Mechanical Engineering Department Seminar

3:35pm, March 23, 2016
1130 Mechanical Engineering
111 Church Street SE, Minneapolis, MN 55455

Design Solutions to Engineering Challenges in Energy Harvesting

Sang-Gook Kim

Professor; Massachusetts Institute of Technology

New product design has been frequently stymied by the laws of nature and limited material performances. Two cases will be discussed on how these challenges can be overcome/circumvented by design thinking: 1) piezoelectric MEMS energy harvesting; 2) solar energy harvesting for full spectrum water splitting.

Energy harvesting at MEMS scale promisingly offers exciting applications such as large wireless sensor networks, wearable sensors and Internet of Things (IoT), where chemical batteries cannot serve power effectively. However, the mismatches between the working conditions of linear resonant MEMS energy harvesters and the characteristics of the ambient vibrations have long hindered wide applications of this technology. With recent achievements in MEMS energy harvesting, the remaining and major challenge of the energy harvesting technology is whether a decent amount of power could be harvested at low frequencies (<50Hz) and low g's (<0.5g). This is against the scaling law of linear resonant systems. A buckled beam based bi-stable nonlinear oscillator has been proposed to solve this challenge. Analytical modeling with simulation and preliminary meso-scale testing have shown the critical metrics work – power harvesting at low frequencies (<50Hz) and low g's (<0.5g). The design concept has been further validated by micro-fabricating MEMS prototypes and testing their dynamic responses.

A dielectric filled photonic crystal nanostructure was developed to survive the high operating temperature over 1000 ^{o}C for more than 30 years. The key design idea was to make the surface optically selective, but geometrically flat, which minimizes the inevitable surface diffusion. We recently found that this solar absorber could enhance the efficiency of solar energy harvesting if photoelectric hot carrier generation in metal-semiconductor junctions could be injected to photochemical cells below the bandgap of the semiconductor. We demonstrated a broadband sub-bandgap photoresponse at 590 nm which is believed due to surface plasmon absorption at the thin gold layer over TiO_2. Applications of our results will lead to low-cost and carbon neutral water splitting and thermo-photovoltaic energy conversion.

Bio: Sang-Gook Kim is a professor in the Department of Mechanical Engineering at MIT. He received his B.S. degree from Seoul National University (1978), M.S. from KAIST (1980), and Ph.D. from MIT (1985). He held positions at Axiomatics Co., Cambridge, MA (1986) and Korea Institute of Science and Technology (1986-1991). Then he became a corporate executive director at Daewoo Corporation, Korea, and directed the Central Research Institute of Daewoo Electronics Co. until 2000 when he joined MIT. He is currently the Micro/Nano Area Head of the Department of Mechanical Engineering at MIT. Prof. Kim's research has been in the field of product realization throughout his career at both the industry and academia. His recent research includes piezoelectric MEMS energy harvesting, micro ultrasonic transducers and nano-engineered energy conversion systems. He is a fellow of CIRP (International Academy for Production Engineering), fellow of ASME, overseas member of Korean National Academy of Engineering and a member of IEEE.