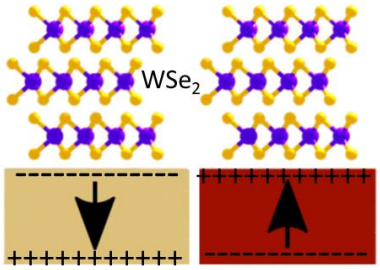
Proximity effects between 2D materials and ferroelectrics

Context

For their atomic thinness and exceptional electronic properties, 2D materials like graphene and transition metal dichalcogenides (TMD) are promising materials to build new compact and energy efficient electronic and spintronic devices [*Science* ***353****, 6298 (2022); Nature* ***606****, 663 (2022)*]. A key property of those materials is their two dimensional character which makes them highly sensitive to their environment. Thus, it offers the key opportunity to tune their electronic properties by proximity effects when the 2D material is put in contact with another functional material. In particular, the non-volatile electric field generated by a ferroelectric film will strongly affect the electronic properties of a 2D material in proximity. As shown in the figure, we could recently demonstrate a giant effect on the electronic structure of WSe_2, a 2D semiconductor, in contact with $BiFeO_3$, a well-known ferroelectric material (*under review in Nano Letters*). In spintronics, the application of an electric field to modify the spin-orbit coupling or ferromagnetic properties would represent a real breakthrough for the development of ultralow power consumption magnetic memories. Though it is almost impossible with bulk materials used today in spintronic devices, it is feasible with 2D materials in proximity with a ferroelectric material. During this internship, our goal is to study the proximity effect between a 2D material and a ferroelectric material. More specifically, we will investigate the modification of spin-orbit coupling in $PtSe_2$ and the modification of ferromagnetic properties in $CrTe_2$ by proximity effects with a ferroelectric material ($BiFeO_3$ or $LiNbO_3$). For this purpose, the 2D spintronics team of Spintec has developed a unique platform to grow 2D materials on large areas by molecular beam epitaxy as well as a method to transfer them on ferroelectric materials. This double competency is unique worldwide.



3 layers of WSe_2 in contact with $BiFeO_3$.

Work program & Skills acquired during internship

The student will grow 2D materials ($PtSe_2$ and $CrTe_2$) by molecular beam epitaxy on mica substrates and transfer them onto ferroelectric films with well-defined electrical polarization. Then, she/he will investigate the modification of spin-orbit coupling in $PtSe_2$ by magnetotransport and spin pumping measurements as well as the ferromagnetic properties of $CrTe_2$ by MOKE, SQUID and Hall measurements. All these equipments are available in the lab. She/he will develop skills in ultra-high vacuum techniques, growth of thin films, cryogenics, electrical and magnetic measurements. The student will benefit from local, national and European collaborative environments.

The internship will be followed by a PhD thesis with an extension to the fabrication of 2D ferroelectric materials to build "all 2D" heterostructures and to insulating 2D ferromagnetic materials like $Cr_2Ge_2Te_6$ to enhance the proximity effects. The internship and thesis will be in very close collaboration with the Unité Mixte CNRS-Thales in Palaiseau (France).

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Requested background: Master 2, good knowledge of solid-state physics and magnetism, taste for experimental work and exploration of new materials
Duration: 6 months
Start period: March 2023
Possibility of PhD thesis : YES
Proposal number : do not fill in