Mechanical & Aerospace Engineering

seminar

Nanoscale Heat Transfer: Thermal Conductivity of Polymer and Hybrid Organic-Inorganic Materials

October 31, 2014 at 1:30pm in SCOB 210

abstract

Thermal transport plays an important role in energy conversion efficiency and device reliability. There were significant progresses on the understanding of thermal conductivity and phonon transport mechanisms over the past 2 decades, owing much to the challenging needs in high efficiency energy conversion, high speed electronics, and high power lasers. In concurrence with such technical challenges, significant progresses in computational power makes first-principles prediction of materials possible. Ultrafast lasers can now probe materials both at sub-femtosecond timescale and at atomic or sub-nanometer length scale. In this seminar, I will quickly highlight a few notable accomplishments in the field in the context on the efforts in building multiscale-multiphysics simulation platforms for the study of phonon transport and thermal conductivity in nanostructured materials.

In the second part of the seminar, I will discuss some of our efforts towards the understanding and engineering thermal transport in polymers and hybrid organic-inorganic materials, which are of interest to thermal management and thermoelectric applications. I will show that the thermal conductivity of ultra-thin polymer films can both increase and decrease. We find that the effective thermal conductivity (both cross-plane and in-plane) of ultra-thin polymer films increase with the decreasing thickness, which is a trend significantly different from inorganic films, mainly due to the changing of chain structure near the PS/substrate interface. Yet in another example, much lower thermal conductivity were obtained in atomic/molecular layer deposited hybrid organic–inorganic zincone thin films compared to that of W/Al2O3 inorganic nanolaminates reported by Costescu et al. [Science 2004, 303, 989–990], suggesting that the dramatic material difference between organic and inorganic materials may provide a route for producing materials with ultralow thermal conductivity.

Coupled with its low thermal conductivity, polymer thermoelectric composites are attractive for energy harvesting and localized cooling where temperature gradients are moderate, surfaces are irregular, toxic or rare elements are avoided, and low-cost processing is preferred. ***(cont'd.)***

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(abstract cont'd.) Though great progresses have been made for p-type polymers with a thermoelectric figure of merit (*ZT*) up to 0.42, there has been a paucity of unipolar n-type composites for this purpose . I will also report the measurement and understanding on the low thermal conductivity of an N-type flexible hybrid TiS_2-organic superlattice showing ZT >0.1, making possible the realization of flexible thermoelectric devices for wearable electronics, with both n- and p-type materials available.

biosketch

Dr. Ronggui Yang is the S.P. Chip and Lori Johnson Faculty Fellow in Engineering and an Associate Professor of Mechanical Engineering directing the Nano-enabled Energy Conversion, Storage, and Thermal Management Systems group (NEXT) at the University of Colorado at Boulder. Dr. Yang received his Ph.D degree focusing on Nanoscale Transport Phenomena with Prof. Gang Chen in Mechanical Engineering from MIT in February 2006. Since January 2006, he started his faculty career as an assistant professor at CU-Boulder and has been promoted to associate professor with early tenure in summer 2011 (two-year ahead of the normal clock at CU-Boulder). Dr. Yang has won the ITS Young Investigator Award in 2014 and the Goldsmid Award in 2005 from the International Thermoelectrics Society, the Bergles-Rohsenow Young Investigator Award in Heat Transfer in 2010 from ASME, an NSF CAREER Award in 2009, the MIT Technology Review's TR35 Award, the DARPA Young Faculty Award in 2008, and a NASA Tech Brief Award for a Technical Innovation in 2004. He has also won the Provost's Achievement Award (2012), the Dean's Performance Award (2010), the Woodward Outstanding Faculty of Mechanical Engineering (2011) and the Outstanding Research Award in Mechanical Engineering (2008 & 2013) from the University of Colorado at Boulder. He was endowed with the S.P. Chip and Lori Johnson Faculty Fellow for 2013-2017 and the Sanders Faculty Fellow for 2008-2012.