Nanoscale Electromechanical Sensors and their Emerging Applications

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Nanoscale devices with mechanical degrees of freedom offer compelling characteristics that make them not only interesting tools for fundamental studies, but also intriguing candidates for technological applications. In particular, nanoelectromechanical systems (NEMS) *vibrating* in their *resonant* modes provide promising opportunities and comparative advantages for developing novel transducers and sensors, in the previously inaccessible regimes. In fundamental physics, recently there have been considerable interests and intensive efforts in exploiting high-frequency NEMS for quantum measurements. In technology development, significant milestones have been achieved using prototypical devices and systems, and rapid progresses are currently being made in both static and resonant sensing; plus new applications are emerging. At the interface between understanding fundamentals and creating practical technologies, there are challenges and also enormous opportunities for *engineering* NEMS sensors and exploring their ultimate limits.

This tutorial will give an introduction to fundamentals of NEMS sensors and an overview of recent efforts in engineering nanoscale electromechanical devices for sensors in physical sciences. After discussing the basic concepts and fundamental aspects of such devices, I shall introduce prototypes of devices enabled by the state-of-the-art nanofabrication techniques (including both top-down and bottom-up approaches) and advanced materials. I will then mainly focus on fundamental principles and technological advances in NEMS sensors for ultrasensitive detection of force, displacement, mass, temperature, and other physical quantities, along with the best achieved sensitivities and ultimate limits. Representative examples of resonant sensing and high-speed, high-precision operations in these physical domains will be featured. Finally, I will review and highlight some latest efforts on integrating ultrasensitive NEMS sensors into today's systems-on-chip and other mainstream technologies.

Short Bio

Philip Feng is currently an Assistant Professor in Electrical Engineering at Case. His research is primarily focused upon nanoscale devices and systems, particularly nanoscale sensors and transducers that involve advanced materials and solid-state integrated circuits. Prior to joining the faculty at Case, during 2007-2010, Feng was at the Kavli Nanoscience Institute, Caltech, where he served as a Staff Scientist, Project Leader, and a Co-Principal Investigator. He earned a Ph.D. from Caltech in 2006. He has ~30 technical papers published in high-impact journals and micro/nano conferences (these have received >900 citations in the past 5 years), over a dozen invited lectures at peer-reviewed conferences, and >20 invited colloquiums. He has been invited and privileged to serve for many scientific journals and conferences (including IEEE IEDM, IFCS, NANO, & Transducers).