INTERNSHIP PROPOSAL

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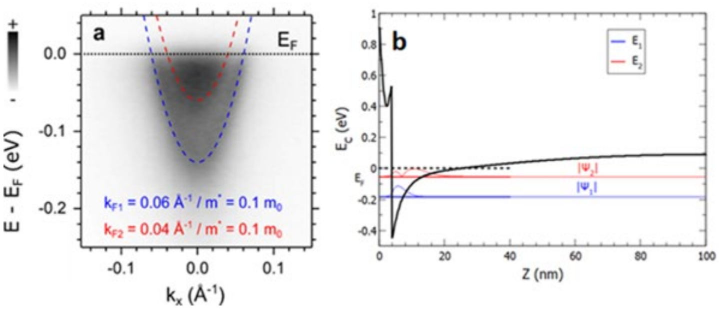
Internship location: MPQ lab

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

Unveil thermoelectric properties of 2D α-In2Se3

Recently bidimensional (2D) van der Waals (vdW) III−VI semiconductors have drawn intense attention due to their unique electronic properties[1]. Among these materials, In_2Se_3 in its most studied α and β phases, shows a great potential for a wide variety of applications in electronics, photonics and even thermoelectricity, due to its good mobility, excellent photoresponsivity, exotic ferroelectricity, and unique band structure[2-4]. In_2Se_3 possess an in- and out-of-plane ferroelectricity, which remains robust down to the monolayer limit. Moreover, very recently, 2H α-In_2Se_3 single crystals have also shown the occurrence of a 2D electron gas (2DEG) at their surface[5] (see Fig.), with high electron density (~10^{13} elec/cm2) even at room temperature, comparable to what achieved in AlGaN/GaN material systems. First-principles calculations based on the density functional theory and Boltzmann transport theory show that monolayered α-In_2Se_3 is also a great candidate for high-performance thermoelectric materials with the power factor PF and the figure of merit ZT as high as 0.02W/mK^2 and 2.18 at room temperature[4].
In this context, the main goal of the internship is to go a step forward in the investigation of the thermoelectric properties of α-In_2Se_3 and the influence of the 2DEG formed at its surface on the electric and thermoelectric response. The student will fabricate α-In_2Se_3 based devices in a 4 contacts configuration with a local gate for electric and thermoelectric investigation. The activity will cover sample fabrication in clean room (dry transfer of the 2D material, e-beam lithography, etching, metal deposition …) and electrical measurements in a multi-probe station as a function of the temperature. The team has a strong expertise in the investigation of charge and spin transport in 2D materials and in clean room micro and nano fabrication techniques. This expertise will be exploited in the project.



resolution ARPES spectrum of 2H α-In_2Se_3 in the vicinity of the Fermi energy showing two parabolic bands. Red and blue dashed lines correspond to a fit with a nearly free electron dispersion. (b) Corresponding surface potential (black line) and wave functions (red and blue lines) related to the confined states. Extracted from [5].

1. J. Li et al, ACS Nano 15 18683 (2021)
2. Z. Yu et al. Nano Lett. 17, 5508 (2017)
3. P. Hou et al., ACS Appl. Electron. Mater. 2, 140 (2020)
4. T. Nian et al., Appl. Phys. Lett. 118, 033103 (2021)
5. G. Kramer et al., ACSNano 17, 19, 18924 (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