Internship offer 2024/2025:
Graphene nanostructuring for energy conversion at nanoscale

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Research on new thermoelectric (TE) devices and materials for thermal management at nanoscale is highly demanded in nanoelectronics. Energy conversion of TE nanogenerators aims to recover waste heat in nanoelectronics, improving device performances. Following this objective, the TE efficiency *ZT*, defined as $ZT=S^2\sigma T/k$ (*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 behavior 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]. Controlling separately phonon and electron transport is the main goal in the research on new low dimensional TE materials.

The internship focuses on the experimental investigation of the electric, thermoelectric and thermal properties of devices based on nanostructured graphene, allowing to engineer new TE low dimensional materials and also to investigate fundamental properties relative to phonon and electron transport. Nanostructuring will be engineered by a network of holes, with 300-400nm diameter and 50-150nm edge width, aiming to control separately the phonon and electron mean free paths. The student 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.

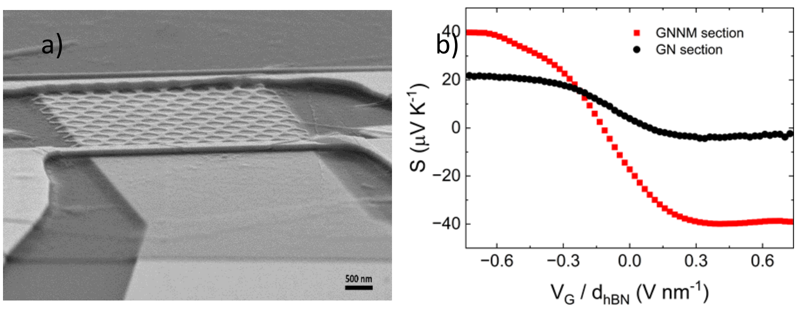

Fig: a) SEM image of a graphene-based nanostructured device for electric and thermoelectric measurements.
b) Absolute value of the Seebeck coefficient for nanostructured (red data) and pristine (black data) multilayer graphene.

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)

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

Possibility to go on with a PhD? YES
Envisaged fellowship? EDPIF competition and/or PhD funding request submitted in projects