Size dependent and material structure coupling effects on the dynamics of nanocrystalline arc resonators

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Abstract. The adequate modeling of the dynamic of the micro/nano arc resonators is vital for their successful implementation. In this work, the couple stress theory is combined with the classical Euler-Bernoulli beam model to derive a size-dependent model in which the micro-rotation effects of the grain is considered, aiming to characterize the frequency tunability of a micro/nano arc resonators as monitoring either the axial load or the electrostatic force. The arc dimensions are optimized to be able to show various phenomena in the same arc: crossing, veering, and snap-through. The variation of the three lowest natural frequencies is monitored, showing the influence of the size effect on the frequency tuning and the pull-in instability as the scale shrinks from micro- to nano-scale. The simulation results show significant changes in the static pull-in voltage and the natural frequencies as the scale of the system is shrunk.

Introduction

Arc resonators have been the center of focus for several applications, such as sensing and filtering. Arc resonators at the micro- and nano-scale can be manufactured by intentional fabrication. The work previously done in this topic was carried out at the micro-scale where the classical continuum theories of materials science are applicable. However, due to the intensive decrease in size to the micro- and nano-scale, these theories may no longer apply since they lack the suitable length scales that can capture the size-dependent behavior at the micro/nano-scale. Therefore, to account for the size-dependent behavior, the couple stress theory is used [1]. The phenomena of frequency crossing [2], veering [2], and snap-through [3] have long attracted attention in the classical structural dynamics. In this work, the aim is to study analytically the effects of shrinking the arc resonator from micro to nano scale as well as characterize their frequency tenability and nonlinear behaviors. To do so, the micro/nano arc dimensions are optimized to be able to show several phenomena in the same arc: crossing, veering, and snap-through. Also, to enhance the activation of symmetric and anti-symmetric modes, the arc resonators is electrostatically actuated using a partial electrode configuration [2].

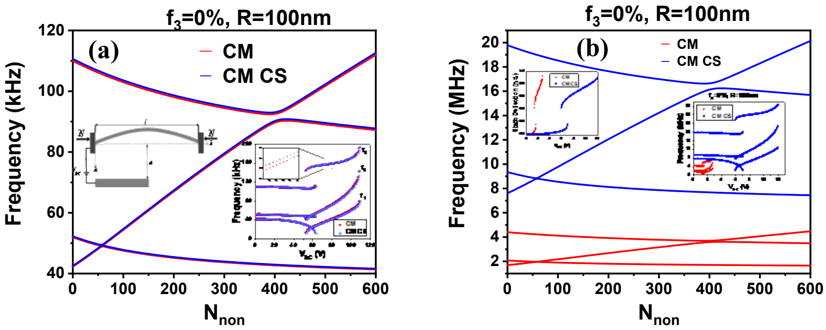

Figure 1: Impacts of the size dependency and material structure on the coupled frequencies when subjected to axial load and electrostatic force (the insets). (a)MEMS scale. (b) NEMS scale.

Results and Discussion

As shown in Figure 1, the variations of the first three frequencies with respect to the axial load are shown for micro- and nano-scale, respectively. Clearly, the couple stress size dependent effect has a negligible effect on the frequencies of the system at the micro-scale. This is expected because the couple stress effect should be more pronounced at smaller scales. On the other hand, when the system is shrunk down to nano-scale, it is obvious that the size dependent effects take place. It should be mentioned that the general trend of the frequencies variations is similar with considering the differences in the increase in the frequencies due to the stiffening effect. These preliminary results show the importance of accurately modeling micro/nano arc resonators. In the final version of this conference paper, the material structure effects and their coupling with size dependency will be investigated on the coupled frequencies, crossing/veering, as well as their nonlinear responses and possible broadband resonances.

References

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