PhD Project

Ferroelectric control of spin-charge interconversion in Rashba two-dimensional electron gases

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The conversion of a charge current into a spin current, carrying not charges but angular momentum, can be done in quantum materials using the spin-orbit coupling (SOC). Two-dimensional electron gases (2DEGs) that appear at surfaces and interfaces of transition metal oxides such as $SrTiO_3$ and $KTaO_3$ typically display a large SOC and some of the largest spin-charge conversion efficiencies reported so far, especially at low temperatures. In addition to this strong SOC, recent works have shown that $KTaO_3$-based 2DEGs could be superconducting at few kelvins[1], making it a more accessible and ideal platform to envision potential signatures of topological superconductivity and Majorana particles.[2]

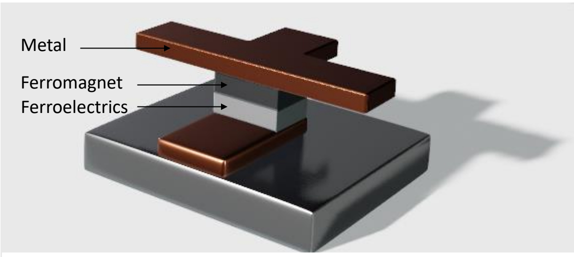

Figure 1 : Scheme of our new ferroelectric spintronics device. The dimensions are nanometric.

We recently demonstrated that when, in addition to hosting 2DEGs, some of these oxides can become ferroelectric under some stimuli or isovalent cationic substitution[3,4], they then have a natural potential to generate an electrically-switchable, highly efficient spin-charge interconversion, that can be used to develop new ferroelectric devices (fig. 1).
At the cross-road between spintronics, ferroelectricity and quantum materials physics, these devices can generate, convert and manipulate spin currents or magnetization[5] using electric fields and in a non-volatile way, thus without resorting to the energy-costly magnetization switching by applying current or a large magnetic field. This makes ferroelectric 2DEGs already good candidates for ultralow-power, post-CMOS logic devices and potentially for next-generation robust quantum computing.
The PhD project aims at exploring the possibilities offered by these features, in particular for the development of devices similar to the magneto-electric spin-orbit logic devices as for instance recently proposed by Intel[6]. Novel ferroelectric oxide 2DEG systems will be investigated to optimize the interconversion signal and the power consumption and to bring the targeted devices closer to applications at cryogenic temperatures (cryogenic memories, low power control electronics for qubits) or at room temperature. The PhD candidate will realize device nanofabrication in order to measure the spin-charge interconversion electrically, perform finite element method simulations of these devices and will participate in the paper writing and patent submission. The student will also interact with the team of SPINTEC dealing with the electrical design of logic devices. This project will benefit from the large collective momentum in our teams towards the development and integration of these devices, with ongoing ANR and EU projects, and more importantly with a valorization project based on this technology with the start-up Nellow, the main partner of this project.

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[1] Liu et al., Science 371 (2021): 716 ; Chen et al., Science 372 (2021): 721
[2] Barthélémy et al., EPL 133 (2021) : 17001
[3] Noël, Bréhin, Vila et al., Nature 580.7804 (2020): 483-486.
[4] Bréhin, Vila *et al.*, Phys. Rev. Materials 4 (2020) : 041002.
[5] Bréhin *et al.*, Nature Physics 19 (6) (2023) : 823-829.
[6] Manipatruni et al., Nature 565.7737 (2019): 35.