MEMS and NEMS Technical Group
Room C120-122 - Session MN2-WeM

Nanomechanics

Moderators: Vikrant Gokhale, US Naval Research Laboratory, **Robert Roberts**, The University of Texas at El Paso

11:00am **MN2-WeM-10 Spatial Mapping and Analysis of Graphene Nanomechanical Resonator Networks***, **Benjamín Alemán**,* University of Oregon **INVITED**

Networks of nanoelectromechanical (NEMS) resonators are useful analogs for a variety of many-body systems and enable disruptive applications in sensing, phononics, and mechanical information processing. A challenge toward realizing practical NEMS networks is the ability to characterize the constituent resonator building blocks and their coupling. In this work, we demonstrate a scalable optical technique to spatially map graphene NEMS networks and read out the fixed-frequency collective response as a single vector. Using the response vectors, we introduce an efficient algebraic approach to accurately quantify the site-specific elasticity, mass, damping, and coupling parameters of network clusters. In a departure from multiple regression, our algebraic analysis uses just two measured response vectors to fully characterize the network parameters, and does so without any a priori parameter estimates or iterative computation. We apply this suite of techniques to single-resonator and coupled-pair clusters, and find excellent agreement with expected parameter values and broader spectral response. Our approach offers a new, non-regressive means to accurately characterize a range of classical and quantum resonator systems and fills in a vital gap for programming NEMS networks.

11:40am **MN2-WeM-12 Nonlinear Stiffness and Nonlinear Damping in Atomically Thin MoS_2 Nanomechanical Resonators***, **Tahmid Kaisar**,* University of Florida, Gainesville*; J. Lee,* University of Texas at El Paso*; D. Li, S. W. Shaw,* Florida Institute of Technology*; P. Feng,* University of Florida, Gainesville

Resonant micro/nanoelectromechanical systems (MEMS/NEMS) exhibits rich nonlinear responses because of their relatively small size and high vibration amplitude [1]. In this work, we provide experimental results and a quantitative study of nonlinear dynamics in atomically-thin nanomechanical resonators made of single-layer, bi-layer, and tri-layer (1L, 2L, and 3L) molybdenum disulfide (MoS_2) vibrating drumheads. For these two-dimensional (2D) MoS_2 resonators operating in the very high-frequency band, a synergistic study with calibrated measurements and analytical modeling on the observed nonlinear responses have resulted in nonlinear damping and cubic and quintic order nonlinear stiffness. We find that the *quintic* force can be ~20% of the Duffing force at larger amplitudes, and thus it generally cannot be ignored in a nonlinear dynamics analysis. Though the nonlinear stiffness of 2D NEMS has been studied in literature, to date, there has been no experimental demonstration and investigation of nonlinear damping in 2D semiconductor NEMS resonators. This study provides the first quantification of nonlinear damping and frequency detuning characteristics in 2D semiconductor nanomechanical resonators and elucidates their origins and dependency on engineerable parameters, setting a foundation for future exploration and utilization of the rich nonlinear dynamics in 2D nanomechanical systems.

[1] Cross, M.C.; Lifshitz, R. In *Review of Nonlinear Dynamics and Complexity*; Schuster, H., Ed.; Wiley: New York, **2008**; Chapter 1.

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