Efficient Anchor Design for Quality Factor Enhancement in a Silicon Nitride-on-Silicon Lateral Bulk Mode Resonator

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Abstract

Introduction: The development of on-chip high frequency micromechanical resonators for frequency and timing applications as a replacement for quartz crystals warrants comparable performance in terms of metrics notably, the Quality Factor. Anchor loss is one of the major loss mechanisms that causes a reduction in the quality factor of high frequency micromechanical resonators. This study illustrates the importance of anchor design in mitigating anchor loss in high frequency resonators. The performances of two different anchor configurations for a silicon nitride-on-silicon lateral mode bar resonator have been compared using simulations performed in COMSOL Multiphysics®.

Use of COMSOL Multiphysics: Finite element method was used to model the resonator and the simulations were carried out using the Structural Mechanics Module of COMSOL. Eigenfrequency and Frequency Domain Analysis were performed on the two types of resonator configurations in order to obtain the mode shape as shown in Figure 1 and the frequency response. For the purposes of anchor loss study the simulations were performed using sections of the structures rather than the entire structures and symmetry boundary conditions were applied to the respective edges. Perfectly Matched Layers (PMLs) were employed (as shown in Figure 2) to model the energy lost into the substrate.

Results: Performances of the two designs were compared using two metrics namely Stored Energy Density which is the volume average of the elastic strain energy density within the resonator volume, and the Leaky Power that denotes the flux of mechanical energy from the anchors to the substrate, both of which are measures of the energy retaining capability of the resonators. These two metrics directly influence the Quality Factor. The obtained Stored Energy Density for the first design is 9.025×10-4 J/m3, and for the second design is 188.9×10-4. The Leaky Power obtained was 0.37545 W/m2 for the first design and 0.13406 W/m2 for the second. Thus, the efficiency of the second design as compared to the first has been demonstrated.

Conclusion: Two different anchor configurations of the lateral bulk mode resonator were compared for anchor losses. Less power is leaked through the anchors into the substrate in the second design which means a higher quality factor for the MEMS resonator.

Reference

1. Sunil A. Bhave, Roger T. Howe , "Silicon Nitride-on-Silicon bar resonator using Internal Electrostatic Transduction", The 13th International Conference on Solid-State Sensors, Actuators and Microsystems, Seoul, Korea, June 5-9, 2005.
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Figures used in the abstract

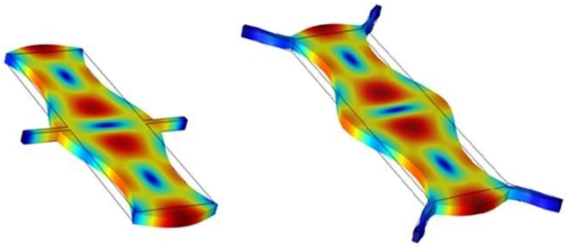

Figure 1: Mode shapes for the two anchor configurations corresponding to a frequency of 118.5MHz

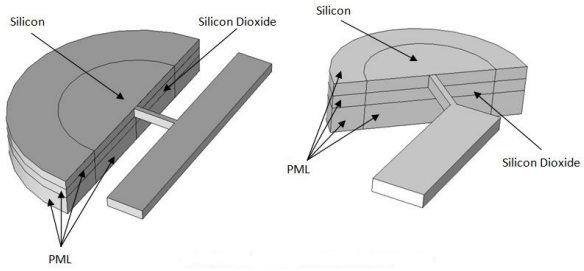

Figure 2: Material arrangement in the resonant structures