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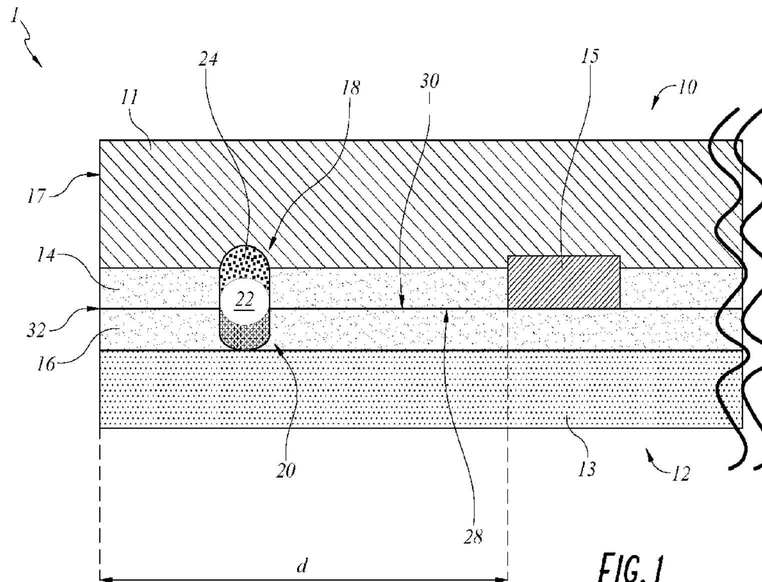
(54) **Title:** BONDED STRUCTURES



(57) **Abstract:** A bonded structure is disclosed. The bonded structure can include a first element that has a first bonding surface. The bonded structure can further include a second element that has a second bonding surface. The first and second bonding surfaces are bonded to one another along a bonding interface. The bonded structure can also include an integrated device that is coupled to or formed with the first element or the second element. The bonded structure can further include a channel that is disposed along the bonding interface around the integrated device to define an effectively closed profile The bonded structure can also include a getter material that is disposed in the channel. The getter material is configured to reduce the diffusion of gas into an interior region of the bonded structure.

[Continued on next page]

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BONDED STRUCTURES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Non-Provisional Application No. 16/011,525 entitled "BONDED STRUCTURES," filed June 18, 2018 and U.S. Provisional Application No. 62/609,683 entitled "BONDED STRUCTURES," filed December 22, 2017, the entire disclosure of which is incorporated herein by reference for all purposes.

BACKGROUND

Field

[0002] The field generally relates to bonded structures, and in particular, to bonded structures having a getter material for sealing an internal portion of the bonded structures.

Description of the Related Art

[0003] In semiconductor device fabrication and packaging, some integrated devices are sealed from the outside environs in order to, *e.g.*, reduce contamination or prevent damage to the integrated device. For example, some microelectromechanical systems (MEMS) devices include a cavity defined by a cap attached to a substrate with an adhesive such as solder. However, some adhesives may be permeable to gases, such that the gases can, over time, pass through the adhesive and into the cavity. Moisture or some gases, such as hydrogen or oxygen gas, can damage sensitive integrated devices. Other adhesives, such as solder, may have other long-term reliability issues. Accordingly, there remains a continued need for improved seals for integrated devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Specific implementations of the invention will now be described with reference to the following drawings, which are provided by way of example, and not limitation.

[0005] Figure 1 is a schematic cross-sectional view of a portion of a bonded structure including a first element and a second element.

[0006] Figure 2 is a schematic cross-sectional view of a portion of a bonded structure having a cavity.

[0007] Figure 3 is a sectional plan view of the bonded structure of Figure 2.

[0008] Figure 4 is a schematic cross-sectional view of the bonded structure having a plurality of spaces for receiving getter material(s) disposed in the first and second elements.

[0009] Figure 5 is a schematic cross-sectional view of a bonded structure having a first space comprising a first opening in the first element and a second space comprising a second opening in the second element, with the first and second spaces being laterally or horizontally spaced from one another.

[0010] Figure 6 is a schematic cross-sectional view of a bonded structure in which a first space comprising a first opening in the second element and a second space comprising a second opening in the second element, with the first and second spaces being horizontally spaced.

[0011] Figure 7 is a schematic cross-sectional view of a bonded structure in which an element has a plurality of spaces that are horizontally spaced from one another.

[0012] Figure 8 is a sectional plan view of the bonded structure having a plurality of channels disposed around an interior region of the bonded structure.

[0013] Figure 9 is a schematic side cross-sectional view of a bonded structure with a getter layer disposed in the cavity.

[0014] Figure 10A is a cross sectional view of the first element prior to forming an opening for receiving a getter material.

[0015] Figure 10B is a cross sectional view of the first element of Figure 10A after forming the opening and prior to receiving the getter material.

[0016] Figure 10C is a cross sectional view of the first element of Figure 10B after disposing the getter material in the opening.

[0017] Figure 11A is a cross sectional view of a bonded structure, according to an embodiment.

[0018] Figure 11B is a cross sectional view of the bonded structure of Figure 11A after forming an opening in the bonded structure.

[0019] Figure 11C is a cross sectional view of the bonded structure of Figure 11B after disposing a getter material in the opening.

[0020] Figure 11D is a cross sectional view of the bonded structure of Figure 11C after plugging the opening.

[0021] Figure 12 is a schematic diagram of an electronic system incorporating one or more bonded structures.

DETAILED DESCRIPTION

[0022] Various embodiments disclosed herein relate to bonded structures that connect two elements (which may comprise semiconductor elements) in a manner that effectively seals interior portions and/or integrated devices of the semiconductor elements from the outside environs. For example, in some embodiments, a bonded structure can comprise a plurality of semiconductor elements bonded to one another along a bonding interface. An integrated device can be coupled to or formed with a semiconductor element. For example, in some embodiments, the bonded structure can comprise a microelectromechanical systems (MEMS) device in which a cap (a first semiconductor element) is bonded to a carrier (a second semiconductor element). A MEMS element (the integrated device) can be disposed in a cavity defined at least in part by the cap and the carrier. In other embodiments, the element(s) can comprise other types of elements, such as optical elements, etc.

[0023] In some arrangements, the bonded structure can comprise a getter material disposed between the first and second elements. In some embodiments, the getter material may absorb and/or occlude incident moisture or gases. In some embodiments, the getter material can prevent gases (or significantly reduce an amount of the gas(es)) from reaching interior regions and/or integrated devices of the bonded structure. In some embodiments, the getter material can be disposed in a space provided along the bonding surface. In some embodiments, the first and second elements can be directly bonded without an intervening adhesive, *e.g.*, such that bonding interfaces of the first and second elements contact one another.

[0024] Figure 1 is a schematic cross sectional view of a portion of a bonded structure 1 according to various embodiments. The bonded structure can include a first element 10, a second element 12, a getter material 24 disposed in a space or void 22 and an

integrated device 15. The integrated device 15 can comprise any suitable type of device, such as an integrated circuit, a micro electro mechanical systems (MEMS) device, etc. In some embodiments, a first bonding surface 28 of the first element 10 and a second bonding surface 30 of the second element 12 can be bonded at a bonding interface 32 by way of direct bonding, e.g., without an intervening adhesive.

[0025] Figure 2 is a schematic side cross sectional view of a portion of the bonded structure 1 according to another embodiment. Unlike the bonded structure 1 of Figure 1, the bonded structure 1 of Figure 2 includes a cavity 26 for receiving an integrated device. For example, the integrated device 15 shown in Figure 1 can be disposed in the cavity 26 in Figure 2. Figure 3 is a sectional plan view of the bonded structure 1 of Figure 2. It should be understood that the bonded structure 1 can include more than one integrated device 15 and/or more than one cavity 26, in some embodiments.

[0026] In some embodiments, the second element 12 can comprise a carrier to which the first element 10 is bonded. In some embodiments, the carrier can comprise an integrated device die, such as a processor die configured to process signals transduced by the integrated device 15. In some embodiments, the integrated device 15 can comprise a MEMS element, such as a MEMS switch, an accelerometer, a gyroscope, etc. The integrated device 15 can be coupled to or formed with the first semiconductor element 10 or the second semiconductor element 12. In some embodiments, the carrier can comprise a substrate, such as a semiconductor substrate (e.g., a silicon interposer with conductive interconnects), a printed circuit board (PCB), a ceramic substrate, a glass substrate, or any other suitable carrier. In such embodiments, the carrier can transfer signals between the integrated device 15 and a larger packaging structure or electronic system (not shown). In some embodiments, the carrier can comprise an integrated device die, such as a processor die configured to process signals transduced by the integrated device 15. In some embodiments, the integrated device 15 can comprise a MEMS element, such as a MEMS switch, an accelerometer, a gyroscope, etc. The integrated device 15 can be coupled to or formed with the first semiconductor element 10 or the second semiconductor element 12.

[0027] In some configurations, it can be important to isolate or separate the integrated device die 15 from the outside environs, *e.g.*, from exposure to gases and/or contaminants. For example, for some integrated devices, exposure to moisture or gases (such

as hydrogen or oxygen gas) can damage the integrated device 15 or other components. In other examples, leakage of any other gases from the outside environment (*e.g.*, oxygen, nitrogen, etc.) may not be desired, as it may change the pressure inside the cavity, effectively altering the device performance. Accordingly, it can be important to provide a seal that effectively or substantially seals (*e.g.*, hermetically or near-hermetically seals) the integrated device 15 (Figure 1) and/or the cavity 26 (Figure 2) from gases.

[0028] In some embodiments, the space 22 can comprise a first opening 18 in the first element 10 and a second opening 20 in the second element 12, such as in the embodiments of Figures 1 to 3. Even though the first and second openings 18, 20 shown in Figure 1 may be generally aligned to define the space 22, in practice, there can be offsets between positions of the first and second openings 18, 20. In some embodiments, the space 22 can be enclosed. However, as shown in some other embodiments, the space 22 may only comprise one opening in either the first or the second elements 10, 12 (see Figures 6 and 7). The openings 18, 20 can comprise trenches formed at the bonding surface(s) 28, 30 of the first and/or second elements 10, 12. The space or void 22 with the getter material 24 can extend around the device in an effectively closed profile. In some embodiments, the space or void 22 can comprise a continuous channel around the integrated device 15 and/or the cavity 26, as shown in Figure 3. However, in other embodiments, the space 22 may not comprise a continuous channel. Rather, the space 22 can comprise a plurality of space portions and/or a plurality of channel portions around the integrated device 15 and/or the cavity 26, which collectively define an effectively closed profile around the device 15 and/or cavity 26. Thus, the space 22 with getter material 24 can define an effectively closed profile around the device 15 and/or cavity 26 to seal the device 15 and/or cavity 26 from the outside environs, regardless of whether the space 20 is continuous or includes gaps.

[0029] The disclosed embodiments can utilize getter materials that can collect free gases incident to them by, for example, absorption and/or occlusion. Different getter materials can have different properties. For example, aluminum (Al) can have a getter capacity of about 1 Pa-l/mg against oxygen (O_2). Barium (Ba) can have a getter capacity of about 0.69 Pa-l/mg against carbon dioxide (CO_2), about 11.5 Pa-l/mg against hydrogen (H_2), and about 2 Pa-l/mg against (O_2). Titanium (Ti) can have about 4.4 Pa-l/mg against (O_2). Thus, in some embodiments, the getter material 24 can be selected based on the types of

gases that are likely be present in the environment of which the bonded structure 1 would be used. Accordingly, the getter material 24 in the space 22 disposed along the bonding surface 32 can effectively provide seals for preserving hermetical or near-hermetical property for the integrated device 15 and/or the cavity 26. In some embodiments, for example, the getter material 24 can comprise one of or any two or more combination of Al, Ba, Ti, magnesium (Mg), niobium (Cb), zirconium (Zr), thorium (Th), phosphorus (P), vanadium (V), iron (Fe), and/or any other getter materials suitable. The getter material 24 can fill the space 22 completely or partially. In some embodiments, the getter material 24 can be coated around an inner periphery of the space 22. In some embodiments, the getter material 24 can comprise a powder form, solid form, liquid form, or any other suitable form for targeted purposes. In some embodiments, the openings 18, 20 can receive two distinct types of getter material. Such embodiments can beneficially act on different gases at the bonding surface 32. In some embodiments, the same getter material 24 can be provided in each element 10, 12. In other embodiments, each element 10, 12 may utilize different getter materials.

[0030] The first and second elements can be bonded in any suitable manner, including by direct bonding. In some embodiments, the direct bond between the first element 10 and the second element 12 can include a direct bond between the first bonding surface 28 of the first element 10 and the second bonding surface 30 of the second element 12. Preparation for bonding top surfaces of respective substrates 11, 13 can include provision of nonconductive layers 14, 16, such as silicon oxide, with exposed openings 18, 20. The bonding surfaces of the first element 10 and the second element 12 can be polished to a very high degree of smoothness (*e.g.*, less than 20 nm surface roughness, or more particularly, less than 5 nm surface roughness) for example, by chemical mechanical polishing (CMP). In some embodiments, the surfaces to be bonded may be terminated with a suitable species and activated prior to bonding. For example, in some embodiments, the bonding surfaces 28, 30 of the bonding layer to be bonded, such as silicon oxide material, may be very slightly etched for activation and exposed to a nitrogen-containing solution and terminated with a nitrogen-containing species. As one example, the surfaces 28, 30 to be bonded may be exposed to an ammonia dip after a very slight etch, and/or a nitrogen-containing plasma (with or without a separate etch). Once the respective surfaces are prepared, the bonding surfaces 28, 30 (such as silicon oxide) of the first and second elements

10, 12 can be brought into contact. The interaction of the activated surfaces can cause the first bonding surface 28 of the first element 10 to directly bond with the second surface 30 of the second element 12 without an intervening adhesive, without application of external pressure, without application of voltage, and at room temperature. In various embodiments, the bonding forces of the nonconductive regions can include covalent bonds that are greater than Van der Waals bonds and exert significant forces between the conductive features. Prior to any heat treatment, the bonding energy of the dielectric-dielectric surface can be in a range from 150-300 mJ/m^2, which can increase to 1500-4000 mJ/m^2 after a period of heat treatment. Additional details of the direct bonding processes used in conjunction with each of the disclosed embodiments may be found throughout U.S. Patent Nos. 7,126,212; 8,153,505; 7,622,324; 7,602,070; 8,163,373; 8,389,378; and 8,735,219, and throughout U.S. Patent Application Publication Nos. 2017/0062366; 2016/0314346; 2017/0200711, the contents of each of which are hereby incorporated by reference herein in their entirety and for all purposes. In still other embodiments, the elements 10, 12 can be bonded with an adhesive.

[0031] In some embodiments, the bonding surface 32 can have a dimension d from an outer edge 17 to the integrated device 15 or the cavity 26, for example, in a range of 10 μm to 600 μm, in a range of 10 μm to 80 μm, in a range of 40 μm to 60 μm, in a range of 100 μm to 600 μm, in a range of 200 μm to 300 μm, etc.

[0032] Figures 4-9 show alternative embodiments of the bonded structure 1. Figure 4 is a schematic cross sectional view of the bonded structure 1 having the space 22 and a second space 23 disposed horizontally adjacent to each other for receiving the getter material 24 and a second getter material 25, respectively. Unless otherwise noted, the components of Figure 4 may be the same as or generally similar to like-numbered components of Figures 1-3. The space 22 can comprise the first and second openings 18, 20 formed in the respective first and second elements 10, 12, and the second space 23 can comprise third and fourth openings 19, 21 formed in the respective first and second elements 10, 12. In some embodiments, the space 22 and the second space 23 can comprise the same or different shapes and/or sizes. In other embodiments, the openings 18, 20, 19 and 21 can comprise the same or different shapes and/or sizes. In some embodiments, the getter material 24 and the second getter material 25 can comprise the same or different getter

materials. It can be beneficial to have different getter materials 24, 25, in some embodiments. For example, different getter materials can act on different types gases to more effectively seal the integrated device and/or the cavity 26 within the bonded structure 1.

[0033] Figure 5 is a schematic cross sectional view of the bonded structure 1 having the space 22 comprising the first opening 18 in the first element 10 and the second space 23 comprising the second opening 20 in the second element 12 disposed horizontally adjacent to each other for receiving the getter material 24 and the second getter material 25 respectively. Unless otherwise noted, the components of Figure 5 may be the same as or generally similar to like-numbered components of Figures 1-4. Unlike the bonded structure 1 of Figures 1-4, the first opening 18 can be formed in the first element 10 and the second opening 20 can be formed in the second element 12. In some embodiments, the first opening 18 and the second opening 20 can comprise the same or different shapes and/or sizes. Further, as shown, the first and second openings 18, 20 can be horizontally mismatched, for example, such that they do not together cooperate to define a common space to receive the getter material. Therefore, the first opening 18 and a portion of the second bonding surface 30 can define the space 22, and the second opening 20 and a portion of the first bonding surface 28 can define the second space 23. Such embodiments that physically separate the spaces 22, 23 can be beneficial because, different getter materials 24, 25 may react with one another, which can affect the performance of the getter materials 24, 25 when the spaces 22, 23 are not separated from one another. Moreover, getter filling processes may limit the type of these reactive getter materials that are to be received within the elements (*e.g.*, within the die or wafer (top or bottom)) e.g. screen printing methods. For example, some filling processes may be suitable for use with some devices or material sets (*e.g.*, with one type of die, carrier, or substrate), and may be unsuitable for other types of devices. By separating the spaces 22, 23 in Figure 5, different processes and materials may be used to fill the spaces in the first and second elements 10, 12, respectively.

[0034] Figure 6 is a schematic cross sectional view of the bonded structure 1 in which the space 22 comprises the opening 18 formed in the first element 10 and the second space 23 comprises the opening 19 formed in the first element 10. As shown, the first and second spaces 22, 23 can be disposed horizontally adjacent to each other for receiving the getter material 24 and the second getter material 25 respectively. Unless otherwise noted, the

components of Figure 6 may be the same as or generally similar to like-numbered components of Figures 1-5. In Figure 6, the opening 18 formed in the first element 10 and a first portion of the second bonding surface 30 can comprise the first space 22, and the opening 19 formed in the first element 10 and a second portion of the second bonding surface 30 can comprise the second space 23. This embodiment can be beneficial because the openings may be formed only on the first element such that formation of the openings can be simpler (e.g., fewer steps in a forming process, etc.) than forming openings in both the first and second elements 10, 12. In some embodiments, having the openings 18, 19 only in the first element 10 can be beneficial since the first element can serve as a dummy element acting as a cap to form a cavity 26. The second element 12 can comprise a functional chip or device die; in such embodiments, providing the openings in only the first element 10 may obviate the use of openings in the second element 12, *e.g.*, an active chip or device die, which can beneficially avoid complications related to the wiring in second element 12. However, it should be understood that, in some embodiments, openings can be formed in the second element 12 as well.

[0035] Figure 7 is a schematic cross sectional view of the bonded structure 1 in which the space 22 comprises the opening 20 formed in the second element 12, the second space 23 comprises the opening 21 formed in the second element 12, and the third space 40 comprises an opening 41 formed in the second element 12. In should be understood that the openings can be formed in the first element 10, in some embodiments. As shown, the first, second and third spaces, 22, 23, 41 can be disposed horizontally adjacent to each other for receiving the getter material 24, the second getter material 25 and a third getter material 42 respectively. Unless otherwise noted, the components of Figure 7 may be the same as or generally similar to like-numbered components of Figures 1-6. The embodiment shown in Figures 6 and 7 are similar except in the embodiment in Figure 7 the third space 40 can be provided for receiving the third getter material 42. The opening 23 formed in the second element 12 and a third portion of the first bonding surface 28 can form the third space 40. In some embodiments, increasing the number of spaces for receiving different getter materials can be beneficial because, as explained above, different getter materials can act on different types of gases making the seal of the bonded structure 1 more hermetical.

[0036] Figure 8 is a sectional plan view of the bonded structure 1 having the spaces 22, 23 separated by gaps. Unless otherwise noted, the components of Figure 8 may be the same as or generally similar to like-numbered components of Figures 1-7. As illustrated in Figure 8, the spaces 22, 23 are disposed to form channels comprising channel portions 52, 53. As shown, the channel portions 52 can be provided around the channel portions 53. Although there are gaps between adjacent channel portions 52, 53, the illustrated embodiment can nevertheless provide an effectively closed profile for the cavity 26. It should be understood that the channel portions 52, 53 can have different shapes and/or sizes. In some embodiments, one of the spaces 22, 23 can comprise a continuous channel and the other can comprise a discontinuous channel. In some embodiments, different channel portions 52, 53 of the spaces 22, 23 can comprise different getter materials suitable for an environment that the bonded structure 1 is to be used in. It should also be appreciated that any of the embodiments disclosed herein can utilize discontinuous channels to define the effectively closed profile. In some embodiments, the bonded structure 1 can have one or more electrical connections (e.g., wiring) between the channel portions 52, 53. In such embodiments, the integrated device and/or the cavity 26 can be accessed from outside of the bonded structure 1 through the connections. In the illustrated embodiment, the channel portions 52 can at least partially cover or overlap the gaps between the channel portions 53 that are disposed within the channel portions 52. For example, the channel portions 52 may be positioned so as to block gases from passing through the gaps between the channel portions 53. Similarly, the channel portions 53 may be positioned so as to block gases that pass through the gaps between the channel portions 52 from entering the cavity 26.

[0037] Figure 9 is a schematic cross sectional view of the bonded structure 1 with a getter layer 34 disposed in the cavity 26. Unless otherwise noted, the components of Figure 9 may be the same as or generally similar to like-numbered components of Figures 1-8. The embodiment illustrated in Figure 9 is similar to the embodiment illustrated in Figure 2 except the bonded structure 1 of Figure 9 further includes the getter layer 34 in the cavity 26. As shown, the getter layer 34 can be provided along an inner wall 35 of the cavity 26. In some embodiments, the getter layer 34 can be activated when residual gas enters into the cavity 26 to absorb and/or occlude the residual gas to maintain ideal environment within the cavity 26. In some embodiments, the getter layer 34 can be used to selectively alter the

pressure within the cavity 26. In some embodiments, the bonded structure can include more than one cavity 26 and each cavity may include different getter layer to alter the pressures in different cavities in the bonded structure 1. As with the getter materials disposed between at the bonding surface, the getter layer 34 can comprise one of or any two or more combination of Al, Ba, Ti, Mg, Cb, Zr, Th, P, V, Fe, and/or any other getter materials suitable.

[0038] Figures 10A-10C show steps for forming the first opening 18 in the first element 10 from the first bonding surface 28 and disposing the getter material 24 in the opening 18. In Figure 10A, the first element can be provided. As shown in Figure 10A, the cavity 26 may be formed in the element 10. The cavity 26 can be formed in any suitable way, *e.g.*, by etching, drilling, etc. As shown in Figure 10B the opening 18 can be formed by way of, for example, etching (wet or dry), drilling (e.g., mechanical drilling, laser drilling, etc.), and/or any other suitable processes. In the embodiment of Figure 10A, the opening 18 can be formed after forming the cavity 26. In other embodiments, however, the cavity 26 can be formed before the opening 18, or the cavity 26 and opening 18 can be formed at the same time. Referring to Figure 10C, after the opening 18 is formed, the getter material 24 can be disposed in the opening 18 by way of, for example, electrochemical deposition, sputter coating, chemical vapor deposition (CVD), physical vapor deposition (PVD), screen printing, etc., and the process can vary depending on the particular material used as the getter material 24. The getter material 24 can be disposed in the opening completely or partially. It should be understood that a similar process can be applied to the second element 12 (see for example Figure 2) to form openings in the second element 12. In some embodiments, after the getter material 24 is disposed in the opening 18, a second element can be provided on the first bonding surface 28 to define the space 22 (see for example Figure 2).

[0039] Figures 11A-11D show steps for forming an trench 38 from a back surface 36 of the first element 10, disposing the getter material 24 in the trench 38, and forming the space or void 22. In Figure 11A, a bonded structure 1 can be provided. As shown in Figure 11B, the trench 38 can be formed by way of, for example, etching (wet, dry), drilling (e.g., mechanical drilling, laser drilling, etc.), and/or any other suitable processes. Referring to Figure 11C, after the trench38 is formed, the getter material 24 can be disposed in the trench 38 by way of, for example, electrochemical deposition, sputter coating, chemical vapor deposition (CVD), physical vapor deposition (PVD), screen printing, but the process can

vary depending on the particular material used as the getter material 24. Turning to Figure 11D, a plug 56 can be provided to plug the trench 38 to define the space 22. The getter material 24 can fully or partially fill the space 22. The plug can comprise, for example, a polymer material (e.g., epoxy, resin, epoxy mold compound, etc.). It should be understood that a similar process can be applied from a back surface 37 of the second element 12.

[0040] In some embodiments, the bonded structure of Figure 11A may already include the space 22 along the bonding interface 32 after bonding the first and second elements 10, 12. The space 22 may not have the getter material therein. In such embodiments, the trench 38 from the back surface 36 of the first element 10 can be provided only for disposing the getter material 24 into the space 22 already formed and not to form the openings for the space 22. This may allow the trench 38 for providing the getter material 24 to have more flexible dimensional configurations than what is illustrated in Figures 11B-11D because the opening 38 may not depend on the dimensions of the space 22 in which the getter material 24 is disposed. For example, the trench 38 may be narrower than the space 22. This can be beneficial, for example, when a thickness of the first element 10 from the front surface to the back surface is relatively thick (e.g., larger than 50 um), because forming the trench 38 in such thick element may create a relatively big trench. If the space 22 were already formed, opening 38 from a back surface 36 may be narrower than a diameter of the space 22, which reduces a dimension of the plug 56.

[0041] Figure 12 is a schematic diagram of an electronic system 80 incorporating one or more bonded structures 1, according to various embodiments. The system 80 can comprise any suitable type of electronic device, such as a mobile electronic device (*e.g.*, a smartphone, a tablet computing device, a laptop computer, etc.), a desktop computer, an automobile or components thereof, a stereo system, a medical device, a camera, or any other suitable type of system. In some embodiments, the electronic system 80 can comprise a microprocessor, a graphics processor, an electronic recording device, or digital memory. The system 80 can include one or more device packages 82 which are mechanically and electrically connected to the system 80, *e.g.*, by way of one or more motherboards. Each package 82 can comprise one or more bonded structures 1. The system 80 shown in Figure 8 can comprise any of the bonded structures 1 and associated seals shown and described herein.

[0042] In one aspect, a bonded structure is disclosed. The bonded structure can include a first element having a first bonding surface, a second element having a second bonding surface. The first and second bonding surfaces can be bonded to one another along a bonding interface. The bonded structure can further include an integrated device that is coupled to or formed with the first element or the second element. The bonded structure can also include a channel that is disposed along the bonding interface around the integrated device.

[0043] In some embodiments, the bonded structure can also include a getter material disposed in the channel. The getter material can be configured to reduce the diffusion of gas into an interior region of the bonded structure. The first and second bonding surfaces can be directly bonded without an intervening adhesive. In some embodiments, the bonding surface can have a dimension from an outer edge to the integrated device in a range of 10 μm to 600 μm. The channel can include a first trench disposed through the first bonding surface and a second trench disposed through the second bonding surface.

[0044] In some embodiments, the bonded structure can include a cavity and the integrated device can be disposed in the cavity. The channel and the getter material can be disposed around the cavity.

[0045] In some embodiments, the channel can comprise a continuous channel surrounding the integrated device. A first group of the channel portions can be filled with the getter material and a second group of the channel portions can be filled with a second getter material.

[0046] In some embodiments, the getter material can comprise at least one of titanium (Ti), tantalum (Ta), aluminum (Al), magnesium (Mg), thorium (Th), niobium (Cb), zirconium (Zr), and phosphorus (P).

[0047] In some embodiments, the channel can be formed in only one of the first and second elements.

[0048] In some embodiments, the channel can comprise a first trench disposed through the first bonding surface and a second trench disposed through the second bonding surface. The channel can comprise a plurality of trenches that are offset laterally along the bonding interface.

[0049] In another aspect, a bonded structure is disclosed. The bonded structure can include a first element, a second element that is directly bonded to the first element along a bonding interface without an intervening adhesive, and a getter material that is disposed in a space along the bonding surface. The getter material is configured to reduce the diffusion of gas into an interior region of the bonded structure.

[0050] In some embodiments, the space can comprise a channel. In some embodiments, the space is enclosed. The bonded structure can also include an integrated device that is coupled to or formed with the first element or the second element. The channel can be disposed around the integrated device to define an effectively closed profile.

[0051] In another aspect a method of forming a bonded structure is disclosed. The method can include providing a first element that has a first bonding surface. An opening is disposed through a portion of the first bonding surface. The method also includes disposing a getter material in the opening. The method further includes bonding a second bonding surface of a second element to the first bonding surface of the first element. The first and second bonding surfaces are bonded such that the opening and a portion of the second element cooperate to define a space configured to receive the getter material.

[0052] In some embodiments, the opening can comprise a trench and the space can comprise a channel. In some embodiments, the opening can be provided by etching the first element from the first bonding surface to form a plurality of opening portions around the integrated device.

[0053] In some embodiments, the method can also include forming the opening and forming a second opening in the first element. The second opening are laterally offset from the opening. After the bonding, the second opening and a second portion of the second element can cooperate to define a second space configured to receive a second getter material.

[0054] In some embodiments, the method can also include forming the opening in the first element and forming a second opening in the second element through a portion of the second bonding surface. The opening and the second opening can cooperate to define the space.

[0055] In some embodiments, the method can also include forming the opening by removing a portion of the first element from a back surface of the first element opposite

the first bonding surface. The method can also include filling at least a portion of the opening from the back surface after disposing the getter material to form the for the getter material.

[0056] In some embodiments, the method can also include defining a cavity between the first element and the second element. The integrated device can be disposed in the cavity.

[0057] For purposes of summarizing the disclosed embodiments and the advantages achieved over the prior art, certain objects and advantages have been described herein. Of course, it is to be understood that not necessarily all such objects or advantages may be achieved in accordance with any particular embodiment. Thus, for example, those skilled in the art will recognize that the disclosed implementations may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught or suggested herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

[0058] All of these embodiments are intended to be within the scope of this disclosure. These and other embodiments will become readily apparent to those skilled in the art from the following detailed description of the embodiments having reference to the attached figures, the claims not being limited to any particular embodiment(s) disclosed. Although this certain embodiments and examples have been disclosed herein, it will be understood by those skilled in the art that the disclosed implementations extend beyond the specifically disclosed embodiments to other alternative embodiments and/or uses and obvious modifications and equivalents thereof. In addition, while several variations have been shown and described in detail, other modifications will be readily apparent to those of skill in the art based upon 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. 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 implementations. Thus, it is intended that the scope of the subject matter herein disclosed should not be limited by the particular disclosed embodiments described above, but should be determined only by a fair reading of the claims that follow.

WHAT IS CLAIMED IS:

1. A bonded structure comprising:

a first element having a first bonding surface;

a second element having a second bonding surface, the first and second bonding surfaces bonded to one another along a bonding interface;

an integrated device coupled to or formed with the first element or the second element; and

a channel disposed along the bonding interface around the integrated device.

2. The bonded structure of Claim 1, further comprising a getter material disposed in the channel, the getter material configured to reduce the diffusion of gas into an interior region of the bonded structure.

3. The bonded structure of Claim 2, wherein the first and second bonding surfaces are directly bonded without an intervening adhesive.

4. The bonded structure of Claim 3, wherein the bonding surface has a dimension from an outer edge to the integrated device in a range of 10 μm to 600 μm.

5. The bonded structure of Claim 3, wherein the channel comprises a first trench disposed through the first bonding surface and a second trench disposed through the second bonding surface.

6. The bonded structure of Claim 2, wherein the bonded structure comprises a cavity, the integrated device disposed in the cavity.

7. The bonded structure of Claim 6, wherein the channel and the getter material are disposed around the cavity.

8. The bonded structure of Claim 6, further comprising a getter layer disposed along at least a portion of a sidewall of the cavity.

9. The bonded structure of Claim 2, wherein the channel comprises a continuous channel surrounding the integrated device.

10. The bonded structure of Claim 2, further comprising a second channel around the channel, the second channel filled with a second getter material different from the getter material in the channel.

11. The bonded structure of Claim 2, wherein the channel comprises a plurality of discontinuous channel portions surrounding the integrated device.

12. The bonded structure of Claim 11, wherein a first group of the channel portions are filled with the getter material and a second group of the channel portions are filled with a second getter material.

13. The bonded structure of Claim 2, wherein the getter material comprises at least one of titanium (Ti), tantalum (Ta), aluminum (Al), magnesium (Mg), thorium (Th), niobium (Cb), zirconium (Zr), and phosphorus (P).

14. The bonded structure of Claim 2, wherein the channel is formed in only one of the first and second elements.

15. The bonded structure of Claim 2, wherein the channel comprises a first trench disposed through the first bonding surface and a second trench disposed through the second bonding surface.

16. The bonded structure of Claim 15, wherein the channel comprises a plurality of trenches offset laterally along the bonding interface.

17. The bonded structure of Claim 2, wherein the channel is partially filled with the getter material.

18. A bonded structure comprising:

a first element;

a second element directly bonded to the first element along a bonding interface without an intervening adhesive; and

a getter material disposed in a space along the bonding surface, the getter material configured to reduce the diffusion of gas into an interior region of the bonded structure.

19. The bonded structure of Claim 18, wherein the space comprises a channel.

20. The bonded structure of Claim 18, wherein the space is enclosed.

21. The bonded structure of Claim 19, further comprising an integrated device coupled to or formed with the first element or the second element, wherein the channel is disposed around the integrated device to define an effectively closed profile.

22. A method of forming a bonded structure, the method comprising:

providing a first element having a first bonding surface, an opening disposed through a portion of the first bonding surface;

disposing a getter material in the opening; and

bonding a second bonding surface of a second element to the first bonding surface of the first element such that the opening and a portion of the second element cooperate to define a space configured to receive the getter material.

23. The method of Claim 22, wherein the opening comprises a trench and the space comprises a channel.

24. The method of Claim 22, further comprising forming the opening and forming a second opening in the first element, the second opening laterally offset from the opening, wherein, after the bonding, the second opening and a second portion of the second element cooperate to define a second space configured to receive a second getter material.

25. The method of Claim 22, further comprising forming the opening in the first element and forming a second opening in the second element through a portion of the second bonding surface.

26. The method of Claim 25, wherein the opening and the second opening cooperate to define the space.

27. The method of Claim 22, wherein the opening is provided by etching the first element from the first bonding surface to form a plurality of opening portions around the integrated device.

28. The method of Claim 22, further comprising forming the opening by removing a portion of the first element from a back surface of the first element opposite the first bonding surface.

29. The method of Claim 28, further comprising filling at least a portion of the opening from the back surface after disposing the getter material to form the for the getter material.

30. The method of Claim 22, further comprising defining a cavity between the first element and the second element, wherein the integrated device is disposed in the cavity.

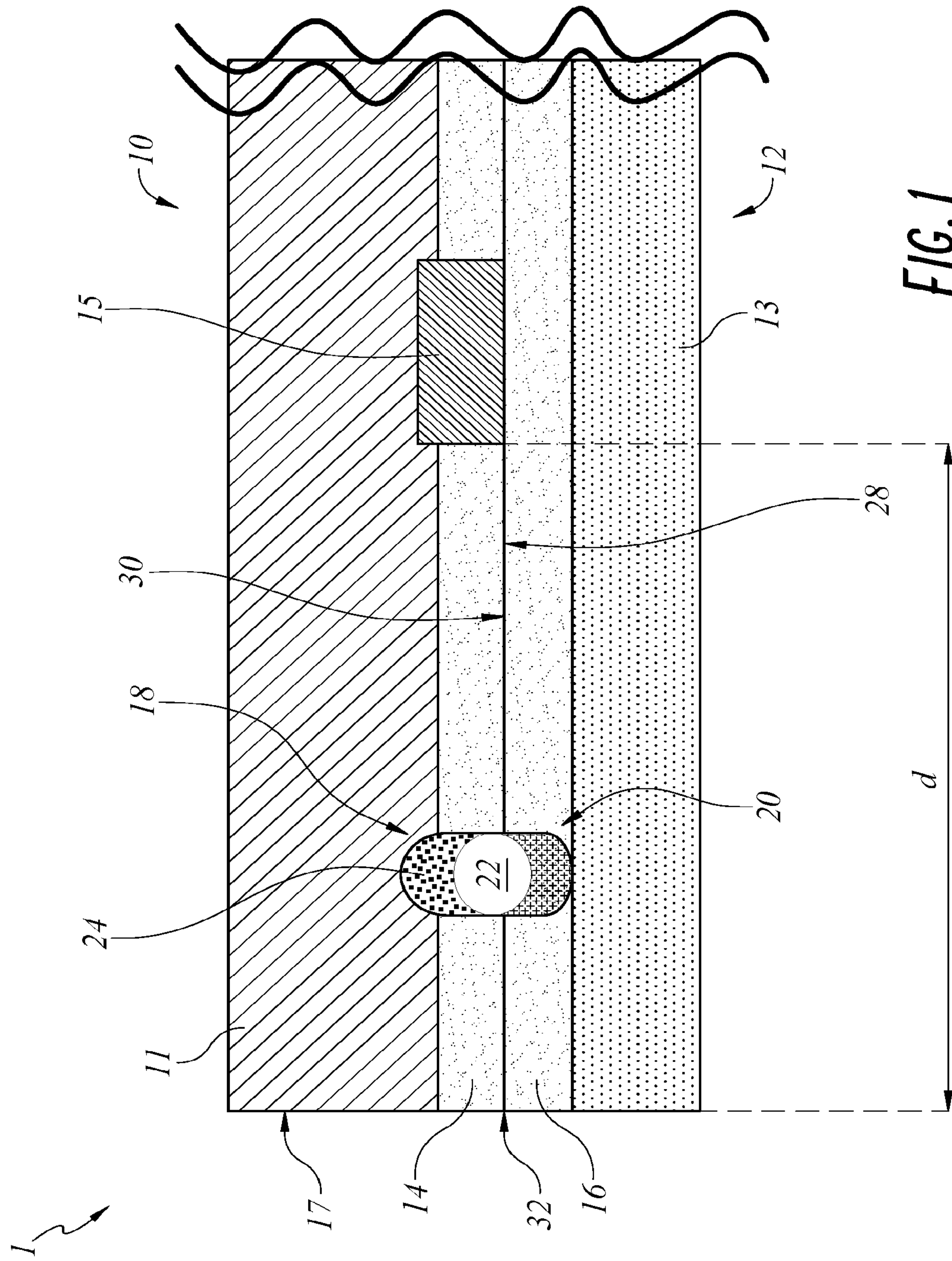
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FIG. 1

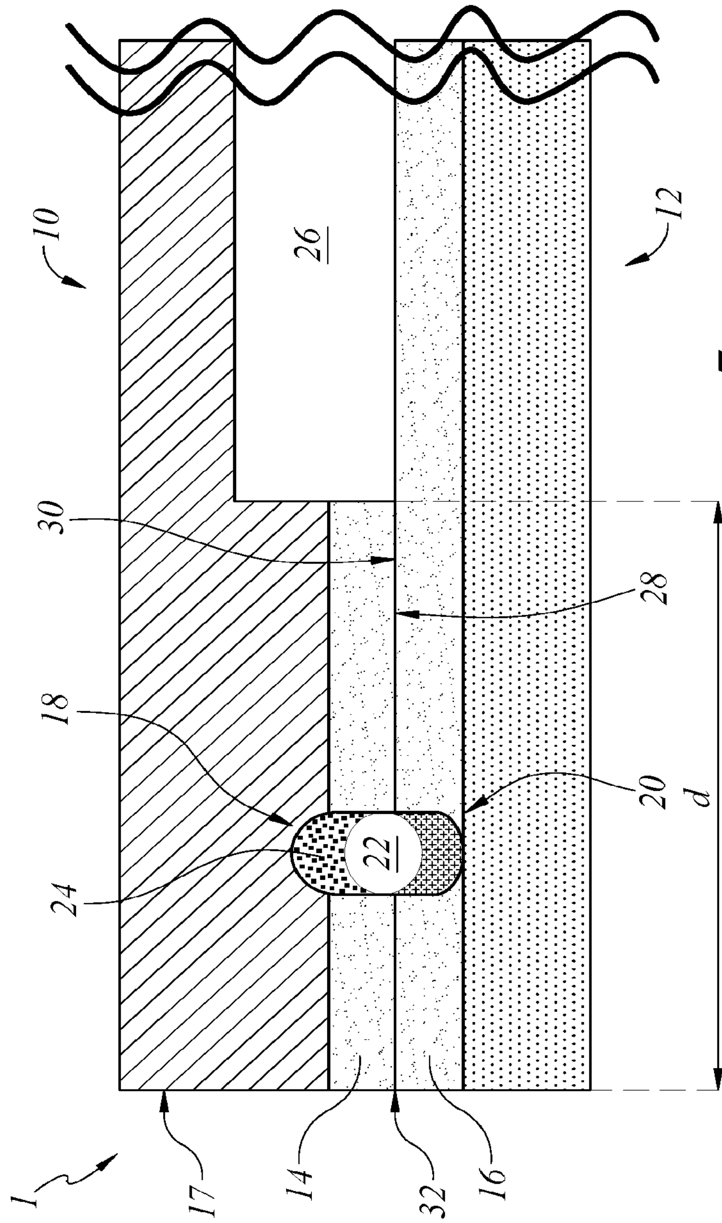

FIG. 2

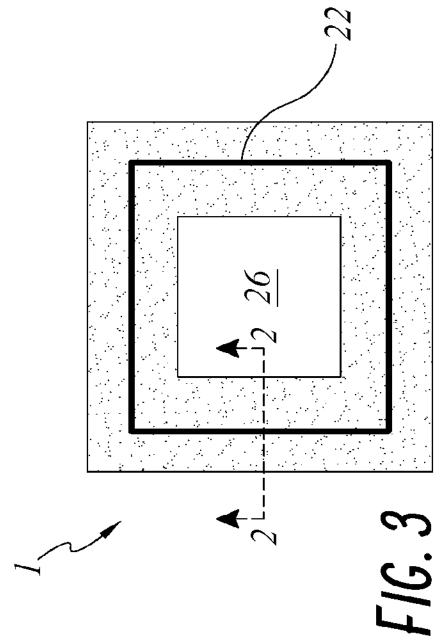

FIG. 3

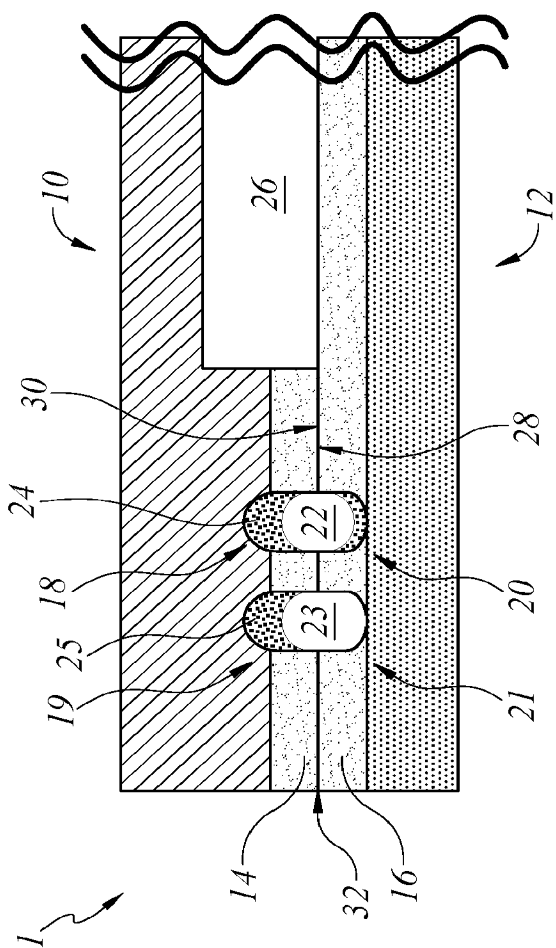

FIG. 4

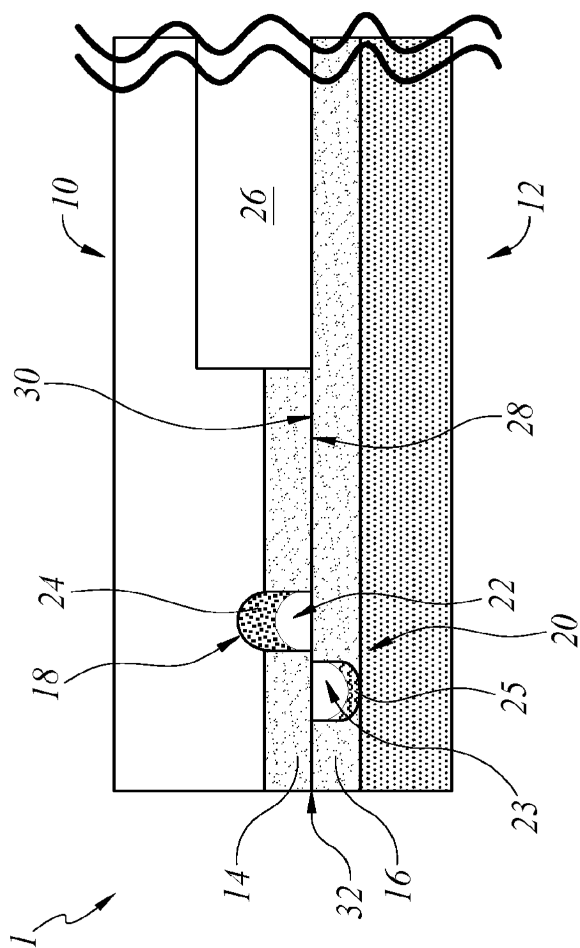

FIG. 5

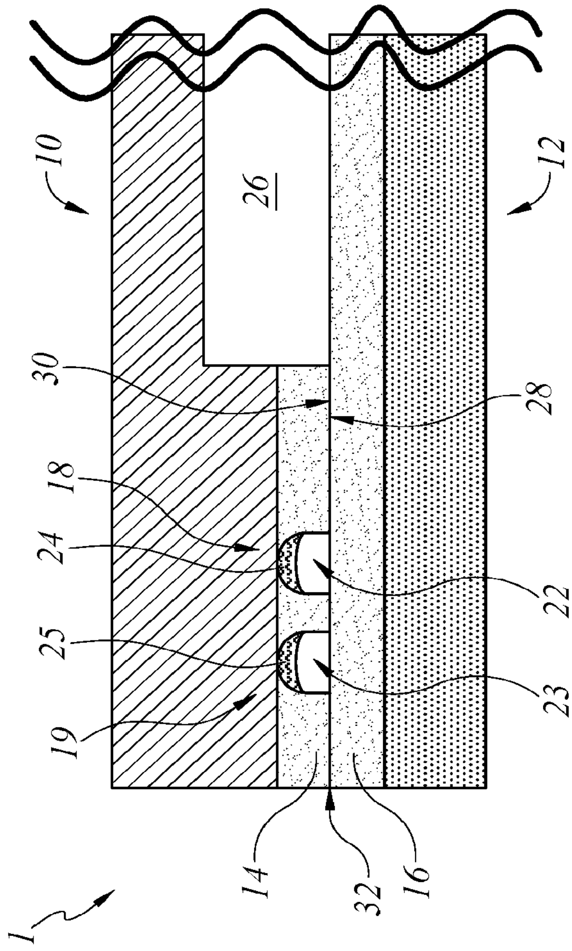

FIG. 6

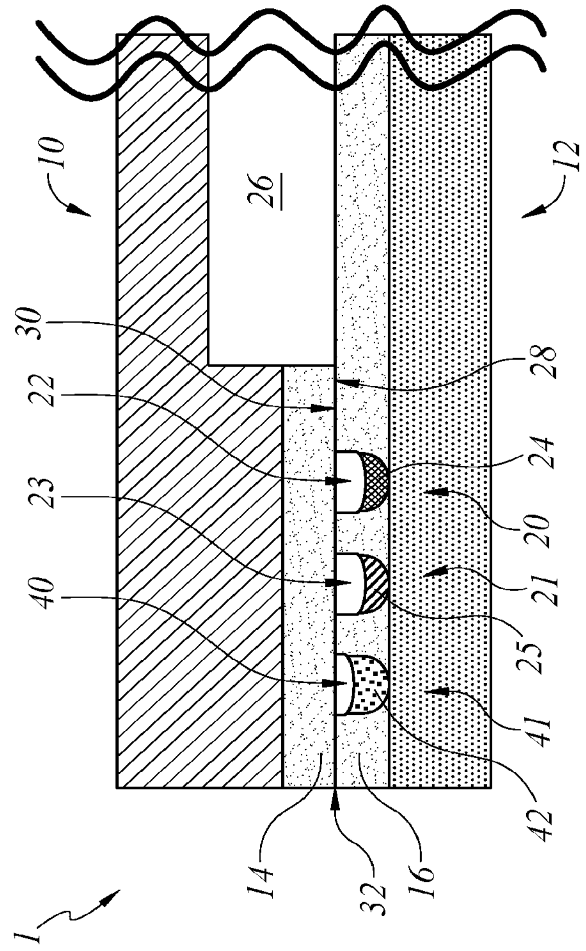

FIG. 7

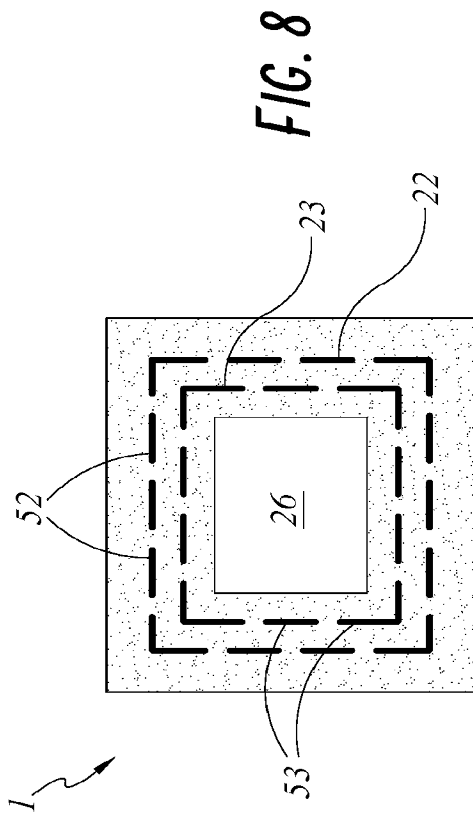

FIG. 8

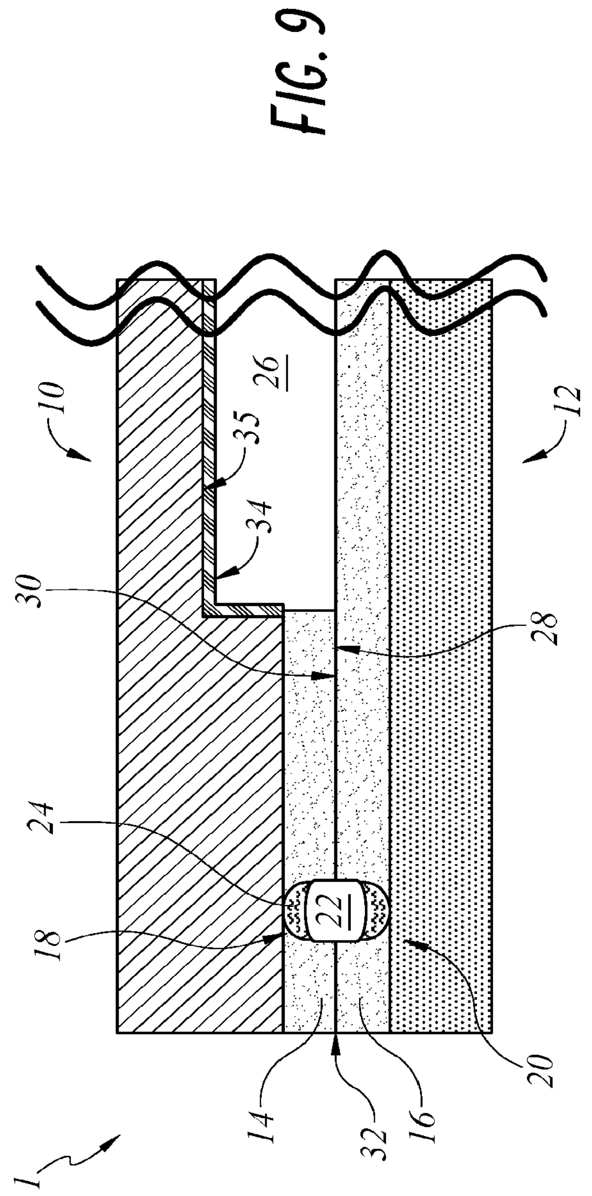

FIG. 9

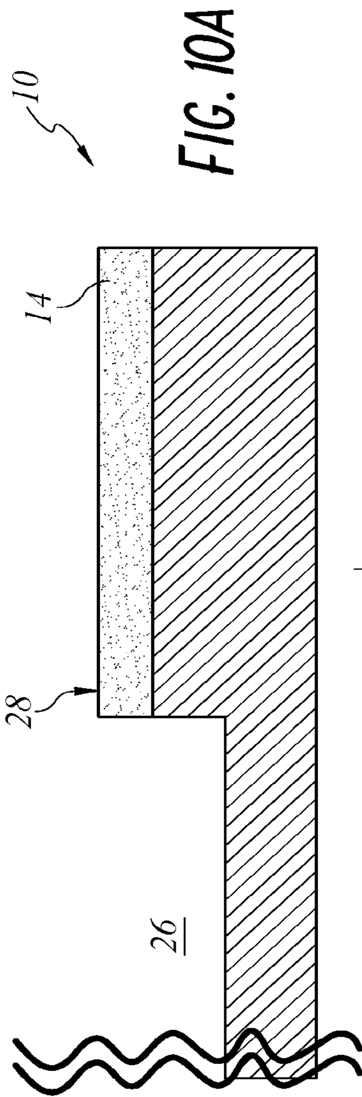

FIG. 10A

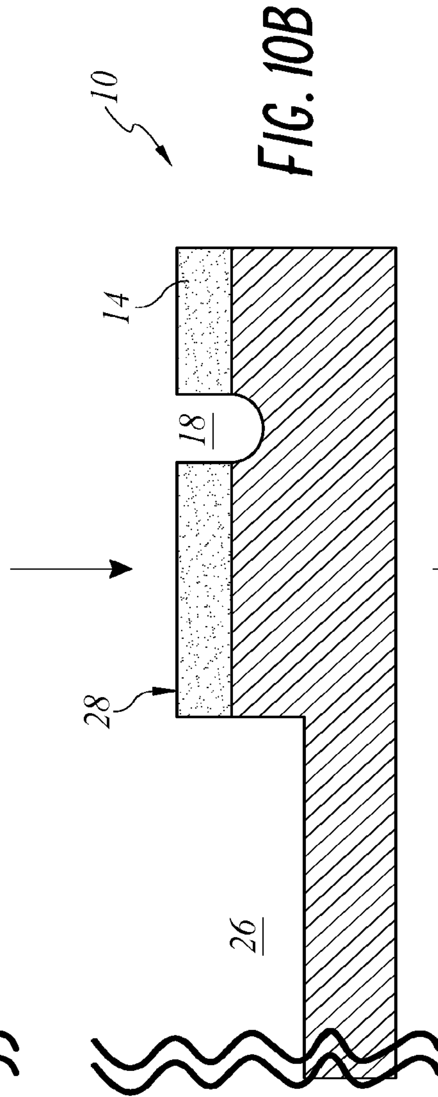

FIG. 10B

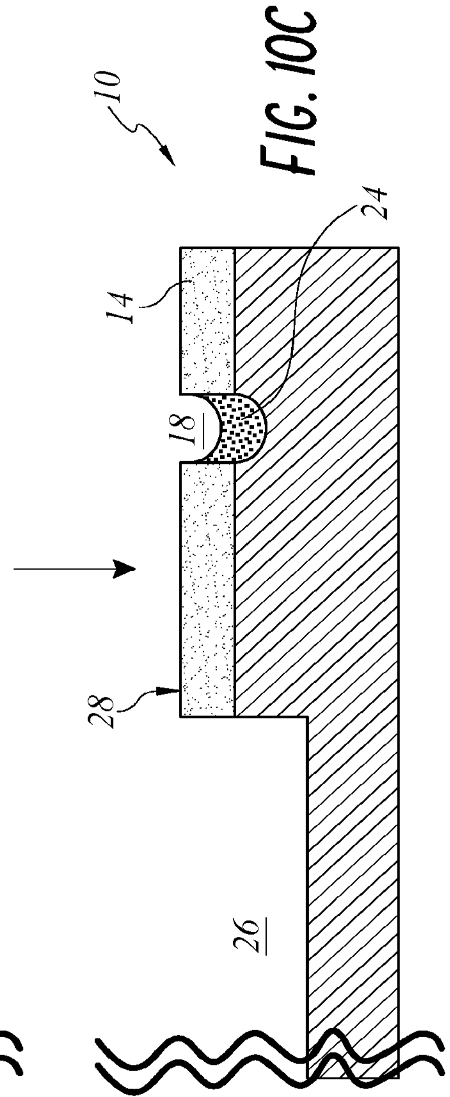

FIG. 10C

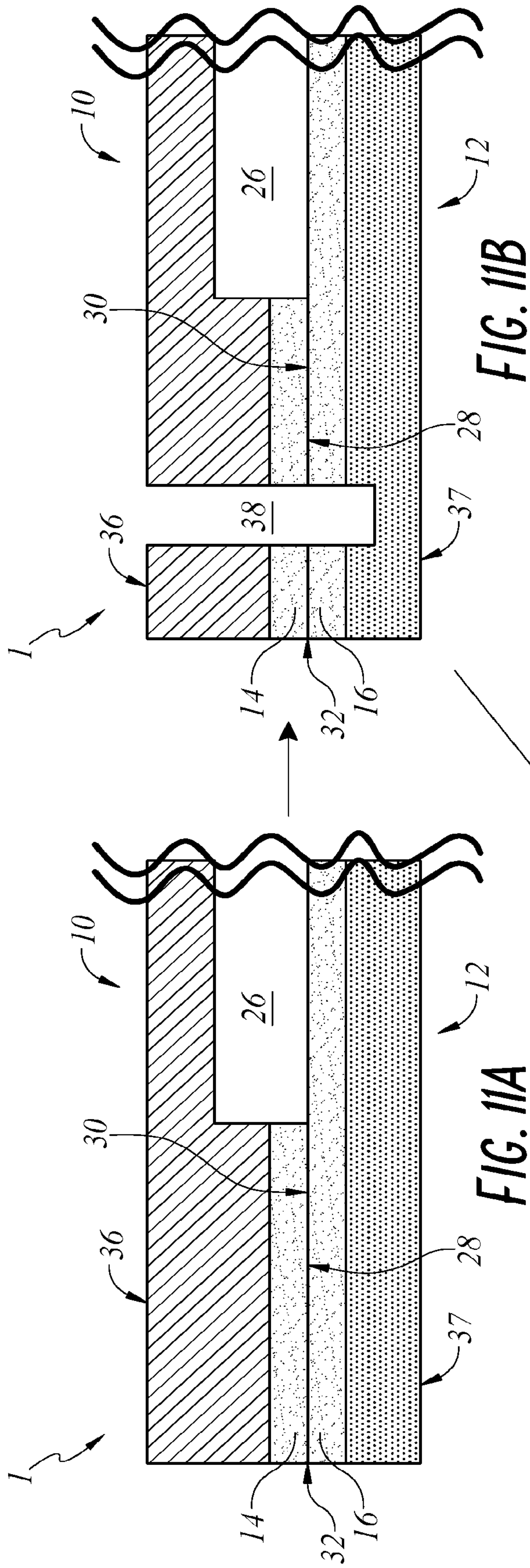

FIG. 11B

FIG. 11A

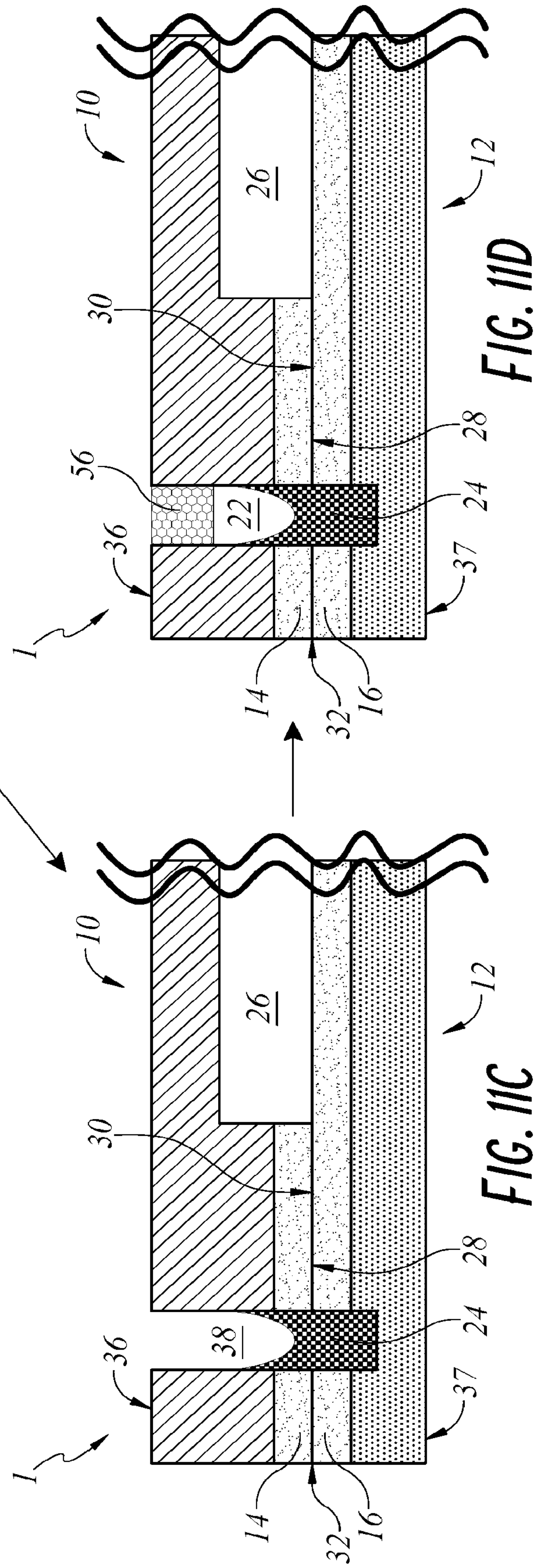

FIG. 11D

FIG. 11C

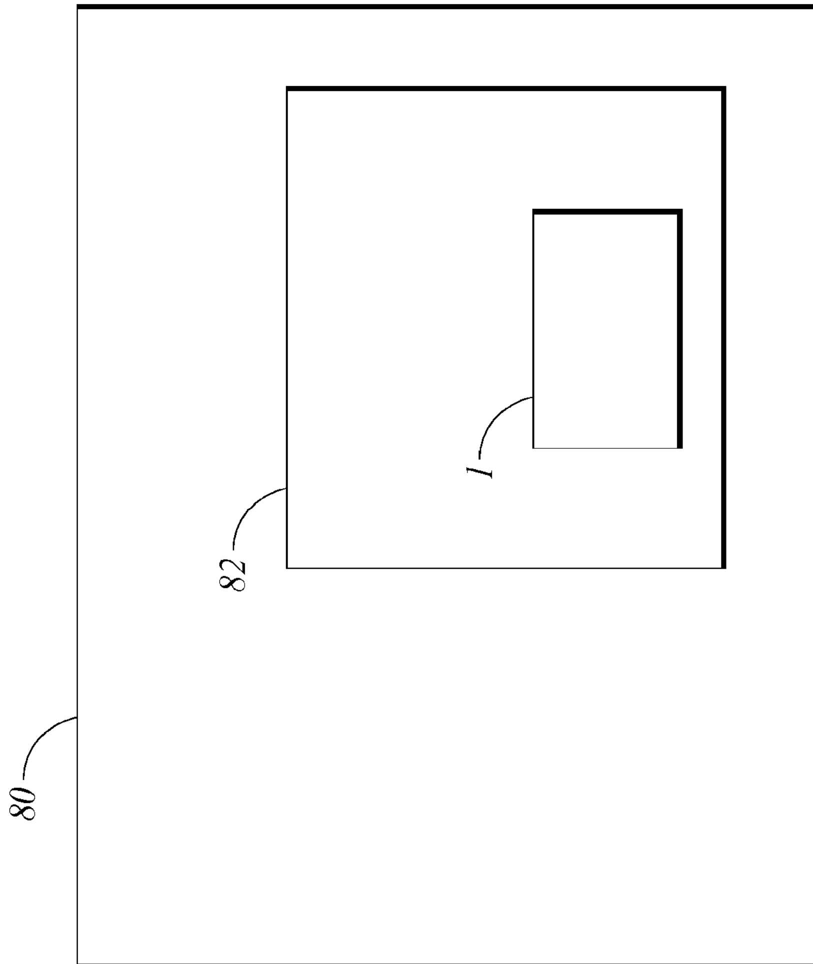

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/060044

A. CLASSIFICATION OF SUBJECT MATTER

H01L 23/00(2006.01)i, H01L 21/18(2006.01)i, H01L 23/485(2006.01)i

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)
H01L 23/00; B29C 65/54; C09J 11/04; C09J 7/02; H01B 1/02; H01L 23/02; H01L 23/26; H01L 23/28; H01L 29/12; H01L 51/52; H01L 21/18; H01L 23/485

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: MEMS, seal package, getter material, channel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007-0295456 A1 (CHRISTOPHER S. GUDEMAN) 27 December 2007 See paragraphs [0028]-[0049] and figures 2-4.	1,2,6-9,13,14,17
A		3-5,10-12,15,16,18-30
Y	WO 2006-100444 A1 (CAMBRIDGE DISPLAY TECHNOLOGY LIMITED et al.) 28 September 2006 See page 10, lines 7-13 and figures 3b-3d.	1,2,6-9,13,14,17
A	US 2007-0222048 A1 (CHENG WEI HUANG) 27 September 2007 See paragraphs [0024]-[0027] and figures 3-4.	1-30
A	US 2011-0290552 A1 (LAUREN PALMATEER et al.) 01 December 2011 See paragraphs [0046]-[0051] and figure 8.	1-30
A	KR 10-2015-0097798 A (TESA SE) 26 August 2015 See paragraph [0124] and figure 6.	1-30

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* 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	Date of mailing of the international search report
07 March 2019 (07.03.2019)	**07 March 2019 (07.03.2019)**

Name and mailing address of the ISA/KR

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189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

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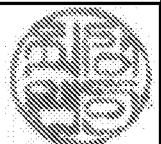
Authorized officer

CHOI, Sang Won



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