Journal of Heat Transfer

Foreword

It is difficult to exactly define when research in micro/nanoscale heat transfer was initiated in the heat transfer community worldwide. There was no single paper that really started the field and there wasn't any single inspiring lecture such as the famous ''There is Plenty of Room at the Bottom,'' that Richard Feynman gave in 1959. The physics and chemistry community had been looking at some microscopic aspects of phase change and transport phenomena for several decades. In fact, a few publications in microscale heat transfer that appeared in this journal can be traced back to the 1960s. However, it is clear that by the end of the 1980s, there was an increasing interest within the heat transfer, as well as the engineering community at large, for studying heat and mass transfer at small length and time scales. This was partly driven by the tremendous success of microelectronics and a clear vision that devices were going to become smaller and faster, and that future developments would require an extensive knowledge base for the continuously shrinking time and length scales that would reach tens of nanometers within decades. This also coincided with the invention of a wide variety of experimental tools such as the scanning tunneling and force microscopes and femtosecond lasers, which provided immediate access to phenomena at nanoscales. The ability to make microdevices using MEMS technology became standardized at around the same time. In addition, computing power became readily available such that molecular dynamic and stochastic simulations of micro/nanoscale thermal phenomena became feasible. All these factors put together led to an intense influx and genesis of new theoretical concepts, experimental techniques, and device designs, which led to a remarkable pace of progress. It is perhaps fair to say that over the past decade, micro/nanoscale heat transfer has been the most exciting and active area of research within the heat transfer community, and has also attracted the most amount of research funding. What is most heartening is that the participation has been highly collaborative and interdisciplinary, involving researchers from mechanical, chemical and electrical engineering, as well as physics, chemistry and materials science. From the very start, research in this field had an international flavor, which led to several focused workshops and symposia involving people from around the world, but mainly from the USA, Asia, and Europe. The number of sessions in conferences as well as the number of publications in this and other scientific journals increased very rapidly. Several books were written on various micro/nanoscale heat transfer topics. New courses on this topic were started at both undergraduate and graduate levels. In fact, perhaps the most positive outcome has been the birth of a new breed of young researchers for whom the boundaries of traditional disciplines have already been torn down.

To reflect upon our rapid progress of the past decade, to define the state of the art today, and to look ahead towards a very promising and perhaps even more progressive future, we decided to put together this special issue on micro/nanoscale heat and mass transfer. The issue contains a few review papers on topics that are mature and have sufficiently well-established research content. By no means do they cover all the topics of micro/nanoscale heat and mass transfer. The purpose of the review papers is to capture the past progress in a field and present new challenges and questions for the future. We hope these papers will serve the community well, in particular, for those who want to enter the field as a new researcher and get abreast with the state of the art of the field. The issue also contains several regular publications that report new research covering various topics in micro/nanoscale heat and mass transfer.

While it is easy and reassuring for us to discuss our research achievements over the past decade, we must continue to ask some hard and sometimes unnerving questions about the field. Why is micro/nanoscale heat and mass transfer important? What impact has it made or, more importantly, can it make? Why is it attracting so much new research funding? Is it just a fad or will it last? Does it have any scientific depth? Is there a roadmap for the future? While we cannot obviously answer all these questions at once, the question of why one should miniaturize is relevant and worth some thought. Two reasons come to mind. The first is a scientific one whereas the second is more technological. The fundamental length scales of nature that are involved in heat and mass transfer happen to be at micro and nanoscales. For example, the wavelength and mean free path of electrons and phonons in solids, mean free path of molecules in gases at atmospheric pressure, and the range of intermolecular forces in liquids generally lie in the length scale range of 100 nm or below. If one can probe and understand phenomena at these length scales, it may be possible to control and engineer heat and mass transfer in unprecedented ways. The second key reason is directly related to the fact that we are able to manufacture and manipulate systems at length scales that only a few decades ago were unthinkable. It is worth noting that the commercial success of microelectronics lies not only in the fact that one can fabricate sub-micrometer devices, but more so in the low cost of manufacturing integrated systems using parallel lithographic techniques. If the same manufacturing techniques can be exploited for thermal engineering, it would be possible to design and manufacture thermal micro/nanodevices that are not only inexpensive but also have better performance than their larger counterparts. In fact, if one could combine both these aspects—nanoscale fundamental control and low-cost microfabrication—it seems reasonable to expect commercial devices and systems with new functionality and high performance. It is the dual vision of generating scientific knowledge and enabling commercial technology that ought to stimulate further research in this field. We hope this special issue will play a positive role for achieving this dual vision.

A. Majumdar

G. P. Peterson

D. Poulikakos