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EDITORIAL

A Special Issue on Nanoscale Heat Transfer

Heat transfer behavior in nanostructures can differ significantly from that in macrostructures because of various size and interface effects. Well-established laws that are used to describe heat transfer, such as the Fourier law of heat conduction and the Planck law of blackbody radiation, can fail to be applicable to nanostructures. Although there are scattered works addressing various size effects on heat transfer that can trace back to Planck and Casimir, these effects are usually important only at cryogenic temperatures. Since late 1980s, interests on micro/nano-scale heat transfer surged, driven by increasing challenges in thermal management of microelectronics and photonics devices. The nanoscale heat transfer community at the beginning mainly consisted of researchers from traditional heat transfer field, but has since seen increasing participation from various disciplines including electrical engineering, physics, chemistry, and material science, with a wide range of interesting problems addressed, such as quantum size effects, thermal management, energy conversion and storage, biotechnology, instrumentation, etc.

Nanoscale heat transfer is indeed a field that has lots of interesting problems and unanswered questions that call for attention and contributions from researchers from different disciplines. This special issue aims at giving readers a glimpse of some research problems being addressed, with an emphasis on simulation and modeling. In the Henry and Chen paper, the authors discuss phonon mean free path and contributions of various phonon groups to heat conduction in silicon obtained via molecular dynamics simulation. Although silicon is arguably the best known material, this paper shows that our knowledge on detailed heat conduction mechanism in silicon is rather limited. Domingues et al. computed thermal contact resistance between two nanoparticles with molecular dynamics simulation technique. Contact resistance is a major issue in thermal management of microelectronics. Chen et al. discussed the effect of interfacial coupling on the thermal conductivity of superlattices. This is a topic of great interest to thermoelectrics and semiconductor lasers with opposite aims. In thermoelectrics, one wants to reduce thermal conductivity, while for semiconductor lasers, a high thermal conductivity is desirable for thermal management. Treatment on classical size effects often start with Boltzmann equation, which in its full form is a complex integral-differential equation. Baker and Constantinou introduced a variance reduction method to solve the full Boltzmann equation. Although the paper deals with gas transport, the methodology may be useful for electron and phonon transport. Ohara discussed heat conduction mechanisms at liquid–solid interface, examining in detail contributions to heat flux from different modes of motion of liquid molecules and effects of solid crystalline surfaces. Vladkov and Barrat used molecular dynamics simulation to investigate the thermal conductivity of nanofluids—a colloid made of nanoparticles dispersed in a liquid. Heat conduction mechanisms in such colloidal fluids have been a subject of intense scrutiny and debate recently due to its possible high thermal conductivity and potential application in thermal management. Joulain explored the relationship between conduction and radiation, and showed that the radiative heat transfer exchanged in the near field can be interpreted as a conduction heat transfer due to the propagation of optical phonons using fluctuating electrodynamics calculation. Lee et al. studies the mechanisms for enhanced transmission in nanoscal slit arrays, a phenomenon sometimes called extraordinary transmission. Jin and Xu explored the transmission of electromagnetic waves via a bowtie antenna, and showed that the resonance frequency depends sensitively on the shape, an effect that can be explored for various sensing applications. Ruan and Kaviany carried *ab initio* calculation to investigate the electron-phonon and electron-vibration coupling for laser cooling of ion-doped solids. Okazaki et al. presented quantum molecular dynamics simulations aiming at understanding the oxygen reduction pathway in proton exchange membranes. This issue concludes with a paper by a lattice-Boltzmann based simulation of heat transfer in electro-osmotic drive flow in micro and nanochannels, which has applications in both thermal management and biomedical technology.

Although the topics covered in this special issue is by no means inclusive of the field of nanoscale heat transfer, we hope they serve as some good examples to illustrate this dynamic field and draw more researchers into this field.

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EDITORIAL

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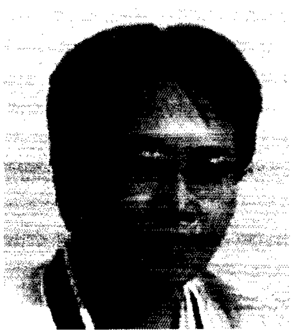
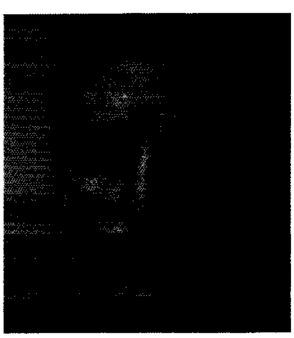


Dr. Ronggui Yang is an assistant professor of Mechanical Engineering directing the Nanoscale and Ultrafast Thermal Sciences and Applications Lab (NUTS) at the University of Colorado at Boulder since January 2006. Ronggui Yang received his Ph.D. degree from Massachusetts Institute of Technology (MIT) in December 2005. His research interests are on nanoscale and ultrafast thermal sciences, and their applications in energy and information technologies and biomedical engineering. He is the winner of the Best Paper Award in Research category of ASME InterPACK 2005, the winner of the 2005 Goldsmid Award from the International Thermoelectric Society, and a recipient of the NASA Certificate of Recognition for a Technical Innovation in 2004. He currently holds four pending patents and has published ~20 journal papers on nanoscale energy transport and conversion.



Dr. Sebastian Volz is a Research Fellow of the CNRS (National Scientific Research Center) heading the Micro and Nanoscale Heat Transfer research network (France). He is leading research activities in the Molecular and Macroscopic Energetics and Combustion Lab (EM2C) at Ecole Centrale Paris. Sebastian Volz received his Ph.D. degree from ENSMA (France, Oct. 1996). After a post-doc stay at UCLA (1998), he joined ENSMA in France as a faculty member (1999–2001), and moved to CNRS and EM2C in 2001. His research interests are on the physical modeling and the characterization of heat transfer in nanostructures for energy conversion, bio and materials applications. He received the bronze medal of the CNRS in 2004. He has published more than 40 journal papers and has recently edited a collaborative work in a book on micro and nanoscale heat transfer (Springer TAP 107).