DUAL MEMBRANE PIEZOELECTRIC MICROELECTROMECHANICAL SYSTEM MICROPHONE

BACKGROUND

Technical Field

Embodiments disclosed herein relate to piezoelectric microelectromechanical system microphones and to devices including same.

Description of Related Technology

A microelectromechanical system (MEMS) microphone is a micro-machined electromechanical device to convert sound pressure (e.g., voice) into an electrical signal (e.g., voltage). MEMS microphones are widely used in mobile devices such as cellular telephones, headsets, smart speakers, and other voice-interface devices/systems. Capacitive MEMS microphones and piezoelectric MEMS microphones (PMMs) are both available in the market. PMMs requires no bias voltage for operation, therefore, they provide lower power consumption than capacitive MEMS microphones. The single membrane structure of PMMs enable them to generally provide more reliable performance than capacitive MEMS microphones in harsh environments. Existing PMMs are typically based on either diaphragm MEMS structures or cantilever MEMS structures.

SUMMARY

In accordance with one ~~aspect~~example, there is provided a piezoelectric microelectromechanical system microphone. The piezoelectric microelectromechanical system microphone comprises a piezoelectric element configured to deform and generate an electrical potential responsive to impingement of sound waves on the piezoelectric microelectromechanical system microphone, a sensing electrode disposed on the piezoelectric element and configured to sense the electrical potential, and a passive membrane mechanically coupled to the surface of the piezoelectric element to increase sensitivity of the piezoelectric microelectromechanical system microphone.

In one aspect, the present disclosure refers to a piezoelectric microelectromechanical system microphone comprising, a piezoelectric element configured to deform and generate

an electrical potential responsive to impingement of sound waves on the piezoelectric microelectromechanical system microphone, the piezoelectric element being mechanically secured to a supporting substrate including an acoustic port, a sensing electrode disposed on the piezoelectric element and configured to sense the electrical potential, a passive membrane mechanically coupled to the surface of the piezoelectric element by a column having a cross-sectional area that is less than a surface area of the piezoelectric element and less than a surface area of the passive membrane, the passive membrane being mechanically secured to the supporting substrate between the piezoelectric element and the acoustic port, and one or more vent apertures defined in a support mechanically securing the passive membrane to the supporting substrate.

In some ~~embodiment~~examples, the passive membrane is mechanically coupled to the surface of the piezoelectric element by a column having a cross-sectional area that is less than a

surface area of the piezoelectric element and less than a surface area of the passive membrane.

In some ~~embodiment~~examples, the column has a length less than a distance by which a center of the piezoelectric element is displaced when exposed to a maximum sound pressure for which the piezoelectric microelectromechanical system microphone is rated.

In some ~~embodiment~~examples, the piezoelectric element is mechanically secured to a supporting substrate including an acoustic port and the passive membrane is mechanically secured to the supporting substrate between the piezoelectric element and the acoustic port.

In some ~~embodiment~~examples, the piezoelectric microelectromechanical system microphone further comprises one or more vent apertures defined in a support mechanically securing the passive membrane to the supporting substrate.

In some ~~embodiment~~examples, the membrane is mechanically secured to the supporting substrate with a micromechanical spring.

In some ~~embodiment~~examples, the passive membrane is mechanically secured to the supporting substrate with a material having a greater compliance than a material of which the passive membrane is formed.

In some ~~embodiment~~examples, the passive membrane has a surface area that is less than a surface area of the piezoelectric element.

In some ~~embodiment~~examples, the passive membrane has a surface area that is about the same as a surface area of the piezoelectric element.

In some ~~embodiment~~examples, the passive membrane has a surface area that is greater than a surface area of the piezoelectric element.

In some ~~embodiment~~examples, the passive membrane is mechanically secured to the supporting substrate in an enlarged diameter region of the supporting substrate.

In some ~~embodiment~~examples, the piezoelectric element has a diaphragm structure clamped to a supporting substrate about its perimeter.

In some ~~embodiment~~examples, the passive membrane is mechanically coupled to the surface of the piezoelectric element by a column extending from a center of a surface of the passive membrane to a center of the surface of the piezoelectric element.

In some ~~embodiment~~examples, the sensing electrode includes both inner electrode regions proximate a center region of the piezoelectric element and outer electrodes proximate the perimeter of the piezoelectric element.

In some ~~embodiment~~examples, the sensing electrode includes inner electrode regions proximate a center region of the piezoelectric element but lacks outer electrodes proximate the perimeter of the piezoelectric element.

In some ~~embodiment~~examples, the piezoelectric element includes an upper film of piezoelectric material and a lower film of piezoelectric material, an upper sensing electrode disposed on an upper surface of the upper film, a lower sensing electrode disposed on a lower surface of the lower film, and a middle sensing electrode disposed between the upper film and lower film.

In some ~~embodiment~~examples, the piezoelectric element has a cantilever structure including a plurality of cantilevers, each of the plurality of cantilevers having a base clamped to a supporting substrate, and a tip that is free to be displaced vertically responsive to impingement of sound waves on the piezoelectric microelectromechanical system microphone.

In some ~~embodiment~~examples, the passive membrane is mechanically coupled to the piezoelectric element by columns extending from a surface of the passive membrane to respective regions proximate the tips of each of the plurality of cantilevers.

In some ~~embodiment~~examples, the columns have a combined cross-sectional area that is less than a surface area of the piezoelectric element and less than a surface area of the passive membrane.

In some ~~embodiment~~examples, the piezoelectric element includes an upper film of piezoelectric material and a lower film of piezoelectric material, an upper sensing electrode disposed on an upper surface of the upper film, a lower sensing electrode disposed on a lower surface of the lower film, and a middle sensing electrode disposed between the upper film and lower film.

In some ~~embodiment~~examples, the piezoelectric microelectromechanical system microphone further comprises one or more vent apertures defined in the passive membrane.

In some ~~embodiment~~examples, the piezoelectric microelectromechanical system microphone is included in an electronic device.

CLAIMS

1. A piezoelectric microelectromechanical system microphone comprising:

a piezoelectric element configured to deform and generate an electrical potential responsive to impingement of sound waves on the piezoelectric microelectromechanical system microphone, the piezoelectric element being mechanically secured to a supporting substrate including an acoustic port;

a sensing electrode disposed on the piezoelectric element and configured to sense the electrical potential; and

a passive membrane mechanically coupled to the surface of the piezoelectric element.

2. The piezoelectric microelectromechanical system microphone of claim 1 wherein the passive membrane is mechanically coupled to the surface of the piezoelectric element by a column having a cross-sectional area that is less than a surface area of the piezoelectric element and less than a surface area of the passive membrane., the passive membrane being mechanically secured to the supporting substrate between the piezoelectric element and the acoustic port; and

one or more vent apertures defined in a support mechanically securing the passive membrane to the supporting substrate.

23. The piezoelectric microelectromechanical system microphone of claim 1 wherein the column has a length less greater than a distance by which a center of the piezoelectric element is displaced when exposed to a maximum sound pressure for which the piezoelectric microelectromechanical system microphone is rated.

34. The piezoelectric microelectromechanical system microphone of any preceding claim 1 wherein the piezoelectric element is mechanically secured to a supporting substrate including an acoustic port and the passive membrane is mechanically secured to the supporting substrate with a micromechanical spring. between the piezoelectric element and the acoustic port.

~~5. The piezoelectric microelectromechanical system microphone of claim 4 further comprising one or more vent apertures defined in a support mechanically securing the passive membrane to the supporting substrate.~~

~~6. The piezoelectric microelectromechanical system microphone of claim 4 wherein the membrane is mechanically secured to the supporting substrate with a micromechanical spring.~~

4~~7~~. The piezoelectric microelectromechanical system microphone of claim ~~4~~1 or claim 2 wherein the passive membrane is mechanically secured to the supporting substrate with a material having a greater compliance than a material of which the passive membrane is formed.

5~~8~~. The piezoelectric microelectromechanical system microphone of any preceding claim ~~1~~ wherein the surface area of the passive membrane ~~has a surface area that~~ is less than the~~a~~ surface area of the piezoelectric element.

6~~9~~. The piezoelectric microelectromechanical system microphone of any of claims 1 to 4 wherein the surface area of the passive membrane ~~has a surface area that~~ is about the same as the~~a~~ surface area of the piezoelectric element.

7~~10~~. The piezoelectric microelectromechanical system microphone of ~~claim 1~~any of claims 1 to 4 wherein the surface area of the passive membrane ~~has a surface area that~~ is greater than ~~a~~the surface area of the piezoelectric element.

8~~11~~. The piezoelectric microelectromechanical system microphone of claim ~~10~~7 wherein the passive membrane is mechanically secured to the supporting substrate in an enlarged diameter region of a cavity of the supporting substrate.

912. The piezoelectric microelectromechanical system microphone of any preceding claim 1 wherein the piezoelectric element has a diaphragm structure clamped to athe supporting substrate about its perimeter.

1013. The piezoelectric microelectromechanical system microphone of claim 912 wherein the passive membrane is mechanically coupled to the surface of the piezoelectric element by a column extendingextends from a center of a surface of the passive membrane to a center of the surface of the piezoelectric element.

1114. The piezoelectric microelectromechanical system microphone of claim 912 wherein the sensing electrode includes both inner electrode regions proximate a center region of the piezoelectric element and outer electrodes proximate the perimeter of the piezoelectric element.

1215. The piezoelectric microelectromechanical system microphone of claim 912 wherein the sensing electrode includes inner electrode regions proximate a center region of the piezoelectric element but lacks outer electrodes proximate the perimeter of the piezoelectric element.

1316. The piezoelectric microelectromechanical system microphone of claim 912 wherein the piezoelectric element includes an upper film of piezoelectric material and a lower film of piezoelectric material, an upper sensing electrode disposed on an upper surface of the upper film, a lower sensing electrode disposed on a lower surface of the lower film, and a middle sensing electrode disposed between the upper film and lower film.

1417. The piezoelectric microelectromechanical system microphone of any preceding claim 1 wherein the piezoelectric element has a cantilever structure including a plurality of cantilevers, each of the plurality of cantilevers having a base clamped to thea supporting substrate, and a tip that is free to be displaced vertically responsive to impingement of sound waves on the piezoelectric microelectromechanical system microphone.

15~~18~~. The piezoelectric microelectromechanical system microphone of claim 14~~17~~ wherein the passive membrane is mechanically coupled to the piezoelectric element by columns extending from a surface of the passive membrane to respective regions proximate the tips of each of the plurality of cantilevers.

16~~19~~. The piezoelectric microelectromechanical system microphone of claim 15~~18~~ wherein the columns have a combined cross-sectional area that is less than the~~a~~ surface area of the piezoelectric element and less than ~~a~~the surface area of the passive membrane.

17~~20~~. The piezoelectric microelectromechanical system microphone of ~~claim 17~~any of claims 14 to 16 wherein the piezoelectric element includes an upper film of piezoelectric material and a lower film of piezoelectric material, an upper sensing electrode disposed on an upper surface of the upper film, a lower sensing electrode disposed on a lower surface of the lower film, and a middle sensing electrode disposed between the upper film and lower film.

18~~21~~. The piezoelectric microelectromechanical system microphone of any preceding claim ~~1~~ further comprising one or more vent apertures defined in the passive membrane.

19~~22~~. The piezoelectric microelectromechanical system microphone of any preceding claim ~~1~~ included in an electronic device.