Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: **ANR**

Engineering 2D materials 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 occurring 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.
Recently, 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). The main goal of the internship is to investigate experimentally the electric and thermoelectric properties of devices based on engineered 2D materials such as Van der Waals heterostructures with different 2D materials (GN ou WSe2). The 2D material of choice acting as the active thermoelectric element, will be engineered by nanolithography (i.e. network of holes) or surface functionalization (electrografting).
Preliminary results have been already achieved in the TELEM team on GN/hBN/WSe2 vdW heterostructures (Fig.1). The Seebeck coefficient of such devices has been measured at room temperature revealing a maximum value of almost 800 µV/K as a function of the gate voltage.

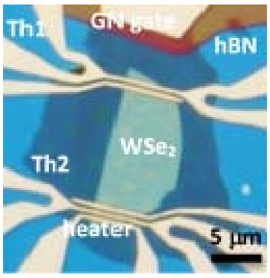

Fig. 1 GN/hBN/WSe_2 based device with 5 Pd nanowires having the function of heating element, local thermometers (Th1 and Th2) and electrical contacts.

[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)

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