RADIO FREQUENCY ACOUSTIC DEVICE WITH LATERALLY DISTRIBUTED REFLECTORS

BACKGROUND

Technical Field

The present disclosure generally relates to bulk acoustic wave resonators.

Description of the Related Art

A bulk acoustic wave resonator is a device having a piezoelectric material between two electrodes. When an electromagnetic signal is applied to one of the electrodes, an acoustic wave is generated in the piezoelectric material and propagates to the other electrode.

Depending on the thickness of the piezoelectric material, resonance of such an acoustic wave is established, and on the other electrode, an electromagnetic signal having a frequency corresponding to the resonant acoustic wave is generated. Thus, such a bulk acoustic wave resonator can be utilized to provide filtering functionality for an electromagnetic signal such as a radio-frequency (RF) signal.

In many applications, the piezoelectric material between the electrodes is relatively thin and implemented as a film. Thus, a bulk acoustic wave resonator is sometimes referred to as a thin-film bulk acoustic wave resonator (TFBAR) or as a film bulk acoustic wave resonator (FBAR).

SUMMARY

In accordance with an example disclosed herein there is provided a bulk acoustic wave resonator device. The bulk acoustic wave resonator comprises a piezoelectric material layer having an upper surface and a lower surface, a first metal layer having a lower surface disposed on the upper surface of the piezoelectric material layer and an upper surface, a second metal layer having an upper surface disposed on the lower surface of the piezoelectric material layer and a lower surface, and a laterally distributed raised frame including a first raised frame disposed on the upper surface of the first metal layer and having an inner raised frame section with a tapered portion and a non-tapered portion and an outer raised frame section, and a second raised frame disposed beneath the first metal layer and the outer raised frame section, but not

beneath the inner raised frame section, the inner raised frame section of the first raised frame being laterally disposed from a central active region of the bulk acoustic wave resonator device by a first distance, the outer raised frame section of the first raised frame being laterally disposed from the central active region of the bulk acoustic wave resonator device by a second distance, the second distance being greater than the first distance, the laterally distributed raised frame configured to improve reflection of lateral mode waves and to reduce conversion of main mode waves into lateral mode waves.

In one aspect, the present disclosure refers to a bulk acoustic wave resonator device comprising, a piezoelectric material layer having an upper surface and a lower surface, a first metal layer having a lower surface disposed on the upper surface of the piezoelectric material layer and an upper surface, a second metal layer having an upper surface disposed on the lower surface of the piezoelectric material layer and a lower surface, and a laterally distributed raised frame including a first raised frame disposed on the upper surface of the first metal layer and having an inner raised frame section with a tapered portion and a non-tapered portion and an outer raised frame section, and a second raised frame disposed beneath the first metal layer and the outer raised frame section, but not beneath the inner raised frame section, the second raised frame including an inner tapered portion and an outer non-tapered portion, the inner raised frame section of the first raised frame being laterally disposed from a central active region of the bulk acoustic wave resonator device by a first distance, the outer raised frame section of the first raised frame being laterally disposed from the central active region of the bulk acoustic wave resonator device by a second distance, the second distance being greater than the first distance.

In some examples, the first raised frame is formed of a metal.

In some examples, the second raised frame is formed of an oxide.

In some examples, the outer raised frame section of the first raised frame has a width and a substantially uniform thickness across the width.

In some examples, the second raised frame includes an inner tapered portion and an outer non-tapered portion.

In some examples, the inner tapered portion of the second raised frame has a taper angle of from 10° and 60°.

In some examples, the outer non-tapered portion of the second raised frame has a width and a substantially uniform thickness across the width.

In some examples, the tapered portion of the inner raised frame section of the first raised frame has a taper angle of from 5° to 45°.

In some examples, the bulk acoustic wave resonator device further comprises a dielectric layer disposed on the upper surface of the first metal layer and defining a recessed frame region surrounding the central active region.

In some examples, the bulk acoustic wave resonator device does not include a recessed frame region.

In some examples, the tapered portion of the inner raised frame section of the first raised frame has a width that is less than a width of the non-tapered portion of the inner raised frame section of the first raised frame.

In some examples, the tapered portion of the inner raised frame section of the first raised frame has a width that is greater than a width of the non-tapered portion of the inner raised frame section of the first raised frame.

In some examples, the second raised frame has an upper surface in contact with the lower surface of the first metal layer.

In some examples, the second raised frame has a lower surface in contact with the upper surface of the second metal layer.

In some examples, the second raised frame has an upper surface in contact with the piezoelectric material layer.

In some examples, the second raised frame has an upper surface in contact with the piezoelectric material layer.

In some examples, the second raised frame has a lower surface in contact with the piezoelectric material layer, the second raised frame dividing the piezoelectric material layer into an upper piezoelectric material layer and a lower piezoelectric material layer.

In some examples, the first raised frame is formed of a material with a higher acoustic impedance than a material of which the second raised frame is formed and a higher acoustic impedance than a material of which the piezoelectric material layer is formed.

In some examples, the second raised frame is formed of a material with a lower acoustic impedance than a material of which the first raised frame is formed and a lower acoustic impedance than a material of which the piezoelectric material layer is formed.

In some examples, the bulk acoustic wave resonator device is a film bulk acoustic wave resonator device including a cavity defined below the second metal layer.

In some examples, the bulk acoustic wave resonator device is a solidly mounted resonator including a Bragg reflector disposed beneath the second metal layer.

In some examples, the tapered portion of the inner raised frame section of the first raised frame has a linear taper.

In some examples, the tapered portion of the inner raised frame section of the first raised frame has a concave taper.

In some examples, the tapered portion of the inner raised frame section of the first raised frame has a convex taper.

In some examples, the second raised frame includes an inner tapered portion having a linear taper.

In some examples, the second raised frame includes an inner tapered portion having a concave taper.

In some examples, the second raised frame includes an inner tapered portion having a convex taper.

In some examples, a radio frequency filter includes a bulk acoustic wave resonator device as described above.

The radio frequency filter may be included in a radio frequency module.

The radio frequency module may be included in a radio frequency device.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of this disclosure will now be described, by way of non-limiting example, with reference to the accompanying drawings.

FIG. 1A is a cross-sectional view of an example of a FBAR device including one or more tapered raised frames;

FIG. 1B is an enlarged cross-sectional view of a first raised frame of the FBAR device of FIG. 1A;

FIG. 1C is an enlarged cross-sectional view of a second raised frame of the FBAR device of FIG. 1A;

FIG. 2 is a cross-sectional view of another example of a FBAR device including one or more tapered raised frames;

FIG. 3 is a cross-sectional view of another example of a FBAR device including one or more tapered raised frames;

FIG. 4 is a cross-sectional view of another example of a FBAR device including one or more tapered raised frames;

FIG. 5 is a cross-sectional view of another example of a FBAR device including one or more tapered raised frames;

FIG. 6 is a cross-sectional view of another example of a FBAR device including one or more tapered raised frames;

FIG. 7 illustrates examples of cross-sectional profiles of raised frame portions, according to certain embodiments;

FIG. 8 illustrates results of a simulation of the effect of raised frame thickness and taper angle on quality factor in a FBAR device;

CLAIMS

1. A bulk acoustic wave resonator device comprising:

a piezoelectric material layer having an upper surface and a lower surface;

a first metal layer having a lower surface disposed on the upper surface of the piezoelectric material layer and an upper surface;

a second metal layer having an upper surface disposed on the lower surface of the piezoelectric material layer and a lower surface; and

a laterally distributed raised frame including a first raised frame disposed on the upper surface of the first metal layer and having an inner raised frame section with a tapered portion and a non-tapered portion and an outer raised frame section, and a second raised frame disposed beneath the first metal layer and the outer raised frame section, but not beneath the inner raised frame section, the second raised frame including an inner tapered portion and an outer non-tapered portion, the inner raised frame section of the first raised frame being laterally disposed from a central active region of the bulk acoustic wave resonator device by a first distance, the outer raised frame section of the first raised frame being laterally disposed from the central active region of the bulk acoustic wave resonator device by a second distance, the second distance being greater than the first distance.

2. The bulk acoustic wave resonator device of claim 1 wherein the first raised frame is formed of a metal.

3. The bulk acoustic wave resonator device of claim 2 wherein the second raised frame is formed of an oxide.

4. The bulk acoustic wave resonator device of any preceding claim wherein the outer raised frame section of the first raised frame has a width and a substantially uniform thickness across the width.

5. The bulk acoustic wave resonator device of any preceding claim wherein the inner tapered portion of the second raised frame has a taper angle of from 10° and 60°.

6. The bulk acoustic wave resonator device of any preceding claim wherein the outer non-tapered portion of the second raised frame has a width and a substantially uniform thickness across the width.

7. The bulk acoustic wave resonator device of any preceding claim wherein the tapered portion of the inner raised frame section of the first raised frame has a taper angle of from 5° to 45°.

8. The bulk acoustic wave resonator device of any preceding claim further comprising a dielectric layer disposed on the upper surface of the first metal layer and defining a recessed frame region surrounding the central active region.

9. The bulk acoustic wave resonator device of any preceding claim wherein the bulk acoustic wave resonator device does not include a recessed frame region.

10. The bulk acoustic wave resonator device of any preceding claim wherein the tapered portion of the inner raised frame section of the first raised frame has a width that is less than a width of the non-tapered portion of the inner raised frame section of the first raised frame.

11. The bulk acoustic wave resonator device of any of claims 1 to 9 wherein the tapered portion of the inner raised frame section of the first raised frame has a width that is greater than a width of the non-tapered portion of the inner raised frame section of the first raised frame.

12. The bulk acoustic wave resonator device of any preceding claim wherein the second raised frame has an upper surface in contact with the lower surface of the first metal layer.

13. The bulk acoustic wave resonator device of any preceding claim wherein the second raised frame has a lower surface in contact with the upper surface of the second metal layer.

14. The bulk acoustic wave resonator device of claim 13 wherein the second raised frame has an upper surface in contact with the piezoelectric material layer.

15. The bulk acoustic wave resonator device of any of claims 1 to 11 wherein the second raised frame has an upper surface in contact with the piezoelectric material layer.

16. The bulk acoustic wave resonator device of claim 15 wherein the second raised frame has a lower surface in contact with the piezoelectric material layer, the second raised frame dividing the piezoelectric material layer into an upper piezoelectric material layer and a lower piezoelectric material layer.

17. The bulk acoustic wave resonator device of claim 1 wherein the first raised frame is formed of a material with a higher acoustic impedance than a material of which the second raised frame is formed and a higher acoustic impedance than a material of which the piezoelectric material layer is formed.

18. The bulk acoustic wave resonator device of claim 1 wherein the second raised frame is formed of a material with a lower acoustic impedance than a material of which the first raised frame is formed and a lower acoustic impedance than a material of which the piezoelectric material layer is formed.

19. The bulk acoustic wave resonator device of claim 1 wherein the bulk acoustic wave resonator device is a film bulk acoustic wave resonator device including a cavity defined below the second metal layer.

20. The bulk acoustic wave resonator device of claim 1 wherein the bulk acoustic wave resonator device is a solidly mounted resonator including a Bragg reflector disposed beneath the second metal layer.

21. The bulk acoustic wave resonator device of claim 1 wherein the tapered portion of the inner raised frame section of the first raised frame has a linear taper.

22. The bulk acoustic wave resonator device of claim 1 wherein the tapered portion of the inner raised frame section of the first raised frame has a concave taper.

23. The bulk acoustic wave resonator device of claim 1 wherein the tapered portion of the inner raised frame section of the first raised frame has a convex taper.

24. The bulk acoustic wave resonator device of claim 1 wherein the inner tapered portion of the second raised frame has a linear taper.

25. The bulk acoustic wave resonator device of claim 1 wherein the inner tapered portion of the second raised frame has a concave taper.

26. The bulk acoustic wave resonator device of claim 1 wherein the inner tapered portion of the second raised frame has a convex taper.

27. A radio frequency filter including the bulk acoustic wave resonator device of any of the above claims.

28. A radio frequency module including the radio frequency filter of claim 27.

29. A radio frequency device including the radio frequency module of claim 28.