SUMMARY

[0005] The innovations described in the claims each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of the claims, some prominent features of this disclosure will now be briefly described.

[0005a] In an aspect, the present disclosure refers to a laterally excited bulk acoustic wave device comprising: a support substrate; a solid acoustic mirror on the support substrate; a piezoelectric layer on the solid acoustic mirror, the piezoelectric layer having a thickness between 0.2 micrometers to 0.4 micrometers; and an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode arranged to laterally excite a bulk acoustic wave.

[0005b] In another aspect, the present disclosure refers to an acoustic wave filter comprising: a laterally excited bulk acoustic wave resonator including a first solid acoustic mirror on a first substrate, a piezoelectric layer on the first solid acoustic mirror, and an interdigital transducer electrode on the piezoelectric layer, the piezoelectric layer having a thickness between 0.2 micrometers to 0.4 micrometers; and a plurality of acoustic wave resonators, the laterally excited bulk acoustic wave resonator and the plurality of acoustic wave resonators together configured to filter a radio frequency signal.

[0005c] In another aspect, the present disclosure refers to a radio frequency module comprising: an acoustic wave filter having a laterally excited bulk acoustic wave resonator and a plurality of acoustic wave resonators, the laterally excited bulk acoustic wave resonator including a first solid acoustic mirror on a first substrate, a piezoelectric layer on the first solid acoustic mirror, and an interdigital transducer electrode on the piezoelectric layer, the piezoelectric layer having a thickness between 0.2 micrometers to 0.4 micrometers; and a radio frequency circuit element coupled to the acoustic wave filter, the acoustic wave filter and the radio frequency circuit element being enclosed within a common package.

[0006] In one example, a laterally excited bulk acoustic wave device is disclosed. The laterally excited bulk acoustic wave device can include a support substrate, a solid acoustic mirror on the support substrate, a piezoelectric layer on the solid acoustic mirror, and an interdigital transducer electrode on the piezoelectric layer. The interdigital transducer

WHAT IS CLAIMED IS:

1. A laterally excited bulk acoustic wave device comprising:

a support substrate;

a solid acoustic mirror on the support substrate;

a piezoelectric layer on the solid acoustic mirror, the piezoelectric layer having a thickness between 0.2 micrometers to 0.4 micrometers; and

an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode arranged to laterally excite a bulk acoustic wave.

2. The laterally excited bulk acoustic wave device of claim 1 wherein the support substrate is arranged to increase heat dissipation of the laterally excited bulk acoustic wave device.

3. The laterally excited bulk acoustic wave device of claim 1 wherein heat associated with the bulk acoustic wave is arranged to flow through the solid acoustic mirror to the support substrate.

4. The laterally excited bulk acoustic wave device of claim 1 wherein the support substrate has a thermal conductivity that is higher than a thermal conductivity of the piezoelectric layer.

5. The laterally excited bulk acoustic wave device of claim 1 wherein the solid acoustic mirror is arranged to confine acoustic energy such that the support substrate is free from acoustic energy during operation of the laterally excited bulk acoustic wave device.

6. The laterally excited bulk acoustic wave device of claim 1 wherein the solid acoustic mirror is an acoustic Bragg reflector that includes alternating low impedance and high impedance layers.

7. The laterally excited bulk acoustic wave device of claim 6 wherein at least one of the low impedance layers and at least one of the high impedance layers are free from acoustic energy during operation of the laterally excited bulk acoustic wave device.

8. The laterally excited bulk acoustic wave device of claim 6 wherein the high impedance layers each have a thickness in arrange from 0.14 λ_p to 0.30 λ_p or from 0.35 λ_p to 0.45 λ_p, in which λ_p is a wave length of longitudinal wave velocity.

9. The laterally excited bulk acoustic wave device of claim 1 wherein the piezoelectric layer is an aluminum nitride layer.

10. The laterally excited bulk acoustic wave device of claim 1 wherein the piezoelectric layer is a lithium niobate layer or a lithium tantalate layer.

11. The laterally excited bulk acoustic wave device of claim 1 wherein the laterally exited bulk acoustic wave device has a resonant frequency in a range from 4.5 gigahertz to 10 gigahertz.

12. The laterally excited bulk acoustic wave device of claim 1 wherein the laterally exited bulk acoustic wave device has a resonant frequency in a range from 10 gigahertz to 25 gigahertz.

13. The laterally excited bulk acoustic wave device of claim 1 wherein the piezoelectric layer has the thickness in a range from 0.2 micrometers to 0.4 micrometers.

14. An acoustic wave filter comprising:

a laterally excited bulk acoustic wave resonator including a first solid acoustic mirror on a first substrate, a piezoelectric layer on the first solid acoustic mirror, and an interdigital transducer electrode on the piezoelectric layer, the piezoelectric layer having a thickness between 0.2 micrometers to 0.4 micrometers; and

a plurality of acoustic wave resonators, the laterally excited bulk acoustic wave resonator and the plurality of acoustic wave resonators together configured to filter a radio frequency signal.

15. The acoustic wave filter of claim 14 wherein the acoustic wave filter is a band pass filter.

16. The acoustic wave filter of claim 14 wherein the plurality of acoustic wave resonators include a second laterally excited bulk acoustic wave resonator.

17. The acoustic wave filter of claim 14 wherein the laterally excited bulk acoustic wave resonator has a resonant frequency in a range from 4.5 gigahertz to 25 gigahertz.

18. A radio frequency module comprising:

an acoustic wave filter having a laterally excited bulk acoustic wave resonator and a plurality of acoustic wave resonators, the laterally excited bulk acoustic wave resonator including a first solid acoustic mirror on a first substrate, a piezoelectric layer on the first solid acoustic mirror, and an interdigital transducer electrode on the piezoelectric layer, the piezoelectric layer having a thickness between 0.2 micrometers to 0.4 micrometers; and

a radio frequency circuit element coupled to the acoustic wave filter, the acoustic wave filter and the radio frequency circuit element being enclosed within a common package.

19. The radio frequency module of claim 18 wherein the radio frequency circuit element is a radio frequency amplifier arranged to amplify a radio frequency signal.

20. The radio frequency module of claim 19 where the radio frequency amplifier is a low noise amplifier or a power amplifier.