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(54) **MULTI-LAYER COMPOSITE BACKPLATE FOR MICROMECHANICAL MICROPHONE**

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(60) Provisional application No. 61/827,982, filed on May 28, 2013.

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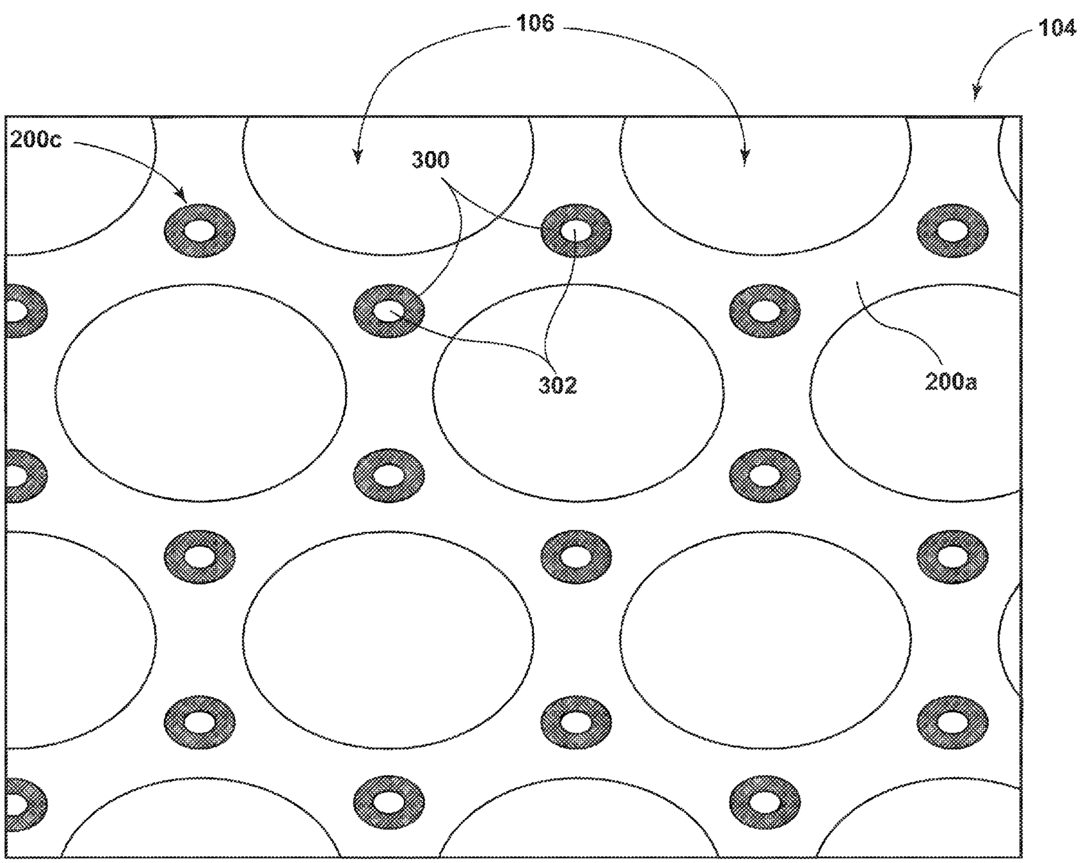
(52) **U.S. Cl.**

CPC ***H04R 19/005*** (2013.01); ***H04R 19/04*** (2013.01); ***B81B 7/0006*** (2013.01); *B81B 2201/0257* (2013.01); *B81B 2207/07* (2013.01)

(57) **ABSTRACT**

Backplates for MEMS devices. In one embodiment, the backplate includes an interconnect layer, a first layer, a second layer and a plurality of openings. The interconnect layer includes a first side and a second side that is opposite from the first side. The first layer is coupled to the first side of the interconnect layer. The second layer is coupled to the second side of the interconnect layer. The plurality of openings are located between a first side of the backplate and a second side of the backplate.



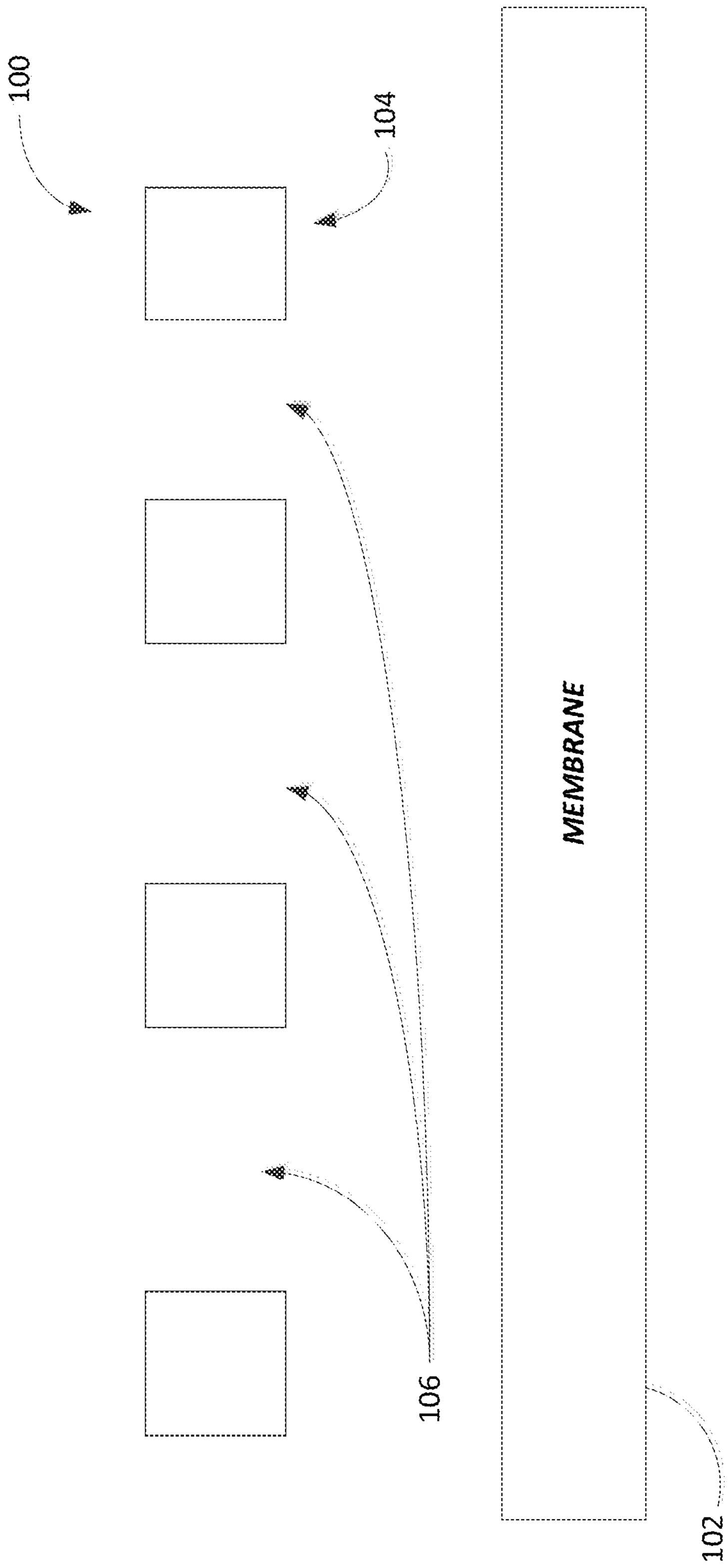


FIG. 1

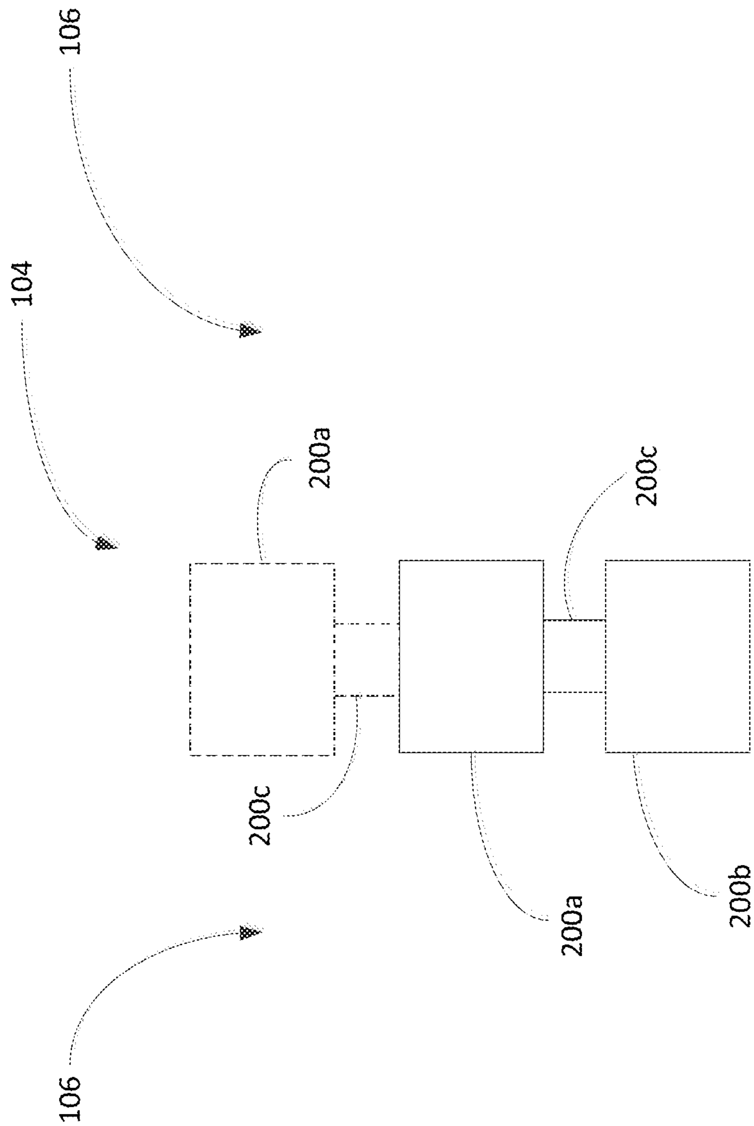


FIG. 2

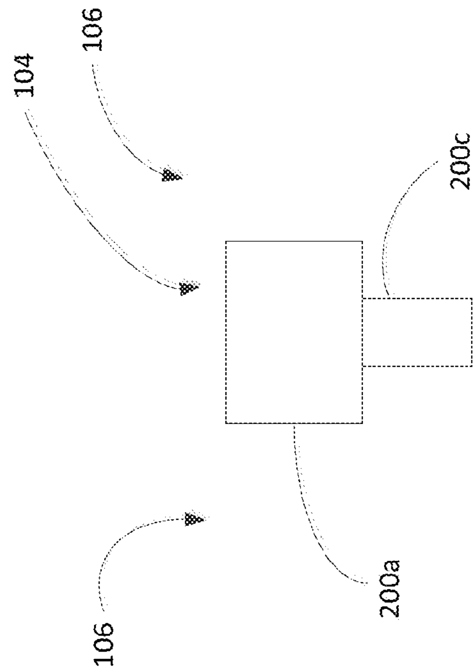


FIG. 3b

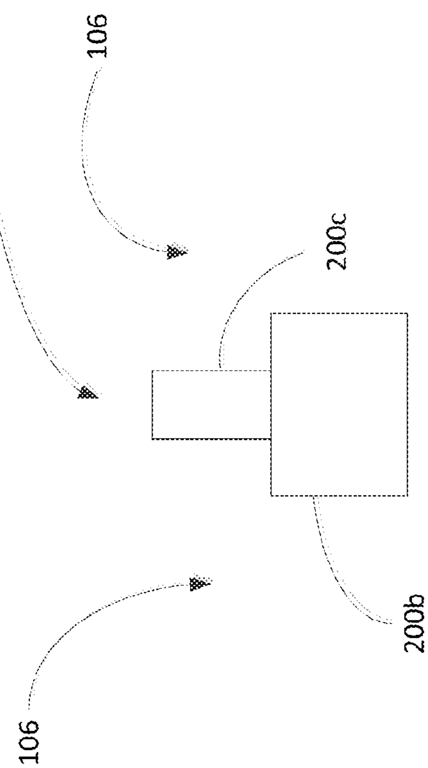


FIG. 3a

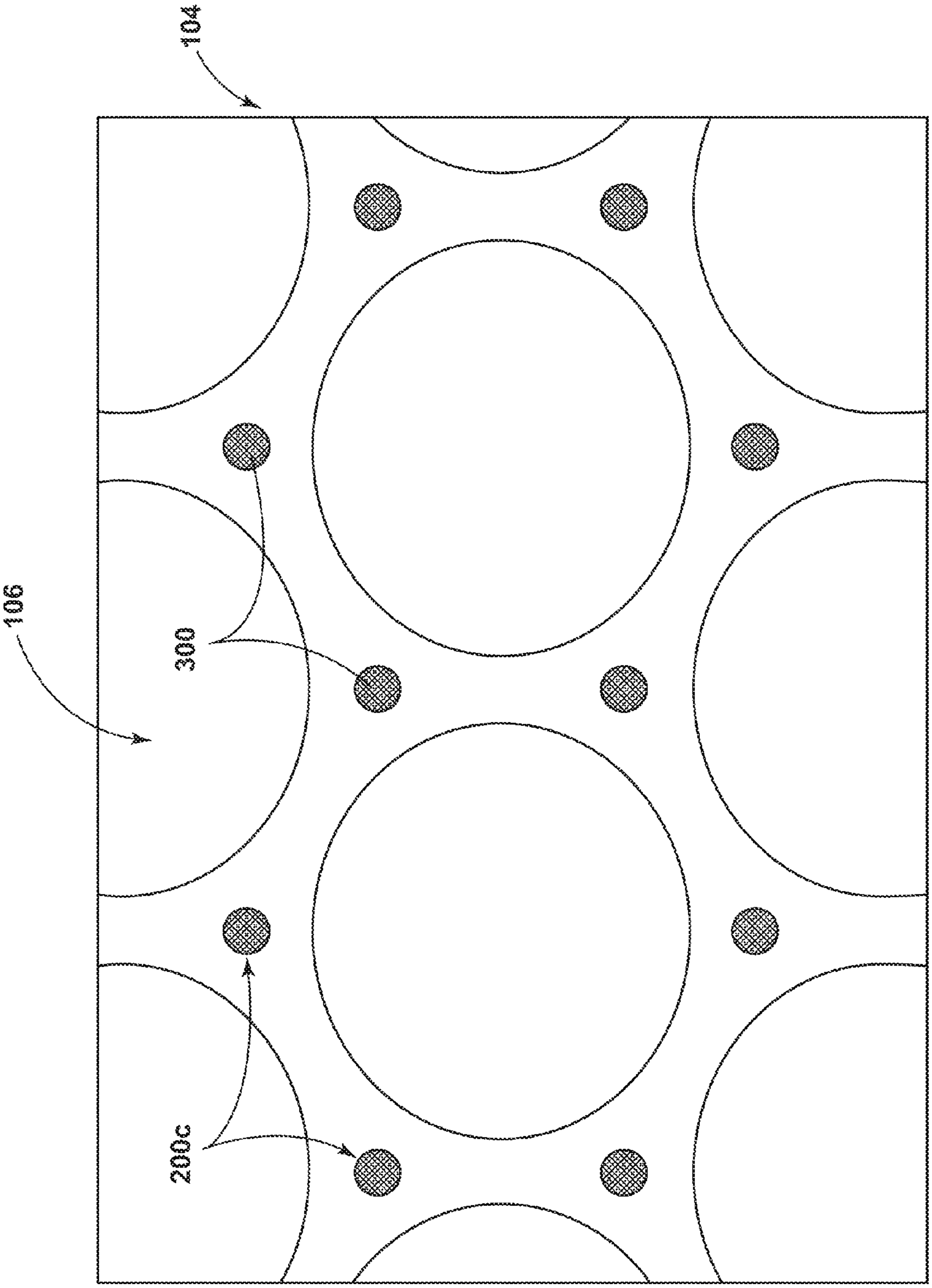


FIG. 4a

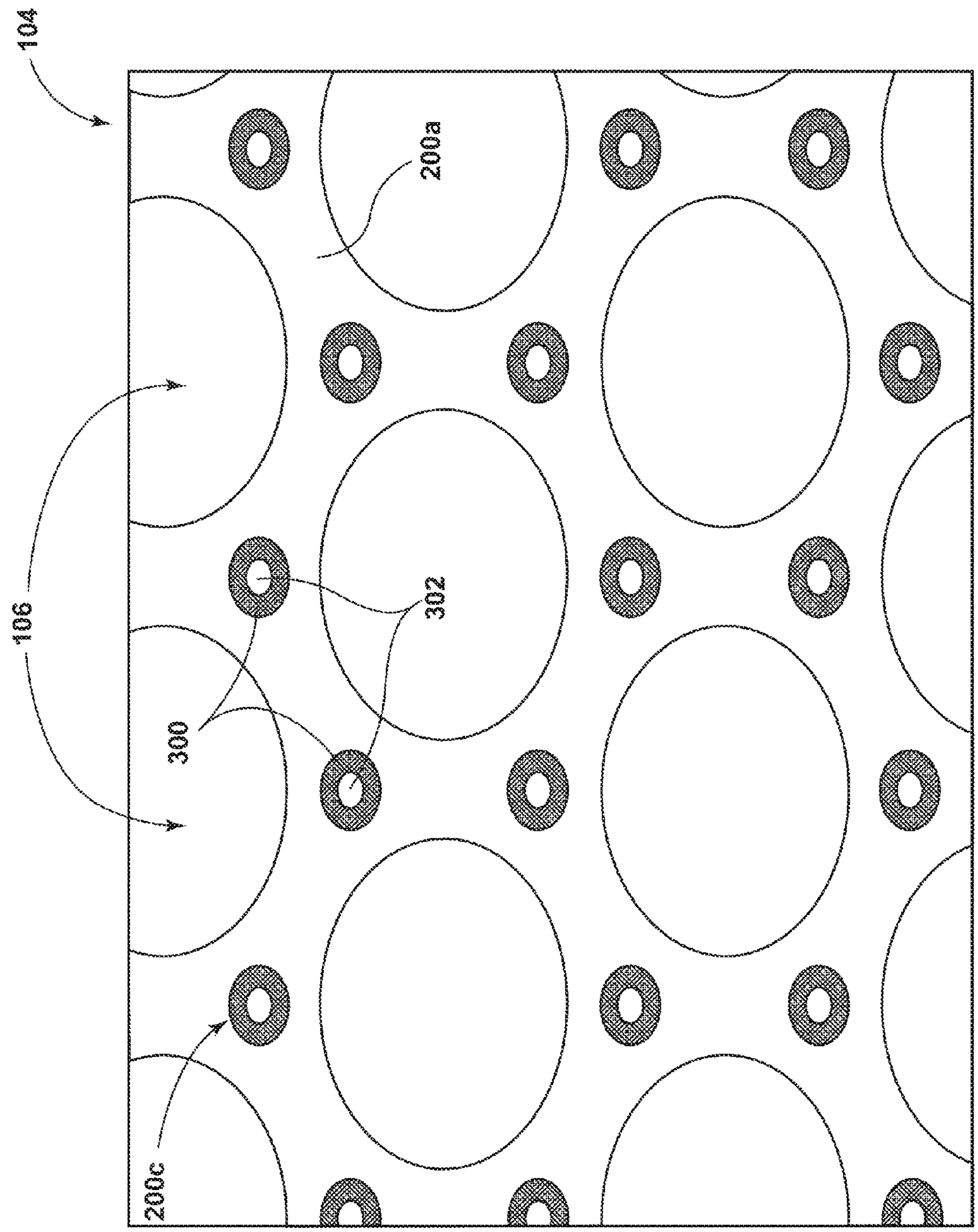


FIG. 4b

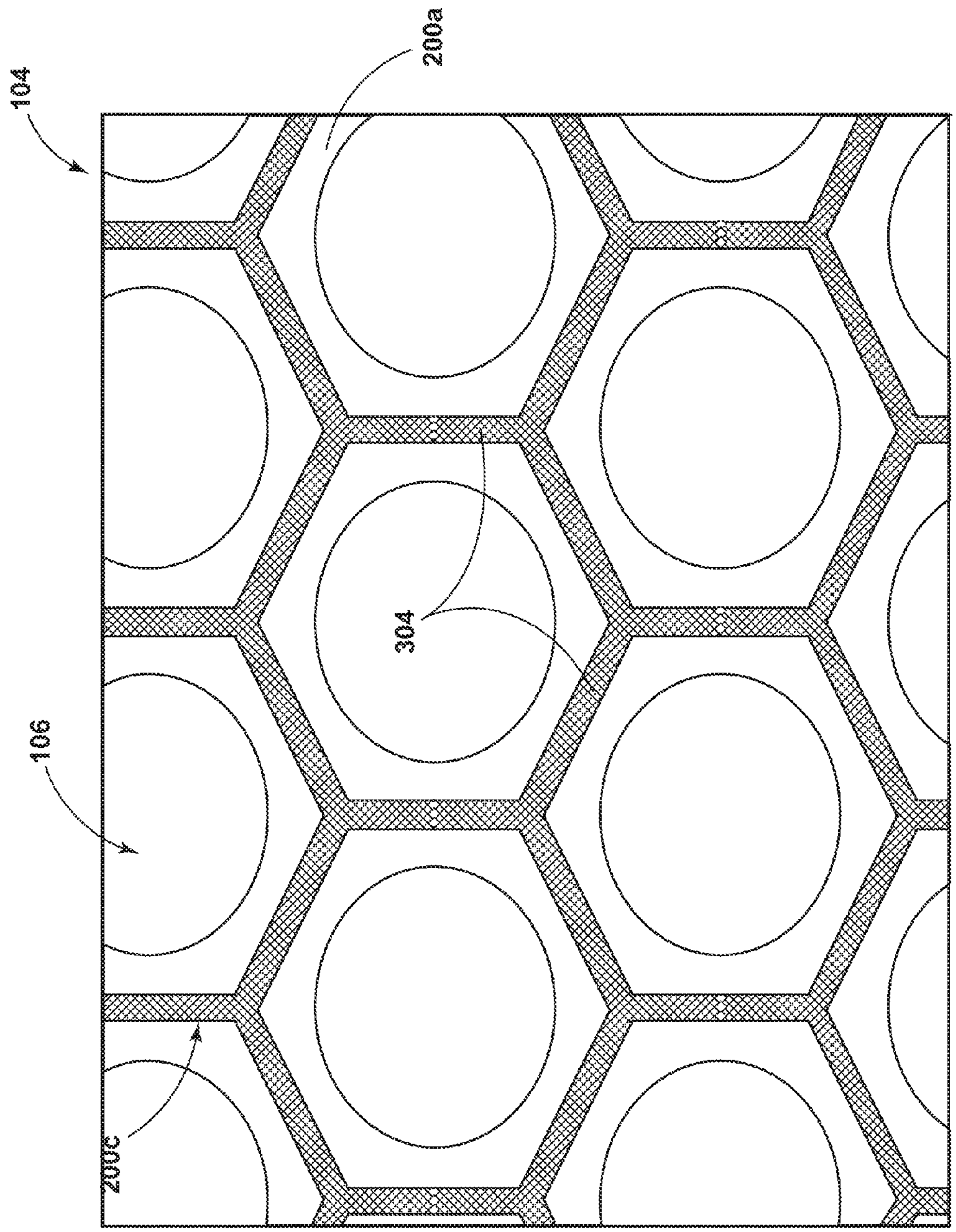


FIG. 4c

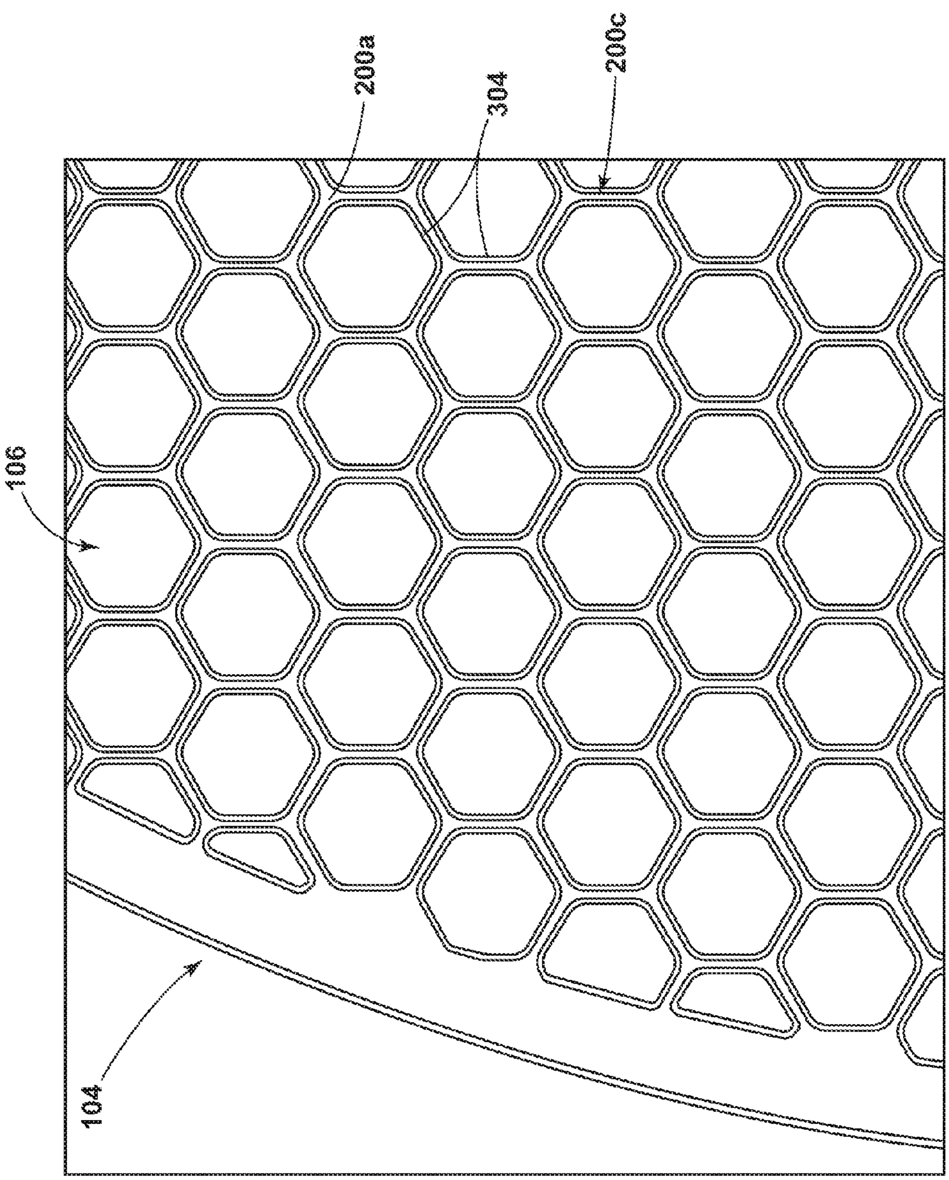


FIG. 4d

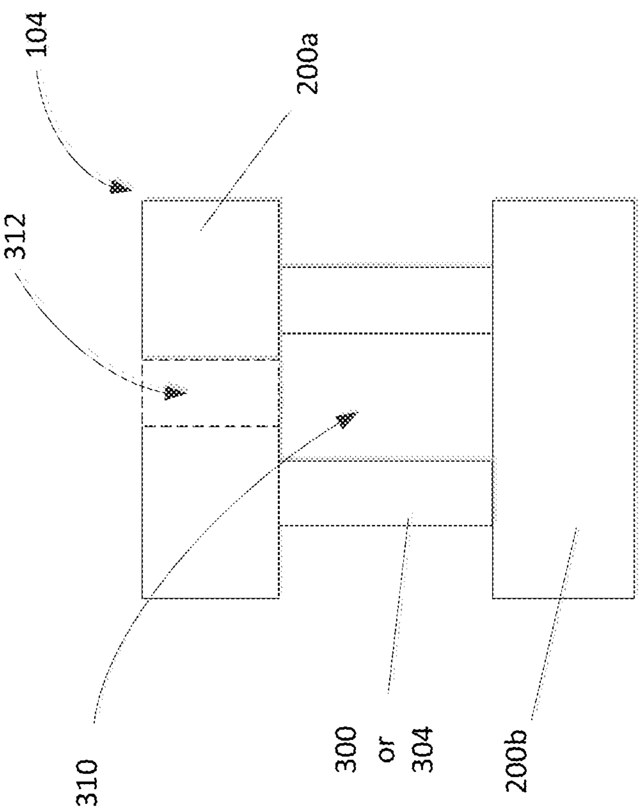


FIG. 5a

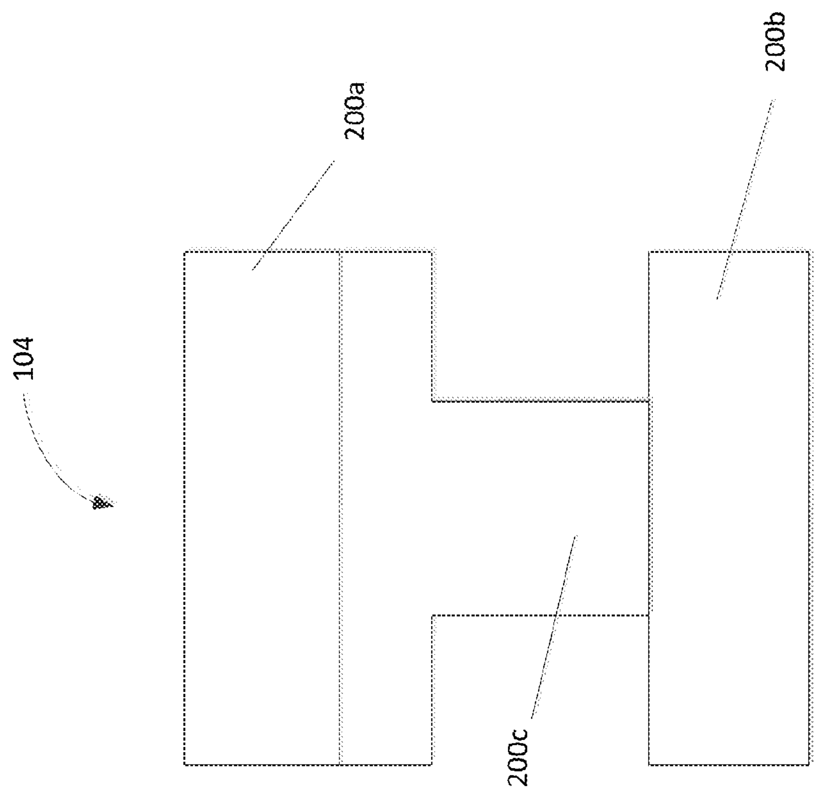


FIG. 5b

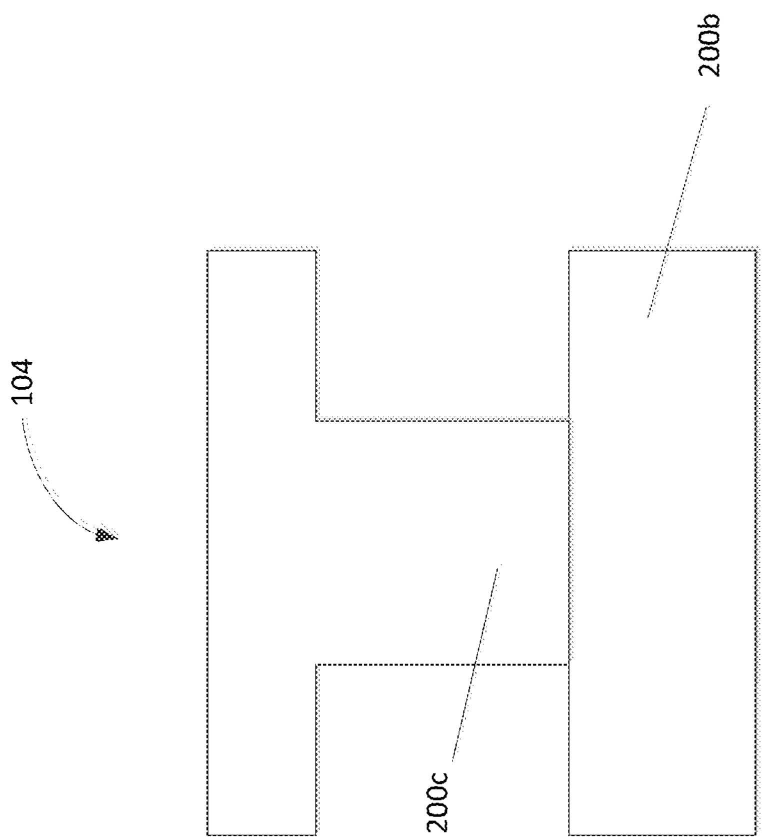


FIG. 5c

MULTI-LAYER COMPOSITE BACKPLATE FOR MICROMECHANICAL MICROPHONE

RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 14/894,390, entitled "MULTI-LAYER COMPOSITE BACKPLATE FOR MICROMECHANICAL MICROPHONE" filed Nov. 27, 2015, which is incorporated herein by reference in its entirety. U.S. patent application Ser. No. 14/894,390 is a 371 application of International Application No. PCT/2014/039793, entitled "MULTI-LAYER COMPOSITE BACKPLATE FOR MICROMECHANICAL MICROPHONE" filed May 28, 2014, the entire contents of which is also incorporated herein by reference. International Application No. PCT/2014/039793 claims priority to U.S. Provisional Application No. 61/827,982, entitled "MULTI-LAYER COMPOSITE BACKPLATE FOR MICROMECHANICAL MICROPHONE" filed May 28, 2013, the entire contents of which is also incorporated herein by reference.

BACKGROUND

[0002] The present disclosure relates to micromechanical systems ("MEMS"), such as, for example, MEMS microphone systems.

SUMMARY

[0003] One embodiment provides a backplate for a MEMS device. In one embodiment, the backplate includes an interconnect layer, a first layer, a second layer and a plurality of openings. The interconnect layer includes a first side and a second side that is opposite from the first side. The first layer is coupled to the first side of the interconnect layer. The second layer is coupled to the second side of the interconnect layer. The plurality of openings are located between a first side of the backplate and a second side of the backplate.

[0004] Another embodiment provides a backplate for a MEMS device. In one embodiment, the backplate includes a plurality of openings, a first layer, a second layer, and an interconnect layer. The interconnect layer is positioned between the first layer and the second layer. The interconnect layer couples the first layer to the second layer.

[0005] Yet another embodiment provides a backplate for a MEMS device. In one embodiment, the backplate includes a plurality of openings, a first layer, and an interconnect layer. The interconnect layer is coupled to the first layer. The interconnect layer includes a first portion and a second portion. The second portion is positioned between the first portion and the first layer. A width of the second portion is different than a width of the first portion.

[0006] Still another embodiment provides a MEMS microphone system. The system includes a membrane and a perforated counter electrode opposite the membrane, also referred to as a backplate regardless of position relative to the membrane. The backplate includes multiple thin layers of varying materials which are stacked to produce a rigid, strong, and flat backplate. Thick MEMS layers are prone to stress gradients which cause curvature, but by alternating thin layers of different materials it is possible to minimize backplate curvature. Additionally, through a composite layered backplate, it is possible to combine tensile material layers with compressive material layers to adjust the amount of net tension in the backplate affecting the strength and rigidity of the backplate. Thin layers can also be more easily patterned to tighter tolerances. In particular, one embodiment of the disclosure related to CMOS MEMS provides a backplate including an upper metal layer and a lower metal layer with similar embodiments related to traditional MEMS using other material layers. An interconnect layer connects the two metal layers. The interconnect layer can have a smaller width than the metal layers and can be constructed from a different metal (e.g., tungsten). The interconnect layer can be constructed of multiple materials including using a sacrificial material (e.g. silicon dioxide) encapsulated by another material or combination of materials. In one embodiment, an upper layer is used to encapsulate and protect an unetched but otherwise sacrificial interconnect layer. The upper and lower layers may each also be constructed with different widths, different thicknesses, and different opening sizes with respect to each other. A person skilled in the art would know that the structures described herein are made by known methods such as depositing layers and patterning them.

[0007] Yet another embodiment provides a MEMS device. In one embodiment, the MEMS device includes a membrane, and a reinforced backplate having a plurality of openings. The reinforced backplate include a first layer, and a second layer coupled to the first layer.

[0008] Other aspects of the disclosure will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic cross-sectional view of a portion of a MEMS microphone system.

[0010] FIG. **2** is side, cross-sectional view of a composite backplate.

[0011] FIGS. **3***a* and **3***b* are side, cross-sectional views of alternative constructions of a composite backplate.

[0012] FIGS. **4***a* and **4***b* are top, plan views of a composite backplate including an interconnect layer composed of discrete posts.

[0013] FIG. **4***c* is a top, plan view of a composite backplate including an interconnect layer composed of a continuous wall.

[0014] FIG. **4***d* is a top, plan view of a composite backplate including an interconnect layer composed of individual continuous walls surrounding each backplate opening.

[0015] FIGS. **5***a-c* are side, cross-sectional views of alternative configurations of a composite backplate.

DETAILED DESCRIPTION

[0016] Before any embodiments of the disclosure are explained in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The disclosure is capable of other embodiments and of being practiced or of being carried out in various ways.

[0017] FIG. **1** is a side, cross-sectional view of a portion of a MEMS microphone system **100**. As described in further detail below, the system includes a membrane **102** that moves in response to acoustic pressures and a counter electrode opposite the membrane (referred to as a backplate) **104**. An electrical circuit detects movement of the membrane **102** relative to the backplate **104** (e.g., due to varying capacitance) and generates an electrical signal indicative of the acoustic pressure (i.e., sound). CMOS and/or ASIC components (e.g., integrated with the system **100** or external to the system **100**) process the electrical signal. As illustrated in

[0018] FIG. **1**, the backplate **104** can include holes or vents **106** that allow air to pass between the membrane **102** and the backplate **104**. For optimal performance and durability, the backplate needs a balance between size and strength. For example, a thick backplate provides robust strength but reduces the acoustic noise performance of the system **100**. Similarly, a thin or highly perforated backplate may not provide adequate strength and may not provide adequate particle filtration. By using a composite construction of thin material layers, as show in FIG. **2**, it is also possible to pattern thinner web sections between vent holes allowing for the placement of more and potentially smaller vent holes **106** in the backplate. Furthermore, the design of the backplate, including both the thickness of the backplate and the size and number of vent hole openings **106**, impacts the microphone capacitance and sensitivity and impacts the acoustic signal-to-noise ratio of the system. Therefore, the design of the backplate impacts the performance of the system **100**.

[0019] FIG. **2** is a cross-sectional view of the backplate **104** in more detail. As illustrated in FIG. **2**, for one embodiment of this disclosure, the backplate **104** includes an upper metal layer **200***a* and a lower metal layer **200***b*. An interconnect layer **200***c* connects the upper layer **200***a* and the lower layer **200***b*. Each of the upper and lower metal layers can include a composite stack of different metals. For example, in one embodiment related to CMOS MEMS, at least one of the upper and lower layers **200***a* and **200***b* are composed of a stack of the following layers: titanium nitride, titanium, aluminum copper, titanium, and titanium nitride. Also, in some embodiments, at least one of the layers **200***a*, **200***b*, and **200***c* is formed out of an insulator rather than metal. Accordingly, in general, the composite backplate **104** can include conductive or insulating upper and lower layers **200***a* and **200***b* and a conductive or insulating interconnect layer **200***c*.

[0020] The vertical interconnect layer **200***c* can be constructed of a different material than the upper and lower layers **200***a* and **200***b*, such as a standard CMOS via material layer such as tungsten. In some embodiments, as illustrated in FIG. **2**, the interconnect layer **200***c* has a smaller width than the upper layer **200***a* and/or the lower layer **200***b*. Also, in some embodiments, each layer has a different width. Furthermore, in an additional embodiment, the interconnect material **200***c* is removed so that the upper layer **200***a* connects directly to the lower layer **200***b*.

[0021] In addition, as illustrated in FIG. **2**, additional layers can be added to the backplate **104**. For example, as illustrated in phantom, another interconnect layer **200***c* and another upper metal layer **200***a* can be added to the backplate. Similarly, as illustrated in FIGS. **3***a* and **3***b*, in some embodiments, only one of the upper and lower layers **200***a* and **200***b* are used in the backplate **104** where no metal (or insulator) layer is present above or below the interconnect layer **200***c*.

[0022] The interconnect layer **200***c* can be provided as discrete connections (e.g. as intermittent linear segments or circular posts) or as a continuous wall. For example, FIG. **4***a* is a top, plan view of the backplate **104** where the interconnect layer **200***c* is formed to create posts **300** positioned between the holes **106**. As illustrated in FIG. **4***a*, the posts **300** can be solid. In other embodiments, as illustrated in FIG. **4***b*, the posts **300** can be constructed as a ring wall that surrounds a core **302** (e.g., an oxide core). The core **302** can contain one or more materials or can be hollow. Although the posts **300** are illustrated in FIGS. **4***a* and **4***b* as being circular, it should be understood that the posts **300** can have any desired shape, such as triangular, square, polygonal, etc., and any size.

[0023] In some embodiments, rather than being constructed as discrete posts **300**, the interconnect layer **200***c* can be constructed as walls. For example, FIG. **4***c* is a top, plan view of the backplate **104** where the interconnect layer **200***c* consists of a single continuous wall **304** between the holes **106**. Although the walls **304** are illustrated in FIG. **4***c* as continuous straight walls, the walls **304** can be continuous or intermittent and straight or curved and can include one or more multiple walls (e.g., two parallel walls encapsulating a region between the walls that can be hollow or filled with one or more materials). FIG. **4***d* is a top, plan view of the backplate **104** where the interconnect layer **200***c* is constructed of multiple materials including one material used to form a plurality of continuous walls surrounding the backplate perimeter and each backplate opening in order to encapsulate and protect a second interconnect layer material in a region interior to the walls.

[0024] FIGS. **5***a-c* illustrate additional alternative constructions for the composite backplate **104**. In particular, FIG. **5***a* illustrates a composite backplate **104** including an interconnect layer **200***c* having a double wall **304** (see FIG. **4***c*) or discrete ring posts **300** (see FIGS. **4***a* and **4***b*). The wall **304** or ring posts **300** protect a core **310** that can be filled with a different material than the interconnect layer **200***c*, such as silicon dioxide. In other embodiments, the core **310** can be hollow. An optional release hole **312** can be formed in the upper layer **200***a*. The release hole **312** allows removal of material to create a core **310** that is hollow. It should be understood that the release hole **312** can alternatively or in addition be included in the lower layer **200***b*.

[0025] FIG. **5***b* illustrates an alternative backplate **104** that includes an interconnect layer **200***c* (e.g., formed as either walls **304** or posts) where an upper portion of layer **200***c* is wider or has a different shape than the lower portion. For example, in some embodiments, as illustrated in FIG. **5***b*, the upper portion of the layer **200***c* matches a shape or size of the upper layer **200***a*. Forming the interconnect layer **200***c* in this fashion stiffens and provide more support to the upper layer **200***a*. It should be understood that the constructions of the interconnect layer **200***c* illustrated in FIG. **5***b* can alternatively or in addition be used with the lower layer **200***b*.

[0026] A similar construction of the interconnect layer **200***c* can also be used with no upper layer **200***a* to form the backplate **104** (see FIG. **5***c*). As previously noted, forming the interconnect layer **200***c* as illustrated in FIG. **5***c* stiffens and provides support to the backplate **104** (e.g., the lower layer **200***b*). It should be understood that the constructions of the interconnect layer **200***c* illustrated in FIG. **5***c* can alternatively or in addition be used when the backplate **104** does not include a lower layer **200***b*.

[0027] Thus, embodiments of the disclosure provide, among other things, a composite backplate that is thin and highly perforated yet strong and flat with adequate tensile properties. The composite backplate can also provide better particle filtration with less reduction of acoustic signal-to-noise ratio than existing backplates. It should be understood that the same patterns can be used as a front plate in a MEMS system. Also, the backplate (or frontplate) of this construction can be formed using CMOS MEMS material layers or traditional MEMS material layers and processing steps.

What is claimed is:

1. A backplate for a MEMS device, the backplate comprising:
- an interconnect layer including a first side and a second side opposite the first side;
- a first layer coupled to the first side of the interconnect layer;
- a second layer coupled to the second side of the interconnect layer; and
- a plurality of openings located between a first side of the backplate and a second side of the backplate.

2. The backplate of claim **1**, wherein the interconnect layer includes a plurality of discrete posts.

3. The backplate of claim **2**, wherein the each of the plurality of discrete posts has a shape selected from a group consisting of circular, triangular, square, and polygonal.

4. The backplate of claim **2**, wherein each of the plurality of discrete posts includes a core and a ring wall surrounding the core.

5. The backplate of claim **4**, wherein the core includes an oxide core.

6. The backplate of claim **1**, wherein the first layer or the second layer is an electrically conductive material, and wherein the interconnect layer is an electrically insulating material.

7. The backplate of claim **1**, wherein the first layer or the second layer is an electrically insulating material, and wherein the interconnect layer is an electrically conductive material.

8. A backplate for a MEMS device, the backplate comprising:
- a plurality of openings;
- a first layer;
- a second layer; and
- an interconnect layer positioned between the first layer and the second layer, the interconnect layer coupling the first layer to the second layer.

9. The backplate of claim **8**, wherein the interconnect layer includes two walls extending from the first layer to the second layer, and
- a region positioned between the two walls and extending from the first layer to the second layer.

10. The backplate of claim **9**, wherein the first layer or the second layer includes a release hole that is positioned adjacent to the region.

11. The backplate of claim **9**, wherein the region is hollow.

12. The backplate of claim **9**, wherein the two walls are constructed of a first material, and wherein the region is constructed of a second material.

13. The backplate of claim **8**, wherein the interconnect layer includes a plurality of discrete posts, and wherein each of the plurality of discrete posts includes a core and a ring wall surrounding the core.

14. The backplate of claim **13**, wherein the first layer or the second layer includes a release hole that is positioned adjacent to the core.

15. A backplate for a MEMS device, the backplate comprising:
- a plurality of openings;
- a first layer; and
- an interconnect layer coupled to the first layer and including a first portion, and
  - a second portion positioned between the first portion and the first layer, wherein a width of the second portion is different than a width of the first portion.

16. The backplate of claim **15**, wherein a width of the first layer is equal to the width of the first portion.

17. The backplate of claim **15**, wherein the interconnect layer is constructed of a different material than the first layer.

18. The backplate of claim **15**, wherein the first layer is constructed of an electrically conductive material, and wherein the interconnect layer is constructed of an electrically insulating material.

* * * * *