M2 Internship proposal, March-Septembre 2019

Heat dissipation beyond diffusion in microelectronics-related configurations and impact on local strain close to boundaries

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Context:

Heat transfer through conduction is mediated by heat diffusion at macroscopic scale, but not at nanometer-scale: it is instead mediated by ballistic heat conduction. This regime takes place when energy carriers (air molecules, electrons in metals, collective atomic vibrations called phonons in crystalline solids) move freely between domain boundaries and do not interact in the volume between each other through collisions (the mean free path is larger than the domain size). It is crucial to study the transition between the diffusive and the ballistic regimes, when energy carriers interact weakly with each other (few collisions) and with the domain boundaries. In addition, the impact of thermal boundaries at surfaces is critical in some microsystems since the surface-to-volume ratio becomes larger.
During this internship the candidate will investigate this transition following previous works that have considered metallic tracks on top of silicon wafers (see Fig. (a)). In the proposed work finite heat sources will be considered. In addition, the interplay with interfaces will be considered.

Hot spots in microelectronic devices are known to lead to internal stress close to boundaries. One of the goals of the internship will be to analyze if ballistic dissipation can lead to a different type of strain than the one usually considered in standard simulations tools based on the Fourier heat equation.

This internship will provide an opening towards nanotechnologies and is based on numerical work.

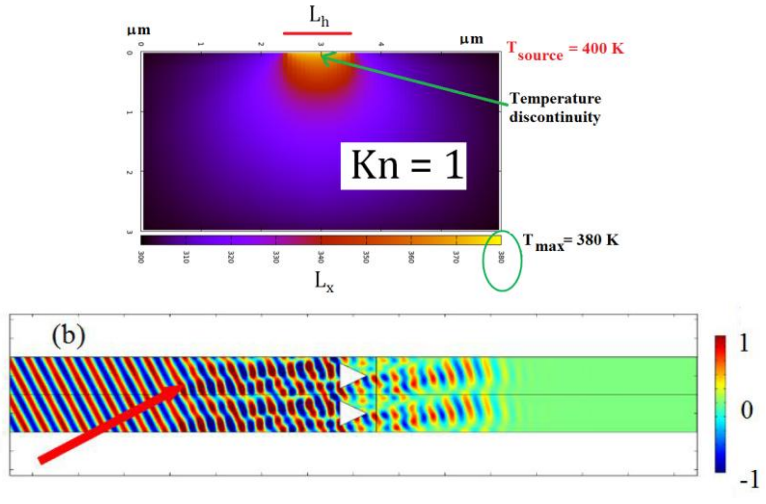

Figure: (a) Heat dissipation below a Joule-heated metallic track of width close to the heat carrier mean free path, i.e. in the ballistic regime. (b) Computation of the energy transfer across a nanostructure by phonons assimilated to elastic waves.

References :

- Thermal transport phenomena beyond the diffusive regime**,** P.-O. Chapuis, T. Nghiem, C. Abs Da Cruz, E. Nefzaoui**,** Special session on Nanoscale Thermal Modeling and Measurement, 23rd International Conference on Mixed Design of Integrated Circuits and Systems – MIXDES, June 23-25, 2016, Lodz (Poland), 'Invited lecture'
- Phononic thermal resistance due to a finite periodic array of nano-scatterers, Trang Nghiem and P.-O. Chapuis, Journal of Applied Physics 120, 044305 (2016)

Work to be performed:

- Understanding of the concept
- Adaptation of the numerical code for the new configuration
- Comparison with previous experimental and numerical data
- Final report

Dates: March-September 2019

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