Nanomechanical Devices Vibrating at Microwave Frequencies in Simple Liquids

Authors : Debadi Chakraborty, John E. Sader

Abstract : Nanomechanical devices have emerged as a versatile platform for a host of applications due to their extreme sensitivity to environmental conditions. For example, mass measurements with sensitivity at the atomic level have recently been demonstrated. Ultrafast laser spectroscopy coherently excite the vibrational modes of metal nanoparticles and permits precise measurement of the vibration characteristics as a function of nanoparticle shape, size and surrounding environment. This study reports that the vibration of metal nanoparticles in simple liquids, like water and glycerol are not described by conventional fluid mechanics, i.e., Navier Stokes equations. The intrinsic molecular relaxation processes in the surrounding liquid are found to have a profound effect on the fluid-structure interaction of mechanical devices at nanometre scales. Theoretical models have been developed based on the non-Newtonian viscoelastic fluid-structure interaction theory to investigate the vibration of nanoparticles immersed in simple fluids. The utility of this theoretical framework is demonstrated by comparison to measurements on single nanowires and ensembles of metal rods. This study provides a rigorous foundation for the use of metal nanoparticles as ultrasensitive mechanical sensors in fluid and opens a new paradigm for understanding extremely high frequency fluid mechanics, nanoscale sensing technologies, and biophysical processes.

Keywords : fluid-structure interaction, nanoparticle vibration, ultrafast laser spectroscopy, viscoelastic damping
Conference Title : ICFMT 2016 : International Conference on Fluid Mechanics and Thermodynamics
Conference Location : New York, United States
Conference Dates : June 06-07, 2016