

BULK ACOUSTIC WAVE RESONATOR WITH STACKED PIEZOELECTRIC LAYERS

BACKGROUND

Technical Field

Embodiments of this disclosure relate to acoustic wave devices, specifically bulk
5 acoustic wave resonators and electronic devices and modules including same.

Description of Related Technology

Acoustic wave devices, for example, bulk acoustic wave (BAW) devices may be
utilized as components of filters in radio frequency electronic systems. For instance, filters
10 in a radio frequency front end of a mobile phone can include acoustic wave filters. Two
acoustic wave filters can be arranged as a duplexer.

SUMMARY

In accordance with one example, there is provided a bulk acoustic resonator
15 comprising a membrane including a piezoelectric film having multiple layers of piezoelectric
material. At least one of the multiple layers of piezoelectric material has a different dopant
concentration than another of the multiple layers of piezoelectric material.

In accordance with one aspect, there is provided a bulk acoustic resonator comprising
a membrane including a piezoelectric film having an odd number of more than two layers of
20 piezoelectric material, a centermost of the more than two layers of piezoelectric material
having a higher doping level than others of the more than two layers of piezoelectric
material.

In some examples, the multiple layers of piezoelectric material are arranged
asymmetrically with respect to thickness wherein an upper layer of the multiple layers of
25 piezoelectric material has a different thickness than a lower layer of the multiple layers of
piezoelectric material.

In some examples, the piezoelectric film includes two layers of piezoelectric material,
a first of the two layers of piezoelectric material being closer to an input side of the
piezoelectric film and having a higher doping level than a second of the two layers of
30 piezoelectric material.

In some examples, wherein the first layer of piezoelectric material is formed of aluminum nitride (AlN) doped with scandium (Sc) and the second layer of piezoelectric material is formed of undoped AlN.

5 In some examples, the first layer of piezoelectric material has a substantially same thickness as a thickness of the second layer of piezoelectric material.

In some examples, the piezoelectric film includes more than two layers of piezoelectric material, a first of the more than two layers of piezoelectric material being closer to an input side of the piezoelectric film and having a higher doping level than others of the more than two layers of piezoelectric material.

5 In some examples, wherein the first of the more than two layers of piezoelectric material is formed of AlN doped with Sc and others of the more than two layers of piezoelectric material are formed of undoped AlN.

10 In some examples, the more than two layers of piezoelectric material are arranged symmetrically with respect to doping concentration and thickness in a direction from the input side to an output side of the piezoelectric film.

 In some examples, the more than two layers of piezoelectric material are arranged asymmetrically with respect one of doping concentration or thickness in a direction from the input side to an output side of the piezoelectric film.

15 In some examples, the piezoelectric film includes an odd number of more than two layers of piezoelectric material, a centermost of the more than two layers of piezoelectric material having a higher doping level than others of the more than two layers of piezoelectric material.

20 In some examples, the centermost of the more than two layers of piezoelectric material has a greater thickness than the others of the more than two layers of piezoelectric material.

 In some examples, the more than two layers of piezoelectric material are configured symmetrically with respect to doping concentration and thickness in a direction from the input side to an output side of the piezoelectric film.

25 In some examples, the centermost of the more than two layers of piezoelectric material has a thickness approximately equal to a sum of the thicknesses of the others of the more than two layers of piezoelectric material.

 In some examples, the centermost of the more than two layers of piezoelectric material is formed of AlN doped with Sc and the others of the more than two layers of piezoelectric material are formed of undoped AlN.

30 In some examples, the bulk acoustic wave resonator is configured as a film bulk acoustic wave resonator.

In some examples, the bulk acoustic wave resonator is configured as solidly mounted resonator.

In some examples, the bulk acoustic wave resonator is included in a radio frequency filter.

5 In some examples, the bulk acoustic wave resonator is included in an electronic device module.

In some examples, the bulk acoustic wave resonator is included in an electronic device.

10 In accordance with another example, there is provided a method of forming a bulk acoustic wave resonator. The method comprises forming a membrane for the bulk acoustic wave resonator by forming a first piezoelectric film having a first doping concentration on a second piezoelectric material film having a second doping concentration different from the first doping concentration.

15 In accordance with another aspect, there is provided a method of forming a bulk acoustic wave resonator comprising forming a membrane for the bulk acoustic wave resonator by forming an odd number of more than two layers of piezoelectric material, a centermost of the more than two layers of piezoelectric material having a higher doping level than others of the more than two layers of piezoelectric material.

20 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. 1 is a simplified cross-sectional diagram of an example of film bulk acoustic wave resonator;

25 FIG. 2 is a simplified cross-sectional diagram of an example of a solidly mounted resonator;

FIG. 3A illustrates the layers of a membrane of a simulated film bulk acoustic resonator (FBAR) used to evaluate the effect on generation of spurious harmonic signals of arrangement of differently doped layers in a dual layer piezoelectric material film;

FIG. 3B illustrates the results of simulations of the H2 harmonic of the FBAR having the membrane structure of FIG. 3A with different arrangements of differently doped layers in the piezoelectric material film;

5 FIG. 3C illustrates the results of simulations of the H3 harmonic of the FBAR having the membrane structure of FIG. 3A with different arrangements of differently doped layers in the piezoelectric material film;

CLAIMS

1. A bulk acoustic resonator comprising a membrane including a piezoelectric film having an odd number of more than two layers of piezoelectric material, a centermost of the more than two layers of piezoelectric material having a higher doping level than others of the more than two layers of piezoelectric material.
2. The bulk acoustic resonator of claim 1 wherein the multiple layers of piezoelectric material are arranged asymmetrically with respect to thickness, wherein an upper layer of the multiple layers of piezoelectric material has a different thickness than a lower layer of the multiple layers of piezoelectric material.
3. The bulk acoustic resonator of claim 1 wherein the more than two layers of piezoelectric material are arranged asymmetrically with respect one of doping concentration or thickness in a direction from the input side to an output side of the piezoelectric film.
4. The bulk acoustic resonator of claim 1 wherein the centermost of the more than two layers of piezoelectric material has a greater thickness than the others of the more than two layers of piezoelectric material.
5. The bulk acoustic resonator of claim 4 wherein the more than two layers of piezoelectric material are configured symmetrically with respect to doping concentration and thickness in a direction from the input side to an output side of the piezoelectric film.
6. The bulk acoustic resonator of claim 4 wherein the centermost of the more than two layers of piezoelectric material has a thickness approximately equal to a sum of the thicknesses of the others of the more than two layers of piezoelectric material.
7. The bulk acoustic resonator of claim 1 wherein the centermost of the more than two layers of piezoelectric material is formed of AlN doped with Sc and the others of the more than two layers of piezoelectric material are formed of undoped AlN.

8. The bulk acoustic wave resonator of claim 1 configured as a film bulk acoustic wave resonator.

5 9. The bulk acoustic wave resonator of claim 1 configured as a solidly mounted resonator.

10. The bulk acoustic wave resonator of claim 1 included in a radio frequency filter.

10 11. The bulk acoustic wave resonator of claim 10 included in an electronic device module.

12. The bulk acoustic wave resonator of claim 11 included in an electronic device.

15 13. A method of forming a bulk acoustic wave resonator comprising forming a membrane for the bulk acoustic wave resonator by forming an odd number of more than two layers of piezoelectric material, a centermost of the more than two layers of piezoelectric material having a higher doping level than others of the more than two layers of piezoelectric material.

20