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(54) **Title**: STRUCTURALLY INTEGRATING METAL OBJECTS INTO ADDITIVE MANUFACTURED STRUCTURES

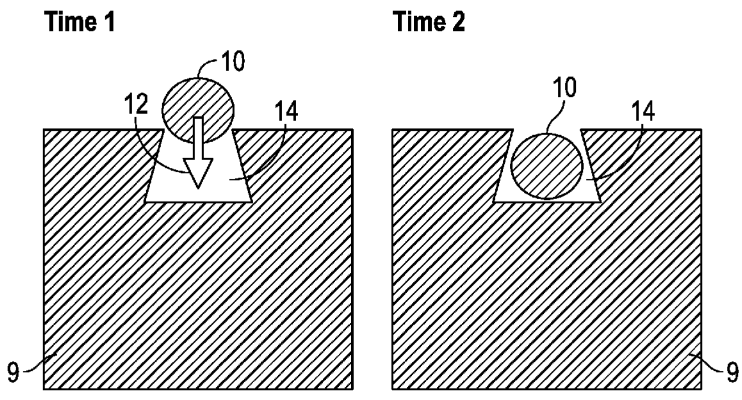

FIG. 1

(57) **Abstract**: Methods, systems, and devices for the manufacture of 3D printed components with structurally integrated metal objects using an additive manufacturing system enhanced with a range of possible secondary embedding processes. One or more layers of a three- dimensional substrate can be created by depositing a substrate, and then one or more 3D printed components can be configured on the substrate with one or more metal objects using additive manufacturing enhanced by one or more secondary embedding processes.

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STRUCTURALLY INTEGRATING METAL OBJECTS INTO ADDITIVE MANUFACTURED STRUCTURES

TECHNICAL FIELD

[0001] Embodiments are related to the field of additive manufacturing. Embodiments further relate to the manufacture of three-dimensional (3D) printed components with structurally integrated metal objects using an additive manufacturing system enhanced with a range of possible secondary embedding processes.

BACKGROUND

[0002] The next generation of manufacturing technology will require complete spatial control of material and functionality as structures are created layer-by-layer, thereby providing fully customizable, high value, multi-functional products for the consumer, biomedical, aerospace, and defense industries. With contemporary additive manufacturing ("AM" – also known more popularly as 3D printing) providing the base fabrication process, a comprehensive manufacturing suite will be integrated seamlessly to include: 1) additive manufacturing of a wide variety of robust plastics/metals; 2) micromachining; 3) laser ablation; 4) embedding of wires, metal surfaces, and fine-pitch meshes submerged within the thermoplastics; 5) micro-dispensing; and 6) robotic component placement.

[0003] Collectively, the integrated technologies will fabricate multi-material structures through the integration of multiple integrated manufacturing systems (multi-technology) to provide multi-functional products (e.g., consumer wearable electronics, bio-medical devices, defense, space, and energy systems, etc.). Paramount to this concept is the embedding of highly conductive and densely routed traces and surfaces within the 3D printed dielectric structures.

BRIEF SUMMARY

[0004] The following summary is provided to facilitate an understanding of some of the innovative features unique to the disclosed embodiments and is not intended to be a full description. A full appreciation of the various aspects of the embodiments disclosed herein can be gained by taking the entire specification, claims, drawings, and abstract as a whole.

[0005] It is, therefore, one aspect of the disclosed embodiments to provide for the manufacture of 3D printed components with structurally metal objects using an additive manufacturing system enhanced with a range of possible secondary embedding processes.

[0006] It is another aspect of the disclosed embodiments to provide for an additive manufacturing system for embedding metal objects within a structure in order to provide additional functionality such as improved mechanical strength or increased thermal or electrical conductivity.

[0007] The aforementioned aspects and other objectives and advantages can now be achieved as described herein. In an example embodiment, a method of making a three-dimensional electronic or electromechanical component/device can be implemented, which includes steps or operations for creating one or more layers of a three-dimensional substrate by depositing a substrate; and configuring on the substrate one or more 3D printed components with one or more metal objects utilizing additive manufacturing enhanced by one or more secondary embedding processes.

[0008] In another example embodiment, a three-dimensional electronic or electromechanical apparatus can be implemented, which includes one or more layers of a three-dimensional substrate deposited on a substrate; and one or more 3D printed component configured on the substrate with one or more metal objects utilizing additive manufacturing enhanced by one or more secondary embedding processes.

[0009] Method, systems, and devices are thus disclosed for the manufacture of 3D printed components with structurally integrated metal objects using an additive manufacturing system enhanced with a range of possible secondary embedding processes. The term "structurally integrated" is defined as being connected to the structure in a such a way as to (1) require a force to remove the metal object from the structure, and (2) provide an improvement in the properties of the plastic structure mechanically, thermally, and/or electrically.

[0010] Metal structures include wires with diameters ranging from sub-micron sizes upwards to almost any diameter, beams of rectangular, triangular, or any other arbitrary cross sectional geometry, lattice structures, wire meshes, metal foils, metal sheets. Any additive manufacturing system or any enhanced version of such a system that includes other complementary manufacturing processes to improve the fabricated structure either inside or outside the build envelope is included.

[0011] Secondary processes can include, but are not limited to (1) pressing the metal object into a printed press-fit channel, (2) pressing and curing the object into a channel or surface that is lined with deposited adhesive, (3) pressing a pre-coated adhesive object into a channel or surface and curing, (4) extruding both thermoplastic and thermoplastic embedded wire, (5) pressing an object into a channel and stapling the object into the structure at regular intervals, (6) pressing a pre-adhesive-coated metal foil onto a 3D printed surface, milling the metal foil to expose some fraction of the underlying 3D printed surface, continuing the 3D printing ensuring adhesion of the new thermoplastic layers to the exposed underlying thermoplastic layers, and once complete, providing a fully embedded and integrated foil piece within the thermoplastic structure, and (7) the copper wire and thermoplastic material are simultaneously deposited such that the copper wire is embedded within the thermoplastic material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The accompanying figures, in which like reference numerals refer to identical or functionally-similar elements throughout the separate views and which are incorporated in and form a part of the specification, further illustrate the present invention and, together with the detailed description of the invention, serve to explain the principles of the present invention.

[0013] FIG. 1 illustrates a cross-sectional view of a press-fit channel that can be 3D printed and then filled with a pressed metal object, in accordance with a preferred embodiment;

[0014] FIG. 2 illustrates a cross-sectional view of a channel that can be 3D printed and then filled with the pressed metal object and then stapled at regular intervals, in accordance with an alternative embodiment;

[0015] FIG. 3 illustrates a cross-sectional view of a channel, which can be 3D printed, filled with adhesive, and then filled with a pressed metal object and subsequently cured, in accordance with an alternative embodiment;

[0016] FIG. 4 illustrates a cross-sectional view of a channel that can be 3D printed, filled with adhesive-coated wire, and subsequently cured, in accordance with an alternative embodiment;

[0017] FIG. 5 illustrates cross-sectional views of an extruded thermoplastic filament wherein some filaments include a coaxial metal wire that can be used as interconnect or for reinforcements from a structural standpoint, in accordance with an alternative embodiment;

[0018] FIG. 6 illustrates a method in which a sheet that can be adhesively fixed to a 3D printed surface, milled to allow for openings to the original thermoplastic surface in order to allow for adhesion to subsequent thermoplastic layers, and for the full embedding of the foil in the structure, in accordance with an alternative embodiment; and

[0019] FIG. 7 illustrates a pictorial cross-sectional diagram depicting the use of a tool having two extrusion tips and one metal wire-dispensing tip, in accordance with an alternative embodiment.

DETAILED DESCRIPTION

[0020] The particular values and configurations discussed in these non-limiting examples can be varied and are cited merely to illustrate at least one embodiment and are not intended to limit the scope thereof.

[0021] The embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which illustrative embodiments of the invention are shown. The embodiments disclosed herein can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to identical, like, or similar elements throughout, although such numbers may be referenced in the context of different embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0022] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an", and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0023] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0024] The disclosed embodiments relate in general to the manufacture of 3D printed components with structurally integrated (defined below in A) metal objects (defined below in B) using an additive manufacturing system (defined below in C) enhanced with a range of possible secondary embedding processes (defined below in D).

[0025] Section A – "Structurally integrated" can be defined as being connected to the structure in a such a way as to (1) require a force to remove the metal object from the structure, and (2) provide an improvement in the properties of the plastic structure mechanically, thermally, and/or electrically.

[0026] Section B – Metal objects or structures can include wires with diameters ranging from sub-micron sizes upwards to almost any diameter, beams of rectangular, triangular, or any other arbitrary cross-sectional geometry, lattice structures, wire meshes, metal foils, metal sheets.

[0027] Section C – An additive manufacturing system or any enhanced version of such a system can include other complementary manufacturing processes to improve the fabricated structure either inside or outside the build envelope.

[0028] Section D – The term "secondary processes" can include, but is not limited to, for example, (1) pressing the metal object into a printed press-fit channel, (2) pressing and curing the object into a channel or surface that is lined with deposited adhesive, (3) pressing a pre-coated adhesive object into a channel or surface and curing, (4) pressing an object into a channel and stapling the object into the structure at regular intervals, (5) pressing a pre-adhesive-coated metal foil onto a 3D printed surface, milling the metal foil to expose some fraction of the underlying 3D printed surface, continuing the 3D printing ensuring adhesion of the new thermoplastic layers to the exposed underlying thermoplastic layers, and once complete, providing a fully embedded and integrated foil piece within the thermoplastic structure.

[0029] FIG. 1 illustrates a cross-sectional view of a press-fit channel 14 that can be 3D printed and then filled with a pressed metal object 10, in accordance with a preferred embodiment. The channel 14 can be formed from a structure 9, which maintains one or more channels such as channel 14. Note that in FIG. 1, the press-fit channel 14 and pressed metal object 10 are shown at Time 1 and Time 2. Arrow 12 indicates the direction or path taken by the pressed metal object 10 into the press-fit channel 14, as shown at Time 1. Then, as shown at Time 2 in FIG. 1, the pressed metal object 10 is shown within the press-fit channel 14. The cross-sectional view depicted in FIG. 1 thus illustrates 3D printed press fit channels and indicates that subsequent 3D printing is possible.

[0030] FIG. 2 illustrates a cross-sectional view of a channel (e.g., possibly press-fit design) 14 that can be 3D printed and then filled with the pressed metal object 10 and then stapled at regular intervals, in accordance with an alternative embodiment. Thus, the press-fit channel 14 is shown at Time 1 in FIG. 2 with respect to arrow 12 and the pressed metal object 10. At Time 2 shown in FIG. 2, the metal object 10 is shown stapled via wire 15 and within the channel 14. The 3D printed channel 14 can thus hold the wire 15 (which can be press fit, but not necessary), which is stapled to the structure 9 within channel 10. Subsequent 3D printing is possible.

[0031] FIG. 3 illustrates a cross-sectional view of channel 14 (e.g., possibly a press-fit design), which can be 3D printed, filled with adhesive, and then filled with a pressed metal object and subsequently cured, in accordance with an alternative embodiment. As shown at Time 1, the metal object 10 is shown with respect to channel 14 and arrow 12. An adhesive 17 is shown filled within channel 14. At time 2, the channel 14, adhesive 17, and metal object 10 are depicted as subject to a curing 16 (e.g., curing energy). Thus, 3D printed channels can hold the metal object, such as a wire (and may be press fit, but not necessarily). UV or thermal cured adhesive 17 can be deposited in the channel 14. As shown at Time 1 in FIG. 3, the metal object 10 an be inserted into channel 14 having the adhesive 17 and then cured (via curing 16) as depicted at Time 2. Subsequent 3D printing is possible.

[0032] FIG. 4 illustrates a cross-sectional view of a channel 14 (e.g., possibly a press-fit design) that can be 3D printed, filled with adhesive-coated wire, and subsequently cured, in accordance with an alternative embodiment. As shown at Time 1 in FIG. 14, the metal object 10 is coated with a thermally curable adhesive 18 and then inserted (as indicated by arrow 12) into the channel 14. The 3D printed channel 14 can hold the metal object 10 (which can be press fit as shown, but not necessary), and can then be subject to a curing cycle (i.e., curing 16), as shown at Time 2. Subsequent printing is possible.

[0033] FIG. 5 illustrates cross-sectional views of an extruded thermoplastic filament where some filaments include a coaxial metal wire that can be used as interconnect or for reinforcements from a structural standpoint, in accordance with an alternative embodiment. Example filaments 51 and 53 are depicted in FIG. 5. Filaments 51 can include, for example, an arrangement 58 composed of a thermoplastic filament 51 having a metal core. Extrusion and coextrusion tips 56 are also shown with respect to the thermoplastic filament configuration or arrangement 58. Examples of metal(s) 54 and thermoplastic 52 are depicted in the context of filaments 51. Example filaments 53 are shown with features including a separate thermoplastic filament and metal wire arrangement 60. Extrusion and coextrusion tips 62 are also illustrated in FIG. 5 with respect to filaments 52.

[0034] The thermoplastic and metal wire can be simultaneously fed into an extrusion head. The materials can be fed in as a thermoplastic filament with a metal core. Alternatively, a separate thermoplastic filament and metal wire can be fed into the extrusion head. Within the head, the metal wire will be placed in the center of the hot, flowing plastic and coextruded at the exit of the extrusion tip. At the exit of the extrusion tip, the wire and thermoplastic are coextruded such that the thermoplastic is covering the wire. The thermoplastic covering the wire allows fusion to previously deposited material such that the wire is fixed within the part or on the surface of the part.

[0035] FIG. 6 illustrates a method 70 in which a sheet 80 that can be adhesively fixed to a 3D printed surface, milled to allow for openings to the original thermoplastic surface in order to allow for adhesion to subsequent thermoplastic layers and for the full embedding of the foil in the structure, in accordance with an alternative embodiment. The method 70 shown in FIG. 6 includes process steps 72, 74, 76, and 78 with respect to the cross-sectional and top views of the structure. As shown at step 72, the initial structure 80 is provided. Then, as depicted at step 74, an operation can be implemented in which a foil 84 is attached with an adhesive on top of the initial structure 80. Then, as shown at step 76, the foil 84 can be milled exposing the original structure 80 below. Thereafter, as depicted at step 76, the foil 84 can be completely embedded and new layers of thermoplastic can adhere to the original structure 80.

[0036] FIG. 7 illustrates a pictorial cross-sectional diagram depicting the use of a tool 80 having two extrusion tips and one metal wire-dispensing tip, in accordance with an alternative embodiment. The wire-dispensing tip would lead the motion and the extrusion tips would follow. In this configuration, the wire will be placed in the desired location before being encapsulated (or embedded) by the overlaying thermoplastic beads. The tool 80 includes a double extruder head 86 and, for example, extruded thermoplastic 88 and an embedded metal wire 90. A wire feeder 82 is shown with respect to another portion of the wire 90.

[0037] The tool 80 shown in FIG. 7 can utilize, for example, two extrusion tips and one copper wire-dispensing tip (e.g., the wire feeder 82). Such a copper wire-dispensing tip would lead the motion and the extrusion tips would follow. In this configuration, the copper wire 90 will be placed in the desired location before being encapsulated (or embedded) by the overlaying thermoplastic beads.

[0038] Methods, systems, and devices are thus disclosed for the manufacture of 3D printed components with structurally integrated metal objects using an additive manufacturing system enhanced with a range of possible secondary embedding processes. Secondary processes include, but are not limited to (1) pressing the metal object into a printed press-fit channel, (2) pressing and curing the object into a channel or surface that is lined with deposited adhesive, (3) pressing a pre-coated adhesive object into a channel or surface and curing, (4) extruding both thermoplastic and thermoplastic embedded wire, (5) pressing an object into a channel and stapling the object into the structure at regular intervals, (6) pressing a pre-adhesive-coated metal foil onto a 3D printed surface, milling the metal foil to expose some fraction of the underlying 3D printed surface, continuing the 3D printing ensuring adhesion of the new thermoplastic layers to the exposed underlying thermoplastic layers, and once complete, providing a fully embedded and integrated foil piece within the thermoplastic structure, and (7) the copper wire and thermoplastic material are simultaneously deposited such that the copper wire is embedded within the thermoplastic material.

[0039] Based on the foregoing, it can be appreciated that a number of embodiments, preferred and alternative, are disclosed herein. In one example embodiment, a method of making a three-dimensional electronic or electromechanical component/device can be implemented, which includes the steps or operations of creating one or more layers of a three-dimensional substrate by depositing a substrate; and configuring on the substrate one or more 3D printed components with one or more metal objects utilizing additive manufacturing enhanced by one or more secondary embedding processes.

[0040] In some example embodiments, the secondary embedding process can involve pressing the metal object(s) into one or more printed press-fit channels configured from the substrate. In another example embodiment, the secondary embedding process can involve pressing and curing the object into a channel or a surface of a substrate that is lined with deposited adhesive. In still another example embodiment, the secondary embedding process can involve pressing a pre-coated adhesive object into a channel or a surface of a substrate followed by exposure thereof to a curing. In some example embodiments, the secondary embedding process can include extruding a thermoplastic and a thermoplastic embedded wire. In still another example embodiment, the secondary embedding process can include pressing the object into a channel and stapling the metal object into a structure of the substrate at regular intervals.

[0041] In still another example embodiment, the secondary embedding process can include pressing a pre-adhesive-coated metal foil onto a 3D printed surface; milling metal foil to expose a fraction of an underlying 3D printed surface; continuing 3D printing to ensure adhesion of new thermoplastic layers to exposed underlying thermoplastic layers; and once complete, providing a fully embedded and integrated foil piece within a thermoplastic structure.

[0042] In some example embodiments, the secondary embedding process can involve simultaneously depositing the metal object(s) and the material, wherein the metal object is embedded within the thermoplastic material. In some example embodiments, the metal object may be a copper wire.

[0043] In another example embodiment, a three-dimensional electronic or electromechanical apparatus can be implemented, which includes one or more layers of a three-dimensional substrate deposited on a substrate; and one or more 3D printed components configured on the substrate with the metal object utilizing additive manufacturing enhanced by a secondary embedding process.

[0044] It will be appreciated that variations of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also, that various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

CLAIMS

1. A method of making a three-dimensional electronic or electromechanical component/device, comprising the steps of:

creating at least one layer of a three-dimensional substrate by depositing a substrate; and

configuring on said substrate at least one 3D printed component with at least one metal object using additive manufacturing enhanced by at least one secondary embedding process.

2. The method of claim 1 wherein said at least one secondary embedding process comprises pressing said at least one metal object into at least one printed press-fit channel configured from said substrate.

3. The method of claim 1 wherein said at least one secondary embedding process comprises pressing and curing said at least one object into a channel or a surface of a substrate that is lined with deposited adhesive.

4. The method of claim 1 wherein said at least one secondary embedding process comprises pressing a pre-coated adhesive object into a channel or a surface of a substrate followed by exposure thereof to a curing.

5. The method of claim 1 wherein said at least one secondary embedding process comprises extruding a thermoplastic and a thermoplastic embedded wire.

6. The method of claim 1 wherein said at least one secondary embedding process comprises pressing said at least one object into a channel and stapling said at least one metal object into a structure of said substrate at regular intervals.

7. The method of claim 1 wherein said at least one secondary embedding process comprises:

pressing a pre-adhesive-coated metal foil onto a 3D printed surface;

milling metal foil to expose a fraction of an underlying 3D printed surface;

continuing 3D printing to ensure adhesion of new thermoplastic layers to exposed underlying thermoplastic layers; and

once complete, providing a fully embedded and integrated foil piece within a thermoplastic structure.

8. The method of claim 1 wherein said at least one secondary embedding process comprises simultaneously depositing said at least one metal object and said material, wherein said at least one metal object is embedded within said thermoplastic material.

9. The method of claim 8 wherein said at least one metal object comprises a copper wire.

10. A three-dimensional electronic or electromechanical apparatus, comprising:

at least one layer of a three-dimensional substrate deposited on a substrate; and

at least one 3D printed component configured on said substrate with at least one metal object using additive manufacturing enhanced by at least one secondary embedding process.

11. The apparatus of claim 10 wherein said at least one secondary embedding process comprises pressing said at least one metal object into at least one printed press-fit channel configured from said substrate.

12. The apparatus of claim 10 wherein said at least one secondary embedding process comprises pressing and curing said at least one object into a channel or a surface of a substrate that is lined with deposited adhesive.

13. The apparatus of claim 10 wherein said at least one secondary embedding process comprises pressing a pre-coated adhesive object into a channel or a surface of a substrate followed by exposure thereof to a curing.

14. The apparatus of claim 10 wherein said at least one secondary embedding process comprises extruding a thermoplastic and a thermoplastic embedded wire.

15. The apparatus of claim 10 wherein said at least one secondary embedding process comprises pressing said at least one object into a channel and stapling said at least one metal object into a structure of said substrate at regular intervals.

16. The apparatus of claim 10 wherein said at least one secondary embedding process comprises:

pressing a pre-adhesive-coated metal foil onto a 3D printed surface;

milling metal foil to expose a fraction of an underlying 3D printed surface;

continuing 3D printing to ensure adhesion of new thermoplastic layers to exposed underlying thermoplastic layers; and

once complete, providing a fully embedded and integrated foil piece within a thermoplastic structure.

17. The apparatus of claim 10 wherein said at least one secondary embedding process comprises simultaneously depositing said at least one metal object and said material, wherein said at least one metal object is embedded within said thermoplastic material.

18. The apparatus of claim 17 wherein said at least one metal object comprises a copper wire.

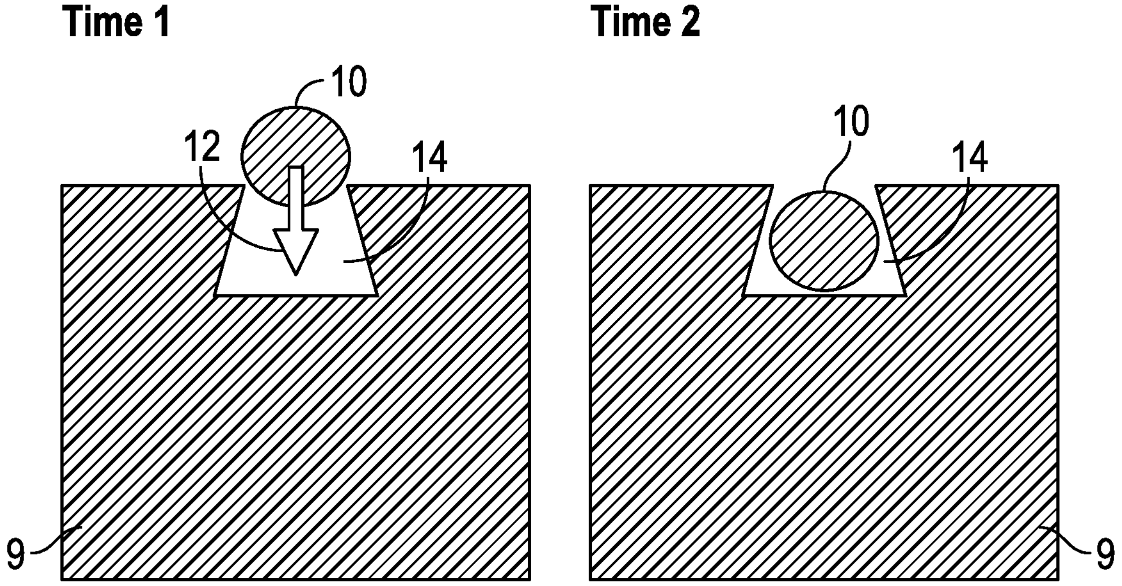

FIG. 1

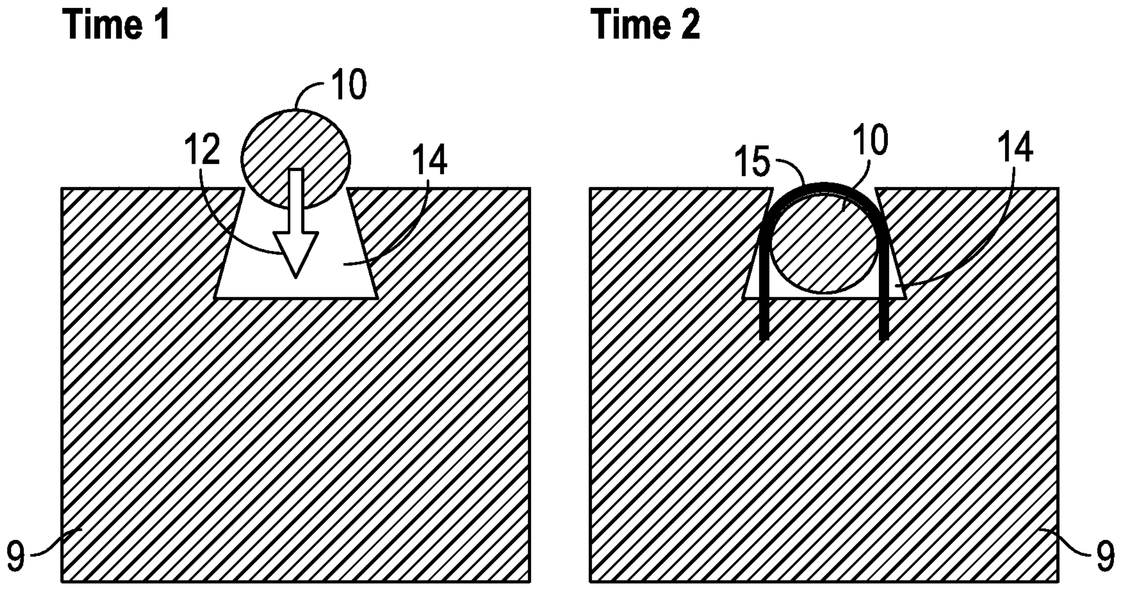

FIG. 2

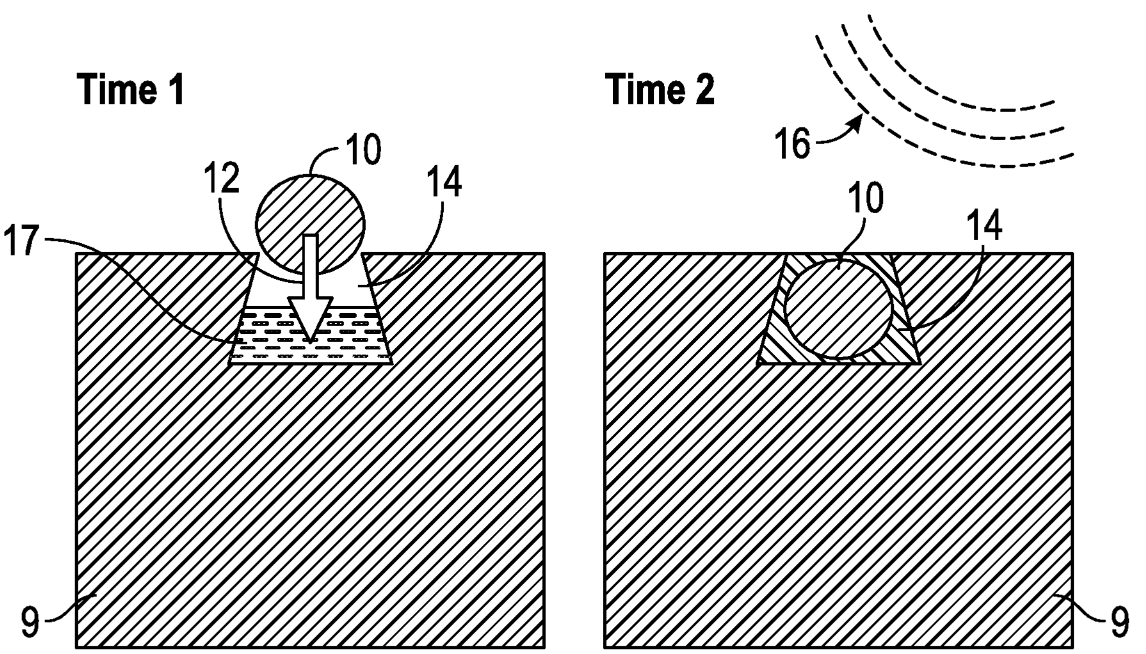
Time 1
Time 2
10
12
14
17
16
10
14
9
9

FIG. 3

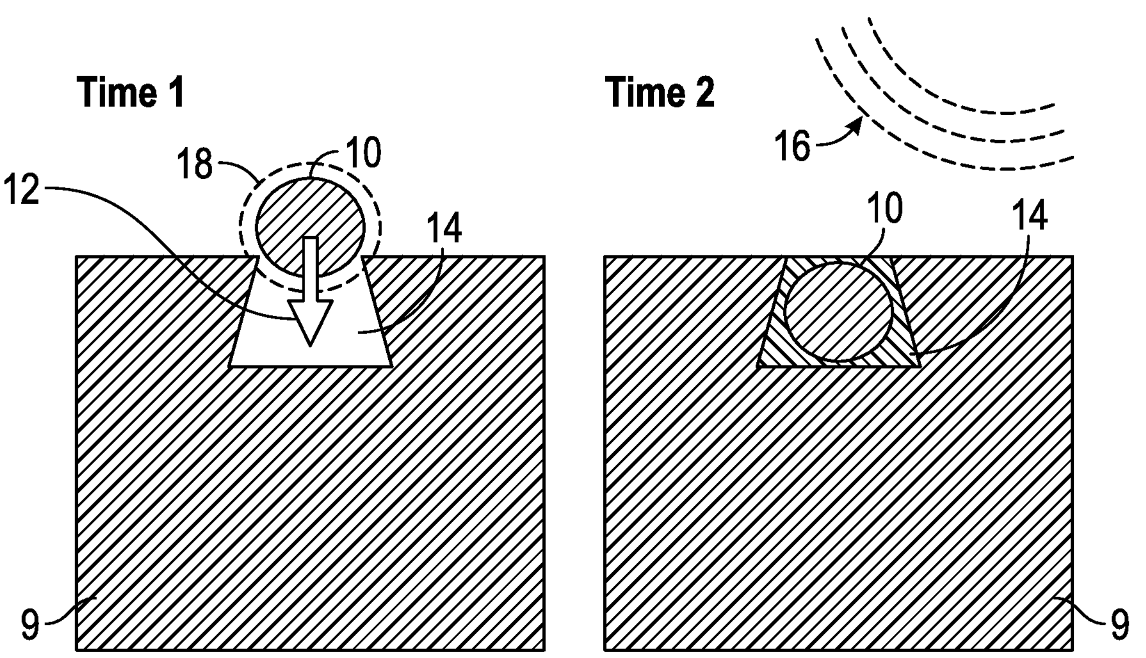
Time 1
Time 2
18
10
12
14
16
10
14
9
9

FIG. 4

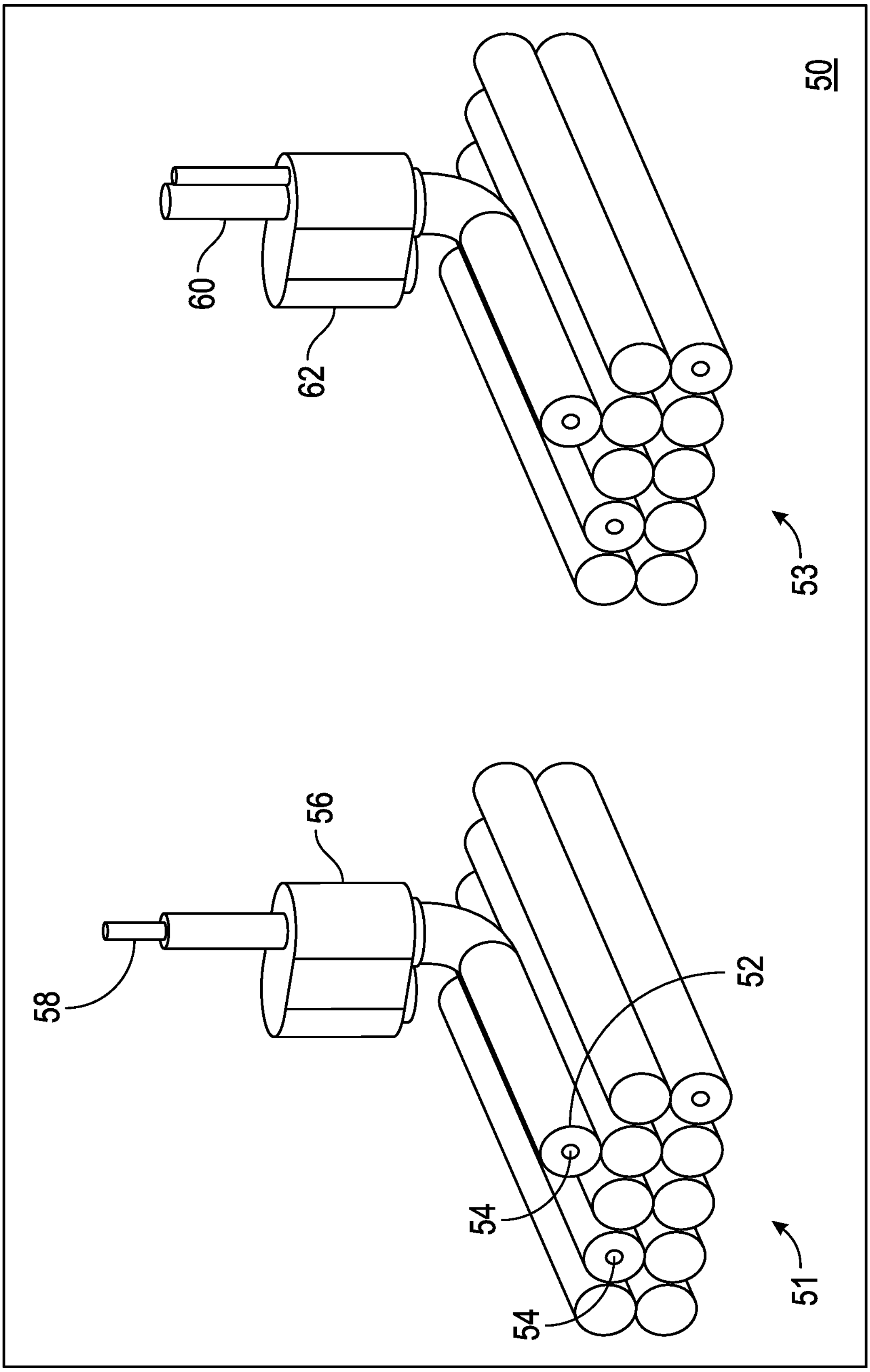

FIG. 5

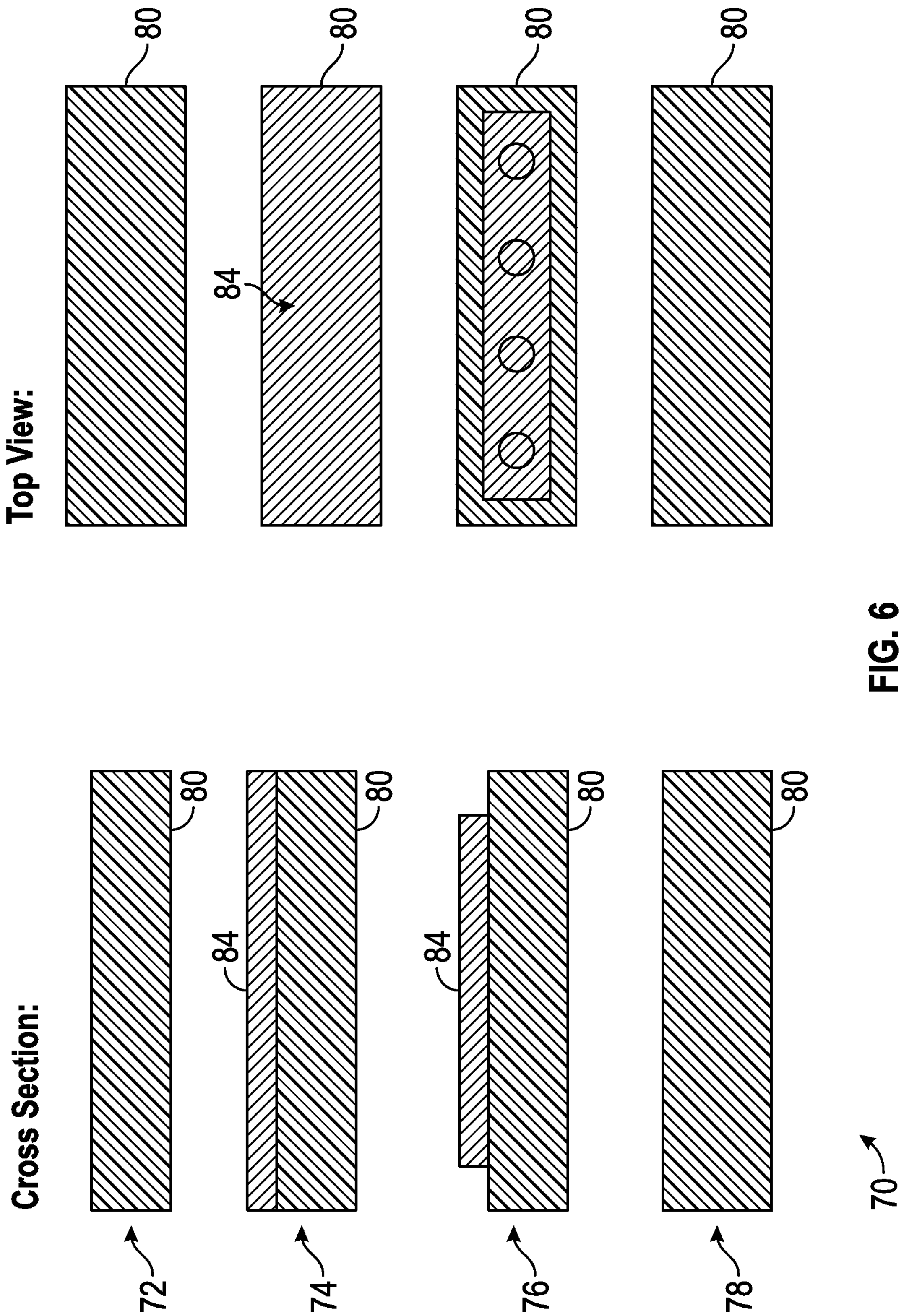

FIG. 6

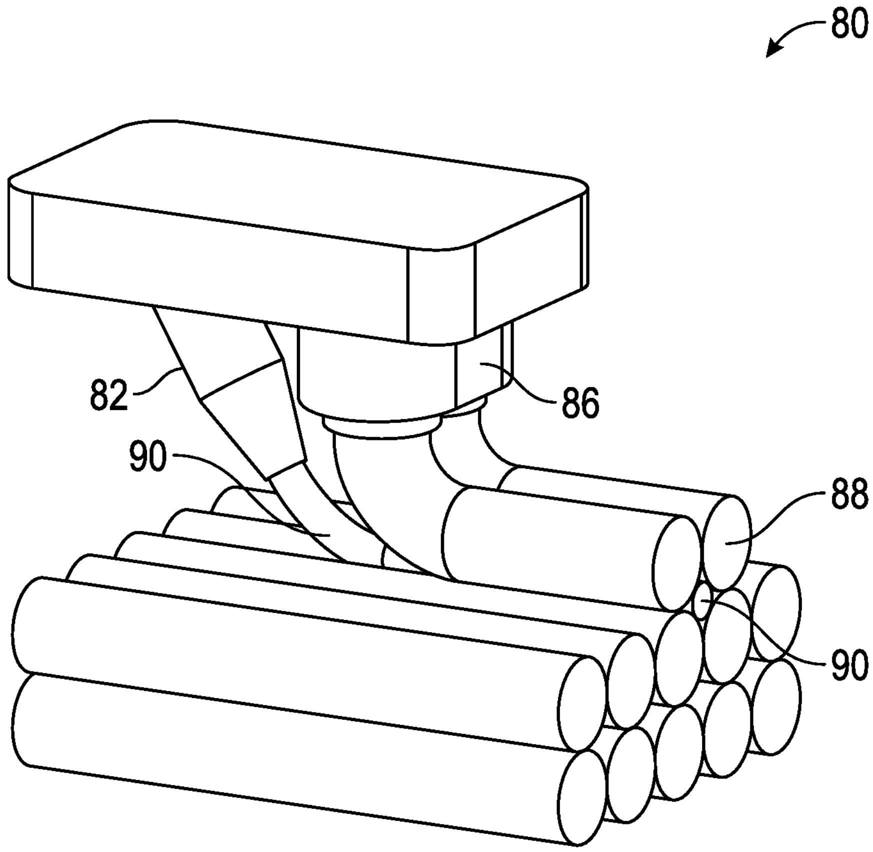

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/22292

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A01J 21/00 (2016.01)
CPC - B29C 67/0059; B29C 67/0077; B22F 3/008
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)
CPC: B29C67/0059; B29C67/0077; B22F3/008; B33Y10/00; B29C67/0051; B33Y30/00; B29C70/681; Y10T29/49171; Y10T29/49172
IPC(8): A01J 21/00 (2016.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 425/375; 425/447; 361/760; 425/517; 264/493; 264/445; 264/104; 264/486; 264/401; 264/449; 700/98; 438/156; 438/118; 361/809; 29/739; 29/832; 433/2; 156/264; 156/275.5; 156/272.8; 156/379.9; 156/538; 156/267; 156/512; 156/380.9; 156/379.8; 425/174.4

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Pat Base (AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO), Google Patent, Google Scholar; Search terms:3D printing additive manufacturing substrate embedded metal adhesive cure channel foil wire thermoplastic mill exposed surface pre-coat staple regular intervals three dimensional platform layer film enclose deposit insert glue

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y ---- A	US 2014/0268604 A1 (WICKER) 18 September 2014 (18.09.2014) para [0010], [0012], [0013], [0044], [0046], [0049], [0051], [0053], [0056], [0059], [0069], [0087]; abstract	1-2, 8-11 and 17-18 ---- 3-6 and 12-15 ---- 7 and 16
Y	US 2014/0277664 A1 (STUMP) 18 September 2014 (18.09.2014) para [0038], [0039], [0066]	3 and 12
Y	US 2008/0233528 A1 (KIM et al.) 25 September 2008 (25.09.2008) para [0083], [0084], [0100]	4 and 13
Y	US 2012/0261163 A1 (TAI et al.) 18 October 2012 (18.10.2012) [0012], [0033]; abstract	5 and 14
Y	US 2,123,609 A (MITCHELL) 12 July 1938 (12.07.1938) pg 1, col 1, ln 21-29; pg 2, col 1, ln 31-34; claim 2	6 and 15
A	US 5,637,175 A (FEYGIN et al.) 10 June 1997 (10.06.1997) col 12, ln 37-39; claim 25	7 and 16
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☐ Further documents are listed in the continuation of Box C. ☐

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Date of the actual completion of the international search	Date of mailing of the international search report
24 May 2016 (24.05.2016)	12 JUL 2016

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