The thread may be moved after or during the arrangement of the build material that comprises the predetermined arrangement 2. For example, prior to arranging the predetermined arrangement 2, the thread may at least partially be positioned within an aperture 11 of the build plate 8 or an aperture 13 of a prior predetermined arrangement of build material 4. Once a predetermined arrangement 2 has been arranged or partly arranged, the thread may be moved through the conduit 12. In an alternative non-limiting example, the thread may be moved through the conduit by the entire length of the conduit or a portion of conduit length following arrangement of predetermined arrangement 2, or may be moved after any number of arrangements of build material. Thus, the present invention comprises forming a conduit by arranging the build material, and moving a thread through the conduit.

The method steps shown in figures 1C and 1D may be repeated to produce a three dimensional object. As each iteration of the steps of 1C and 1D are performed, the predetermined arrangement of build material 2 may comprise some or all of the prior predetermined arrangements 4 of build material in the subsequent iteration. The above described embodiment refers to the predetermined arrangements of build material sequentially arranged as layers. However, the present disclosure also envisions the predetermined arrangements being arranged in a continual deposition process.

The above described embodiment refers to the conduit comprising at least one aperture of the build plate. However, the disclosure need not be limited to such. For example, in embodiments, at least one conduit through which at least one thread may be moved may be comprised only of apertures in predetermined arrangements of build material. For example, the one or more predetermined arrangements may form a conduit having an entrance on a surface other than the surface facing the build plate. A thread may be moved through this conduit by feeding directly through the entrance rather than via an aperture in the build plate. In embodiments, an object may be formed having any combination of threads that have passed through apertures of the build plate and threads that have not passed through apertures of the build plate.

Moving the thread through the conduit may refer to moving the thread along the threads axial direction and within the conduit. Moving the thread through the conduit may comprise feeding or pushing the thread. The thread may pass through the build plate and any number of prior predetermined arrangements of build material.

In embodiments, the moving of one or more threads may be assisted by the additional application of oscillatory movement to the at least one thread, vibration of the at least one thread or flow of a fluid through the at least one conduit. In embodiments, moving the at least one thread may comprise pushing the thread through the conduit, and optionally, the pushing of the at least one thread may be actuated by a stepper motor.

In embodiments, moving the at least one thread may comprise determining the length of the conduit that is unoccupied by the thread and moving the thread by a distance that corresponds to the determined unoccupied length. Where the aperture is aligned non-parallel to the build direction (Z direction) the distance may, for example, be approximated as a straight line. The length of the straight line may be derived based on the angle and the thickness of the predetermined layer. Alternatively, the distance may be known or derived from a digital record of the three dimensional shape.

Referring to figure 2, a three dimensional object 20 or part thereof is shown on a build plate 8. The three dimensional object 20 may be produced by any of the methods or systems described herein. The three dimensional object 20 comprises a plurality of arrangements of build material 4. Each arrangement of build material 4 shown comprises an aperture, which together, form a conduit 12, along with an aperture 11 of the build plate 8. The apertures in the plurality of arrangements 4 within a short distance from the build plate 8 are sized to form an entrance portion 21 from the build plate 8 to the conduit in the build material. In the embodiment of figure 2, the apertures of the arrangements of build material 4 that are comprised as part of the entrance portion 21 of the conduit 12 decrease in cross sectional area as the distance from the build plate 8 increases, i.e. they form an internal taper or funnel from the build plate. As the tip of thread 8 moves from the aperture 11 in the build plate 8, the entrance portion may guide the thread into the conduit. The entrance portion may improve the tolerance when co-locating the aperture of the object with the aperture of the build plate 11. The entrance portion 21 may be inwardly tapered, funnel shaped or otherwise shaped with a cross sectional area that decreases away from the build plate 8. This may be particularly beneficial when the tip of the conduit is being moved from the aperture of build plate 8 into the first arrangement of build material arranged on the build plate 8.

In some situations an object to be formed may require two or more conduits with entrances at spacings different to the spacings of the build plate apertures. In embodiments, a sacrificial portion comprising a plurality of predetermined layers may be arranged onto the build plate first. The layers of the sacrificial portion may comprise conduits having entrances that align with apertures in the build plate, and exits that align with the entrances to the conduits of the object. The object may then be arranged on top of the sacrificial portion. In this embodiment, the sacrificial portion may then be removed from the formed object. A sacrificial portion may also be used in embodiments where the increased width of entrance portions 21 prevents two adjacent conduits being formed close together at the build plate.

In embodiments, one or more apertures of the build plate may comprise an extension or projection that extends from the build plate in the build direction. The extension may function to guide the thread into the conduit of the object. The first predetermined arrangement of build material that is placed against the build plate may be arranged so that the build material that forms the walls of the first aperture is placed around the extension. This may further reduce the likelihood of a thread buckling as the extension guides the thread into the first aperture within the object.

In embodiments, the extension may be in the form of a tube through which the thread is passed, or it may be in the form of a tubular plug which is pushed through the aperture. In embodiments, the extension may extend from the build plate between 0.5 mm and 10 mm, for example. In embodiments, the first predetermined arrangement of build material may be arranged against the build plate, the extension may then be positioned by moving the extension through the aperture of the build plate, into the aperture of the first predetermined arrangement of build material. This may be performed manually or automatically by the system. In a further example, the extension may be integrated as part of a plug that can be inserted into an aperture of the build plate so that the extension projects from the build plate in the build direction. The insertion of the plug may be actuated, for example the plug may be attached to a plate parallel to the build plate. Once one or more predetermined arrangements have been arranged against the build plate, the plug and plate may be moved towards the build plate so that the extension passes through an aperture of the build plate and into an aperture of the first predetermined arrangement. A thread may then be fed though the plug, the extension and into the first aperture of the predetermined arrangement.

Referring to figure 3, a three dimensional object 30 or a part thereof is shown on a build plate 8. The three dimensional object 30 may be produced by any of the methods or systems described herein. The three dimensional object 30 may comprise a plurality of arrangements of build material 4. In the embodiment of figure 3, the arrangements 4 comprise a plurality of apertures to form a plurality of conduits 34 a,b,c for threads 38 a,b,c, shown by the region 31. Region 32 shows a plurality of apertures shaped to receive a component 37. In figure 3, the component apertures form a recess or void 36 shaped to accommodate a component 37. The component 37 may be placed into the recess 36 and subsequent arrangements of build material placed to enclose the component 36 in build material. The recess 36 allows connection from threads 38 a,b,c in their respective conduits 34 a,b,c. The component 37 may comprise receiving portions 39, 35 that allow the threads 38 a,b,c to connect to the component 37. For example, the connection may be, amongst others, electrical or optical.

The receiving portions 39, 35 may comprise elements that form a secure mechanical connection upon receiving a thread, or may form a connection upon application of radiation e.g. via a laser, ultrasound, heat/IR source or UV source. The receiving element may comprise a funnel shaped portion to direct the thread into the receiving elements. The receiving element may comprise a material that contracts or melts to form a permanent connection upon the application of heat or radiation. The connection element 39 may allow the thread to terminate at the component, or the element 35 may allow the thread 38c to continue through the connection element 39, whilst still making a connection to the component. This may allow multiple components to be interconnected in a three dimensional object. For example, a connection element may comprise a conductive loop through which the thread passes. The conductive loop may optionally shrink to form a mechanical connection with the thread if radiation is applied. This may be performed as part of a finishing step, for example. These embodiments may be used for forming objects that perform complex functions in a single manufacturing process. The threads may be used to carry or receive electrical, optical or other signals to the components which may, for example, be components that process or otherwise change or convert the signals, e.g. processors or other electronic components. Thus entire circuits comprising multiple interconnected functional elements may be achieved that are integrated or embedded within a single object which may be produced using a single system.

The component 37 may comprise one or more functional elements. The component 37 may send or receive signals via one or more threads, or may be powered by an electrical current supplied through one or more threads, for example. Examples of a functional element include an LED, actuator, sensor, wireless receiver, antenna or an electronic component such as a transistor, resistor, amplifier, transformer, inductor, capacitor, etc. In embodiments, a thread may also be formed into a functional element, for example by coiling or arranging it, so that it can function as an antenna, receiver, heat sink or heat source, amongst others.

In embodiments, the component, 37 may comprise a device such as an actuator, a vibration device, low friction material, or a passive guide, or any other device that may be arranged in the object to provide thread feed assistance from within the object. This may be particularly beneficial for objects with long conduits, or conduits having tortuous paths.

Referring to figure 4, a three dimensional object 40 or part thereof is shown on a build plate 8. The three dimensional object 40 may be produced by any of the methods or apparatus described herein. The three dimensional object 40 comprises a conduit 12 that extends from a surface of the object that is not facing the build plate 42 to a top surface 43 of the object 40. A guide stem 41 which may be an external conduit is shown that connects the aperture 11 in the build plate 8 to the conduit 12 of the object. The guide stem may be used to guide a thread 14 into the conduit 12 of the object 40 via a surface not facing the build plate. An object may be produced comprising a thread that extends into the object 40 from any surface of the object using a guide stem. Similarly, the conduit may enter through the top surface 43, or may leave the object and re-enter via the same or another surface, for example, or may connect two or more adjacent objects formed simultaneously by the same system. Once the object has been formed, the guide stem 41 may be disconnected from the object 40, e.g. by cutting or breaking off, thus, the guide stem may be considered as a sacrificial portion. The guide stem 41 may additionally be formed so that the guide stem 41 comprises an entrance portion as described in figure 2 above. The guide stem may be formed by depositing predetermined arrangements of build material to form the external conduit. These may be deposited at the same time, or as part of the predetermined arrangements that form the object 40. A guide stem 41 may be used in combination with any embodiment described herein.

An additive manufacturing system for producing a three dimensional object may comprise a build plate 8, the build plate 8 having at least one aperture 11 therein, as shown in any of figures 1 to 6. The additive manufacturing system may additionally comprise a thread feed unit to move a thread 14 through the conduits 12 formed from apertures in the build plate 11 and predetermined arrangements 4 of build material.

Referring to figure 5A, an additive manufacturing system 50 is shown. The additive manufacturing system comprises at least one controller (not shown), at least one build plate 8, at least one thread feed unit 51 and at least one build material arrangement unit 52.

The controller may comprise any controller described herein. The controller is adapted to control the thread feed unit 51 and build material arrangement unit 52. The controller may comprise processing means. The processing means may comprise a processor or other electrical circuitry operable to provide a control function to the various components in the systems defined herein including the thread feed unit and build material arrangement unit. Electrical circuitry may be distributed, including across the additive manufacturing system. The electrical circuitry may also be distributed on another component in communication with an additive manufacturing system, which may include a network-based, including as a remote server, or cloud-based computer or portable electronic device, which may include a mobile phone. Electrical circuitry may comprise electrical components known to the skilled person, including passive components, e.g. combinations of transistors, transformers, resistors, capacitors or the like. The electrical circuitry may be partially embodied on a processor, including as an ASIC, microcontroller, FPGA, microprocessor, state machine or the like. The processor can include a computer program stored on a memory and/or programmable logic, for execution of a process. The memory can be a computer-readable storage medium. Executable processes of the controller may include any method steps described herein.

The thread feed unit 51 may comprise any thread feed unit described herein. The thread feed unit 51 is adapted to feed at least one thread through at least one aperture in the build plate. In embodiments, a thread feed unit may comprise a spool for holding a thread, and an actuator arranged to move the thread from the spool through a conduit. The movement of thread through the conduit may be actuated by an actuator, which may be, for example, a stepper motor. The actuator may be controlled by the controller. In embodiments, the actuator may operate one or more rollers to pull thread from the spool and push it through the conduit. In embodiments, a tube or other hollow structure may be used to guide the thread from the spool to the aperture of the build plate. In embodiments, the controller may execute instructions for determining the distance a thread is to be moved through a conduit. The controller may generate a signal to control the actuator to move the thread the determined distance. A thread feed unit 51 may be actuated by any suitable actuation means, and need not be limited to stepper motors. Non-limiting examples of suitable actuators include electric motors other than stepper motors, hydraulic systems or piezo-based actuators. The thread feed unit may comprise any mechanical arrangement suitable for moving thread through a conduit that may be controlled by a controller. In addition to an actuator, a thread feed unit may comprise a thread contacting unit and a transmission mechanism to transfer actuation from the actuator to the thread contacting unit to move the thread. Non-limiting examples of a thread contacting unit include a pair of pinch rollers, s-rollers and belt drives. Non-limiting examples of a transmission mechanism include gear arrangements, belt arrangements and worm drive arrangements.

The build material arrangement unit 52 may comprise any build material arrangement unit described herein. In figure 5A the build material arrangement unit 52 is shown as a powder deposition apparatus. A powder deposition apparatus may function by spreading a thin layer of powdered build material onto the build plate or onto a prior printed layer. The powder may be spread by an actuated blade (not shown) from a powder hopper. In some systems a binding substance may be deposited onto the powder layer in a pattern corresponding to a predetermined arrangement. This forms a printed pattern of bound powder surrounded by unbound powder (not shown) in each layer. Once the part is produced, the unbound powder may then be removed.

The predetermined arrangement is arranged to comprise an aperture and positioned so that a conduit is formed by one or more apertures in the arrangements of build material. The build platform 8 may be lowered as shown by the arrow in 5A, as subsequent arrangements of build material are deposited onto prior arrangements of build material. Thus, the build direction of the object is opposite to the direction of movement of the build plate shown by the arrow in figure 5A. The present invention may be used with any build material arrangement unit type, and need not be limited to powdered deposition apparatus of figure 5A. Similar powder deposition build material arrangement units may function by depositing a layer of powder as described above, then selectively fusing or sintering the powder to form a predetermined arrangement, e.g. by application of heat via a laser. The diagram of figure 5A is also equally applicable to a build material arrangement unit 52 that functions by fused deposition modelling, where material is extruded onto the build plate into the shape of a predetermined arrangement. Any known build material arrangement units that a skilled person would consider as compatible with the present invention are also envisioned. Non-limiting examples include: fused deposition modelling; stereolithography; digital light processing; laminated object manufacturing; or powder deposition.

Referring to figure 5B, an additive manufacturing system 55 is shown. The additive manufacturing system 55 comprises at least one controller (not shown), at least one build plate 8, at least one thread feed unit 51 which may be any as described herein. The system 55 additionally comprises at least one build material arrangement unit 52. In this example, the build material arrangement unit is a stereolithographic unit, arranged to create a 3D object by directing light to a photosensitive polymer. The forming of an object is initiated by lowering build plate 8 to contact the photosensitive polymer. Radiation (e.g. UV, visible spectrum laser light) is focussed through the container of a photosensitive polymer to selectively harden the polymer to the build plate. The radiation is applied so that a layer is hardened against the build plate in a predetermined arrangement. The build plate is then raised as shown by the arrow in 5B and radiation focussed so that another predetermined arrangement is formed against the prior predetermined arrangement. In this case the build direction of the object is opposite to the direction shown by the arrow in figure 5B. The build direction is shown in figure 5A and figure 5B as vertically upwards or downwards, however it is intended that the present disclosure is not limited to build material arrangement units with these build directions. For example, the present disclosure is also envisioned for use with build material arrangement units that operate with a horizontal direction amongst other.

In embodiments, an additive manufacturing system may comprise a thread feed assistance means. In embodiments, a method of producing a three dimensional object may comprise a step of assisting movement of a thread, which may comprise using a thread feed assistance means.

Thread feed assistance may comprise, for example, applying linear or rotational vibration or oscillatory motion to a thread. Vibration or oscillation may be applied by a stepper motor of a thread feed unit, or by any other actuator. An actuator may be integrated with the thread feed unit, or external thereto. Alternatively, a vibrating unit may be arranged to vibrate the thread. This may include, for example, a piezo element arranged to transfer vibrations to the thread, or an ultrasound emitter arranged to oscillate the tip of the thread as it moves through the conduit. Alternatively an actuator may be arranged to rotate the thread as it is moved through a conduit.

Thread feed assistance may comprise applying a friction reducing agent to the thread or conduit. This may comprise a coating such as PTFE, or a liquid lubricant.

Thread feed assistance may comprise clearing the conduit of debris, such as unwanted build material. This may comprise directing a gas (e.g. air) or liquid (e.g. water, oil) through the conduit. Thread feed assistance may comprise applying heat to or cooling a thread or conduit.

Thread feed assistance may comprise providing a friction reducing feature to the tip of a thread. This may comprise applying a cap having a shape or material that reduces friction or sticking against the sides of the conduit, or shaping the tip e.g. providing a smooth surface.

A thread feed assistance means may comprise any apparatus for applying any form of thread feed assistance as described herein.

Referring to figure 6, an embodiment additive manufacturing system 60 is shown. The embodiment additive manufacturing system 60 comprises a 3D printer, for example, a Projet® 6000 HD by 3D Systems. The 3D printer comprises a controller, a build plate 64 comprising multiple apertures 61 a,b,c and a build material arrangement unit. The build plate may comprise a regular array of evenly spaced apertures, e.g. apertures arranged as a grid. The build material arrangement unit 68 is a stereolithographic 3D printing system that uses a UV laser to direct UV laser light to a photopolymerisable polymer 67 e.g. VisiJet® SL clear. The additive manufacturing system 60 additionally comprises three feed mechanisms 62 a,b,c arranged to feed a copper strand through apertures 61 a,b,c in the build plate 64. The feed mechanisms 62 a,b,c each comprise a spool 63 a,b,c loaded with a copper strand. The feed mechanism comprises a stepper motor and gear arrangement to drive a pair of pinch rollers 65 a,b,c between which a thread is moved. A flexible tube 66 a,b,c extends from each pair of pinch rollers to the apertures in the build plate. Activation of the stepper motor drives the pinch rollers to move the threads through the flexible tubes to the build plate apertures, and also through conduits in the object. Additional secondary feed rollers may also be used, these may be positioned between the tubes and build platform, for example.

In embodiments, a flexible tube may extend from a thread feed unit to an aperture. In embodiments, the tube may comprise a connector or plug at one end, to facilitate connection to an aperture of the build plate. The flexible tube may be connectable to different apertures on a build plate. This may allow a tube to be more easily disconnected from one aperture and reconnected to another aperture, or to an aperture in an exposed face of an object on the build plate.

Forming an object using the additive manufacturing system 60 of figure 6 comprises instructing the 3D printer to print an object based on a digital representation of the object. The digital representation of the object comprises at least one conduit within the body of the object. Software may be used to convert the digital representation of the object into instructions for the build material arrangement unit to arrange build material in a series of layers, which, when combined, form an object to the digital representation, including at least one conduit within the object. Software is also used to determine the increment distance of the thread, i.e. the distance the thread should be moved after each layer of build material that forms the object is arranged. This is converted to signals to drive the stepper motors of the thread feed units accordingly. The increment distance the thread is moved will depend on the thickness of a layer and angle of the conduit relative to the build direction.

Referring to figure 7 A, B and C and figure 8, a method for modifying a digital record of a three dimensional shape is shown. The method comprises the steps of receiving a digital record 81 of a three dimensional shape 71; receiving 82 a start 72 and an end point 73 for at least one conduit in the three dimensional shape 71; determining 83 a conduit path 74 for the at least one conduit in the three dimensional shape based on the start and end points 72, 73 and the digital record 71 of the three dimensional shape and modifying 84 the digital record 71 to comprise the determined conduit path.

The modified digital record may then be used for any method for producing a three dimensional object described herein, or may be used with any additive manufacturing system described herein. Thus a method may comprise the steps of receiving a digital record of a three dimensional shape; receiving a start and an end point for at least one conduit in the three dimensional shape; determining a conduit path for the at least one conduit in the three dimensional shape based on the start and end points and the digital record of the three dimensional shape; modifying the digital record to comprise the determined conduit path; converting the digital record to instructions corresponding to a series of predetermined arrangements and optionally creating instructions to control moving a thread. The instructions may be executable to operate any additive manufacturing system described herein to produce an object comprising at least one thread embedded therein.

In embodiments, the conduit path may be determined to avoid objects or voids in the three dimensional shape. For example, an object may be of irregular shape or comprise voids or regions through which a conduit cannot pass. The conduit path may have to be arranged around such regions. Thus, a method for determining a conduit path may comprise identifying such regions and arranging a conduit path to avoid these regions.

In embodiments, the conduit path may be determined to minimise conduit length and/or to maximise the smallest radii of curvature of the conduit path. For example, a determined conduit path may be analysed for minimum radii along its length. The path may be iteratively changed to increase the minimum radius along the conduit length. Similarly, the path may be iteratively changed to reduce the path length, or a combination of both may be used. Reducing radii or path length may reduce the friction of the thread in the conduit and improve the ease of moving the thread through a conduit.

In embodiments, adjacent conduit paths may be determined so that no adjacent conduits are less than a predetermined minimum distance apart.

In embodiments, the method may additionally comprise any of receiving information of the at least one thread to be inserted into the at least one conduit path; determining a minimum radius of the conduit path based on the received information of the at least one thread; wherein determining conduit path so that no conduit path radii is less than the determined minimum radius. The minimum radius that a thread may be moved through may be depend in part on the thread used. Therefore, a method may comprise receiving information about the thread and using this to determine the minimum radius.

The minimum radius a thread may be moved through will depend on, amongst others, the material of the thread, its cross section, or the stiffness of the thread. Thus, the received information of the at least one thread may comprise any of: thread material information; thread cross section information; or thread stiffness information.

In embodiments, the conduit path may be determined so that the conduit comprises an entrance portion as described herein. The entrance portion may correspond to an entrance portion of at least one conduit of the three dimensional object, where the cross sectional area of the entrance portion is larger than the rest of the at least one conduit.

In embodiments, one or more build plate apertures through which a thread is to pass to may be identified based on: the conduit path, the digital record or instructions corresponding to a series of predetermined arrangements. The build plate aperture may be identified automatically by software. Identification may comprise outputting position data (e.g. coordinates or a reference number) corresponding to apertures on the build plate. Alternatively, a laser light or similar controlled by the controller may be used to identify the aperture(s) of the build plate. A user may then arrange one or more thread feed units to move thread through the one or more identified apertures. In alternative embodiments, a thread feed unit may be actuated and controlled by the controller to connect the thread feed unit to an identified aperture.

In embodiments, a plurality of thread feed units may be connected to a plurality of apertures in the build plate. The controller may identify the apertures through which a thread is to move, and may only actuate the thread feed units that correspond to the identified apertures.

In embodiments, the conduit path may be determined so that a portion of the conduit path comprises a guide stem portion that corresponds to a guide stem portion in a produced three dimensional object. Where an entrance point or exit point of a conduit is on a surface of the object not facing a build plate, a guide stem may be added to guide the thread from the build plate to the entrance point of the conduit in the object. The guide stem may be a sacrificial portion that may be removed from the object once produced.

In embodiments, the conduit path may comprise a conduit cross section that is proportional to a thread cross section. For example, where the thread is a ribbon i.e. has a width greater than thickness, the conduit may have a similarly proportioned cross section, only larger in area to accommodate the thread. Therefore, the method may comprise applying a non-isotropic minimum radii based on the cross section of the thread.

One or more threads may comprise a functional element. Examples include any functional element disclosed herein, including amongst others: a thread comprising one or more LEDs, electronic components, actuators, antennas, receivers, emitters or sensors.

One or more threads may comprise any of an electrically conductive element, and/or a thermally conductive element. An electrically conductive element may, for example, be a constituent of a thread having a thermal conductivity appropriate for use solely for conducting heat away from a heat source, and may have a thermal conductivity greater than the build material. An electrically conductive element may be a constituent of a thread having sufficient electrical conductivity to be used to carry an electrical signal, and may have an electrical conductivity greater than the build material.

One or more threads may comprise a data transmission element. A data transmission element may be considered to be any element capable of carrying data in the form of a signal. This may include, amongst others, fibre optic cable, coaxial cable or other wave guide, electrical wire or other electrically conductive elements. Thus a thread may be comprised as part of a circuit. Alternatively a circuit comprising a plurality of conductive threads may be moved through one or more conduits.

One or more threads may comprise a structural element. A structural element may be a constituent of a thread that performs a structural function. Examples of a structural function may include joining two disconnected objects together, e.g. to form a hinge between the objects, or to increase compression or tensile strength of the object.

One or more threads may comprise a shape memory alloy, for example nitinol. A pre-shaped thread may be formed, then inserted into a conduit for deployment from the conduit at a later stage. For example, a stent may be preloaded into an applicator for later deployment where it will adopt its previous shape.

In embodiments, the three dimensional object may undergo a finishing process step. The finishing process step may comprise removal of a sacrificial portion of the three dimensional object. The finishing process step may comprise flowing a hardenable material or adhesive through the conduit to seal the thread within the conduit. A finishing process step may comprise application of heat or UV to cure the object.

Examples of thread materials may include metals, such as any of copper; gold; silver; aluminium; steel or alloys thereof.

A three dimensional object printing kit (not shown) may comprise an additive manufacturing system as described herein along with any thread described herein and optionally a build material for the additive manufacturing system. A thread feed unit and build plate as described herein, may be combined with a build material arrangement unit to provide a system of the present disclosure

In embodiments, the system may comprise a cutting unit to cut a thread after it has been moved into a conduit. In further embodiments, a method may comprise cutting a thread after it has been moved into a conduit. A cutting unit may comprise a mechanically actuated blade or heating element, and may be controlled by the controller.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word ‘comprising’ does not exclude the presence of other elements or steps than those listed in a claim. Furthermore, the terms “a” or “an,” as used herein, are defined as one, or more than one. Also, the use of introductory phrases such as “at least one” and “one or more” in the claims should not be construed to imply that the introduction of another claim element by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim element to inventions containing only one such element, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an”. The same holds true for the use of definite articles. Unless stated otherwise, terms such as “first” and “second” are used to arbitrarily distinguish between the elements such terms describe. Thus, these terms are not necessarily intended to indicate temporal or other prioritization of such elements. The mere fact that certain measures are recited in mutually different claims does not indicate that a combination of these measures cannot be used to advantage.

Unless otherwise explicitly stated as incompatible, or the physics or otherwise of the embodiments, example or claims prevent such a combination, the features of the foregoing embodiments and examples, and of the following claims may be integrated together in any suitable arrangement, especially ones where there is a beneficial effect in doing so. This is not limited to only any specified benefit, and instead may arise from an “ex post facto” benefit. This is to say that the combination of features is not limited by the described forms, particularly the form (e.g. numbering) of the example(s), embodiment(s), or dependency of the claim(s). Moreover, this also applies to the phrase “in one embodiment”, “according to an embodiment” and the like, which are merely a stylistic form of wording and are not to be construed as limiting the following features to a separate embodiment to all other instances of the same or similar wording. This is to say, a reference to ‘an’, ‘one’ or ‘some’ embodiment(s) may be a reference to any one or more, and/or all embodiments, or combination(s) thereof, disclosed. Also, similarly, the reference to “the” embodiment may not be limited to the immediately preceding embodiment.

The foregoing description of one or more implementations provides illustration and description, but is not intended to be exhaustive or to limit the scope of the invention to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various implementations of the present disclosure.

Claims

1. A method of additive manufacture for the production of a three dimensional object comprising:

arranging build material in at least one predetermined arrangement onto a prior arrangement of build material or onto a build plate, wherein the at least one predetermined arrangement comprises at least one aperture, the aperture cooperating with at least one aperture in the prior arrangement of build material or in the build plate to form at least one conduit extending through the aperture in the build plate; and

moving at least one thread through the at least one conduit to at least partially occupy the aperture in the arranged predetermined arrangement of build material.

2. A method according to claim 1, wherein the steps of claim 1 are repeated to produce a three dimensional object comprising at least one conduit and at least one thread within the at least one conduit.
3. A method according to any previous claim, wherein the predetermined arrangement of build material comprises two or more apertures to form two or more conduits, and threads are moved through each conduit.
4. A method according to any previous claim, wherein the at least one thread is moved after each predetermined arrangement of build material is arranged.
5. A method according to any previous claim, wherein the at least one thread is moved through the at least one conduit by a distance equal to the length the conduit increases as each predetermined arrangement of build material is arranged.
6. A method according to any previous claim, wherein moving the at least one thread comprises determining the length of the conduit that is unoccupied by the thread and moving the thread by a distance that corresponds to the determined unoccupied length.
7. A method according to any previous claim, wherein the at least one thread is moved through the at least one conduit at the same rate as the conduit increases in length.
8. A method according to any previous claim, comprising arranging build material in a first predetermined arrangement onto a build plate, then arranging further build material in a second predetermined arrangement onto the first predetermined arrangement.
9. A method according to any previous claim, comprising any of the following steps:

determining at least one conduit path through a three dimensional shape that corresponds to a three dimensional object to be produced;

creating instructions to arrange build material in a plurality of predetermined arrangements based on the three dimensional shape and the at least one determined conduit path;

creating instructions to control the moving of at least one thread into the conduit;

arranging build material and/or moving at least one thread by executing the instructions.

10. A method according to any previous claim, wherein moving the at least one thread comprises pushing the thread through the conduit, and optionally, wherein the thread is pushed by a stepper motor.

11. A method according to any previous claim, wherein moving the at least one thread comprises the application of one or more of: oscillatory movement of the at least one thread, vibration of the at least one thread; and/or flow of a fluid through the at least one conduit.

12. A method according to any previous claim, wherein the at least one conduit comprises an entrance portion having a cross sectional area that is larger than the cross sectional area of the rest of the conduit.

13. A method according to any previous claim, wherein the predetermined arrangement comprises at least one component aperture sized to receive at least one component.

14. A method according to claim 13, comprising placing a component within the at least one component aperture.

15. A method according to claim 14, comprising moving at least one thread through at least one conduit, to make a connection with the at least one component placed within the at least one component aperture.

16. A method according to any of claims 14 or 15, wherein the component comprises a functional element.

17. A method according to any of claims 15 or 16, wherein the component comprises a receiving portion to engage with a thread.

18. A method according to any previous claim, wherein a portion of the conduit is surrounded by a sacrificial portion of arranged build material to be removed from the three dimensional object.

19. A method according to any previous claim, wherein the thread comprises an electrical circuit, or part of an electrical circuit.

20. A method according to any previous claim wherein arranging build material comprises using one of: fused deposition modelling; stereolithography; digital light processing; laminated object manufacturing; or powder deposition.

21. An additive manufacturing system comprising:

at least one controller;

a build plate;

at least one build material arrangement unit controlled by the at least one controller, to arrange build material into at least one predetermined arrangement onto the build plate or onto an adjacent predetermined arrangement of build material, the predetermined arrangement comprising an aperture to cooperate with an aperture in an adjacent predetermined arrangement or an aperture in the at least one build plate, to form at least one conduit; and

at least one thread feed unit controlled by the at least one controller; the at least one thread feed unit to move at least one thread through the at least one conduit.

22. Additive manufacturing system according to claim 21, wherein the at least one thread feed unit is arranged to move a thread through an aperture in the build plate.

23. Additive manufacturing system according to any of claims 21 or 22, wherein the at least one thread feed unit comprises an actuator controlled by the controller, optionally wherein the actuator is a stepper motor.

24. Additive manufacturing system according to any of claims 21 to 23, wherein the at least one build material arrangement unit comprises one of: fused deposition modelling apparatus; stereolithography apparatus; digital light processing apparatus; or powder fusing apparatus.

25. Additive manufacturing system according to any of claims 21 to 24, wherein the build plate is configured to move upwards as build material is arranged, or alternatively, wherein the build plate is configured to move downwards as build material is arranged.

26. Additive manufacturing system according to any of claims 21 to 25, comprising thread feed assistance means.

27. Additive manufacturing system according to claim 26, wherein the thread feed assistance means comprises any of: a conduit clearing device, a thread vibration means; a thread friction reducing means, a thread heating means or a thread cooling means.

28. Additive manufacturing system according to claim 27, wherein conduit clearing device comprises apparatus for the application of fluid pressure to the at least one conduit.

29. Additive manufacturing system according to claim 27 or 28, wherein thread vibration means comprises an ultrasound emitter or an actuator for vibrating the thread.

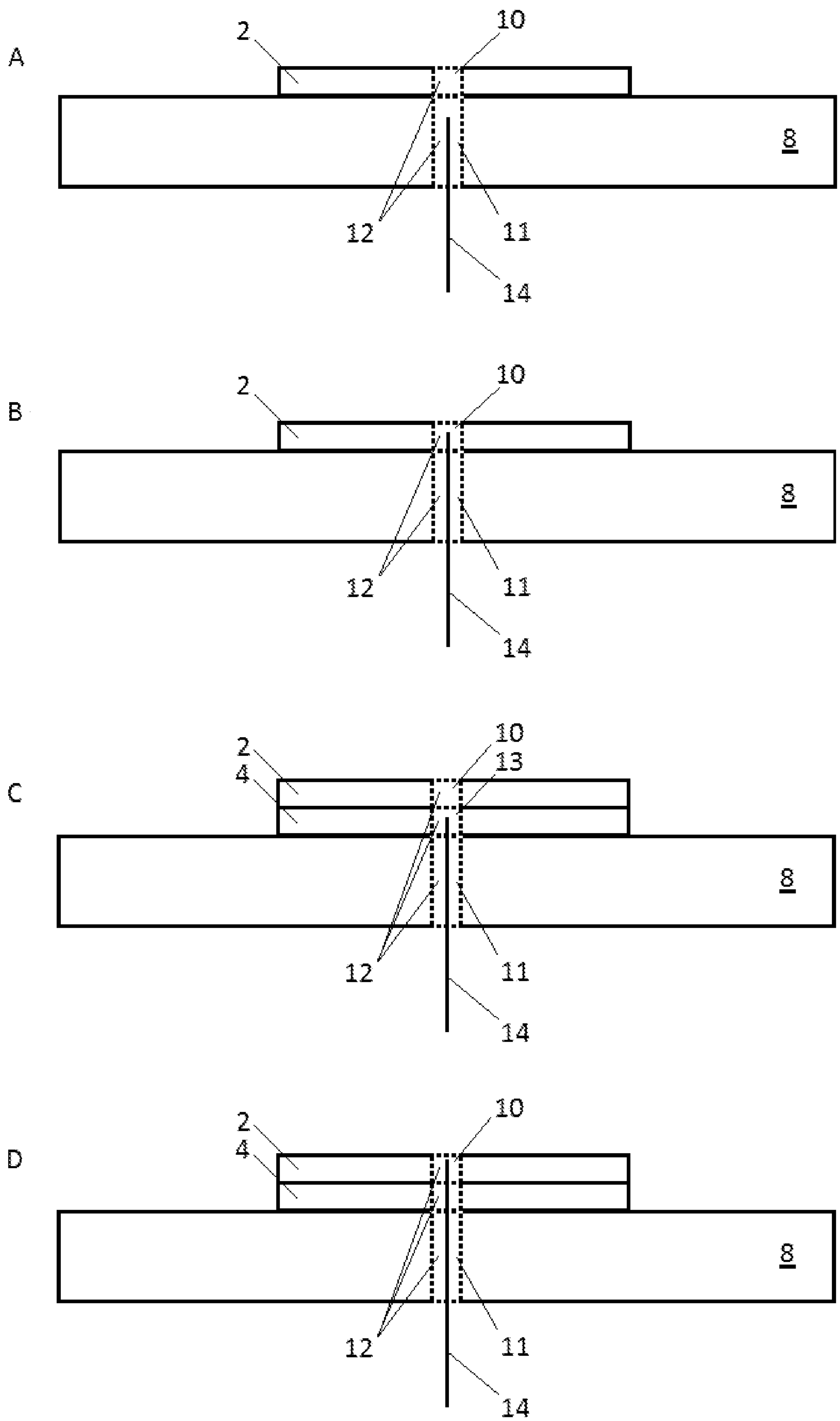

Fig. 1

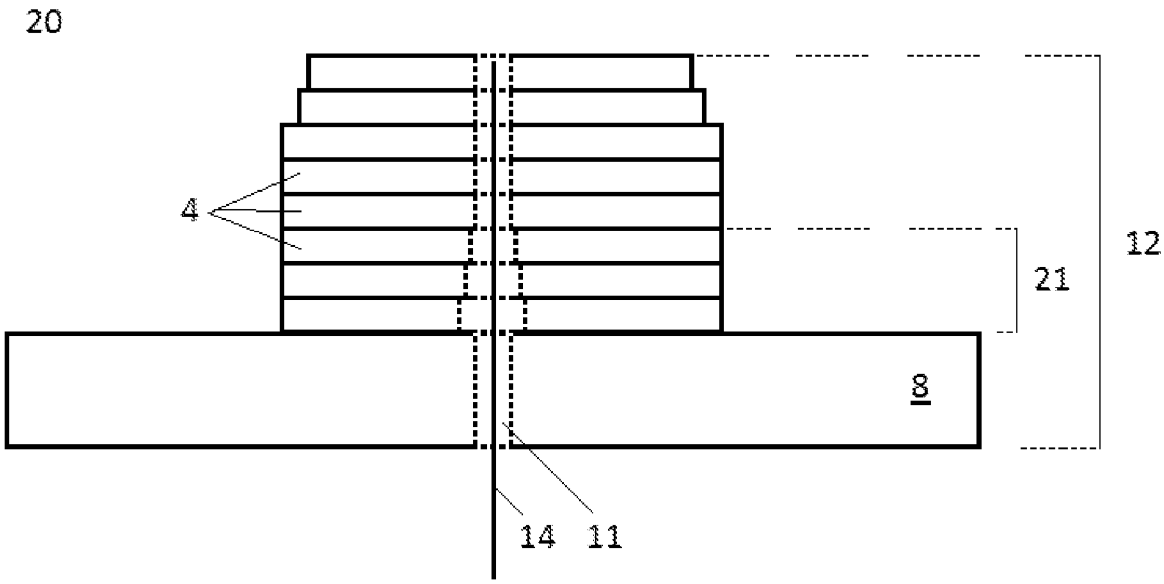

Fig. 2

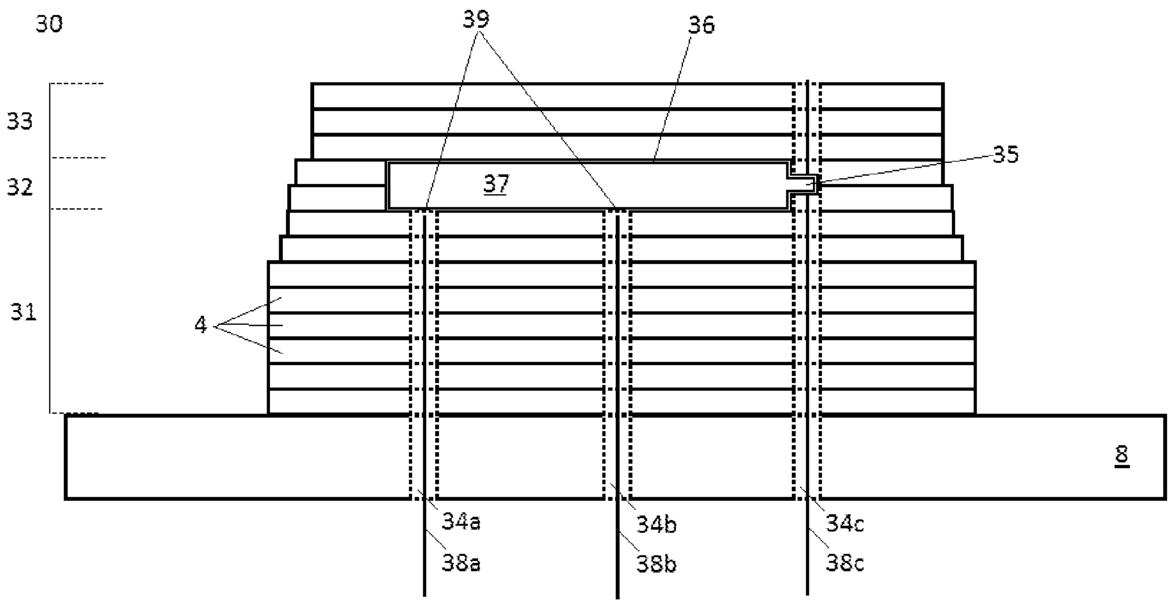

Fig. 3

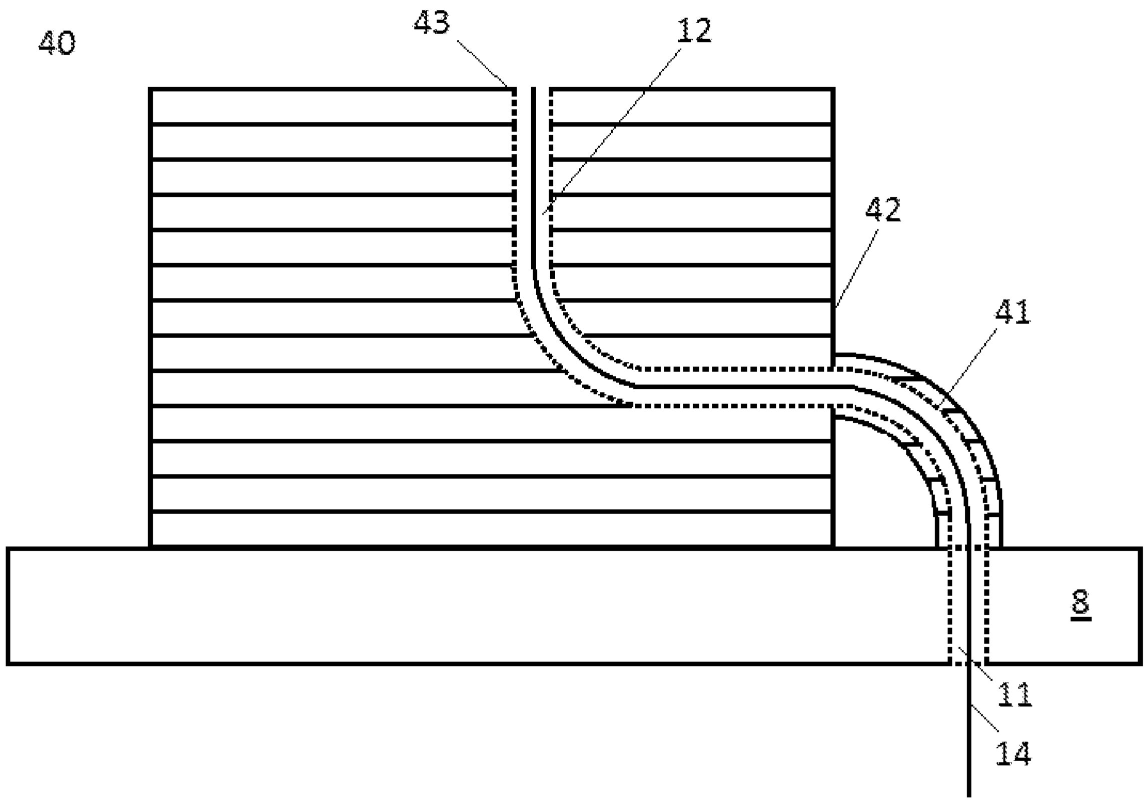

Fig. 4

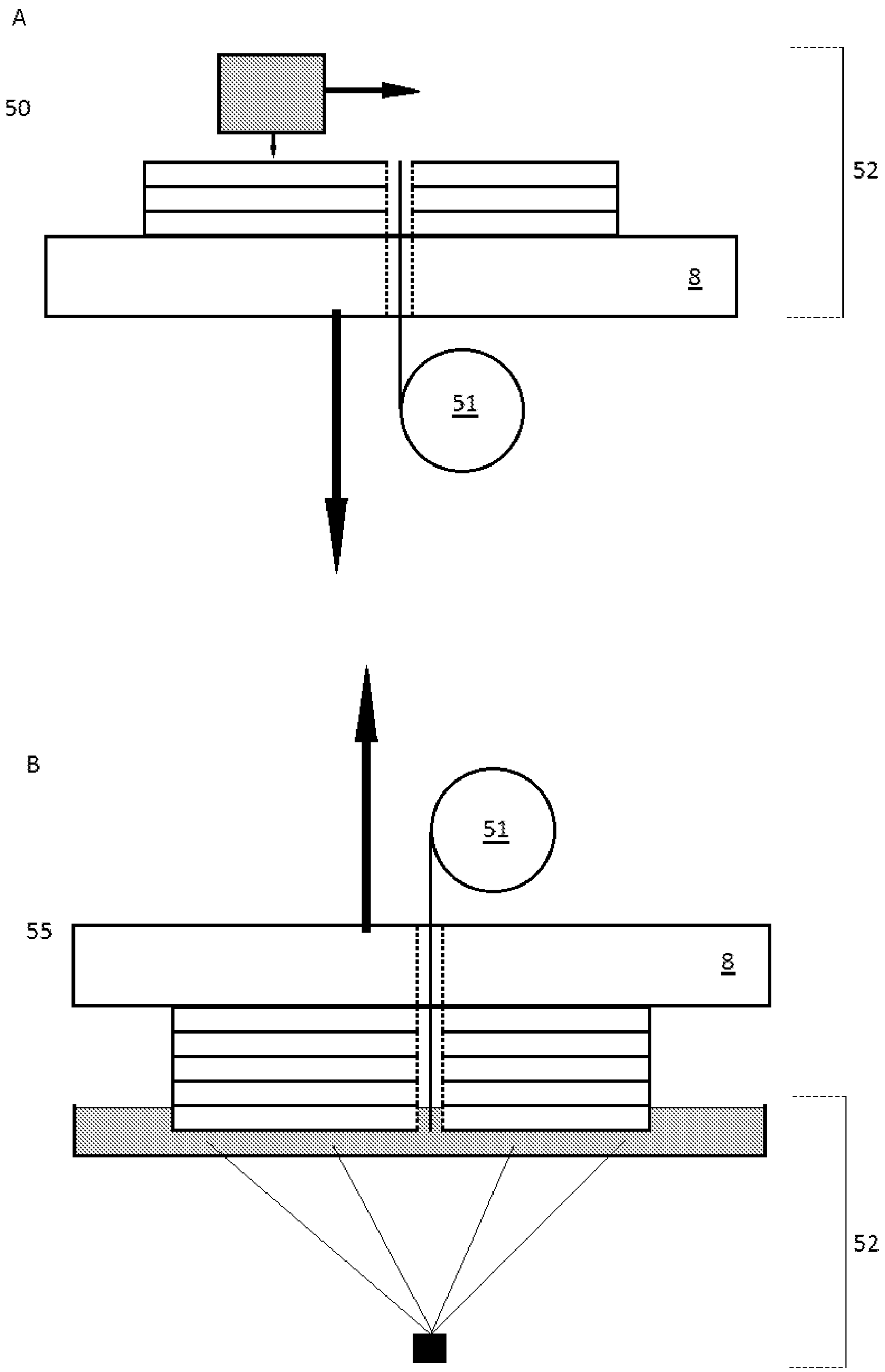

Fig. 5

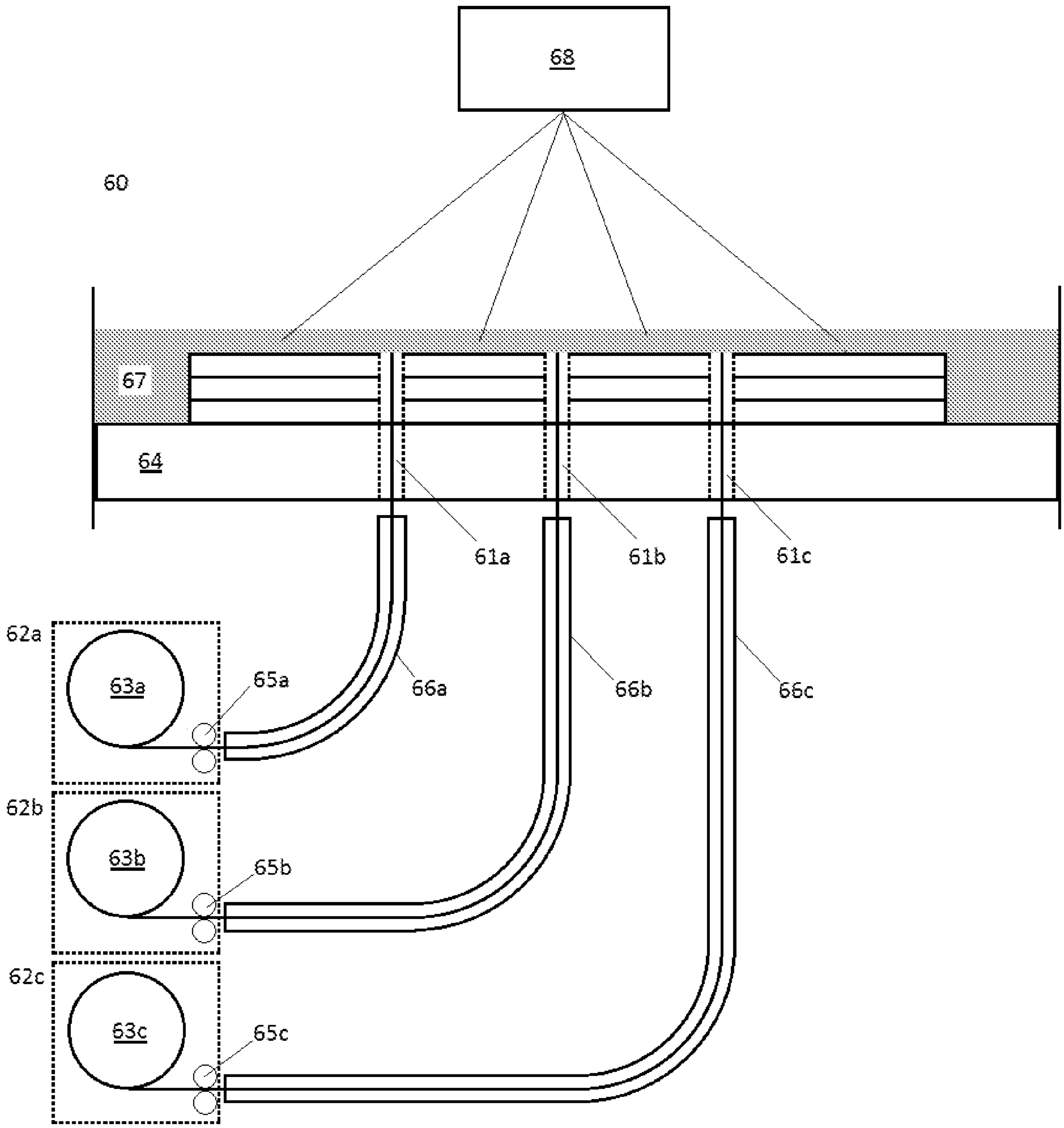
68
60
67
64
61a
61b
61c
62a
63a
65a
66a
66b
66c
62b
63b
65b
62c
63c
65c

Fig. 6

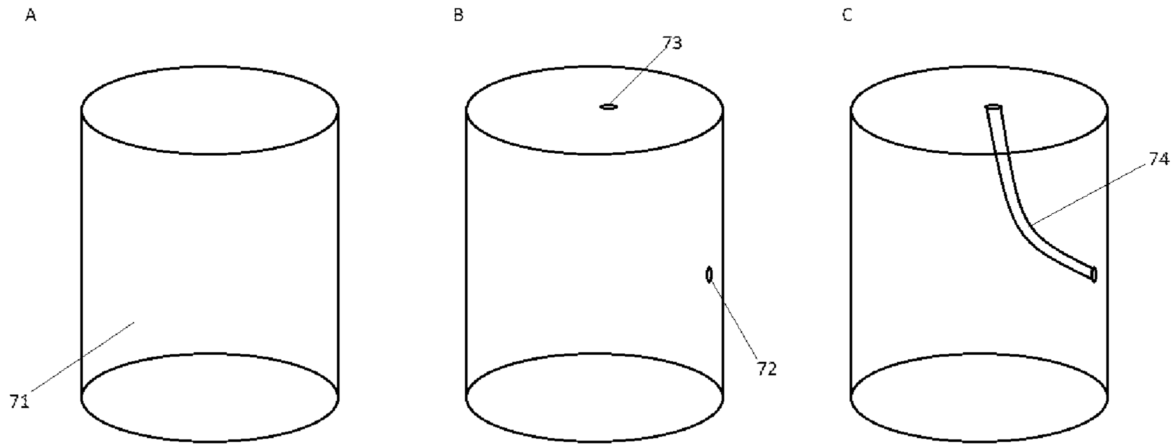

Fig. 7

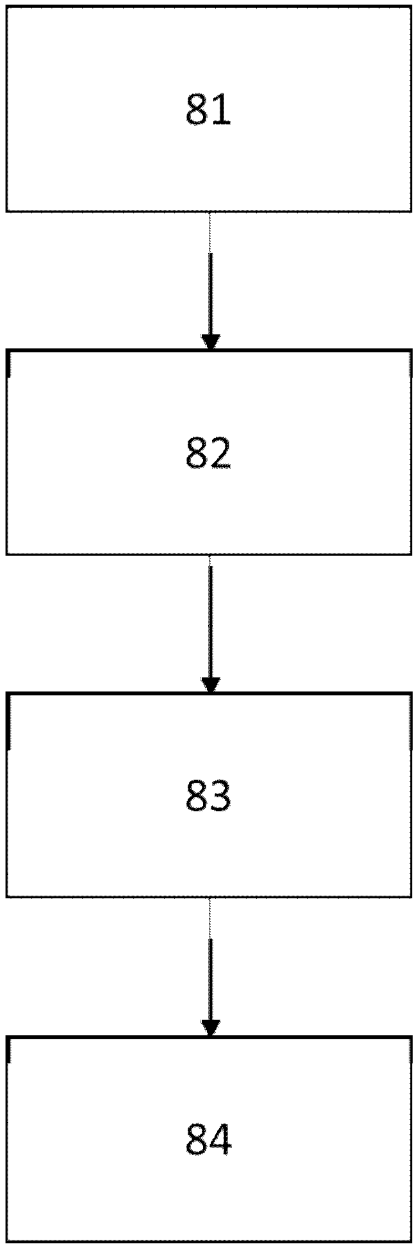

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2018/050377

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C64/321 B22F3/105 B29C64/336 B29C70/68
ADD.

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 B22F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/172030 A1 (VARIAN SEMICONDUCTOR EQUIPMENT ASS INC [US]) 27 October 2016 (2016-10-27)	1-3,8, 10-20
A	paragraph [0062] - paragraph [0064] figures 1A,8A,8B	4-7,9, 21-29
A	US 2016/271876 A1 (LOWER ROBERT BRUCE [US]) 22 September 2016 (2016-09-22) paragraph [0031] - paragraph [0038] paragraph [0054] paragraph [0119] - paragraph [0125] claims	1-29
A	US 2016/020501 A1 (LINDSEY JOHN R [US]) 21 January 2016 (2016-01-21) claims 1,8	1-29

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 May 2018	11/05/2018

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

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1

International application No
PCT/GB2018/050377

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2016/146374 A1 (PHILIPS LIGHTING HOLDING BV [NL]) 22 September 2016 (2016-09-22) page 1, line 28 - page 2, line 10 claims -----	1-29

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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