Internship/PhD topic: “Engineering multiferroicity at the 2D-scale”

Lab: Structures, Properties and Modelling of Solids (SPMS)

Keywords: ferroelectrics, ferromagnets, multiferroics, 2D materials, experimental

Topics: solid-state/materials physics, ferroelectrics, ferromagnets, multiferroics, 2D materials, transition metal dichalcogenides, material characterisation: x-ray diffraction, electronic microscopy, atomic force microscopy, electrical measurements, spectroscopy…

Supervision: Cosme Milesi-Brault, Brahim Dkhil + collaboration with University of Arkansas

Quick summary of the internship/thesis project:
The quest for improved device performance has long driven advances in semiconductor technology through continuous miniaturization. As physical and economic limits emerge, research increasingly turns towards alternative strategies to enable new functionalities [1]. Two-dimensional (2D) materials represent a revolutionary class, inherently atomically thin, with unique electronic properties and compatible with silicon. In particular, the emergence of ferroelectricity (i.e., spontaneous polarization that can be switched by an electric field) in 2D monolayers, multilayers, and artificial structures such as twisted layers, offers further advantages, as ferroelectricity has traditionally been difficult to achieve in highly scaled materials.

2D ferroics are novel materials of great interest and still quite badly known. We will study 2D materials experimentally through a large range of structural, dielectric and magnetic measurements. We will use in-situ XRD, Raman spectroscopy, STEM, EELS/EDX, piezoforce microscopy, temperature and field-dependent dielectric measurements including ferroelectric polarisation, permittivity measurements…

Some of the most promising materials that we will study are $CuInP_2S_6$ [2, 3] which recently displayed strong ferroelectric polarization even at the scale of a few layers of materials and $CuCrP_2S_6$ which ferroelectricity could be coupled to a ferromagnetic order [4], making it a multiferroic material. Other promising 2D ferroelectric materials such as In_2Se_3 [5] will also be studied.

During this internship/PhD, the candidate will:

- Join a dynamic and internationally recognized team
- Study experimentally novel 2D materials in a joint laboratory between SPMS and Physics department of Arkansas, USA
- Contribute and participate to the work dissemination by writing papers and participating to international conferences and workshops

Main experimental techniques/simulation tools/methods:
In situ XRD, Raman spectroscopy, STEM, EELS/EDX, piezoforce microscopy, temperature and field-dependent dielectric measurements including ferroelectric polarisation, permittivity measurements…

Bibliography:
[1] Graef M. , More Than Moore White Paper. IEEE International Roadmap for Devices and Systems Outbriefs, 1-47, (2021).

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[2] Fucai L. et. al., Room-temperature ferroelectricity in $CuInP_2S_6$ ultrathin flakes, *Nat Commun* **7**, 12357 (2016)
[3] Xue F. et al. Observation of switchable polar skyrmion bubbles down to the atomic layers in van der Waals ferroelectric $CuInP_2S_6$. *Nat Commun* **16**, 2349 (2025)
[4] Weng Fu I. et. al., Direct observation of intrinsic room-temperature ferroelectricity in 2D layered $CuCrP_2S_6$, *Nat Commun* **14,** 7304 (2023)
[5] Cui C. et al., Intercorrelated in-plane and out-of-plane ferroelectricity in ultrathin two-dimensional layered semiconductor In_2Se_3. Nano Lett. **18**, 1253-1258 (2018).