INTERNSHIP PROPOSAL

Laboratory name: Matériaux et Phénomènes Quantiques (MPQ)
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Internship location: MPQ lab

Thesis possibility after internship: YES
Funding: YES - If YES, which type of funding: EDPIF competition/submitted project funding

Graphene nanostructuring for energy conversion at nanoscale

Research on new thermoelectric (TE) devices and materials for thermal management at nanoscale is highly demanded in nanoelectronics. In particular, energy conversion of TE nanogenerators aims to recover waste heat in nanoelectronics, improving device performances. Following this objective, 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. Active TE materials must have low thermal conductivity and high electrical conductivity, which is an antonymic behaviour in common bulk materials but it can be achieved in nanostructured systems[1]. The discovery of 2D materials has open new routes of investigation in this domain, high ZT values have been predicted in graphene nanostructure[2] and transition metal dicalcogenides (TMD) have revealed high Seebeck coefficients[3].
The main goal of the internship is to experimentally investigate the electric (σ), thermoelectric (S) and thermal properties (k) of devices based on nanostructured graphene. Nanostructuring will be engineered by a network of holes, with 300-400nm diameter and 50-150nm edge width, aiming to reduce the phonon mean free path without affecting significantly the electron mean free path. The students will be involved in sample fabrication in clean room (dry transfer of the 2D material, e-beam lithography, etching, metal deposition …), electrical measurements (σ, S) and modulated thermoreflectance measurements (k) (coll. INSP – Paris). The team has recently demonstrated the ability of achieving a complete thermoelectrical characterization of 2D materials-based devices[4,5] and has already achieved promising preliminary results (see Fig.). The team's expertise in the investigation of charge and spin transport in 2D materials and in clean room micro and nano fabrication techniques will be exploited in the project.

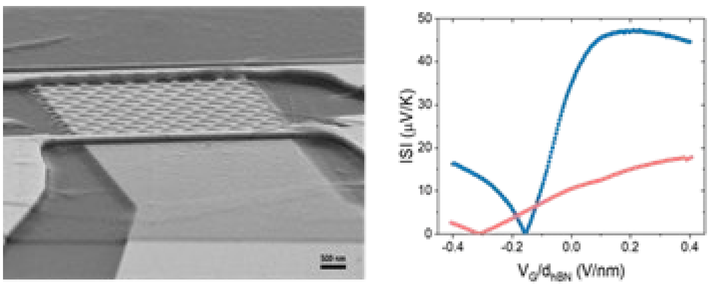

Fig: a) SEM image of a graphene-based nanostructured device for electric and thermoelectric measurements. b) Absolute value of the Seebeck coefficient for nanostructured (bleu data) and pristine (pink data) multilayer graphene.

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. S. Timpa et al., J. Appl. Phys. 130, 185102 (2021)
5. M. Rahimi et al., Phys. Rev. Appl. 19, 034075 (2023)

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	NO