FREQUENCY CONTROL OF SPURIOUS SHEAR HORIZONTAL MODE BY ADDING HIGH VELOCITY LAYER IN A LITHIUM NIOBATE FILTER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Serial No. 62/684,330, titled FREQUENCY CONTROL OF SPURIOUS SHEAR HORIZONTAL MODE BY ADDING HIGH VELOCITY LAYER IN A LITHIUM NIOBATE FILTER, filed June 13, 2018 and to U.S. Provisional Patent Application Serial No. 62/693,027, titled FREQUENCY CONTROL OF SPURIOUS SHEAR HORIZONTAL MODE BY ADDING HIGH VELOCITY LAYER IN A LITHIUM NIOBATE FILTER, filed July 2, 2018. Each of these applications is incorporated herein by reference in its entirety.

BACKGROUND

In the field of information communication devices, for example, mobile phones, there is an increasing desire to include additional features within the device while also maintaining or reducing the space occupied by electronic circuitry of the device. Various information communication devices include filters to define frequency bands at which the devices transmit and receive signals. These filters may include surface acoustic wave elements formed on piezoelectric substrates. One method for reducing the size of such filters may include forming multiple surface acoustic wave elements for a filter in a single integrated circuit or multiple filters within a single integrated circuit.

SUMMARY

In accordance with an aspect disclosed herein, there is provided an electronic device. The electronic device comprising:a first surface acoustic wave (SAW) resonator and a second SAW resonator, each including interleaved interdigital transducer (IDT) electrodes, the first and second SAW resonators being formed on a same piezoelectric substrate, the first SAW resonator having IDT electrodes with a different finger pitch than the IDT electrodes of the second SAW resonator;a dielectric material layer disposed on the IDT electrodes of the first and second SAW resonators; anda high velocity layer disposed within the dielectric material layer disposed on the IDT electrodes of the first SAW resonator and within the dielectric material layer disposed on the IDT electrodes of the second SAW resonator, a normalized thickness of the high velocity layer within the dielectric film covering the IDT electrodes of the first SAW resonator being different from a normalized thickness of

the high velocity layer within the dielectric film covering IDT electrodes of the second SAW resonator. In another aspect, there is an electronic device comprising: a first filter and a second filter, each including surface acoustic wave (SAW) resonators disposed on a same piezoelectric substrate, the first filter having a passband different than a passband of the second filter;a dielectric film covering the SAW resonators of the first and second filters; and a high velocity layer disposed within the dielectric film covering the SAW resonators of the first filter and at least one of the SAW resonators of the second filter, the second filter including one or more SAW resonators lacking the high velocity layer, a normalized height of the high velocity layer within the dielectric film covering the SAW resonators of the first filter being different from a normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter. In another aspect, there is an electronic device comprising: a first surface acoustic wave (SAW) resonator and a second SAW resonator, each including interleaved interdigital transducer (IDT) electrodes, the first and second SAW resonators being formed on a same piezoelectric substrate, the first SAW resonator having IDT electrodes with a different finger pitch than the IDT electrodes of the second SAW resonator; a dielectric material layer disposed on the IDT electrodes of the first and second SAW resonators; and a high velocity layer disposed within the dielectric material layer disposed on the IDT electrodes of the first SAW resonator and within the dielectric material layer disposed on the IDT electrodes of the second SAW resonator, a normalized height of the high velocity layer within the dielectric film covering the IDT electrodes of the first SAW resonator being different from a normalized height of the high velocity layer within the dielectric film covering IDT electrodes of the second SAW resonatorThe electronic device comprises a first surface acoustic wave (SAW) resonator and a second SAW resonator, each including interleaved interdigital transducer (IDT) electrodes, the first and second SAW resonators being formed on a same piezoelectric substrate, the first SAW resonator having IDT electrodes with a different finger pitch than the IDT electrodes of the second SAW resonator, a dielectric material layer disposed on the IDT electrodes of the first and second SAW resonators, and a high velocity layer disposed within the dielectric material layer disposed on the

CLAIMS

What is claimed is:

1. An electronic device comprising:

a first surface acoustic wave (SAW) resonator and a second SAW resonator, each including interleaved interdigital transducer (IDT) electrodes, the first and second SAW resonators being formed on a same piezoelectric substrate, the first SAW resonator having IDT electrodes with a different finger pitch than the IDT electrodes of the second SAW resonator;

a dielectric material layer disposed on the IDT electrodes of the first and second SAW resonators; and

a high velocity layer disposed within the dielectric material layer disposed on the IDT electrodes of the first SAW resonator, the second SAW resonator lacking a high velocity layer disposed within the dielectric material layer disposed on the IDT electrodes.

2. The electronic device of claim 1 wherein the first SAW resonator exhibits a shear wave spurious mode having a resonance frequency above an anti-resonance frequency of a Rayleigh vibrational mode of the first SAW resonator.

3. The electronic device of claim 2 wherein the first and second SAW resonators are electrically coupled to one another and are included in a ladder filter including at least one series SAW resonator electrically coupled in series between an input port and an output port of the ladder filter and at least one parallel SAW resonator electrically connected between a terminal of the at least one series SAW resonator and ground.

4. The electronic device of claim 3 wherein the resonant frequency of the shear wave spurious mode occurs at a frequency outside a passband of the ladder filter.

5. The electronic device of claim 4 wherein a cut angle of the piezoelectric substrate and a thickness of the dielectric material layer relative to the finger pitch of the first SAW resonator are selected to minimize an intensity of a shear wave at the resonance frequency of the shear wave spurious mode.

6. The electronic device of claim 5 wherein the dielectric layer comprises silicon dioxide.

7. The electronic device of claim 6 wherein the high velocity layer comprises one or more of silicon nitride, silicon oxynitride, aluminum nitride, aluminum oxide, or diamond.

8. The electronic device of claim 7 wherein the dielectric layer of the first SAW resonator is split into an upper layer and a lower layer by the high velocity layer.

9. The electronic device of claim 8 wherein the high velocity layer is located between about 0% and about 40% of the thickness of the dielectric material above the IDT electrodes of the first SAW resonator.

10. The electronic device of claim 1 included in an electronic device module.

11. The electronic device of claim 10 wherein the electronic device module is a radio frequency device module.

12. An electronic device comprising:

a first filter and a second filter, each including surface acoustic wave (SAW) resonators disposed on a same piezoelectric substrate, the first filter having a passband different than a passband of the second filter;

a dielectric film covering the SAW resonators of the first and second filters; and

a high velocity layer disposed within the dielectric film covering the SAW resonators of the first filter, the second filter including one or more SAW resonators lacking the high velocity layer.

13. The electronic device of claim 12 wherein the dielectric film covering at least one of the SAW resonators of the first filter has a different thickness than the dielectric film covering at least one of the SAW resonators of the second filter.

~~14. The electronic device of claim 13 wherein a normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is different from the normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~15. The electronic device of claim 14 wherein the high velocity layer disposed within the dielectric film covering the at least one of the SAW resonators of the first filter has a same thickness as the high velocity layer disposed within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~16. The electronic device of claim 14 wherein the high velocity layer disposed within the dielectric film covering the at least one of the SAW resonators of the first filter has a different thickness than the high velocity layer disposed within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~17. The electronic device of claim 16 wherein a normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is the same as the normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~18. The electronic device of claim 12 wherein the dielectric film covering the SAW resonators of the first filter includes an upper portion disposed on an upper surface of the high velocity layer and a lower portion disposed between a lower surface of the high velocity layer and upper surfaces of interdigital transducer electrodes of at least one of the SAW resonators of the first filter.~~

~~19. The electronic device of claim 18 wherein a thickness of the lower portion of the dielectric film covering the at least one of the SAW resonators of the first filter has a different thickness than the lower portion of the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~20. The electronic device of claim 19 wherein a normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is the same as the normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~21. The electronic device of claim 20 wherein a normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is different than the normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~22. The electronic device of claim 18 wherein a thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter has a different thickness than the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~23. The electronic device of claim 22 wherein a normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is the same as the normalized thickness the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.~~

~~24. The electronic device of claim 12 wherein at least one of the first filter or the second filter is a ladder filter including a plurality of series resonators and a plurality of parallel resonators, the high velocity layer being disposed within the dielectric film covering at least one of the plurality of series resonators and at least one of the plurality of parallel resonators.~~

~~25. The electronic device of claim 12 wherein at least one of the first filter or the second filter is a multi-mode SAW filter.~~

~~26. The electronic device of claim 25 wherein at least one of the first filter or the second filter is a dual mode SAW filter.~~

~~27. The electronic device of claim 12 included in an electronic device module.~~

~~28. The electronic device of claim 27 wherein the electronic device module is a radio frequency device module.~~

~~29 A surface acoustic wave (SAW) resonator comprising:~~

~~an interleaved interdigital transducer (IDT) electrode;~~

~~a dielectric material layer disposed on the IDT electrode of the SAW resonator; and~~

~~a high velocity layer disposed within the dielectric material layer disposed on the IDT electrode of the SAW resonator.~~

~~30. The resonator of claim 29 wherein the high velocity layer has dimensions sufficient to cause a temperature coefficient of frequency of a resonant frequency of the SAW resonator to be shifted closer to zero as compared to a substantially similar SAW resonator lacking the high velocity layer.~~

~~31. The resonator of claim 29 wherein the IDT electrode includes a stack of at least two layers, each of the layers including a different material.~~

Claims

1. An electronic device comprising:

a first surface acoustic wave (SAW) resonator and a second SAW resonator, each including interleaved interdigital transducer (IDT) electrodes, the first and second SAW resonators being formed on a same piezoelectric substrate, the first SAW resonator having IDT electrodes with a different finger pitch than the IDT electrodes of the second SAW resonator;

a dielectric material layer disposed on the IDT electrodes of the first and second SAW resonators; and

a high velocity layer disposed within the dielectric material layer disposed on the IDT electrodes of the first SAW resonator and within the dielectric material layer disposed on the IDT electrodes of the second SAW resonator, a normalized thickness of the high velocity layer within the dielectric film covering the IDT electrodes of the first SAW resonator being different from a normalized thickness of the high velocity layer within the dielectric film covering IDT electrodes of the second SAW resonator.

2. The electronic device of claim 1 wherein the first SAW resonator exhibits a shear wave spurious mode having a resonance frequency above an anti-resonance frequency of a Rayleigh vibrational mode of the first SAW resonator.

3. The electronic device of claim 2 wherein the first and second SAW resonators are electrically coupled to one another and are included in a ladder filter including at least one series SAW resonator electrically coupled in series between an input port and an output port of the ladder filter and at least one parallel SAW resonator electrically connected between a terminal of the at least one series SAW resonator and ground.

4. The electronic device of claim 3 wherein the resonant frequency of the shear wave spurious mode occurs at a frequency outside a passband of the ladder filter.

5. The electronic device of claim 4 wherein a cut angle of the piezoelectric substrate and a thickness of the dielectric material layer relative to the finger pitch of the first SAW resonator are selected to minimize an intensity of a shear wave at the resonance frequency of the shear wave spurious mode.

6. The electronic device of claim 5 wherein the dielectric layer comprises silicon dioxide.

7. The electronic device of claim 6 wherein the high velocity layer comprises one or more of silicon nitride, silicon oxynitride, aluminum nitride, aluminum oxide, or diamond.

8. The electronic device of claim 7 wherein the dielectric layer of the first SAW resonator is split into an upper layer and a lower layer by the high velocity layer.

9. The electronic device of claim 8 wherein the high velocity layer is located between about 0% and about 40% of the thickness of the dielectric material above the IDT electrodes of the first SAW resonator.

10. The electronic device of claim 1 included in an electronic device module.

11. The electronic device of claim 10 wherein the electronic device module is a radio frequency device module.

12. An electronic device comprising:

a first filter and a second filter, each including surface acoustic wave (SAW) resonators disposed on a same piezoelectric substrate, the first filter having a passband different than a passband of the second filter;

a dielectric film covering the SAW resonators of the first and second filters; and

a high velocity layer disposed within the dielectric film covering the SAW resonators of the first filter and at least one of the SAW resonators of the second filter, the second filter including one or more SAW resonators lacking the high velocity layer, a normalized height of the high velocity layer within the dielectric film covering the SAW resonators of the first filter being different from a normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.

13. The electronic device of claim 12 wherein the dielectric film covering at least one of the SAW resonators of the first filter has a different thickness than the dielectric film covering at least one of the SAW resonators of the second filter.

14. The electronic device of claim 13 wherein the dielectric film covering the SAW resonators of the first filter includes an upper portion disposed on an upper surface of the high velocity layer and a lower portion disposed between a lower surface of the high velocity layer and upper surfaces of interdigital transducer electrodes of at least one of the SAW resonators of the first filter.

15. The electronic device of claim 14 wherein a thickness of the lower portion of the dielectric film covering the at least one of the SAW resonators of the first filter has a different thickness than a lower portion of the dielectric film covering the at least one of the SAW resonators of the second filter.

16. The electronic device of claim 15 wherein a normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is the same as the normalized height of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.

17. The electronic device of claim 16 wherein a normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is different than the normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.

18. The electronic device of claim 14 wherein a thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter has a different thickness than the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.

19. The electronic device of claim 18 wherein a normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is the same as the normalized thickness the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.

20. The electronic device of claim 12 wherein the high velocity layer disposed within the dielectric film covering at least one of the SAW resonators of the first filter has a different thickness than the high velocity layer disposed within the dielectric film covering the at least one of the SAW resonators of the second filter.

21. The electronic device of claim 20 wherein a normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the first filter is the same as the normalized thickness of the high velocity layer within the dielectric film covering the at least one of the SAW resonators of the second filter.

22. The electronic device of claim 12 wherein at least one of the first filter or the second filter is a multi-mode SAW filter.

23. The electronic device of claim 22 wherein at least one of the first filter or the second filter is a dual mode SAW filter.

24. The electronic device of claim 12 included in an electronic device module.

25. The electronic device of claim 24 wherein the electronic device module is a radio frequency device module.

26. The electronic device of claim 12 wherein the high velocity layer disposed within the dielectric film covering at least one of the SAW resonators of the first filter has a same thickness as the high velocity layer disposed within the dielectric film covering the at least one of the SAW resonators of the second filter.

27. The electronic device of claim 12 wherein at least one of the first filter or the second filter is a ladder filter including a plurality of series resonators and a plurality of parallel resonators, the high velocity layer being disposed within the dielectric film covering at least one of the plurality of series resonators and at least one of the plurality of parallel resonators.

28. An electronic device comprising:

a first surface acoustic wave (SAW) resonator and a second SAW resonator, each including interleaved interdigital transducer (IDT) electrodes, the first and second SAW resonators being formed on a same piezoelectric substrate, the first SAW resonator having IDT electrodes with a different finger pitch than the IDT electrodes of the second SAW resonator;

a dielectric material layer disposed on the IDT electrodes of the first and second SAW resonators; and

a high velocity layer disposed within the dielectric material layer disposed on the IDT electrodes of the first SAW resonator and within the dielectric material layer disposed on the IDT electrodes of the second SAW resonator, a normalized height of the high velocity layer within the dielectric film covering the IDT electrodes of the first SAW resonator being different from a normalized height of the high velocity layer within the dielectric film covering IDT electrodes of the second SAW resonator.

29. The electronic device of claim 28 wherein the dielectric film layer disposed on the IDT electrodes of the first SAW resonator has a different thickness than a thickness of the dielectric film layer disposed on the IDT electrodes of the second SAW resonator.

30. The electronic device of claim 29 wherein the high velocity layer is disposed within the dielectric material layer disposed on the IDT electrodes of the first SAW resonator at a same height as a height at which high velocity layer is disposed within the dielectric material layer disposed on the IDT electrodes of the second SAW resonator.

31. The electronic device of claim 28 wherein the dielectric film layer disposed on the IDT electrodes of the first SAW resonator has a different normalized thickness than a normalized thickness of the dielectric film layer disposed on the IDT electrodes of the second SAW resonator.