Journal of Nanotechnology in Engineering and Medicine

Guest Editorial

Guest Editorial for the Special Issue on Micro/Nanoscale Transport Phenomena

Before the advent of the ubiquitous term "nanotechnology" in the scientific literature, study of microscale transport phenomena (e.g., boiling on microstructured surfaces) and nanoscale transport phenomena (e.g., combustion/surface catalysis, electrokinetic flows, slip flows, etc.) has been explored quite extensively in the thermal-fluids literature. Hence, the topics explored in this special issue can be misconstrued to be a mature area.

Advances in numerical techniques, engineering, fabrication, and metrology/testing capabilities in the realm of micro/nano-length scales have enabled the development of new frontiers in research and applications. Particularly, the application of micro/nanotechnology enabled metrology platforms in scientific investigations (such as scanning probe microscopies) has provided surprising fundamental insights into transport phenomena, especially in these small-scale regimes. The exploration of fundamental issues in micro/nanoscale transport has wide ranging implications—from energy systems (e.g., nanofluids for concentrated solar power and thermal energy storage) to thermal management (chip cooling) to manufacturing systems (nanolithography, nanosynthesis) to nanosensors (metamaterials, homeland security, biosecurity) to biotechnology/biomedical devices (autonomous microfluidics/multiphase flows, lab-on-chip, biochemical reactions, nanofluids for cancer therapy, ciliary transport, ligand–receptor interactions, etc.). The diversity of applications is also the genesis of a fair share of controversies (e.g., stability of nanobubbles, stability issues of nanofluids for thermophysical measurements, etc.).

Hence, this special issue is dedicated to the publication of recent developments in simulations and experiments involving transport phenomena at small length scales. The motivation is to enhance the fundamental knowledge about these physical phenomena as they relate to the variety of applications in engineering and medicine. This special issue was inspired by the themes and topics covered in past ASME conferences such as the Micro/Nano-Scale Heat and Mass Transfer Conference; International Conference on Nanochannels, Microchannels, and Minichannels; and Heat Transfer, Fluids and Nanochannels, Microchannels, and Minichannels Conferences. This special issue, therefore, contains the latest innovations in research activities relating to nanomaterials, nanofabrication, diagnostics, metrology, and testing techniques with emphasis on exploring the fundamental issues in micro/nanoscale transport phenomena (fluid flow, mass transfer, conduction/convection heat transfer, radiation interactions, bio/chemical reactions, multiphase flows, thermophysical/chemical properties, peculiar behavior of confined materials, computational modeling of coupled transport mechanisms, etc.).

The special issue is aimed for a broad audience of readers in the fields of engineering, materials, thermophysical sciences, and life sciences. Hence, the published articles in this special issue encompass technical papers, review papers, and opinion articles. The opinion articles make this special issue unique and hopefully will be a trend setter for future issues of this Journal as well as other journals (within ASME and by other publishers). Hence, I am particularly grateful to the contributors of the opinion articles.

ASME—Setting the Standard

In spirit of the ASME motto—and as a guest editor of this special issue—I would like to use this opportunity to start a discussion on setting the standards of scientific investigation for the two salient themes in micro/nanoscale transport phenomena: (1) nanocoatings or nanostructured surfaces; and (2) nanoparticle additives (conventionally called "nanofluids" for the liquid phase and "nanocomposites" for the solid phase of the solvents). Hopefully, these discussions will enable the development of a standard protocol for manuscript submission on these topics to this Journal and other ASME journals. Establishment of such basic protocols for experimental and numerical studies will set the standards for other publishers as well as help to minimize the controversies in the literature.

Review of the thermal-fluids literature shows that heat transfer enhancements (e.g., for boiling) reported for various nanocoatings are often inconsistent. Similarly, experimental studies (e.g., measurement of thermophysical properties, convection heat transfer, phase change phenomena such as boiling, etc.) and theoretical/ numerical studies for nanofluids are widely inconsistent. A closer look at these reports shows that some of the investigators did not report if they characterized the heat exchanging surfaces before and after the experiments. Also, some of the investigators needed to provide a detailed account of the steps in the synthesis/fabrication protocols (both: for obtaining the nanocoatings or nanostructures; and/or the nanoparticle mixing process in the solvents/matrix materials). Similarly, pure solvents which are typically Newtonian fluids often become non-Newtonian when doped even with minute concentration of nanoparticles. Hence, the following recommendations are made to the investigators for submission of manuscripts to the future issues of this Journal:

(1) For experimental studies involving nanocoatings/nanostructures—the integrity of these surfaces should be characterized before and after the experiments.
   (a) In addition, detailed information about the synthesis/fabrication protocols should be provided.
   (b) Often the results are a function of the experimental design such as size effects (e.g., heater size) and measurement protocols. Investigators should be cognizant of such issues and consider these effects in the design of experiments/apparatus as well as explicitly explore these issues in the discussion section of the submitted manuscript.

(2) For experimental studies involving nanofluids/nanocomposites—the level of agglomeration of the nanoparticles should be characterized before and after each experiment (preferably using electron microscopy techniques such as SEM and also preferably TEM).
   (a) This will also help to verify the actual size of nanoparticles (which can be inconsistent with manufacturer specifications due to agglomeration). This will also

help to verify the level of stability of the nanoparticles—which is often a source of controversy in the results reported in prior literature.
   (b) The level of precipitation of nanoparticles on the conduit walls should also be verified using microscopy techniques.
(3) For numerical studies—the nanofluids should preferably be modeled as non-Newtonian fluids while the solvent can be Newtonian or non-Newtonian.
   (a) The appropriate rheological model should be based on experimental evidence for the class of nanoparticle-solvent system being modeled (e.g., shear thinning, shear thickening, etc.).
   (b) Generic numerical models utilizing parametric studies (e.g., by parametrically varying viscosity, thermal conductivity, density, etc.) involving Newtonian nanofluid models are often not desirable. Such approaches have been explored quite extensively in the literature and are potentially outside the scope of this Journal.
(4) For numerical studies involving nanocoatings/nanostructures or wettability variation (e.g., hydrophobic/hydrophilic or oleophobic/oleophillic surfaces) appropriate slip lengths for velocity, temperature, concentration, etc., should be considered—preferably by parametrically varying the relevant parameters of interest (e.g., Kapitza length).
(5) It is also recommended that all the relevant parameters in each experiment be measured, monitored, and characterized thoroughly for each study.
   (a) Resorting to assumptions for estimating the material property values should be avoided as much as possible. For example, in the literature reports on the convection heat transfer of nanofluids, often the thermal conductivity is measured exclusively (usually by employing intrusive measurement techniques that are quite susceptible to precipitation on the probe surfaces—while a nonintrusive metrology technique would be preferred for better reliability); while the viscosity is typically assumed to follow Einstein's equations (which is not consistent with the non-Newtonian rheology often displayed by nanofluids); and the specific heat capacity is typically calculated using the simple mixture rule (which is not applicable for solid–liquid mixtures, especially for nanomaterial samples containing nanoparticles below a certain critical size of $5\,\mathrm{nm} \sim 10\,\mathrm{nm}$).
   (b) Hence, any study should also include a discussion on the possibility of the measurement technique affecting the material properties or experimental results (compared to what would be the actual/true value of the relevant parameter).

Hence, the investigators would perform a great service to the scientific community by thoroughly measuring, monitoring, and characterizing all the relevant experimental parameters with due diligence—both before and after the commencement of the experiments (e.g., before and after synthesizing the nanoparticle mixtures, integrity of nanocoatings/nanostructures as well as, before and after performing, say, the convection experiments).

Acknowledgment

The articles in the special issue will be published in Vol. 3, Nos. 3 and 4 of the Journal due to different submission and processing stages. I am grateful to the contributors (authors and co-authors). Their enthusiasm and support resulted in an unprecedented number of manuscript submissions for a special issue in this Journal. Also, as I mentioned before—I am particularly grateful to the contributors of the opinion articles. I am also grateful to the reviewers for their patience, promptness, help, and support for the peer review process. We were able to complete the first round of the reviews within a month of submission of the articles for a majority of the submissions. Also, the review process was quite rigorous resulting in an acceptance rate of $\sim$40%. For this, I am grateful to the reviewers for their due diligence as well as for their efforts in upholding and enhancing the technical quality of this special issue. The sustained culture of promptness and diligence will surely invigorate the impact of the Journal.

In addition I would like to thank Dr. Kunal Mitra (Professor of Mechanical & Aerospace Engineering at the Florida Institute of Technology) for his tireless efforts, flexibility, and support while serving as an Associate Editor for this special issue. Finally, I would like to thank Dr. James Klausner (2011–2012 Chair of ASME Heat Transfer Division/HTD; Professor of Mechanical & Aerospace Engineering at the University of Florida; currently on IPA to ARPA-E) for his help in publicizing the special issue to the thermal-fluids community using the email distribution lists within ASME.

I sincerely hope that this is a harbinger for the publication of more special issues on a regular basis in this Journal on similar topics; and with articles of increasingly better technical quality—that provide additional insights into the fundamental aspects of transport phenomena for various applications, including in engineering and medicine.

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