



(51) International Patent Classification:
H01R 12/00 (2006.01)

(21) International Application Number:
PCT/US2010/036295

(22) International Filing Date:
27 May 2010 (27.05.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/183,324 2 June 2009 (02.06.2009) US

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(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, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, 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, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

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

(54) Title: COMPOSITE POLYMER-METAL ELECTRICAL CONTACTS

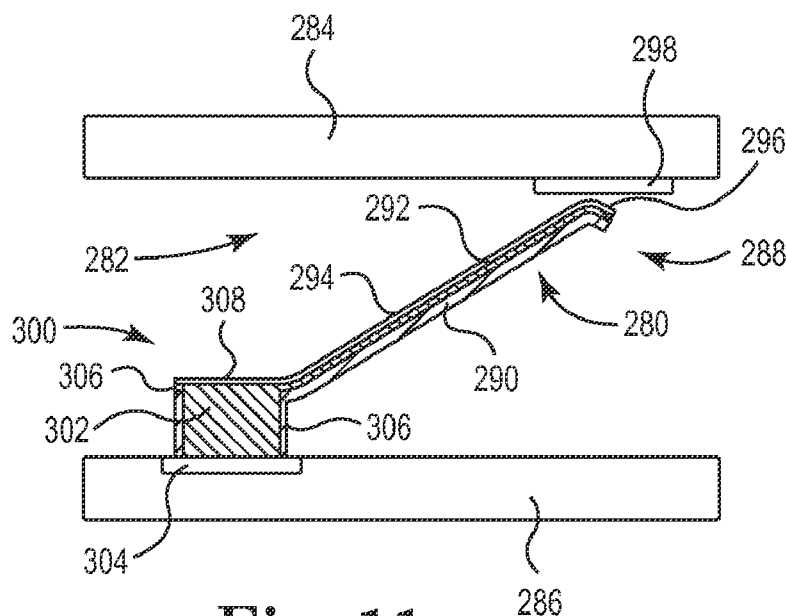


Fig. 11

(57) Abstract: An array of composite polymer-metal contact members adapted to form solder free electrical connections with a first circuit member. The contact members include a resilient polymeric base layer and an array of metalized traces printed on selected portions of the base layer. Conductive plating is applied to the metalized layer to create an array of conductive paths. The resilient polymeric base layer, the metalized layer, and the conductive plating have an aggregate spring constant sufficient to maintain distal portions of the contact members in a cantilevered configuration and to form a stable electrical connection between the distal portions and the first circuit member solely by compressive engagement.

COMPOSITE POLYMER-METAL ELECTRICAL CONTACTS

Technical Field

[0001] The present application relates to a high performance composite polymer-metal contact members, and to an electrical interconnect using such composite contact members.

Background of the Invention

[0002] Traditional IC sockets are generally constructed of an injection molded plastic insulator housing which has stamped and formed copper alloy contact members stitched or inserted into designated positions within the housing. These contact members can be in a flat or “blank” format, or they can be produced with a series of forms, bends, and features to accommodate a desired function such as retention within the plastic housing.

[0003] The designated positions in the insulator housing are typically shaped to accept and retain the contact members. The assembled socket body is then generally processed through a reflow oven which melts and attaches solder balls to the base of the contact member. During final assembly onto a printed circuit board (“PCB”), the desired interconnect positions on the circuit board are printed with solder paste or flux and the socket assembly is placed such that the solder balls on the socket contacts land onto the target pads on the PCB. The assembly is then reheated to reflow the solder balls on the socket assembly. When the solder cools it essentially welds the socket contacts to the PCB, creating the electrical path for signal and power interaction with the system.

[0004] During use, this assembled socket receives one or more packaged integrated circuits and connects each terminal on the package to the corresponding terminal on the PCB. The terminals on the package are held against the contact members by applying a load to the package, which is expected to maintain intimate contact and reliable circuit connection throughout the life of the system. No permanent connection is required. Consequently, the packaged integrated circuit can be removed or replaced without the need for reflowing solder connections.

[0005] As processors and electrical systems evolve, several factors have impacted the design of traditional sockets. Increased terminal count, reductions in

the terminal pitch (i.e., the distance between the contacts), and signal integrity have been main drivers that impact socket and contact design. As terminal count increases, the IC packages get larger due to the additional space needed for the terminals. As the IC packages grow larger the relative flatness of the IC package and corresponding PCB becomes more important. A certain degree of compliance is required between the contacts and the terminal pads to accommodate the topography differences and maintain reliable connections.

[0006] The contact geometries are typically designed as a compromise of size, shape and features to accommodate the required deflection, plastic deformation, contact retention, assembly features, etc. Contacts often include retention features that add electrical parasitic effects. Pitch reduction often reduces the available area for spring members. The cost of the contact members as a component is often directly related to the material content, the speed at which the contacts are stamped, and the amount and type of plating. The contact itself may only be a portion of the material in the coil of raw alloy used, with the excess either discarded or recycled.

[0007] For mechanical reasons, longer contact members are preferred because they have desirable spring properties. Long contact members, however, tend to reduce the electrical performance of the connection by creating a parasitic effect that impacts the signal as it travels through the contact. Long contact members also require thinner walls in the housing in order to meet pitch requirements, increasing the risk of housing warpage and cross-talk between adjacent contact members. The demands of pitch reduction often reduce the available area for spring features. Often such contact members require retention features that add electrical parasitic effects.

[0008] The contact members are typically made from a selection of Copper based alloys. The copper based alloys represent a compromise of material properties. Stainless steel has too much resistance, copper is too ductile, and silver is too expensive. Since copper oxidizes, the contacts are typically plated with nickel to prevent migration, and a final coating of either a precious metal like gold or a solderable metal such as tin. In very cost sensitive applications, the contacts are sometimes selectively plated at the interface points where they will connect to save the cost of the plating.

[0009] Next generation systems will operate above 5 GHz and beyond. Traditional sockets and interconnects will reach mechanical and electrical limitations that mandate alternate approaches.

Brief Summary of the Invention

[0010] The present disclosure is directed to composite contact members that will enable next generation electrical performance. The present disclosure merges the long-term reliability provided by polymer-based compliance, with the electrical performance of metal conductors. The polymer materials are typically dielectric or insulative, and provide advantages with regard to plastic deformation, fatigue or other properties, over conventional metal contacts.

[0011] The present disclosure is directed to an array of composite polymer-metal contact members adapted to form solder free electrical connections with a first circuit member. The contact members include a resilient polymeric base layer and an array of metalized traces printed on selected portions of the base layer. Conductive plating is applied to the metalized layer to create an array of conductive paths. The resilient polymeric base layer, the metalized layer, and the conductive plating have an aggregate spring constant sufficient to maintain distal portions of the contact members in a cantilevered configuration and to form a stable electrical connection between the distal portions and the first circuit member solely by compressive engagement.

[0012] The use of additive printing processes permits the material set in a given layer to vary. Additive printing technologies permit a wide variety of materials to be applied on a layer with a registration relative to the features of the previous layer. Selective addition of conductive, non-conductive, or semi-conductive materials at precise locations to create a desired effect has the major advantages in tuning impedance or adding electrical function on a given layer. Tuning performance on a layer by layer basis relative to the previous layer greatly enhances electrical performance.

[0013] In one embodiment a mechanically stable metalized portion is printed on proximal portions of the contact members. The metalized portion is adapted to bond to a second circuit member. In another embodiment, solder balls are bonded to the metalized portions.

[0014] In another embodiment, dielectric layers are selectively printed on the polymeric base to create recesses corresponding to a target conductive trace. A

conductive material is printed in at least a portion of the recesses to create the conductive trace. Conductive plating is optionally applied to the conductive traces. The conductive material can be sintered conductive particles or a conductive ink. The resulting conductive traces preferably have substantially rectangular cross-sectional shapes, corresponding to the second recesses.

[0015] In one embodiment, pre-formed conductive trace materials are located in the recesses. The recesses are then plated to form conductive traces with substantially rectangular cross-sectional shapes. In another embodiment, a conductive foil is pressed into at least a portion of the recesses. The conductive foil is sheared along edges of the recesses. The excess conductive foil not located in the recesses is removed and the recesses are plated to form conductive traces with substantially rectangular cross-sectional shapes.

[0016] In another embodiment, a housing is coupled to proximal portions of the contact members. The housing retains the distal portions in the cantilevered configuration, and permit the distal portions flex relative to the housing during compressive engagement with the first circuit member.

[0017] In another embodiment, a proximal portion of the polymeric base layer is optionally bonded to a second circuit member so the distal portions of the contact members are maintained in a cantilevered relationship to the second circuit member. In yet another embodiment, proximal portions of the conductive paths are bonded to contact pads on a second circuit member so the distal portions of the contact members are maintained in a cantilevered relationship to the second circuit member. One or more electrical devices are optionally printed on the polymeric base layer and electrically coupled to at least one of the conductive paths.

[0018] The present disclosure is also directed to an electrical assembly where proximal portions of the contact members are bonded to contact pads on a second circuit member and distal portions of the contact members compressively coupled to contact pads on the first circuit member. The first and second circuit members are selected from one of a dielectric layer, a printed circuit board, a flexible circuit, a bare die device, an integrated circuit device, organic or inorganic substrates, or a rigid circuit.

[0019] The present disclosure is also directed to a method for forming an array of composite polymer-metal contact members adapted to establish a solder free electrical connections with a first circuit member. The method includes printing an

array of metalized traces on selected portions of a polymeric base layer. An array of conductive paths is plated on the array of metalized traces. Dielectric material is optionally printed between the metalized traces. The resilient polymeric base layer, the metalized layer, and the conductive plating have an aggregate spring constant sufficient to maintain distal portions of the contact members in a cantilevered configuration. The proximal portions of the contact members are secured, such as for example, to a second circuit member or an interconnect housing. A stable electrical connection is formed between the distal portions of the contact members and the first circuit member solely by compressive engagement.

[0020] One embodiment includes printing mechanically stable metalized portions at proximal portions of the contact members. These metalized portions are bonded to contact pads on a second circuit member. Alternatively, solder balls are bonded to the metalized portions. Another embodiment includes coupling proximal portions of the contact members to a housing so the distal portions of the contact members flex relative to the housing during compressive engagement with the first circuit member.

[0021] The present method is also directed to bonding a proximal portion of the polymeric base layer to a second circuit member so the distal portions are maintained in a cantilevered relationship to the second circuit member. In another embodiment, proximal portions of the conductive paths are bonded to contact pads on a second circuit member so the distal portions are maintained in a cantilevered relationship to the second circuit member. One or more electrical devices are printed on the polymeric base layer and electrically coupling the electrical devices to at least one of the conductive paths.

[0022] The present method is also directed to forming an electrical assembly by bonding proximal portions of the present contact members to contact pads on a second circuit member and compressively coupling distal portions of the contact members to contact pads on the first circuit member.

[0023] The present disclosure employs an additive processes that combine the mechanical or structural properties of a polymer material, while adding metal materials in an unconventional fashion, to create electrical paths that are refined to provide electrical performance improvements. By adding or arranging metallic particles, conductive inks, plating, or portions of traditional alloys, the composite contact members reduces parasitic electrical effects and impedance mismatch,

potentially increasing the current carrying capacity or simplify the assembly process by combining contacts in a group without shorting.

[0024] In one embodiment, tiny metal particles mixed with the plastic resin before molding. The molded article is then exposed to ablation to create a plate-able matrix when placed in plating chemistry.

[0025] The present contact members can serve as a platform to add passive and active circuit features to improve electrical performance or internal function and intelligence. For example, electrical features and devices are printed onto the contact members using, for example, inkjet printing technology or other printing technologies. The ability to enhance the contact members, such that it mimics aspects of the IC package and a PCB, allows for reductions in complexity for the IC package and the PCB.

[0026] The printing process permits the fabrication of functional structures, such as conductive paths and electrical devices, without the use of masks or resists. Features down to about 10 microns can be directly written in a wide variety of functional inks, including metals, ceramics, polymers and adhesives, on virtually any substrate - silicon, glass, polymers, metals and ceramics. The substrates can be planar and non-planar surfaces. The printing process is typically followed by a thermal treatment, such as in a furnace or with a laser, to achieve dense functionalized structures.

Brief Description of the Several Views of the Drawing

[0027] Figure 1A is a side view of a composite polymer-metal contact member in accordance with an embodiment of the present disclosure.

[0028] Figure 1B is a perspective view of an alternate composite polymer-metal contact member in accordance with an embodiment of the present disclosure.

[0029] Figure 2 is a side view of a multi-layered composite polymer-metal contact member in accordance with an embodiment of the present disclosure.

[0030] Figure 3 is a side view of an alternate multi-layered composite polymer-metal contact member in accordance with an embodiment of the present disclosure.

[0031] Figure 4 is a side view of an alternate multi-layered composite polymer-metal contact member with printed electrical devices in accordance with an embodiment of the present disclosure.

[0032] Figure 5 is a side view of a composite polymer-metal contact member with a non-planar configuration in accordance with an embodiment of the present disclosure.

[0033] Figure 6 is a side view of a composite polymer-metal contact member with a resilient layer printed at a distal portion in accordance with an embodiment of the present disclosure.

[0034] Figure 7 is a side view of a composite polymer-metal contact member with protrusions printed at a distal portion in accordance with an embodiment of the present disclosure.

[0035] Figure 8 is a top view of an array of composite polymer-metal contact members in accordance with an embodiment of the present disclosure.

[0036] Figure 9 is a top view of an alternate array of composite polymer-metal contact members in accordance with an embodiment of the present disclosure.

[0037] Figure 10 is a top view of an array of composite polymer-metal contact members with printed shielding in accordance with an embodiment of the present disclosure.

[0038] Figure 11 is a side view of an array of composite polymer-metal contact members in a cantilevered configuration in accordance with an embodiment of the present disclosure.

[0039] Figure 12 is a side view of an alternate array of composite polymer-metal contact members in a cantilevered configuration in accordance with an embodiment of the present disclosure.

[0040] Figure 13 is a side view of another alternate array of composite polymer-metal contact members in a cantilevered configuration in accordance with an embodiment of the present disclosure.

[0041] Figure 14 is a side view of an array of composite polymer-metal contact members attached to an interconnect housing in accordance with an embodiment of the present disclosure.

[0042] Figure 15 is a side view of an array of composite polymer-metal contact members bonded to a circuit member in accordance with an embodiment of the present disclosure.

[0043] Figure 16 is a bottom view of an interconnect assembly using the composite polymer-metal contact members in accordance with an embodiment of the present disclosure.

[0044] Figure 17 is a side view of the interconnect assembly of Figure 16.

[0045] Figure 18 is a side view of an alternate interconnect assembly using the composite polymer-metal contact members in accordance with an embodiment of the present disclosure.

Detailed Description of the Invention

[0046] Contact members according to the present disclosure may permit fine contact-to-contact spacing (pitch) on the order of less than 1.0 mm pitch, and more preferably a pitch of less than about 0.7 millimeter, and most preferably a pitch of less than about 0.4 millimeter. Such fine pitch contact members are especially useful for communications, wireless, and memory devices. The disclosed low cost, high signal performance contact members, which have low profiles and can be soldered to the system PC board, are particularly useful for desktop and mobile PC applications.

[0047] The disclosed contact members permit IC devices to be installed and uninstalled without the need to reflow solder. The solder-free electrical connection of the IC devices is environmentally friendly. In another embodiment, the contact members can be formed directly on one of the circuit members.

[0048] Figure 1A is a side cross-sectional view of a composite contact member 50 in accordance with an embodiment of the present disclosure. In one embodiment, conductive traces 54 are printed on polymeric base 52 using conductive ink. The metallic particles in conductive traces 54 can be coined, embossed, sintered, a metal shape of traditional copper alloy or combination of these methods. The conductive traces 54 is then preferably plated 56 with a precious metal or other solderable material. The plating 56 facilitates soldering and prevents oxide formation.

[0049] In one embodiment, the polymeric base 52 is formed by mixing tiny metal particles with the plastic resin. The cured resin is then ablated to expose a portion of the metal particles, which can be plated using conventional techniques.

[0050] The base polymer 50 may be constructed of any of a number of dielectric materials that are currently used to make sockets, semiconductor packaging, and printed circuit boards. Examples may include UV stabilized tetrafunctional epoxy resin systems referred to as Flame Retardant 4 (FR-4); bismaleimide-triazine thermoset epoxy resins referred to as BT-Epoxy or BT Resin; and liquid crystal polymers (LCPs), which are polyester polymers that are extremely unreactive, inert

and resistant to fire. Other suitable plastics include phenolics, polyesters, and Ryton® available from Phillips Petroleum Company.

[0051] Figure 1B illustrates another embodiment of composite contact member 50B in accordance with an embodiment of the present disclosure. Dielectric material 60B is printed on the polymeric base 52B to create recesses or trenches 62B in which conductive traces 54B are then formed. The recesses 62B in the dielectric material 60B are then metalized to create conductive traces 54B. The use of a printed dielectric material to form recesses in which the conductive traces are formed has application to any of the embodiments disclosed herein.

[0052] Metalizing can be performed by printing conductive particles followed by a sintering step, by printing conductive inks, or a variety of other techniques. The metalizing material is preferably of copper or similar metallic materials such as phosphor bronze or beryllium-copper. The resulting conductive traces 54B are optionally plated to improve conductive properties. The plating is preferably a corrosion resistant metallic material such as nickel, gold, silver, palladium, or multiple layers thereof.

[0053] The dielectric material 60B may be constructed of any of a number of materials that provide electrostatic dissipation or to reduce cross-talk between adjacent conductive traces 54B. An efficient way to prevent electrostatic discharge ("ESD") is to construct one of the layers 52B, 60B from materials that are not too conductive but that will slowly conduct static charges away. These materials preferably have resistivity values in the range of 10^5 to 10^{11} Ohm-meters.

[0054] In one embodiment, the conductive traces 54B are formed by depositing a conductive material in a first state in the recesses 62B in the dielectric material, and then processed to create a second more permanent state. For example, the metallic powder is printed and subsequently sintered, or the curable conductive material flows into the recesses 62B and is subsequently cured. As used herein "cure" and inflections thereof refers to a chemical-physical transformation that allows a material to progress from a first form (e.g., flowable form) to a more permanent second form. "Curable" refers to an uncured material having the potential to be cured, such as for example by the application of a suitable energy source.

[0055] The recesses 62B permit control of the location, cross section, material content, and aspect ratio of the conductive traces 54B. Maintaining the conductive traces 54B with a cross-section of 1:1 or greater provides greater signal integrity

than traditional subtractive trace forming technologies. For example, traditional methods take a sheet of a given thickness and etches the material between the traces away to have a resultant trace that is usually wider than it is thick. The etching process also removes more material at the top surface of the trace than at the bottom, leaving a trace with a trapezoidal cross-sectional shape, degrading signal integrity in some applications. Using the recesses 62B to control the aspect ratio of the conductive traces 54B results in a more rectangular or square cross-section of the conductive traces 54B, with the corresponding improvement in signal integrity.

[0056] In another embodiment, pre-patterned or pre-etched thin conductive foil circuit traces are transferred to the recesses. For example, a pressure sensitive adhesive can be used to retain the copper foil circuit traces in the recesses 62B. The trapezoidal cross-sections of the pre-formed conductive foil traces are then post-plated. The plating material fills the open spaces in the recesses 62B not occupied by the foil circuit geometry, resulting in a substantially rectangular or square cross-sectional shape corresponding to the shape of the recesses 62B.

[0057] In another embodiment, a thin conductive foil is pressed into the recesses 62B, and the edges 64B of the recesses 62B acts to cut or shear the conductive foil. The process locates a portion of the conductive foil in the recesses or channels 62B, but leaves the negative pattern of the conductive foil not wanted outside and above the channels for easy removal. Again, the foil in the channels are preferably post plated to add material to increase the thickness of the conductive traces 54B and to fill any voids left between the conductive foil and the recesses 62B.

[0058] Figure 2 is a side cross-sectional view of an alternate composite contact member 70 in accordance with an embodiment of the present disclosure. Opposing surfaces 72, 74 of polymeric base 76 are metalized 78, 80. The polymeric layer 76 acts as a plating resist for full or selective plating. The polymer layer 76 is preferably selected to provide certain dielectric properties. In one embodiment, the contact member 70 can be shaped and sized to provide a desired impedance, redundant contact points, Kelvin interface with separate circuit paths, or plated 82 to encapsulate at least a portion of the polymer base 76. In some embodiments, portions of the composite contact member 70 are encapsulated with a suitable encapsulating materials, such as for example, Sylgard available from Dow Coming

Silicone of Midland, Mich. and Master Sil 713 available from Master Bond Silicone of Hackensack, N.J.

[0059] In the illustrated embodiment, conductive plating 82 is bifurcated at first end 84 to create two separate circuit connections 86, 88. Second end 90, on the other hand, exhibits continuous conductive plating 92.

[0060] Figure 3 illustrates an alternate composite contact member 100 that incorporates vias 102 that electrically couple metalized layers 104, 106. In one embodiment, the base polymer 108 is treated like a printed circuit, with multi-layer connections like vias 102 or larger conductive elements 110 created by leaving voids or in the base polymer 108. Metallization can be selective in any geometry to drive plating to only desired areas with exposed metal. In another embodiment, dielectric plating mask can be printed onto the metallization if desired to alter the plating geometry.

[0061] Figure 4 illustrates an alternate composite contact member 140 with additional functionality created during the printing process. In one embodiment, internal or segmented compliance is created at location 142 by leaving a void in the polymeric base 144, or by printing a different polymeric material, such as for example, resilient material 146. Creating the location 142 using printing technology permits a variety of internal features, undercuts, or cavities that are difficult or typically not possible to make using conventional molding or machining techniques, referred to herein as a "non-moldable feature." The resilient material 146 is selected to elastically deform under pressure, but to substantially resume its original shape when the force is removed. In another embodiment, location 142 may include a material with a different dielectric from the rest of the polymeric base 144.

[0062] In the illustrated embodiment, metal plating 150, 152 is bifurcated at end 154. Metal plating 150, 152 is electrically decoupled from metal plating 156 by portion 158 of the base polymer 144.

[0063] In another embodiment, additional circuitry or electrical devices 148 can be printed on the composite contact member 140, such as at the location 142. The devices 148 can be ground planes, power planes, electrical connections to other circuit members, dielectric layers, conductive traces, transistors, capacitors, resistors, RF antennae, shielding, filters, signal or power altering and enhancing devices, memory devices, embedded IC, and the like. For example, the electrical devices 148 can be formed using printing technology, adding intelligence to the

contact member 140. Features that are typically located on circuit members be incorporated into the contact member 140 in accordance with an embodiment of the present disclosure. As used herein, the term "circuit members" refers to, for example, a packaged integrated circuit device, an unpackaged integrated circuit device, a printed circuit board, a flexible circuit, a bare-die device, an organic or inorganic substrate, a rigid circuit, or any other device capable of carrying electrical current.

[0064] The availability of printable silicon inks provides the ability to print electrical devices 148, such as disclosed in U.S. Pat. No. 7,485,345 (Renn et al.); 7,382,363 (Albert et al.); 7,148,128 (Jacobson); 6,967,640 (Albert et al.); 6,825,829 (Albert et al.); 6,750,473 (Amundson et al.); 6,652,075 (Jacobson); 6,639,578 (Comiskey et al.); 6,545,291 (Amundson et al.); 6,521,489 (Duthaler et al.); 6,459,418 (Comiskey et al.); 6,422,687 (Jacobson); 6,413,790 (Duthaler et al.); 6,312,971 (Amundson et al.); 6,252,564 (Albert et al.); 6,177,921 (Comiskey et al.); 6,120,588 (Jacobson); 6,118,426 (Albert et al.); and U.S. Pat. Publication No. 2008/0008822 (Kowalski et al.), which are hereby incorporated by reference. In particular, U.S. Patent Nos. 6,506,438 (Duthaler et al.) and 6,750,473 (Amundson et al.), which are incorporated by reference, teach using ink-jet printing to make various electrical devices, such as, resistors, capacitors, diodes, inductors (or elements which may be used in radio applications or magnetic or electric field transmission of power or data), semiconductor logic elements, electro-optical elements, transistor (including, light emitting, light sensing or solar cell elements, field effect transistor, top gate structures), and the like.

[0065] The electrical devices 148 can also be created by aerosol printing, such as disclosed in U.S. Patent Nos. 7,674,671 (Renn et al.); 7,658,163 (Renn et al.); 7,485,345 (Renn et al.); 7,045,015 (Renn et al.); and 6,823,124 (Renn et al.), which are hereby incorporated by reference.

[0066] Printing process are preferably used to fabricate various functional structures, such as conductive paths and electrical devices, without the use of masks or resists. Features down to about 10 microns can be directly written in a wide variety of functional inks, including metals, ceramics, polymers and adhesives, on virtually any substrate - silicon, glass, polymers, metals and ceramics. The substrates can be planar and non-planar surfaces. The printing process is typically

followed by a thermal treatment, such as in a furnace or with a laser, to achieve dense functionalized structures.

[0067] Ink jet printing of electronically active inks can be done on a large class of substrates, without the requirements of standard vacuum processing or etching. The inks may incorporate mechanical, electrical or other properties, such as, conducting, insulating, resistive, magnetic, semi conductive, light modulating, piezoelectric, spin, optoelectronic, thermoelectric or radio frequency.

[0068] A plurality of ink drops are dispensed from the print head directly to a substrate or on an intermediate transfer member. The transfer member can be a planar or non-planar structure, such as a drum. The surface of the transfer member can be coated with a non-sticking layer, such as silicone, silicone rubber, or Teflon.

[0069] The ink (also referred to as function inks) can include conductive materials, semi-conductive materials (e.g., p-type and n-type semiconducting materials), metallic material, insulating materials, and/or release materials. The ink pattern can be deposited in precise locations on a substrate to create fine lines having a width smaller than 10 microns, with precisely controlled spaces between the lines. For example, the ink drops form an ink pattern corresponding to portions of a transistor, such as a source electrode, a drain electrode, a dielectric layer, a semiconductor layer, or a gate electrode.

[0070] The substrate can be an insulating polymer, such as polyethylene terephthalate (PET), polyester, polyethersulphone (PES), polyimide film (e.g. Kapton, available from DuPont located in Wilmington, DE; Upilex available from Ube Corporation located in Japan), or polycarbonate. Alternatively, the substrate can be made of an insulator such as undoped silicon, glass, or a plastic material. The substrate can also be patterned to serve as an electrode. The substrate can further be a metal foil insulated from the gate electrode by a non-conducting material. The substrate can also be a woven material or paper, planarized or otherwise modified on at least one surface by a polymeric or other coating to accept the other structures.

[0071] Electrodes can be printed with metals, such as aluminum or gold, or conductive polymers, such as polythiophene or polyaniline. The electrodes may also include a printed conductor, such as a polymer film comprising metal particles, such as silver or nickel, a printed conductor comprising a polymer film containing graphite or some other conductive carbon material, or a conductive oxide such as tin oxide or indium tin oxide.

[0072] Dielectric layers can be printed with a silicon dioxide layer, an insulating polymer, such as polyimide and its derivatives, poly-vinyl phenol, polymethylmethacrylate, polyvinylidenedifluoride, an inorganic oxide, such as metal oxide, an inorganic nitride such as silicon nitride, or an inorganic/organic composite material such as an organic-substituted silicon oxide, or a sol-gel organosilicon glass. Dielectric layers can also include a bicyclobutene derivative (BCB) available from Dow Chemical (Midland, Mich.), spin-on glass, or dispersions of dielectric colloid materials in a binder or solvent.

[0073] Semiconductor layers can be printed with polymeric semiconductors, such as, polythiophene, poly(3-alkyl)thiophenes, alkyl-substituted oligothiophene, polythienylenevinylene, poly(para-phenylenevinylene) and doped versions of these polymers. An example of suitable oligomeric semiconductor is alpha-hexathienylene. Horowitz, Organic Field-Effect Transistors, Adv. Mater., 10, No. 5, p. 365 (1998) describes the use of unsubstituted and alkyl-substituted oligothiophenes in transistors. A field effect transistor made with regioregular poly(3-hexylthiophene) as the semiconductor layer is described in Bao et al., Soluble and Processable Regioregular Poly(3-hexylthiophene) for Thin Film Field-Effect Transistor Applications with High Mobility, Appl. Phys. Lett. 69 (26), p. 4108 (December 1996). A field effect transistor made with a-hexathienylene is described in U.S. Pat. No. 5,659,181, which is incorporated herein by reference.

[0074] A protective layer can optionally be printed onto the electrical devices. The protective layer can be an aluminum film, a metal oxide coating, a polymeric film, or a combination thereof.

[0075] Organic semiconductors can be printed using suitable carbon-based compounds, such as, pentacene, phthalocyanine, benzodithiophene, buckminsterfullerene or other fullerene derivatives, tetracyanonaphthoquinone, and tetrakisimethylanimoethylene. The materials provided above for forming the substrate, the dielectric layer, the electrodes, or the semiconductor layer are exemplary only. Other suitable materials known to those skilled in the art having properties similar to those described above can be used in accordance with the present disclosure.

[0076] The ink-jet print head preferably includes a plurality of orifices for dispensing one or more fluids onto a desired media, such as for example, a conducting fluid solution, a semiconducting fluid solution, an insulating fluid solution,

and a precursor material to facilitate subsequent deposition. The precursor material can be surface active agents, such as octadecyltrichlorosilane (OTS).

[0077] Alternatively, a separate print head is used for each fluid solution. The print head nozzles can be held at different potentials to aid in atomization and imparting a charge to the droplets, such as disclosed in U.S. Pat. No. 7,148,128 (Jacobson), which is hereby incorporated by reference. Alternate print heads are disclosed in U.S. Pat. No. 6,626,526 (Ueki et al.), and U.S. Pat. Publication Nos. 2006/0044357 (Andersen et al.) and 2009/0061089 (King et al.), which are hereby incorporated by reference.

[0078] The print head preferably uses a pulse-on-demand method, and can employ one of the following methods to dispense the ink drops: piezoelectric, magnetostrictive, electromechanical, electro pneumatic, electrostatic, rapid ink heating, magneto hydrodynamic, or any other technique well known to those skilled in the art. The deposited ink patterns typically undergo a curing step or another processing step before subsequent layers are applied.

[0079] While ink jet printing is preferred, the term "printing" is intended to include all forms of printing and coating, including: pre-metered coating such as patch die coating, slot or extrusion coating, slide or cascade coating, and curtain coating; roll coating such as knife over roll coating, forward and reverse roll coating; gravure coating; dip coating; spray coating; meniscus coating; spin coating; brush coating; air knife coating; screen printing processes; electrostatic printing processes; thermal printing processes; and other similar techniques.

[0080] Figures 5 illustrate a composite contact member 170 that has been formed into a desired shape 172. In the illustrated embodiment, the polymeric base 174 is thermally deformed, such as by hot stamping or hot forming, to set the shape 172. In an alternate embodiment, the polymeric base 174 is injection molded to create the desired shape. The aggregate spring constant of the composite contact member 170 is the sum of the polymeric base 174, the metalizing layer 176 and the plating 178. The resulting contact member 170 is both self-supporting and resilient. As used herein, "self-supporting" refers to sufficient resiliency to form a stable electrical connection solely by compressive engagement.

[0081] Figure 6 illustrates an alternate composite contact member 190 with added compliance at contact surface 192. Resilient material 194 is printed on polymeric base 196 under the metalizing layer 198 and the plating 200 proximate the contact

surface 192. Consequently, the contact surface 192 has increased compliance when engaged with a circuit member.

[0082] Figure 7 illustrates an alternate composite contact member 210 with a plurality of protrusions 212 printed on contact surface 214. The protrusions 212 can be an oxide penetrating material or simply additional metalizing material 216. The subsequent plating 218 follows the contours of the protrusions 212.

[0083] Figure 8 illustrates array 230 of composite contacts 232 printed on polymeric base 234. The polymeric base 234 can be selectively metalized and plated to create a streamlined conductive path 236 on each polymeric beam 238. The polymeric beams 238 provide compliance, while supporting the conductive paths 236. In one embodiment, the polymeric base layer 234 is a continuous sheet and the polymeric material 234 between the individual contacts 232 is preferably removed after application of the plating layer 236.

[0084] In one embodiment, one or more of the layer are printed to provide electrostatic dissipation or to reduce cross-talk between the contact members 232. An efficient way to prevent electrostatic discharge ("ESD") is to construct one of the layers from materials that are not too conductive but that will slowly conduct static charges away. These materials preferably have resistivity values in the range of 10^5 to 10^{11} Ohm-meters. The ESD material also permits metallization to be applied en-masse under static charge at the desired areas. Electrical devices 242 can be printed between the individual composite contact members 232.

[0085] Figure 9 illustrates an alternate array 250 of composite contact members 252 with printed dielectric layer or shielding traces 254 added to reduce cross-talk between adjacent conductive paths 256. Figure 10 illustrates an alternate array 260 of composite contact members 262, 264 configured as ganged ground pins, and an isolated signal pin 266. Electrical device 268 is printed on composite contact member 266, as discussed above.

[0086] Figure 11 is a side view of an array of composite contact member 280 deployed as an interconnect assembly 282 between circuit members 284, 286, in accordance with an embodiment of the present disclosure. Distal portions 288 of each composite contact member 280 include polymer base 290, metalizing layer 292, and plating layer 294, arranged in a cantilevered relationship with the first circuit member 284.

[0087] Proximal portion 300 includes enlarged metalized portion 302 that is electrically coupled, preferably by soldering, to contact pad 304 on second circuit member 286. In the illustrated embodiment, polymer base 290 extends down side surfaces 306 of the metalized portion 302, increasing the structural stability of the individual contact members 280. Plating layer 294 preferably extends along top surface 308 of the metalized portion 302, also adding structural stability. The metalized portion 302 anchors the composite contact member 280 to the second circuit member 286 with sufficient strength to permit the distal portion 288 to electrically couple with contact pad 298 on the first circuit member 284 solely by compression. No solder is required.

[0088] Bonding the array of composite contact members 280 directly to the second circuit member 286 eliminates the need for an intermediate housing typically used to retain the contact members of conventional interconnect assemblies, permitting a lower profile stack. On some embodiments, the array of composite contact members 280 is substituted for a conventional pin grid array contact set used with certain integrated circuit devices (see e.g., Figure 18).

[0089] Figure 12 illustrates an alternate array of composited contact members 320 bonded to a ball grid array 322 on second circuit member 324 in accordance with an embodiment of the present disclosure. The composite contact members 320 are positioned relative to the second circuit member 324 and the assembly is heated to reflow solder balls 326. Again, the solder connection is sufficiently strong to eliminate the need for an intermediate housing structure. The cantilevered contact members 320 electrically couple with the first circuit member 328 solely by compressive engagement with distal portion 330.

[0090] Figure 13 illustrates an alternate array of composite contact members 340 in which solder ball 342 is bonded to metalizing portion 344. Solder paste or flux 346 is preferably printed on contact pads 348 of the second circuit 350.

[0091] Figure 14 illustrates interconnect assembly 360 using composite contact members 362 in accordance with an embodiment of the present disclosure. Composite contact members 362 are inserted into housing 364, either individually or ganged. Adhesive 366 is then deposited in recesses 368 to retain the composite contact members 362 in housing 364 and to increase structural integrity. In the illustrated embodiment, solder balls 370 are electrically coupled with proximal ends 372 of the composite contact members 362.

[0092] The solder balls 370 can reflow to form a permanent electrical contact with second circuit member 374. Distal portions 376 of composite contact members 362 flex relative to the housing 364 to provide compliant engagement with first circuit member 378.

[0093] Figure 15 is a side view of an array of composite contact members 400 forming an interconnect assembly 402 between circuit members 404, 406, in accordance with an embodiment of the present disclosure. Polymer base 408 is bonded to surface 410 of the second circuit member 406 so plating layers 412 are electrically coupled with contact pads 414. Bonding can be achieved using adhesives, ultrasonic welding, and the like. In one embodiment, plating layer 412 is soldered to contact pads 414. In another embodiment, the polymer base 408 has sufficient stiffness to compressively engage plating layer 412 with the contact pads 414.

[0094] The polymer base 408 supports distal ends 416 of the contact members 400 to maintain a compressive electrical coupling with first circuit member 404. In the illustrated embodiment, the contact members 400 include one or more electrical devices 418, 420.

[0095] Figures 16 and 17 illustrate an assembly 430 including arrays of composite contact members 432 interconnecting first and second circuit members 434, 436, in accordance with an embodiment of the present disclosure. The second circuit member 436 is shown in phantom in Figure 16 to simulate viewing the bottom of first circuit member 434 through the second circuit member 436. Individual contact members 432 compressively engage with contact pads 438 on the first circuit member, as discussed above. In one embodiment, the assembly 430 is a socket electrically coupling the first and second circuit members 434, 436.

[0096] Figure 18 illustrates an assembly 450 including arrays of composite contact members 452 interconnecting first and second circuit members 454, 456, in accordance with an embodiment of the present disclosure. The polymeric base 458 is bonded to side surface 460 of second circuit member 456. In one embodiment, plating layer 462 is electrically coupled to contact pads 464. The composite contact members 452 simulate a pin grid array used on some integrated circuit devices. The compliance of the individual contact members 452 permits compressive coupling with first circuit member 454.

[0097] Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range is encompassed within the embodiments of the disclosure. The upper and lower limits of these smaller ranges which may independently be included in the smaller ranges is also encompassed within the embodiments of the disclosure, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either both of those included limits are also included in the embodiments of the present disclosure.

[0098] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the embodiments of the present disclosure belong. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the embodiments of the present disclosure, the preferred methods and materials are now described. All patents and publications mentioned herein, including those cited in the Background of the application, are hereby incorporated by reference to disclose and described the methods and/or materials in connection with which the publications are cited.

[0099] The publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present disclosure is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates which may need to be independently confirmed.

[00100] Other embodiments of the disclosure are possible. Although the description above contains much specificity, these should not be construed as limiting the scope of the disclosure, but as merely providing illustrations of some of the presently preferred embodiments of this disclosure. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments may be made and still fall within the scope of the present disclosure. It should be understood that various features and aspects of the disclosed embodiments can be combined with or substituted for one another in order to form varying modes of the disclosed embodiments of the disclosure. Thus, it is intended

that the scope of the present disclosure herein disclosed should not be limited by the particular disclosed embodiments described above.

[00101] Thus the scope of this disclosure should be determined by the appended claims and their legal equivalents. Therefore, it will be appreciated that the scope of the present disclosure fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present disclosure is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean “one and only one” unless explicitly so stated, but rather “one or more.” All structural, chemical, and functional equivalents to the elements of the above-described preferred embodiment(s) that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device or method to address each and every problem sought to be solved by the present disclosure, for it to be encompassed by the present claims. Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims.

What is claimed is:

1. An array of composite polymer-metal contact members adapted to form solder free electrical connections with a first circuit member, the contact members comprising:

a resilient polymeric base layer;
an array of metalized traces printed on selected portions of the base layer;
conductive plating applied to the metalized layer comprising an array of conductive paths; and

the resilient polymeric base layer, the metalized layer, and the conductive plating comprising an aggregate spring constant sufficient to maintain distal portions of the contact members in a cantilevered configuration and to form a stable electrical connection between the distal portions and the first circuit member solely by compressive engagement.

2. The contact members of claim 1 comprising a mechanically stable metalized portion printed on proximal portions of the contact members, the metalized portion adapted to bond to a second circuit member.

3. The contact members of claim 1 comprising:
a metalized portion at proximal ends of the contact members; and
a solder balls bonded to the metalized portions.

4. The contact members of claim 1 comprising a housing coupled to proximal portions of the contact members, wherein the distal portions flex relative to the housing during compressive engagement with the first circuit member.

5. The contact members of claim 1 wherein a proximal portion of the polymeric base layer is bonded to a second circuit member so the distal portions of the contact members are maintained in a cantilevered relationship to the second circuit member.

6. The contact members of claim 1 wherein proximal portions of the conductive paths are bonded to contact pads on a second circuit member so the distal portions of the contact members are maintained in a cantilevered relationship to the second circuit member.

7. The contact members of claim 1 comprising a plurality of electrical devices printed on the polymeric base layer and electrically coupled to at least one of the conductive paths.

8. An electrical assembly comprising proximal portions of the contact members of claim 1 bonded to contact pads on a second circuit member and distal portions of the contact members compressively coupled to contact pads on the first circuit member.

9. The electrical assembly of claim 8 wherein the first and second circuit members are selected from one of a dielectric layer, a printed circuit board, a flexible circuit, a bare die device, an integrated circuit device, organic or inorganic substrates, or a rigid circuit.

10. An array of composite polymer-metal contact members adapted to form solder free electrical connections with a first circuit member, the contact members comprising:

a resilient polymeric base layer;

at least one dielectric layer selectively printed on the polymeric base to form recesses corresponding to a desired circuit trace;

a conductive material printed in at least a portion of the recesses comprising conductive traces, the conductive traces comprising exposed terminals adapted to electrically couple to the first circuit member; and

the resilient polymeric base layer, the dielectric material, and the conductive traces comprising an aggregate spring constant sufficient to maintain distal portions of the contact members in a cantilevered configuration and to form a stable electrical connection between the distal portions and the first circuit member solely by compressive engagement.

11. The contact members of claim 10 wherein conductive traces comprise substantially rectangular cross-sectional shapes.

12. The contact members of claim 10 comprising one or more electrical devices printed on one or more of the polymeric base layer or the dielectric layer and electrically coupled to the conductive trace.

13. A method for forming an array of composite polymer-metal contact members adapted to establish a solder free electrical connections with a first circuit member, the method comprising:

printing an array of metalized traces on selected portions of a polymeric base layer;

plating an array of conductive paths on the array of metalized traces, the resilient polymeric base layer, the metalized layer, and the conductive plating

comprising an aggregate spring constant sufficient to maintain distal portions of the contact members in a cantilevered configuration;

securing proximal portions of the contact members; and

forming a stable electrical connection between the distal portions of the contact members and the first circuit member solely by compressive engagement.

14. The method of claim 13 comprising the steps of:

printing mechanically stable metalized portions at proximal portions of the contact members; and

bonding the metalized portions to contact pads on a second circuit member.

15. The method of claim 13 comprising:

printing metalized portions at proximal ends of the contact members; and

bonding solder balls to the metalized portions.

16. The method of claim 13 comprising coupling proximal portions of the contact members to a housing, wherein the distal portions of the contact members flex relative to the housing during compressive engagement with the first circuit member.

17. The method of claim 13 comprising bonding a proximal portion of the polymeric base layer to a second circuit member so the distal portions are maintained in a cantilevered relationship to the second circuit member.

18. The method of claim 13 comprising bonding proximal portions of the conductive paths to contact pads on a second circuit member so the distal portions are maintained in a cantilevered relationship to the second circuit member.

19. The method of claim 13 comprising printing a plurality of electrical devices on the polymeric base layer and electrically coupling the electrical devices to at least one of the conductive paths.

20. The method of claim 13 comprising forming the polymeric base layer into a non-planar shape.

21. The method of claim 13 comprising:

selectively printing at least one dielectric layer on the polymeric base to form recesses corresponding the array of metalized traces; and

printing a conductive material in at least a portion of the recesses.

22. A method of forming an electrical assembly comprising the steps of:
bonding proximal portions of the contact members of claim 13 to contact pads
on a second circuit member; and
compressively coupling distal portions of the contact members to contact pads
on the first circuit member.

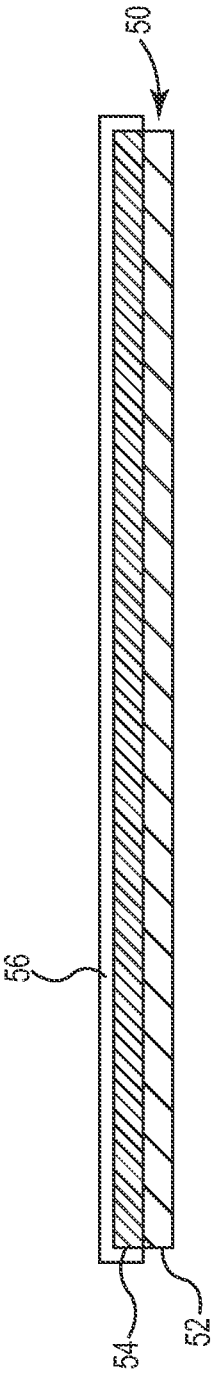


Fig. 1A

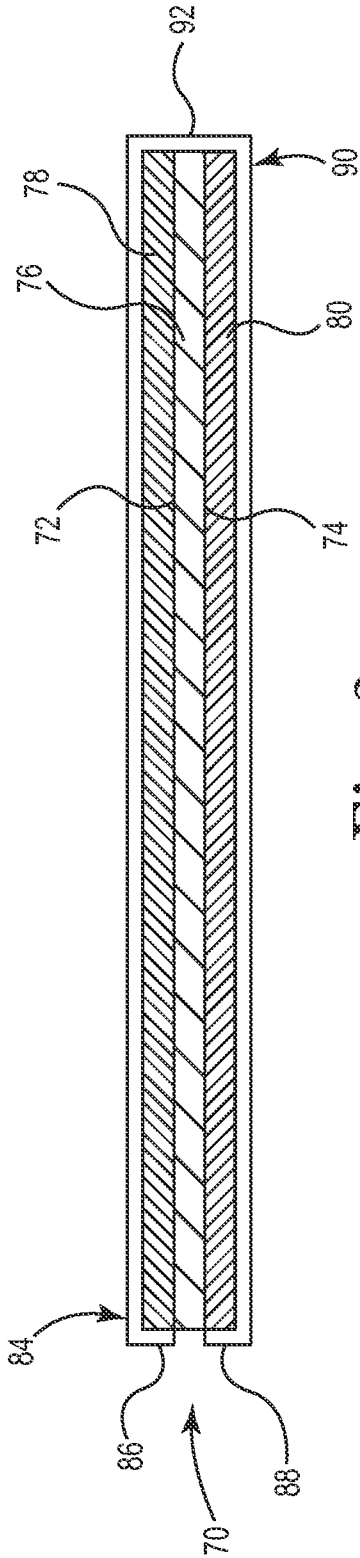


Fig. 2

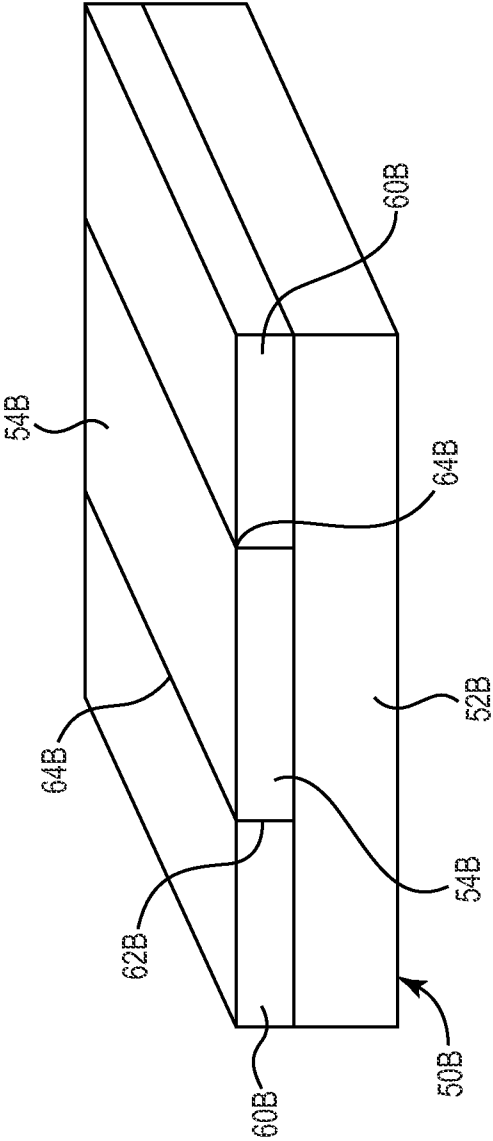


Fig. 1B

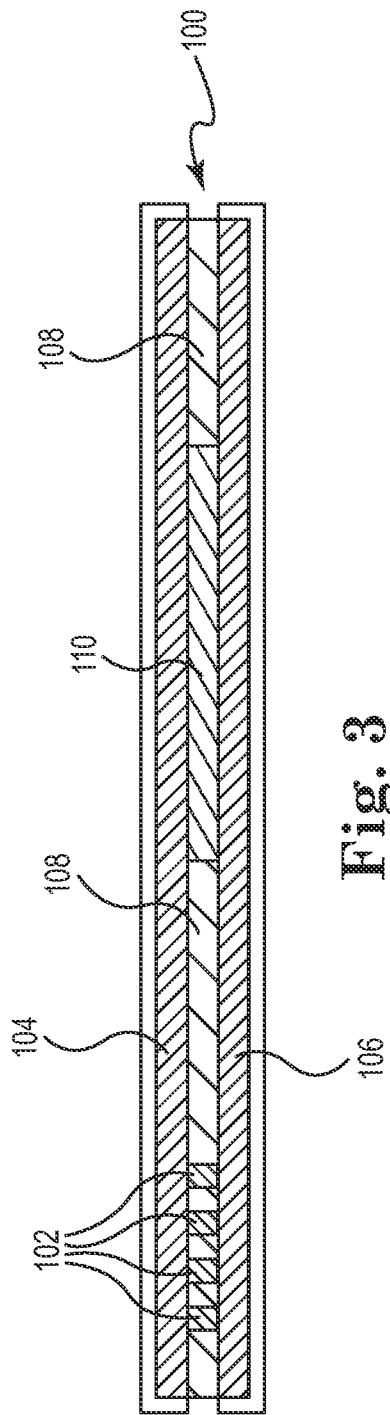


Fig. 3

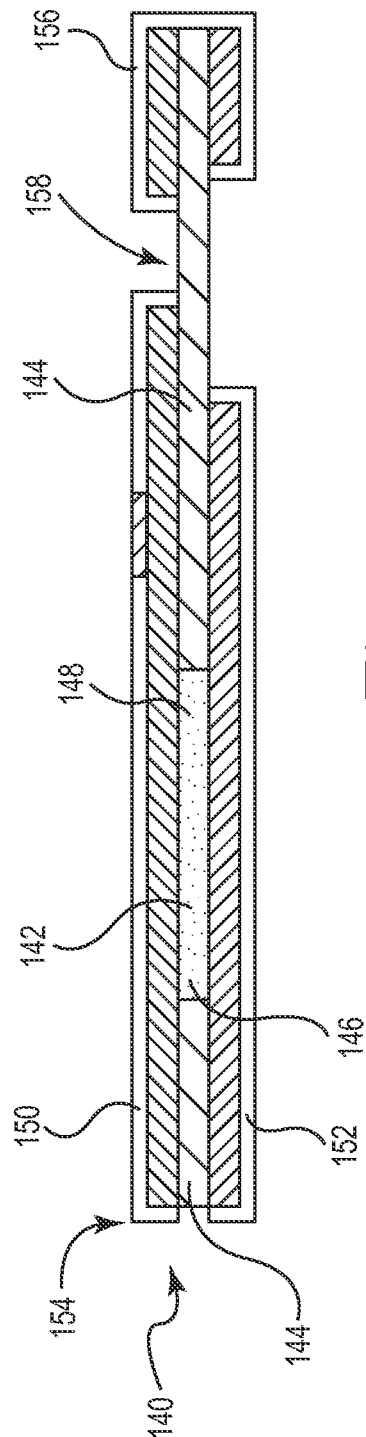


Fig. 4

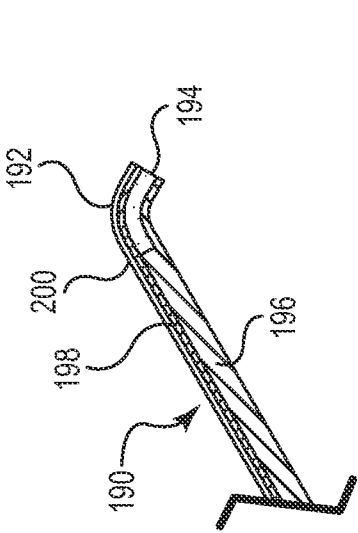


Fig. 6

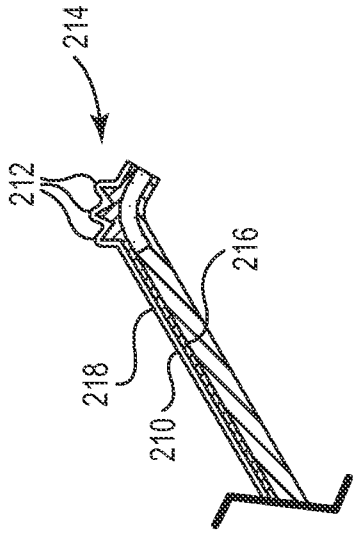


Fig. 7

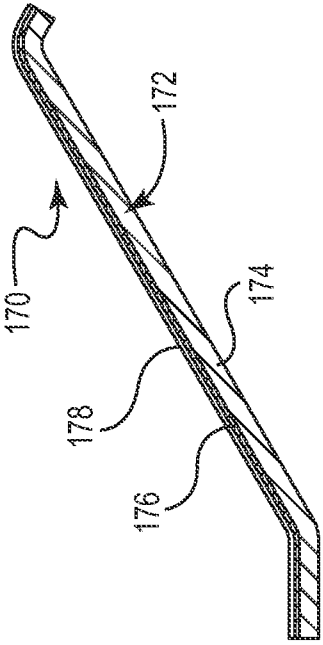


Fig. 5

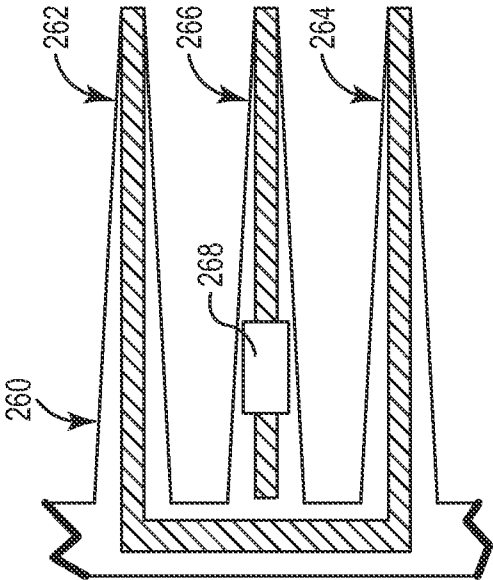


Fig. 10

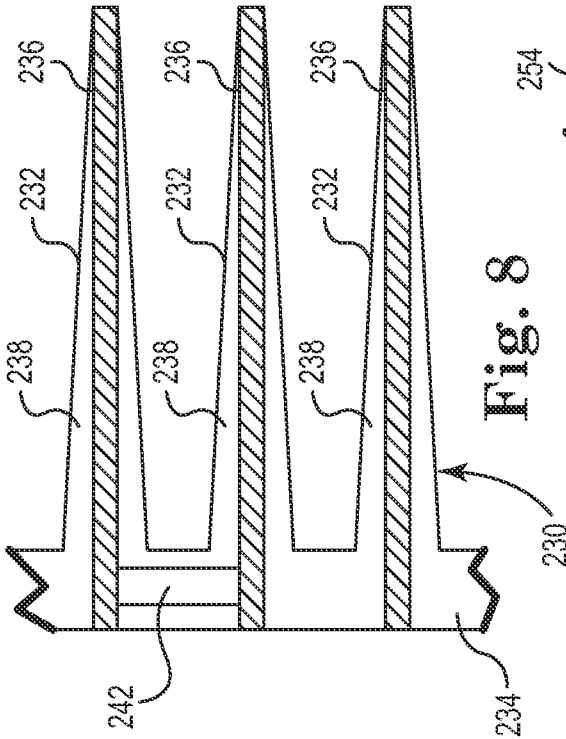


Fig. 8

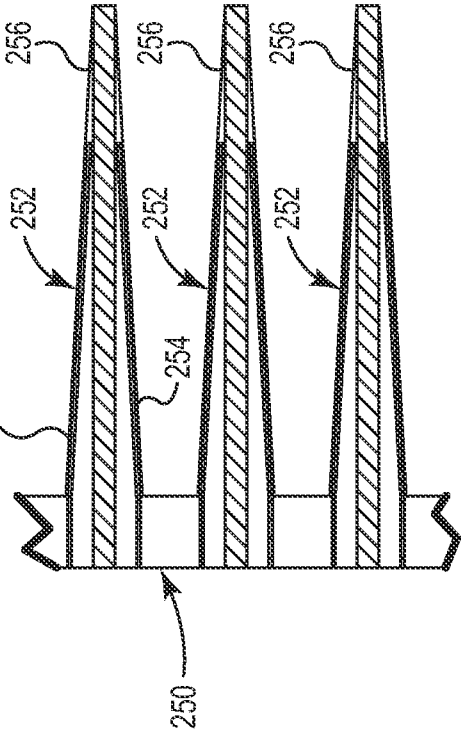


Fig. 9

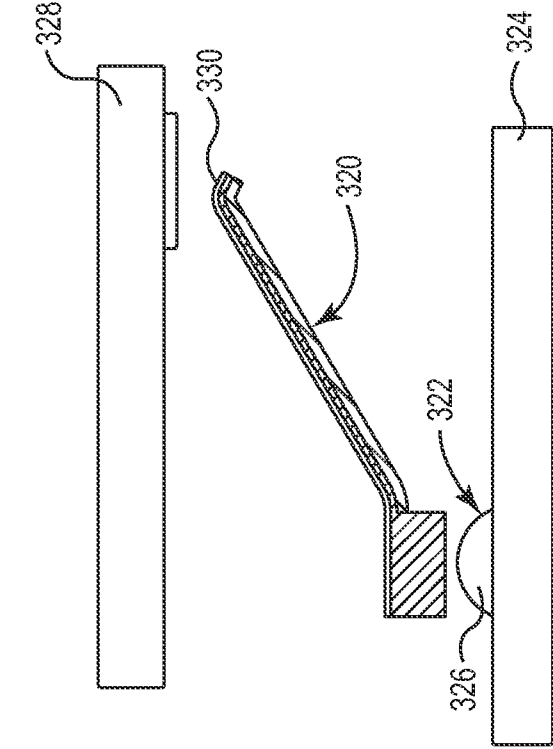


Fig. 12

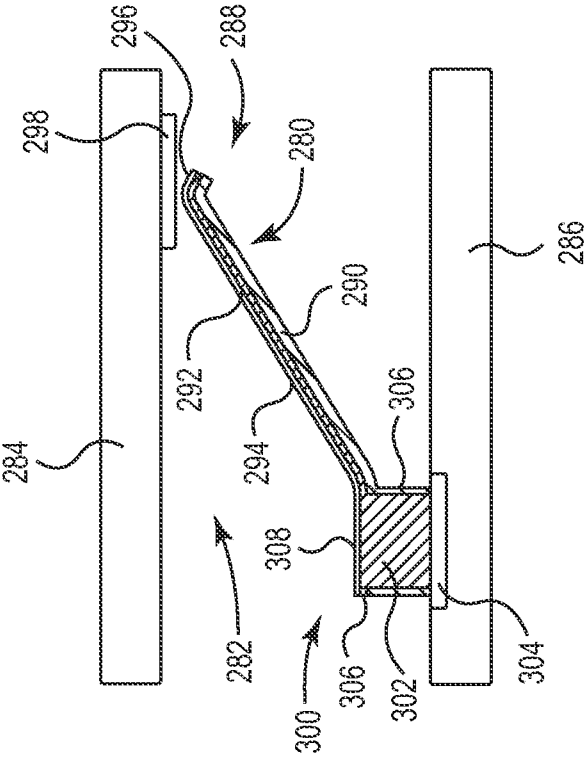


Fig. 11

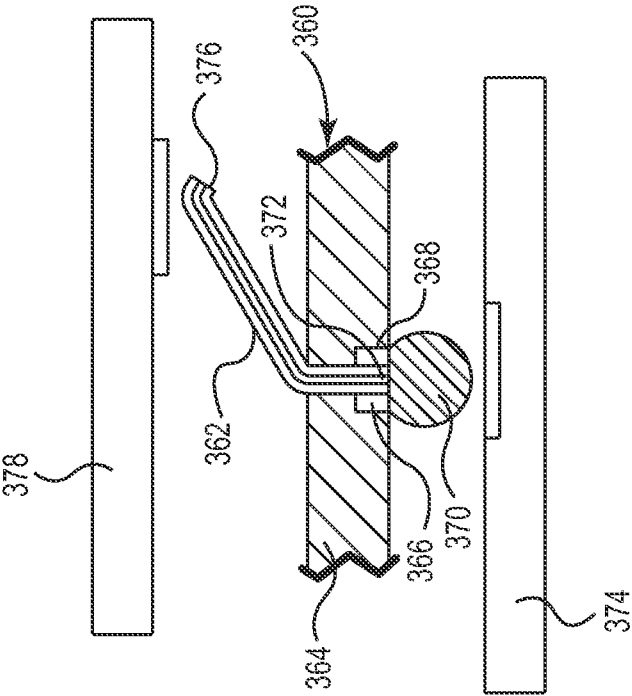


Fig. 14

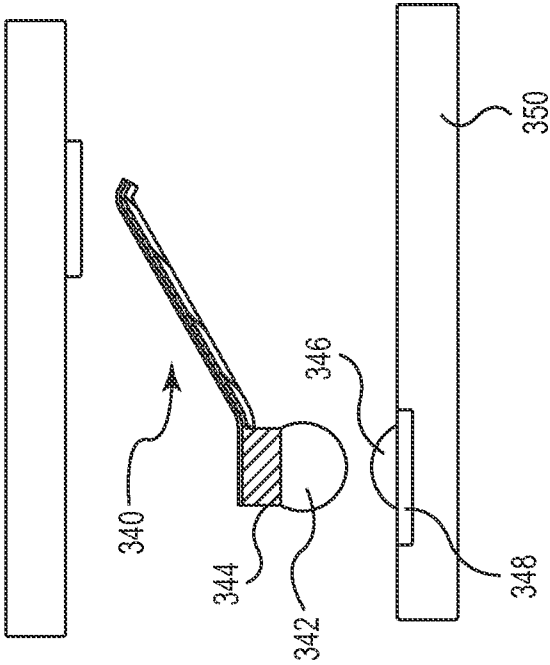


Fig. 13

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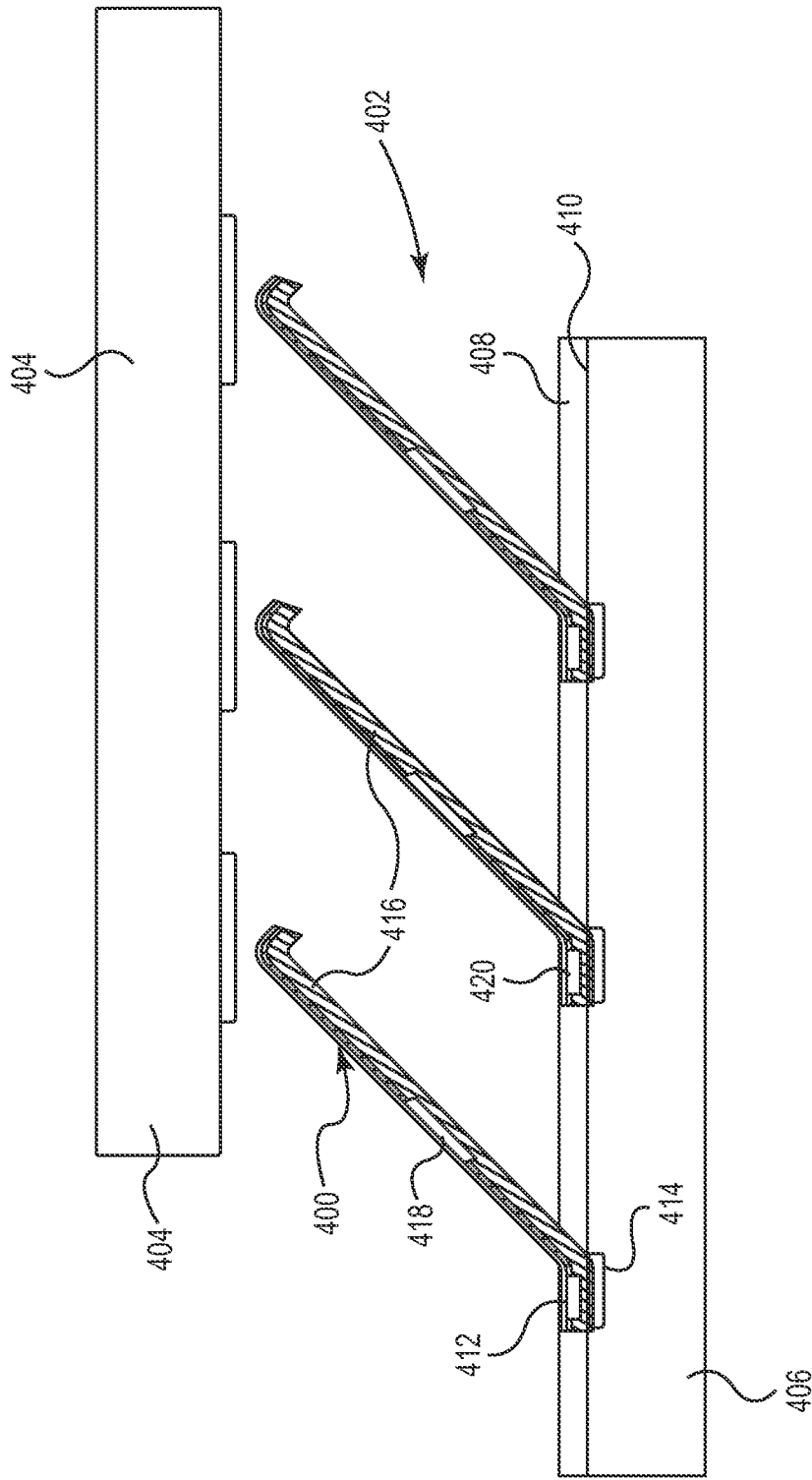


Fig. 15

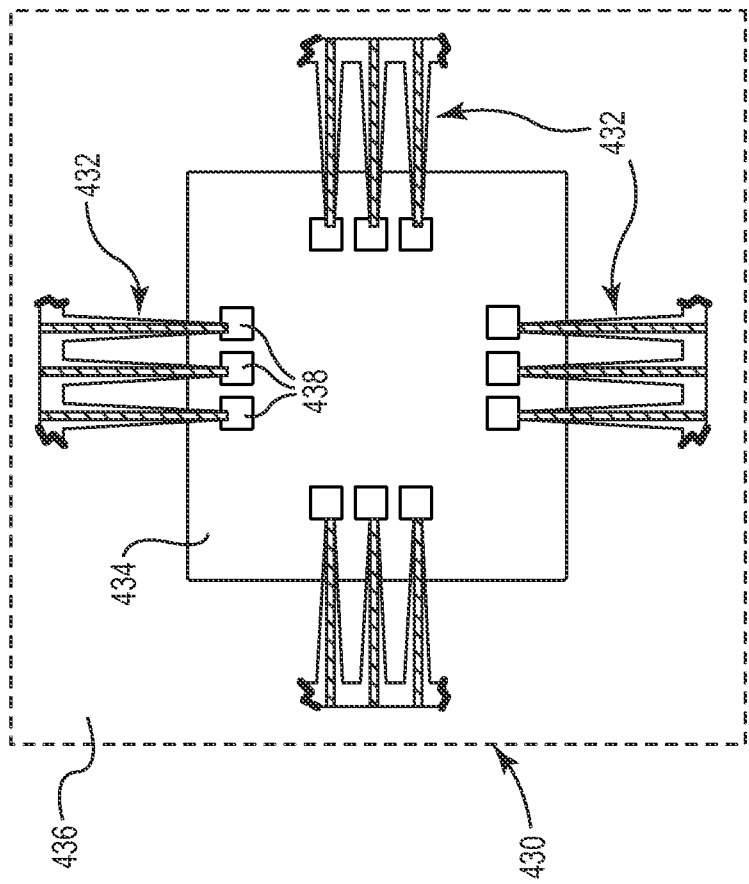


Fig. 16

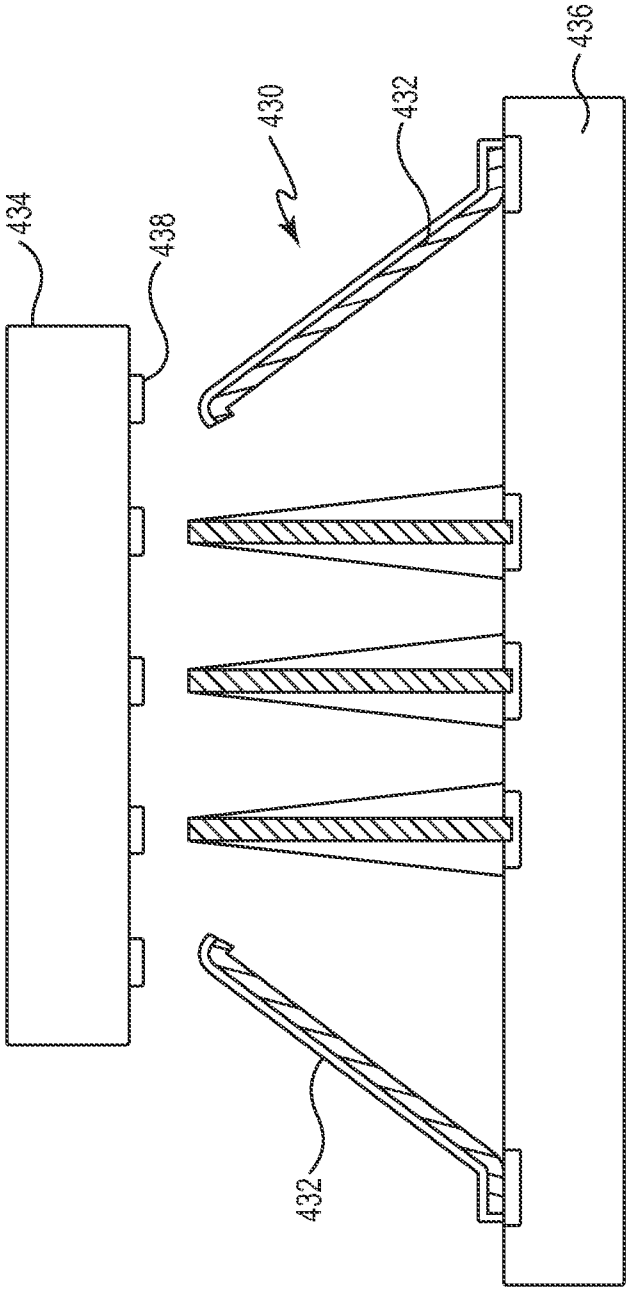


Fig. 17

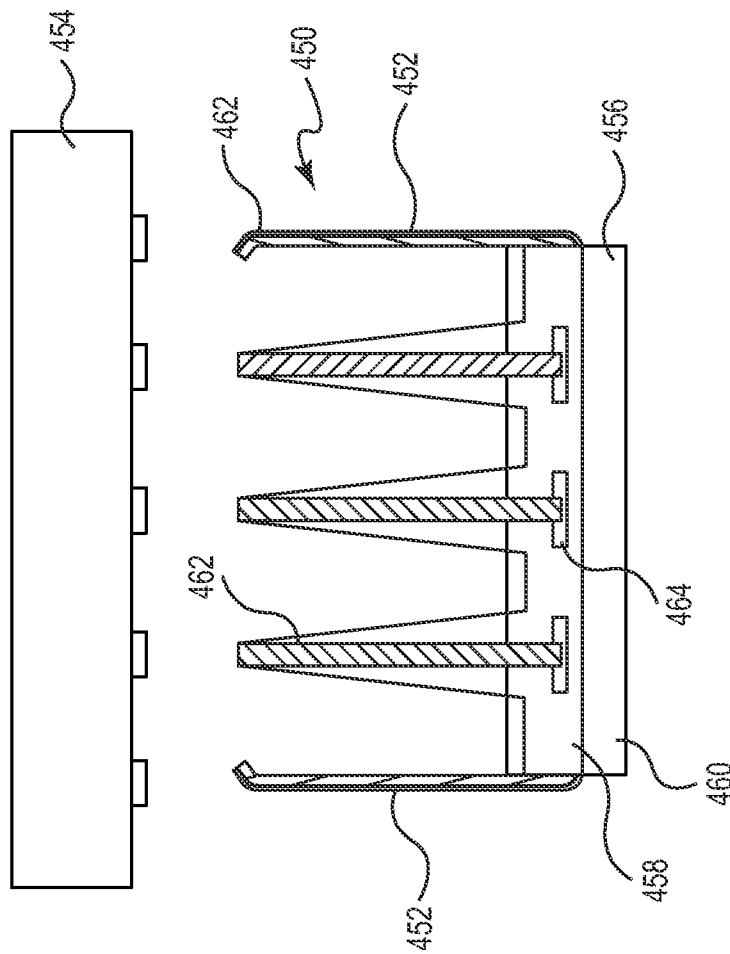


Fig. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/036295

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - H01R 12/00 (2010.01) USPC - 439/66 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC(8) - H01R 12/00 (2010.01) USPC - 439/65, 66, 86, 591, 632 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) USPTO EAST System (US, USPG-PUB, EPO, DERWENT)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0087064 A1 (DANIEL et al) 27 April 2006 (27.04.2006) entire document	1-22
Y	US 2007/0296090 A1 (HEMBREE) 27 December 2007 (27.12.2007) entire document	1-22
Y	US 2004/0048523 A1 (HUANG et al) 11 March 2004 (11.03.2004) entire document	3, 15
Y	US 2002/0098740 A1 (OOYA) 25 July 2002 (25.07.2002) entire document	4, 16
Y	US 2007/0273394 A1 (TANNER et al) 29 November 2007 (29.11.2007) entire document	10-12, 21
☐ Further documents are listed in the continuation of Box C. ☐		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 21 July 2010		Date of mailing of the international search report 30 JUL 2010
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774