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# Editorial

This special issue of the International Journal of Thermal Sciences is mainly devoted to a series of 11 papers dealing with *microscale heat transfer*. These papers have been selected among 44 presented at the École Nationale Supérieure de Mécanique et d'Aérotechnique (ENSMA-POITIERS, France) during the Eurotherm Seminar N° 57 organised from 8th to 10th July 1998 by the Laboratoire d'Études Thermiques (UMR CNRS 6608).

With the development of some recent high level technologies (submicronic electronics and microsystems, micromanufacturing and material processing, use of pico- and femto-lasers, medical techniques etc.), a new challenge has recently appeared, about the way heat can be transferred under extreme conditions, involving very tiny scales, both at space level and at time level (micro/nanometers, and micro/nano/picoseconds).

All the usual heat transfer modes, involving the different states of matter, are then to be reconsidered, as for instance:

– in conduction, when a solid is submitted to a very short laser pulse (pulse duration less than the phonon relaxation time), or when the size of the object is less than the phonon mean path (nano-wires),

– in a convective flow in channels when the diameter becomes of the order of the mean free path of the fluid molecules,

– in micro heat pipes for which the solid/liquid/vapour interaction of the liquid films drastically alters the heat transfer,

– in a nanoporous material with an hydrophobic fluid for which a very strange behaviour occurs both for fluid flow and heat transfer,

– in radiation when the size of the objects becomes less than the photon wavelength.

At *space level*, the concept of thermal conductivity in a solid is to be reconsidered, as soon as the thickness of a solid sample becomes lower than some mean free paths of heat carriers. The transmission of energy is also highly dependent on the influence of the boundaries, and on the structural properties of the interfaces. The new mechanisms controlling this transfer lead, for instance, to important discrepancies between the bulk conductivity values obtained by a classical evaluation, an those given by a more relevant physical analysis adapted to these very small scales. The thermal characterisation of thin films in solid state devices, opto-electronic and photonic devices, for instance, need today such a new approach, to provide valuable data. The same challenge can be expected in bioheat transfer when tackling the thermal response of a cell to a heat pulse, or to a freezing process (heat and mass transfer, intra- and extracellular ice development, inducing chemical and mechanical damages).

At *time level*, the heat propagation has also to be reconsidered as phenomena of heat transfer reach a time duration of the order less than the collision time in gases, or less than the phonon relaxation time in solids. The anomalous behaviour had already been recognised, with a rather macroscopic and phenomenological analysis proposed by Vernotte and Cattaneo in the end of the fifties. Still motivated by microelectronics, but also by material processing or biomedical applications (ophthalmology, inversion of radiative data in light–tissues interaction and new optical imaging etc.), recent works are bringing a new insight to the "short time" heat conduction or radiation problems.

New approaches need to be investigated both at theoretical and at experimental levels, and at the same time new types of modelling tools (like molecular dynamics or Monte-Carlo simulation) appear to be rather appropriate for atomic and molecular description of heat transfers.

Let us emphasise now some attractive features of the different papers presented, that will successively deal with: conduction in nanostructures; liquid/vapour change of phase; thermal imaging at microscale; thin films properties measurements; and will end with a very clever localisation of heat sources in electronic circuits.

We first introduce the paper of Dr. G. Chen which illustrates the fundamental differences between conduction in nanostructures and macrostructures based on his personal experience in the field of heat conduction in superlattices, nanowires and nanoparticles. Size effects include, for instance, the increased phonon scattering at the boundaries and interfaces, the phonon rarefaction surrounding small structures. Using essentially the phonon representation, the paper also compares its results with those provided by molecular dynamics. The author clearly demonstrates that when the size of a nanostructure becomes comparable or smaller than the phonon mean free path, the importance of phonon/boundaries collisions induces a very significant decrease of the conductivity. It particularly emphasises the practical applications of “phonon engineering”, in the field of microelectronics, opto-electronics and thermoelectric applications.

More oriented towards continuous liquid vapour phase transition, the paper of Z.Y. Guo et al. uses molecular dynamics and Monte Carlo simulation techniques to predict thermodynamic parameters of microscale argon systems. They can retrieve, for instance, the van der Waals isotherms loop in a $P$–$V$ diagram, but also show that the thickness of the vapour–liquid interface may become very large near the critical point.

J. Straub presents then a very interesting study of microscale boiling heat transfer under microgravity and $1g$ conditions, involving a series of tests performed onboard Spacelab during IML 2 Space Shuttle Mission. Motivated by electronic cooling in space, these experiments which use a small 0.26 mm thermistor as a heater conclude that even in microgravity, the heat transfer coefficients are still very high, allowing thus boiling to be applied for cooling processes in microgravity.

A theoretical model for predicting the heat transfer in a microheatpipe is presented by V. Sartre et al. The effect of the interfacial evaporation phenomena is taken into account, and the presence of high heat transfer rates is demonstrated in what is called the microregion (evaporating thin film).

An experimental investigation of mini- and micro-heat exchangers is conducted by I. Hapke et al., to improve the understanding of the physics of vaporization processes. The dimension of the channels (about 1 mm) is relatively small compared to the diameter of bubbles that appear.

A consequence is a strong disturbance of the flow in the channel, and of the heat transfer associated to these phenomena.

Leaving now all these microscale convection heat transfers, we shall present four papers dealing with attempts of thermal imaging at very tiny space level.

The first one, written by D. Fournier et al., demonstrates the ability of photothermal methods to image heat diffusion processes at micron scale. These photothermal images are interesting tools to determine the local diffusivity at single grain scale, to reveal thermal barrier at grain boundaries, and to look at heat diffusion in microelectronic circuits.

L. Thiery et al. study the thermal behaviour of fibers tips used in scanning near field optical microscopes (SNOM). They use for this an ultrasmall thermocouple (0.5 μm diameter) and show a drastic temperature increase due to internal heating of the tip, which can alter the imaging process.

Two papers of N. Trannoy et al. reveal the thermal effects induced by laser irradiation in scanning tunneling microscope, and show the complexity of thermal interaction between the tip and the sample, in these new generations of thermal imaging systems.

The thermal conductivity of $ZrO_2$ thin films ranging from 500 Å to 1 μm has been measured by S. Orain et al. by using an original photothermal technique. As it was discussed in the first paper (Chen), it was actually found that for these thicknesses, the thermal conductivity of $ZrO_2$ has decreased by one order of magnitude when compared to the case of the bulk material.

This series ends with an original paper from S. Dilhaire et al. using an optical probe for the measurement of temperature and dilatations based on the preliminary identification of the temperature coefficient of thermoreflectance. A very clever application concerns the localisation of heat sources upon integrated circuits, by laser probing.

This special issue attempts to illustrate the strong interest of this emerging field of microscale heat transfer. There is no way today to escape the understanding of these phenomena, to be able to master a lot of new technologies. We hope that this Eurotherm seminar will be the beginning of a long series and we are looking from now for a centre that would accept to organise the next meeting.

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