

Frequency Tuning of Micro-Electro-Mechanical Devices

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by

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Abstract

In this thesis, a non-destructive way of actively changing the natural frequency of the elastic structure of microelectromechanical devices using an electrostatic pull-in procedure to change the supporting conditions and the vibrating length of the structure was explored.

Variations in micromachining processes cause submicron differences in the size of fabricated microelectromechanical devices, which lead to frequency variations in microresonators. For radio frequency applications where high frequency selectivity and low-noise frequency manipulation are key performance issues, micromachined resonators need to output a fixed frequency to replace current off-chip, passive mechanical resonators used for frequency selection in super-heterodyne transceivers of wireless systems. Additionally in microgyroscopes, there is a need to match the resonant frequency of the driving and detecting modes to improve the functionality and detection sensitivity. This motivates the investigation of post-fabrication techniques that compensate for fabrication defects and errors, and shift the resonant frequency to its designed value. Unlike previously reported frequency tuning methods that depended on stiffness or mass change of the vibrating mechanical structure, large frequency shifts were achieved in this work using length change.

A universal analytical model was developed using variational methods to identify the different states of static deflection of a cantilever during electrostatic pull-in, and to predict the proportional change in frequency of free vibration with applied voltage after the final stable state. A prototype consisting of an array of gold-electroplated cantilevers designed to verify the theoretical findings was fabricated in a three-mask surface silicon micromachining process. Laser-doppler vibrometry experiments on the shortest (nominal length of $390\mu\text{m}$) and longest (nominal length of $1490\mu\text{m}$) cantilevers resulted in a frequency shift of 254.49Hz/V and 224.45Hz/V respectively. The gap between the top and bottom electrodes being larger than designed was the major cause of the discrepancy between the experimental and theoretical results.