

Temperature Compensation in ZnO-based Surface Acoustic Wave Devices and Thin Film Bulk Acoustic Wave Devices

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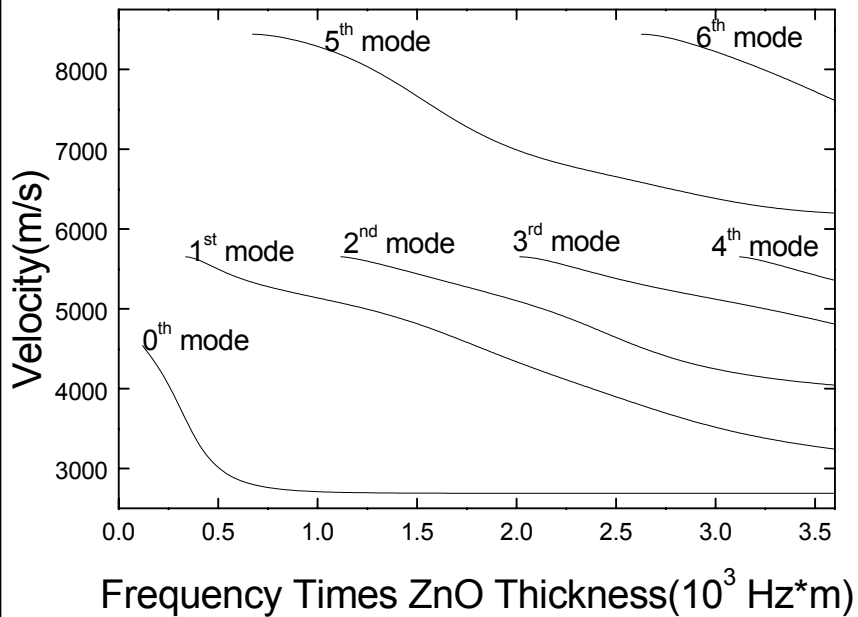
Temperature Compensation Techniques

- Special temperature compensated crystal cuts of piezoelectric substrates
- Examples: ST- and K-cut quartz, langasite (LGS), langanite (LGN), gallium phosphate.
- Multi-layer compensation utilizes materials with opposite signs of TCD to achieve temperature compensation at a specific frequency range.
- Examples: $\text{SiO}_2/\text{LiNbO}_3$, $\text{SiO}_2/\text{LiTaO}_3$, $\text{SiO}_2/\text{ZnO}/\text{diamond}/\text{Si}$.

Advantages of ZnO on SiO₂/Si

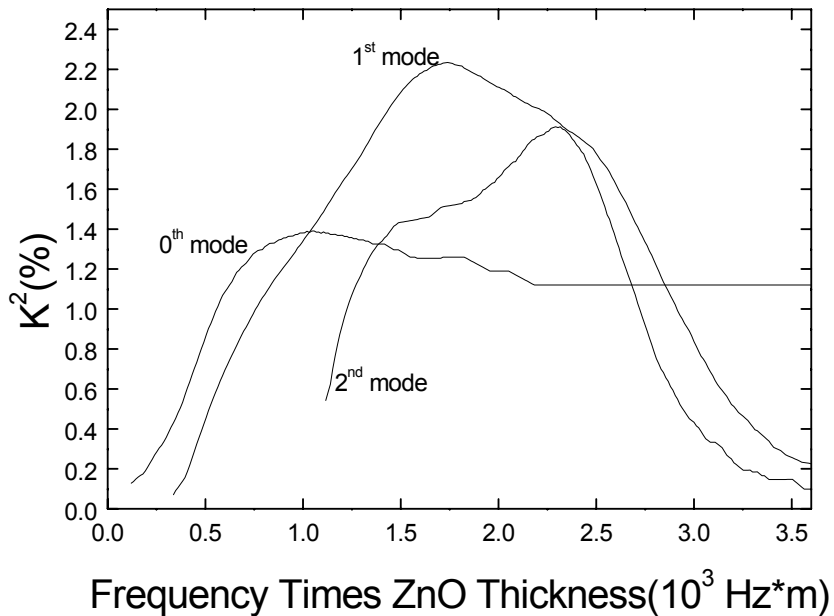
- Potential integration of SAW and BAW devices with Si electronic ICs.
- Temperature compensation possible:
 - ZnO and Si have positive TCD.
 - SiO₂ has negative TCD.
- Layered structure -> multiple generalized SAW wave propagate.

Velocity Dispersion



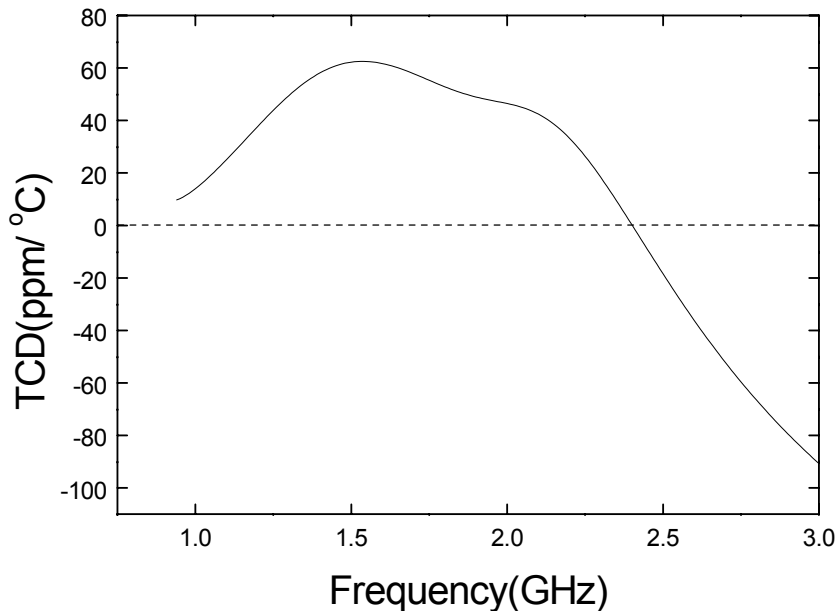
- Figure shows the velocity dispersion when ZnO:SiO₂ thickness ratio is 2:3 and total film thickness is 3 μm . The 2nd GSAW mode has phase velocity of 4315 m/s at 2.4GHz.

Electromechanical Coupling Coefficients



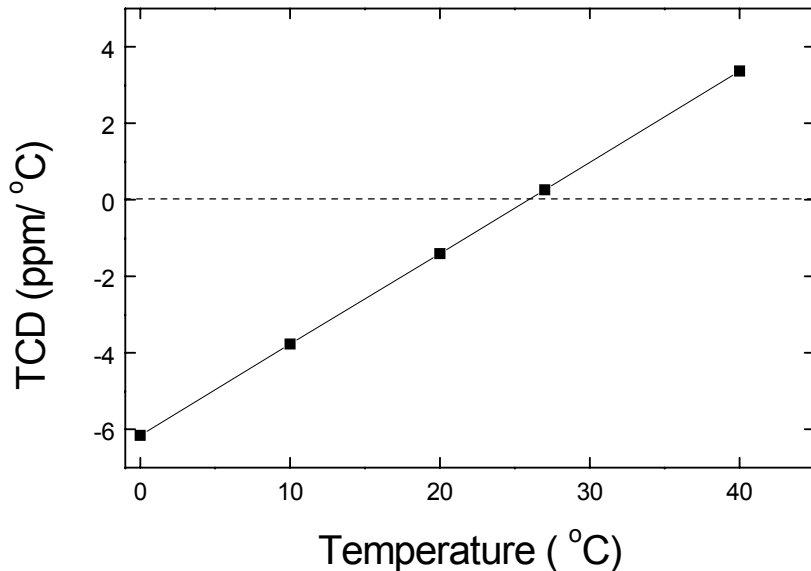
- Figure shows the electromechanical coupling coefficients when ZnO:SiO₂ thickness ratio is 2:3 and total film thickness is 3 μm . The 2nd GSAW mode has K^2 of 1.2% at 2.4GHz

TCD Versus Frequency



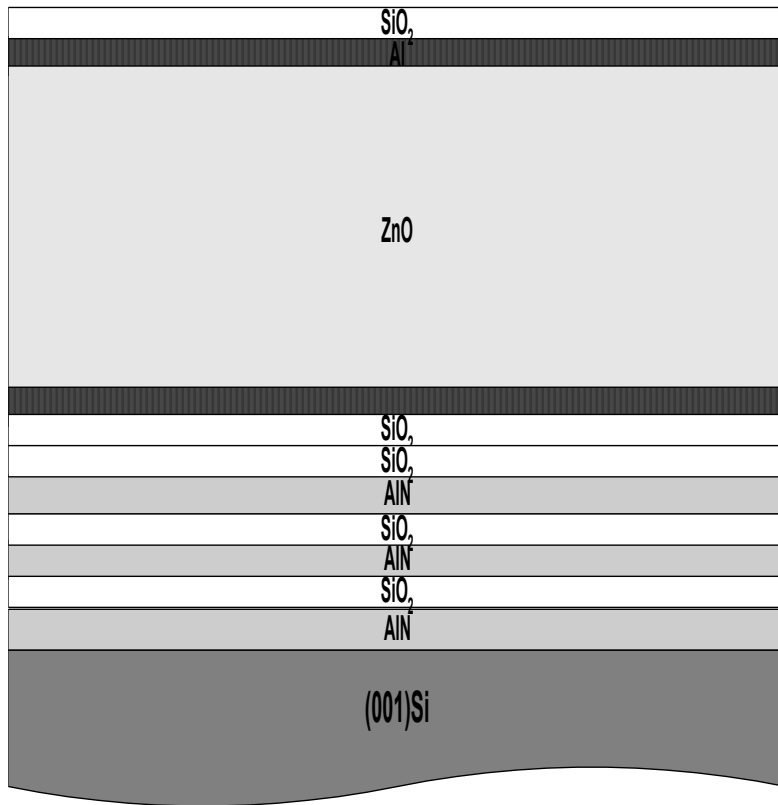
- Figure shows the TCD calculated at 27 °C versus frequency when ZnO:SiO₂ thickness ratio is 2:3 and total film thickness is 3 μ m.
- TCD value at around 2.4 GHz with TCD is as low as 0.2597 ppm/ °C.

TCD Versus Temperature



- Figure shows TCD calculated versus temperature at 2.4GHz when ZnO:SiO₂ thickness ratio is 2:3 and total film thickness is 3 μ m.
- TCD has linear relationship with respect to temperature. Conclusion for SAW part.

Advantages & Applications of Bulk Acoustic Wave (BAW) Resonator & Filter

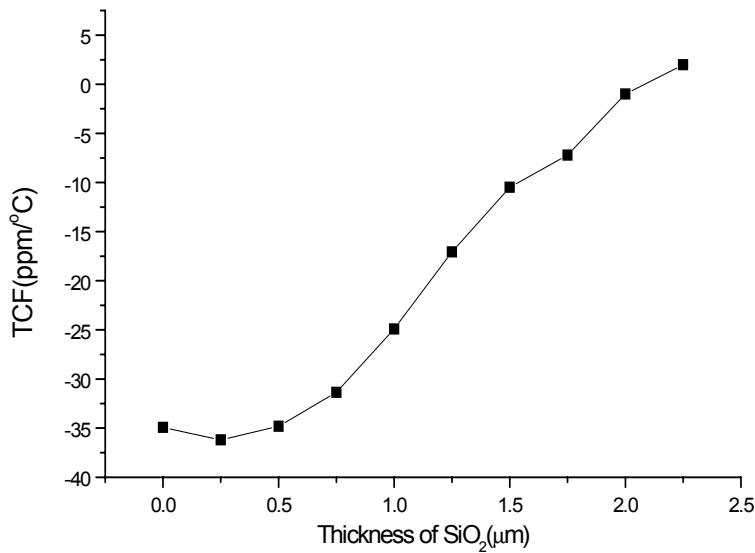


- BAW resonators and filters can work from 500MHz to 10GHz with low insertion loss. It can be integrated with other circuits on Si wafer.
- BAW resonators & filters can be used in wireless communication and radar system. BAW resonator is a basic structure of BAW sensors.

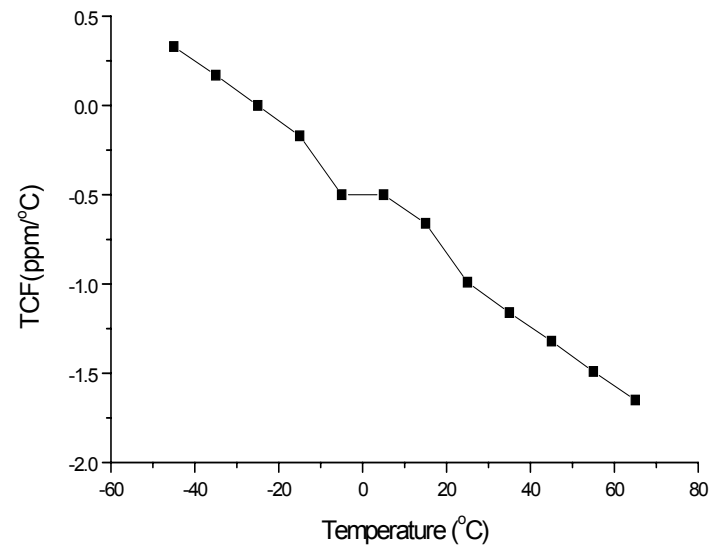
Temperature Compensated BAW Resonator

- For oscillator and narrow fraction bandwidth filter, temperature coefficient of frequency (TCF) is very important.
- For BAW sensor for detecting gas and fluid materials, low TCF is required.

Structure: Al(1000A)/ZnO(2micron)/Au(1000A)/Mirror(6 pairs)/Si(50micron)



Structure: Al(1000A)/ZnO(2micron)/Au(1000A)/Mirror(6 pairs)/Si(50micron)



Conclusion

- **For SAW devices**

1. The simulations using the transfer matrix method show that temperature compensation for the 2nd order generalized SAW mode at 2.4 GHz when ZnO:SiO₂ thickness ratio is 2:3 and total film thickness is 3 μ m.
2. The results provide the feasibility of proper design of the SAW multilayer structures with a SiO₂ layer to achieve temperature compensation in the GHz range

- **For BAW devices**

1. when the thickness ratio of SiO₂ over ZnO is equal to 1, TCF reaches about 0 ppm/°C.
2. In the temperature range of -50°C to 65°C, TCF varies from 0.3 to -1.75ppm/°C.