(12) UK Patent Application (19) GB (11) 2 425 008 (13) A

(43) Date of A Publication **11.10.2006**

(21) Application No: **0605222.9**

(22) Date of Filing: **15.03.2006**

(30) Priority Data:
(31) **11100311** (32) **06.04.2005** (33) **US**

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(51) INT CL:
H03H 9/02 (2006.01) **H03H 9/17** (2006.01)

(52) UK CL (Edition X):
H3U UAB

(56) Documents Cited:
GB 2418791 A **EP 1258989 A2**
EP 1249932 A2 **EP 0973256 A1**
WO 2001/006647 A1

(58) Field of Search:
UK CL (Edition X) **H3U**
INT CL **H03H**
Other: **WPI, EPODOC**

(54) Abstract Title: **FBAR-type acoustic resonator has periheral fill region to improve Q**

(57) An acoustic resonator 10 includes a substrate 12, a first electrode 16, a layer of piezoelectric material 18, a second electrode 20, and a fill region 60. The first electrode 16 is adjacent the substrate 12 and the first electrode 12 has an outer perimeter. The piezoelectric layer 18 is adjacent the first electrode 12. The second electrode 20 is adjacent the piezoelectric layer (18) and the second electrode 20 has an outer perimeter. The fill region 60 is in one of the first and second electrodes 16, 18.

The presence of fill material in the fill region 60 is said to improve the Q of the resonator because it modifies acoustic impedance.

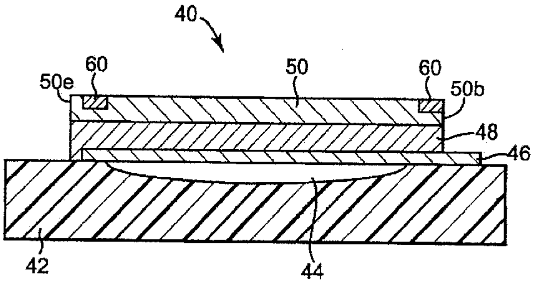

Fig. 3

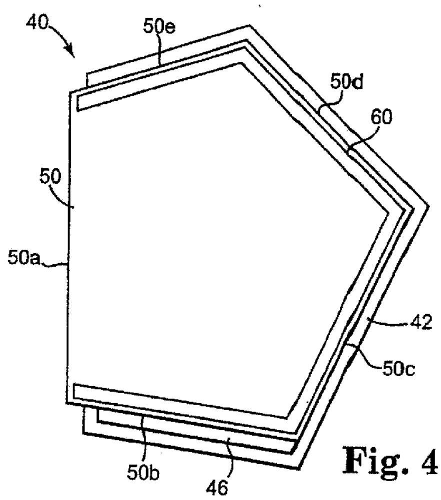

Fig. 4

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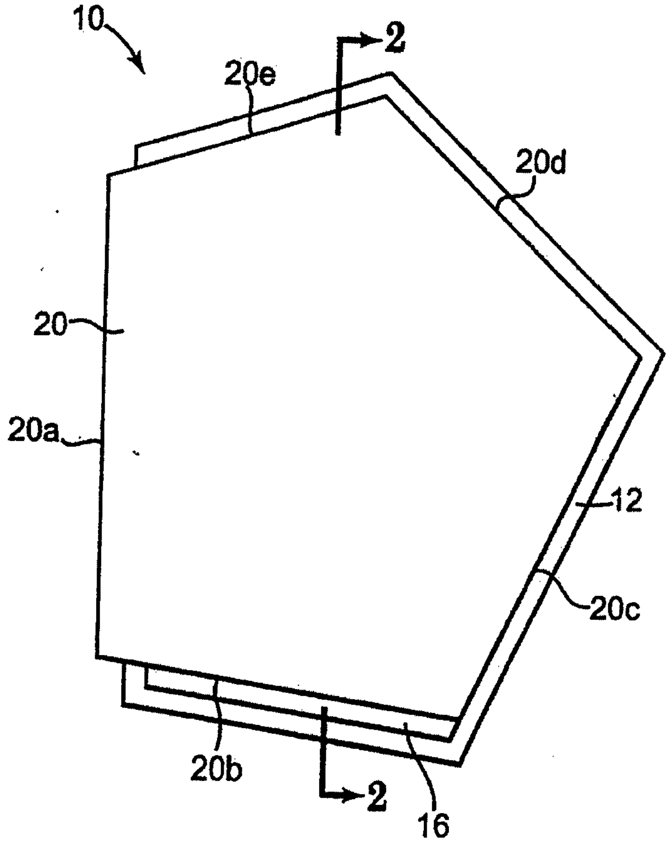


Fig. 1

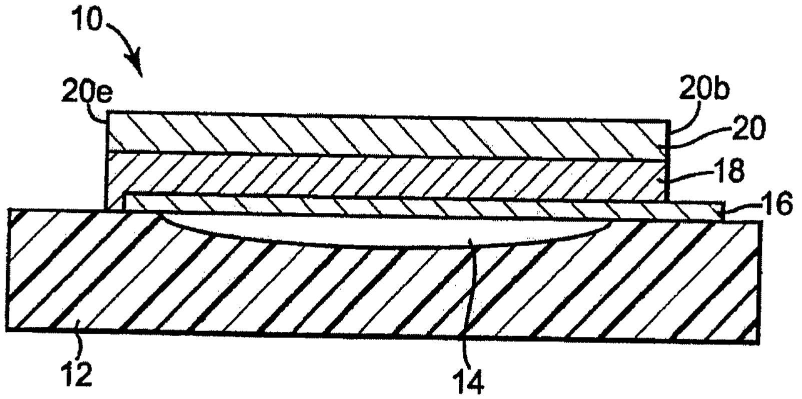


Fig. 2

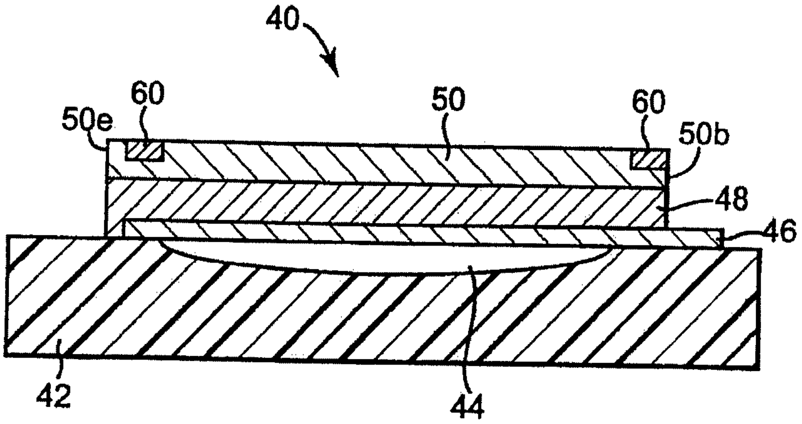


Fig. 3

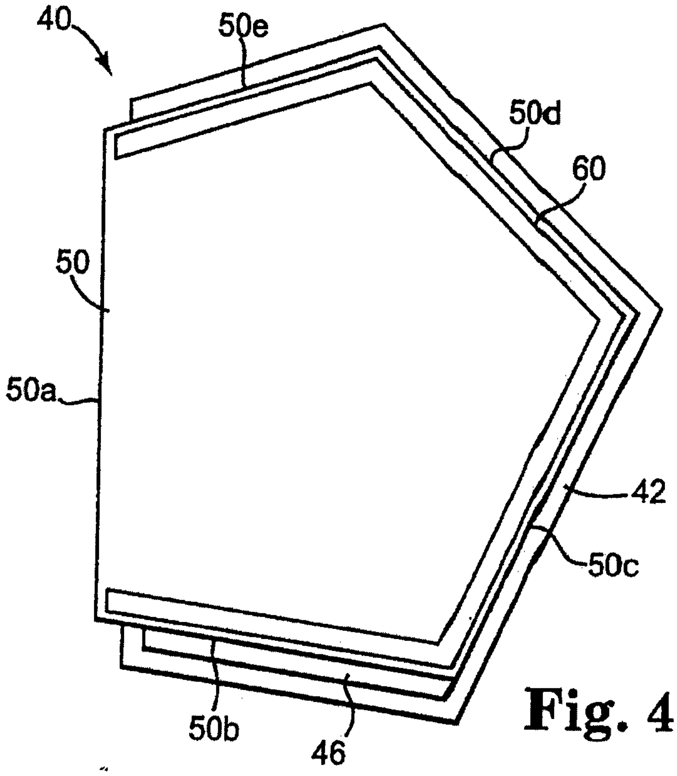
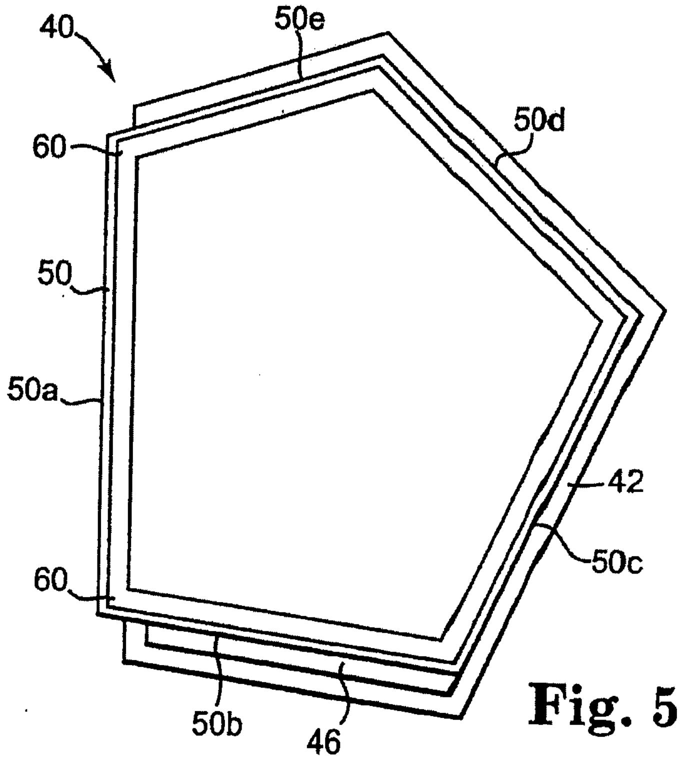

40
50e
50d
60
50
50a
42
50c
50b
46

Fig. 4


40
50e
50d
60
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50a
42
50c
60
50b
46

Fig. 5

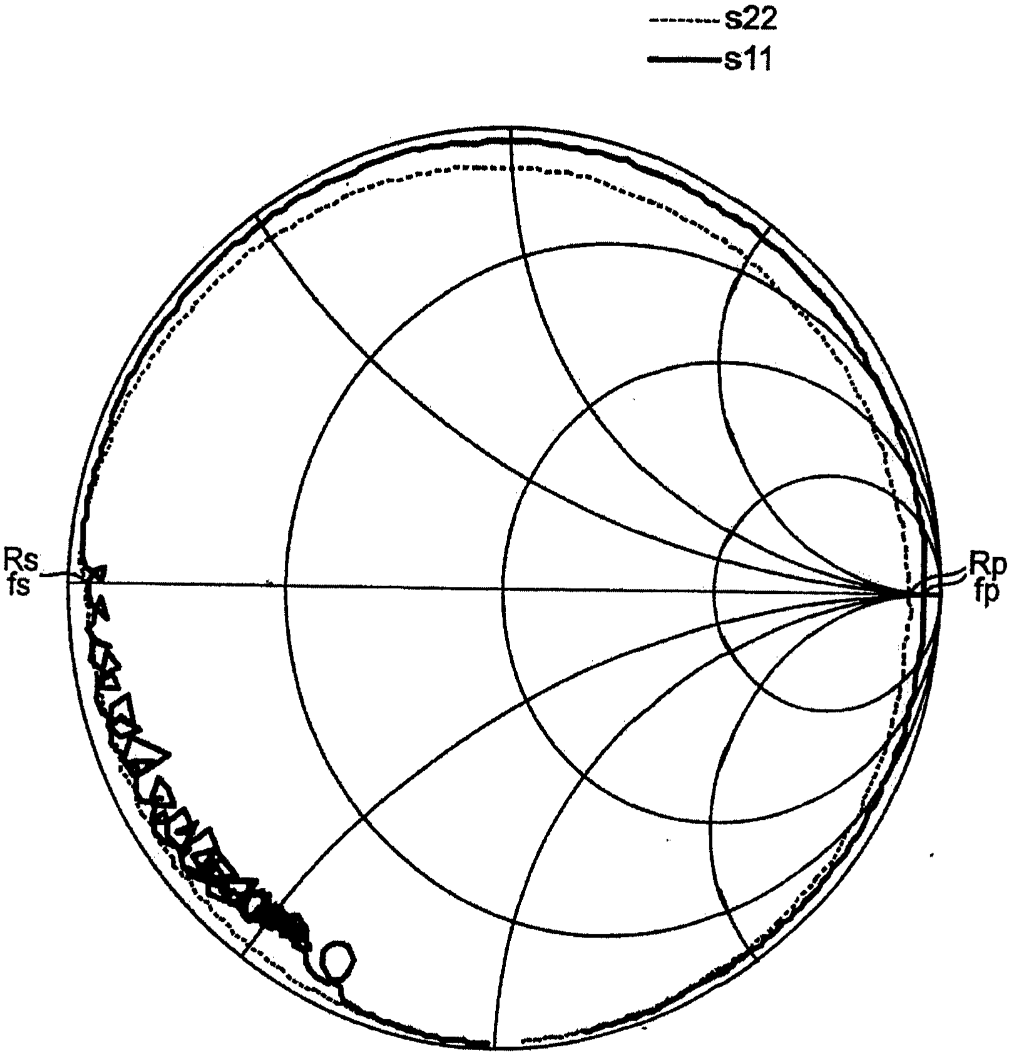

Fig. 6

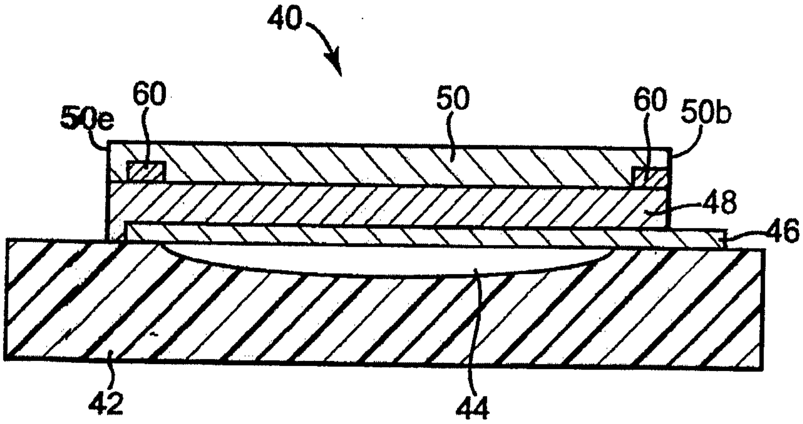

Fig. 7

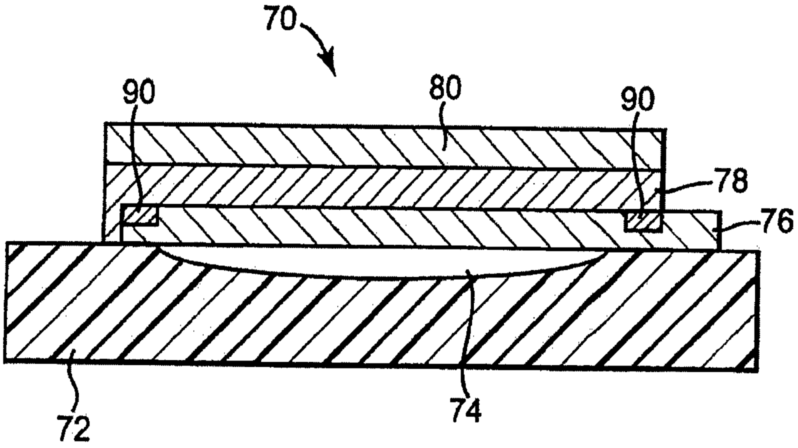

Fig. 8

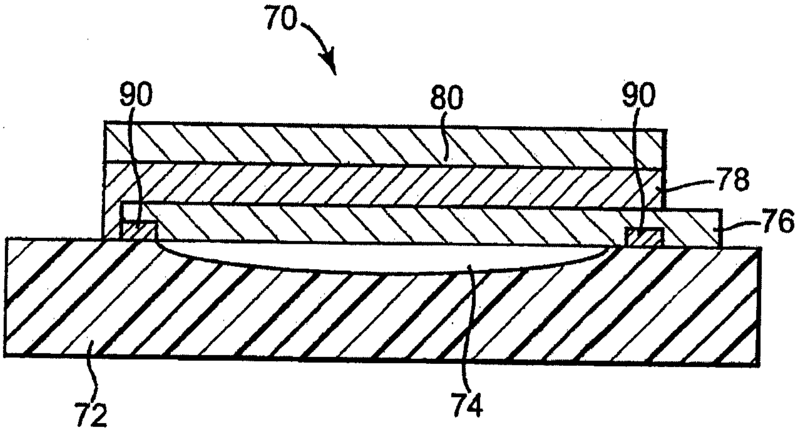

Fig. 9

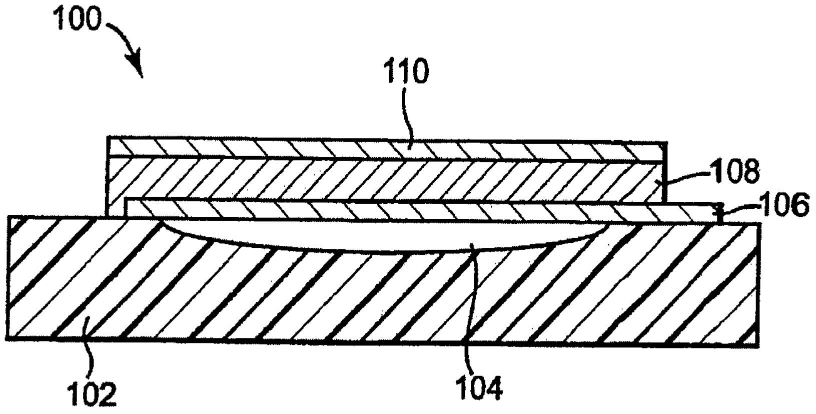

Fig. 10A

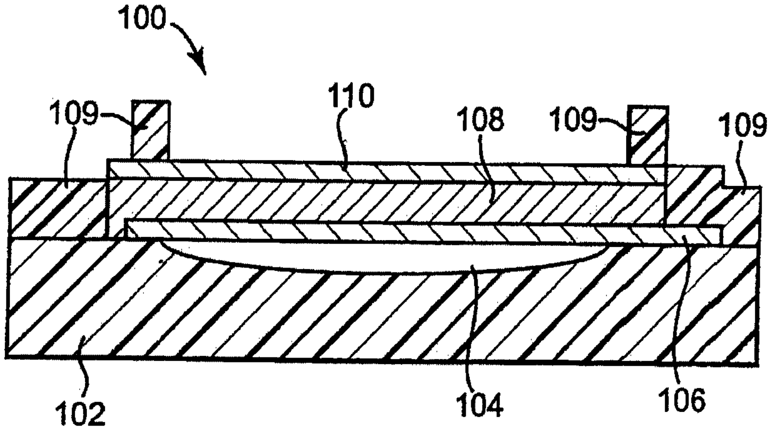

Fig. 10B

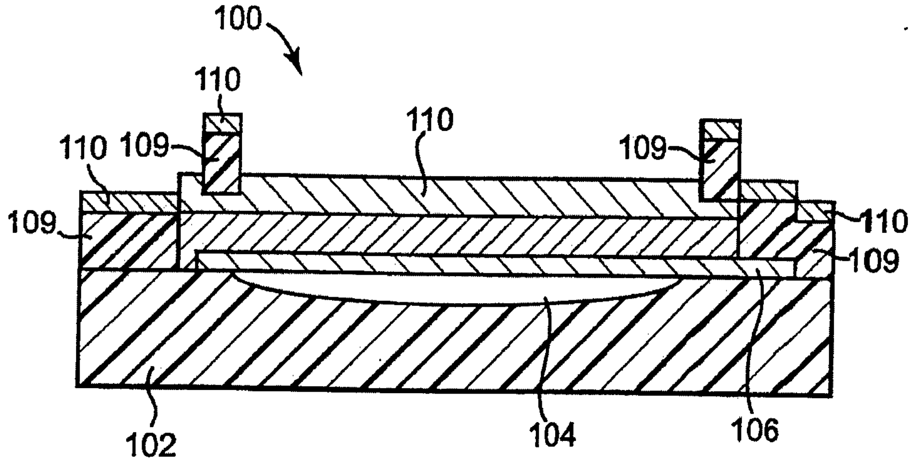

Fig. 10C

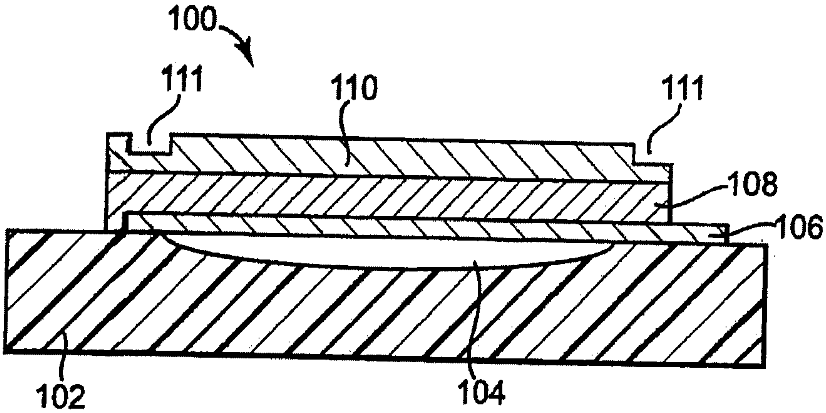

Fig. 10D

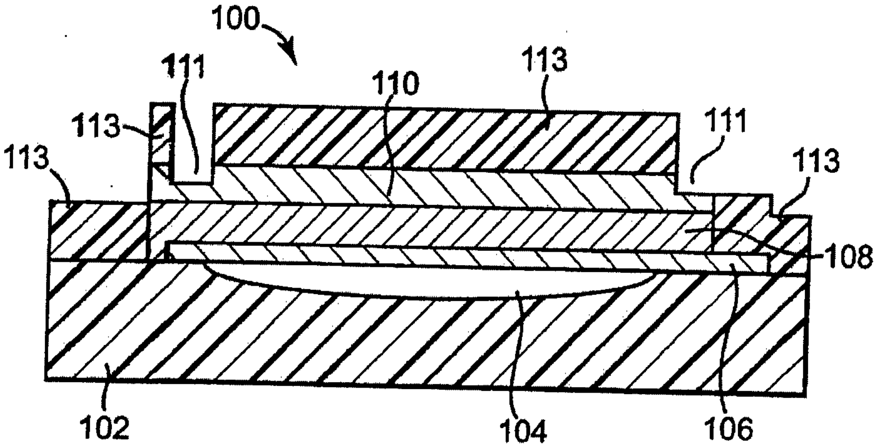

Fig. 10E

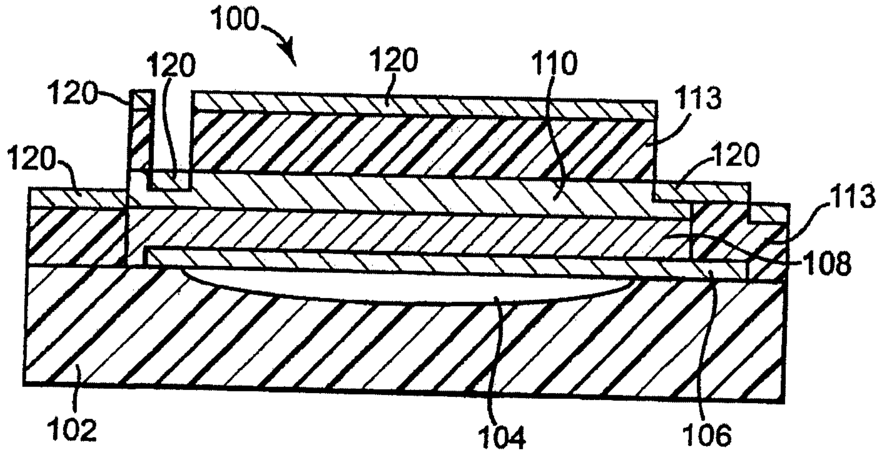

Fig. 10F

ACOUSTIC RESONATOR AND METHOD OF FABRICATING A RESONATOR

The present invention relates to a resonator and to a method of fabricating a resonator.

This Patent Application is related to Utility Patent Application Serial No. 10/867,540, filed on June 14, 2004, entitled "ACOUSTIC RESONATOR PERFORMANCE ENHANCEMENT USING SELECTIVE METAL ETCH."

The need to reduce the cost and size of electronic equipment has created a need for smaller single filtering elements. Thin-Film Bulk Acoustic Resonators (FBARs) and Stacked Thin-Film Bulk Wave Acoustic Resonators (SBARs) represent one class of filter elements with potential for meeting these needs. These filters can collectively be referred to as FBARs. An FBAR is an acoustic resonator that uses bulk longitudinal acoustic waves in thin-film piezoelectric (PZ) material. Typically, an FBAR includes a layer of PZ material sandwiched between two metal electrodes. The combination PZ material and electrodes are suspended in air by supporting the combination around its perimeter or are placed over an acoustic mirror.

When an electrical field is created between the two electrodes, the PZ material converts some of the electrical energy into mechanical energy in the form of acoustic waves. The acoustic waves propagate generally in the same direction as the electric field and reflect off the electrode-air or electrode-acoustic mirror interface at some frequency, including at a resonance frequency. At the resonance frequency, the device can be used as an electronic resonator. Multiple FBARs can be combined such that each is an element in RF filters.

Ideally, the resonant energy in the filter elements is entirely "trapped" in the resonator. In practice, however, dispersive modes exist. These modes can result in a decreased quality factor (Q) for the filter.

The present invention seeks to provide an improved acoustic resonator.

According to an aspect of the present invention there is provided an acoustic resonator as specified in claim 1.

According to another aspect of the present invention there is provided an acoustic resonator as specified in claim 14.

According to another aspect of the present invention there is provided an acoustic resonator as specified in claim 22.

According to another aspect of the present invention there is provided a method of fabricating an acoustic resonator as specified in claim 24.

According to another aspect of the present invention there is provided a method of fabricating an acoustic resonator as specified in claim 29.

Summary

One embodiment of the present invention provides an acoustic resonator that includes a substrate, a first electrode, a layer of piezoelectric material, a second electrode, and a fill region. The first electrode is adjacent the substrate, and the first electrode has an outer perimeter. The piezoelectric layer is adjacent the first electrode. The second electrode is adjacent the piezoelectric layer and the second electrode has an outer perimeter. The fill region is in one of the first and second electrodes.

Embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 illustrates a top plan view of an FBAR.

Figure 2 illustrates a cross-sectional view of an FBAR.

Figure 3 illustrates a cross-sectional view of an FBAR according to one embodiment of the present invention.

Figure 4 illustrates a top plan view of one embodiment of the FBAR illustrated in Figure 3.

Figure 5 illustrates a top plan view of an alternative embodiment of the FBAR illustrated in Figure 3.

Figure 6 illustrates Q circles for two exemplary FBARs plotted on a Smith chart.

Figure 7 illustrates a cross-sectional view of an FBAR according to one embodiment of the present invention.

Figure 8 illustrates a cross-sectional view of an FBAR according to another embodiment of the present invention.

Figure 9 illustrates a cross-sectional view of an FBAR according to another embodiment of the present invention.

Figures 10A-10F are cross-sectional views illustrating various stages of fabrication of an FBAR according to another embodiment of the present invention.

In the following Detailed Description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. In this regard, directional terminology, such as "top," "bottom," "front," "back," "leading," "trailing," etc., is used with reference to the orientation of the Figure(s) being described. Because components of embodiments of the present invention can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

Figures 1 and 2 illustrate top and cross-sectional views, respectively, of a Thin-Film Bulk Acoustic Resonator FBAR 10. FBAR 10 includes substrate 12, depression 14, first electrode 16, piezoelectric (PZ) layer 18, and second electrode 20. In Figure 1, PZ layer 18 and depression 14 are hidden from view. Second electrode 20 has a perimeter that is illustrated in Figure 1 as pentagon-shaped, having edges 20a, 20b, 20c, 20d and 20e. Two edges, 20b and 20e, are illustrated in the cross-sectional view of Figure 2. Typically, contracts (not illustrated) are coupled to first electrode 16 and to second electrode 20 and a passivation layer (not illustrated) may cover top electrode 20. The contacts facilitate connecting the first and second electrodes 16 and 20 to a source of voltage.

First electrode 16, PZ layer 18, and second electrode 20 collectively form an FBAR membrane. The FBAR membrane is adjacent substrate 12 and suspended over depression 14 to provide an electrode-air interface. In one embodiment, depression 14 is created by etching away a portion of substrate 12. Depression 14 is deep enough so that sufficient electrode-air interface is created under the FBAR membrane.

In another embodiment, the FBAR membrane may be placed adjacent an acoustic mirror (not illustrated in Figures 1 and 2) formed within substrate 12. In this way, an electrode-acoustic mirror interface is formed. The resonator thus formed is a Solid Mounted Resonator (SMR).

In one embodiment, substrate 12 is made of silicon (Si) and PZ layer 18 is made from aluminum nitride (AlN). Alternatively, other piezoelectric materials may be used for PZ layer 18. In one embodiment, first and second electrode 16 and 20 may be made of molybdenum (Mo). Alternatively, other materials may be used for the electrodes. In one embodiment, the contacts may be made of gold (Au). Alternatively, other materials may be used for the contacts.

FBAR 10 illustrated in Figures 1 and 2 is configured to use longitudinal or shear acoustic waves propagating in PZ layer 18. When an electric field is created between first and second electrodes 16 and 20 via an impressed voltage, the piezoelectric material of PZ layer 18 converts some of the electrical energy into mechanical energy in the form of acoustic waves. So configured, FBAR 10 exhibits dispersive modes resulting in a quality factor (Q) loss for FBAR 10.

Figure 3 illustrates a cross-sectional view of FBAR 40 in accordance with one embodiment of the present invention. FBAR 40 includes substrate 42, depression 44, first electrode 46, piezoelectric (PZ) layer 48, second electrode 50 and filled region 60. Typically, contacts (not illustrated in Figure 3) are coupled to first and second electrodes 46 and electrode 50, and a passivation layer covers the second electrode (also not illustrated in Figure 3). The contacts facilitate connecting first and second electrodes 46 and 50 to a voltage source. First electrode 46, PZ layer 48, and second electrode 50 collectively form an FBAR membrane, which may be placed over a depression 44 or over an acoustic mirror as discussed above. The FBAR membrane is illustrated adjacent substrate 42 and suspended over depression 44 to provide an electrode-air interface. As with previous embodiments, an electrode-acoustic mirror interface is also obtainable using an SMR design in accordance with the present invention.

Second electrode 50 and the other layers of the FBAR membrane have a perimeter that can be of various configurations. For example, the perimeters of each can be pentagon-shaped, similar to FBAR 10 above. They could also be any of various polygonal shapes, circular, or various irregular shapes. The cross-sectional view illustrated in Figure 3 illustrates two locations along the perimeter of second electrode 50, edges 50b and 50e. In one embodiment, an edge of PZ layer 48 is generally aligned with edge 50b of second electrode 50 in the vertical direction in FBAR 40 as illustrated in Figure 3.

In FBAR 40 illustrated in Figure 3, a filled region 60 has been added into second electrode 50 adjacent the edge 50b and near edge 50e of second electrode 50. In one embodiment, fill region 60 is located just outside the perimeter of depression 44. In this way, when the perimeter or outside diameter of depression 44 is extended in the vertical direction (as oriented in the illustration of Figure 3), fill region 60 is just "outside" the perimeter of depression 44.

In other embodiments, fill region 60 overlaps the perimeter of depression 44 such that part of fill region 60 is "inside" and part is "outside" the perimeter of depression 44. In still other embodiments, fill region 60 lies entirely "inside" the perimeter of depression 44.

Fill region 60 improves the performance of FBAR 40, resulting in improved insertion loss and improved resonator quality factor Q of FBAR 40. The overall quality-factor Q of FBAR 40 depends proportionally on a parameter of resistance called R_p. In FBAR 40, the R_p may be improved by fill region 60.

An electric field is created between first and second electrodes 46 and 50 via an impressed voltage. The piezoelectric material of PZ layer 48 converts some of the electrical energy into mechanical energy in the form of acoustic waves. Some of the acoustic waves in FBAR 40 are longitudinal acoustic waves of any mode type, while others are transverse acoustic waves of the compression, shear, or drum mode type. FBAR 40 is designed to use longitudinal acoustic waves propagating in the thickness extensional direction in the PZ layer 48 as the desired resonator mode. However, FBAR 40, which provides fill region 60, reduces or suppresses energy loss, thereby improving the Q of the filter. In one embodiment, fill region 60 helps trap energy from lateral modes in FBAR 40.

In one embodiment, fill region 60 is filled with a material that is different than that used for second electrode 50. In that case, the material in fill region 60 will have different dispersion characteristics than will the remaining material of second electrode 50, which in one case is Mo. Adding this material with differing dispersion characteristics can improve insertion loss and improve the resonator quality factor Q of FBAR 40. In one embodiment, the material in fill region 60 increases the FBAR membrane's stiffness at its edge. In one case, the material in fill region 60 is such that it increases the acoustic impedance of the fill region 60 relative to that at the center of the FBAR membrane. Such material may be denser than the electrode material. For example, the material in fill region 60 can be W, while second electrode 50 is made of Mo. In other embodiments first and second electrodes 46 and 50 may be metal such at Pt, W, Cu, Al, Au, or Ag. In alternative embodiments, material in fill region 60 could also be made of materials such as polymide, BCB, SiO_2, Si_3N_4, or other dielectrics, AlN, ZnO, $LiNbO_3$, PZT, $LiTaO_3$, Al_2O_3, or other piezoelectric materials, Pt, W, Cu, Al, Au, Ag, or other metals or alloys of metal.

In one embodiment, fill region 60 has a depth in second electrode 50 that is on the order of hundreds to thousands of angstroms, and a width on the order of fractions of a micron to microns or even large, up to that portion of the width of second electrode 50 that extends beyond or outside the perimeter of depression 44. In one embodiment, second electrode 50 is selectively etched to form a recessed feature that is then filled in with material to form fill region 60. In one embodiment, second electrode 50 is constructed using a lift-off technique to form a recessed feature that is filled in with material to form fill region 60.

Figures 4 and 5 illustrate plan views of FBAR 40 of Figure 3 in accordance with alternative embodiments of the present invention. As illustrated in Figures 4 and 5, FBAR 40 includes substrate 42, first electrode 46, and second electrode 50. In Figures 4 and 5, piezoelectric (PZ) layer 48 and depression 44 are hidden from view. Typically, contacts (not illustrated in the Figures) are coupled to first and second electrodes 46 and 50, and a passivation layer (also not illustrated in the Figures) covers second electrode 50.

In Figures 4 and 5, fill region 60 is illustrated extending adjacent the perimeter of second electrode 50. In the Figures, the perimeter of second electrode 50 is generally pentagon-shaped having five relatively straight edges (50a, 50b, 50c, 50d, and 50e), but may also be essentially any polygonal shape, circular in shape, or have any other smooth or irregular shape.

In Figure 5, fill region 60 is illustrated extending adjacent the perimeter of second electrode 50 along all of the give edges of the pentagon-shaped.

electrode, that is, adjacent edges 50a, 50b, 50c, 50d, and 50e. Figure 4 illustrates an alternative embodiment of FBAR 40 where fill region 60 extends adjacent the perimeter of second electrode 50 along four of the five edges of the pentagon-shaped electrode, that is, adjacent edges 50b, 50c, 50d, and 50e. In one embodiment, a contact is attached to the fifth edge 50a of second electrode 50, so fill region 60 does not extend along that edge in that embodiment.

As one skilled in the art will understand, any number of alternative fill regions 60 may be provided adjacent the edges of second electrode 50 consistent with the present invention. Fill region 60 may be continuously extending along some or all of the edges of second electrode 50 as illustrated, fill regions 60 may have smaller segments that are not continuous along the edge, and other shapes and configurations of fill regions 60 can be used, especially where second electrode 50 is a shape other than a pentagon.

Figure 6 illustrates Q circles for two exemplary FBARs plotted on a Smith chart, and illustrates improvement in R_p and therefore Q in one of the FBARs. As is known in the art, a Smith Chart is a polar plot of a complex impedance (used in Figure 6 to illustrate measures of s11 and s22 scattering parameters). These s11 and s22 scattering parameters represent a ratio of complex amplitudes of backward and forward waves. The Smith Chart aids in translating the reflection coefficients into impedance and it maps part of the impedance placed into a unit circle. The improved performance of FBAR 40 is demonstrated by the Q circles illustrated in Figure 6. Figure 6 illustrates the S-parameter measurements of an exemplary filled device, such as FBAR 40 with fill region 60. As illustrated, the filled device of FBAR 40 with fill region 60 (solid line labeled S11) has a much improved R_p versus that of a control device, such as that illustrated in Figure 2 (dashed line labeled S22) in the upper half of the chart.

Generally, the horizontal axis passing through the unit circle represents real impedance, the area above the axis represents inductive reactance and the area below represents capacitive reactance. The left-hand portion of the chart at zero reactance represents series resonance frequency (*fs*) and occurs where the Q circle crosses the real axes on the left side of the Smith Chart. The left-hand portion of the chart also demonstrates the parameter of resistance R_s. The right-hand portion of the chart at zero reactance represents parallel resonant frequency (*fp*) and occurs where the Q circle crosses the real axes on the right side of the Smith Chart. The right-hand portion of the chart also demonstrates the parameter of resistance R_p. The closer that a plot of FBAR filter characteristics on a Smith Chart is to the perimeter of the Smith Chart, the higher the Q will be for that FBAR. Also, the more smooth that the curve is, the lower the noise is in the FBAR.

In Figure 6, the performance of FBAR 40 as a filter is illustrated by the solid line Q circle s11 and the performance of a prior art FBAR without a filled region in the electrode is illustrated by the dashed line Q circle s22. As evident, FBAR 40 improves the quality of the filter near the frequency *fp*. FBAR 40, illustrated by Q circle s11, more closely approximates a unit circle in the upper half of the unit circle and is representative of a less lossy device in that area, which improves the performance of FBAR 40 when used in a filter.

Figure 6 also illustrates that FBAR 40 used as a filter actually enhances spurious modes below the series resonant frequency *fs*, as indicated in the lower-left side or "southwest" quadrant of the unit circle. When FBAR 40 is used in applications where the increase in noise in this frequency regime does not impair the device performance, the improvements illustrated in the other areas of the unit circle can be exploited. For example, in some embodiments FBAR 40 is used as a resonator in a filter application that employs a half-ladder topology. The performance of the filter benefits from the improved R_p, and any noise introduced by the increased spurious modes lies outside the filter passband.

Figure 7 illustrates a cross-sectional view of FBAR 40 in accordance with an alternative embodiment of the present invention. FBAR 40 is essentially the same as that illustrated in Figure 3, and includes substrate 42, depression 44, first electrode 46, piezoelectric (PZ) layer 48, second electrode 50 and fill region 60. Two edges, 50b and 50e, of the perimeter of second electrode 50 are also illustrated. In addition, however, FBAR 40 illustrated in Figure 7, has fill region 60 formed in a surface of second electrode 50 that is opposite the surface in which fill region 60 was formed in Figure 3. As FBAR 40 is depicted in Figure 3, fill region 60 is on the "top" surface of second electrode 50, whereas as FBAR 40 is depicted in Figure 7, fill region 60 is on the "bottom" surface of second electrode 50. In one embodiment, fill region 60 depicted in Figure 7 is also outside the edge of the perimeter of depression 44. In alternative embodiments fill region 60 overlaps the perimeter of depression 44, and in other embodiments, fill region 60 lies entirely inside the perimeter of depression 44.

In one embodiment, the performance of FBAR 40 as illustrated in Figure 7 is essentially the same as that described above for FBAR 40 as depicted in Figure 3. Fill region 60 on the "bottom" surface of second electrode 50 can be achieved in a variety of ways known by those skilled in the art. For example, the structure illustrated in Figure 7 could be constructed by using a lift-off process (i.e., mask, material deposition, and lift-off) after piezoelectric deposition, followed by deposition of the top electrode material.

Figures 8 and 9 illustrate cross-sectional views of FBAR 70 in accordance with other embodiments of the present invention. FBAR 70 includes substrate 72, depression 74, first electrode 76, piezoelectric (PZ) layer 78, second electrode 80, and fill material 90. Typically, contacts (not illustrated in the Figures) are coupled to first and second electrodes 76 and 80. Also, an optional passivation layer (not illustrated in the Figures) may be used to cover second electrode 80. The contacts facilitate connecting first and second electrodes 76 and 80 to a voltage source. First electrode 76, PZ layer 78, and second electrode 80 collectively form an FBAR membrane, which may be placed over a depression 74 or over an acoustic mirror as discussed above. The FBAR membrane is illustrated adjacent substrate 72 and suspended over depression 74 to provide an electrode-air interface. As with previous embodiments, an electrode-acoustic mirror interface is also obtainable using an SMR design in accordance with the present teachings.

FBAR 70 is similar to FBAR 30 illustrated in Figure 3; however, FBAR 70 has fill region 90 inserted in first electrode 76, rather than in the second electrode as above. Fill region 90 inserted in first electrode 76 also improves the performance of FBAR 70, resulting in improved insertion loss and improved resonator quality factor Q of FBAR 70. In Figure 8, fill region 90 is illustrated adjacent the "top surface" of first electrode 76 and in Figure 9, fill region 90 is illustrated adjacent the "bottom surface" of first electrode 76. In each case, fill region 90 is illustrated just outside the perimeter of depression 74. In this way, when the perimeter or outside diameter of depression 44 is extended in the vertical direction (as oriented in the illustration of Figures 8 and 9), fill region 90 is just "outside" the perimeter of depression 74. In other embodiments, fill region 90 overlaps the perimeter of depression 74, and in other embodiments, fill region 90 lies entirely inside the perimeter of depression 74. Like fill region 60 described previously with respect to FBAR 40, fill region 90 improves the performance of FBAR 70, resulting in improved noise reduction and improved resonator quality factor Q of FBAR 70.

As with embodiments above, fill region 90 is filled with a material that is different than that used for second electrode 80. In that case, the material in fill region 90 will have different dispersion characteristics than will the remaining material of second electrode 80, which in one case is Mo. Adding this material with differing dispersion characteristics can improve insertion loss and improve the resonator quality factor Q of FBAR 70. In one embodiment, the material in fill region 90 increases the FBAR membrane's stiffness at its edge. In one case, the material in fill region 90 is such that it increases the acoustic impedance of the fill region 90 relative to that at the center of the FBAR membrane. Such material may be denser than the electrode material. For example, the material in fill region 90 can be W, while second electrode 80 is made of Mo. In other embodiments first and second electrodes 76 and 80 may be metal such as Pt, W, Cu, Al, Au, or Ag. In other embodiments, material in fill region 90 could also be made of materials such as polyimide, BCB, SiO_2, Si_3N_4, or other dielectrics, AlN, ZnO, $LiNbO_3$, PZT, $LiTaO_3$, Al_2O_3, or other piezoelectric materials, Pt, W, Cu, Al, Au, Ag, or other metals or alloys of metals.

FBARs 40 and 70 may be fabricated in a variety of ways consistent with the present teachings. In one embodiment, for example, a recessed region is created in the top electrode by first depositing electrode metal to a thickness slightly less than the desired thickness. Then a photo mask is used to pattern the center region of the resonator. The remaining thickness of electrode metal is then deposited, and a lift-off process is used to remove the resist remaining in the recessed area. An additional photo mask is then used to pattern the fill region. Fill material is deposited in the fill region, and the mask and fill material outside the fill region are removed in a lift-off process. In another embodiment, the recessed region maybe produced by first depositing electrode metal to the desired thickness, patterning the electrode with a photo mask, and etching the recessed region. In another embodiment, the fill material maybe produced by first depositing fill material, patterning the fill region with a photo mask, and etching away the fill material outside the fill region.

Figures 10A-10F are cross-sectional views illustrating various intermediate stages of fabrication of FBAR 100 according to one embodiment of the present invention. FBAR 100 is similar to those illustrated in Figures 3-9, and includes substrate 102, depression 104, first electrode 106, piezoelectric (PZ) layer 108, and second electrode 110, which collectively form an FBAR membrane. Figure 10A illustrates FBAR 100 prior to formation of a fill region 120 (illustrated in Figure 10F and analogous to above-described fill regions 60 and 90).

Figure 10B illustrates FBAR 100 with a photo mask 109 deposited over the FBAR membrane. Photo mask 109 is used to pattern a recessed region using a lift-off process. Figure 10C illustrates FBAR 100 of Figure 10B after additional electrode material metal 110 is deposited, but before the lift-off process. Figure 10D illustrates FBAR 100 after the lift-off process. The lift off process removes photo mask 109 and all metal 110 that is on photo mask 109. In this way, the lift-off process defines a recessed region 111.

Next, Figure 10E illustrates FBAR 100 with a photo mask 113 deposited over the FBAR membrane to pattern the fill. Figure 10F illustrates FBAR 100 of Figure 10E after fill material 120 deposition, but before the lift-off process. After the lift off process, FBAR 40 of Figure 3 illustrates the resulting structure. In some embodiments, the FBAR may additionally utilize at least one passivation layer.

A filled recessed region on the bottom electrode may be constructed similarly. Furthermore, the top of the fill region does not necessarily need to align with the surface of the electrode, whether the fill region resides in the top electrode or bottom electrode. The recess in the FBAR can be generated by a lift-off process, but can also be made with an etch step. The fill material may be patterned in the recessed region by first masking with a photo mask, depositing metallization, and then using a lift-off to leave fill material in the recessed region. Fill material can also be added by first using a metal deposition, followed by a photo mask and an etch.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the claims. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein.

The disclosures in United States patent application No. 11/100,311, from which this application claims priority, and in the abstract accompanying this application are incorporated herein by reference.

CLAIMS

1. An acoustic resonator including:
a substrate;
a first electrode adjacent the substrate, wherein the first electrode has an outer perimeter;
a piezoelectric layer adjacent the first electrode;
a second electrode adjacent the piezoelectric layer, wherein the second electrode has an outer perimeter, and
a fill region in one of the first and second electrodes.

2. An acoustic resonator according to claim 1, wherein a depression is formed in the substrate and wherein the depression has a depression perimeter.

3. An acoustic resonator according to claim 2, wherein the fill region in one of the first and second electrodes is outside the depression perimeter.

4. An acoustic resonator according to claim 2, wherein the fill region in one of the first and second electrodes is inside the depression perimeter.

5. An acoustic resonator according to claim 2, wherein the fill region in one of the first and second electrodes overlaps the depression perimeter.

6. An acoustic resonator according to any preceding claim, wherein an acoustic mirror is formed in the substrate and wherein the first electrode spans the acoustic mirror.

7. An acoustic resonator according to any preceding claim, including a passivation layer adjacent the second electrode, the passivation layer lying in a second plane that is generally parallel to a first plane.

8. An acoustic resonator according to any preceding claim, wherein the fill region in one of the first and second electrodes is adjacent the outer perimeter.

9. An acoustic resonator according to any preceding claim, wherein at least one of the first and second electrodes comprise a material that is a different material than a material in the fill region.

10. An acoustic resonator according to claim 8, wherein the fill material is a material selected from the group comprising dielectrics, metals, metal alloys, piezoelectrics, Mo, Pt, Al, Cu, W, Au, Ag, polyimide, BCB, SiO_2, Si_3N_4, AlN, ZnO, $LiNbO_3$, PZT, $LiTaO_3$, and Al_2O_3.

11. An acoustic resonator according to any preceding claim, wherein the fill region extends around a substantial portion of the outer perimeter of one of the first and second electrodes.

12. An acoustic resonator according to any preceding claim, wherein the fill region has a depth in one of the first and second electrodes that is of the order of hundreds to thousands of angstroms and a width on the order of fractions of a micron to tens of microns.

13. An acoustic resonator according to any preceding claim, wherein the fill region is offset from the outer perimeter of one of the first and second electrodes by zero to 10s of microns.

14. An acoustic resonator including:
a substrate having a first surface;
a first electrode adjacent the first surface of the substrate;
a layer of piezoelectric material adjacent the first electrode;
a second electrode adjacent the layer of piezoelectric material, the second electrode lying in a first plane; and
a fill region configured in the second electrode.

15. An acoustic resonator according to claim 14, wherein a depression having a depression perimeter is formed in the first surface of the substrate and wherein the first electrode spans the depression.

16. An acoustic resonator according to claim 14, wherein an acoustic mirror is formed in the first surface of the substrate and wherein the first electrode spans the acoustic mirror.

17. An acoustic resonator according to claim 14 or 15, wherein the fill region in the second electrode is outside the depression perimeter.

18. An acoustic resonator according to claim 14 or 15, wherein the fill region in the second electrode is inside the depression perimeter.

19. An acoustic resonator according to claim 14 or 15, wherein the fill region in the second electrode overlaps the depression perimeter.

20. An acoustic resonator according to any one of claims 14 to 19, wherein the second electrode comprises a material that is a different material than that in the fill region.

21. An acoustic resonator according to claim 20, wherein the fill material is denser than the electrode material such that it increases the acoustic impedance of the fill region relative to that at the center the acoustic resonator.

22. An acoustic resonator including:

a substrate;

a first electrode adjacent the substrate;

a second electrode adjacent the layer of piezoelectric material, when the first electrode, the layer of piezoelectric material and the second electrode together form an acoustic membrane having an outer edge and a center; and means for increasing the acoustic impedance of the outer edge of the acoustic membrane relative to that at the center the acoustic membrane.

23. An acoustic resonator according to claim 22, wherein the second electrode comprises a fill region having a material that is different than the material in the second electrode.

24. A method of fabricating an acoustic resonator including the steps of:
providing a substrate;
fabricating a first electrode adjacent the substrate;
fabricating a piezoelectric layer adjacent the first electrode;
depositing electrode material to form a second electrode up to a first thickness adjacent the piezoelectric layer;
depositing a first photo mask over the second electrode;
depositing additional electrode material to form the second electrode up to a second thickness;
removing the photo mask thereby revealing a recessed region in the second electrode; and
filling the recessed region with a fill material.

25. A method according to claim 24, including depositing a second photo mask over the second electrode before filling the recessed region.

26. A method according to claim 24 or 25, including forming a depression in the substrate.

27. A method according to claim 25 or 26, including filling the recessed region with a different material than the electrode material.

28. A method according to any one of claims 24 to 27, wherein filling the recessed region includes filling with a material selected from the group comprising

dielectrics, metals, metal alloys, piezoelectrics Mo, Pt, Al, Cu, W, Au, Ag, polyimide, BCB, SiO_2, Si_3N_4, AlN, ZnO, $LiNbO_3$, PZT, $LiTaO_3$ and Al_2O_3.

29. A method for fabricating an acoustic resonator including the steps of:
providing a substrate;
fabricating a first electrode adjacent the substrate;
fabricating a piezoelectric layer adjacent the first electrode;
depositing electrode material to form a second electrode;
depositing a first photo mask over the second electrode;
etching the second electrode to form a recessed region in the second electrode; and
filling the recessed region with a fill material.

30. An acoustic resonator substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

31. A method of fabricating an acoustic resonator substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

For Innovation

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Application No:	GB0605222.9	**Examiner:**	Peter Easterfield
Claims searched:	1 to 29	**Date of search:**	7 July 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,E	at least 1, 14, 22, 24, 29	GB 2418791 A (AGILENT) see para [0042] & claims 4, 12
A	22	EP 1258989 A2 (NOKIA)
A	22	EP 1249932 A2 (NOKIA)
A	22	EP 0973256 A1 (MITSUBISHI)
A	22	WO 01/06647 A1 (NOKIA)

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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

H3U

Worldwide search of patent documents classified in the following areas of the IPC

H03H

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC