The focus of this work is to design and implement resonators for ultra-stable high-frequency silicon-based MEMS oscillators. Specifically, two novel types of resonators are introduced that push the performance of silicon-based MEMS resonators to new limits. Oscillator stability is dependent on the resonator quality factor and temperature coefficient of frequency. Thin film Piezoelectric-on-Silicon (TPoS) resonators have been shown to be suitable for oscillator applications due to their combined high quality factor, coupling efficiency, power handling and doping-dependent temperature-frequency behavior. This thesis is an attempt to utilize the TPoS platform and optimize it for extremely stable high-frequency oscillator applications.

To achieve the said objective, two main research venues are explored. Firstly, quality factor is systematically studied and anisotropy of single crystalline silicon (SCS) is exploited to enable high-quality factor side-supported radial-mode (aka breathing mode) thin-film piezoelectric-on-substrate (TPoS) disc resonators through minimization of anchor-loss. It is demonstrated that the displacement of the disc periphery is not uniform for the radial-mode in SCS discs. It is then experimentally demonstrated that in TPoS disc resonators with tethers aligned to [100], unloaded quality factor improves from ~450 for the second harmonic mode at 43 MHz to ~11,500 for the eighth harmonic mode at 196 MHz.

Secondly, thickness quasi-Lamé modes are studied and demonstrated in TPoS resonators for the first time. It is shown that thickness quasi-Lamé modes (TQLM) could be efficiently excited in silicon with very high quality factor (Q). A quality factor of 23.2 k is measured in partial vacuum at 185 MHz for a fundamental TQLM-TPoS resonators designed within a circular acoustic isolation frame. Quality factor of 12.6 k and 6 k are also measured for the second- and third-order harmonic TQLM TPoS resonators at 366 MHz and 555 MHz respectively. Turn-over temperatures between 40 °C to 125 °C are also designed and measured for TQLM TPoS resonators fabricated on degenerately-doped n-type silicon substrates. The reported extremely high quality factor, very low motional resistance, and tunable turn-over temperatures >80 °C make these resonators a great candidate for ultra-stable oven-controlled high-frequency MEMS oscillators.

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The public is welcome to attend.