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(54) CAPACITIVE MEMS MICROPHONE, MICROPHONE UNIT AND ELECTRONIC DEVICE

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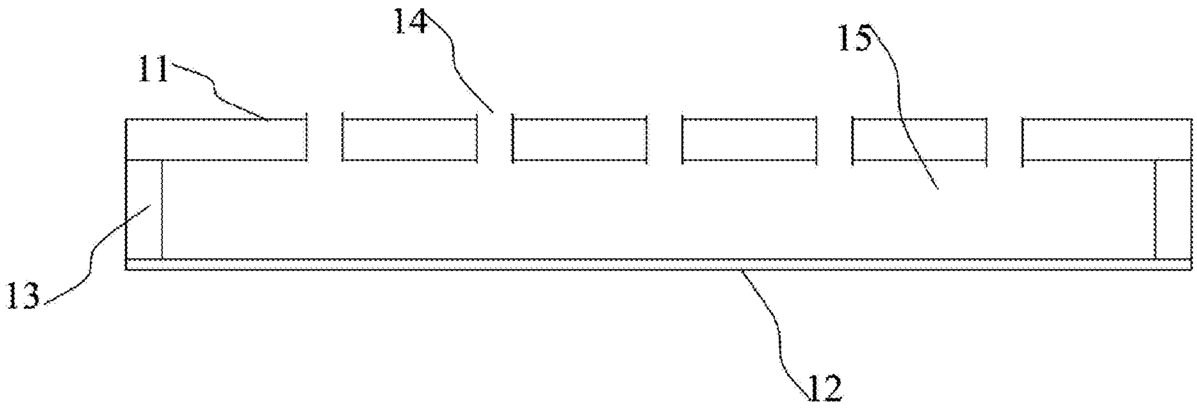
(57) ABSTRACT

Disclosed in embodiments of the present disclosure are a capacitive MEMS microphone, a microphone unit and an electronic device. The capacitive MEMS microphone includes: a back electrode plate; a diaphragm; and a spacer for separating the back electrode plate from the diaphragm, wherein in a state where no operating bias is applied, at least a portion of the diaphragm is pre-deviated in a direction away from the back electrode plate relative to a flat position.



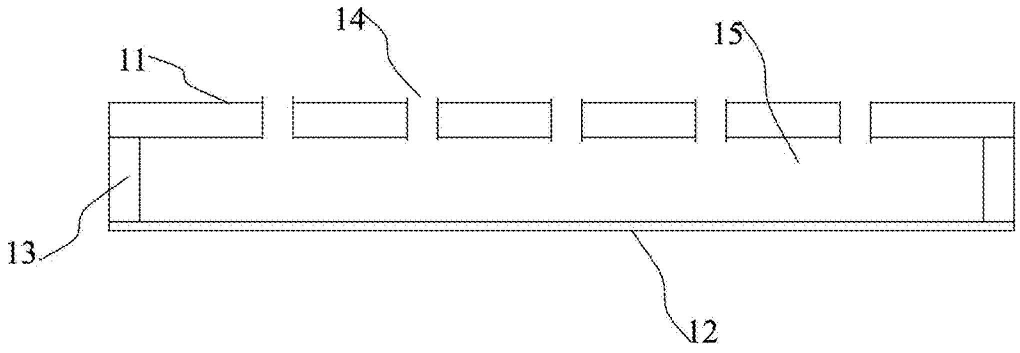


FIG. 1

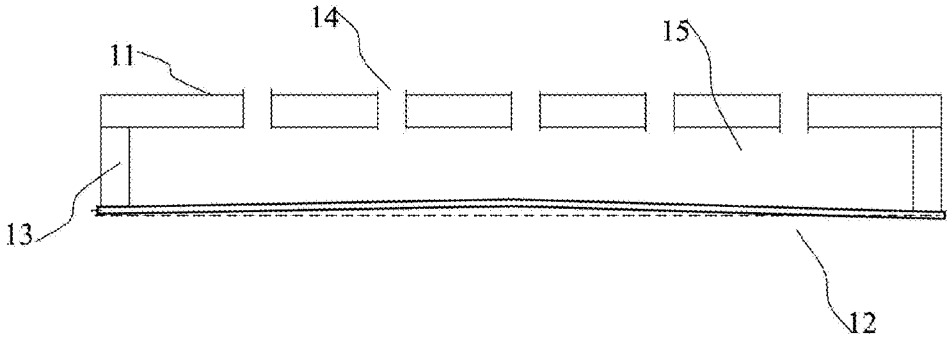


FIG. 2

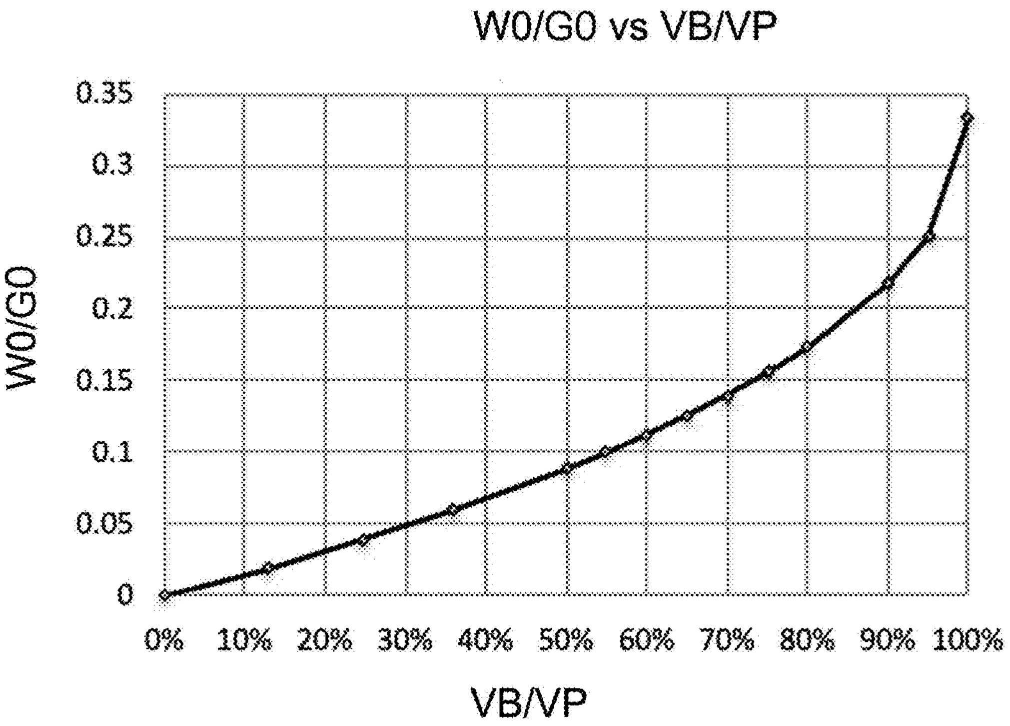

W0/G0 vs VB/VP
W0/G0
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
VB/VP

FIG. 3

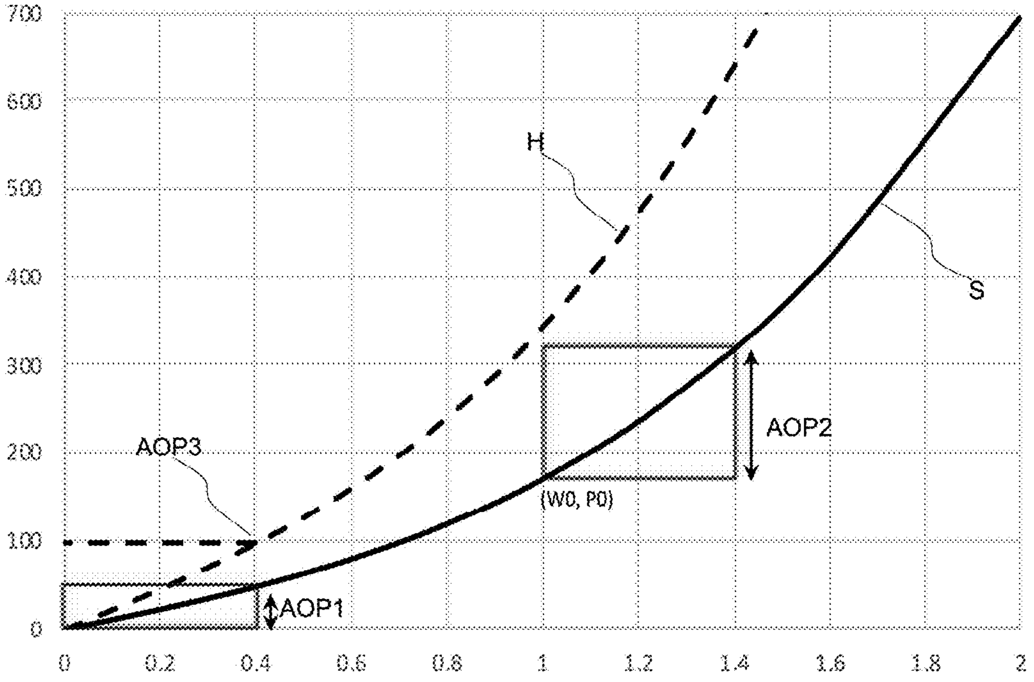

700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
H
S
AOP3
AOP2
AOP1
(W0, P0)

FIG. 4

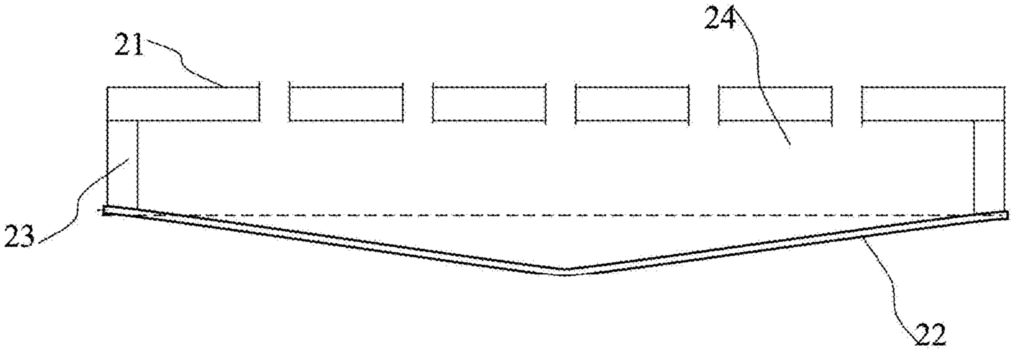


FIG. 5

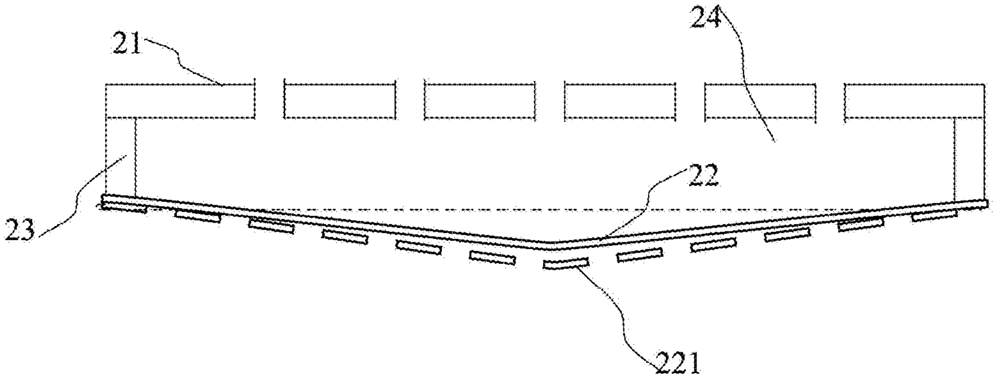


FIG. 6

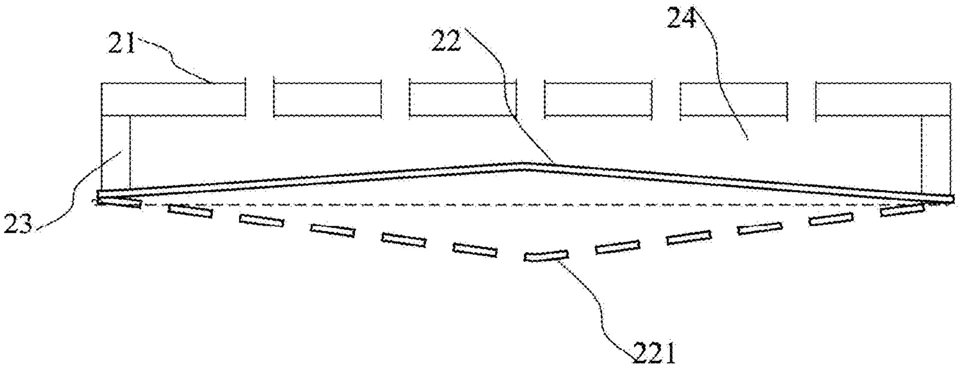


FIG. 7

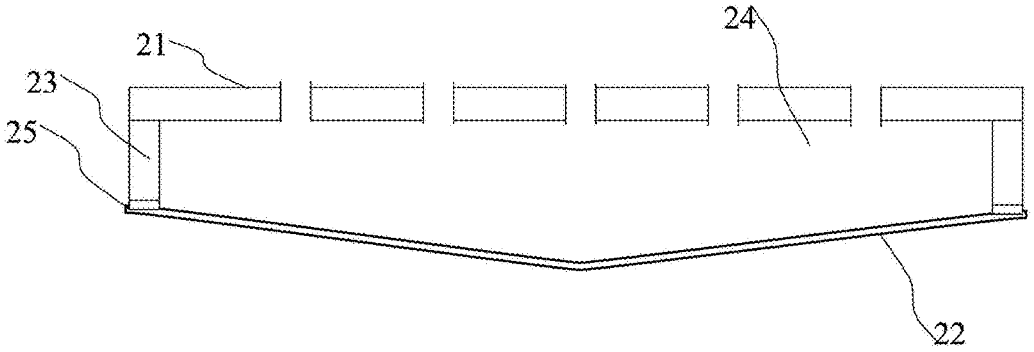


FIG. 8

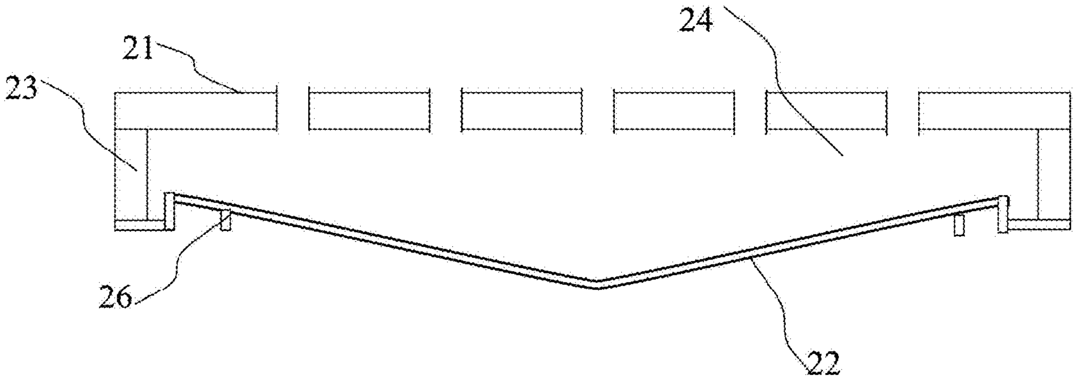


FIG. 9

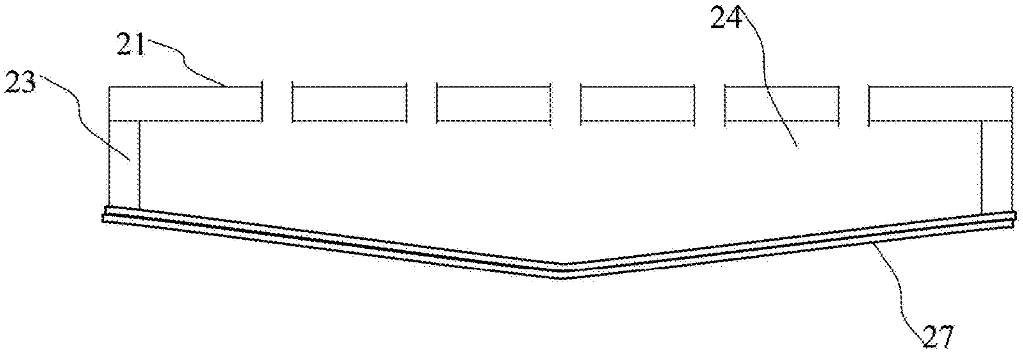


FIG. 10

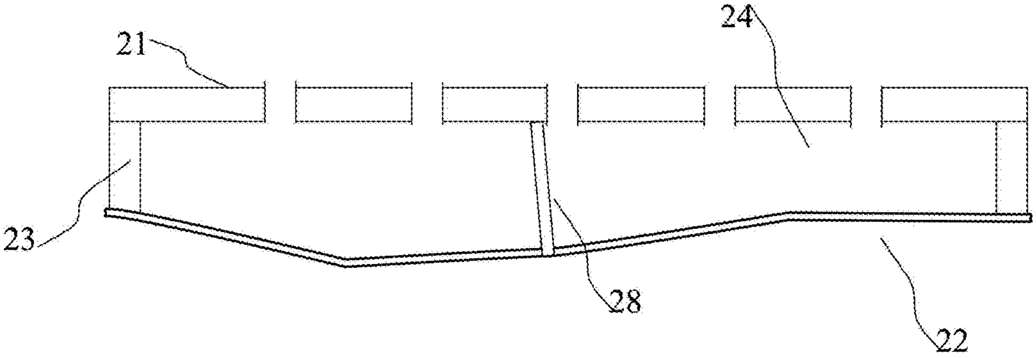


FIG. 11

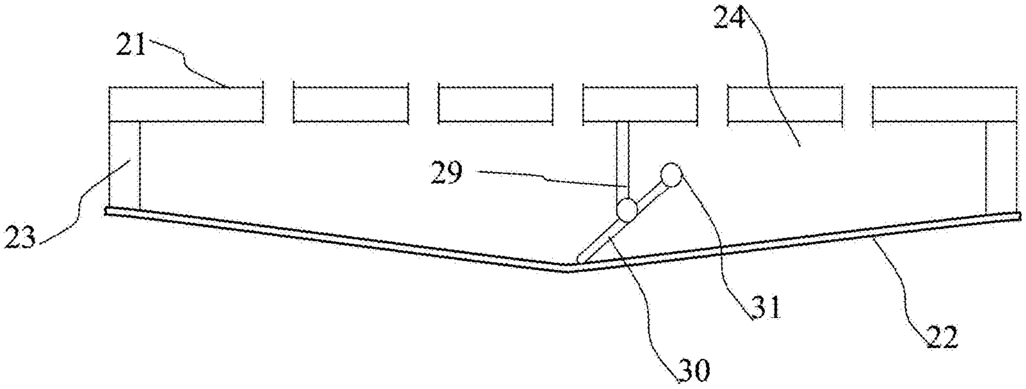


FIG. 12

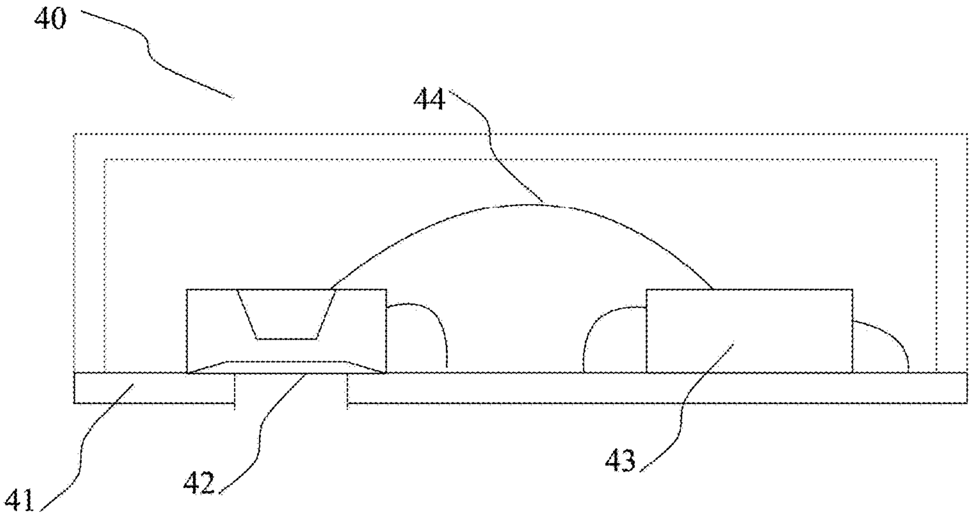


FIG. 13

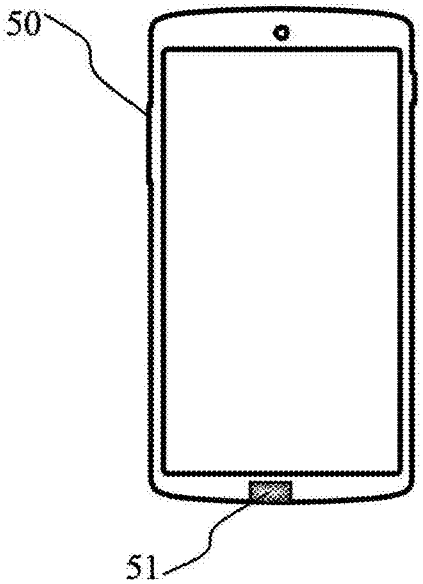


FIG. 14

CAPACITIVE MEMS MICROPHONE, MICROPHONE UNIT AND ELECTRONIC DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a National Stage of International Application No. PCT/CN2020/099425, filed on Jun. 30, 2020, which claims priority to Chinese Patent Application No. 202010548789.X, filed on Jun. 16, 2020, both of which are hereby incorporated by reference in their entireties.

TECHNICAL FIELD

[0002] The present disclosure relates to the field of a capacitive MEMS (micro-electro-mechanical system) microphone, and in particular to a capacitive MEMS microphone, a microphone unit and an electronic device.

BACKGROUND

[0003] A MEMS (micro-electro-mechanical system) microphone is a microphone chip manufactured with MEMS technology, which is small in size and can be widely used for various electronic devices, such as mobile phones, tablets, monitoring devices, wearable devices, etc.

[0004] The capacitive MEMS microphone is in a dual-ends capacitor structure. FIG. **1** shows the structure of a capacitive MEMS microphone. As shown in FIG. **1**, the capacitive MEMS microphone includes a back electrode plate **11**, a diaphragm **12**, and a spacer **13** located between the back electrode plate **11** and the diaphragm **12**. The spacer **13** is used for separating the back electrode plate **11** from the diaphragm **12**. The spacer **13** may be a separate spacing layer, or a part of the chip substrate.

[0005] In FIG. **1**, the back electrode plate **11**, the diaphragm **12** and the spacer **13** enclose a back cavity **15** of the capacitive MEMS microphone. A hole **14** in communication with the back cavity **15** may be formed in the back electrode plate **11**. A vent hole (not shown) may also be formed in the diaphragm **12**.

[0006] As shown in FIG. **2**, under an operating bias, the diaphragm **12** bends toward the back electrode plate **11**. In order to ensure the mechanical linear performance of the diaphragm **12**, under a condition that the operating bias is applied, the diaphragm **12** has a low static deflection when it is in a stationary state, that is, the ratio of a static effective displacement (static effective deflection) of the diaphragm **12** relative to a flat position to the thickness of the diaphragm **12** is W_0/t which is less than 0.5, wherein W_0 is the effective displacement of the diaphragm **12** in the stationary state under the operating bias, and t is the thickness of the diaphragm **12**.

[0007] The diaphragm **12** of FIG. **2** is configured to have great stiffness so that the diaphragm **12** has low static deflection. This diaphragm is less sensitive.

[0008] Therefore, there is a need to provide a new capacitive MEMS microphone.

SUMMARY

[0009] Embodiments of the present disclosure provides a new technical solution for a capacitive MEMS microphone.

[0010] According to a first aspect of the present disclosure, a capacitive MEMS microphone is provided, including: a back electrode plate; a diaphragm; and a spacer for separating the back electrode plate from the diaphragm, wherein in a state where no operating bias is applied, at least a portion of the diaphragm is pre-deviated in a direction away from the back electrode plate relative to a flat position.

[0011] According to a second aspect of the present disclosure, a microphone unit is provided, including a unit shell, a capacitive MEMS microphone disclosed herein and an integrated circuit chip, wherein the capacitive MEMS microphone and the integrated circuit chip are provided in the unit shell.

[0012] According to a third aspect of the present disclosure, an electronic device is disclosed, comprising a microphone unit disclosed herein.

[0013] In various embodiments, it is possible to reduce the overall non-linearity of the microphone by using a diaphragm with a great static deflection.

[0014] It should be understood that the above general description and the following detailed description are only exemplary and explanatory, and are not intended to limit the embodiments of the present specification.

[0015] In addition, there is no need for any one of the embodiments of the present disclosure to achieve all the above-mentioned effects.

[0016] Other features and advantages of the present disclosure will become apparent from the following detailed description of exemplary embodiments of the present disclosure with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In order to more clearly explain the embodiments of the present disclosure or the technical solutions in the prior art, the drawings required in the description of the embodiments or the prior art will be briefly described below. It will be apparent that the drawings in the following description are only some of the embodiments described in the embodiments of the present disclosure, and other drawings can be obtained by those skilled in the art according to these drawings.

[0018] FIG. **1** shows a schematic diagram of a micro-electro-mechanical microphone of the prior art.

[0019] FIG. **2** shows the schematic diagram of the micro-electro-mechanical microphone of in the prior art, wherein the diaphragm has a low static deflection in a state where the operating bias is applied.

[0020] FIG. **3** shows a graph of the effective displacement of the diaphragm in a static state versus an operating bias.

[0021] FIG. **4** shows a schematic diagram of the acoustic overload point of the diaphragm.

[0022] FIG. **5** shows a schematic diagram of a capacitive MEMS microphone according to one embodiment disclosed herein.

[0023] FIG. **6** shows a schematic diagram of the capacitive MEMS microphone according to another embodiment disclosed herein.

[0024] FIG. **7** shows a schematic diagram of the capacitive MEMS microphone according to yet another embodiment disclosed herein.

[0025] FIG. **8** shows a schematic diagram of the capacitive MEMS microphone according to yet another embodiment disclosed herein.

[0026] FIG. **9** shows a schematic diagram of the capacitive MEMS microphone according to yet another embodiment disclosed herein.

[0027] FIG. **10** shows a schematic diagram of the capacitive MEMS microphone according to yet another embodiment disclosed herein.

[0028] FIG. **11** shows a schematic diagram of the capacitive MEMS microphone according to yet another embodiment disclosed herein.

[0029] FIG. **12** shows a schematic diagram of a microphone unit according to one embodiment disclosed herein.

[0030] FIG. **13** shows a schematic diagram of an electronic device according to one embodiment disclosed herein.

DETAILED DESCRIPTION

[0031] Various exemplary embodiments of the present disclosure will now be described in detail with reference to the accompanying drawings.

[0032] The following description of at least one exemplary embodiment is in fact merely illustrative and is in no way intended to constitute any limitation to the present disclosure and its application or use.

[0033] It should be noted that similar reference numerals and letters denote similar items in the accompanying drawings, and therefore, once an item is defined in a drawing, and there is no need for further discussion in the subsequent accompanying drawings.

[0034] In the following, different embodiments and examples of the present disclosure are described with reference to the accompanying drawings.

[0035] Here, a capacitive MEMS microphone is provided. As shown in FIG. **5**, the capacitive MEMS microphone includes a back electrode plate **21**, a diaphragm **22** and a spacer **23**. The spacer **23** is used to separate the back electrode plate **21** from the diaphragm **22**. The spacer **23** may be a separate spacing layer, or a part of the chip substrate.

[0036] FIG. **5** shows the case where no operating bias is applied to the diaphragm **22**. In a state where the operating bias is not applied, at least a portion of the diaphragm **22** is pre-deviated in a direction (that is, a direction in which the distance between the diaphragm **22** and the back electrode plate **21** is increased) away from the back electrode plate. In FIG. **5**, the diaphragm **22** as a whole is pre-deviated. In other embodiments, however, the diaphragm may be divided into multiple parts, and a portion of them may be pre-deviated. Here, pre-deviation refers to a deviated state before the diaphragm works under sound pressure.

[0037] The ratio of a first static effective displacement Woo of the at least a portion of the diaphragm **22** that is pre-deviated to the thickness t of the diaphragm is greater than or equal to 0.2 and less than or equal to 3, i.e., $0.2<=\leq W_{00}/t\geq 3$.

[0038] For example, in the MEMS microphone in FIG. **5**, an air gap G_{00} between the flat position shown by the dotted line and the back electrode plate **21** is 1-5 μm, and the thickness t of the diaphragm **22** is 0.1-1.5 μm.

[0039] With the pre-deviation setting, it is possible to increase the strength of the diaphragm so as to improve THD (Total Harmonic Distortion) and/or AOP (Acoustic Overload Point).

[0040] In addition, since the diaphragm is pre-deviated, it is possible to prevent the diaphragm from being pressed to the back electrode plate to a certain extent when the operating voltage is applied. In addition, the stress for pre-deviation of the diaphragm will also affect the stress distribution of the diaphragm itself. With the pre-deviation, it is possible to manufacture the MEMS microphone with a smaller gap, which makes the fabrication process easier and the device's breakdown voltage VP lower. In addition, this approach may reduce the bias power supply requirements for the MEMS microphone. For example, a standard CMOS voltage below 15V may meet its bias power supply requirements without using a high-voltage BCD (Bipolar-CMOS-DMOS) process, which may reduce the chip area and cost of the MEMS microphone.

[0041] FIGS. **6** and **7** show two states of the diaphragm **22** with the operating bias applied. As shown in FIG. **6**, the diaphragm **22** leaves the original position **221** but is still outside the flat position of the diaphragm shown by the dotted line (away from the back electrode plate **21**) with the operating bias applied. In FIG. **7**, the diaphragm **22** leaves the original position **221** and is located within the flat position of the diaphragm (near the back electrode plate **21**) shown by the dotted line with the operating bias applied.

[0042] In the embodiment shown in FIGS. **6** and **7**, under the state of applying the operating bias, it is possible to make the ratio of the second static effective displacement of the diaphragm **22** relative to the flat position to the thickness of the diaphragm greater than or equal to 0.5, preferably greater than or equal to 1. Here, "static" refers to a state where no sound pressure is applied.

[0043] In this way, it is possible to make the mechanical non-linearity of the diaphragm to a degree that is similar in magnitude but opposite in direction to the non-linearity of capacitance detection, thereby greatly reducing the overall non-linearity of the MEMS microphone to further improve THD and AOP performance.

[0044] Next, the working principle and performance of the capacitive MEMS microphone including the back electrode plate **21** and diaphragm **22** shown in FIGS. **6** and **7** will be explained in conjunction with FIGS. **3** and **4**. This capacitive MEMS microphone may also be called a dual-end capacitive MEMS microphone. The diaphragm **22** of the capacitive MEMS microphone shown in FIGS. **6** and **7** has a great deflection.

[0045] In a capacitive MEMS microphone, the amount of charge is constant (fixed), that is, at audio frequencies, the amount of charge Q=CV is constant, wherein C and V are respectively the capacitance and voltage between diaphragm and back electrode plate. Therefore, the signal output may be expressed as:

$$vo=-x/(1-x)\cdot VB \qquad \text{(formula 1)}$$

[0046] Here, x=w/G0, is the ratio of the displacement w of the diaphragm **22** to the static air gap G_0 between the back electrode plate **21** and the diaphragm **22**, and VB is the operating bias between the back electrode plate **21** and the diaphragm **22**. The static air gap G_0 is the effective static air gap between the diaphragm with the operating bias VB applied and the back electrode plate. VB may represent a bias voltage that enables the diaphragm to be in a desired operating state.

[0047] When the output signal is obtained with the capacitance detection between the back electrode plate and the diaphragm, the non-linearity generated by the capacitance detection may be expressed as:

$$|vo^+/vo^-|=[(1-x^-)/(1-x^+)]\cdot(x^+/x^-) \qquad \text{(formula 2)}$$

[0048] Here, the meanings of vo and x in Formula 2 are as above, and the superscripts + and − correspond to the positive and negative half periods of the sound pressure accepted by the diaphragm, respectively. When the sound pressure is positive, x changes toward the direction in which the air gap G decreases. Formula 2 shows one of the main sources of non-linearity in dual-end capacitive MEMS microphones.

[0049] A traditional microphone utilizes the mechanical linearity of the diaphragm, that is, tries to make the displacement w of the diaphragm proportional to the sound pressure p, i.e., $x^-=-x^+$, $x^+=x>0$, wherein for x, the direction towards which the air gap G decreases is positive. At this point, the non-linearity of the microphone may be expressed as:

$$|vo^+/vo^-|=(1+x)/(1-x) \quad \text{(formula 3)}$$

[0050] In formula 3, the positive signal output is greater than the negative signal output, and the degree of non-linearity of the microphone is directly related to x.

[0051] In addition, the non-linearity of the microphone itself may be expressed as:

$$P=aW+bW^3 \quad \text{(formula 4)}$$

[0052] Here, P and W are the total pressure and total displacement received by the diaphragm, and a and b are positive constants.

[0053] The static effective displacement (an effective displacement under the operating bias) of the diaphragm in the static state (that is, a state in which the operating bias VB is applied but the sound pressure p is not applied) is W_0. Since the operating bias VB is applied between the diaphragm and the back electrode plate of the capacitive microphone, $W_0>0$. When a sound pressure p is applied to the diaphragm, the displacement of diaphragm is w^+ in the positive half cycle of the sound pressure p (positive sound pressure), and is w^- in the negative half cycle of the sound pressure p (negative sound pressure), and w^+ is slightly lower than w^-.

[0054] Formula 4 may also be expressed as:

$$p+P_0=a(W_0+w)+b(W_0+w)^3 \quad \text{(formula 5)}$$

[0055] Here, p is the sound pressure (with positive and negative half cycles), P0>0 is the static pressure generated by the electrostatic force, and w is an additional displacement of the diaphragm generated by the sound pressure (can be a positive or negative value).

[0056] FIG. **3** shows the relationship between the static effective displacement W_0 and the operating bias VB. In FIG. **3**, the abscissa is VB/VP, wherein VP indicates the breakdown voltage of the microphone, and the ordinate is W_0/G_0. In order to ensure the reliability of microphone devices, VB/VP<75% is usually set, and the corresponding W_0/G_0 is about 16%. By setting VB, it is possible to adjust the static deflection of the diaphragm **22**, or adjust the ratio W_0/t of the static effective displacement W_0 of the diaphragm **22** relative to the flat position to the thickness t of the diaphragm.

[0057] In a traditional capacitive MEMS microphone, in order to pursue mechanical linearity, it is necessary to select a diaphragm which has a low static deflection at a static state (no sound pressure is applied), or the ratio W_0/t of the static effective displacement W_0 of the diaphragm **22** relative to the flat position to the thickness t of the diaphragm is equal to or lower than 0.5. The non-linearity of this microphone mainly comes from capacitance detection.

[0058] Here, it is proposed to counteract the non-linearity of the capacitance detection by increasing the static deflection of the diaphragm.

[0059] Specifically, considering the above formulas 1-5, the overall non-linearity of the capacitive MEMS microphone may be expressed as:

$$|vo^+/vo^-|=A\cdot B \quad \text{(formula 6)}$$

Here, $A=(1-x-)/(1-x+)\sim(1+x)/(1-x)>1$,

$B=(x^+/x^-)=[a+3b(W_0+w^-)2]/[a\pm 3b(W_0\pm w^+)^2]$

$\sim[a+3b(W_0-w)]/[a+3b(W_0+w)]<1$, wherein $w^+=w\sim-w->0$

[0060] If the non-linearity of the capacitive MEMS microphone is considered comprehensively, it can be found in formula 6 that A is larger than 1 and B is lower than 1. Therefore, by adjusting A or B, it is possible to reduce the non-linearity caused by the asymmetry of the positive and negative cycles of the signal output, thereby improving THD (Total Harmonic Distortion) and AOP (Acoustic Overload Point).

[0061] In the present disclosure, with the operating bias VB and/or pre-deviation, it is possible to adjust "pre-deviation amount" (static deflection of the diaphragm) such that $W_0/t\geq 0.5$, preferably $W_0/t\geq 1$. This pre-deviation allows A in Formula 6 to be at least partially neutralized by B, thereby improving the degree of non-linearity of the output signal or the sound pressure level at a certain degree of non-linearity. For example, it is possible to significantly improve a sound pressure level of THD of 1% or AOP at THD of 10%.

[0062] FIG. **4** shows the relationship between pre-deviation amount and AOP. In FIG. **4**, the abscissa indicates the ratio W_0/t of the static deflection of the diaphragm to the thickness of the diaphragm, and the ordinate indicates the static pressure P_0. In FIG. **4**, the solid line indicates properties of a soft diaphragm S, and the dashed line indicates properties of a hard diaphragm H. As shown in FIG. **4**, the diaphragm S has a low AOP1 when the initial static deflection of diaphragm S is low. If the hard diaphragm H is used, the diaphragm H has a low AOP3 at a low static deflection. The hard diaphragm H, however, may have a reduced sensitivity. When the static deflection of the diaphragm S is set large, for example, when the static deflection of the diaphragm S is set at a point corresponding to (W_0, P_0), AOP2 of the diaphragm S is significantly increased relative to AOP1. In this way, it is possible to improve performances such as AOP while retaining the advantages (e.g., sensitivity) of the soft diaphragm.

[0063] Here, with the pre-deviation, it is possible to cause the diaphragm to be in a state of great deflection in advance. As shown in FIG. **6**, when the operating voltage is applied, the diaphragm **22** moves toward the back electrode plate **21**, but it is still outside the flat position shown in the dotted line. In addition, as shown in FIG. **7**, it is possible to place the diaphragm **22** within the flat position shown by the dotted line by applying the operating bias. In the case of applying the operating voltage, the diaphragms shown in FIGS. **6** and **7** have increased deflection. In this way, it is possible to artificially introduce the mechanical (geometric) non-linearity of diaphragm, that is, the asymmetry of the mechanical response of sound pressure in the positive and negative half cycles. The deformation of the diaphragm is w^+ when a positive sound pressure is applied (being pressed towards the back electrode plate), and is w^- when a negative sound pressure is applied (away from the back electrode plate), and w+ is lower than w−. This can compensate for the non-linearity introduced by the capacitance detection, that is, the output signal may be indicated as $v_{out} \sim -x/(1-x)VB$, wherein $x=w/G_0$, w is the displacement of the diaphragm caused by the sound pressure, G_0 is the effective static air gap when an operating bias is applied and the sound pressure is not applied, and VB is operating bias. Under a positive sound pressure, $x>0$, and the output signal is greater than $x*VB$; and under a negative sound pressure, the output signal is lower than $x*VB$. Considering $w+/w- \sim (1-x)/(1+x)$ at a specific sound pressure level, it is possible to use the mechanical non-linearity of diaphragm to compensate for the non-linearity caused by the capacitance detection, thereby improving the THD and AOP of a capacitive MEMS microphone.

[0064] At least a portion of the diaphragm may be pre-deviated by a stress structure. FIGS. **8-12** show a pre-deviated embodiment.

[0065] In the embodiment shown in FIG. **8**, the stress structure is realized by a stress ring **25** disposed at the periphery of the diaphragm. The stress ring **25** may include a tensile stress ring and/or a compressive stress ring. For example, the diaphragm **22** made of free polysilicon is provided with a tensile stress silicon nitride film ring at the inner periphery (the periphery at a side near the back electrode plate **21**) and/or a compressive stress film ring at the outer periphery (the periphery at a side near the back electrode plate **21**).

[0066] In the embodiment shown in FIG. **9**, the stress structure is realized by a corrugated membrane **26** arranged at the periphery of the diaphragm. By setting different orientations of the corrugated membrane, it is possible to provide different stresses to the diaphragm **22**. For example, the tensile stress may be provided by textures facing the inside (towards the back electrode plate **21**), and the compressive stress may be provided by textures facing the outside.

[0067] In the embodiment shown in FIG. **10**, the stress structure is realized by a complex membrane structure **27** arranged at the diaphragm. For example, the complex membrane structure **27** shown in FIG. **10** include an inner membrane having a compressive stress and an outer membrane having a tensile stress such that that the diaphragm is pre-deviated.

[0068] FIGS. **11** and **12** show an embodiment in which the diaphragm is pre-deviated by a support structure.

[0069] In the embodiment of FIG. **11**, a support **28** is located between the diaphragm and the back electrode plate. One end of the support **28** is fixed to the back electrode plate **21**, and the other end of the support **28** is fixed to the diaphragm **22** and separates the diaphragm **22** into at least two portions. During processing, the support **28** may be deformed due to stress, and thus is tilted. The deformation of the support **28** causes one of the at least two portions of the diaphragm to deviate outwardly relative to the back electrode plate **21** and the other portion to deviate inwardly relative to the back electrode plate **21**, as shown in FIG. **11**. In this way, it is possible for the diaphragm to produce deviation in two different directions, and the deviation in two different directions can balance the performance of the diaphragm.

[0070] Further, in order to reduce parasitic capacitance, the support **28** may be a columnar body.

[0071] In the example of FIG. **11**, a support **29** is located between the diaphragm **22** and the back electrode plate **21**. One end of the support **29** is fixed to the back electrode plate, and the other end of the support **29** supports an upwarped element **30**. A first side of the upwarped element **30** is in contact with the diaphragm **22**, and a second side of the upwarped element **30** has an electrostatic circuit **31**. When an operating bias is applied, the electrostatic circuit **31** is attracted by the back electrode plate **21**, so that the first side of the upwarped element **30** pushes the diaphragm to bulge outwardly, as shown in FIG. **12**. In this way, it is possible to control the degree to which the diaphragm is pre-deviated by controlling the quantity of electricity in the electrostatic circuit **31**.

[0072] FIG. **13** shows a schematic diagram of a microphone unit according to one embodiment disclosed herein.

[0073] As shown in FIG. **13**, the microphone unit **40** includes a unit shell **41**, the capacitive MEMS microphone **42** described above, and an integrated circuit chip **43**. The capacitive MEMS microphone **42** and the integrated circuit chip **43** are provided in the unit shell **41**. The capacitive MEMS microphone **42** corresponds to an air inlet of the unit shell **41**. The circuits in the capacitive MEMS microphone **42**, the integrated circuit chip **43** and the unit shell **41** are connected through leads **44**.

[0074] FIG. **14** shows a schematic diagram of a microphone unit according to one embodiment disclosed herein.

[0075] As shown in FIG. **14**, the electronic device **50** may include a microphone unit **51** shown in FIG. **8**. The electronic device **50** may be mobile phones, tablets, monitoring devices, wearable devices, etc.

[0076] The above is only the specific implementation of the embodiment of the present disclosure. It should be noted that for those of ordinary skill in the art, several improvements and modifications can also be made without departing from the principles of the embodiments of the present disclosure, and these improvements and modifications should also be regarded as the protection scope of the embodiments of the present specification.

1. A capacitive MEMS microphone, comprising:

a back electrode plate;

a diaphragm; and

a spacer separating the back electrode plate from the diaphragm,

wherein in a state where no operating bias is applied, at least a portion of the diaphragm is pre-deviated in a direction away from the back electrode plate relative to a flat position.

2. The capacitive MEMS microphone of claim **1**, wherein a ratio of a first static effective displacement of the at least a portion of the diaphragm that is pre-deviated to a thickness of the diaphragm is greater than or equal to 0.2 and less than or equal to 3.

3. The capacitive MEMS microphone of claim **1**, wherein in a state where the operating bias is applied, a ratio of a second static effective displacement of the diaphragm relative to the flat position to a thickness of the diaphragm is greater than or equal to 0.5.

4. The capacitive MEMS microphone of claim **3**, wherein the ratio of the second static effective displacement to the thickness of the diaphragm is greater than or equal to 1.

5. The capacitive MEMS microphone of claim **1**, wherein at least a portion of the diaphragm is pre-deviated with a stress structure.

6. The capacitive MEMS microphone of claim **5**, wherein the stress structure is selected from the group consisting of:

- a stress ring disposed on periphery of the diaphragm;
- a corrugated membrane disposed on periphery of the diaphragm; and
- a complex membrane structure disposed on the diaphragm.

7. The capacitive MEMS microphone of claim **5**, wherein the stress structure includes a support located between the diaphragm and the back electrode plate, a first end of the support is fixed to the back electrode plate, a second end of the support is fixed to the diaphragm and separates the diaphragm into at least two portions, and deformation of the support causes one of the at least two portions of the diaphragm to deviate outwardly relative to the back electrode plate and the other portion to deviate inwardly relative to the back electrode plate.

8. The capacitive MEMS microphone of claim **5**, wherein the stress structure includes a support located between the diaphragm and the back electrode plate, a first end of the support is fixed to the back electrode plate, a second end of the support supports an upwarped element wherein a first side thereof is in contact with the diaphragm and a second side thereof has an electrostatic circuit, and when an operating bias is applied, the electrostatic circuit is attracted by the back electrode plate so that the first side of the upwarped element pushes the diaphragm to bulge outwardly.

9. A microphone unit, comprising a unit shell, the capacitive MEMS microphone of claim **1** and an integrated circuit chip, wherein the capacitive MEMS microphone and the integrated circuit chip are provided in the unit shell.

10. An electronic device, comprising the microphone unit of claim **9**.

11. The capacitive MEMS microphone of claim **2**, wherein in a state where the operating bias is applied, a ratio of a second static effective displacement of the diaphragm relative to the flat position to a thickness of the diaphragm is greater than or equal to 0.5.

12. The capacitive MEMS microphone of claim **11**, wherein the ratio of the second static effective displacement to the thickness of the diaphragm is greater than or equal to 1.

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