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(57) **ABSTRACT**

Hermetically sealed packages having organic electronic devices are presented. A number of sealing mechanisms are provided to hermetically seal the package to protect the organic electronic device from environmental elements. A metal alloy sealant layer is employed proximate to the organic electronic device. Alternatively, a metal alloy sealant layer in combination with primer layer may also be implemented. Further, superstrates and edge wraps may be provided to completely surround the organic electronic device.

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A cross-sectional view of a semiconductor device structure. The structure consists of several layers: a top layer (22) with a cross-hatch pattern, a middle layer (20) with a diagonal hatch pattern, and a bottom layer (12) with a diagonal hatch pattern. A central region (14) is defined by a horizontal line. On the left and right sides, there are vertical structures (18) with a diagonal hatch pattern, and a layer (24) with a cross-hatch pattern. The bottom layer (12) is the thickest and has a diagonal hatch pattern.

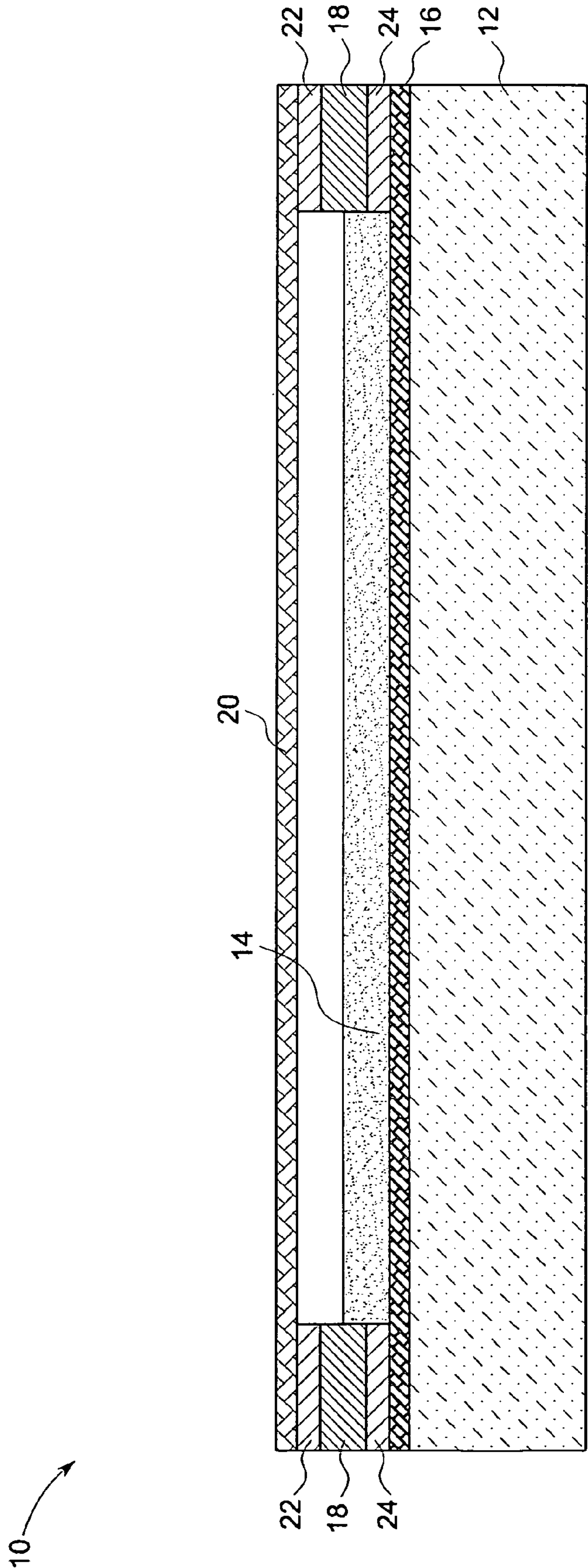


FIG. 1

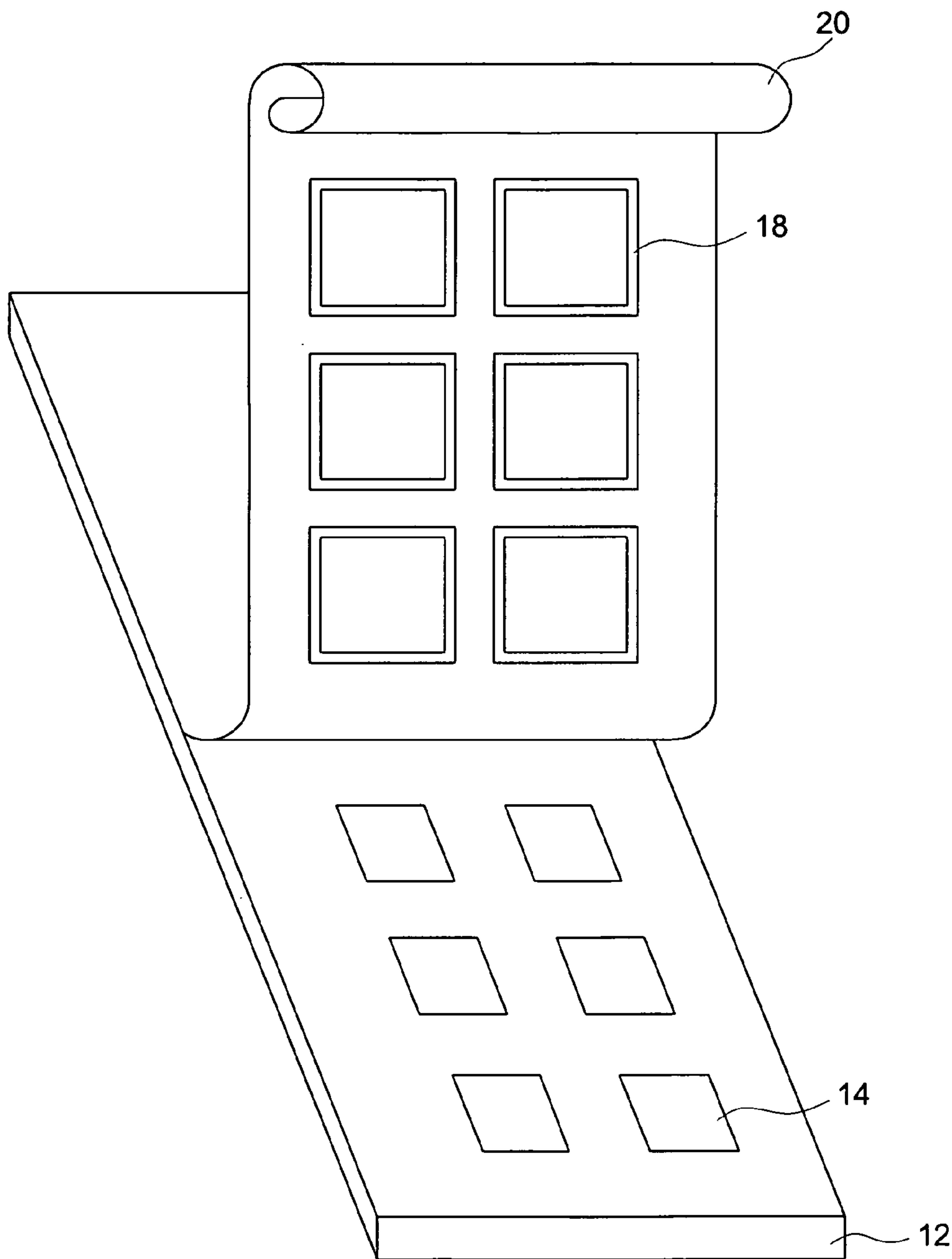


FIG. 2

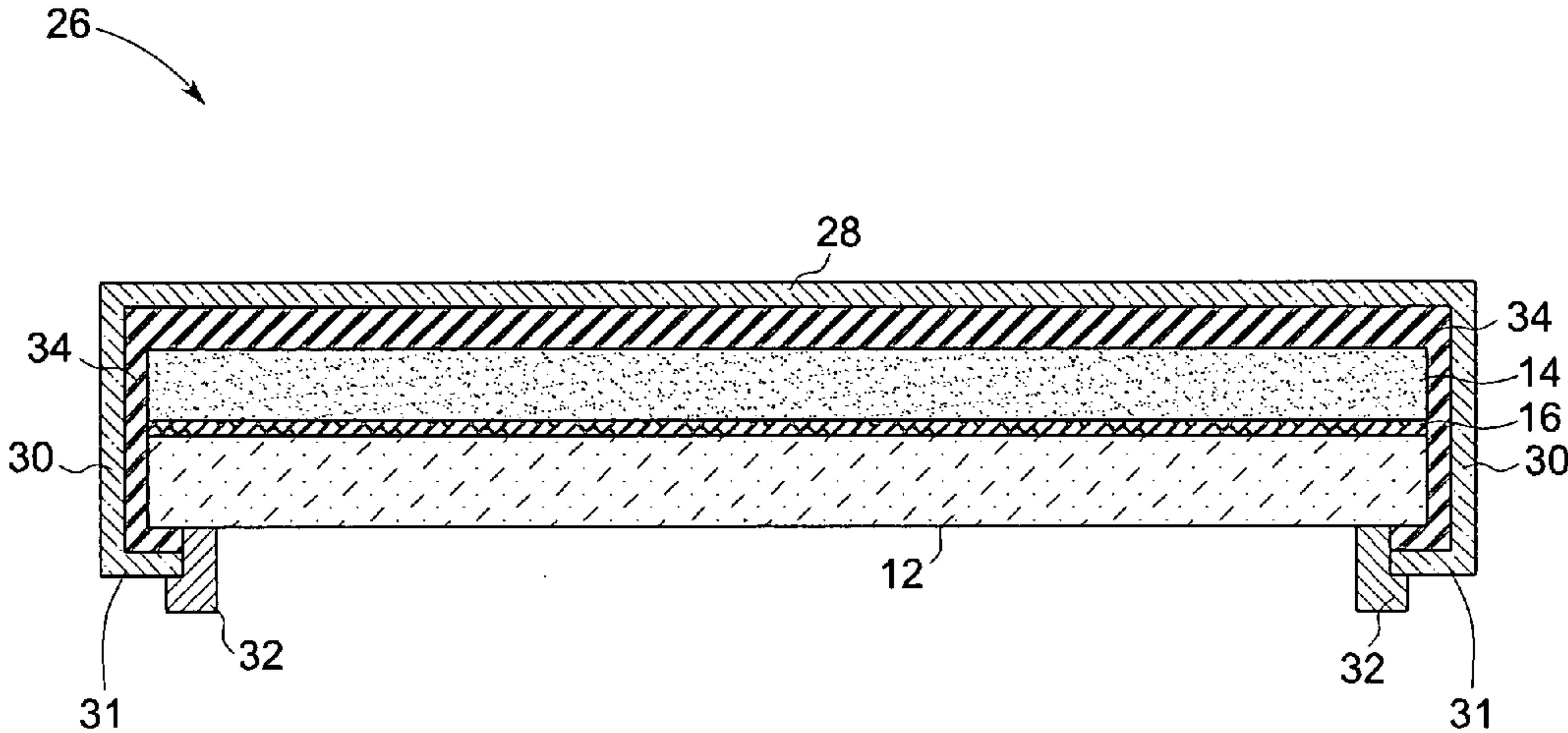


FIG. 3

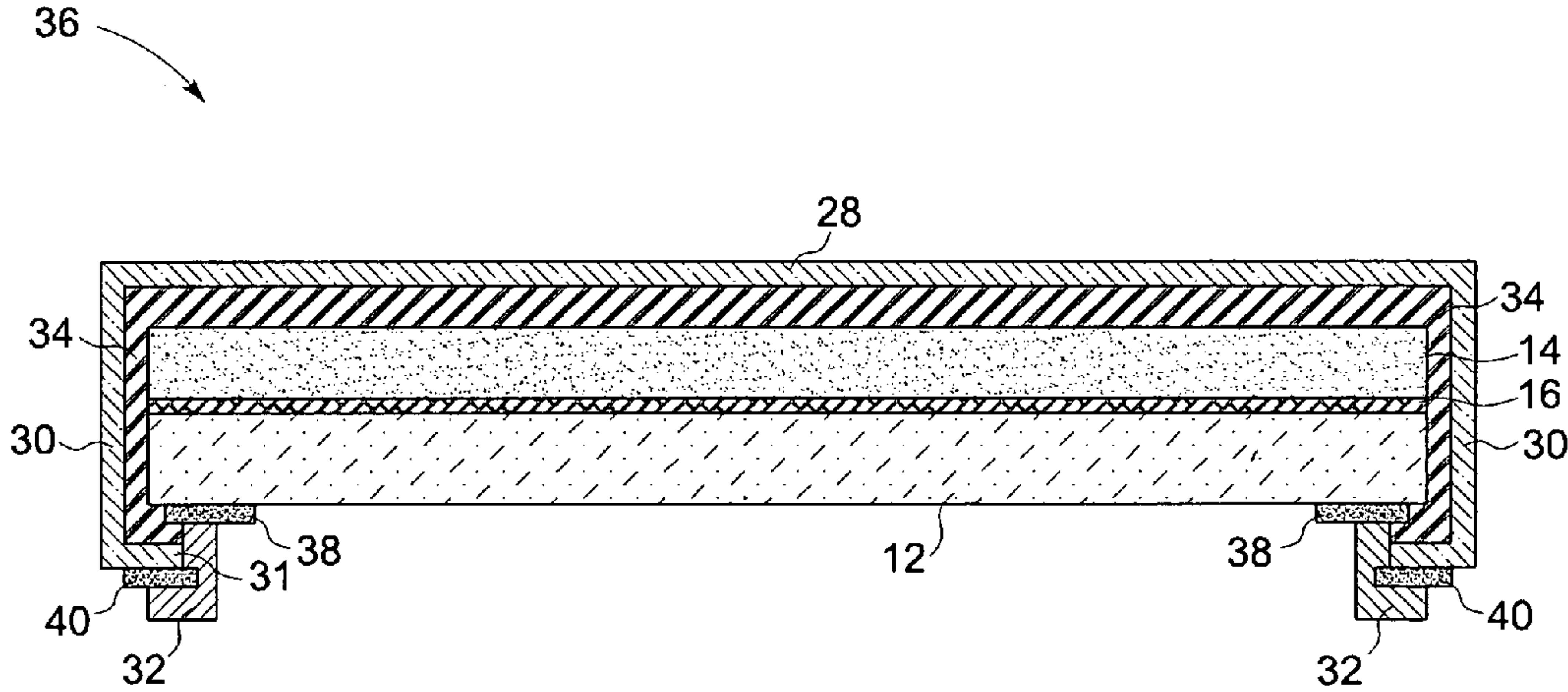


FIG. 4

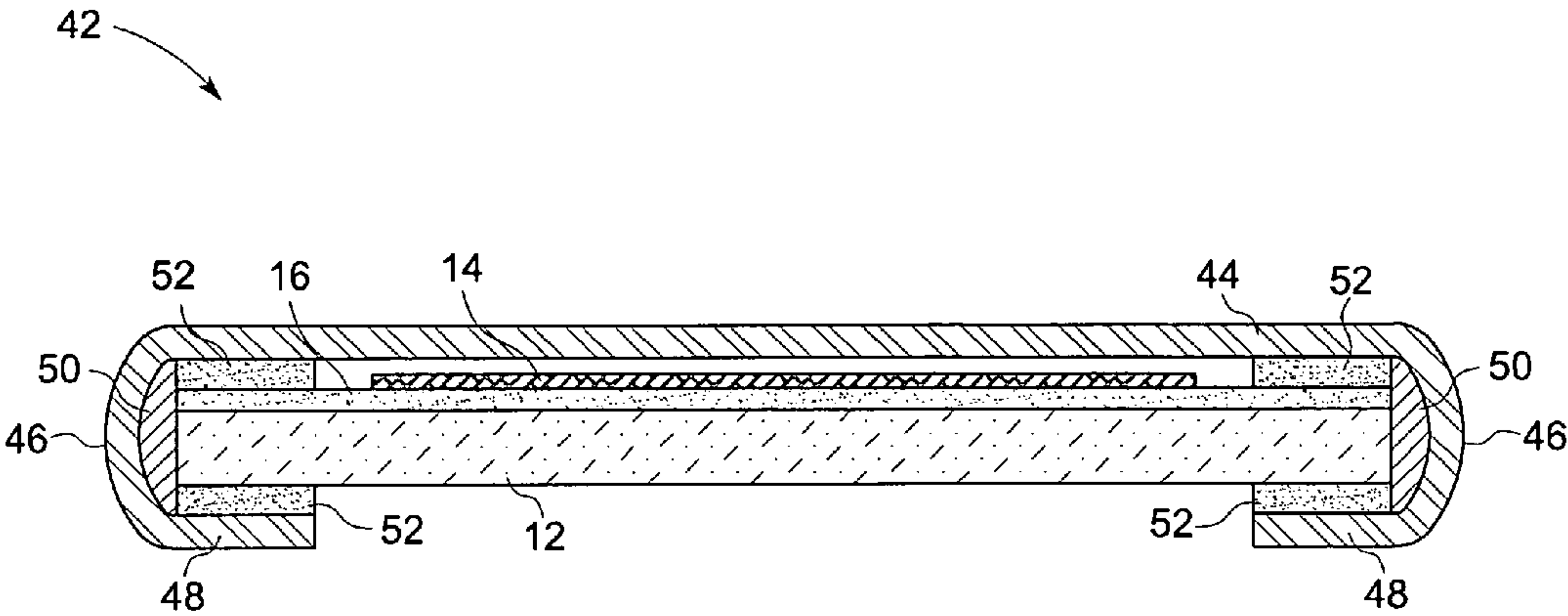


FIG. 5

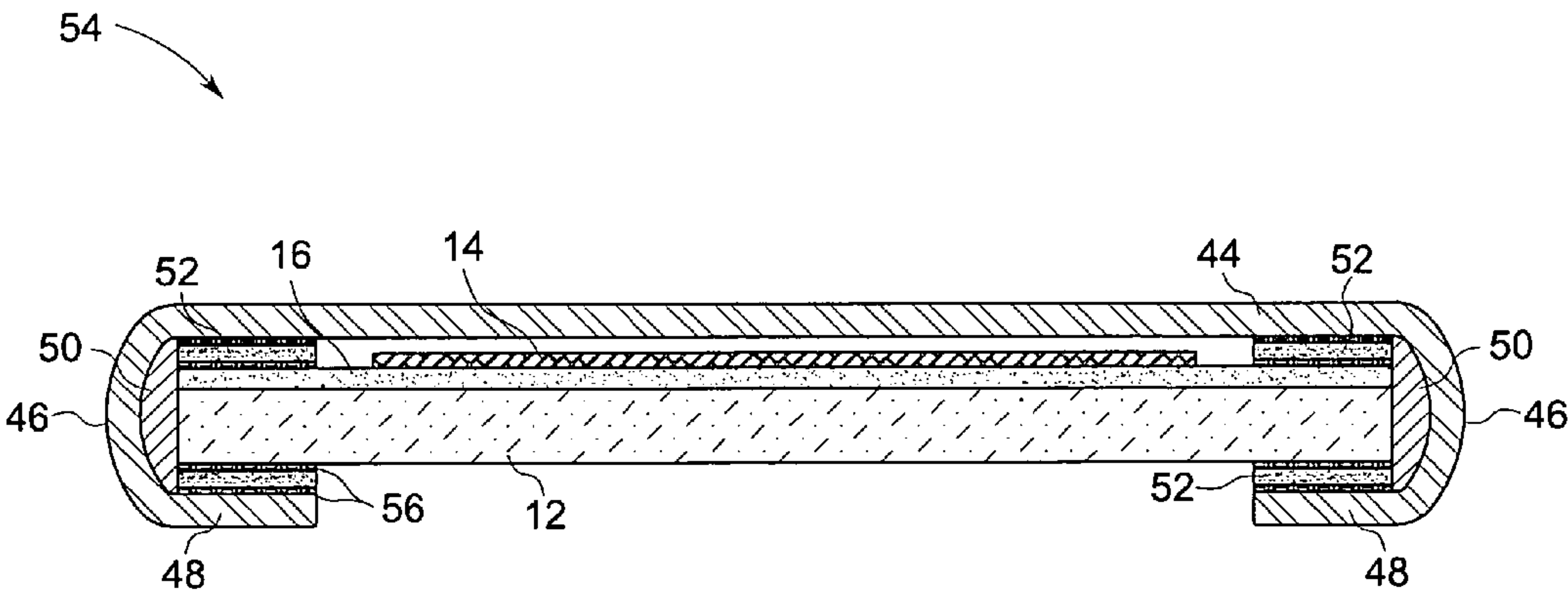


FIG. 6

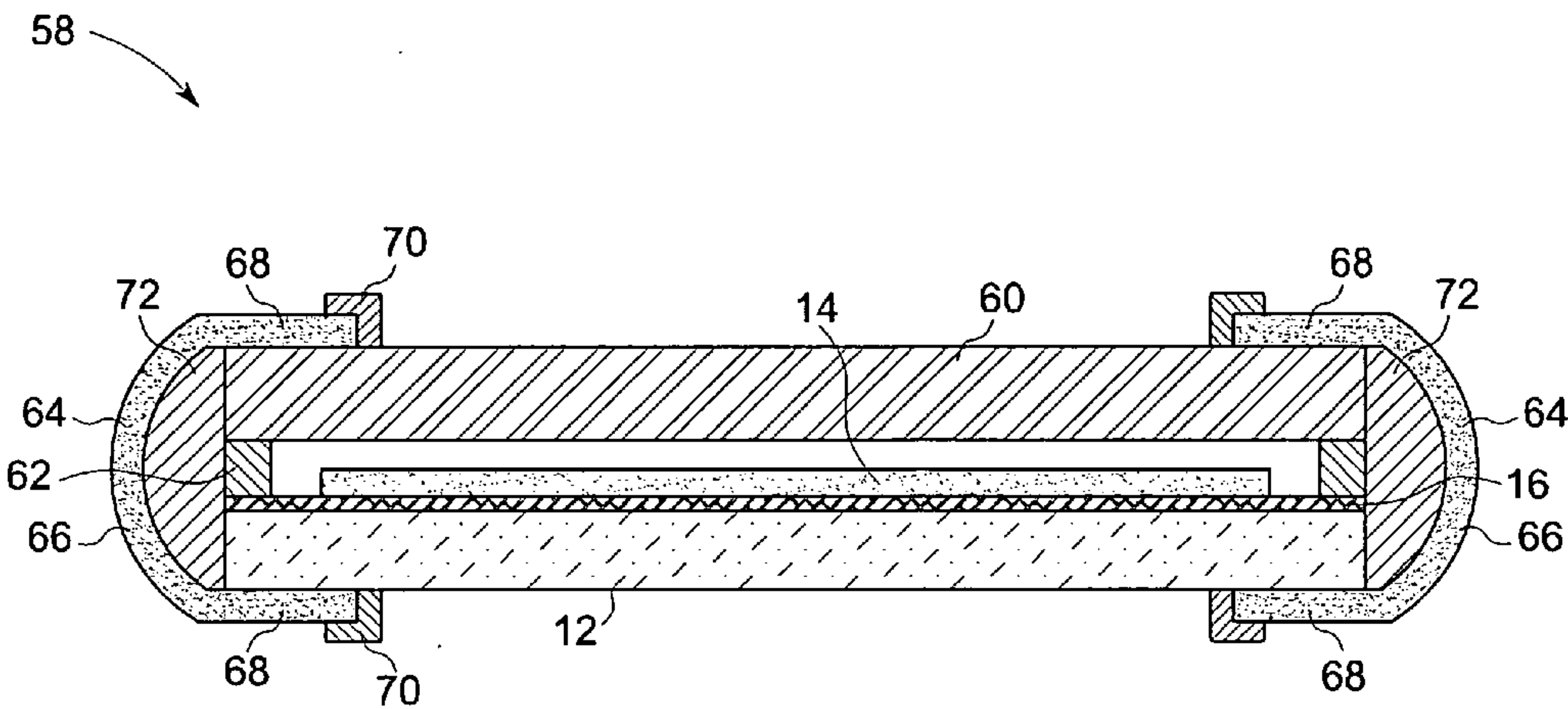


FIG. 7

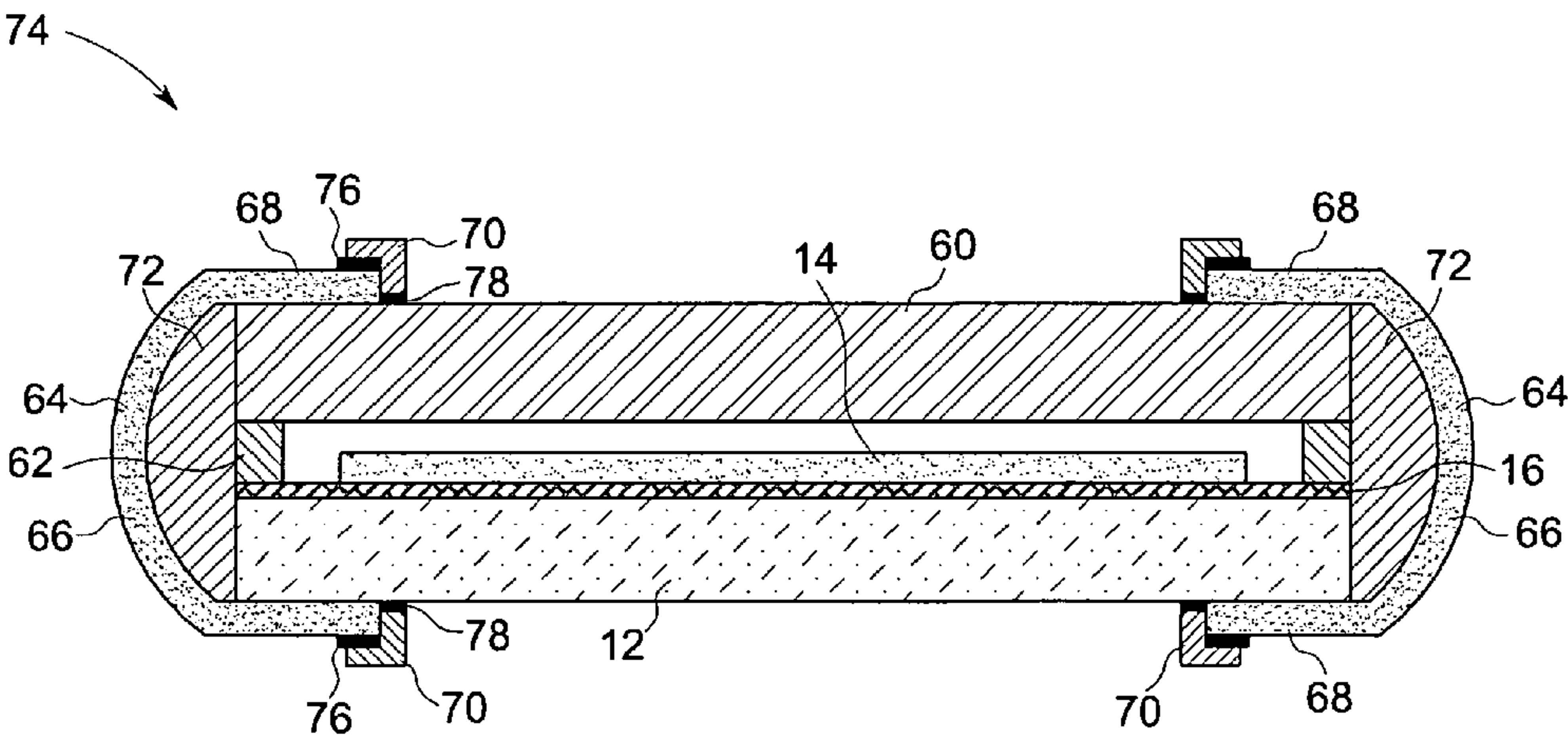


FIG. 8

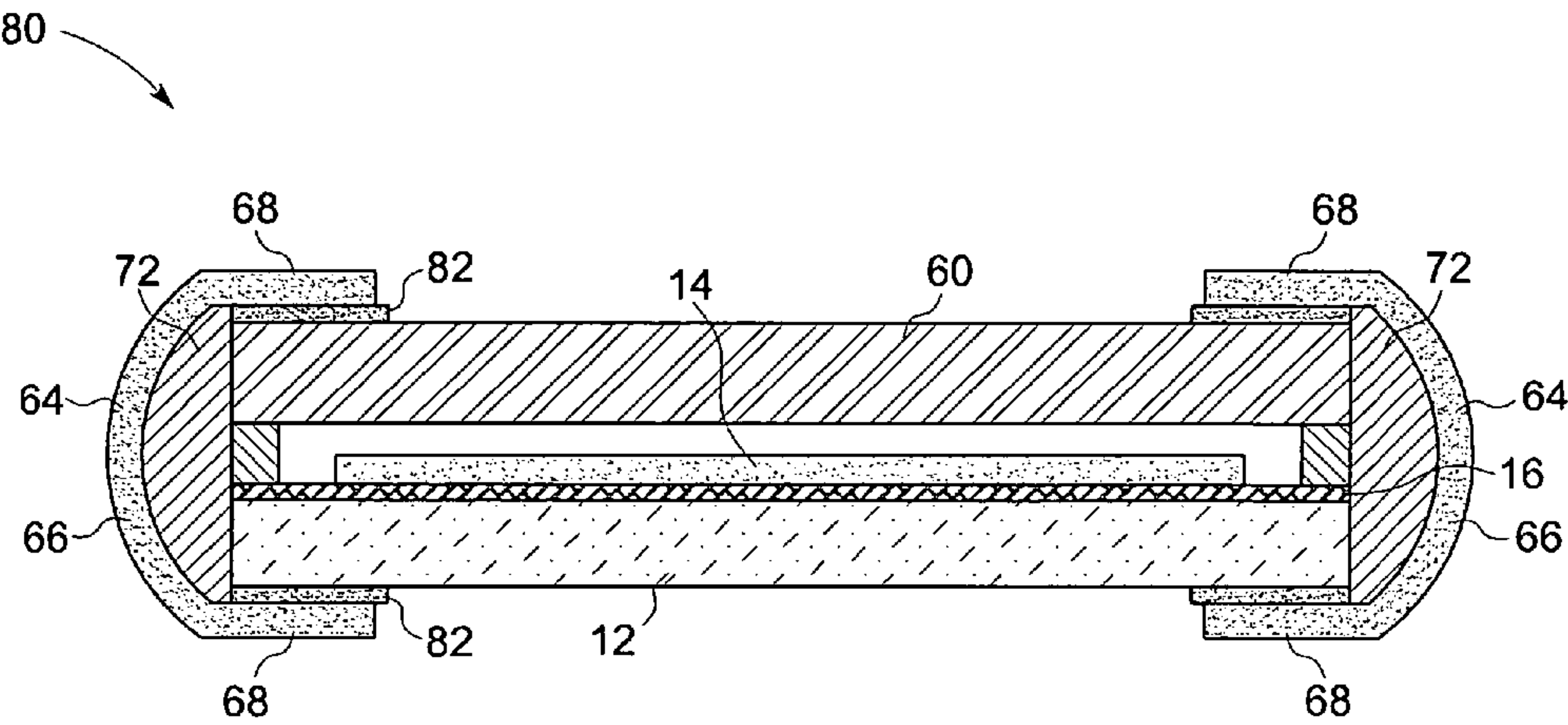


FIG. 9

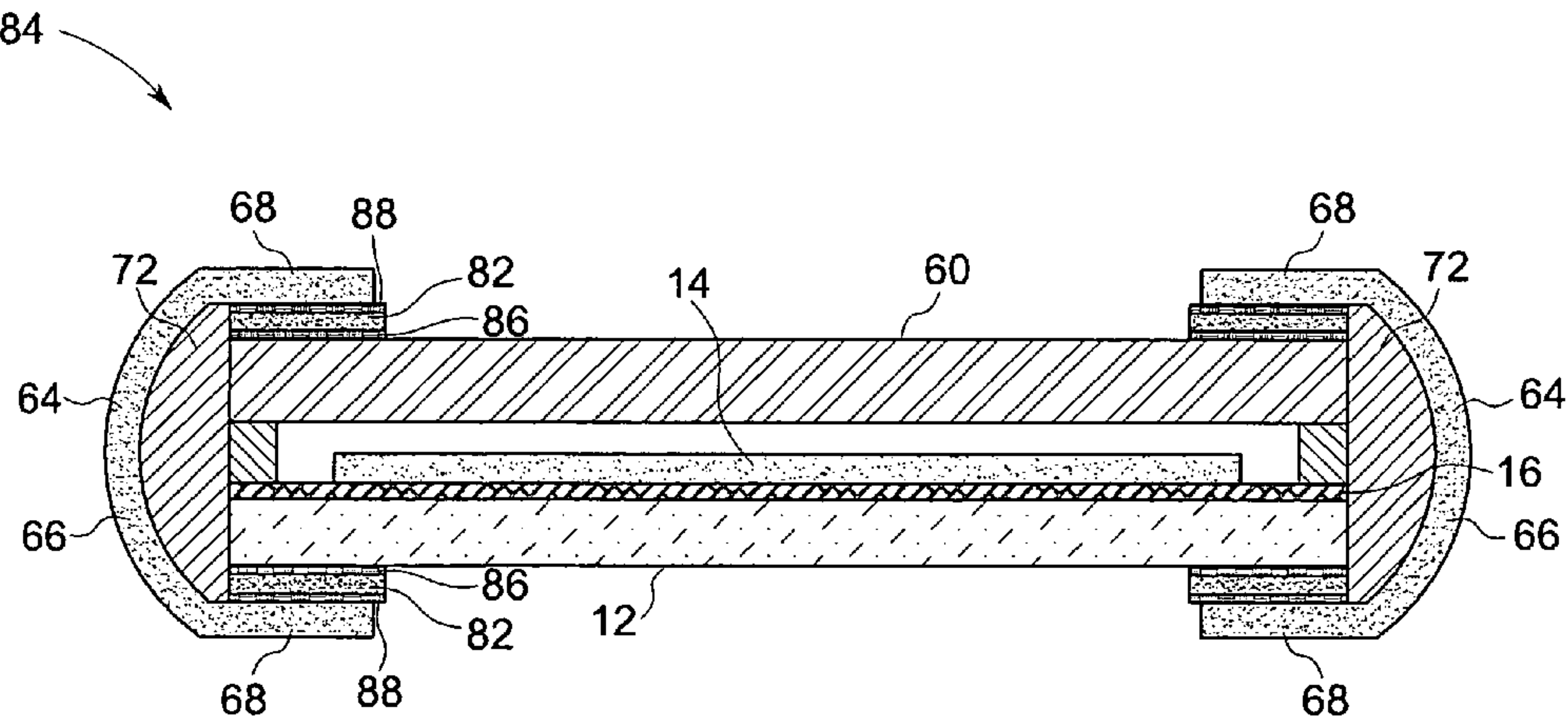


FIG. 10

100

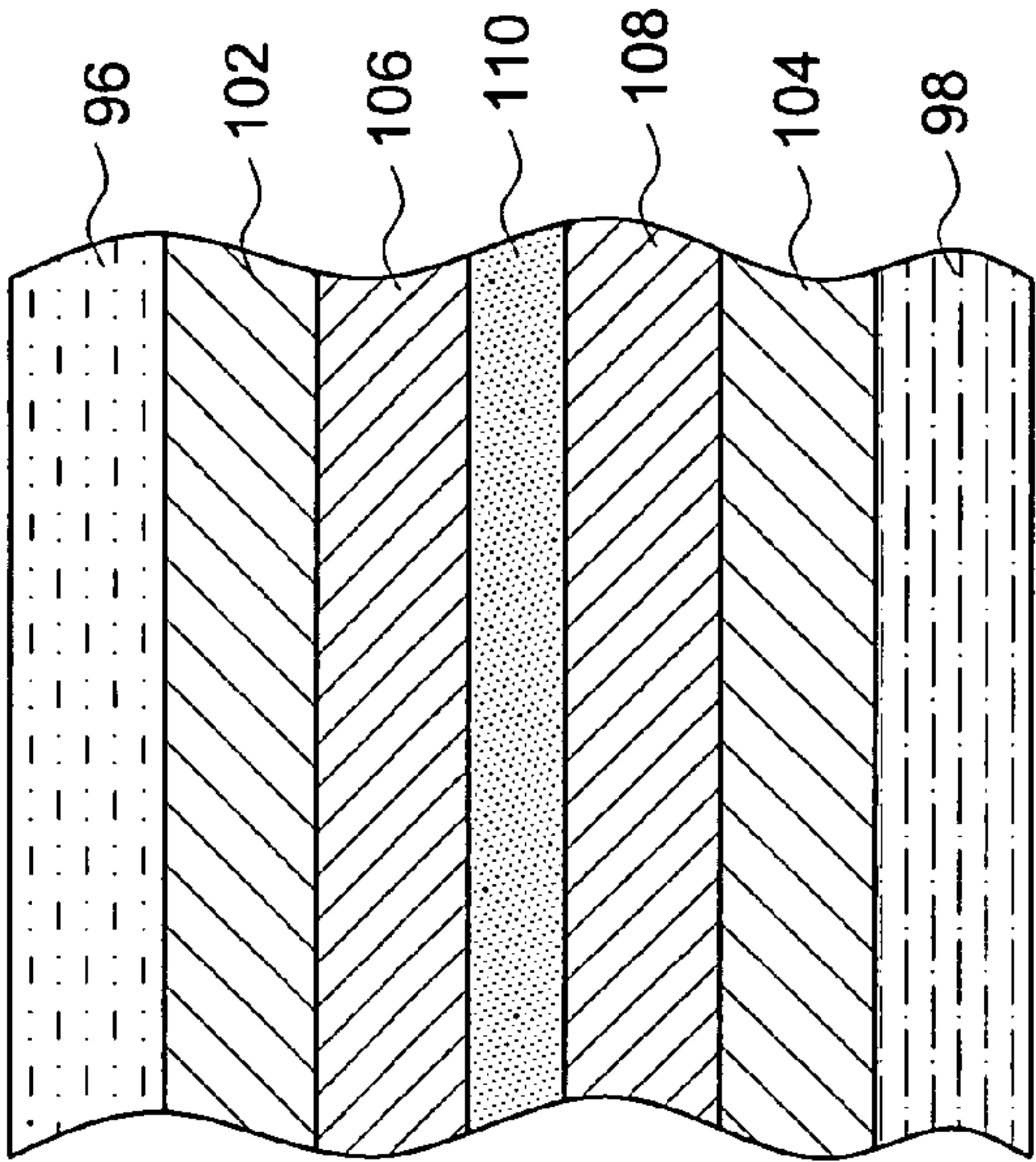


FIG. 12

90

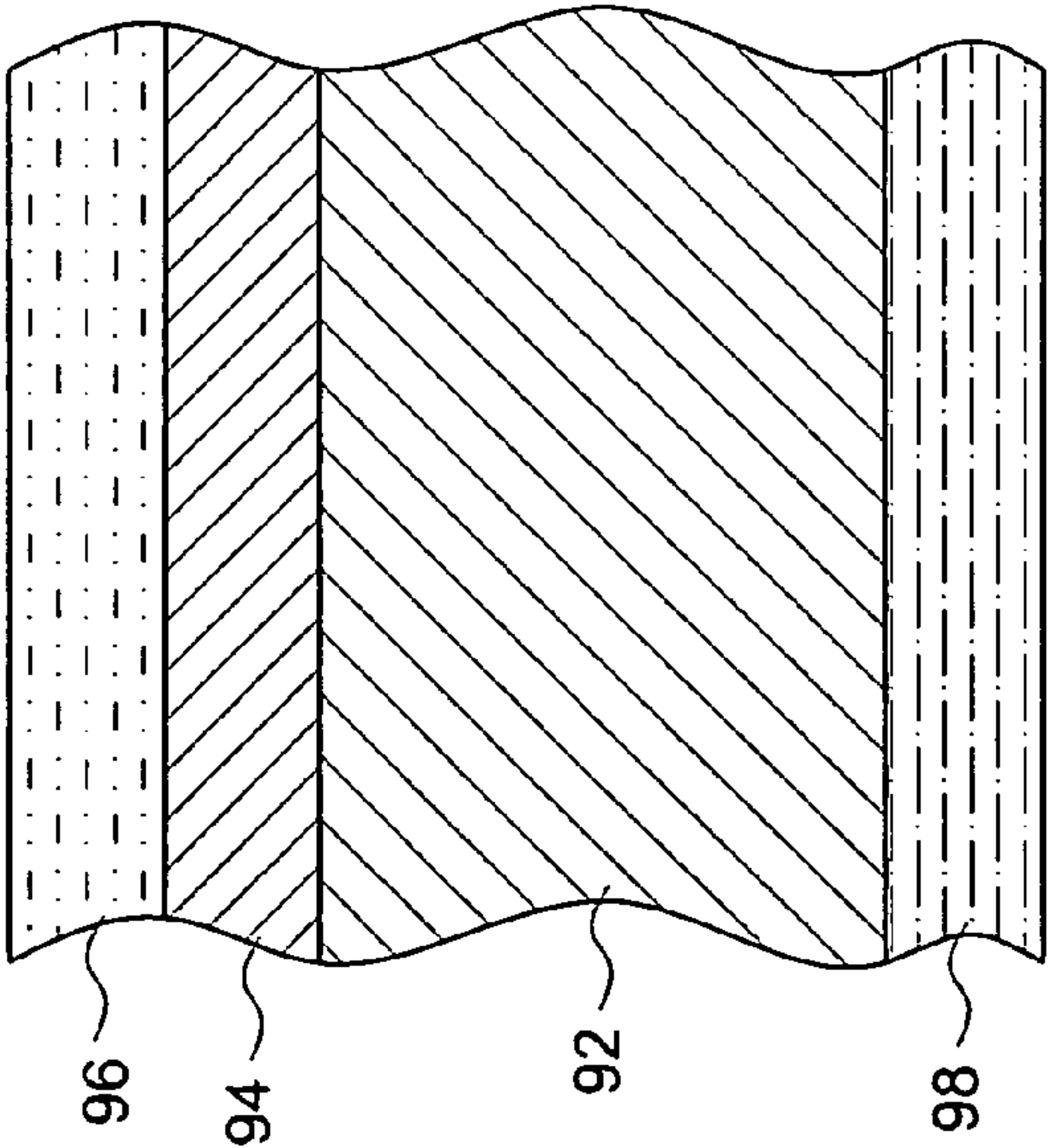


FIG. 11

HERMETICALLY SEALED PACKAGE AND METHODS OF MAKING THE SAME

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH & DEVELOPMENT

[0001] This invention was made with Government support under contract number 70NANB3H3030 awarded by National Institute of Standards and Technology. The Government has certain rights in the invention.

BACKGROUND

[0002] The invention relates generally to hermetically sealed electronic packages. More particularly, the invention relates to electronic packages employing organic devices and having a low temperature hermetic seal and methods of making the same.

[0003] Organic devices are low cost and high performance alternatives of the silicon semiconductor devices and are employed in various applications, such as, organic light emitting diodes (OLEDs), organic light sensors, organic transistors, organic solar cells, and organic lasers.

[0004] However, these organic devices may require protection from environmental elements such as, moisture or oxygen, to prevent degradation of the device. Most of these devices are made of a layered structure incorporating different layers of materials each having diverse functionalities. One common way to protect these devices includes providing encapsulation to the layered structure. Typically, the procedure to encapsulate the organic device includes sandwiching the organic device between a substrate and an encapsulation layer such that there is a continuous perimeter seal around the device. Often, sheets of glass, metal, or plastics having barrier coatings are used to sandwich the device. These sheets are joined together with adhesives, often based on epoxies. While the sheet materials provide excellent hermetic properties, the adhesives may not.

[0005] In the past, thinner layers of adhesives have been employed between the substrate and the encapsulation layer to limit the diffusion of undesirable elements such as, water and/or oxygen into the package. While the rate of diffusion is reduced by employing thinner layers of adhesives, the adhesive remains quite permeable to environmental elements. As will be appreciated, adhesives having fewer interfacial voids at the unions of the adhesive and the sheet materials lead to slower diffusion rates of the adhesive into the package during fabrication, thereby resulting in insufficient coverage of the encapsulant perimeter around the device. Additionally, moisture absorber or getters may be employed on the surface of the encapsulant or may be incorporated into the package to prevent any intruding water from entering the package. However, these materials are expensive and also have limited capacity in terms of preventing the permeation of environmental elements into the encapsulant.

[0006] Accordingly, there is a need for electronic packages employing sealing materials that reduce the permeation of environmental elements through the edges of the devices, as compared to conventional devices.

BRIEF DESCRIPTION

[0007] In accordance with one aspect of the present technique, a hermetically sealed package is provided. The her-

metically sealed package includes a first substrate and an organic electronic device disposed on the first substrate. Further, the hermetically sealed package includes a first primer layer disposed on the first substrate. The first primer layer is disposed about the perimeter of the organic electronic device. The hermetically sealed package also includes a metal alloy sealant layer disposed on the first primer layer and about the perimeter of the organic electronic device and a second primer layer disposed on the metal sealant layer. Furthermore, the package includes a second substrate disposed on the second layer of primer and disposed above and proximate to the organic electronic device.

[0008] In accordance with another aspect of the present technique, a hermetically sealed package is provided. The package includes a first substrate, an organic electronic device disposed on an upper surface of the substrate and an insulating adhesive layer disposed above the organic electronic device. Further, the hermetically sealed package includes a superstrate coupled to the insulating adhesive layer and disposed proximate to the organic electronic device. The superstrate comprises a peripheral portion adapted to wrap around edges of the package such that the peripheral portion of the superstrate is coupled to a lower surface of the substrate opposite the organic electronic device. Furthermore, the package includes a metal alloy sealant layer disposed on the lower surface of the substrate such that the peripheral portion of the superstrate is hermetically sealed to the lower surface of the substrate.

[0009] In accordance with yet another aspect of the present technique, a hermetically sealed package is provided. The hermetically sealed package includes a first substrate having an inner side and an outer side, an organic electronic device disposed on the inner side of the first substrate and an insulating layer disposed above the organic electronic device. The hermetically sealed package also includes a second substrate having an inner side and an outer side, where the second substrate is coupled to the insulating adhesive such that the inner side of the second substrate is disposed proximate the organic electronic device. Further, the hermetically sealed package also includes an edge wrap coupled to the outer sides of each of the first and second substrates and configured to hermetically seal the peripheral edges of the package, and a metal alloy sealant layer coupled to the outer sides of each of the first and second substrates and to the edge wrap such that the edge wrap is hermetically sealed to the outer sides of each of the first and second substrates.

[0010] In accordance with another aspect of the present technique, a method of fabricating a hermetically sealed electronic package is provided. The method includes the steps of disposing a plurality of organic electronic devices on a substrate, providing a metal foil having approximately the same dimensions as the substrate. Further, the method also includes patterning the metal foil with a plurality of patterns comprising a metal alloy sealant, wherein each of the plurality of patterns is sized to completely surround the organic electronic devices upon coupling the metal foil with the substrate and coupling the metal foil to the substrate.

DRAWINGS

[0011] These and other features, aspects, and advantages of the present invention will become better understood when

the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0012] **FIG. 1** is a cross sectional view of an exemplary hermetically sealed package employing a metal alloy sealant layer, according to one embodiment of the present technique;

[0013] **FIG. 2** is a perspective view of one method of fabricating a hermetically sealed package for an organic electronic device, according to one embodiment of the present technique;

[0014] **FIG. 3** is a cross sectional view of an exemplary hermetically sealed package employing a superstrate, according to another embodiment of the present technique;

[0015] **FIG. 4** is a cross sectional view of an alternate embodiment of the hermetically sealed package of **FIG. 3** employing a primer;

[0016] **FIG. 5** is a cross sectional view of an exemplary hermetically sealed package employing a superstrate, according to another embodiment of the present technique;

[0017] **FIG. 6** is a cross sectional view of an alternate embodiment of the hermetically sealed package of **FIG. 5** employing a primer;

[0018] **FIG. 7** is a cross sectional view of an exemplary hermetically sealed package employing an edge wrap, according to one embodiment of the present technique;

[0019] **FIG. 8** is a cross sectional view of an alternate embodiment of the edge wrap of **FIG. 7** employing a primer;

[0020] **FIG. 9** is a cross sectional view of an exemplary hermetically sealed package employing an edge wrap, according to another embodiment of the present technique;

[0021] **FIG. 10** is a cross sectional view of another alternate embodiment of the edge wrap of **FIG. 9** employing a primer;

[0022] **FIG. 11** is a cross sectional view of an exemplary composite substrate that may be implemented in conjunction with the present techniques; and

[0023] **FIG. 12** is a cross sectional view of another exemplary composite substrate that may be implemented in conjunction with the present techniques.

DETAILED DESCRIPTION

[0024] Organic electronic devices have been encapsulated by a variety of techniques to circumvent the deleterious effects of environmental elements such as, moisture and oxygen. Currently, sheets of glass, metals, or plastics are used to sandwich the organic electronic devices. Typically, these sheets are coupled by use of adhesives, such as epoxy-based adhesives. While, the sheet materials provide superior hermetic properties, the adhesives are generally permeable to moisture and oxygen. It is therefore desirable to develop a material that may be employed to couple the sheets while providing hermeticity to the packages containing organic electronic devices.

[0025] Referring to **FIG. 1**, a cross-sectional side view of an exemplary embodiment of a hermetically sealed package **10** is illustrated. In the presently contemplated configuration,

the hermetically sealed package **10** is illustrated diagrammatically as including a first substrate **12** configured to receive an organic electronic device **14**. In some embodiments, the first substrate **12** may include a flexible substrate. As used herein, the term “flexible” generally means being capable of being bent into a shape having a radius of curvature of less than approximately 100 cm. In other embodiments, the first substrate **12** may include a composite structure. The first substrate **12** may comprise a single layer or a structure having a plurality of adjacent layers of different materials. In accordance with aspects of the present technique, the first substrate **12** may include materials, such as, but not limited to, plastic, metal foil, or glass. The first substrate **12** is generally thin, having a thickness in a range from about 0.25 mils to about 50.0 mils, and preferably in a range from about 0.5 mils to about 10.0 mils. In accordance with aspects of the present technique, the first substrate **12** may also comprise a substantially transparent film. As used herein, “substantially transparent” refers to a material allowing a total transmission of at least about 50%, preferably at least about 80%, of visible light (i.e., having a wave length in a range from about 400 nm to about 700 nm).

[0026] In certain embodiments, the first substrate **12** may include a flexible substrate that is compatible with roll-to-roll processing. Advantageously, implementing a roll of film for the flexible substrate enables the use of high-volume, low cost, reel-to-reel processing and fabrication of the hermetically sealed package **10**. The roll of film may have a width of 1 foot, for example, on which a number of components (e.g., organic electronic devices) may be fabricated. By using rollable substrates, manufacturability of the device may be improved.

[0027] Moreover, the first substrate **12** may have an index of refraction varying in a range from about 1 to about 2.5, and preferably in a range from about 1 to about 2. The first substrate **12** generally may comprise any flexibly suitable polymeric material. Additionally, the first substrate **12** may comprise polycarbonates, polyarylates, polyetherimides, polyethersulfones, polyimides, such as Kapton H or Kapton E (made by Dupont) or Upilex (made by UBE Industries, Ltd.), polynorbornenes, such as cyclic-olefins (COC), liquid crystal polymers (LCP), such as polyetheretherketone (PEEK), polyethylene terephthalate (PET), and polyethylene naphthalate (PEN).

[0028] In addition, the hermetically sealed package **10** may include an organic electronic device **14** disposed on the first substrate **12**. In certain embodiments, the organic electronic device **14** may include one of an electroluminescent device (such as an organic light emitting device (OLED)), an organic photovoltaic cell, an organic photo-detector, an organic electrochromic device, an organic sensor, or combinations thereof. In these embodiments, the organic electronic device **14** may include a number of organic semiconductor layers disposed between two conductors or electrodes. Although not illustrated in **FIG. 1**, the electrodes of the organic electronic device **14** are electrically coupled to an external current source, which is used to initiate the light producing reactions in the organic electronic device **14**. In accordance with aspects of the present technique, the organic electronic device **14** may be fabricated onto the first substrate **12** using a roll-to-roll process.

[0029] In certain embodiments, a barrier coating **16** may be disposed between the first substrate **12** and the organic

electronic device **14** to prevent moisture and oxygen diffusion through the first substrate **12**. In certain embodiments, the barrier coating **16** may be disposed or otherwise formed on the surface of the first substrate **12** such that the barrier coating **16** completely covers the first substrate **12**. As will be appreciated by one of ordinary skill in the art, the barrier coating **16** may include any suitable reaction or recombination products for reacting species. In certain embodiments, the barrier coating **16** may have a thickness ranging from about 10 nm to about 10,000 nm, and preferably in a range from about 10 nm to about 1,000 nm. As will be appreciated, it is desirable to choose the thickness of the barrier coating **16** that does not impede the transmission of light through the first substrate **12**, such as a barrier coating **16** that causes a reduction in light transmission of less than about 20%, and preferably less than about 5%. It is also desirable to choose a barrier coating material and thickness that does not significantly reduce the flexibility of the first substrate **12**, and whose properties do not significantly degrade with bending.

[0030] In certain embodiments, the barrier coating **16** may be disposed by any suitable deposition techniques, such as physical vapor deposition, plasma-enhanced chemical-vapor deposition (PECVD), radio-frequency plasma-enhanced chemical-vapor deposition (RFPECVD), expanding thermal-plasma chemical-vapor deposition (ETPCVD), reactive sputtering, electron-cyclodrawn-residence plasma-enhanced chemical-vapor deposition (ECRPECVD), inductively coupled plasma-enhanced chemical-vapor deposition (ICPECVD), sputter deposition, evaporation, atomic layer deposition (ALD), or combinations thereof.

[0031] In certain embodiments, the barrier coating **16** may include materials such as, but not limited to, organic material, inorganic material, ceramics, metals, or combinations thereof. Typically, these materials are reaction or recombination products of reacting plasma species and are deposited onto the surface of the first substrate **12**. In certain embodiments, the organic materials may comprise carbon, hydrogen, oxygen and optionally, other minor elements, such as sulfur, nitrogen, silicon, etc., depending on the types of reactants. Suitable reactants that result in organic compositions in the coating are straight or branched alkanes, alkenes, alkynes, alcohols, aldehydes, ethers, alkylene oxides, aromatics, etc., having up to 15 carbon atoms. Inorganic and ceramic coating materials typically comprise oxide, nitride, carbide, boride, oxynitride, oxycarbide, or combinations thereof of elements of Groups IIA, IIIA, IVA, VA, VIA, VIIA, IB, and IIB; metals of Groups IIIB, IVB, and VB, and rare-earth metals. For example, silicon carbide can be deposited onto a substrate by recombination of plasmas generated from silane (SiH₄) and an organic material, such as methane or xylene. Silicon oxycarbide can be deposited from plasmas generated from silane, methane, and oxygen or silane and propylene oxide. Silicon oxycarbide also can be deposited from plasmas generated from organosilicone precursors, such as tetraethoxysilane (TEOS), hexamethyldisiloxane (HMDSO), hexamethyldisilazane (HMDSN), or octamethylcyclotetrasiloxane (D4). Silicon nitride can be deposited from plasmas generated from silane and ammonia. Aluminum oxycarbonitride can be deposited from a plasma generated from a mixture of aluminum titrate and ammonia. Other combinations of reactants, such as metal oxides, metal nitrides, metal oxynitrides, silicon oxide, silicon nitride, silicon oxynitrides may be chosen to obtain a desired coating composition.

[0032] In other embodiments, the barrier coating **16** may comprise hybrid organic/inorganic materials or multilayer organic/inorganic materials. The organic materials may comprise acrylates, epoxies, epoxyamines, xylenes, siloxanes, silicones, etc. The choice of the particular reactants can be appreciated by those skilled in the art. Most metals may also be suitable for the barrier coating **16** in applications where transparency of the first substrate **12** is not required. As will be appreciated, the first substrate **12** may comprise a composition, which incorporates the first barrier layer **16** to provide a hermetic substrate.

[0033] Further, as mentioned above, the hermetically sealed package **10** includes a second substrate **20** which may be coupled to the first substrate **12** by the metal alloy sealant layer **18**. In some embodiments, the second substrate **20** may be disposed such that the peripheral portion of the second substrate **20** is patterned to wrap around the edges of the package **10**. In these embodiments, the peripheral portion of the second substrate **20** may be coupled to a side of the first substrate **12** opposite the barrier coating **16**. In other words, the peripheral portion of the second substrate **20** may be configured to be coupled to the side of the first substrate **12** opposite the barrier coating **16** thereby hermetically sealing the package **10**. In these embodiments, the second substrate may also be referred to as "superstrate". These exemplary embodiments will be illustrated and described further with reference to **FIGS. 3-6**. In an alternate embodiment, an edge encapsulating material configured to hermetically seal the peripheral edges of hermetically sealed package may be disposed along the perimeter of the organic electronic device **14** between the first and second substrates **12** and **20**. These exemplary embodiments will be illustrated and described with reference to **FIGS. 7-10**.

[0034] In accordance with aspects of the present technique, the second substrate **20** may comprise a thin material having a low permeability. In accordance with aspects of the present technique, the second substrate may or may not be transparent, depending on the application. In certain embodiments, the second substrate **20** may include a reflective material, such as a metal foil, to reflect light produced by the organic electronic device **14**. In certain embodiments, the second substrate **20** may include aluminum foil, stainless steel foil, copper foil, tin, Kovar, Invar, etc. In applications where reflective light is less critical, the second substrate **20** may comprise thin glass, sapphire, mica or barrier coated plastics having a low permeability. Generally, the second substrate **20** is applied to reflect any radiation emitted away from the first substrate **12** and direct such radiation towards the first substrate **12** such that the total amount of radiation emitted in this direction is increased. Advantageously, the second substrate **20** may include a material to prevent diffusion of reactive or reactive environmental elements, such as oxygen and moisture, into the organic electronic device **14**. The second substrate **20** is sufficiently thin so as not to reduce the flexibility of the entire device. Further, as described below with reference to **FIGS. 11 and 12**, the second substrate may include a number of layers of various metals or metal compound to further reduce the diffusion of oxygen and water vapor into the organic electronic device **14**. In one embodiment, the inner side of the second substrate **20**, directly adjacent to the organic electronic device **14**, is reflective while the outer layers comprise non-reflective materials or compounds such as metal oxides, nitrides, carbides, oxynitrides, or oxycarbides which may be imple-

mented to reduce the rate of diffusion of oxygen and water into the organic electronic device **14**.

[0035] In accordance with aspects of the present technique, to provide hermeticity, a metal alloy sealant layer **18** is disposed proximate to the organic electronic device **14**. Hereinafter, the metal alloy sealant layer will be interchangeably referred to as metal alloy sealant. In the illustrated embodiment of **FIG. 1**, the metal alloy sealant **18** is disposed about the entire perimeter of the organic electronic device **14** such that the organic electronic device **14** is completely surrounded by the metal alloy sealant **18**. Generally, the metal alloy sealant **18** comprises an adhesive material such that it may be employed to couple the first substrate **12** or the barrier coating **16** to the second substrate **20**, thereby completely enclosing the organic electronic device **14**. The metal alloy sealant layer **18** may generally include any material having low permeability and providing adhesion. Techniques for disposing the metal alloy sealant layer **18** will be described further herein with reference to **FIG. 2**. As described in detail below, in certain embodiments, the metal alloy sealant **18** may be directly coupled to the first or second substrates of the hermetically sealed package **10**. Whereas, in other embodiments, one or more primer layers such as a first primer layer **22** and/or a second primer layer **24** or both may be disposed between the metal alloy sealant layers **18** and the first and/or second substrates **12** and **20**. As described further below, the primer layers **22** and **24** may be utilized to facilitate adhesion between the metal alloy sealant **18** and the substrates **12** and **20**.

[0036] In certain embodiments, the metal alloy sealant **18** may be applied to the package **10** by heating the package **10** above the melting point of the metal alloy sealant. Upon heating, the metal alloy sealant **18** melts and flows, thereby forming a continuous layer, which upon solidification forms a seal which is impervious to water and oxygen. Accordingly, it is desirable to employ a metal alloy sealant **18** having a melting point of less than about 150° C. so that it does not alter the properties of the layers of the organic electronic device **14** while heating the metal alloy to form a melt. Simultaneously, it is also desirable to have the melting point of the metal alloy sealant greater than the operating temperature of the organic electronic device, so that the seal does not lose its hermeticity during operational conditions of the organic electronic device **14**. Accordingly, in certain embodiments, the metal alloy sealant material may include alloys of bismuth, tin, lead, indium, cadmium, or combinations thereof.

[0037] In certain embodiments, the metal alloy sealant **18** may include metal alloy having a volume percent of bismuth ranging from about 0 to about 50%, or a volume percent of tin ranging from about 5% to about 50%, or a volume percent of lead ranging from about 0 to about 50%, or a volume percent of indium ranging from about 0 to about 55%, or a volume percent of cadmium ranging from about 0 to about 15%. In an exemplary embodiment, the metal alloy sealant may include a volume percent of bismuth ranging from about 42% to about 46%, a volume percent of tin ranging from about 6% to about 10%, a volume percent of lead ranging from about 20% to about 24%, a volume percent of indium ranging from about 17% to about 21%, and a volume percent of cadmium ranging from about 3% to about 7%. In another exemplary embodiment, the metal alloy sealant **18** may include a volume percent of bismuth

ranging from about 47% to about 51%, a volume percent of tin ranging from about 10% to about 12%, a volume percent of lead ranging from about 16% to about 20%, and a volume percent of indium ranging from about 19% to about 23%. In yet another exemplary embodiment, the metal alloy sealant **18** may include a volume percent of bismuth ranging from about 48% to about 52%, a volume percent of tin ranging from about 10% to about 12%, a volume percent of lead ranging from about 23% to about 27%, and a volume percent of cadmium ranging from about 10% to about 14%. In another exemplary embodiment, the metal alloy sealant **18** may include a volume percent of bismuth ranging from about 53% to about 57% and a volume percent of tin ranging from about 40% to about 44%. In another exemplary embodiment, the metal alloy sealant **18** may include a volume percent of tin ranging from about 46% to about 50% and a volume percent of indium ranging from about 50% to about 54%.

[0038] Additionally, in some embodiments, a primer layer such as a first primer layer **22** and a second primer layer **24** may be disposed on either side of the metal alloy sealant layer **18** as illustrated in **FIG. 1**. As will be appreciated by those skilled in the art, the primer layers wet the surface of the first substrate **12** (or barrier coating **16**) and/or the second substrate **20** and thereby, facilitate adhesion between the metal alloy sealant layer **18** and the first and/or second substrates **12** and **20**. In an exemplary embodiment, the first or second primer layer **22** and **24** or both may include tin. Further, in some embodiments, the primer layers **22** and **24** may be electrodeposited on the surfaces of the first and/or second substrates **12** and **20**. In other embodiments, the primer layer may be deposited using deposition techniques, such as, but not limited to, evaporation and sputtering. In some embodiments, the primer layers **22** and **24** may have a thickness varying in a range from about 10 nm to about 10,000 nm.

[0039] **FIG. 2** illustrates an exemplary process for fabricating a number of hermetically sealed packages, such as the package **10** discussed with reference to **FIG. 1**. As will be appreciated, the first substrate **12** may be fed from a polymer film roll. In an exemplary embodiment, the roll may be sized such that the two packages **10** can be fabricated adjacent to one another, as illustrated in **FIG. 2**. The first substrate **12** is coated with the barrier coating **16** and organic electronic devices **14** are arranged thereon. In some embodiments, the second substrate **20** may also be fed from a roll. In the illustrated embodiment, the metal alloy sealant **18** is disposed onto the surface of the second substrate **20** to form the seal around the entire peripheral portion of the organic electronic device **14**, once the second substrate **20** is coupled to the first substrate **12**. In certain embodiments, the metal alloy sealant **18** may be screen-printed, inkjet printed, laminated or disposed onto the surface of the second substrate **20** by any other suitable means. Once roll-to-roll manufacturing is completed, the hermetically sealed package **10** may be excised from the rolls. As will be appreciated, other fabrication techniques may be implemented to construct the hermetically sealed packages **10**.

[0040] Referring to **FIG. 3**, a cross sectional side view **26** of an alternate embodiment of the hermetically sealed package illustrated in **FIG. 1** is shown. As with the embodiment illustrated in **FIG. 1**, the hermetically sealed package **26** includes a first substrate **12**, a barrier coating **16**, and an

organic electronic device 14. Further, in the illustrated embodiment, the hermetically sealed package 26 also includes a second substrate 28. As described above, in the illustrated embodiment, the second substrate comprises a superstrate 28. In the illustrated embodiment, the superstrate 28 includes edges 30 which are sized such that they can be wrapped around the edges of the first substrate 12 and coupled to the outer side of the first substrate 12 (i.e., the side of the first substrate 12 that is opposite to the side having the barrier coating 16) to form a peripheral portion 31. In the illustrated embodiment, the edges 30 of the superstrate 28 are adhesively coupled to the outer side of the first substrate 12 using a metal alloy sealant 32. The metal alloy sealant 32 may comprise the same material as the metal alloy sealant 18. As will be appreciated, to effectively protect the organic electronic device 14 from moisture and oxygen, the metal alloy sealant 32 advantageously comprises a material having a low permeability. Further, the hermetically sealed package 26 may include an insulating adhesive 34 disposed between the organic electronic device 14 and the second substrate 28 to insulate the device 14 from the second substrate 28. As illustrated in FIG. 3, the metal alloy sealant 32 is employed to seal the peripheral portion of the insulating adhesive 34, as well.

[0041] FIG. 4 illustrates another alternate embodiment of a hermetically sealed package 36 employing a superstrate 28 and primer layers 38 and 40. As with the illustrated embodiments, in FIGS. 1 and 3, the hermetically sealed package 36 includes a first substrate 12, a barrier coating 16, and an organic electronic device 14. In the illustrated embodiment, the edges 30 of the superstrate 28 are adhesively coupled to the outer side of the first substrate 12 using a metal alloy sealant 32. Further, an insulating adhesive 34 is disposed between the organic electronic device 14 and the superstrate 28. In certain embodiments, one or more primer layers may be employed in the hermetically sealed package 36 to enhance adhesion of the metal alloy sealant 32 to the peripheral portion 31 of the superstrate 28 and/or the outer side of the first substrate 12. In the presently contemplated embodiment, the primer layer 38 may be disposed between the metal alloy sealant 32 and the outer side of the first substrate 12 and the primer layer 40 may be disposed between the metal alloy sealant 32 and the peripheral portion 31 of the first substrate 12. As will be appreciated, the primer layers 32 and 40 may vary in material composition. In certain embodiments, the primer layers 38 and 40 may include tin.

[0042] FIG. 5 illustrates another exemplary embodiment of the hermetically sealed package 42 employing a superstrate 44. As with the illustrated embodiments, in FIGS. 1, 3 and 4, the hermetically sealed package 42 includes a first substrate 12, a barrier coating 16, and an organic electronic device 14. In the illustrated embodiment, the package 42 includes a superstrate 44 having edges 46 and peripheral portions 48. In certain embodiments, to further provide hermeticity a desiccant or a getter material may be employed in the hermetically sealed package 42 having a superstrate 44 as the second substrate. In these embodiments, the desiccant or getter material may be disposed within the pockets formed by wrapping the edges of the superstrate 44. As will be appreciated, the desiccant comprises a material having a high affinity for water or oxygen and is implemented as a drying agent. Advantageously, the desiccant or getter 50 absorbs moisture or oxygen thereby further pro-

tecting the organic electronic device 14. In certain embodiments, the desiccant or getter 50 may comprise calcium oxide, silica gel, Hisil, Zeolite, calcium sulfate (DRIER-ITE), barium oxide, or other reactive metals for instance. As will be appreciated, the desiccant or getter 50 may be omitted.

[0043] In the presently contemplated embodiment, the superstrate 44 is coupled to the first substrate 12 by employing a metal alloy sealant layer 52 about the perimeter of the organic electronic device 14. Additionally, the peripheral portion 48 of the superstrate 44 is coupled to the outer side of the first substrate 12 using a metal alloy sealant layer 52. The metal alloy sealant 52 may comprise the same material as the metal alloy sealant 18.

[0044] FIG. 6 illustrates another exemplary embodiment of a hermetically sealed package 54 employing a superstrate. As with the illustrated embodiments, in FIGS. 1, 3, 4 and 5 the hermetically sealed package 54 includes a first substrate 12, a barrier coating 16, and an organic electronic device 14. In the illustrated embodiment, the package 54 includes a superstrate 44 having edges 46 and peripheral portions 48. In certain embodiments, to further provide hermeticity a desiccant or a getter material may be employed in the hermetically sealed package 54. As with FIG. 5, in these embodiments, the desiccant or getter material 50 may be disposed within the pockets formed by wrapping the edges 46 of the superstrate 44. In the presently contemplated embodiment, the superstrate 44 is coupled to the first substrate 12 by employing a metal alloy sealant layer 52 about the perimeter of the organic electronic device 14. Additionally, the peripheral portions 48 of the superstrate 44 are coupled to the outer side of the first substrate 12 using a metal alloy sealant layer 52. Further, in the illustrated embodiment, one or more primer layers, such as primer layers 56 may be employed adjacent to the metal alloy sealant layer 52 and the second surface. The metal alloy sealant 52 may comprise the same material as the metal alloy sealant 18.

[0045] Referring now to FIG. 7, a cross sectional view of another hermetically sealed package 58 is illustrated. As with the embodiments illustrated in FIGS. 1, and 3-6, the hermetically sealed package 58 includes a first substrate 12, a barrier coating 16, and an organic electronic device 14. Additionally, the package 58 includes a second substrate 60. In the presently contemplated embodiment, the second substrate 60 may be a reflective substrate like superstrate 28 or may be a flexible substrate like the first substrate 12. Although not illustrated, a barrier coating, such as a barrier coating 16 may be disposed on the surface of the second substrate 60, which is closer to the organic electronic device 14. Additionally, an adhesive 62 may be disposed between the first and second substrates 12 and 60 and close to the edges of the two substrates to couple the two substrates together.

[0046] Next, the edges of the structure so formed may be sealed by implementing edge wraps 64 to provide improved hermeticity to the package 58. In the illustrated embodiment, edge wraps 64 includes side portions 66 and peripheral portions 68. Further, the edge wraps 64 are coupled to the substrates 12 and 60 via a metal alloy sealant 70, as illustrated in FIG. 7. In the illustrated embodiment, the metal alloy sealant 70 is disposed on the first and second

substrates **12** and **60** close to the peripheral portions **68** of the edge wraps **64** such that the metal alloy sealant **70** hermetically seals the package **58**. In certain embodiments, the edge wraps **64** may include aluminum foil, stainless steel foil, copper foil, tin, Kovar, Invar, etc. and may be insulative or conductive. Advantageously, the edge wraps **64** may provide a more robust hermetically sealed package since cracks in the hermetic coating of the second substrate, for example superstrate, are eliminated. As with the exemplary embodiments described with reference to **FIGS. 5 and 6**, a desiccant or getter material **72** may be disposed within the pockets created by wrapping the edge wraps **64** around the edges of the package **58**.

[0047] **FIG. 8** illustrates an alternate embodiment of the hermetically sealed package of **FIG. 7**. In the illustrated embodiment, the hermetically sealed package **74** includes a first substrate **12**, a barrier coating **16**, a second substrate **60** and an organic electronic device **14**. In the presently contemplated embodiment, the hermetically sealed package **74** includes a metal alloy sealant **70** as discussed with reference to **FIG. 7**. Additionally, to enhance the adhesion of the metal alloy sealant and thereby, improve the hermeticity of the package **74**, one or more primer layers, such as primer layers **76** and **78** may be disposed between the metal alloy sealant **70** and the surfaces on which the metal alloy sealant **70** is disposed. For example, a primer layer **76** may be disposed between the metal alloy sealant **70** and the peripheral portion **68** of the edge wraps **64**. Further, a primer layer **78** may be disposed between the metal alloy sealant **70** and the side portions of the first substrate **12** or the second substrate **60** or both. As will be appreciated, the material composition of the primer layers **76** and **78** may be same or different.

[0048] As with **FIGS. 7 and 8**, **FIG. 9** illustrates another exemplary embodiment of a hermetically sealed package **80** employing edge wraps **64** according to aspects of the present technique. In the illustrated embodiment, the hermetically sealed package **80** includes a first substrate **12**, a barrier coating **16**, a second substrate **60** and an organic electronic device **14**. In the presently contemplated embodiment, the hermetically sealed package **80** includes a metal alloy sealant, which is in the form of a layer **82** and is disposed between the peripheral portions **68** of the edge wrap **64** and about the perimeter of the first and second substrates **12** and **60**. The metal alloy sealant layer **82** includes the same composition as metal alloy sealant **18** of **FIG. 1**.

[0049] **FIG. 10** illustrates an alternate exemplary embodiment of **FIG. 9**. In the illustrated embodiment, the hermetically sealed package **84** includes the metal alloy sealant layer **82**, which has one or more primer layers, such as primer layers **86** and **88** disposed on either side of the metal alloy sealant layer **82** such that the primer layer is disposed between the metal alloy sealant layer **82** and the second surface. In the illustrated embodiment, the second surface refers to the surface of the first or second substrates **12** or **60**. As discussed above, with reference to **FIG. 1**, application of primer facilitates adhesion of the metal alloy sealant layer with the other surface. In the illustrated embodiment, the primer layer **86** is disposed between the metal alloy sealant **82** and the first or second substrates **12** and **60**. Similarly, the primer layer **88** is disposed between the metal alloy sealant and the peripheral portions **68** of the edge wraps **64**.

[0050] **FIGS. 1-10** provide a description of a first substrate **12** having an organic electronic device fabricated

thereon and configured to provide improved hermeticity. As described further below, the first substrate **12** may comprise a composite structure.

[0051] **FIG. 11** illustrates a flexible composite substrate **90** having a composite structure. In the illustrated embodiments, the flexible composite substrate **90** includes a substantially transparent flexible film **92**. In one embodiment, the transparent flexible film may have a thickness varying in a range from about 0.25 mils to about 50.0 mils. In another embodiment, the transparent flexible film **92** may have a thickness varying in a range from about 0.5 mils to about 10.0 mils. In certain embodiments, the transparent flexible film **92** may have an index of refraction ranging from about 1.05 to about 2.5. In some embodiments, the transparent flexible film **92** may have an index of refraction ranging from about 1.1 to about 1.6. Further, the transparent flexible film **92** generally comprises any flexibly suitable polymer material. For example, the film **92** may comprise polycarbonates, polyarylates, polyetherimides, polyethersulfones, polyimides, such as Kapton H or Kapton E (made by Dupont) or Upilex (made by UBE Industries, Ltd.), polynorbornenes, such as cyclic-olefins (COC), liquid crystal polymers (LCP), such as polyetheretherketone (PEEK), polyethylene terephthalate (PET), and polyethylene naphthalate (PEN).

[0052] To provide hermeticity, the film **92** is coated with a transparent barrier coating **94** to prevent moisture and oxygen diffusion through the film **92** and to an organic electronic device (not shown). As with barrier coating **16**, the barrier coating **94** may be disposed or otherwise formed on the surface of the film **92**. In certain embodiments, the barrier coating **94** may be disposed at a thickness ranging from about 10 nm to about 10,000 nm, and preferably from about 10 nm to about 1,000 nm. It is generally desirable to choose a coating thickness that does not impede the transmission of light through the film **92**, such as a barrier coating **94** that causes a reduction in light transmission of less than about 20%, and preferably less than about 5%. The coating may be disposed by any suitable deposition techniques, such as plasma-enhanced chemical-vapor deposition (PECVD), for example.

[0053] As described in **FIG. 1** with reference to the barrier coating **16**, the barrier coating **94** may comprise organic, inorganic or ceramic materials, for instance. The materials are reaction or recombination products of reacting plasma species and are deposited onto the surface of the film **92**. Organic coating materials may comprise carbon, hydrogen, oxygen and optionally, other minor elements, such as sulfur, nitrogen, silicon, etc., depending on the types of reactants. Suitable reactants that result inorganic compositions in the coating are straight or branched alkanes, alkenes, alkynes, alcohols, aldehydes, ethers, alkylene oxides, aromatics, etc., having up to 15 carbon atoms. Inorganic and ceramic coating materials typically comprise oxide, nitride, carbide, boride, or combinations thereof of elements of Groups IIA, IIIA, IVA, VA, VIA, VIIA, IB, and IIB; metals of Groups IIB, IVB, and VB, and rare-earth metals. For example, silicon carbide can be deposited onto a substrate by recombination of plasmas generated from silane (SiH₄) and an organic material, such as methane or xylene. Silicon oxycarbide can be deposited from plasmas generated from silane, methane, and oxygen or silane and propylene oxide. Silicon oxycarbide also can be deposited from plasmas

generated from organosilicone precursors, such as tetraethoxysilane (TEOS), hexamethyldisiloxane (HMDSO), hexamethyldisilazane (HMDSN), or octamethylcyclotetrasiloxane (D4). Silicon nitride can be deposited from plasmas generated from silane and ammonia. Aluminum oxycarbonitride can be deposited from a plasma generated from a mixture of aluminum tartarate and ammonia. Other combinations of reactants, such as metal oxides, metal nitrides, metal oxynitrides, silicon oxide, silicon nitride, silicon oxynitrides may be chosen to obtain a desired coating composition.

[0054] Further, the barrier coating 94 may comprise hybrid organic/inorganic materials or multilayer organic/inorganic materials. The inorganic materials may be chosen from A-F elements and the organic materials may comprise acrylates, epoxies, epoxyamines, xylenes, siloxanes, silicones, etc. The choice of the particular reactants can be appreciated by those skilled in the art.

[0055] The substrate 90 may also comprise a coating or protective layer 96 that is chemically resistant and has a low coefficient of thermal expansion ("CTE"). The protective layer 96 may be implemented to advantageously prevent the underlying materials from being chemically attacked by chemicals commonly used during fabrication of the substrate 90 or the organic package. Further, because of the low CTE, the protective layer 96 also allows processing of the substrate 90 at high temperatures. The protective layer 96 may comprise acrylates, epoxies, epoxyamines, xylenes, siloxanes, silicones, etc. potentially filled with inorganic fillers such as silica particles, for instance and may be deposited by a roll coating, slot coating, bar coating, spin-coating, and other known wet chemical coating techniques. Alternatively the protective layer 96 may comprise inorganic and ceramic coating materials which typically comprise oxide, nitride, carbide, boride, or combinations thereof of elements from Groups IIA, IIIA, IVA, VA, VIA, VIIA, IB, and IIB, or metals from Groups IIIB, IVB, and VB, and rare-earth metals, which can be deposited with deposition techniques, such as plasma-enhanced chemical-vapor deposition (PECVD), radio-frequency plasma-enhanced chemical-vapor deposition (RFPECVD), expanding thermal-plasma chemical-vapor deposition (ETPCVD), reactive sputtering, electron-cyclodrawn-residence plasma-enhanced chemical-vapor deposition (ECRPECVD), inductively coupled plasma-enhanced chemical-vapor deposition (ICPECVD), sputter deposition, evaporation, atomic layer deposition (ALD), or combinations thereof.

[0056] The outer surface of the composite substrate 90 may also include a protective layer 98. The protective layer 98 generally comprises a layer/coating that is abrasion resistant and has a low coefficient of thermal expansion. The layer 98 may be implemented to prevent the substrate 90 from being scratched when handling. Further, because of the low CTE, the protective layer 98 also allows processing of the substrate 98 at high temperatures. The protective layer 98 may comprise any of those materials described above with respect to layer 96 and may be deposited by any of the deposition techniques described above with regard thereto.

[0057] FIG. 12 illustrates an alternate embodiment of a flexible composite substrate 100 which may be implemented in accordance with the previously described sealing techniques. The composite substrate 100 of FIG. 12 is similar to

the substrate illustrated with respect to FIG. 11. The difference between the substrate 100 and the substrate 90 is the use of two layers of film 102 and 104 as opposed to one layer of film 92 (as in FIG. 11). In the illustrated embodiment, each of the two films 102 and 104 has a barrier coating (not shown) disposed or deposited on the films. Further, the two barrier coatings 106 and 108 may be coupled by employing an adhesive layer 110.

[0058] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

1. A hermetically sealed package comprising:

a first substrate configured to receive an organic electronic device;

an organic electronic device disposed on the first substrate;

a first primer layer disposed on the first substrate, wherein the first primer layer is disposed about the perimeter of the organic electronic device;

a metal alloy sealant layer disposed on the first primer layer and about the perimeter of the organic electronic device;

a second primer layer disposed on the metal sealant layer; and

a second substrate disposed on the second layer of primer and disposed above and proximate to the organic electronic device.

2. The hermetically sealed package of claim 1, wherein the first substrate comprises a flexible substrate.

3. The hermetically sealed package of claim 1, wherein the first substrate comprises a composite structure.

4. The hermetically sealed package of claim 1, wherein the first substrate comprises a polymeric material.

5. The hermetically sealed package of claim 1, wherein the first substrate comprises a plastic, a metal foil, or a glass.

6. The hermetically sealed package of claim 1, comprising a barrier coating disposed between the first substrate and the organic electronic device.

7. The hermetically sealed package of claim 1, wherein the organic electronic device comprises an organic electroluminescent device or an organic photovoltaic device.

8. The hermetically sealed package of claim 1, wherein a melting point of the metal alloy sealant is configured to be greater than an operating temperature of the organic electronic device.

9. The hermetically sealed package of claim 1, wherein the metal alloy sealant layer comprises alloys of bismuth, or tin, or lead, or indium, or cadmium, or combinations thereof.

10. The hermetically sealed package of claim 9, wherein a volume percent of bismuth ranges from about 0 to about 50%, or a volume percent of tin ranges from about 5% to about 50%, or a volume percent of lead ranges from about 0 to about 50%, or a volume percent of indium ranges from about 0 to about 55%, or a volume percent of cadmium ranges from about 0 to about 15%.

11. The hermetically sealed package of claim 1, wherein the second substrate comprises a superstrate.

12. A hermetically sealed package comprising:

a first substrate configured to receive an organic electronic device;

an organic electronic device disposed on an upper surface of the substrate;

an insulating adhesive layer disposed above the organic electronic device;

a superstrate coupled to the insulating adhesive layer and disposed proximate to the organic electronic device, wherein the superstrate comprises a peripheral portion adapted to wrap around edges of the package such that the peripheral portion of the superstrate is coupled to a lower surface of the substrate opposite the organic electronic device; and

a metal alloy sealant layer disposed on the lower surface of the substrate such that the peripheral portion of the superstrate is hermetically sealed to the lower surface of the substrate.

13. The hermetically sealed package of claim 12, further comprising a desiccant material disposed within pockets formed by wrapping the edges of the package with the superstrate.

14. The hermetically sealed package of claim 12, further comprising a primer layer disposed between the metal alloy sealant layer and the lower surface of the substrate and between the metal alloy sealant layer and the peripheral portion of the superstrate.

15. The hermetically sealed package of claim 14, wherein the primer layer comprises tin.

16. A hermetically sealed package comprising:

a first substrate having an inner side and an outer side;

an organic electronic device disposed on the inner side of the first substrate;

an insulating layer disposed above the organic electronic device;

a second substrate having an inner side and an outer side, wherein the second substrate is coupled to the insulating adhesive such that the inner side of the second substrate is disposed proximate the organic electronic device;

an edge wrap coupled to the outer sides of each of the first and second substrates and configured to hermetically seal the peripheral edges of the package; and

a metal alloy sealant layer coupled to the outer sides of each of the first and second substrates and to the edge wrap such that the edge wrap is hermetically sealed to the outer sides of each of the first and second substrates.

17. The hermetically sealed package of claim 16, wherein each of the first substrate and the second substrate comprises a composite structure.

18. The hermetically sealed package of claim 16, wherein the edge wrap comprises a metal foil.

19. The hermetically sealed package of claim 16, further comprising a primer layer disposed between the edge wrap and the outer sides of each of the first and second substrates.

20. The hermetically sealed package of claim 16, further comprising a desiccant material disposed within pockets formed by wrapping the edges of the package with the edge wrap.

21. A method of fabricating a hermetically sealed electronic package comprising:

disposing a plurality of organic electronic devices on a substrate;

providing a metal foil having approximately the same dimensions as the substrate;

patterning the metal foil with a plurality of patterns comprising a metal alloy sealant, wherein each of the plurality of patterns is sized to completely surround the organic electronic devices upon coupling the metal foil with the substrate; and

coupling the metal foil to the substrate.

22. The method of claim 21, comprising heating the metal alloy sealant to form a melt of the metal alloy sealant.

23. The method of claim 21, further comprising:

disposing a first primer layer between the substrate and each of the plurality of patterns; and

disposing a second primer layer around the perimeter of each of the plurality of organic electronic devices.

24. The method of claim 23, wherein at least one of the first and second primer layer comprises tin.

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