Modeling and Simulation of Mechanically Coupled MEMS Resonators Using COMSOL Multiphysics®

J. Wiswell[1], M. Guvench[1]

[1]University of Southern Maine, Gorham, ME, USA

Abstract

Introduction: In this project, COMSOL Multiphysics® and SolidWorks® are employed to model and simulate a mechanically coupled MEMS resonator with varying masses. These resonators consist of three main components: springs on each end to allow the structure to move, a shuttle mass for loading the structure, and electrode fingers attached to the shuttle mass to electrically detect resonance. The long beams connecting the two resonators have tethers attached to drive the device. Due to the complexity of a thermally driven resonator, a prescribed displacement was applied in the simulation.
The 3D resonator structure was created in SolidWorks®, exported as a parasolid, and then imported into COMSOL Multiphysics®. The units used by SolidWorks® are inches, which had to be converted to micrometers once the structure was imported into COMSOL Multiphysics®. The structure was then scaled and exported as a mphbin file for further simulation. In the simulation, the structure was fixed by the four outer corners of the springs, and a prescribed displacement was exerted at the tethers attached to the mechanical coupling beams.

Use of COMSOL Multiphysics: Due to the complexity and expense of fabrication of MEMS devices, COMSOL Multiphysics® was a critical part of this project. COMSOL Multiphysics® allowed us to evaluate the performance of the device with a variety of loading masses, providing detailed information about resonator response under varying frequency inputs. The software facilitated the simulation of this structure for a variety of masses. The Eigenfrequency study significantly reduced the simulation time from a several hours to a few minutes. The results produced by COMSOL Multiphysics® were determined to be an invaluable asset for testing the actual device.

Results: The simulations showed two resonant frequencies for this resonator. The first for the gold loaded side was 30.68kHz, and the second for the non loaded side was 33.00kHz. The simulation showed that the two resonators resonated at at each other's resonant frequencies. However, the total displacement of the resonators at the opposite resonator's resonant frequency showed half as much displacement as the other side. Since both resonators resonate at both frequencies, the device needed to be probed only once to detect both of the resonant frequencies. COMSOL Multiphysics® was an invaluable asset for this project.

Conclusion: COMSOL Multiphysics® was utilized in simulating a series of mechanically-coupled resonators. The simulation showed that the two mechanically-coupled resonators

resonated at both frequencies, requiring only one of the resonators' outputs to be probed during physical testing. The frequency sweep simulation in COMSOL Multiphysics® produced a very accurate and useful result; however, these simulations often took days to complete, and the default probe output produced misleading results. The Eigen frequencies were determined to be mostly accurate and are expected to provide a starting point for a more accurate simulation result. The gold device used in the simulation was also fabricated, and the results produced by COMSOL Multiphysics® were determined to be a good representation of how the actual device behaves.

Figures used in the abstract

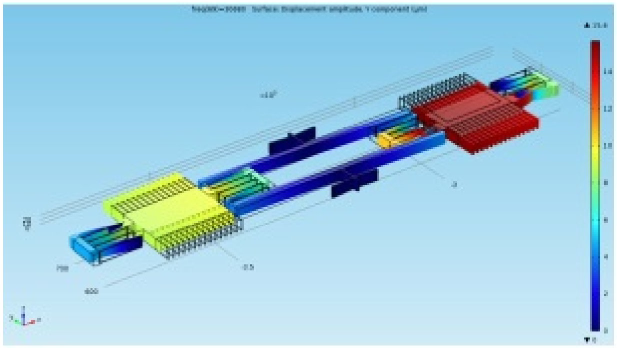

Figure 1: Mechanically Coupled Resonators Displacement Graph at loaded sides resonant frequency.