



(51) International Patent Classification:

*H05K 3/32* (2006.01) *G01R 1/04* (2006.01)  
*H05K 7/10* (2006.01) *H05K 3/30* (2006.01)

(21) International Application Number:

PCT/US2022/045058

(22) International Filing Date:

28 September 2022 (28.09.2022)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: **HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.** [US/US]; 10300 Energy Drive, Spring, Texas 77389 (US).

(72) Inventors: **JHAVERI, Sanil Parag**; 1501 Page Mill Rd, Palo Alto, California 94304-1100 (US). **WITTKOPF, Jar-rid Alexander**; 1501 Page Mill Rd, Palo Alto, California 94304-1100 (US).

(74) Agent: **MCFARLAND, Elena K.** et al.; SHOOK, HARDY, & BACON, L.L.P., 2555 Grand Boulevard, Kansas City, MO 64108-2613 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

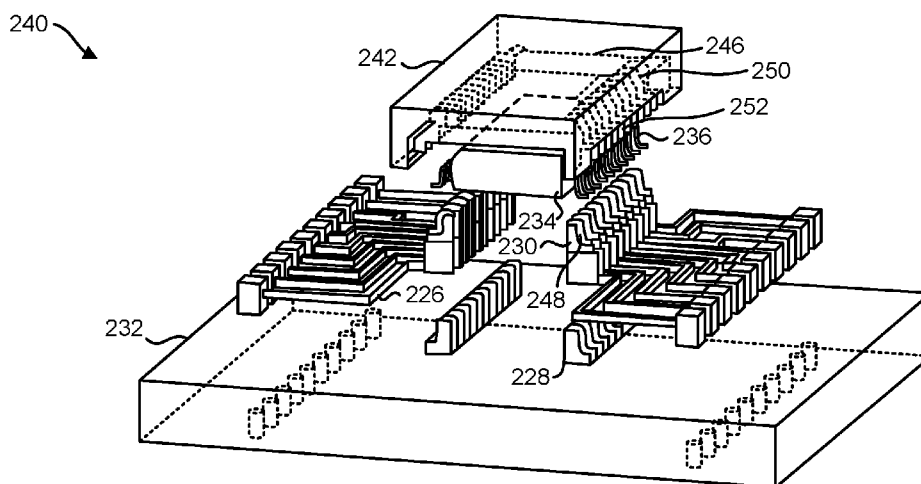
CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: RETENTION STRUCTURES



**FIG. 2**

(57) Abstract: Examples of retention structures 242 are described herein. In some examples, an apparatus 240 includes a three-dimensional (3D) printed substrate 232. In some examples, the apparatus includes a 3D printed contact 230 included in the 3D printed substrate 232 to interface with an external circuit package 234. In some examples, the apparatus 240 includes a retention structure 242 to hold the external circuit package 234 on a top side of the external circuit package.



## RETENTION STRUCTURES

### BACKGROUND

**[0001]** Three-dimensional (3D) solid objects may be produced from a digital model using additive manufacturing. Additive manufacturing may be used in rapid prototyping, mold generation, mold master generation, and short-run manufacturing. Additive manufacturing involves the application of successive layers of build material. In some additive manufacturing techniques, the build material may be cured or fused.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0002]** Figure 1 is a diagram illustrating an exploded perspective view of an example of an apparatus;

**[0003]** Figure 2 is a diagram illustrating an exploded perspective view of an example of an apparatus;

**[0004]** Figure 3 is a diagram illustrating a bottom perspective view of an example of the retention structure of Figure 2;

**[0005]** Figure 4 is a diagram illustrating a perspective view of an example of an apparatus;

**[0006]** Figure 5 is a diagram illustrating a perspective view of an example of a 3D printed substrate;

**[0007]** Figure 6 is a diagram illustrating a perspective view of an example of the 3D printed substrate of Figure 5 with inserted pins;

**[0008]** Figure 7 is a diagram illustrating a top view and a side view of an example of a 3D printed substrate;

**[0009]** Figure 8 is a block diagram of an example of an electronic device that may be used to design and/or manufacture a structure or structures described herein;

**[0010]** Figure 9 is a block diagram illustrating an example of a computer-readable medium for apparatus design;

**[0011]** Figure 10 is a flow diagram illustrating an example of a method for automatically designing a structure or structures described herein;

**[0012]** Figure 11 is a flow diagram illustrating an example of a method for designing a conformal structure(s); and

**[0013]** Figure 12 is a flow diagram illustrating an example of method for manufacturing a structure(s) in accordance with some of the techniques described herein.

## DETAILED DESCRIPTION

**[0014]** It may be helpful for a 3D printed object (e.g., 3D printed electronics) to interface with an electronic component (e.g., an integrated circuit (IC) package). Some approaches to interface a 3D printed object with an electronic component may utilize techniques (e.g., soldering) that may be unsuitable for 3D printed conductive surfaces due to using high temperatures that can damage the 3D printed object. Moreover, some conductive surfaces (e.g., printed circuits with sintered silver nanoparticles) may have difficulty achieving good surface conductivity without post-processing or accommodation in the design and print process.

**[0015]** Some examples of the techniques described herein may utilize a retention structure to interface with (e.g., interlock) an electronic component, mechanically support the electronic component on a substrate (e.g., 3D printed substrate), align a contact(s) of the electronic component onto the substrate, and/or provide a contact structure to reduce contact resistance with the electronic component and the substrate. Some examples of the techniques described herein may allow for interfaces with enhanced reliability and/or may provide enhanced assembly by aiding in alignment. Some examples of the

techniques described herein may be utilized in integrating an electronic component between nesting and/or interlocking designs. Some examples of the techniques described herein may be utilized with 3D printing.

**[0016]** Some examples of 3D printing may selectively deposit an agent or agents (e.g., droplets). An agent is a printable substance (e.g., fluid, solution, liquid, particles, etc.). In some examples, agents may be deposited at a pixel level to enable control over voxel-level energy deposition. For instance, thermal energy may be projected over material in a build area, where a phase change (for example, melting and solidification) in the material may occur depending on the voxels where the agents are deposited. Examples of agents include fusing agent and detailing agent. A fusing agent is an agent that causes material to fuse (e.g., sinter, melt, etc.) when exposed to energy. A detailing agent is an agent that reduces or prevents fusing.

**[0017]** A voxel is a representation of a location in a 3D space. For example, a voxel may represent a volume or component of a 3D space. For instance, a voxel may represent a volume that is a subset of the 3D space. In some examples, voxels may be arranged on a 3D grid. For instance, a voxel may be rectangular or cubic in shape. Examples of a voxel size dimension may include 25.4 millimeters (mm)/150  $\approx$  170 microns for 150 dots per inch (DPI), 490 microns for 50 DPI, 2 mm, etc. A set of voxels may be utilized to represent a build volume.

**[0018]** A build volume is a volume in which an object or objects may be manufactured. A “build” may refer to an instance of 3D manufacturing. For instance, a build may specify the location(s) of object(s) in the build volume. In some examples, an “object” may refer to an area and/or volume in a build indicated for forming an object.

**[0019]** Fusing agent and/or detailing agent may be used in 3D manufacturing to provide selectivity to fuse objects and/or ensure accurate geometry. For example, fusing agent may be used to absorb lamp energy, which may cause material to fuse in locations where the fusing agent is applied. Detailing agent may be used to modulate fusing by providing a cooling effect at the interface between an object and material (e.g., powder). Detailing agent may be used for

interior features (e.g., holes), corners, and/or thin boundaries. An amount or amounts of agent (e.g., fusing agent and/or detailing agent) and/or a location or locations of agent (e.g., fusing agent and/or detailing agent) may be determined for manufacturing an object or objects. For instance, an agent map may be determined. An agent map is data (e.g., an image) that indicates a location or locations to apply agent. For instance, an agent map may be utilized to control an agent applicator (e.g., nozzle(s), print head(s), etc.) to apply agent to material for manufacturing. In some examples, an agent map may be a two-dimensional (2D) array of values indicating a location or locations for placing agent on a layer of material.

**[0020]** In some examples, a structure(s) described herein may be manufactured by three-dimensional (3D) printing, another manufacturing technique(s), or a combination thereof. For instance, some examples may be manufactured with a plastic(s), polymer(s), semi-crystalline material(s), and/or metal(s), etc. Some 3D printing techniques may be powder-based and driven by powder fusion. Some examples of 3D printing that may be utilized to manufacture some examples of the structures described herein may include Fused Deposition Modeling (FDM), Multi-Jet Fusion (MJF), Selective Laser Sintering (SLS), binder jet, Stereolithography (SLA), Selective Laser Melting (SLM), Electron Beam Melting (EBM), Metal Jet Fusion, metal binding printing, liquid resin-based printing, etc. For instance, a retention structure, a substrate, and/or a part thereof may be manufactured with 3D printing.

**[0021]** In some examples of 3D printing, a binding agent (e.g., adhesive) may be printed onto material in a build volume to bind powder (e.g., particles) and form a precursor object (e.g., “green part”). The precursor object may be heated (in an oven or heating apparatus, for example) to sinter the precursor object and form a solid part.

**[0022]** Throughout the drawings, similar reference numbers may designate similar or identical elements. When an element is referred to without a reference number, this may refer to the element generally, with and/or without limitation to any particular drawing or figure. In some examples, the drawings are not to scale and/or the size of some parts may be exaggerated to more clearly

illustrate the example shown. Moreover, the drawings provide examples in accordance with the description. However, the description is not limited to the examples provided in the drawings.

**[0023]** Figure 1 is a diagram illustrating an exploded perspective view of an example of an apparatus 120. The apparatus 120 is a device or a portion of a device. For instance, the apparatus 120 may be a device that includes electronic circuitry. The apparatus 120 may include a 3D printed substrate 112. The 3D printed substrate 112 is a 3D printed object that includes a conductor(s) (e.g., trace(s), wire(s), conductive line(s), connector(s), etc.). For instance, the 3D printed substrate 112 may be printed with a 3D printer. The 3D printed substrate 112 may include a non-conductive portion(s) (e.g., a plastic body) and a conductive portion(s) (e.g., metal channel(s), trace(s), route(s), etc.). In some examples, the 3D printed substrate 112 may be rectangular, irregularly shaped, curved, prismatic, polygonal, circular (e.g., tubular), or a combination thereof.

**[0024]** The apparatus 120 may include a 3D printed contact 110. The 3D printed contact 110 is a conductor to interface with (e.g., touch, contact, mechanically intersect with, join with, etc.) another conductor (e.g., circuitry, circuit package, lead, pin, and/or coupler, etc.). For instance, the 3D printed contact 110 may be formed from 3D printed metal particles (e.g., silver, gold, copper, etc.). In some examples, a 3D printer may print a conductor(s) and/or conductive region(s) (e.g., contact(s), trace(s), etc.). For instance, a 3D printer may print a conductive agent that includes conductive particles (e.g., silver nanoparticles). The conductive agent may be printed on build material (e.g., polymer). The conductive agent may be sintered (with the build material, for instance) to form a conductor(s). In some examples, the conductive agent may be printed in a region(s) indicated by a conductive agent map. In some examples, the 3D printed contact 110 may protrude from the 3D printed substrate 112. For instance, the 3D printed contact 110 may extend beyond a surface of the 3D printed substrate 112. In some examples, the 3D printed contact 110 may be disposed flush with the 3D printed substrate 112. For instance, the 3D printed contact 110 may be disposed at a level with (e.g., approximately coplanar with) a surface of the 3D printed substrate 112. In some

examples, the 3D printed contact 110 may be buried in the 3D printed substrate 112. For instance, the 3D printed contact 110 may be disposed below a surface of the 3D printed substrate 112. The 3D printed contact 110 may be connected to a trace, route, wire, etc., in the 3D printed substrate 112. While one 3D printed contact 110 is illustrated in Figure 1, one 3D printed contact or multiple 3D printed contacts may be included in the 3D printed substrate 112 in some examples.

**[0025]** In some examples, detailing agent may be applied to the 3D printed contact 110 during printing. For instance, detailing agent may be applied to material (e.g., powder) adjacent to (e.g., on) the 3D printed contact 110. The detailing agent may reduce fusing of material (e.g., non-conductive material) on the 3D printed contact 110, which may enhance surface conductivity of the 3D printed contact 110. For instance, detailing agent may be applied to the 3D printed contact 110 to produce and/or enhance surface electrical contactability during printing.

**[0026]** The 3D printed contact 110 may be disposed to interface with an external circuit package 114. A circuit package is a circuit component(s) (e.g., integrated circuit) included in packaging. For instance, a circuit package may include circuitry encased in protective packaging (e.g., plastic, glass, and/or ceramic, etc.). Examples of a circuit package may include a single in-line package (SIP), dual in-line package (DIP), ceramic DIP (CDIP), molded DIP (MDIP), plastic DIP (PDIP), glass-sealed ceramic DIP (CERDIP), quadruple in-line package (QIP), quad flat package (QFP), small outline integrated circuit (SOIC), dual-flat no-leads (DFN), small outline transistor (SOT23), etc. Some examples of the techniques described herein may be utilized to reinforce the connection of surface mount devices such as QFP, SOIC, DFN, SOT23, etc. In some examples, a circuit package (e.g., external circuit package) may be a connector interface and/or may include a connector interface. For instance, a circuit package may be a Universal Serial Bus (USB) connector interface, an Ethernet connector interface, High-Definition Multimedia Interface (HDMI) connector interface, a Video Graphics Array (VGA) connector interface, a power connector interface, etc.

**[0027]** An external circuit package is a circuit package that is external to a substrate to which the circuit package may be attached. For instance, the external circuit package 114 is external to the 3D printed substrate 112. In some examples, the external circuit package 114 may be manufactured separately from the 3D printed substrate 112. For instance, the external circuit package 114 may be manufactured utilizing another technique (e.g., molding, etching, lamination, electroplating, etc.) besides 3D printing. In some examples, the external circuit package 114 may not be embedded in the 3D printed substrate 112. For instance, the package or packaging of the external circuit package 114 may not be disposed within a 3D printed object (e.g., may not be embedded in printed layers of a 3D printed object). In some examples, the external circuit package 114 may be attached to the 3D printed substrate 112 after 3D printing of the 3D printed substrate 112 is complete. For instance, the external circuit package 114 and the 3D printed substrate 112 may be assembled after 3D printing of the 3D printed substrate 112 is complete and/or without further 3D printing to assemble the external circuit package 114 and the 3D printed substrate 112. In some examples, the external circuit package 114 may not be buried (e.g., may not be completely buried) in 3D printed material. In some examples, additional 3D printing may be performed after the external circuit package 114 is assembled with the 3D printed substrate.

**[0028]** In some examples, the external circuit package 114 may include a lead 116. A lead 116 is a conductor (e.g., pin, wire, ribbon, tooth, etc.) to connect the external circuit package 114 to a contact. For instance, the lead 116 may be disposed to contact the 3D printed contact 110. While one lead 116 is illustrated in Figure 1, one lead or leads may be included in the external circuit package 114 in some examples.

**[0029]** The apparatus 120 may include a retention structure 122 to hold the external circuit package 114 on a top side 124 of the external circuit package 114. A retention structure is a structure to retain assembly of an external circuit package and a substrate. For instance, the retention structure 122 may retain assembly of the external circuit package 114 and the 3D printed substrate 112.

**[0030]** In some examples, the retention structure 122 may be 3D printed. For example, the retention structure 122 may be 3D printed with the 3D printed substrate 112 (e.g., printed in a same build and/or batch). In some examples, the retention structure 122 may be manufactured separately from the 3D printed substrate 112. For instance, the retention structure 122 may be 3D printed in a separate build or batch. In some examples, the retention structure 122 may be manufactured utilizing a different technique than 3D printing. For instance, the retention structure 122 may be manufactured using molding (e.g., injection molding), casting, machining, and/or stamping, etc. In some examples, the retention structure 122 may be manufactured with a same material utilized to manufacture the 3D printed substrate 112. In some examples, the retention structure 122 may be manufactured with a material that is different from a material utilized to manufacture the 3D printed substrate 112.

**[0031]** The retention structure 122 may hold the external circuit package 114 on a top side 124 of the external circuit package 114. As used herein, a “top side” of an external circuit package may refer to a side and/or surface of an external circuit package that is away from (e.g., opposite from) an interfacing side of an external circuit package. An interfacing side may be a side disposed towards a contact and/or substrate (e.g., towards the 3D printed substrate 112 and/or the 3D printed contact 110). For instance, the retention structure 122 may contact the top side 124 of the external circuit package 114 and/or may be situated on or over the top side 124 of the external circuit package 114.

**[0032]** In some examples, the retention structure 122 is a cap to be disposed on the top side 124 of the external circuit package 114. For instance, the retention structure 122 may be disposed on the top side 124 of the external circuit package 114 during assembly. In some examples, the retention structure 122 may include a depression (not shown in Figure 1) to house the top side 124 of the external circuit package 114. For instance, a bottom portion of the retention structure 122 may include a depression or well, within which the external circuit package 114 (e.g., top side 124) may be disposed during assembly. An example of a cap retention structure with a depression is described in relation to Figures 2–3.

**[0033]** In some examples, the retention structure 122 includes a ridge (not shown in Figure 1) to engage the top side of the lead 116 of the external circuit package 114. For instance, the ridge may provide support to press the lead 116 onto the 3D printed contact 110.

**[0034]** In some examples, the retention structure 122 comprises a clip (not shown in Figure 1) attached to the 3D printed substrate 112. For instance, the clip may be an arm extending from the 3D printed substrate 112 with an edge that may engage (e.g., mechanically interfere with) a portion of the top side 124. An example of clips is described in relation to Figure 4.

**[0035]** In some examples, the 3D printed contact 110 may be buried in the 3D printed substrate 112. In some examples, the 3D printed substrate 112 may include an insertion region (not shown in Figure 1). The insertion region may be utilized to insert the lead 116 and/or a pin into contact with the 3D printed contact 110. The insertion region may include a hole and/or unfused material (e.g., powder) in the 3D printed substrate 112. For instance, the lead 116 may be inserted into the insertion region into contact with the buried 3D printed contact 110. In some examples, a pin may be inserted into the insertion region into contact with the buried 3D printed contact 110. The lead 116 may be placed into contact with the pin to interface with the buried 3D printed contact 110. Examples of buried contacts and pins are given in relation to Figures 5–8.

**[0036]** Some examples of the techniques described herein may be utilized in conjunction with a bonding technique(s). For instance, soldering, bonding adhesive (e.g., conductive adhesive), low temperature solder paste (e.g., tin-bismuth alloy to melt in a range of 150–175 degrees), and/or anisotropic conductive film (ACF), etc., may be utilized to attach a lead(s) to a contact(s).

**[0037]** Figure 2 is a diagram illustrating an exploded perspective view of an example of an apparatus 240. The apparatus 240 may be an example of the apparatus 120 described in relation to Figure 1. The apparatus 240 may include a 3D printed substrate 232, 3D printed contacts 230, and a retention structure 242. The 3D printed substrate 232, 3D printed contacts 230, and/or retention structure 242 may be examples of corresponding elements described in relation to Figure 1. Figure 3 is a diagram illustrating a bottom perspective view of an

example of the retention structure 242 of Figure 2. Figure 2 and Figure 3 are described together.

**[0038]** The 3D printed substrate 232 includes traces 226. For instance, the traces 226 may be disposed within the 3D printed substrate 232. Each of the traces may be respectively coupled to the 3D printed contacts 230. In the example of Figure 2, the contacts 230 protrude from the 3D printed substrate 232. For instance, the 3D printed contacts 230 extend beyond the upper surface of the 3D printed substrate 232. In the example of Figure 2, detailing agent 248 is applied to the 3D printed contacts 230 during printing.

**[0039]** The 3D printed contacts 230 are disposed to interface with an external circuit package 234. In the example of Figure 2, the external circuit package 234 includes two rows of leads 236. The leads 236 are disposed to contact the 3D printed contacts 230. In the example of Figure 2, the 3D printed substrate 232 includes protrusions 228 to isolate the leads 236 of the external circuit package 234. For instance, some examples of a 3D printed substrate may include a protrusion or protrusions. A protrusion may be a barrier, wall, etc., to be situated between 3D printed contacts and/or between leads of an external circuit package. In the example of Figure 2, the protrusions 228 may be situated between the 3D printed contacts 230. In the example of Figure 2, the protrusions 228 extend above the 3D printed contacts 230, where the protrusions 228 may serve to isolate the leads 236 of the external circuit package 234 when the external circuit package 234 is assembled with the 3D printed substrate 232. For instance, the protrusions 228 may be situated between the leads 236 to electrically insulate the leads 236 and/or to help avoid contact between the leads 236. In some examples, the protrusions 228 may provide an alignment feature(s) with the external circuit package 234 and/or with the retention structure 242.

**[0040]** The retention structure 242 may hold the external circuit package 234 on a top side of the external circuit package 234. For instance, the retention structure 242 may retain the external circuit package 234 on the 3D printed substrate 232. The retention structure 242 may also align the external circuit package 234 with the 3D printed substrate 232. For instance, the retention

structure 242 includes alignment features 252. The alignment features 252 may interlock with the protrusions 228 of the 3D printed substrate 232.

**[0041]** In the example of Figure 2, the retention structure 242 is a cap to be disposed on the top side of the external circuit package 234. For instance, the retention structure 242 may be disposed on the top side 124 of the external circuit package 234 during assembly. In the example of Figure 2, the retention structure 242 includes a depression 246 to house the top side of the external circuit package 234. For instance, the bottom portion of the retention structure 242 includes a depression 246 (e.g., well), within which the external circuit package 234 may be disposed during assembly. In some examples, the depression 246 may be shaped relative to the top side of the external circuit package 234. For instance, the depression 246 may be shaped relative to an upper portion (e.g., top, upper side(s), and/or other features) of the external circuit package 234 to allow the upper portion of the external circuit package 234 to fit in the depression 246. In some examples, the depression 246 may be determined as a geometric subtraction (with or without a margin) between a model for the retention structure 242 and the upper portion of a model of the external circuit package 234.

**[0042]** In the example of Figure 2, the retention structure 242 includes ridges 250 to engage the top sides of the leads 236 of the external circuit package 234. For instance, the ridges 250 provide support to press the leads 236 onto the 3D printed contacts 230.

**[0043]** Figure 4 is a diagram illustrating a perspective view of an example of an apparatus 454. The apparatus 454 may be an example of the apparatus 120 described in relation to Figure 1. The apparatus 454 may include a 3D printed substrate 456, 3D printed contacts 458 (e.g., buried contacts), and retention structures 460, 462. The 3D printed substrate 456, 3D printed contacts 458, and/or retention structures 460, 462 may be examples of corresponding elements described in relation to Figure 1.

**[0044]** In the example of Figure 4, the retention structures 460, 462 are clips attached to the 3D printed substrate 456. For instance, the clips are arms extending from the 3D printed substrate 456 with edges 464, 466 to engage

(e.g., mechanically interfere with) portions of the top side of an external circuit package. In some examples, the retention structures 460, 462 may be 3D printed (with the 3D printed substrate 456 or separate from the 3D printed substrate 456). In some examples, the retentions structures 460, 462 may be manufactured using a manufacturing technique other than 3D printing (e.g., injection molding, machining, etc.). In some examples, the retention structures 460, 462 may be manufactured separately from the 3D printed substrate 456 and assembled (e.g., attached) to the 3D printed substrate 456 after printing. In some examples, a 3D printed substrate may include a slot(s) to attach a retention structure(s) (e.g., clip(s)). For instance, the 3D printed substrate 456 includes slots with snap fittings to attach the clips and/or an adhesive and/or fastener(s) may be utilized to attach the clips to the 3D printed substrate 456.

**[0045]** Figure 5 is a diagram illustrating a perspective view of an example of a 3D printed substrate 570. The 3D printed substrate 570 may be an example of the 3D printed substrate 112 described in relation to Figure 1. The 3D printed substrate 570 may include 3D printed contacts 572 (e.g., buried contacts). The 3D printed contacts 572 may be examples of the 3D printed contact 110 described in relation to Figure 1. Figure 6 is a diagram illustrating a perspective view of an example of the 3D printed substrate 570 of Figure 5 with inserted pins 676. Figure 5 and Figure 6 are described together.

**[0046]** In the example of Figure 5, the 3D printed contacts 572 are buried in the 3D printed substrate 570. In the example of Figure 5, the 3D printed substrate 570 includes insertion regions 574. The insertion regions 574 may be utilized to insert the pins 676 (and/or leads) into contact with the 3D printed contacts 572. The insertion regions 574 may be holes and/or unfused material (e.g., powder) in the 3D printed substrate 570. For instance, the pins 676 are inserted through the insertion regions 574 into contact with the buried 3D printed contacts 572. In some examples, leads of an external circuit package may be placed into contact with the pins 676 to interface with the buried 3D printed contacts 572.

**[0047]** Some examples of the techniques described herein may be utilized without adhesive or soldering to create a joint. Some examples of the

techniques described herein may create a mechanically stronger joint(s). Some examples of the techniques described herein may utilize a contact(s) that can be printed below a surface, which may reduce conductor spreading, enhance fusion of composite contacts, and/or may provide enhanced electrical isolation. Some examples of the techniques described herein may reduce assembly complexity and/or may enhance contact with another contact type(s). Some examples of the techniques described herein may utilize friction (e.g., friction between a 3D printed substrate and a lead(s) and/or pin(s), etc.) to create a joint(s).

**[0048]** Figure 7 is a diagram illustrating a top view and a side view of an example of a 3D printed substrate 778. The 3D printed substrate 778 may be an example of the 3D printed substrate 112 described in relation to Figure 1. The 3D printed substrate 778 may include a 3D printed contact 780 (e.g., buried contact). The 3D printed contact 780 be an example of the 3D printed contact 110 described in relation to Figure 1.

**[0049]** In the example of Figure 7, the 3D printed contact 780 is disposed below the surface of (e.g., buried in) the 3D printed substrate 778. In the example of Figure 7, a pin 782 is inserted into contact with the 3D printed contact 780. For instance, the pin 782 may be inserted via an insertion region of the 3D printed substrate 778 into contact with the 3D printed contact 780. In the example of Figure 7, the pin 782 includes an anchor feature 786 (e.g., barbs) to interface with the 3D printed contact 780. For instance, the anchor feature 786 may anchor the pin 782 in the 3D printed contact 780. In some examples, another anchor feature(s) 787 (e.g., barbs) may be situated on the shaft of the pin 782. For instance, the other anchor feature(s) 787 may anchor the shaft of the pin 782 in the 3D printed substrate 778. In some examples, the pin 782 may not include an anchor feature 786 and/or other anchor feature(s) 787.

**[0050]** In the example of Figure 7, a head 784 of the pin 782 is exposed. In some examples, a lead of an external circuit package may be attached (e.g., soldered) to the head 784. In the example of Figure 7, the head 784 is rectangularly shaped. In some examples, a head of a pin may have another shape (e.g., elliptical shape, circular shape, irregular shape, etc.). In the

example of Figure 7, the head 784 has a width dimension of 1 millimeter (mm), and the pin 782 has a depth dimension of 4 mm. Other sizes may be utilized in some examples.

**[0051]** Some examples of the techniques described herein may utilize a pin (e.g., pin 782) inserted into the 3D printed contact 780 in the 3D printed substrate 778. The pin 782 may be utilized as an anchor point for an electrical joint. In some examples, the 3D printed contact 780 may have a relatively soft composition compared to the surrounding fused material (e.g., polymer) and can be punctured using the pin 782 (e.g., a sharp metallic pin). As described herein, a conductor (e.g., lead, wire, etc.) may be soldered to the head 784 of the pin 782, which may result in a robust joint to deliver stable electrical contact with good mechanical anchoring to the 3D printed substrate 778.

**[0052]** In some examples, performance may be enhanced with a buried 3D printed contact 780. For instance, a buried 3D printed contact 780 may exhibit enhanced fusion properties and more uniform conductivity due to a more controlled thermal environment in the fused object.

**[0053]** In some examples, the pin 782 may puncture the 3D printed substrate 778 to reach the buried 3D printed contact 780. The 3D printed substrate 778 may include an insertion region (e.g., un-fused channel, partially fused channel, etc.) that is printed using detailing agent. The insertion region may act as a guiding path or pilot hole to guide the pin 782 to puncture the buried 3D printed contact 780. An insertion region may act as a surface fiducial to indicate pin placement and/or driving.

**[0054]** In some examples, an insertion region (e.g., detailing agent channel) may be printed in a way that does not produce a clear hole, but that allows for the powder to fuse partially to generate a channel that can be penetrated to guide a pin, but not allow for an exposed conductor to be damaged before assembly. In some examples, insertion regions may aid in the alignment of pins to keep the pins aligned (e.g., parallel) to aid in further assembly or connection to connectors.

**[0055]** In some examples of the techniques described herein, a 3D printed contact may be located on (and/or may be accessible from) a top, side(s),

and/or bottom of a 3D printed substrate. For instance, a pin may be installed on a top, side, or bottom surface of a 3D printed substrate.

**[0056]** In some examples, the pin 782 may have varying designs that could be utilized to enhance mechanical and/or electrical joint capabilities of the inserted pin 782. For instance, head 784 shape, pin diameter, and/or anchor feature(s) may be modified to enhance the capabilities of the connection. For instance, the shape of the head 784 may be modified to allow for enhanced interfacing a corresponding component or lead. The diameter of the pin 782 may be modified to change current carrying capability and/or mechanical strength, etc. The anchor feature(s) may be modified to help the pin 782 seat into the 3D printed substrate 778. For instance, different designs may be utilized if the pin 782 is to be installed into a thin 3D printed substrate with less fused polymer to friction fit.

**[0057]** Figure 8 is a block diagram of an example of an electronic device 802 that may be used to design and/or manufacture a structure or structures described herein. The electronic device 802 may be a computing device, such as a personal computer, a server computer, a printer, a 3D printer, a smartphone, a tablet computer, etc. The electronic device 802 may include (and/or may be coupled to) a processor 804 and/or to a memory 806. The processor 804 may be in electronic communication with memory 806. In some examples, the electronic device 802 may be in communication with (e.g., coupled to, have a communication link with) a manufacturing device (e.g., a 3D printing device). In some examples, the electronic device 802 may be an example of a 3D printing device. In some examples, the electronic device 802 may include additional components (not shown) and/or some of the components described herein may be removed and/or modified without departing from the scope of this disclosure.

**[0058]** The processor 804 may be any of a central processing unit (CPU), a semiconductor-based microprocessor, graphics processing unit (GPU), field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), and/or other hardware device suitable for retrieval and execution of instructions stored in the memory 806. The processor 804 may fetch, decode,

and/or execute instructions (e.g., design instructions 818) stored in the memory 806. In some examples, the processor 804 may include an electronic circuit or circuits that include electronic components for performing a functionality or functionalities of the instructions (e.g., design instructions 818). In some examples, the processor 804 may be utilized to design and/or manufacture one, some, or all of the structures described in relation to one, some, or all of Figures 1–11.

**[0059]** The memory 806 may be any electronic, magnetic, optical, or other physical storage device that contains or stores electronic information (e.g., instructions and/or data). The memory 806 may be, for example, Random Access Memory (RAM), Electrically Erasable Programmable Read-Only Memory (EEPROM), a storage device, an optical disc, and/or the like. In some implementations, the memory 806 may be a non-transitory tangible machine-readable storage medium, where the term “non-transitory” does not encompass transitory propagating signals.

**[0060]** In some examples, the electronic device 802 may also include a data store (not shown) on which the processor 804 may store information. The data store may be volatile and/or non-volatile memory, such as Dynamic Random-Access Memory (DRAM), EEPROM, magnetoresistive random-access memory (MRAM), phase change RAM (PCRAM), memristor, flash memory, and the like. In some examples, the memory 806 may be included in the data store. In some examples, the memory 806 may be separate from the data store. In some approaches, the data store may store similar instructions and/or data as that stored by the memory 806. For example, the data store may be non-volatile memory and the memory 806 may be volatile memory.

**[0061]** In some examples, the electronic device 802 may include a communication interface (not shown) through which the processor 804 may communicate with an external device or devices (not shown), for instance, to receive and/or store information pertaining to an object or objects (e.g., geometry(ies), substrate(s), retention structure(s), external circuit package(s), etc.) to be utilized in design and/or manufacturing. The communication interface may include hardware and/or machine-readable instructions to enable the

processor 804 to communicate with the external device or devices. The communication interface may enable a wired and/or wireless connection to the external device or devices. In some examples, the communication interface may further include a network interface card and/or may also include hardware and/or machine-readable instructions to enable the processor 804 to communicate with various input and/or output devices. Examples of input devices may include a keyboard, a mouse, a display, another electronic device, computing device, etc., through which a user may input instructions into the electronic device 802. In some examples, the electronic device 802 may receive 3D model data 808 from an external device or devices (e.g., 3D scanner, removable storage, network device, etc.).

**[0062]** In some examples, the memory 806 may store 3D model data 808. The 3D model data 808 may be generated by the electronic device 802 and/or received from another device. Some examples of 3D model data 808 include a CAD file(s), a 3D manufacturing format (3MF) file(s), object shape data, mesh data, geometry data, etc. The 3D model data 808 may indicate the shape of an object or objects. For instance, the 3D model data 808 may indicate the shape of a geometry or geometries (e.g., regular and/or irregular geometries), external circuit package model(s), external circuit package dimensions, substrate model(s), and/or retention structure model(s), etc. In some examples, the 3D model data 808 may indicate a shape of one, some, or all of the geometries described herein.

**[0063]** In some examples, the 3D model data 808 may include a library of external circuit package models. For instance, the 3D model data 808 may indicate dimensions (e.g., package size, lead spacing, lead height, lead width, number of leads, etc.) of multiple external circuit packages. The library of external circuit package models may be utilized to automatically design a 3D printed substrate and/or retention structure to interface with and/or accommodate a selected external circuit package.

**[0064]** In some examples, the processor 804 may execute the design instructions 818 to determine a contact location in a substrate of a 3D print model to interface with an external circuit package. For instance, the 3D model

data 808 may include a model of a substrate. The processor 804 may determine a contact location(s) corresponding to a lead(s) of an external circuit package. For example, the processor 804 may locate a contact to interface with a lead (e.g., center a contact in the substrate relative to the lead location). In some examples, the processor 804 may modify a size and/or shape of the contact to conform to a lead size and/or shape. For instance, the processor 804 may generate a contact model to fit under (all or a portion of) a lead.

**[0065]** In some examples, the processor 804 may execute the design instructions 818 to determine a retention structure (e.g., cap and/or clip(s)) to hold the external circuit package on a top side of the external circuit package. For instance, the retention structure may be utilized to retain the external circuit package on the substrate. In some examples, the 3D model data 808 may include a model of a retention structure. The processor 804 may modify the model of the retention structure to accommodate the external circuit package. For instance, the processor 804 may determine a depression in the retention structure to fit (e.g., conform to) an upper portion (e.g., top side) of the external circuit package. In some examples, the depression may be determined utilizing a geometric subtraction (e.g., voxel difference with or without a margin) between a model of a retention structure and the upper portion (e.g., top side) of a model of the external circuit package. In some examples, the depression may be determined by merging an upper surface (e.g., upper mesh surface) of a model of the external circuit package and a model of a retention structure (with or without a margin). In some examples, the processor 804 may determine a dimension(s) and/or placement(s) of a clip(s) to hold the external circuit package on the substrate. For instance, clip placements may be expanded or contracted to accommodate the dimensions of the external circuit package. Clip height may be determined such that an interfering feature or edge would hold the external clip package on the substrate.

**[0066]** In some examples, the processor 804 may execute the design instructions 818 to determine a trace routing in a substrate of a 3D print model based on the external circuit package. For instance, the 3D model data 808 may include a model of a substrate. The processor 804 may determine a trace

routing to connect with the contact location(s) corresponding to a lead(s) of an external circuit package. For example, the processor 804 may locate trace routings to connect to the contacts and to provide a spacing between the trace routings.

**[0067]** In some examples, the processor 804 may execute the design instructions 818 to instruct a 3D printer to print the 3D print model. For instance, the processor 804 may control a print mechanism (e.g., printhead, laser, nozzle, etc.) to print a substrate based on the model of the substrate. In some examples, the processor 804 may control a print mechanism (e.g., printhead, laser, nozzle, etc.) to print a retention structure based on the model of the retention structure. For instance, the processor 804 (e.g., microprocessor) may control printing of the model in accordance with a 3D printing technique or techniques (e.g., SLM, EBM, FDM, and/or binder jet, etc.).

**[0068]** In some examples, the processor 804 may design a socket for a substrate (e.g., 3D printed electronics) using the design instructions 818 and/or the 3D model data 808 that may include a library of socket designs for various electronic components or groups of components (e.g., external circuit package(s)). The processor 804 may utilize a 3D design including the structural and trace routing information and a circuit schematic. The 3D design may indicate target locations where the components in the circuit schematic would be located. The processor 804 may modify the routed trace and the 3D structure to implement the various design elements for the socket. Once these design modifications have been made, the 3D design may be printed, and a resulting apparatus may be assembled.

**[0069]** Figure 9 is a block diagram illustrating an example of a computer-readable medium 988 for apparatus design. The computer-readable medium 988 is a non-transitory, tangible computer-readable medium. The computer-readable medium 988 may be, for example, RAM, EEPROM, a storage device, an optical disc, and the like. In some examples, the computer-readable medium 988 may be volatile and/or non-volatile memory, such as DRAM, EEPROM, MRAM, PCRAM, memristor, flash memory, and the like. In some examples, the memory 806 described in relation to Figure 8 may be an example of the

computer-readable medium 988 described in relation to Figure 9. In some examples, the computer-readable medium 988 may include data (e.g., information and/or instructions) to cause a processor to perform one, some, or all of the operations, aspects, elements, etc., described in relation to one, some, or all of Figures 1–11.

**[0070]** The computer-readable medium 988 may include data (e.g., information and/or instructions). For example, the computer-readable medium 988 may include 3D model data 990 and/or design instructions 992. The 3D model data 990 may include a model(s) of an external circuit package(s), substrate(s), and/or retention structure(s).

**[0071]** The design instructions 992 may include instructions, when executed, cause a processor of an electronic device to determine a contact location in a substrate of a 3D print model to interface with an external circuit package. In some examples, determining the contact location may be performed as described in relation to Figure 8, Figure 10, and/or Figure 11.

**[0072]** In some examples, the design instructions 992 may include instructions, when executed, cause a processor of an electronic device to determine a retention structure to hold the external circuit package on a top side of the external circuit package, where the retention structure is to retain the external circuit package on the substrate. In some examples, determining the retention structure may be performed as described in relation to Figure 8, Figure 10, and/or Figure 11.

**[0073]** In some examples, the design instructions 992 may include instructions, when executed, cause a processor of an electronic device to determine a trace routing in the substrate of the 3D print model based on the external circuit package. In some examples, determining the trace routing may be performed as described in relation to Figure 8, Figure 10, and/or Figure 11.

**[0074]** In some examples, the design instructions 992 may include instructions, when executed, cause a processor of an electronic device to instruct a manufacturing device to place a conductive structure on the contact location to interface with the external circuit package. For instance, the processor may control a manufacturing device (e.g., robotic arm, soldering

machine, welding machine, etc.) to place a conductive structure (e.g., plate, pin, wire, etc.) in contact with the contact location. In some examples, the processor may instruct and/or control a manufacturing device to automatically place (e.g., insert, punch, etc.) a pin on the contact location (e.g., in contact with the contact location). The pin may be utilized to interface with the external circuit package. In some examples, controlling a manufacturing device may include sending instructions to the manufacturing device and/or a manufacturing device controller to place a conductive structure on the contact location.

**[0075]** In some examples, the design instructions 992 may include instructions, when executed, cause a processor of an electronic device to instruct a 3D printer to print the 3D print model. In some examples, instructing the 3D printer may be performed as described in relation to Figure 8 and/or Figure 10.

**[0076]** Figure 10 is a flow diagram illustrating an example of a method 1000 for automatically designing a structure or structures described herein. The method 1000 and/or an element or elements of the method 1000 may be performed by an electronic device. For example, the method 1000 may be performed by the electronic device 802 described in relation to Figure 8.

**[0077]** The electronic device may obtain 1002 an external circuit package model. For instance, the electronic device may receive an external circuit package model (e.g., 3D mesh model, voxel model, etc.) from another device and/or may read an external package model from a storage device. The external circuit package model may indicate a 3D model of an external circuit package selected to interface with a 3D printed substrate and/or to be retained by a retention structure.

**[0078]** The electronic device may perform 1004 a spread transform based on the external circuit package model. In some examples, the spread transform may adjust (e.g., spread and/or contract) a 3D model (e.g., model of a 3D printed substrate) in accordance with external circuit package model dimensions. For instance, traces may be spread and/or contracted in a dimension(s) (e.g., two dimensions, x-y dimensions) to accommodate the

external circuit package model (e.g., to move a contact location(s) to a position(s) to interface with the lead(s) of the external circuit package model).

**[0079]** The electronic device may determine 1006 a plane trace routing. For example, the electronic device may calculate a trace routing in a plane (e.g., two dimensions, x-y dimensions) of the 3D model. The trace routing determination may utilize a procedure to design a trace route(s) between a contact location(s) and a target endpoint(s).

**[0080]** The electronic device may determine 1008 a block trace routing. For example, the electronic device may calculate a trace routing in a region (e.g., 3D region) of the 3D model. The block trace routing determination may allow traces to be routed in three dimensions (e.g., x-y-z dimensions). In some examples, determining 1006 the plane trace routing and/or determining 1008 the block trace routing may include determining a routing within a constrained region (e.g., area and/or volume).

**[0081]** The electronic device may determine 1010 a surface feature. For instance, the electronic device may determine, for the 3D model, a contact type, size, geometry, etc., may determine a guide feature(s) (e.g., holes, unfused powder, etc.), may determine a test point(s), etc.

**[0082]** The electronic device may determine 1012 a conformal structure(s). A conformal structure is a structure to conform to the external circuit package model. For instance, the electronic device may determine an isolation structure(s), guiding structure(s), detailing agent placement, and/or retention structure(s).

**[0083]** The electronic device may perform 1014 a print transform. A print transform may be a transform to account for a printing effect(s). For instance, performing 1014 the print transform may include making an adjustment(s) (e.g., dilation, scaling, etc.) to compensate for global object distortion (e.g., distortion caused by melting effects), object shrinkage, slump, etc.

**[0084]** The electronic device may determine 1016 a region(s). For instance, the electronic device may determine a conductive region and a non-conductive region. In some examples, the electronic device may set voxels in a non-

conductive (e.g., polymer) region of a 3D model to a first value and may set voxels in a conductive region of the 3D model to a second value, etc.

**[0085]** The electronic device may determine 1018 a print map(s). For instance, the electronic device may determine slices (e.g., two-dimensional cross sections) of the 3D model. In some examples, the electronic device may determine an agent map(s). For instance, the electronic device may determine a fusing agent map that indicates a region(s) to apply fusing agent, a detailing agent map that indicates a region(s) to apply detailing agent, and/or another map(s) (e.g., a conductive material map that indicates a region(s) to deposit a conductive material(s)).

**[0086]** The electronic device may provide 1020 the print map(s). For instance, the electronic device may send the print map(s) to a 3D printer for printing. In some examples, the electronic device may be a 3D printer and may execute the print map(s) to print the 3D model.

**[0087]** In some examples, the method 1000 may be performed to design and/or manufacture a component(s) of the structure(s) described in relation to one, some, or all of Figures 1–7 (e.g., apparatus 120, apparatus 240, apparatus 454, 3D printed substrate 570, 3D printed substrate 778, and/or a component(s) thereof). In some examples, an element(s) of the method 1000 may be omitted, combined, and/or subdivided.

**[0088]** Figure 11 is a flow diagram illustrating an example of a method 1100 for designing a conformal structure(s) (e.g., 3D printed substrate and/or retention structure(s)). The method 1100 and/or an element or elements of the method 1100 may be performed by an electronic device. For example, the method 1100 may be performed by the electronic device 802 described in relation to Figure 8. In some examples, the method 1100 may be performed as an element(s) of the method 1000 described in relation to Figure 10.

**[0089]** The electronic device may determine 1102 a contact structure(s). For instance, the electronic device may determine a contract structure(s) in a 3D model that conforms to a contact(s) indicated by an external circuit package model. In some examples, the contact structure(s) may be determined (e.g.,

shaped, sized, etc.) to fit on an underside of a lead(s) of the external circuit package model.

**[0090]** The electronic device may determine 1104 a guiding structure. For instance, the electronic device may determine 1104 an alignment feature(s) in the 3D model (e.g., substrate) to guide assembly of the external circuit package model. In some examples, determining 1104 a guiding structure may include determining an isolation feature(s). For instance, the guiding structure may be an isolation feature(s) to isolate contact structures and/or external circuit package leads. In some examples, the electronic device may determine a size and/or shape of a guiding structure based on a distance(s) between contact structures and/or leads of an external circuit package model.

**[0091]** The electronic device may determine 1106 detailing agent placement. For instance, the electronic device may be a region (e.g., margin) of detailing agent placement on the contact structure(s) of the 3D model (e.g., substrate). In some examples, the detailing agent placement may conform to a top surface of the contact structure(s) in shape with a distance (e.g., 1 mm, 2 mm, etc.) above the top surface.

**[0092]** The electronic device may determine 1108 a retention structure. For instance, the electronic device may determine a size and/or shape of a cap and/or clip(s) (e.g., pressure clip(s)). For instance, the electronic device may determine a cap that conforms to a top side of the external circuit package model and/or that includes a feature(s) to interface with the guiding structure(s) (e.g., alignment feature(s)) of the 3D model (e.g., substrate).

**[0093]** In some examples, the method 1100 may be performed to design and/or manufacture a component(s) of the structure(s) described in relation to one, some, or all of Figures 1–7 (e.g., apparatus 120, apparatus 240, apparatus 454, 3D printed substrate 570, 3D printed substrate 778, and/or a component(s) thereof). In some examples, an element(s) of the method 1100 may be omitted, combined, and/or subdivided.

**[0094]** Figure 12 is a flow diagram illustrating an example of method 1200 for manufacturing a structure(s) in accordance with some of the techniques described herein. The method 1200 and/or an element or elements of the

method 1200 may be performed by an electronic device. For example, the method 1200 may be performed by the electronic device 802 described in relation to Figure 8. For instance, the electronic device 802 may be a 3D printer and/or may control a 3D printer to print a substrate (e.g., apparatus 120, apparatus 240, apparatus 454, 3D printed substrate 570, 3D printed substrate 778, and/or an element(s) thereof, etc.). In some examples, the method 1200 may include one, some, or all of the operations of the method 1000 described in relation to Figure 10. In some examples, an aspect(s) and/or operation(s) described in relation to the method 1200 may be omitted or combined.

**[0095]** The electronic device may control 1202 a 3D printer to print a substrate including a contact to interface with an external circuit package. For instance, the electronic device may send instructions (e.g., agent map(s), slice(s), etc.) to a 3D printer to control the printer to print the substrate and/or a 3D printer may execute instructions (e.g., command a printhead(s)) to print the substrate. For instance, the 3D printer may print fusing agent in a region(s) of build material to print the 3D substrate. The region(s) for fusing agent may be indicated by a fusing agent map. In some examples, the 3D printer may print conductive agent (e.g., agent with conductive particles, silver nanoparticles, etc.) in a region(s) of build material to print a contact(s) and/or trace(s), etc. For instance, the conductive agent may be printed in a region(s) indicated by a conductive agent map.

**[0096]** The electronic device may control 1204 a 3D printer to print detailing agent on the contact. For instance, the electronic device may send instructions (e.g., agent map(s), slice(s), etc.) to a 3D printer to control the printer to print the detailing agent. For instance, the 3D printer may print detailing agent in a region(s) (e.g., layer(s)) on the contact(s). The region(s) for detailing agent may be indicated by a detailing agent map.

**[0097]** In some examples, the method 1200 may include controlling a 3D printer to print a structure(s) (e.g., substrate(s), retention structure(s), contact(s), trace(s), protrusion(s), ridge(s), alignment feature(s), cap(s), clip(s), guide(s), insertion region(s), etc.) described in relation to one, some, or all of Figures 1–11. For instance, the substrate may be printed to include a protrusion to isolate

a lead of the external circuit package (e.g., isolate leads of the external circuit package from each other). In some examples, the method 1200 may include controlling the 3D printer to print a retention structure to hold the external circuit package on a top side of the external circuit package. In some examples, printing the retention structure may include printing a cap with a depression that is dimensioned based on a top side (e.g., a model of the top side) of the external circuit package.

**[0098]** Some examples of the techniques described herein may provide enhanced interfaces for 3D printed substrates. For instance, some examples of the techniques may provide robust interfaces and/or modular designs. Some examples of the techniques described herein may aid in achieving enhanced conductivity using bonding adhesive. Some examples of the techniques described herein may provide increased contact surface area. Some examples of the techniques described herein may provide self-aligning designs. Some examples of the techniques described herein may provide enhanced contact and/or lead isolation.

**[0099]** As used herein, the term “and/or” may mean an item or items. For example, the phrase “A, B, and/or C” may mean any of: A (without B and C), B (without A and C), C (without A and B), A and B (but not C), B and C (but not A), A and C (but not B), or all of A, B, and C.

**[0100]** While various examples of systems and methods are described herein, the systems and methods are not limited to the examples. Variations of the examples described herein may be implemented within the scope of the disclosure. For example, operations, functions, aspects, or elements of the examples described herein may be omitted or combined.

## CLAIMS

1. An apparatus, comprising:  
a three-dimensional (3D) printed substrate;  
a 3D printed contact included in the 3D printed substrate to interface with  
an external circuit package; and  
a retention structure to hold the external circuit package on a top side of  
the external circuit package.
2. The apparatus of claim 1, wherein detailing agent is applied to the 3D  
printed contact to produce surface electrical contactability during printing.
3. The apparatus of claim 1, wherein the 3D printed substrate comprises a  
protrusion to isolate leads of the external circuit package.
4. The apparatus of claim 1, wherein the retention structure is a cap to be  
disposed on the top side of the external circuit package.
5. The apparatus of claim 1, wherein the retention structure comprises a  
depression to house the top side of the external circuit package.
6. The apparatus of claim 1, wherein the retention structure comprises a  
ridge to engage a top side of a lead of the external circuit package.
7. The apparatus of claim 1, wherein the retention structure comprises a clip  
attached to the 3D printed substrate.
8. The apparatus of claim 1, wherein the 3D printed contact protrudes from  
the 3D printed substrate.
9. The apparatus of claim 1, wherein the retention structure is manufactured  
separately from the 3D printed substrate.

10. A method, comprising:  
controlling a 3D printer to print a substrate including a contact to interface with an external circuit package, wherein the substrate comprises a protrusion to isolate a lead of the external circuit package; and  
controlling the 3D printer to print detailing agent on the contact.
11. The method of claim 10, further comprising controlling the 3D printer to print a retention structure to hold the external circuit package on a top side of the external circuit package.
12. The method of claim 11, wherein printing the retention structure comprises printing a cap with a depression that is dimensioned based on the top side of the external circuit package.
13. A non-transitory tangible computer-readable medium comprising instructions when executed cause a processor of an electronic device to:  
determine a contact location in a substrate of a three-dimensional (3D) print model to interface with an external circuit package; and  
determine a retention structure to hold the external circuit package on a top side of the external circuit package, wherein the retention structure is to retain the external circuit package on the substrate.
14. The non-transitory tangible computer-readable medium of claim 13, wherein the instructions when executed cause the processor to instruct a manufacturing device to place a conductive structure on the contact location to interface with the external circuit package.
15. The non-transitory tangible computer-readable medium of claim 14, wherein the instructions when executed cause the processor to instruct the manufacturing device to place a pin on the contact location to interface with the external circuit package.

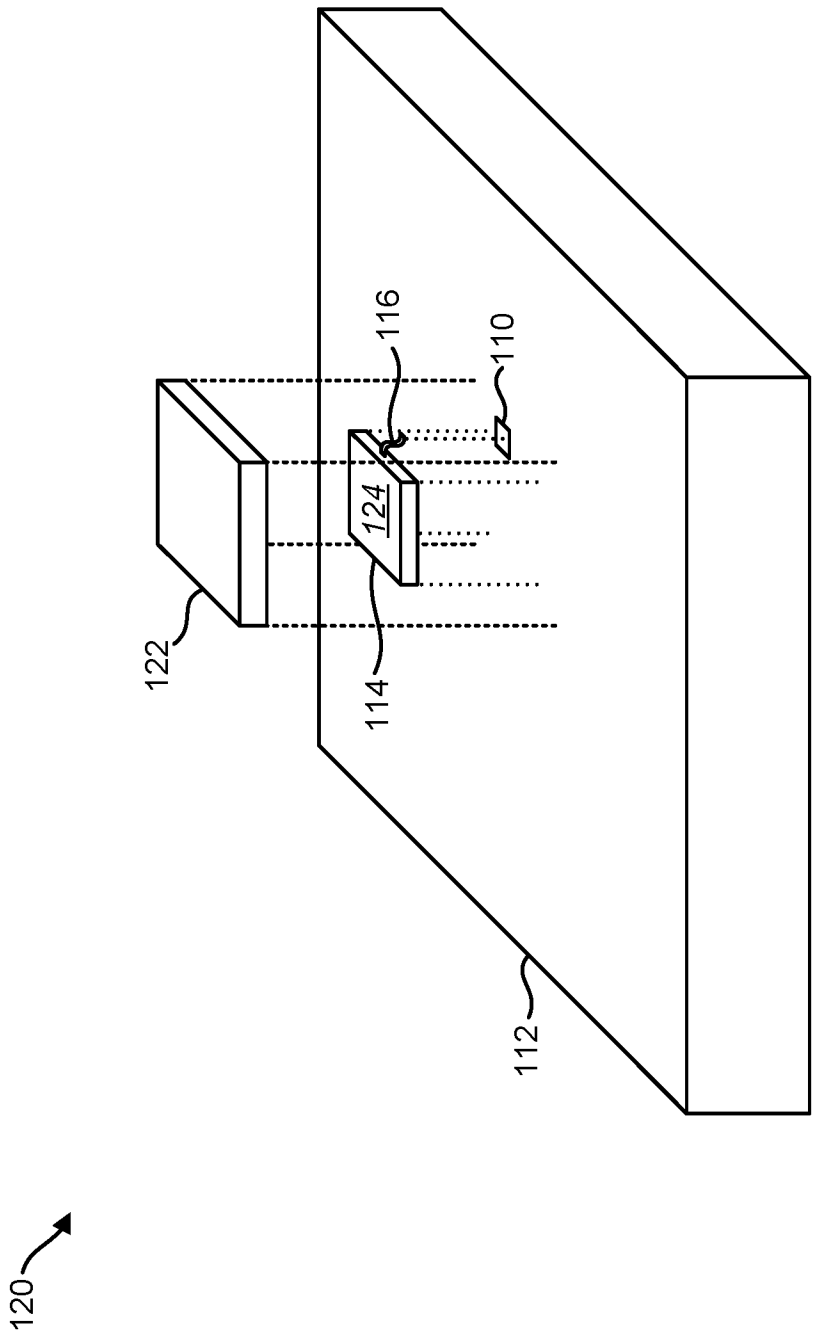


FIG. 1

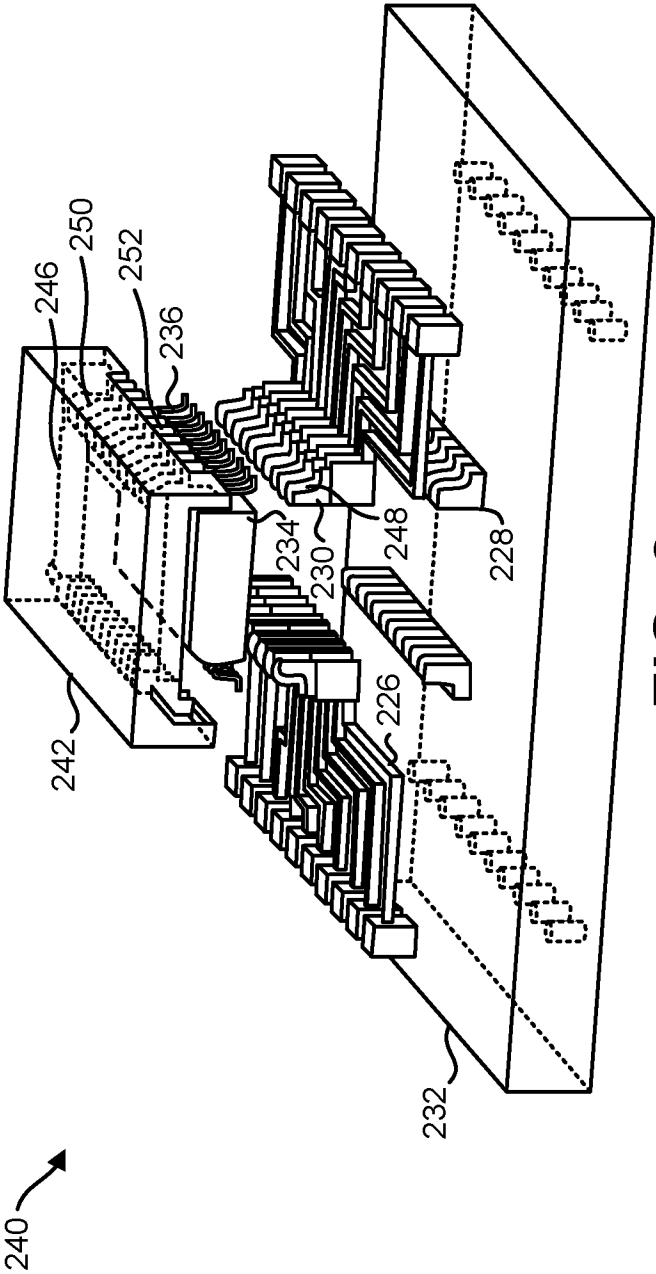


FIG. 2

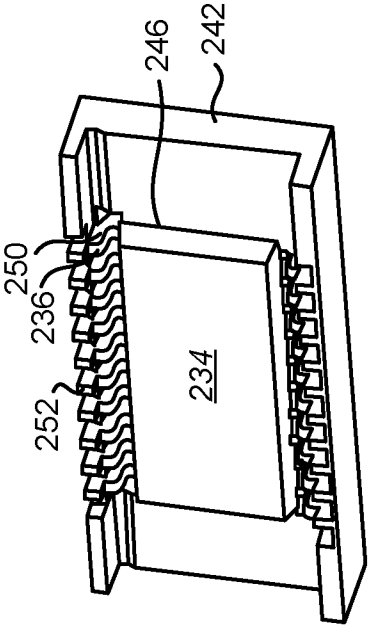


FIG. 3

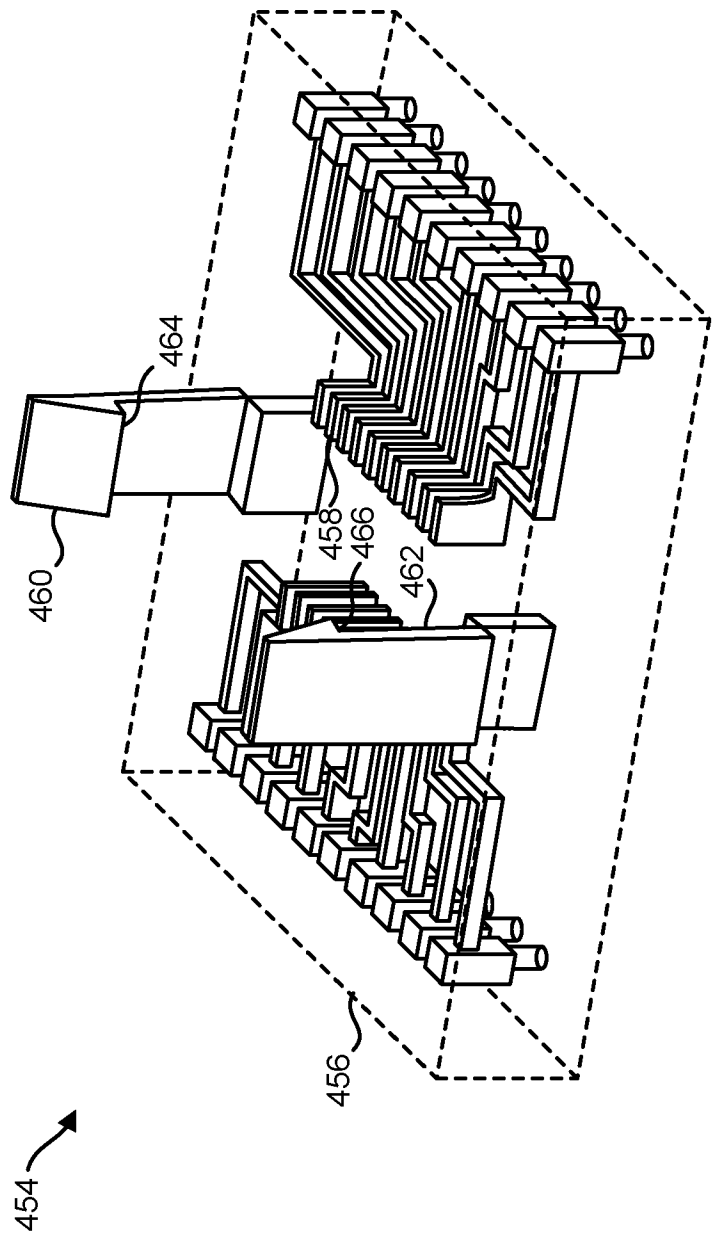


FIG. 4

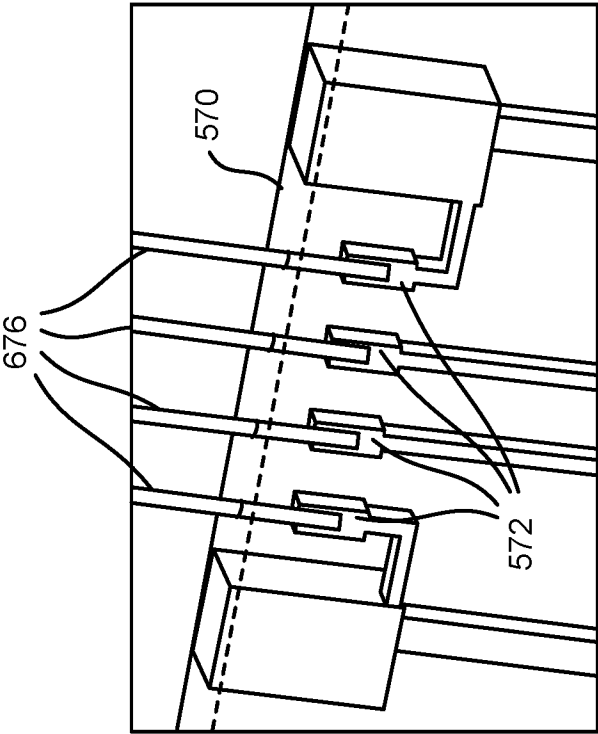


FIG. 6

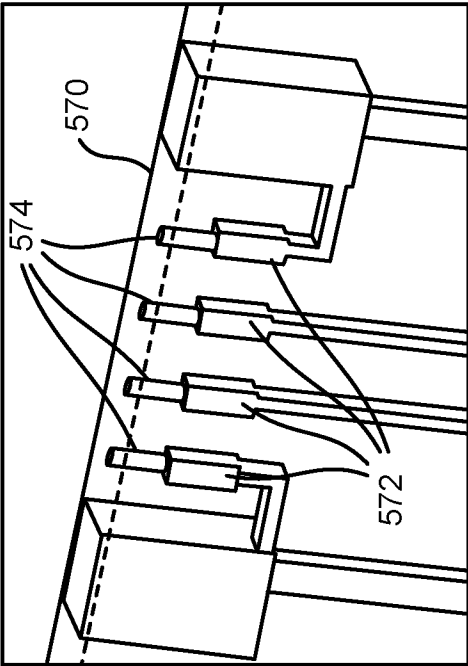


FIG. 5

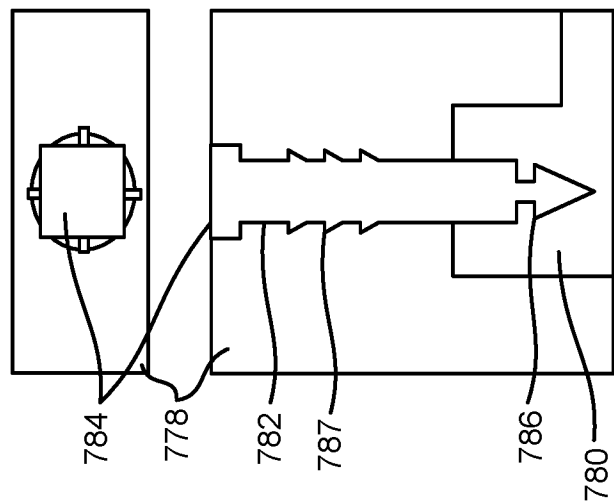


FIG. 7



FIG. 8

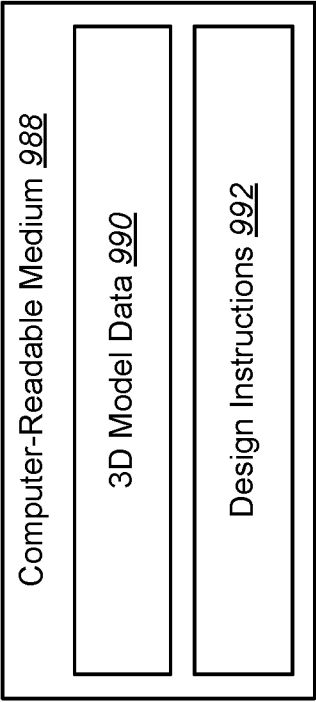


FIG. 9

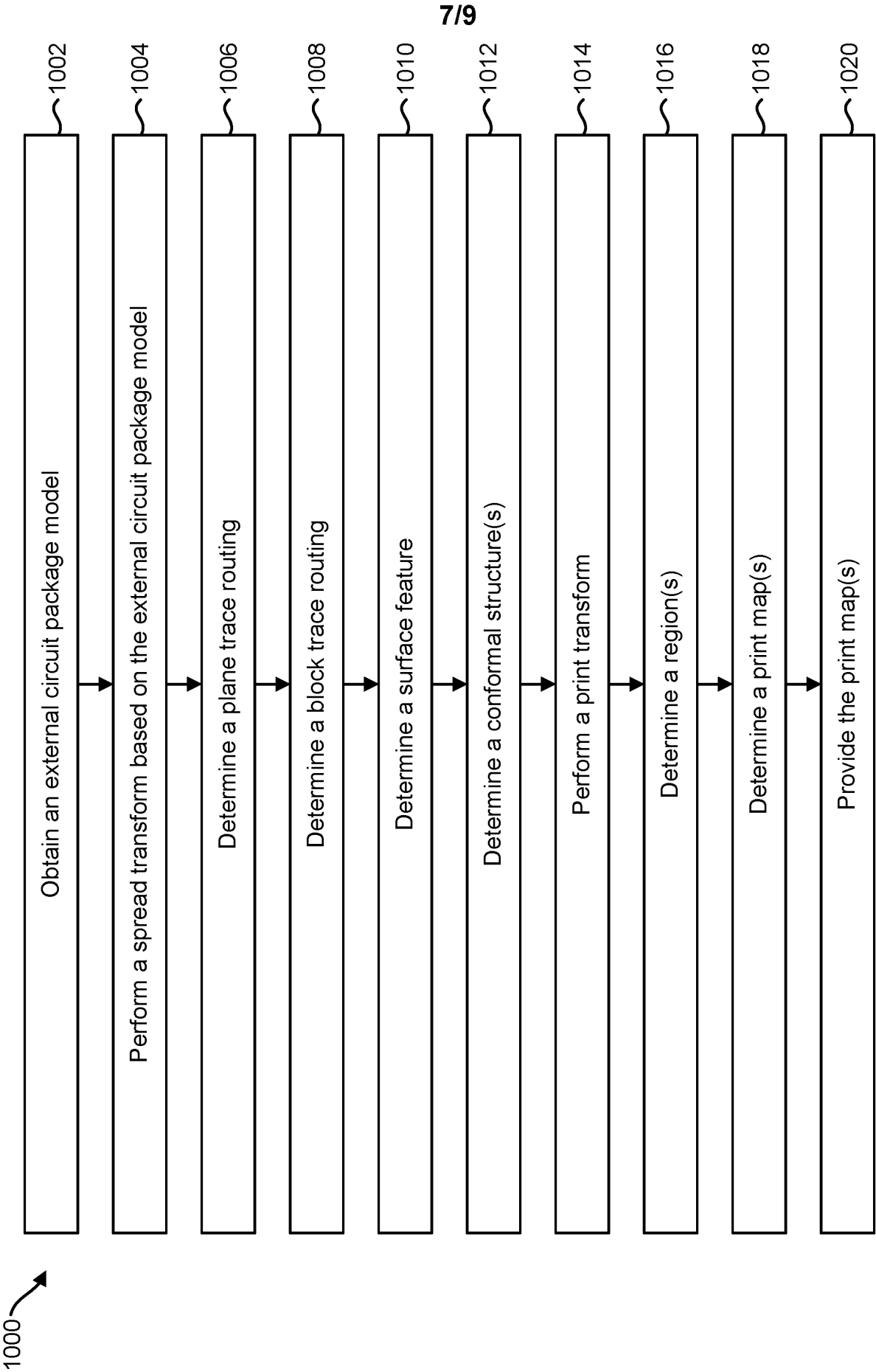


FIG. 10

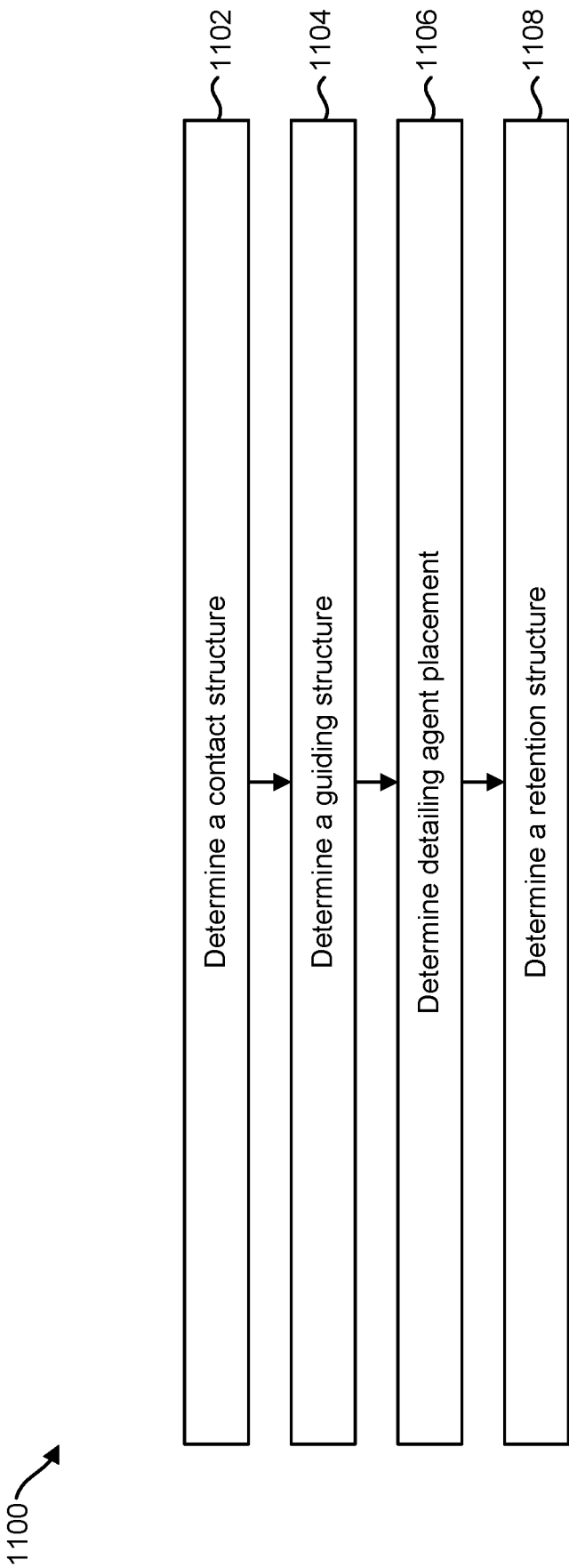


FIG. 11

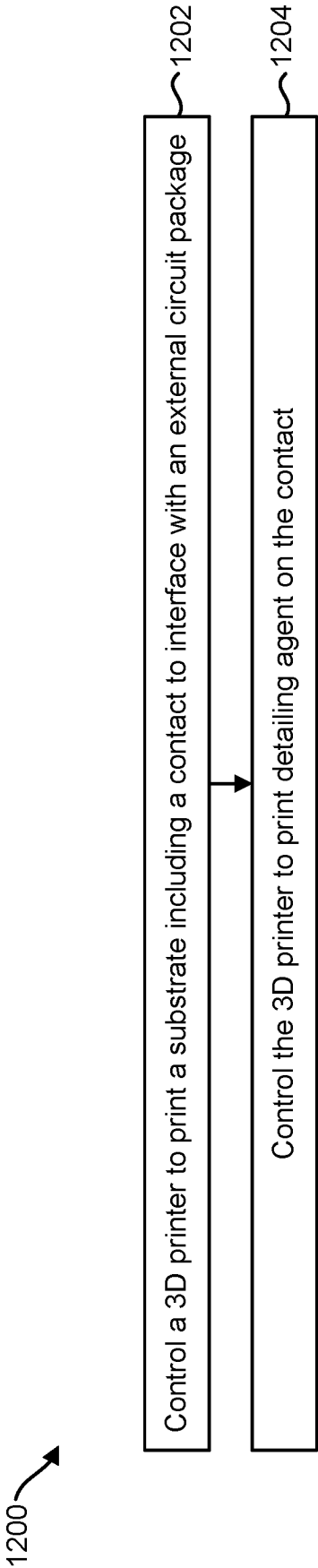


FIG. 12

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2022/045058

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br><b>INV. H05K3/32 H05K7/10 G01R1/04</b><br><b>ADD. H05K3/30</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                   |                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                   |                                                    |
| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br><b>H05K B33Y G01R</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                   |                                                    |
| 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)<br><b>EPO-Internal, WPI Data</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                   |                                                    |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                   |                                                    |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Citation of document, with indication, where appropriate, of the relevant passages                                                                | Relevant to claim No.                              |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | EP 3 367 511 A1 (VALEO ILUMINACION SA [ES]) 29 August 2018 (2018-08-29)                                                                           | 1, 2, 7, 8                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | the whole document                                                                                                                                | 13-15                                              |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | EP 0 457 472 A1 (TEXAS INSTRUMENTS INC [US]) 21 November 1991 (1991-11-21)<br>column 2, line 55 - column 3, line 20;<br>figures 5a, 5b            | 1, 2, 4-15                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | EP 1 191 588 A2 (HIRAI YUKIHIRO [JP])<br>27 March 2002 (2002-03-27)<br>paragraph [0190] - paragraph [0201];<br>figures 25-33                      | 1-3, 5, 7,<br>8, 10-15                             |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | US 2004/201390 A1 (FARNWORTH WARREN M [US]<br>ET AL) 14 October 2004 (2004-10-14)<br>paragraph [0103] - paragraph [0108];<br>figures 4A-4C, 9A-9C | 1-4, 7-15                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | -----<br>-/-                                                                                                                                      |                                                    |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                   |                                                    |
| * Special categories of cited documents :<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>"&" document member of the same patent family |                                                                                                                                                   |                                                    |
| Date of the actual completion of the international search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                   | Date of mailing of the international search report |
| 12 May 2023                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                   | 24/05/2023                                         |
| Name and mailing address of the ISA/<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                   | Authorized officer<br><br><b>Zimmer, René</b>      |

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2022/045058

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                     |                       |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                  | Relevant to claim No. |
| Y                                                    | US 3 774 140 A (REIMER W)<br>20 November 1973 (1973-11-20)<br>the whole document<br>-----                                                                                                                                                                                                                           | 1, 2, 6-9             |
| Y                                                    | WO 2018/226211 A1 (HEWLETT PACKARD<br>DEVELOPMENT CO [US])<br>13 December 2018 (2018-12-13)<br>paragraphs [0016], [0044], [0063],<br>[0079] - [0097]; figures 5, 6<br>-----                                                                                                                                         | 1-15                  |
| T                                                    | FRAZELLE JESSIE: "Out-of-this-world<br>additive manufacturing",<br>COMMUNICATIONS OF THE ACM, ASSOCIATION FOR<br>COMPUTING MACHINERY, INC, UNITED STATES,<br>vol. 64, no. 3,<br>22 February 2021 (2021-02-22), pages<br>58-62, XP058891855,<br>ISSN: 0001-0782, DOI: 10.1145/3424254<br>the whole document<br>----- | 10-15                 |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2022/045058

| Patent document<br>cited in search report |    | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|----|---------------------|----------------------------|---------------------|
| EP 3367511                                | A1 | 29-08-2018          | CN 108470998 A             | 31-08-2018          |
|                                           |    |                     | EP 3367511 A1              | 29-08-2018          |
|                                           |    |                     | US 2018241141 A1           | 23-08-2018          |
| -----                                     |    |                     |                            |                     |
| EP 0457472                                | A1 | 21-11-1991          | DE 69107336 T2             | 14-06-1995          |
|                                           |    |                     | EP 0457472 A1              | 21-11-1991          |
|                                           |    |                     | JP 2976075 B2              | 10-11-1999          |
|                                           |    |                     | JP H0419578 A              | 23-01-1992          |
|                                           |    |                     | US 5139437 A               | 18-08-1992          |
| -----                                     |    |                     |                            |                     |
| EP 1191588                                | A2 | 27-03-2002          | CN 1347143 A               | 01-05-2002          |
|                                           |    |                     | CN 1607653 A               | 20-04-2005          |
|                                           |    |                     | EP 1191588 A2              | 27-03-2002          |
|                                           |    |                     | JP 3440243 B2              | 25-08-2003          |
|                                           |    |                     | JP 2002175859 A            | 21-06-2002          |
|                                           |    |                     | KR 20020024771 A           | 01-04-2002          |
|                                           |    |                     | TW 511197 B                | 21-11-2002          |
|                                           |    |                     | US 2002037657 A1           | 28-03-2002          |
|                                           |    |                     | US 2003060064 A1           | 27-03-2003          |
| -----                                     |    |                     |                            |                     |
| US 2004201390                             | A1 | 14-10-2004          | US 6980017 B1              | 27-12-2005          |
|                                           |    |                     | US 7043831 B1              | 16-05-2006          |
|                                           |    |                     | US 2004201390 A1           | 14-10-2004          |
|                                           |    |                     | US 2006028222 A1           | 09-02-2006          |
| -----                                     |    |                     |                            |                     |
| US 3774140                                | A  | 20-11-1973          | CA 981798 A                | 13-01-1976          |
|                                           |    |                     | US 3774140 A               | 20-11-1973          |
| -----                                     |    |                     |                            |                     |
| WO 2018226211                             | A1 | 13-12-2018          | US 2020108599 A1           | 09-04-2020          |
|                                           |    |                     | WO 2018226211 A1           | 13-12-2018          |
| -----                                     |    |                     |                            |                     |