

INTERNSHIP PROPOSAL

Laboratory name: Matériaux et Phénomènes Quantiques

CNRS identification code: UMR 7162

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Internship location: Lab. MPQ, Université Paris Cité

Thesis possibility after internship: YES

Funding: EDPIF competition

If YES, which type of funding:

Graphene nanostructuring for advanced tuning of thermal properties

Understanding and controlling heat and charge transport in low-dimensional materials is crucial for the development of next-generation nanoelectronics and energy-harvesting devices. Graphene, thanks to its outstanding electrical and thermal conductivities, offers a unique platform to study coupled heat and charge phenomena at the nanoscale^{1,2}. However, its intrinsic high thermal conductivity limits its thermoelectric performance, and directional heat transport (thermal rectification) remains difficult to achieve in its pristine form³.

The internship focuses on the experimental investigation of both thermal rectification and the Seebeck effect in nanostructured supported (on substrate) graphene⁴. The approach relies on geometrical nanostructuring — a periodic network of nano-holes (graphene nanomesh) — to tailor phonon and electron mean free paths, enabling independent control of thermal and electrical transport. This configuration is expected to produce asymmetric heat conduction under reversed temperature gradients and to enhance the Seebeck coefficient by modifying carrier scattering at the edges of the nanostructure. The student will participate in:

- Device fabrication in clean room: dry transfer of graphene flakes, e-beam lithography, and reactive ion etching to define nanomesh patterns with controlled periodicity.
- Electrical and thermoelectric measurements: determination of the Seebeck coefficient (S) and electrical conductivity (σ) under gate control, in correlation with geometry and nanostructuring effects.
- Thermal characterization: evaluation of the thermal conductivity (κ) and rectification ratio (RR) by modulated thermoreflectance (MTR).
- Data analysis and modeling: interpretation of transport data in terms of coupled phonon–electron processes and geometry-dependent effects.

This internship provides hands-on training in 2D material device fabrication, thermoelectric and thermal measurements, and data interpretation for coupled transport phenomena. The work contributes to the understanding of how nanostructuring can tune both heat rectification and thermoelectric conversion in graphene-based systems.

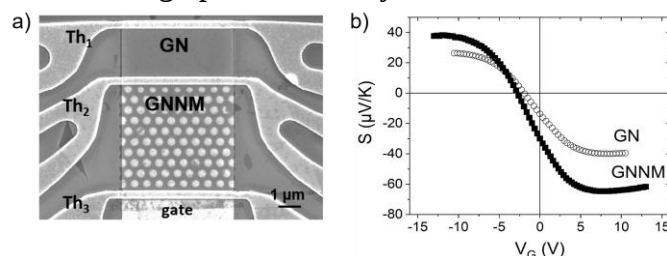


Fig: a) SEM image of a FET device based on multilayer graphene (GN), part of which is nanostructured (GNNM) for electric and thermoelectric measurements. b) Thermopower (S) measurements of the GN and GNNM regions as a function of gate voltage (V_G), showing $\geq 50\%$ increase in the GNNM case [4]

1. H. Song et al, *Joule* **2**, 442 (2018)

2. H. Wang et al. *Nat. Commun.* **8**, 15843 (2017)

3. M. Peyard, *EPL* **76**, 49 (2006)

4. M. Rahimi et al., submitted to *Phys. Rev. Appl.* (arxiv.org/abs/2507.03436)

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