Digital 2D spintronics with electric dipoles: from spinFETs to ferroelectric topological insulators

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In this talk, I will present two strategies—one volatile and one non-volatile—to control the electron spin in 2D materials, where a binary output is obtained by simply reversing the sign of a gate voltage.

First, I will focus on a 2D spinFET concept which proposes to switch electrostatically between two separate sublayers with strong and opposite intrinsic Rashba effects, exploiting the spin-layer-locking mechanism in centrosymmetric materials with local dipole fields [1,2]. In particular, I will discuss a novel monolayer material within this family, LuIO, which we identified with first-principles simulations [3]. Then, I will explain how the ability to split the spin channels in energy diminishes with doping, leading to specific gate-operation guidelines that can apply to all devices based on spin-layer locking [3].

Second, I will show how an emergent ferroelectric quantum spin Hall insulating (QSHI) phase can spontaneously occur—or be engineered—in van der Waals heterostructures [4]. I will illustrate the general idea by considering a heterostructure made of a well-known ferroelectric material, In_2Se_3, and a suitably chosen, easily exfoliable trivial insulator, CuI. In one polarization state the system is trivial, while it becomes a QSHI with a 50 meV band gap upon polarization reversal. Remarkably, the topological band gap is mediated by the interlayer hybridization and allows to maximize the effect of intralayer spin-orbit coupling, promoting a robust ferroelectric topological phase that could not exist in monolayer materials and is resilient against relative orientation and lattice matching between the layers [4].

[1] Q. Liu, Y. Guo, A. J. Freeman, *Tunable Rashba Effect in Two-Dimensional LaOBiS2 Films: Ultrathin Candidates for Spin Field Effect Transistors*, Nano Letters 13, 11 (2013)

[2] H. Zhang, Q. Liu, J.-W. Luo, A. J. Freeman, Alex Zunger, *Hidden spin polarization in inversion-symmetric bulk crystals*, Nature Physics 10, 387–393 (2014)

[3] R. Zhang*, A. Marrazzo*, M. Verstraete, N. Marzari, T. Sohier, *Gate control of spin-layer-locking FETs and application to monolayer LuIO*, Nano Letters 21, 18 (2021)

[4] A. Marrazzo and M. Gibertini, *Twist-resilient and robust ferroelectric quantum spin Hall insulators driven by van der Waals interactions*, npj 2D Materials and Applications 6, 30 (2022)