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(54) Title: ADDITIVE MANUFACTURING APPARATUS

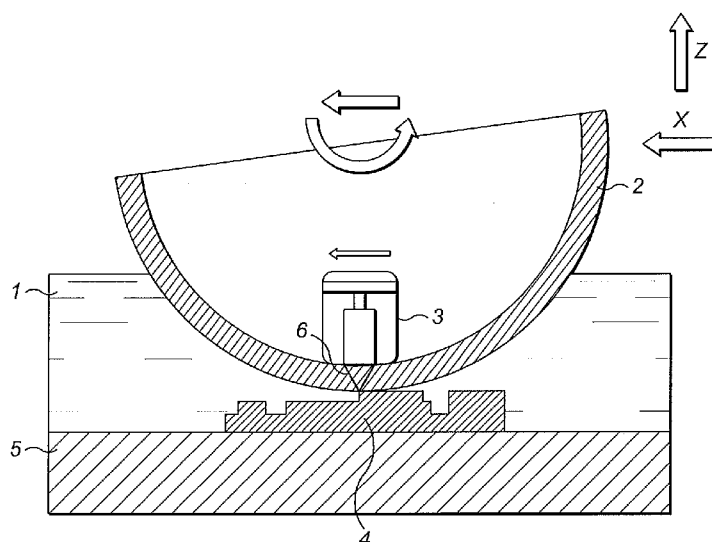


FIG. 1b

(57) Abstract: Additive manufacturing apparatus for successively exposing a plurality of layers of photo-reactive substance to form a build comprises a build support to support the build and a light transmissive member for transmitting light to photo-reactive substance in a layer. At least one of the light transmissive member and the build support is movable relative to the other to vary a selected region of a layer during exposure of the layer such that the position of the light transmissive member determines the thickness of the selected region.

Additive manufacturing apparatus

Description

5 This invention relates to an additive manufacturing apparatus and to an additive manufacturing method. In particular, but not exclusively, it relates to a stereolithography apparatus and to a method of forming a build by stereolithography.

10 Additive manufacturing (also referred to as 3-D printing or rapid prototyping) is a well-established area of technology. There are various forms of additive manufacturing, including laser-sintering, inkjet printing, laminated object manufacturing, fused deposition modelling and stereo-lithography using photo-setting polymers.

15 In a stereolithography (SLA) process, polymer resins are used that are able to harden when exposed to light (usually ultra-violet light). These processes start with the creation of a digital, 3-D model of the desired object on a computer. This 3-D model is then translated into a series of (digital) 2-D slices. These slices are then used to optically expose a thin layer of the resin, the resin hardening where exposed. The slices are successively exposed, one atop the next, gradually creating a copy of the original 3-D object from a series of 2-D slices.

25 When the 3-D digital model is converted into 2-D slices, each point on the slice represents a volume, referred to herein as a “voxel”. The voxel has finite dimensions, corresponding to the resolution of the process; a high-resolution process (i.e. one with small voxels) may produce a precise object, closely approximating the original 3-D model. Lowering the resolution (i.e. increasing the voxel dimensions) results in the object becoming less like the model, which will have an increasingly “stepped” appearance.

30 A number of different stereolithography systems have been developed, including laser-scanning systems, DLP (digital light processing) systems and 2-photon systems.

35 Laser-scanning systems may include a laser, a mechanical system to manipulate the laser beam, a bath of resin, and a build platform comprising a solid plate on which the object is built, which may be detached after the build. The build platform sits within the bath of resin, and can be moved vertically with high precision. Initially, the build

platform is moved close to the surface of the resin, which may be “wiped” with a wiper to ensure that a consistent, thin layer of resin is above the build platform. The laser is then raster-scanned across the surface of the resin, in the pattern of the first “slice” of the object model, hardening it where it exposes the resin. The build platform is then
5 moved down by a small distance into the resin, “wiped”, and the process repeated. The distance that the build platform moves determines the resolution of the object build (i.e. the z-dimension of the voxel).

10 Laser-scanning systems are good at producing large-area objects, but are restricted in resolution as the thickness of each layer is determined by the wiping process and the viscosity and surface tension of the resin.

DLP systems use a digital light processing chip, a silicon based device with large numbers of computer controlled micro-mirrors on its surface. Such chips are also used
15 in digital overhead projectors. DLP systems generally constrain a layer of resin between the build (or build platform) and a “resin tray”, which comprises a flat, optically transparent plate, through which the layer image is projected.

DLP systems may expose a single image (a complete sheet) simultaneously, resulting in
20 a rapid build. The x- and y- limits of the build size are determined by the optical projection system used, as is the x- and y- resolution. This is because the DLP chips incorporate a fixed number of mirrors (typically ~ 1,000,000). Higher resolution over greater areas may be achieved with these systems using step-and-repeat (moving the image several times, exposing part of a layer each time), however problems can occur
25 where the edges of the exposures meet, arising from distortion of the projected images.

DLP systems have limitations when moving the resin tray away from the build in-between layer exposures. Because there is a large, flat plate being pulled away from the build, large forces are required, firstly to separate the plate and build, and secondly to
30 allow the resin to flow into the void created. This can damage the build, takes some considerable time and limits the size that can be produced.

The viscosity of the resin is a relevant parameter, particularly when the build platform is lowered between the building of each layer. SLA systems may “peel” or pull the object
35 platform away from the resin tray, after exposing each layer, introducing large stresses on both the machine and the object, which may disintegrate in the peeling process. This

limits the “delicacy” of the object being built (i.e. the smallest element of the build which can survive the peel), increases the time of the build (peels need to be performed slowly), restricts the size of the build (these effects increase with the area of build), and limits the viscosity of resin that may be used.

5

As described in International (PCT) Patent Application Number PCT/EP2011/052151 from the present applicant, stereolithographic apparatus has also been developed which operate “upside down”, ie: with the build above the light source,

10 The present invention provides an additive manufacturing apparatus for successively exposing a plurality of layers of photo-reactive substance to form a build. The apparatus comprises a build support to support the build, and a light transmissive member for transmitting light to photo-reactive substance in a layer. At least one of the light transmissive member and the build support is movable relative to the other to
15 vary a selected region of a layer during exposure of the layer. The position of the light transmissive member determines the thickness of the selected region.

In embodiments, the selected region comprises a region of photo-reactive substance between the light transmissive member and the build or build support. The selected
20 region may extend from one side of the layer to another opposing side. The selected region may define a straight line across the layer. Varying the selected region may comprise varying the selected region in a direction across the build, e.g: in a direction transverse to (for example at a right angle to) said straight line.

25 In embodiments, the light transmissive member contacts the selected region as the selected region is varied during exposure of the layer.

In embodiments, the thickness of the selected region is the spacing between the light transmissive member and the build (or the build support, in the case of the first layer).
30 In embodiments, the thickness of the selected region remains constant as the selected region is varied such that each layer has a respective constant thickness. Each layer may be one voxel thick. Each layer may have the same thickness.

In embodiments, at least one of the light transmissive member and the build support is
35 arranged to be rolled relative to the other to permit relative movement between the light transmissive member and the build support.

The light transmissive member may comprise a curved member which can be rolled in a direction across the build so as to be movable relative to the build support.

5 In embodiments, the additive manufacturing apparatus further comprises a light source arranged for movement in a direction across the build. The light source may be configured to adopt a position aligned with the selected region of the layer as the light-transmissive member is rolled in a direction across the build.

10 In embodiments, the selected region of the layer is varied in a direction across the build. In alternative embodiments, the build support may comprise a curved member which can be rolled relative to the light transmissive member to cause movement of the build and build support relative to the light transmissive member, thereby to vary the selected region of the layer.

15 In embodiments, at least one of the light transmissive member and the build support may be movable to a position in which the light transmissive member is beyond the edge of the build.

20 The additive manufacturing apparatus may further comprise a light source arranged to direct light to the light transmissive member, The light source may comprise a linear light source. The light source may include a focussing arrangement comprising one or more Gradient-Index (GRIN) lenses. In an embodiment, the light source comprises a linear array of GRIN lenses and a linear array of Light Emitting Diodes (LEDs).

25 The selected region of the layer may extend from one side of the layer to another opposing side. At least one of the light transmissive member and the build support may be movable relative to the other to vary the selected region in a direction across the build.

30 In embodiments, the selected region of the layer comprises a straight line region extending from one side of the layer to the other. At least one of the light transmissive member and the build support may be movable relative to the other to vary the selected region in a direction transverse to the straight line region.

35

In embodiments, the light transmissive member is arranged to maintain only a line of contact with the layer as the selected region is varied.

5 In embodiments, the build support is configured for movement in a first direction, away from the light transmissive member, after a layer has been exposed, so as to allow a subsequent layer to be exposed. At least one of the light transmissive member and the build support may be movable relative to the other in a second direction, transverse to the first direction, thereby to vary the selected region during exposure of the layer.

10 The light transmissive member may comprise an optically transparent member. The optically transparent member may be curved. In alternative embodiments, the light transmissive member comprises a flat optically transparent member. The optically transparent member may have an even thickness.

15 In some embodiments, the light transmissive member comprises one or more optical fibres comprising a surface face region to determine the thickness of the selected region of the layer. The light transmissive member may comprise a plurality of optical fibres having ends collated to form a line which defines said surface face.

20 In embodiments, the additive manufacturing apparatus comprises a stereolithography apparatus.

The present invention also provides an additive building method, comprising successively exposing a plurality of layers of photo-reactive substance to light exiting a
25 light transmissive member responsive to 3D model data, thereby to form a build supported by a build support.

Exposing a layer may comprises varying the relative position of the light transmissive member and the build support to select a region of a layer, wherein the position of the
30 light transmissive member determines the thickness of the selected region, and selectively exposing the selected region to light responsive to model data for said selected region.

Exposing a layer may comprise varying the relative position of the light transmissive
35 member and the build support to successively select different regions of a layer, wherein the position of the light transmissive member determines the thickness of each

selected region, and selectively exposing each selected region to light responsive to respective model data for said selected region.

The photo-reactive substance may comprise a resin such as polymer resin.

5

As used herein, the term “light” includes both visible and non-visible light such as ultra-violet light.

In order that the invention may be more fully understood, embodiments thereof will
10 now be described by way of illustrative with reference to the accompanying drawings, in which:

Figure 1a is a y-plane section of an additive manufacturing apparatus according to an exemplary embodiment;

15

Figure 1b and 1c illustrate different stages of a layer exposure;

Figure 1d shows a curved transparent plate and light source in a “stop” position beyond the edge of the build;

Figure 1e shows the curved transparent plate and light source immediately following a “reverse direction” step;

20

Figure 2 shows an x-plane section of an additive manufacturing apparatus.

Figure 3 is a y-plane section of an additive manufacturing apparatus at the start of a build process.

Referring to Figure 1a, an additive manufacturing apparatus 1 according to an
25 exemplary embodiment of the invention comprises:

a reservoir 1 of liquid photo-reactive substance in the form of photo-setting polymer resin;

a light transmissive member in the form of a cylindrically curved, optically transparent plate 2;

30

a light source in the form of a digitally controlled, linear light source 3;

a build in the form of part built object 4, and

a build support in the form of build platform 5.

The photo-setting polymer resin solidifies when illuminated with sufficient intensity
35 from an optical source of an appropriate wavelength. The resin may include photo-

initiators, optical absorbers, and may be loaded with materials (such as ceramics or electrically conductive particles) to give desired properties to the finished object.

5 The (cylindrically) curved plate 2, is made from an optically transparent material. It is formed to have an even thickness. It transmits light to the resin. Its position determines the thickness of each layer (this is the spacing between the plate 2 and the previous build layer). The outside (resin side) of the plate 2 may be coated with a material layer, designed to minimise adherence between itself and the solidified polymer. It may also be compliant to assist in the separation from the solidified
10 polymer.

The linear light source 3 produces a line of optically illuminated pixels. The line of pixels is focussed at the front (resin side) of the transparent plate 2, or just beyond this interface. The light source 3 is digitally controlled, and may be of various wavelengths
15 depending on the resin used, although shorter wavelengths (blue to U.V.) may be used. As the plate 2 is rolled across the build, the light source 3 moves horizontally (x-direction), remaining at all times above the point where there is a minimum gap 6 between the plate 2 and the build 4. As the source 3 moves across the build, the linear light source 3 exposes a sheet of polymer to generate a slice of the build. In one
20 embodiment of this invention, the light source 3 may comprise a linear array of LED's. These may be digitally driven, and may be focussed to a line of points (pixels) using a focussing arrangement comprising a linear array of Gradient-Index (GRIN) lenses. Rather than a linear 1-D array, a 1.5-D array (a few LED's across) may also be used, with the LED offsets being accommodated in the computer drive software. The LED
25 spacing, and the focussing parameters determine the x- and y- voxel dimensions.

Other examples of suitable linear light sources include LED's connected to Fibre-optic cables, with the cable ends collated into a line (which, again may be focussed with a GRIN array), or a laser beam scanned in a line using moving / rotating mirrors.

30

The build platform 5 is constructed to adhere to the object as it is being built. It is moved in the z-direction after the exposure of each layer, setting a precise distance away from the bottom of the transparent plate 2. This distance determines the z-dimension of the voxels.

35

The apparatus 1 is controlled by a computer (not shown), which causes the apparatus to form an object in accordance with a 3D model (e.g: a computer-aided design (CAD) model).

5 The build process starts with the linear array moved to one side of the system, as shown in Figure 3. The curved optical plate 2 is rolled to the same position. The optical plate 2 is rolled, and the optical array moved linearly. It should be noted that the array and plate 2 are moved so that the array is always focussed at the front of the optical plate 2 (or slightly beyond this point, into the resin) at the position where the plate 2 is closest
10 to the build platform 5.

The build platform 5 is brought up (using computer control) so that the spacing between the bottom of the plate 2 and the top of the build platform 5 equals the Z-voxel dimension. The space is, of course, filled with liquid resin.

15 The linear array is then fired so that pixels in a line under the array are exposed, and the polymer voxels are solidified - it should be noted that only the voxels corresponding to solid space in the CAD model are exposed, this is determined and driven by the computer driving the system.

20 The linear light source 3 is then moved one voxel width in the x-direction, simultaneously rolling the optical plate 2 so that the lowest part of the plate 2 remains directly below the linear light source 3 (or above if the system is designed with the build platform 5 on the top). The array is again fired, giving another line of solidified
25 polymer voxels alongside the first line. This is shown in figures 1a) to 1c) This is repeated until the plate 2 and light source 3 have covered the full extent of the build, and then gone a little beyond the edge of the build (without firing, figure 1d). This is to minimise any damage to the build when the build platform 5 is lowered. In practice, the procedure is (or appears to be) a continuous process.

30 At this point, the build platform 5 will move away from the plate 2 by another voxel spacing, the linear light source 3 and optical plate 2 will reverse direction as shown in figure 1e, and the process of exposing a layer will be repeated, generating another solid layer of the build. This process is repeated, building up layers until the build is
35 completed.

The build platform 5 may be moved more than one voxel away from the build, and then return it to the desired position, to minimise backlash and allow resins, particularly loaded resins to flow freely and homogeneously.

5 An advantage of this system is that it minimises forces on the solidified voxels when separating from the constraining layer (e.g: the curved plate). Such forces can easily damage the build, restricting the capability of the system to produce intricate or delicate parts. The plate 2 moves (slowly) away from the solidified voxels, effectively having only a line contact with the build. Forces are significantly reduced compared to a
10 “peel” (or pull) from a single flat plate 2, particularly when viscous resins (for example filled resins) are used (as a flat plate is pulled up, the resin needs to flow in to fill the space left by the raised plate). This effect is further enhanced by the fact that the resin takes a finite time to fully harden after exposure; rolling the curved plate 2 off the exposed line immediately after exposure can mean that the solidifying polymer has not
15 had sufficient time to adhere to the plate 2.

Apparatus and method according to various embodiments of the invention are directed to high-precision additive manufacturing of large components from a photo-setting polymer resin. In embodiments, an additive manufacturing apparatus is provided
20 including a linear light source. The linear light source may comprise an array of focussed LED sources, or a scanned laser beam. The linear light source may be modulated digitally, and used to solidify individual points (voxels) of photo-setting polymer resin, layer-by-layer to create a solid object. In embodiments, the voxels of resin that are to be illuminated are precisely constrained in one dimension (the Z-
25 plane) between the solidified (i.e. previously illuminated) polymer layer, and a (cylindrically) curved, optically transparent plate. The light passes through the optically transparent plate, and is focussed at the (resin side) of this plate. The plate rolls (i.e. rotates and moves linearly) across the part (in the X-direction) as the line is scanned (in the Y-direction) to create a thin, exposed (2-D) layer (or sheet). As it rolls, the plate
30 squashes the resin into a defined gap (between it and the part-built object). After each layer of the object has been appropriately illuminated, and the corresponding polymer resin voxels solidified, the part is raised in the Z-direction, and the process repeated, building up the object layer by layer.

35 According to an exemplary embodiment, an additive manufacturing apparatus is provided comprising: a linear optical source which allows large-area builds to be made,

and a curved, optically-transparent plate, wherein the plate is arranged to roll across the object, minimising forces on the built object on movement of the build platform.

Many variations and modifications are possible. For example, in some embodiments
5 the curved plate is not rolled across the build, but is rigidly attached to the linear light source, and is effectively “wiped” across the build (i.e. it does not roll). Although this may introduce shear stress in the resin and therefore in the build, this arrangement reduces mechanical complexity of the system.

10 In embodiments, instead of a focussing system and optical plate, a light transmissive member in the form of a linear array of fibre-optic cables, each digitally driven by an LED, may be “wiped” across the build, with a resin layer between the fibre-optic cables and the part-built object. The ends of the fibre-optics may be formed in a flat and straight line, with the X- and Y- Voxel dimensions being determined by the spacing and
15 diameter (and therefore divergence angle) of the fibres. In this case, the Z- dimension is determined by the distance between the fibres and the build.

It should be noted that although Figure 1 shows the light source above the build, alternatively, the additive manufacturing apparatus may also be designed to operate
20 “upside-down”, i.e. with the build support and build above the light source. In this case, a tray may be incorporated into the design of the curved optical plate.

In a further embodiment, the light transmissive member comprises a flat optically transparent plate, and the build support, which may be curved, is rolled over the plate
25 as the linear light source moves linearly. The build platform only contacts the resin layer for the first pass (i.e. before any of the object is built). For subsequent passes, the resin is squashed between the object and the flat (optically transparent) plate. This is potentially simpler to build, but requires the object to be digitally reconstructed using non-cubic voxels.

30 Accordingly to various embodiments of the invention, an additive manufacturing apparatus is provided which can expose a large area (or volume) of resin with high precision (i.e. a small voxel size), and with minimal forces on the object during the build. It is scalable, meaning that it can be used to create systems of any size,
35 potentially of the order of a meter or so, and may be used with a variety of build-materials (such as highly viscous, loaded resin materials) that can be difficult to build

with using other systems. Embodiments of the present invention reduce the “peel time” compared with other additive manufacturing apparatus, and can therefore potentially operate faster.

- 5 Many further modifications and variations are possible, that fall within the scope of the following claims:

Claims

1. Additive manufacturing apparatus for successively exposing a plurality of layers of photo-reactive substance to form a build, comprising a build support to support the build, and a light transmissive member for transmitting light to photo-reactive substance in a layer, wherein at least one of the light transmissive member and the build support is movable relative to the other to vary a selected region of a layer during exposure of the layer such that the position of the light transmissive member determines the thickness of the selected region.
2. Additive manufacturing apparatus as claimed in claim 1, wherein at least one of the light transmissive member and the build support is arranged to be rolled relative to the other to permit relative movement between the light transmissive member and the build support.
3. Additive manufacturing apparatus as claimed in claim 2, wherein the light transmissive member comprises a curved member which can be rolled in a direction across the build and is thereby movable relative to the build support.
4. Additive manufacturing apparatus as claimed in claim 3, further comprising a light source arranged for movement in a direction across the build, wherein the light source is configured to adopt a position aligned with the selected region of the layer as the light-transmissive member is rolled in a direction across the build.
5. Additive manufacturing apparatus as claimed in claim 2, wherein the build support comprises a curved member which can be rolled relative to the light transmissive member to cause movement of the build support relative to the light transmissive member.
6. Additive manufacturing apparatus as claimed in any preceding claim, wherein at least one of the light transmissive member and the build support is movable to a position in which the light transmissive member is beyond the edge of the build.
7. Additive manufacturing apparatus as claimed in any preceding claim, further comprising a light source arranged to direct light to the light transmissive member.

8. Additive manufacturing apparatus as claimed in claim 7, wherein the light source comprises a linear light source.
9. Additive manufacturing apparatus as claimed in claim 8, wherein the light source includes a focussing arrangement comprising one or more Gradient-Index (GRIN) lenses.
10. Additive manufacturing apparatus as claimed in claim 9, wherein the light source comprises a linear array of GRIN lenses and a linear array of Light Emitting Diodes (LEDs).
11. Additive manufacturing apparatus as claimed in any preceding claim, wherein the selected region of the layer extends from one side of the layer to another opposing side, and wherein at least one of the light transmissive member and the build support is movable relative to the other to vary the selected region in a direction across the build.
13. Additive manufacturing apparatus as claimed in any preceding claim, wherein the selected region of the layer comprises a straight line region extending from one side of the layer to another opposing side, and wherein at least one of the light transmissive member and the build support is movable relative to the other to vary the selected region in a direction transverse to the straight line region.
14. Additive manufacturing apparatus as claimed in any preceding claim, wherein the light transmissive member is arranged to maintain only a line of contact with the layer as the selected region is varied.
15. Additive manufacturing apparatus as claimed in any preceding claim, wherein the thickness of the selected region remains constant as the selected region is varied.
16. Additive manufacturing apparatus as claimed in any preceding claim, wherein each layer is one voxel thick.
17. Additive manufacturing apparatus as claimed in any preceding claim, wherein: the build support is configured for movement in a first direction, away from the light transmissive member, after a layer has been exposed, so as to allow a subsequent layer to be exposed; and

wherein at least one of the light transmissive member and the build support is movable relative to the other in a second direction, transverse to the first direction, thereby to vary the selected region during exposure of the layer.

5 18. Additive manufacturing apparatus as claimed in any preceding claim, wherein the light transmissive member comprises an optically transparent member which is curved and has an even thickness.

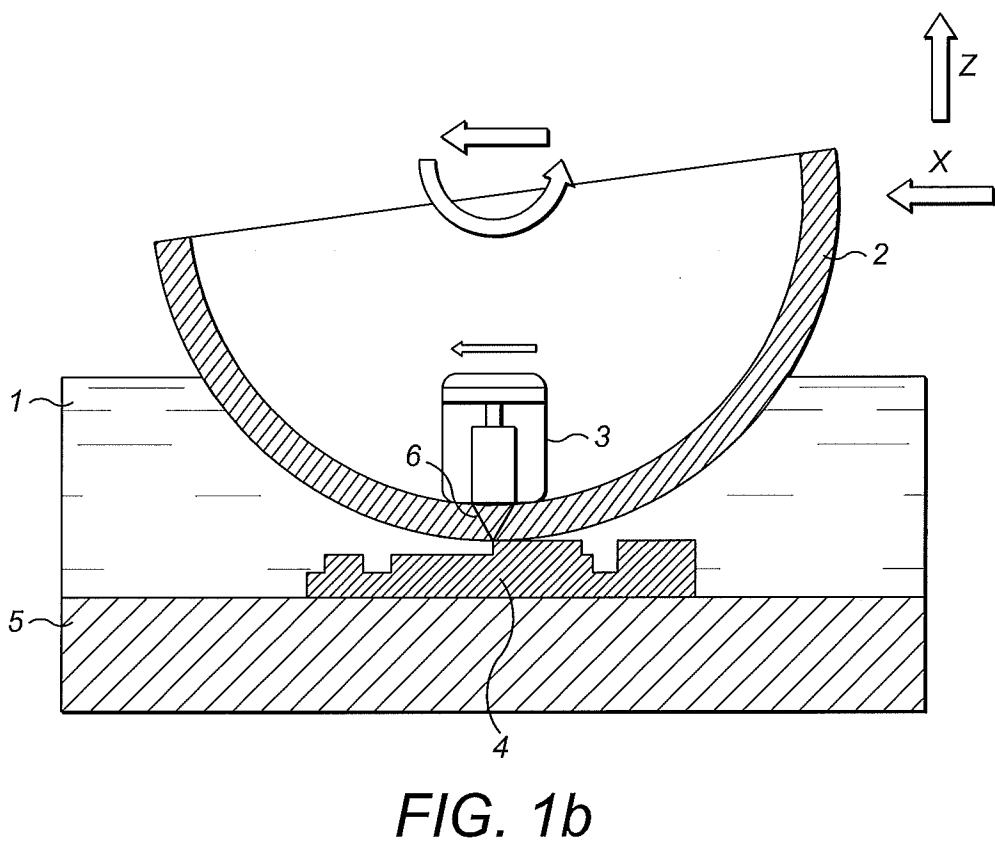
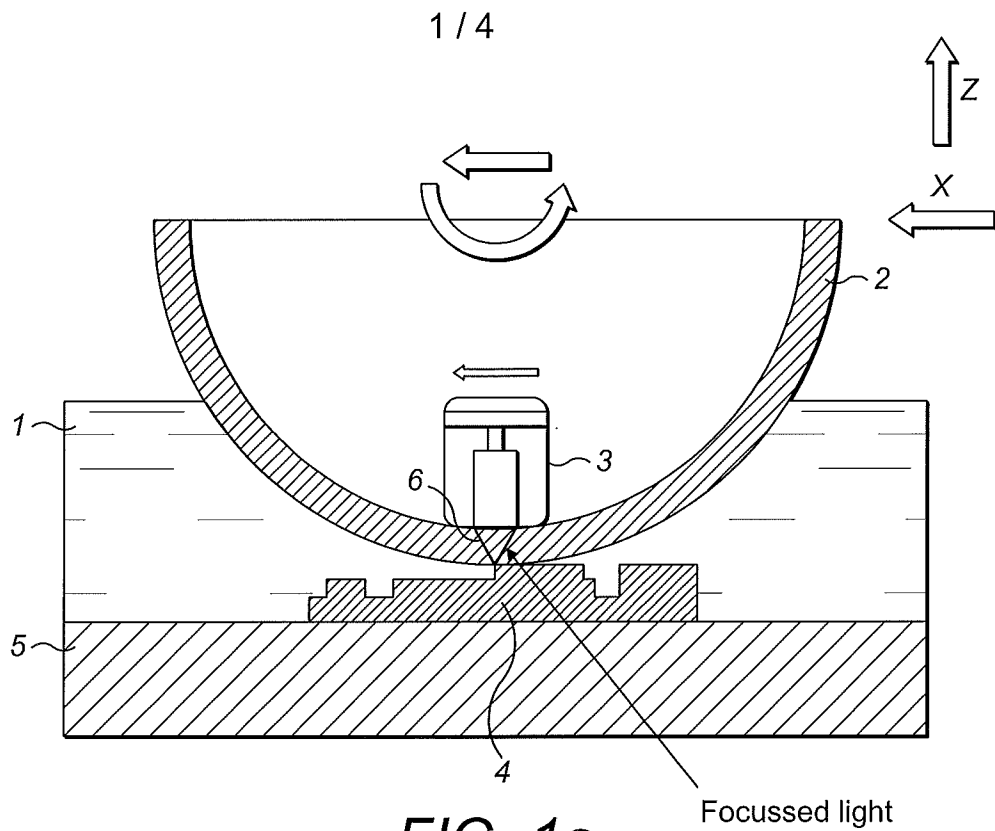
19. Additive manufacturing apparatus as claimed in claim 1, wherein the light
10 transmissive member comprises one or more optical fibres comprising a surface face region to determine the thickness of the selected region of the layer.

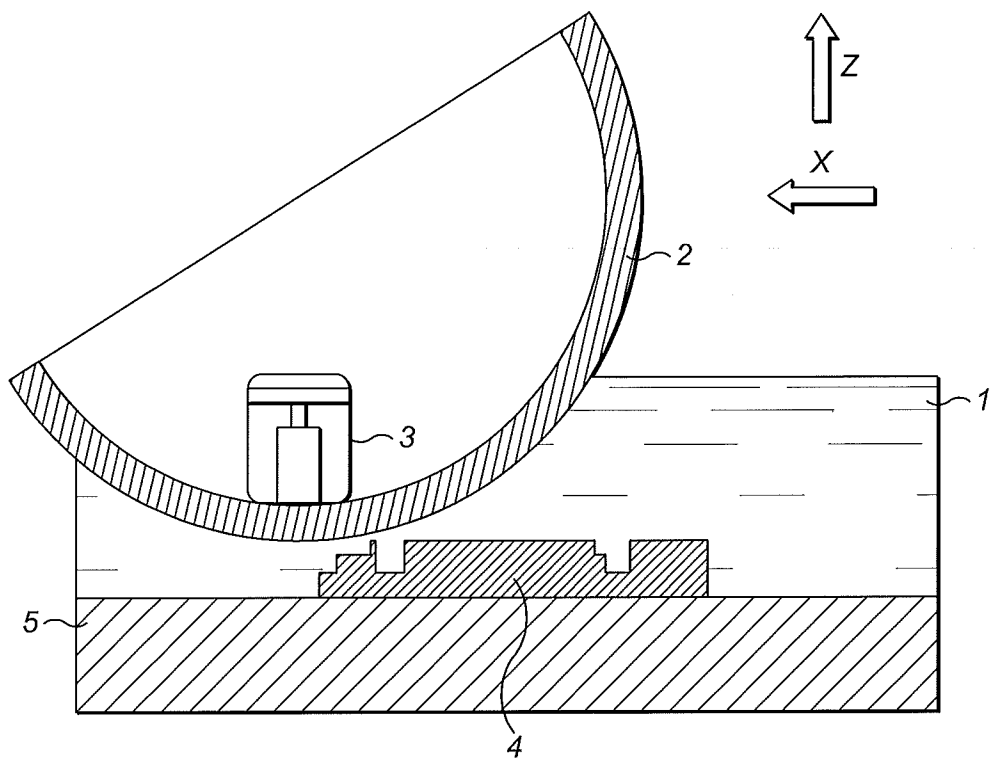
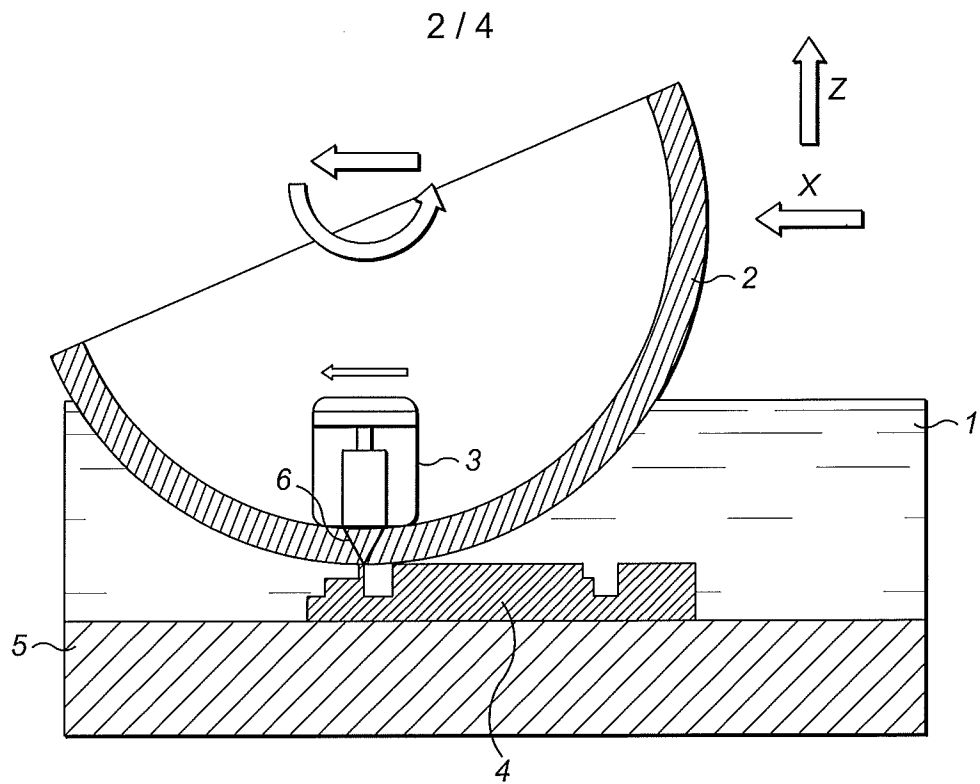
20. Additive manufacturing apparatus as claimed in claim 20, wherein the light transmissive member comprises a plurality of optical fibres having ends collated to
15 form a line which defines said surface face.

21. Additive manufacturing method, comprising:
successively exposing a plurality of layers of photo-reactive substance to light exiting a light transmissive member responsive to 3D model data, thereby to form a
20 build supported by a build support,
wherein exposing a layer comprises:
varying the relative position of the light transmissive member and the build support to select a region of a layer, wherein the position of the light transmissive member determines the thickness of the selected region; and
25 selectively exposing the selected region to light responsive to model data for said selected region.

22. Method as claimed in claim 21, wherein exposing a layer comprises:
varying the relative position of the light transmissive member and the
30 build support to successively select different regions of a layer, wherein the position of the light transmissive member determines the thickness of each selected region; and
selectively exposing each selected region to light responsive to respective model data for said selected region.

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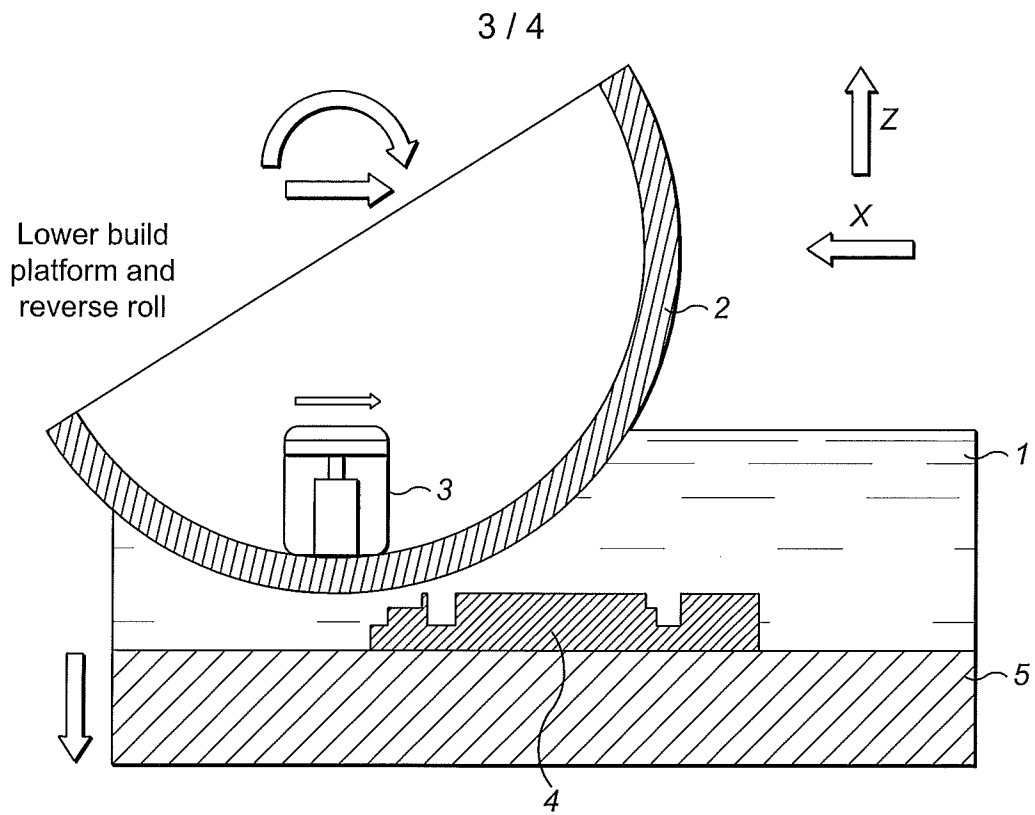


FIG. 1e

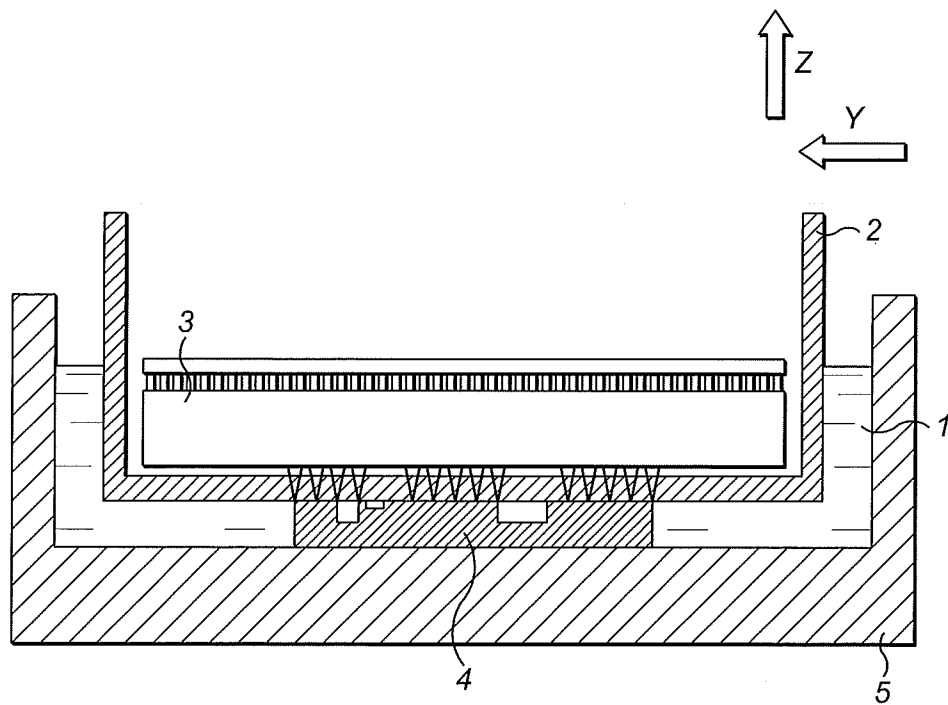
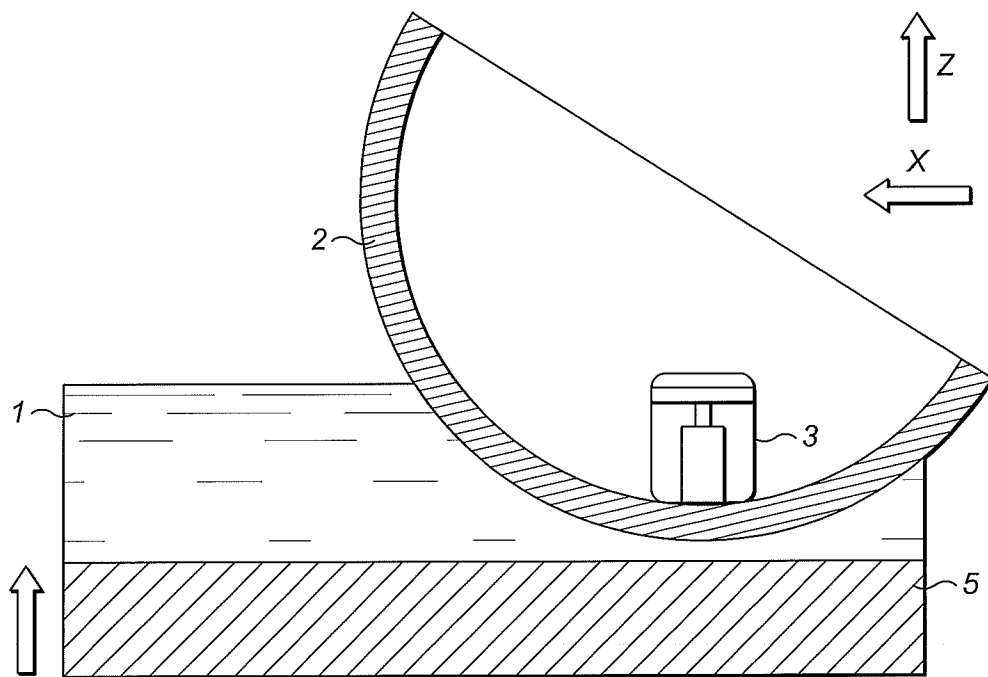


FIG. 2

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Build platform is
moved up until it
is one voxel away
from the bottom
of the plate

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/051757

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C67/00
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

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	US 2012/045617 A1 (YASUKOCHI HIROYUKI [JP]) 23 February 2012 (2012-02-23) figures paragraph [0010] - paragraph [0043] paragraph [0071] - paragraph [0085] paragraph [0097] - paragraph [0113] paragraph [0129] - paragraph [0136] paragraph [0222] - paragraph [0223] -----	1-4, 6-11, 13-22
X	US 2011/101569 A1 (YASUKOCHI HIROYUKI [JP]) 5 May 2011 (2011-05-05) figures 1-10 paragraph [0007] paragraph [0010] - paragraph [0022] paragraph [0028] - paragraph [0031] paragraph [0052] - paragraph [0128] ----- -/-	1-4, 6-11, 13-22 5
A		



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 929 402 A (HULL CHARLES W [US]) 29 May 1990 (1990-05-29) column 7, line 44 - column 8, line 20 column 10, line 33 - line 48 -----	1,19,20, 22
X	EP 2 213 443 A2 (SONY CORP [JP]) 4 August 2010 (2010-08-04) the whole document -----	1,6-11, 13,16, 17,21,22
X	US 6 547 552 B1 (FUDIM EFREM V [US]) 15 April 2003 (2003-04-15) figures 1,2 column 2, line 33 - line 47 -----	1,6-10, 13,21,22
X	EP 1 253 002 A1 (ENVISION TECHNOLOGIES GMBH [DE] ENVISIONTEC GMBH [DE]) 30 October 2002 (2002-10-30) the whole document -----	1,6-11, 13,17, 18,21,22
X	US 6 500 378 B1 (SMITH JEFFREY M [US]) 31 December 2002 (2002-12-31) claims figure 4 -----	1,6-11, 13-18, 21,22

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2013/051757

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012045617 A1	23-02-2012	AT 510306 A2	15-03-2012
		CN 102371680 A	14-03-2012
		JP 2012040757 A	01-03-2012
		US 2012045617 A1	23-02-2012
US 2011101569 A1	05-05-2011	CN 102049858 A	11-05-2011
		JP 2011098484 A	19-05-2011
		US 2011101569 A1	05-05-2011
US 4929402 A	29-05-1990	NONE	
EP 2213443 A2	04-08-2010	CN 101791858 A	04-08-2010
		EP 2213443 A2	04-08-2010
		JP 5267174 B2	21-08-2013
		JP 2010179496 A	19-08-2010
		US 2010196526 A1	05-08-2010
US 6547552 B1	15-04-2003	NONE	
EP 1253002 A1	30-10-2002	AT 378166 T	15-11-2007
		DE 10119817 A1	24-10-2002
		DK 1253002 T3	27-05-2013
		EP 1253002 A1	30-10-2002
		EP 1439051 A2	21-07-2004
		EP 1439052 A2	21-07-2004
		EP 2269809 A1	05-01-2011
		IL 149054 A	05-07-2006
		JP 4438979 B2	24-03-2010
		JP 2002370286 A	24-12-2002
		JP 2008137392 A	19-06-2008
		US 2002153640 A1	24-10-2002
		US 2007063389 A1	22-03-2007
US 6500378 B1	31-12-2002	NONE	