MULTI-LAYER PIEZOELECTRIC SUBSTRATE WITH CONTROLLABLE DELTA TEMPERATURE COEFFICIENT OF FREQUENCY

BACKGROUND

Technical Field

Embodiments of this disclosure relate to acoustic wave devices and filters and to methods and structures for controlling a temperature coefficient of bandwidth in same.

Description of Related Technology

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

SUMMARY

In accordance with one aspect, there is provided an electronic device. The electronic device comprises a multi-layer piezoelectric substrate including a carrier substrate, a layer of piezoelectric material disposed on a front side of the carrier substrate, and a back-side layer of material disposed on a rear side of the carrier substrate, the back-side layer of material having a coefficient of thermal expansion different than a coefficient of thermal expansion of the carrier substrate, and one or more acoustic wave devices disposed on a front side of the multi-layer piezoelectric substrate, the one or more acoustic wave devices exhibiting a lesser difference in temperature coefficient of frequency at respective resonant and antiresonant frequencies than in a substantially similar device lacking the back-side layer of material, wherein the back-side layer of material has a temperature coefficient of frequency different than the temperature coefficient of frequency of the carrier substrate.

In some examples, the one or more acoustic wave devices are included in an acoustic wave filter.

In some examples, the one or more acoustic wave devices form a radio frequency filter.

In some examples, the filter has a near-zero temperature coefficient of bandwidth.

In some examples, the temperature coefficient of frequency at the resonant frequency of the one or more acoustic wave devices is substantially equal to the temperature coefficient of frequency at the antiresonant frequency of the one or more acoustic wave devices.

In some examples, the one or more acoustic wave devices are surface acoustic wave devices. The one or more acoustic wave devices may be temperature compensated surface acoustic wave devices.

In some examples, the one or more acoustic wave devices are bulk acoustic wave devices.

In some examples, the back-side layer of material has a higher temperature coefficient of frequency than the temperature coefficient of frequency of the carrier substrate.

In some examples, the back-side layer of material has a lower temperature coefficient of frequency than the temperature coefficient of frequency of the carrier substrate.

In some examples, the back-side layer of material comprises one of a dielectric or a metal.

In some examples, the back-side layer of material comprises a piezoelectric material.

In some examples, both the back-side layer of material and the layer of piezoelectric material comprise a same piezoelectric material.

In some examples, the back-side layer of material and the layer of piezoelectric material have substantially a same thickness.

In some embodiments, the one or more acoustic wave devices have a near-zero delta temperature coefficient of frequency.

In some examples, the electronic device is included in a radio frequency device module.

In some examples, the radio frequency device module is included in a radio frequency device.

In accordance with another aspect, there is provided a method of forming an electronic device. The method comprises forming a layer of piezoelectric material on a top surface of a carrier substrate, forming a back-side layer of material on a bottom surface of the carrier substrate, the back-side layer of material having a different coefficient of thermal

expansion than a coefficient of thermal expansion of the carrier substrate, and forming one or more acoustic wave devices including portions of the layer of piezoelectric material, the back-side layer of material causing the one or more acoustic wave devices to exhibit a near-zero difference in temperature coefficient of frequency at respective resonant and antiresonant frequencies, wherein the back-side layer of material has a temperature coefficient of frequency different than the temperature coefficient of frequency of the carrier substrate.

In some examples, the method further comprises forming a radio frequency filter from the one or more acoustic wave devices.

In some examples, the method further comprises forming a radio frequency device module including the radio frequency filter.

In some examples, the method further comprises forming a radio frequency electronic device including the 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 simplified plan view of an example of a surface acoustic wave resonator;

FIG. 1B is a simplified plan view of another example of a surface acoustic wave resonator;

FIG. 1C is a simplified plan view of another example of a surface acoustic wave resonator;

FIG. 2 is a cross-sectional view of a portion of a temperature compensated surface acoustic wave resonator having a multi-layer piezoelectric substrate;

FIG. 3 is a simplified cross-sectional diagram of a film bulk acoustic wave resonator;

FIG. 4 is a simplified cross-sectional diagram of a Lamb wave resonator;

FIG. 5 is a simplified cross-sectional diagram of a solidly mounted resonator;

FIG. 6 is a schematic diagram of a radio frequency ladder filter;

FIG. 7 illustrates an example of a multi-layer piezoelectric substrate for an acoustic wave device;

FIG. 8 illustrates strain in multi-layer piezoelectric substrates with different back-side layers at operating temperature;

CLAIMS

1. An electronic device comprising:

a multi-layer piezoelectric substrate including a carrier substrate, a layer of piezoelectric material disposed on a front side of the carrier substrate, and a back-side layer of material disposed on a rear side of the carrier substrate, the back-side layer of material having a coefficient of thermal expansion different than a coefficient of thermal expansion of the carrier substrate; and

one or more acoustic wave devices disposed on a front side of the multi-layer piezoelectric substrate, the one or more acoustic wave devices exhibiting a lesser difference in temperature coefficient of frequency at respective resonant and antiresonant frequencies than in a substantially similar device lacking the back-side layer of material, wherein the back-side layer of material has a temperature coefficient of frequency different than the temperature coefficient of frequency of the carrier substrate.

2. The electronic device of claim 1 wherein the one or more acoustic wave devices are included in an acoustic wave filter.

3. The electronic device of claim 1 wherein the one or more acoustic wave devices form a radio frequency filter.

4. The electronic device of one of claims 2 or 3 wherein the filter has a near-zero temperature coefficient of bandwidth.

5. The electronic device of claim 1 wherein the temperature coefficient of frequency at the resonant frequency of the one or more acoustic wave devices is substantially equal to the temperature coefficient of frequency at the antiresonant frequency of the one or more acoustic wave devices.

6. The electronic device of claim 1 wherein the one or more acoustic wave devices are surface acoustic wave devices.

7. The electronic device of claim 6 wherein the one or more acoustic wave devices are temperature compensated surface acoustic wave devices.

8. The electronic device of claim 1 wherein the one or more acoustic wave devices are bulk acoustic wave devices.

9. The electronic device of any of the above claims wherein the back-side layer of material comprises one of a dielectric or a metal.

10. The electronic device of any of claims 1-8 wherein the back-side layer of material comprises a piezoelectric material.

11. The electronic device of claim 10 wherein both the back-side layer of material and the layer of piezoelectric material comprise a same piezoelectric material.

12. The electronic device of claim 11 wherein the back-side layer of material and the layer of piezoelectric material have substantially a same thickness.

13. The electronic device of any of the above claims wherein the one or more acoustic wave devices have a near-zero delta temperature coefficient of frequency.

14. A radio frequency device module including the electronic device of claim 1.

15. A radio frequency device including the radio frequency device module of claim 14.

16. A method of forming an electronic device, the method comprising:

forming a layer of piezoelectric material on a top surface of a carrier substrate;

forming a back-side layer of material on a bottom surface of the carrier substrate, the back-side layer of material having a different coefficient of thermal expansion than a coefficient of thermal expansion of the carrier substrate; and

forming one or more acoustic wave devices including portions of the layer of piezoelectric material, the back-side layer of material causing the one or more acoustic wave devices to exhibit a near-zero difference in temperature coefficient of frequency at respective resonant and antiresonant frequencies, and wherein the back-side layer of material has a temperature coefficient of frequency different than the temperature coefficient of frequency of the carrier substrate.

17. The method of claim 17 further comprising forming a radio frequency filter from the one or more acoustic wave devices.

18. The method of claim 17 further comprising forming a radio frequency device module including the radio frequency filter of claim 18.

19. The method of claim 19 further comprising forming a radio frequency electronic device including the radio frequency device module of claim 19.