Determination of the Fundamental Resonant Modes of a Polysilicon H-Beam Using COMSOL Multiphysics® Software

T. Thomas[1], M. Sundaram[1], R. Bejgam[1]

[1]BITS, Pilani Campus, Vidya Vihar, Pilani, Rajasthan, India

Abstract

A Polysilicon H-beam is a micro-machined structure consisting of two primary members connected by a third member of much lower width and much greater aspect ratio. This structure exhibits interesting vibration behavior at specific frequencies which are known as resonant modes. A 'mode' may be described as a specific physical shape that the vibrating object assumes at peak oscillation amplitude for a particular resonant frequency. The study of these resonant modes is of great significance in the field of MEMS based electronics as MEMS devices can attain high Q-factor and consequently great frequency selectivity and stability. This project involves the simulation of a Polysilicon structure composed of two beams that are separated by a connecting member in order to determine the principle resonant frequencies and corresponding oscillatory modes.

COMSOL Multiphysics® software was used to simulate the vibration of the structure. Eigen-frequency analysis was done using the Structural Mechanics module. The dimensions of the two primary members is 12 µm x 2.75µm x 2µm, the values of the material properties are taken for the COMSOL Multiphysics® Materials Library module as E = 160e9[Pa], nu = 0.22, ρ = 2320[kg/m^3]. The interfaces of the Polysilicon structure with the Silicon Nitride substrate are treated as fixed constraints as well as the SiN substrate itself. The Polysilicon/SiN interfaces at the four anchor points are 1µm x 2.75µm in cross sectional area. The mesh was taken as free tetrahedral elements, and extra fine (see fig 1). The structure after completion of modeling, meshing and simulation are shown in fig 2 . The number of elements is 10799 and degrees of freedom solved for is 53754.Solution time was 31 seconds.

The first 6 resonant modes frequencies of the structure calculated by COMSOL® simulation are shown below:-
76.43MHz
100.20 MHz
101.95 MHz
118.58 MHz
131.76 MHz
170.18 MHz

Of particular interest are the second and third resonant frequencies: they display symmetric and antisymmetric oscillation as shown in fig 3 and fig 4.

The ability of COMSOL Multiphysics® to simulate complex structural geometries is demonstrated. Future enhancements will include more detailed analysis of adhesive and electrostrictive interaction at the Polysilicon-SiN interface.

Reference

1) K. Wang , C. Nguyen " High Order Medium Frequency Micromechanical Electronic Filters.",1999, IEEE J. Micromechanical Syst. , vol 8, pp. 534-556
2) F.D. Bannon, J.R. Clark and C.T.C Nguyen, 2000, "High-Q Micromechanical Filters", IEEE J. Solid State Circuits, vol 35, pp 512-526
3) A. San Paulo, et. al., 2007 "Suspended Mechanical Structures Based on Elastic Silicon Nanowire Arrays", Nano Letters, volt.7, no. 4. pp. 1100-1104,
4) N. Arellano et al, 2007. Silicon Nanowire Coupled Microresonators, IEEE J
5) Y. Zhao et al, 2008, Simulation and fabrication of SiC based clamped-clamped filter
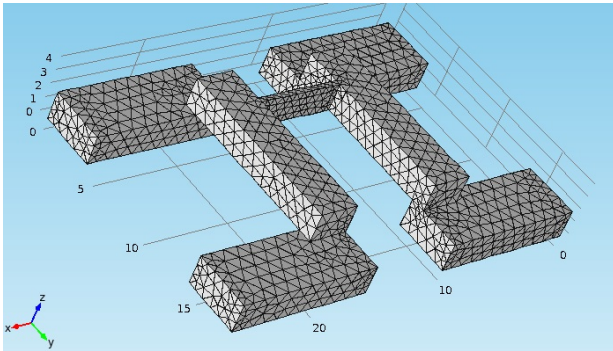
Figures used in the abstract

Figure 1: Structure after applying an extra fine free tetrahedral mesh.
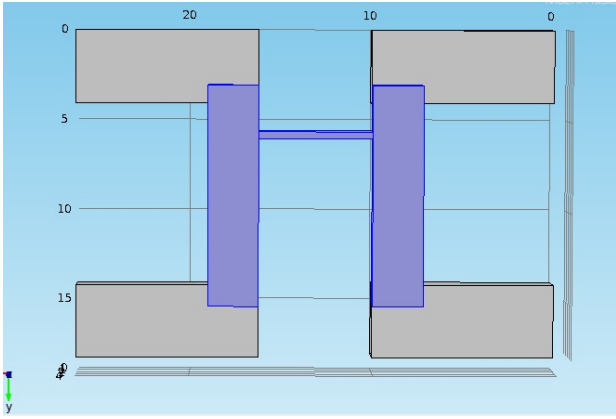
Figure 2: Structure after Material assignment, modeling and meshing are completed.
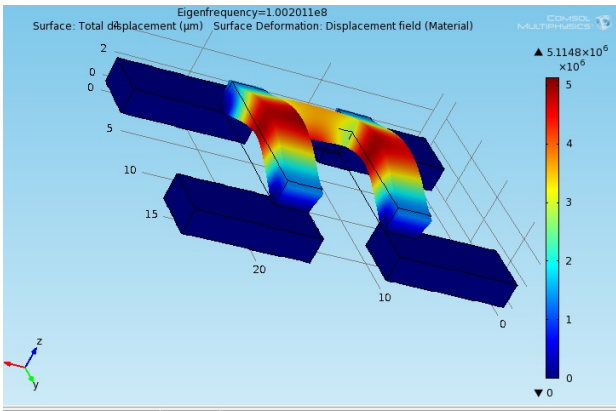

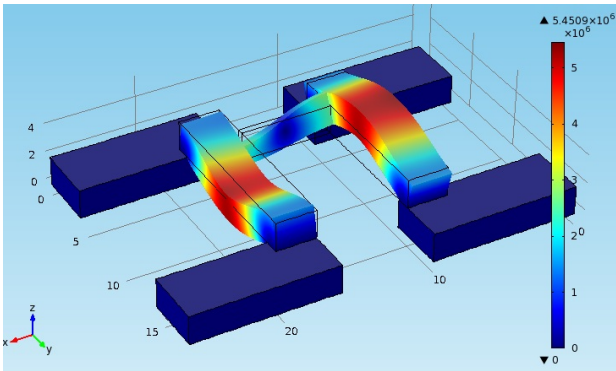**Figure 3**: Second Eigen frequency, showing symmetric oscillation.

Figure 4: Third Eigen frequency, showing anti-symmetric oscillation.