MASTER PHYSIQUE ET APPLICATIONS

Internship/PhD offer

Laboratory: MPQ UMR7162
Director: Cristiano CIUTI
Address: Bât. Condorcet – 10 Rue A. Domon et L. Duquet – 75013 PARIS
Person in charge of the internship/PhD supervision: Maria Luisa DELLA ROCCA
Team : TELEM
Tel: 01 57 27 70 13
e-mail: maria-luisa.della-rocca@u-paris.fr

Graphene nanostructuring for energy conversion at nanoscale

Research on new thermoelectric (TE) devices and materials to improve energy conversion is highly demanded in nanoelectronics. Energy conversion of TE nanogenerators is ruled by the TE effect, the phenomenon occuring when a temperature difference through a material creates an electrical voltage. The TE efficiency ZT, defined as $ZT=S^2\sigma T / k$, with S the Seebeck coefficient, σ the electrical conductivity, k the thermal conductivity and T the temperature, is the relevant parameter that researchers struggle to improve. Values of $ZT >> 1$ are typically sought for a TE material to be exploitable in applications. Active TE materials must have low thermal conductivity and high electrical conductivity, which is an antonymic behavior in common bulk materials due to the Wiedemann-Franz law but it can be achieved in nanostructured systems[1]. This is why managing and understanding heat at the nanoscale constitutes a major on-going scientific and technological challenge. The discovery of 2D materials has open new routes of investigation, high ZT values have been predicted in graphene nanostructure[2] and transition metal dicalcogenides (TMD) have revealed high Seebeck coefficients[3]. Furthermore isolated 2D materials can be precisely assembled layer by layer in a chosen sequence giving rise to the so-called van der Waals heterostructures (vdW)[4].

The main goal of the internship is to investigate experimentally the electric (σ), thermoelectric (S) and thermal properties (k) of devices based on nanostructured graphene, the 2D material of choice for this project acting as the thermoelectric element. Nanostructuring will be engineered by nanolithography (i.e. network of holes) or surface functionalization (electrografting) with the aim to reduce phonon mean free path without affecting significantly the electron mean free path. This will allow enhancing dramatically the figure of merit. The team has recently investigated the transport and thermoelectric properties of 2D materials[5], and has particularly demonstrated an all-electrical approach to measure thermal conductivity in graphene nanowires[6] (see figure). This expertise will be exploited in the project.

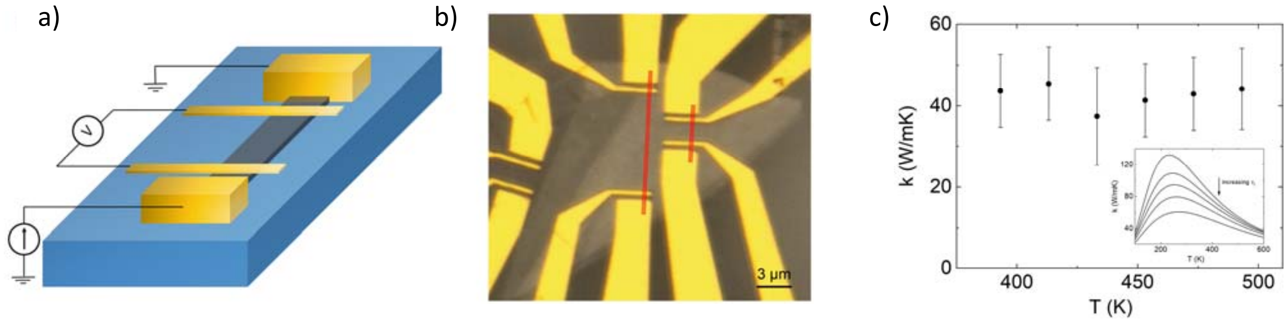

Fig: a) schematics of a graphene based device for self-heating measurements. b) Optical image of a graphene flake and electrical connection for nanowires geometries (in red). c) Measured thermal conductivity of supported multilayer GN in the temperature range 400K – 500K.

1. A. Principi and G. Vignale, *Phys. Rev. Lett.* 115, 056603 (2015)
2. P. Dollfus et al., *J. Phys.: Condens. Matter* 27, 133204 (2015)
3. M. Buscema et al., *Nano. Lett.* 13, 358 (2013)
4. K. Geim and I. V. Grigorieva, *Nature* 499, 419 (2013)
5. S. Timpa et al., *Phys. Rev. Appl.* **14**, 014056 (2020)
6. S. Timpa et al., submitted to *Jour. Appl. Phys.*

Methods and techniques: micro-fabrication in clean room, electrical transport measurements

Possibility to go on with a PhD ? YES
Envisaged fellowship ? EDPIF