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(54) GETTER TECHNOLOGY FOR MICROMACHINED ULTRASONIC TRANSDUCER CAVITIES

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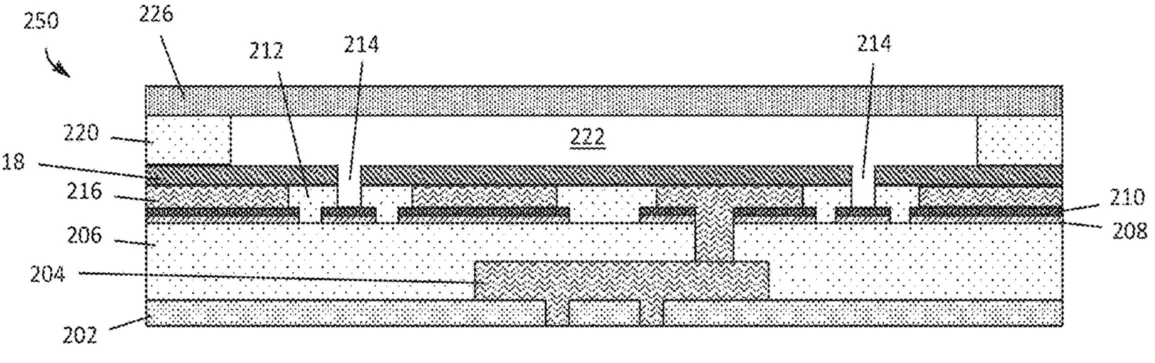
A61B 8/00	(2006.01)

(52) **U.S. Cl.**

CPC ***B06B 1/0292*** (2013.01); ***B81B 7/0038*** (2013.01); ***B81C 1/00285*** (2013.01); ***A61B 8/4494*** (2013.01); *A61B 2562/12* (2013.01); *B81B 2203/0127* (2013.01); *B81B 2203/0315* (2013.01); *B81B 2203/04* (2013.01); *B06B 2201/76* (2013.01); *B81B 2201/0271* (2013.01)

(57) **ABSTRACT**

A method of forming an ultrasonic transducer device includes bonding a membrane to seal a transducer cavity with at least a portion of a getter material layer being exposed, the getter material layer comprising a portion of a bilayer stack compatible for use in damascene processing.



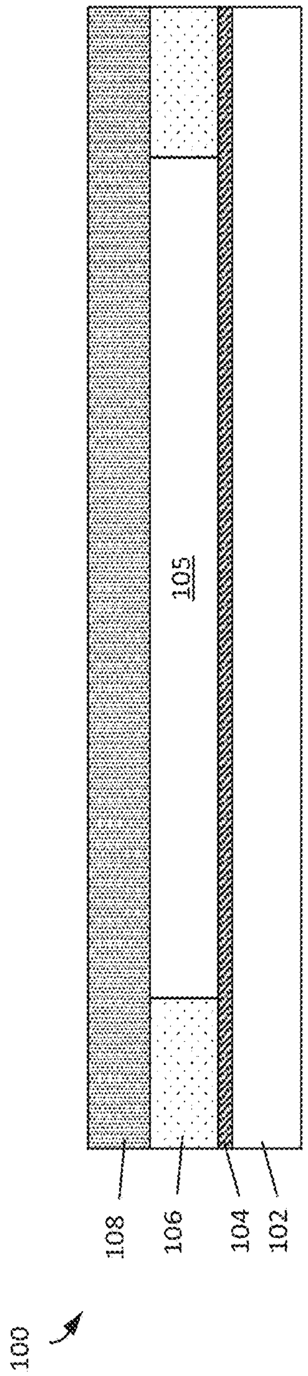


FIG. 1A

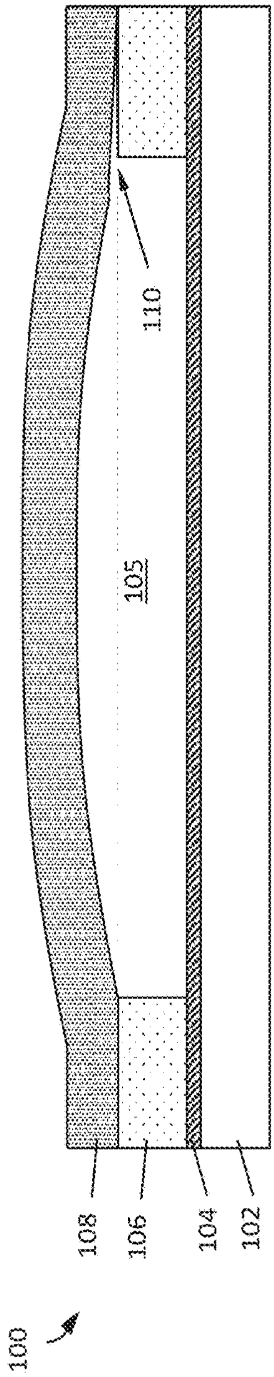


FIG. 1B

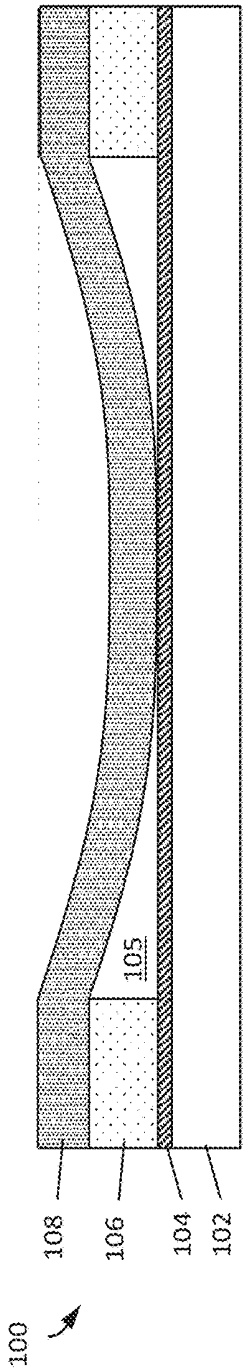


FIG. 1C

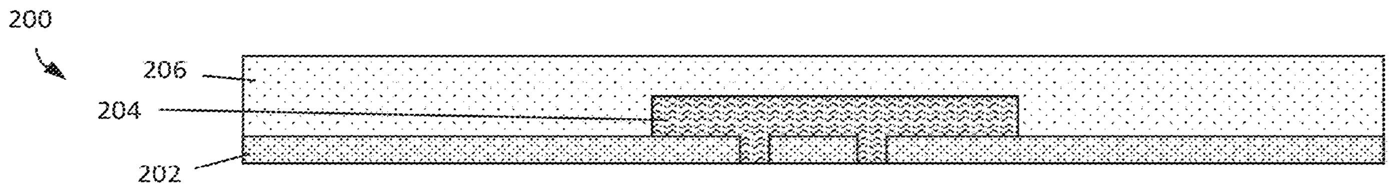


FIG. 2-1

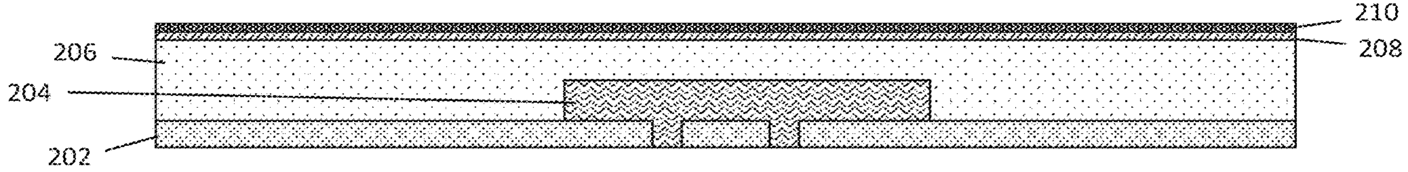


FIG. 2-2

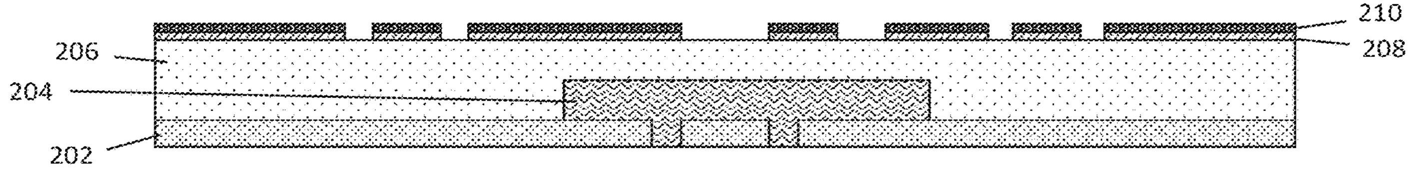


FIG. 2-3

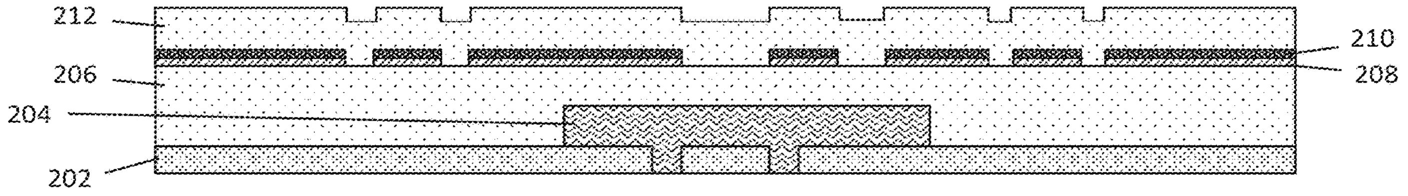


FIG. 2-4

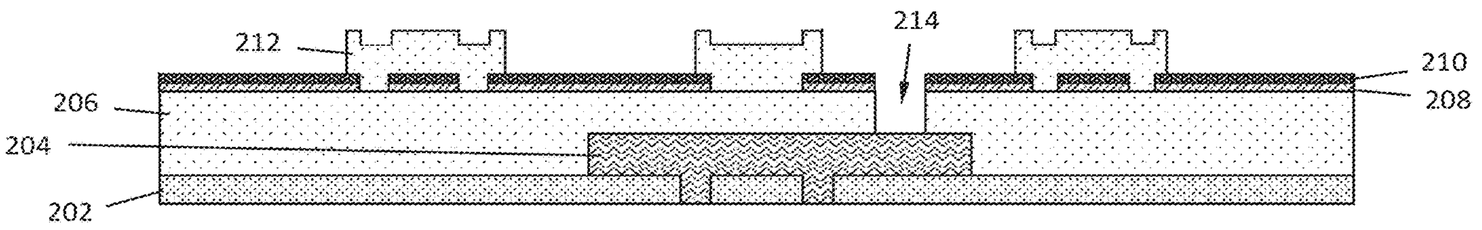


FIG. 2-5

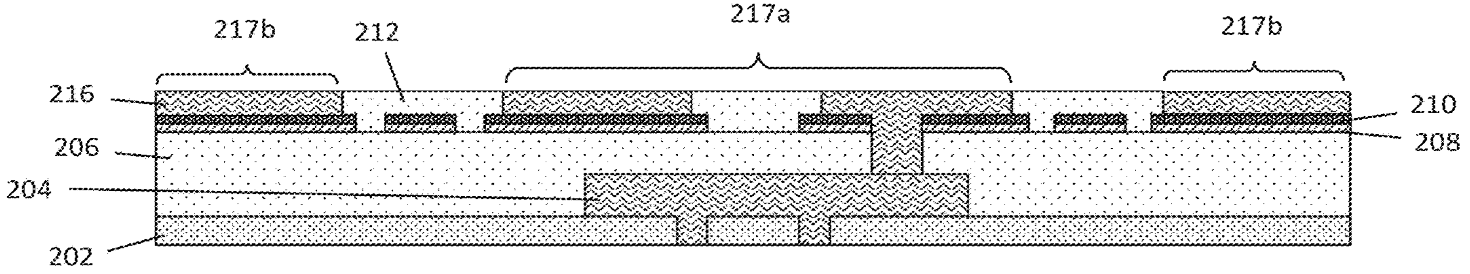


FIG. 2-6

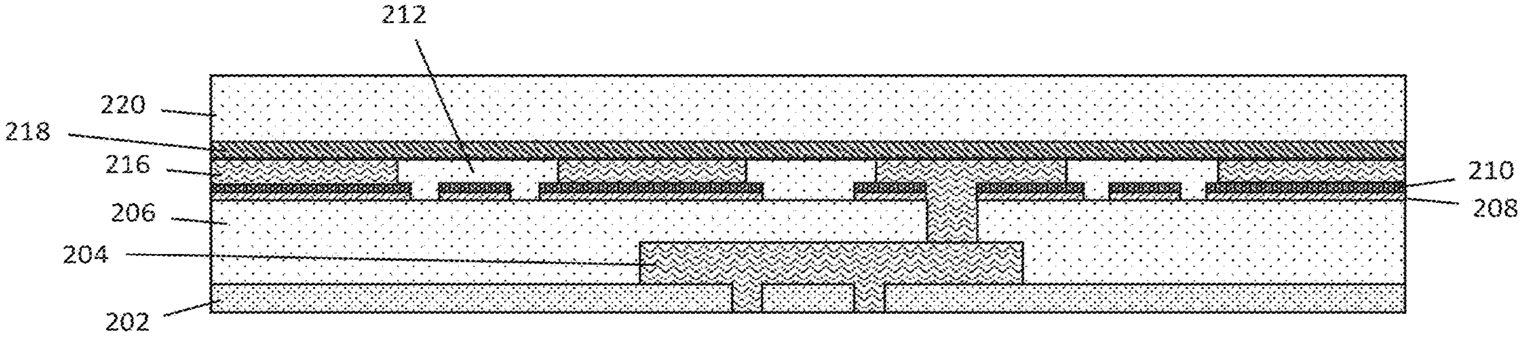


FIG. 2-7

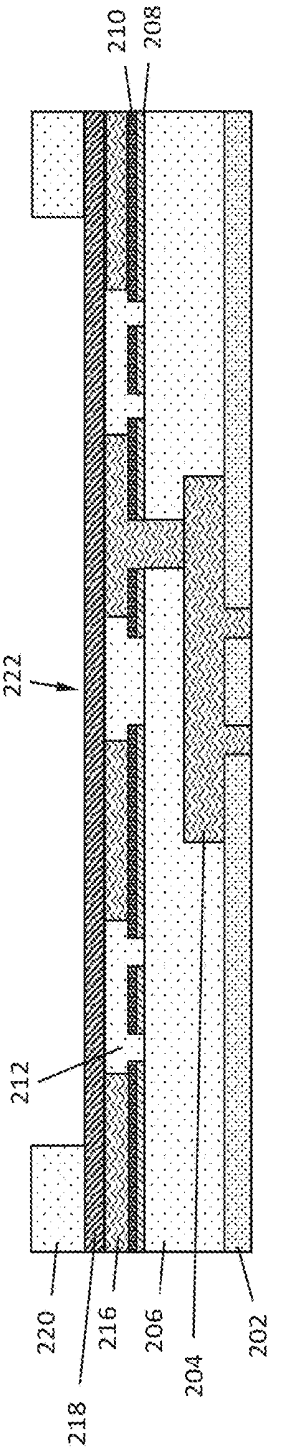


FIG. 2-8

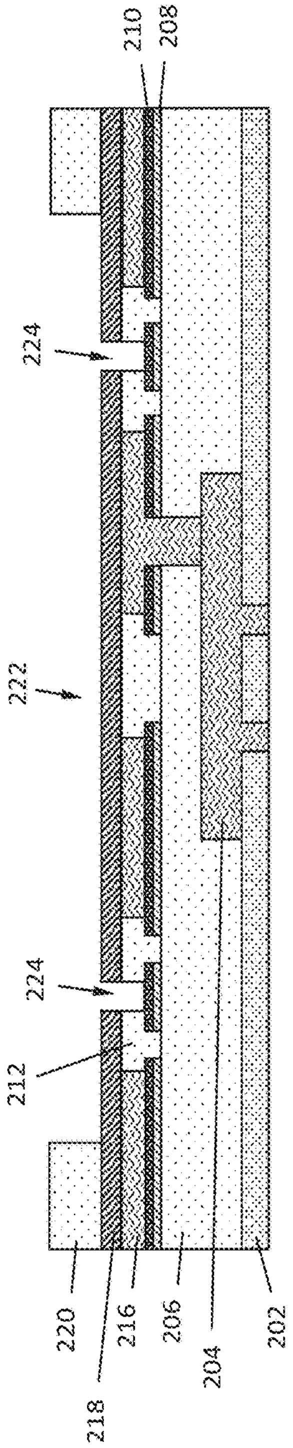


FIG. 2-9

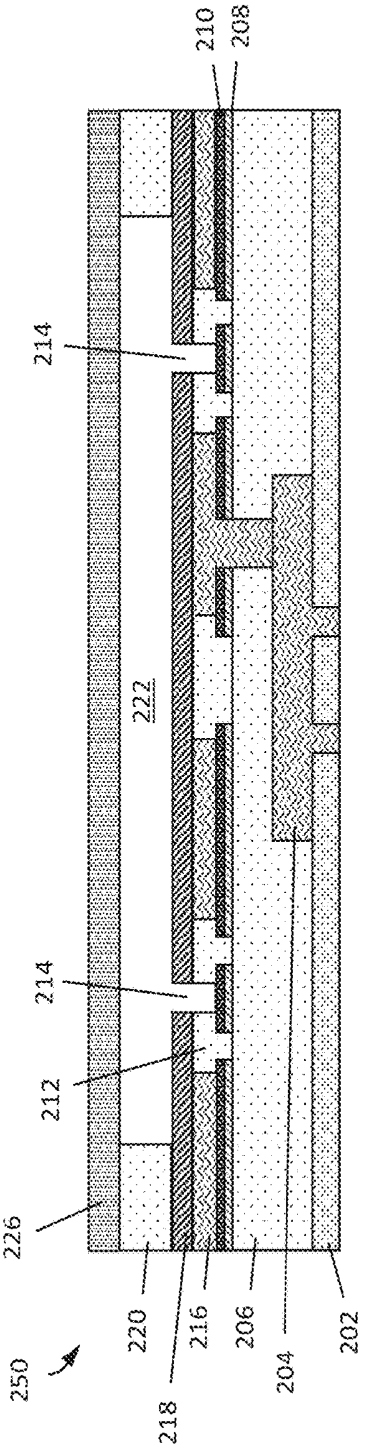


FIG. 2-10

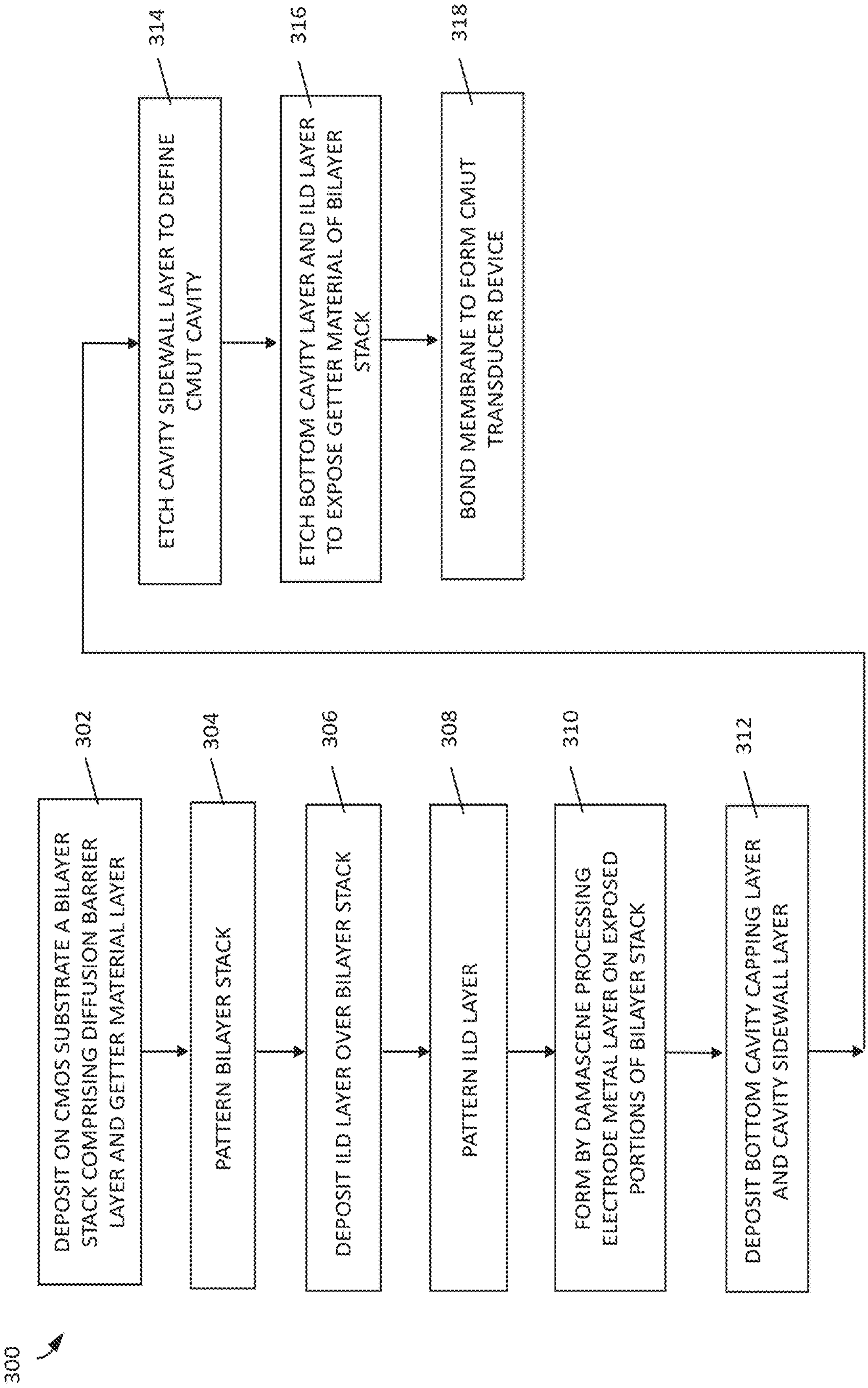

300
302
DEPOSIT ON CMOS SUBSTRATE A BILAYER STACK COMPRISING DIFFUSION BARRIER LAYER AND GETTER MATERIAL LAYER
304
PATTERN BILAYER STACK
306
DEPOSIT ILD LAYER OVER BILAYER STACK
308
PATTERN ILD LAYER
310
FORM BY DAMASCENE PROCESSING ELECTRODE METAL LAYER ON EXPOSED PORTIONS OF BILAYER STACK
312
DEPOSIT BOTTOM CAVITY CAPPING LAYER AND CAVITY SIDEWALL LAYER
314
ETCH CAVITY SIDEWALL LAYER TO DEFINE CMUT CAVITY
316
ETCH BOTTOM CAVITY LAYER AND ILD LAYER TO EXPOSE GETTER MATERIAL OF BILAYER STACK
318
BOND MEMBRANE TO FORM CMUT TRANSDUCER DEVICE

FIG. 3

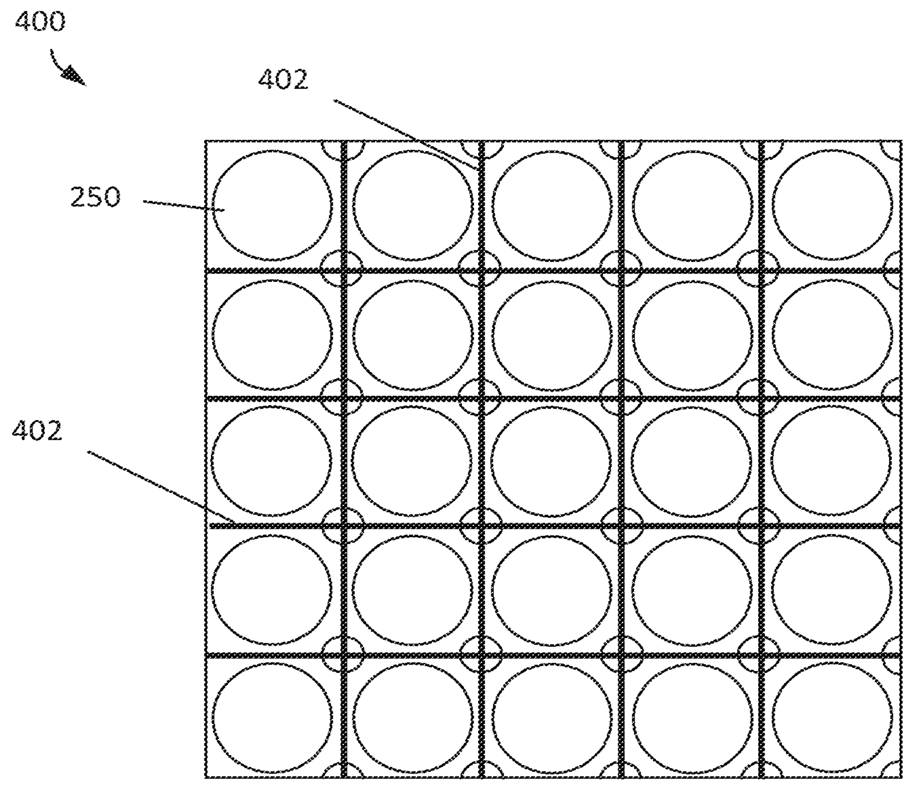


FIG. 4

GETTER TECHNOLOGY FOR MICROMACHINED ULTRASONIC TRANSDUCER CAVITIES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application Ser. No. 62/760,887, filed Nov. 13, 2018 under Attorney Docket No. B1348.70120US00, and entitled "THIN FILM CAVITY GETTER MATERIAL FOR MICROMACHINED ULTRASONIC TRANSDUCER DEVICES," which is hereby incorporated herein by reference in its entirety.

BACKGROUND

[0002] The present disclosure relates generally to micromachined ultrasonic transducers and, more specifically, to a thin film getter material for use in micromachined ultrasonic transducer cavities and transducer manufacturing techniques.

[0003] Ultrasound devices may be used to perform diagnostic imaging and/or treatment, using sound waves with frequencies that are higher than those audible to humans. When pulses of ultrasound are transmitted into tissue, sound waves are reflected off the tissue with different tissues reflecting varying degrees of sound. These reflected sound waves may then be recorded and displayed as an ultrasound image to the operator. The strength (amplitude) of the sound signal and the time it takes for the wave to travel through the body provide information used to produce the ultrasound images.

[0004] Some ultrasound imaging devices may be fabricated using micromachined ultrasonic transducers, including a flexible membrane suspended above a substrate. A cavity is located between part of the substrate and the membrane, such that the combination of the substrate, cavity and membrane form a variable capacitor. When actuated by an appropriate electrical signal, the membrane generates an ultrasound signal by vibration. In response to receiving an ultrasound signal, the membrane is caused to vibrate and, as a result, generates an output electrical signal.

SUMMARY

[0005] In one aspect, a method of forming an ultrasonic transducer device includes bonding a membrane to seal a transducer cavity with at least a portion of a getter material layer being exposed, the getter material layer comprising a portion of a bilayer stack compatible for use in damascene processing.

[0006] In another aspect, a method of forming an ultrasonic transducer device includes forming a diffusion barrier layer over a substrate; forming a getter material layer over the diffusion barrier layer; forming a metal electrode layer over a first portion of the getter material layer; forming a transducer cavity over the metal electrode layer; and bonding a membrane to seal the transducer cavity with at least a second portion of the getter material layer being exposed.

[0007] In another aspect, a method of forming an ultrasonic transducer device includes forming a bilayer stack over a substrate having a first metal layer therein, the bilayer stack comprising a diffusion barrier layer and a getter material layer formed on the diffusion barrier layer; patterning the bilayer stack; forming a first dielectric layer over the patterned bilayer stack; patterning the first dielectric layer so as to expose first portions of the patterned bilayer stack and a portion of the first metal layer, with second portions of the patterned bilayer stack being protected by the patterned first dielectric layer; forming a second metal layer over the first portions of the patterned bilayer stack, the portion of the first metal layer and the patterned first dielectric layer, and planarizing the second metal layer and patterned first dielectric layer; forming a bottom capping layer over the planarized second metal layer and patterned first dielectric layer, and forming a transducer cavity sidewall layer over the bottom capping layer; patterning the transducer cavity sidewall layer to define a transducer cavity; removing a portion of the bottom capping layer and second portions of the patterned first dielectric layer to expose the getter material layer; and bonding a membrane to seal the transducer cavity.

[0008] In another aspect, an ultrasonic transducer device includes a substrate having a first metal layer formed therein, the bilayer stack comprising a diffusion barrier layer and a getter material layer formed on the diffusion barrier layer; a patterned bilayer stack formed above the first metal layer; a second metal layer formed on a first portion of the bilayer stack; a bottom capping layer formed over the second metal layer; and a transducer cavity defined over the bottom capping layer and a membrane that seals the transducer cavity; wherein a portion of the bottom cavity layer has an opening formed therein so as to expose the getter material layer corresponding to a second portion of the bilayer stack.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Various aspects and embodiments of the application will be described with reference to the following figures. It should be appreciated that the figures are not necessarily drawn to scale. Items appearing in multiple figures are indicated by the same reference number in all the figures in which they appear.

[0010] FIG. **1**A is a cross-sectional view of an exemplary micromachined ultrasonic transducer device.

[0011] FIG. **1**B is a cross-sectional view of an exemplary micromachined ultrasonic transducer device having a delamination defect due to high cavity pressure during membrane bonding.

[0012] FIG. **1**C is a cross-sectional view of an exemplary micromachined ultrasonic transducer device having a stuck cell defect due to stiction effects.

[0013] FIGS. **2-1** through **2-10** are a series of cross-sectional views illustrating an exemplary process flow for forming a micromachined ultrasonic transducer device having a thin film getter material according to an embodiment.

[0014] FIG. **3** is a flow diagram describing the exemplary process flow of FIGS. **2-1** through **2-10**.

[0015] FIG. **4** is a top view of an example ultrasonic transducer device formed using the process flow of FIGS. **2-1** through **2-10** and FIG. **3**.

DETAILED DESCRIPTION

[0016] The techniques described herein relate to fabrication of a thin film getter material for micromachined ultrasonic transducer cavities.

[0017] One type of transducer suitable for use in ultrasound imaging devices is a micromachined ultrasonic transducer (MUT), which can be fabricated from, for example, silicon and configured to transmit and receive ultrasound energy. MUTs may include capacitive micromachined ultrasonic transducers (CMUTs) and piezoelectric micromachined ultrasonic transducers (PMUTs), both of which can offer several advantages over more conventional transducer designs such as, for example, lower manufacturing costs and fabrication times and/or increased frequency bandwidth. With respect to the CMUT device, the basic structure is a parallel plate capacitor with a rigid bottom electrode and a top electrode residing on or within a flexible membrane. Thus, a cavity is defined between the bottom and top electrodes. In some designs (such as those produced by the assignee of the present application for example), a CMUT may be directly integrated on an integrated circuit that controls the operation of the transducer. One way of manufacturing a CMUT is to bond a membrane substrate to an integrated circuit substrate, such as a complementary metal oxide semiconductor (CMOS) substrate. This may be performed at temperatures sufficiently low to prevent damage to the devices of the integrated circuit.

[0018] Referring initially now to FIG. **1**A, there is shown a cross-sectional view of an exemplary micromachined ultrasonic transducer device **100**, such as a CMUT. The transducer device **100** includes a substrate, generally designated by **102**, (e.g., a complementary metal oxide semiconductor (CMOS) substrate, such as silicon) having one or more layers such as for example: CMOS circuits, wiring layers, redistribution layers, insulation/passivation layers and one or more metal electrode layers that may serve as a transducer bottom electrode. The substrate **102** (including transducer bottom electrode) may have one or more insulating layers formed thereon, generally designated by layer **104**. A transducer cavity **105** is defined by lithographic patterning and etching of a support layer **106** that is formed on stack **104**. The support layer **106** may be an insulating layer, such as SiO_2 for example, the remaining portions of which provide a support surface to which a transducer membrane **108** is bonded.

[0019] During bonding of the transducer membrane **108** to the support layer **106**, the structure may be subject to relatively high pressures and/or exposed to one or more bonding byproducts such as, for example, nitrogen, oxygen and water vapor. As a result, one possible side effect of such processing is illustrated in FIG. **1**B. As shown, high cavity pressures (e.g., on the order of about 10 atm or more) may result in delamination (indicated by arrow **110**) of the membrane **108** from the support layer **106**.

[0020] In addition, during operation of the transducer device **100**, whether in a transmit mode and/or a receive mode, the transducer membrane **108** may come into physical contact with the top of the stack **104** (i.e., the bottom surface of the cavity **105**), as depicted in FIG. **1**C. This position may be indicative of the so-called "collapse mode" of operation as known in the art. A "collapse mode" (also used interchangeably with the term "collapsed mode") refers to a mode of transducer operation in which at least one portion of a micromachined ultrasonic transducer membrane is mechanically fixed and at least one portion of the membrane is free to vibrate based on a changing voltage differential between the electrode and the membrane. On one hand, operating a micromachined ultrasonic transducer in collapse mode may optimize the acoustic power (output pressure) produced by the transducer. On the other hand, however, one side effect of a micromachined ultrasonic transducer operating in collapse mode may be charge retention (also known as "charge trapping"), wherein the membrane and/or the bottom cavity surface undesirably stores charge or conducts leakage current. As a result, this charge retention may in turn undesirably alter an applied voltage at which membrane collapse is induced during device operation. Another possible side effect of collapse mode for the transducer **100** shown in FIG. **1**C may be stiction, which is associated with the amount of surface area of contact between the membrane **108** and the bottom surface of the cavity **105** wherein the two surfaces inadvertently stick to one another due to excess moisture present in the cavity **105** during membrane bonding.

[0021] Accordingly, FIGS. **2-1** through **2-10** are a series of cross-sectional views illustrating an exemplary process flow for forming a micromachined ultrasonic transducer device having a thin film getter material according to an embodiment. In addition, FIG. **3** is a flow diagram **300** describing the exemplary process flow of FIGS. **2-1** through **2-10**. As will be illustrated in further detail below, not only does the thin film metal serve as a getter for absorbing certain cavity gas species to maintain cavity pressure to a desired level, the exemplary process flow is also capable of smoothly integrating with high-throughput metal (e.g., copper) damascene processing techniques.

[0022] FIG. **2-1** illustrates a CMOS substrate **200**, e.g., a complementary metal oxide semiconductor (CMOS) substrate, such as silicon, having one or more layers (generally designated by **202**) such as for example: CMOS circuits, wiring layers, redistribution layers and insulation/passivation layers. A metal layer **204** (e.g., copper) having a thickness of about 1-2 microns (μm) is formed on the layer(s) **202**, with an interlevel dielectric (ILD) layer **206** (e.g., SiO_2) formed over the metal layer **204** and layer(s) **202**. The ILD layer **206** may have a thickness of about 1-2 μm. It should be appreciated that the various layers depicted in FIG. **2-1** are not necessarily shown to scale, and in particular the layer(s) **202** of CMOS substrate **200** may be thicker than the layers subsequently formed thereon.

[0023] As shown in FIG. **2-2** and indicated in block **302** of FIG. **3**, a bilayer stack comprising a diffusion barrier layer **208** and getter material layer **210** is deposited on the structure of FIG. **2-1**. In an embodiment, the diffusion barrier layer **208** may be formed from a material such as tantalum nitride (TaN) having a thickness of about 8-12 nanometers (nm), which is effective to resist copper diffusion during subsequent device processing. The getter material layer **210** may be a thicker layer of getter material, such as Ta or Ti for example, formed at a thickness of about 50-100 nm. Where Ta is the getter material of choice, processing operations may be simplified in that the same chamber may be used to complete the bilayer stack deposition (e.g., TaN deposition, followed by shutting off nitrogen into the deposition chamber to form Ta getter material).

[0024] Referring to FIG. **2-3** and block **304** of FIG. **3**, the bilayer stack **208**/**210** is patterned (e.g., by photolithography and etching). The resulting pattern of bilayer stack material may correspond to desired locations of a transducer bottom electrode material and transducer cavity getter material. Following the patterning of the bilayer stack **208**/**210**, an ILD layer **212** is formed over the resulting structure, as shown in FIG. **2-4** and indicated in block **306** of FIG. **3**. The ILD layer **212** may be, for example, SiO_2 formed at a thickness of about 300-800 nm, and may be a conformal layer with a resulting topography that corresponds to the topography of the patterned bilayer stack **208/210**.

[0025] As then shown in FIG. **2-5** and indicated in block **308** of FIG. **3**, the ILD layer **212** is patterned (e.g., by photolithography and etching) with the bilayer stack **208/210** serving as an etch stop. The patterning of ILD layer **212** may also define a via **214** that exposes a portion of the metal layer **204**. Following patterning of the ILD layer, a damascene metal plating operation is implemented over the structure, followed by planarization of the excess metal as indicated in block **310** of FIG. **3** to form the structure shown in FIG. **2-6**. Plating may include forming a seed layer (not shown) and a metal layer **216** (e.g., copper) initially formed to a thickness of about 1.5-2.5 μm thick. A chemical mechanical polishing (CMP) operation is then performed to polish the excess copper back and smooth out the existing surface topography as shown in FIG. **2-6**. The remaining metal layer **216** after CMP may have a thickness of about 200-300 nm and, as also shown in FIG. **2-6**, fills the via **214** that was formed in FIG. **2-5** so as to make electrical contact with the metal layer **204**. In the embodiment depicted, the region **217***a* of metal layer **216** that contacts metal layer **204** corresponds to a transducer bottom electrode (e.g., a donut shaped electrode), while the regions **217***b* of metal layer **216** may correspond to bypass metal for the transducer. However, it should be appreciated that since specific transducer bottom electrode patterns are not the focus of the present disclosure, it is contemplated that the present embodiments may also be implemented in conjunction with several other transducer electrode patterns and designs including (but not limited to), multiple segment or ring electrodes, and additional metal patterns used for other purposes besides bottom electrodes.

[0026] Proceeding to FIG. **2-7**, the process continues with the formation of a bottom cavity capping layer **218** and transducer cavity sidewall layer **220** as indicated in block **312** of FIG. **3**. The bottom cavity capping layer **218** may be a thin film layer such as aluminum oxide (Al_2O_3) formed by atomic layer deposition (ALD) at a thickness of about 20-30 nm, and the transducer cavity sidewall layer **220** may be SiO_2 formed at a thickness of about 200-300 nm. A transducer cavity **222** is then formed by patterning the transducer cavity sidewall layer **220** as illustrated in FIG. **2-8** and indicated in block **314** of FIG. **3**.

[0027] Once the cavity etch is complete, another etch is performed to form openings **224** through the bottom cavity capping layer **218** and ILD layer **214** so as to expose portions of the getter material layer **210**, as illustrated in FIG. **2-9** and depicted in block **316** of FIG. **3**. Notably, the exposed portions of the getter material layer **210** correspond to particular locations of the bilayer stack **208/210** that are not used for plating the metal layer **216** (i.e., locations protected by remaining ILD layer **210**). Accordingly, when a membrane layer **226** is bonded to the transducer cavity sidewall layer **220** to seal the cavity **222** and define an ultrasonic transducer **250**, as shown in FIG. **2-10** and indicated in block **318** of FIG. **3**, the exposed getter material layer **210** may absorb certain cavity gas species and help maintain cavity pressure at a desired level. Moreover, by incorporating the getter material with the diffusion barrier layer **208** as part of a bilayer stack, the gettering process scheme is advantageously incorporated with high-throughput damascene processing techniques. From this point, additional processing as known in the art may continue to complete fabrication of an ultrasonic transducer device. It should further be appreciated that although the illustrated embodiments depict a single cavity for ease of illustration, any suitable number of cavities and corresponding electrode structures may be formed (e.g., hundreds, thousands, tens of thousands, etc.)

[0028] FIG. **4** illustrates a top view of an example ultrasonic transducer device **400** that may be formed using the exemplary process flow embodiments described herein. As illustrated, the transducer device **400** includes an array of individual transducers **250**, such as those described above. The specific number of transducers **250** shown in FIG. **4** should not be construed in any limiting sense, and may include any number suitable for a desired imaging application, which may be for example on the order of tens, hundreds, thousands, tens of thousands or more. FIG. **4** further illustrates an example location of metal **402** that may distribute an electrical signal to the membranes (upper electrodes) of the transducers **250**.

[0029] It should be further appreciated that although the exemplary geometric structure of this portion of the ultrasonic transducer **250** is generally circular in shape, other configurations are also contemplated such as for example, rectangular, hexagonal, octagonal, and other multi-sides shapes, etc.

[0030] The above-described embodiments can be implemented in any of numerous ways. For example, the embodiments may be implemented using hardware, software or a combination thereof. When implemented in software, the software code can be executed on any suitable processor (e.g., a microprocessor) or collection of processors, whether provided in a single computing device or distributed among multiple computing devices. It should be appreciated that any component or collection of components that perform the functions described above can be generically considered as one or more controllers that control the above-discussed functions. The one or more controllers can be implemented in numerous ways, such as with dedicated hardware, or with general purpose hardware (e.g., one or more processors) that is programmed using microcode or software to perform the functions recited above.

[0031] Various aspects of the present invention may be used alone, in combination, or in a variety of arrangements not specifically discussed in the embodiments described in the foregoing and is therefore not limited in its application to the details and arrangement of components set forth in the foregoing description or illustrated in the drawings. For example, aspects described in one embodiment may be combined in any manner with aspects described in other embodiments.

[0032] Also, some aspects of the technology may be embodied as a method, of which an example has been provided. The acts performed as part of the method may be ordered in any suitable way. Accordingly, embodiments may be constructed in which acts are performed in an order different than illustrated, which may include performing some acts simultaneously, even though shown as sequential acts in illustrative embodiments.

[0033] Use of ordinal terms such as "first," "second," "third," etc., in the claims to modify a claim element does not by itself connote any priority, precedence, or order of one claim element over another or the temporal order in which acts of a method are performed, but are used merely as labels to distinguish one claim element having a certain name from another element having a same name (but for use of the ordinal term) to distinguish the claim elements.

[0034] Also, the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having," "containing," "involving," and variations thereof herein, is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

[0035] In the claims, as well as in the specification above, all transitional phrases such as "comprising," "including," "carrying," "having," "containing," "involving," "holding," "composed of," and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases "consisting of" and "consisting essentially of" shall be closed or semi-closed transitional phrases, respectively.

What is claimed is:

1. A method of forming an ultrasonic transducer device, the method comprising:

bonding a membrane to seal a transducer cavity with at least a portion of a getter material layer being exposed, the getter material layer comprising a portion of a bilayer stack compatible for use in damascene processing.

2. The method of claim **1**, wherein the bilayer stack comprises a diffusion barrier layer and the getter material layer formed on the diffusion barrier layer.

3. The method of claim **2**, wherein the diffusion barrier layer comprises tantalum nitride (TaN), and the getter material layer comprises one of: tantalum (Ta) or titanium (Ti).

4. The method of claim **1**, further comprising:

patterning the bilayer stack and forming a metal layer on a first portion of the bilayer stack, wherein the exposed portion of the getter material layer corresponds to a second portion of the bilayer stack without the metal layer formed thereon.

5. The method of claim **4**, further comprising exposing the exposed portion of the getter material layer by forming an opening through a bottom capping layer and a dielectric layer disposed over the second portion of the bilayer stack.

6. A method of forming an ultrasonic transducer device, the method comprising:

forming a diffusion barrier layer over a substrate;

forming a getter material layer over the diffusion barrier layer;

forming a metal electrode layer over a first portion of the getter material layer;

forming a transducer cavity over the metal electrode layer; and

bonding a membrane to seal the transducer cavity with at least a second portion of the getter material layer being exposed.

7. The method of claim **6**, wherein the diffusion barrier layer comprises tantalum nitride (TaN), and the getter material layer comprises one of: tantalum (Ta) or titanium (Ti).

8. The method of claim **6**, further comprising:

patterning the getter material layer and the diffusion barrier layer;

forming a dielectric layer over the getter material layer and diffusion barrier layer;

patterning the dielectric layer to expose the first portion of the getter material layer; and

forming the metal electrode layer over the first portion of the getter material layer.

9. The method of claim **8**, wherein forming the metal electrode layer further comprises:

plating the metal electrode layer over the first portion of the getter material layer and the patterned dielectric layer; and

planarizing the plated metal electrode layer and patterned dielectric layer such that the metal electrode layer covers the first portion of the getter material layer and the patterned dielectric layer covers the second portion of the getter material layer.

10. The method of claim **9**, further comprising:

forming a bottom capping layer over the planarized metal electrode layer and patterned dielectric layer;

forming a transducer cavity sidewall layer over the bottom capping layer;

patterning the transducer cavity sidewall layer to define the transducer cavity; and

removing a portion of the bottom capping layer and portions of the patterned dielectric layer to expose the second portion of the getter material layer.

11. A method of forming an ultrasonic transducer device, the method comprising:

forming a bilayer stack over a substrate having a first metal layer therein, the bilayer stack comprising a diffusion barrier layer and a getter material layer formed on the diffusion barrier layer;

patterning the bilayer stack;

forming a first dielectric layer over the patterned bilayer stack;

patterning the first dielectric layer so as to expose first portions of the patterned bilayer stack and a portion of the first metal layer, with second portions of the patterned bilayer stack being protected by the patterned first dielectric layer;

forming a second metal layer over the first portions of the patterned bilayer stack, the portion of the first metal layer and the patterned first dielectric layer, and planarizing the second metal layer and patterned first dielectric layer;

forming a bottom capping layer over the planarized second metal layer and patterned first dielectric layer, and forming a transducer cavity sidewall layer over the bottom capping layer;

patterning the transducer cavity sidewall layer to define a transducer cavity;

removing a portion of the bottom capping layer and second portions of the patterned first dielectric layer to expose the getter material layer; and

bonding a membrane to seal the transducer cavity.

12. The method of claim **11**, wherein the bilayer stack comprises a diffusion barrier layer and the getter material layer formed on the diffusion barrier layer.

13. The method of claim **12**, wherein the diffusion barrier layer comprises tantalum nitride (TaN), and the getter material layer comprises one of: tantalum (Ta) or titanium (Ti).

14. The method of claim **12**, wherein the diffusion barrier layer is formed at a thickness of about 8-10 nanometers (nm), and the getter material layer at a thickness of about 50-100 nm.

15. The method of claim **11**, wherein the bottom capping layer comprises aluminum oxide (Al_2O_3) formed by atomic layer deposition (ALD).

16. The method of claim **15**, wherein the bottom capping layer is formed at thickness of about 20-30 nm.

17. An ultrasonic transducer device, comprising:

- a substrate having a first metal layer formed therein, a bilayer stack comprising a diffusion barrier layer and a getter material layer formed on the diffusion barrier layer;
- a patterned bilayer stack formed above the first metal layer;
- a second metal layer formed on a first portion of the bilayer stack;
- a bottom capping layer formed over the second metal layer; and
- a transducer cavity defined over the bottom capping layer and a membrane that seals the transducer cavity;
- wherein a portion of the bottom cavity layer has an opening formed therein so as to expose the getter material layer corresponding to a second portion of the bilayer stack.

18. The method of claim **17**, wherein the bilayer stack comprises a diffusion barrier layer and the getter material layer formed on the diffusion barrier layer.

19. The method of claim **18**, wherein the diffusion barrier layer comprises tantalum nitride (TaN), and the getter material layer comprises one of: tantalum (Ta) or titanium (Ti).

20. The method of claim **18**, wherein the diffusion barrier layer is formed at a thickness of about 8-10 nanometers (nm), and the getter material layer at a thickness of about 50-100 nm.

21. The method of claim **17**, wherein the bottom capping layer comprises aluminum oxide (Al_2O_3).

22. A method of forming an ultrasonic transducer device, the method comprising:

- sealing an ultrasonic transducer cavity by bonding a membrane to a substrate such that a getter material layer of the substrate is exposed, the getter material layer comprising a portion of a bilayer stack of damascene process materials.

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摘要(译)

一种形成超声换能器装置的方法，包括在暴露的吸气材料层的至少一部分被暴露的情况下结合膜以密封换能器腔，该吸气材料层包括兼容用于镶嵌处理的双层堆叠的一部分。