Internship/PhD topic: Sliding Ferroelectricity in Transition metal Dichalcogenides

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

Supervision: The internship/PhD thesis will be co-supervised by Dganit MEIDAN and Francesco DELODOVICI from SPMS/CS.

Keywords: Sliding ferroelectricity; Van der Waals materials; Transition metal dichalcogenides; Spin orbit coupling

Quick summary of the internship/thesis project:

Context: Van der Waals (vdW) heterostructures are emerging as a powerful platform for next-generation quantum technologies and for revealing extraordinary states of matter. Among the many phenomena they host is a novel mechanism of sliding ferroelectricity, in which out-of-plane polarization arises from the stacking arrangement of otherwise non-polar monolayers [1]. Reversal of the polarization is achieved through a lateral shift, or "sliding," between layers that alters the relative stacking order. Owing to their low switching barriers, these materials offer the potential for fast, energy-efficient read/write operations under low electric fields. The discovery of sliding ferroelectricity has greatly expanded the range of known two-dimensional (2D) ferroelectrics—from a few insulating compounds (e.g. CuInP2S6, SnTe) to a broad family of vdW heterostructures, including insulating h-BN, semiconducting MoS2, and semi-metallic WTe2.

A remarkable aspect of this broader material platform is that ferroelectricity can coexist with metallic or even superconducting behavior—two properties that typically do not appear together. Normally, screening effects in metals suppress ferroelectric effects. However, in layered vdW materials, electrons move mostly within the layers, while the interaction between layers is weak. This unique geometry allows out-of-plane polarization to persist even in metals and superconductors.

Moreover, the polarization in these layered ferroelectrics can interact with and modulate various electronic phases, including superconductivity and topological order. In particular, experiments on bilayer $MoTe_2$ have shown that ferroelectric switching can induce a transition from the superconducting to the normal state [2]. This coupling provides new avenues for designing tunable quantum materials and low-power electronic devices capable of storing or processing information without continuous energy input. In the long term, such mechanisms could enable memory technologies based on controllable topological states rather than conventional charge-based storage

If you are interested, please quickly contact [Dganit Meidan](#) and [Francesco Delodovici](#)

Research Project: In this internship, we will explore how sliding ferroelectricity influences the electronic band structure of vdW bi-layers. Specifically we will first analyze the energetics of various types of domain walls, regions where opposite polarization meets. We will then investigate how electronic properties change across these regions, potentially leading to exotic phenomena, such as localized conductive states, emergent topological states and superconductivity [3], and local variation in spin-orbit related effects. Finally, we will elucidate the link of these effects to the underlying local symmetry reduction and strain effects.

Methods: We will use a combination of first principle DFT simulations, symmetry analysis, effective low energy Hamiltonians and phenomenological lattice models.

Contact: Interested candidates can send a CV, and motivation letter to:
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Bibliography:

[1] M. Wu, & J. Li, Sliding ferroelectricity in 2D van der Waals materials: Related physics and future opportunities, PNAS 118, e2115703118 (2021).

[2] Jindal, A., Saha, A., Li, Z. *et al.* Coupled ferroelectricity and superconductivity in bilayer Td-MoTe2. *Nature* **613**, 48–52 (2023)

[3] Chaudhary, G. , Martin, I. Superconductivity from domain wall fluctuations in sliding ferroelectrics, Phys. Rev. Lett. **133** 246001 (2024)

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