The focus of this work is to study nonlinear behavior in silicon-based micro-resonators and more specifically develop models that could predict acceleration sensitivity and amplitude-frequency nonlinearity in such resonators. Acceleration sensitivity in silicon bulk acoustic wave (BAW) oscillators is studied and a correlation between the resonator alignment to different crystalline planes of silicon and the observed acceleration sensitivity is established. It is shown both with experiment and the proposed finite element model, that the oscillator vibration sensitivity is significantly lower when the silicon-based lateral extensional (LE) mode resonator is aligned to <110> orientation compared to when the same resonator is aligned to <100>.

Amplitude-frequency nonlinearity is the other subject of study in this dissertation. It is postulated that despite the common belief in literature, the third-order elastic coefficients may not be adequate to explain the nonlinear elastic behavior of silicon micro-resonators. The focus is specifically on nonlinearity of degenerately n-type doped LE mode resonators aligned to <100> plane in which spring-hardening effect is observed. It is shown that the existing analytical/numerical calculations and the proposed three-dimensional finite element model, that are based on utilization of third-order elastic coefficients, will all predict spring-softening in such resonators, thus suggesting insufficiency of the nonlinear model. We believe this discrepancy between theory and experiment is due to ignoring higher order elastic nonlinearities of silicon.

As the third project explored in this work, BAW resonators aligned to non-major crystalline planes were designed and fabricated with motivation of reducing amplitude-frequency nonlinearity. Experimental results show high quality factor and low insertion loss for the proposed LE devices aligned to 22.5° off <100>/<110> confirming the efficiency of the design. In addition, it is shown that these devices fabricated on highly n-type doped silicon show significant improvement in amplitude-frequency nonlinearity compared to the same designs aligned to <100> and <110> planes.

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Approved for distribution by Reza Abdolvand, Committee Chair, on June 17, 2019.

The public is welcome to attend.