SCIENCES SORBONNE UNIVERSITÉ

2019-2020

Master thesis proposal

IMPMC
Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie

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Title: Optoelectronics with 2D materials

Keywords: 2D materials, devices

Scientific description:

Photo-detectors and diodes are prime applications of two dimensional (2D) materials because of the spectacular electrical and optical properties obtained in one or few atomic layers of such materials [1-3]. As the prototype 2D material, graphene has high carrier mobility, a broad absorption spectrum and fast response time but weak absorbance and inexistent optical activity due to the absence of a semiconducting gap. 2D transition metal dichalcogenide semiconductors (TMDCs) have much larger optical absorption and their band gap can sometimes be tuned between indirect and direct as a function of the number of layers, a fact that could be crucial for designing efficient photo-detectors [4]. However, the carrier mobility in these semiconductors is relatively low, causing fast recombination of photo-excited electron-hole pairs and deteriorating efficiency. Atomically thin graphene/TMDC heterostructures show a photoresponsivity improvement of several orders of magnitude by combining the conversion efficiency of the semiconductor with the charge transport characteristics of graphene[5,6]. On the other hand, for diodes in particular but also for other devices including optoelectronic devices like LED's, it is extremely important to be able to dope 2D materials in an ambivalent manner and to high doping levels [7]. In our laboratory, firstly we have developed a method for fabricating few atomic layer samples of layered materials including graphene, TMDC's, and III-VI semiconductors. Secondly we have perfected standard techniques for the fabrication of heterostructures of 2D materials and making devices of these using e-beam or physical mask lithography. Thirdly we have developed a very efficient method of electrostatic doping which is compatible with eventually large scale device fabrication [8]. Our group is equipped with multi wavelength Raman, AFM, custom made 2D material fabrication apparatus, low temperature, high vacuum and in magnetic field transport measurements and all necessary instruments for electrical measurements. We also have access to clean-rooms for device fabrication. During this internship, the candidate will fabricate heterostructures and also single material ultra-thin devices which will then be combined with differentiated ambivalent doping in a single device area in an effort to make novel and highly efficient microelectronic and opto-electronic devices.

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[3] Chhowalla, M et al. Nat. Chem. 2013, 5, 263–275.
[4] Mak, K. F. et al. Phys. Rev. Lett. 2010, 105, 136805.
[5] Konstantatos et al. Nat. Nanotechnol. 2012, 7, 363–368.
[6] Chen, Biscaras, Shukla, Nanoscale, 7 14, 5981-5986, (2015)
[7] Zhang et al. Nano Lett., 2013, 13 (7), pp 3023–3028
[8] Biscaras, Chen, Paradisi, Shukla, Nature Commun. 6, 8826 (2015)

Techniques/methods in use: Raman, AFM, Clean room

Applicant skills: Condensed matter physics, Experimental skills

Industrial partnership: no

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Internship location: IMPMC

Possibility for a Doctoral thesis: Yes