Ultra-thin alloys for spintronic applications.

Spintronics, which aims to exploit the electrons spin for the development of novel information storage or logic devices, is nowadays a major and competitive research field in physics. Exploiting spin degree of freedom increases the functionality of electronic devices and enables such devices to overcome physical limitations related to speed and power. Currently, one of the most promising way to achieve the desired control of the electrons spin is by the application of external electric field in presence of the so called Rashba spin–orbit coupling (SOC). The essential feature of Rashba SOC is that a spin-polarized electron moving in an electric field experiences an effective magnetic field which drives the precession of the spin orientation even without an external magnetic field.

A huge effort is made by the scientific community to develop novel materials with strong and controllable Rashba SOC to promote the fabrication of more advanced spintronic devices. The key ingredients necessary to achieve this goal are:

1) A source of spin-orbit coupling which locks together the electrons momentum and spin
2) A net or local dipole field which lift the spin degeneracy (energetically and/or spatially) via spin-orbit interaction without inducing a net magnetic moment in the system
3) The possibility to use the spin-polarized states as conduction channels in the device.

Since the atomic SOC depends on the atom mass, the first requirement can be achieved by including heavy elements in the material. The dipole field can be ensured in two ways: by breaking the inversion symmetry in non-centrosymmetric systems (for example at surfaces or interfaces) lifting the spin-degeneracy of the electronic bands, or by a local dipolar field due to the crystallographic structure and reduced dimensionality of the system (ultra-thin films) which lead to the spatial separation of the spin-polarized states on the opposite sides of the sample. The last requirement implies that the "Rashba material" has to be grown on a non-metallic substrate.

Objectives:

We have recently developed a method which allows us to **implement these three key ingredients in one single process of sample preparation**. By growing a surface alloy between a well-chosen heavy element and a semiconductor in ultra-high vacuum (UHV) environment by molecular beam epitaxy (MBE), we are able to prepare an ultrathin metallic film (alloy) with thicknesses of the order of 1 nm, which possess high spin-orbit interaction due to the heavy element, on top of a non-metallic substrate (see Figure). Moreover, with our method, the thickness of the alloy can be controlled becoming a tunable parameter for the strength of the Rashba-SOC.

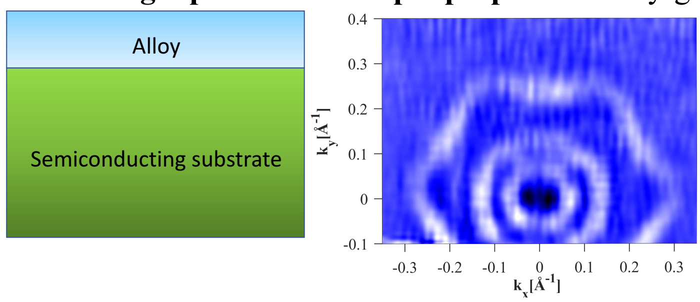

Figure 1: Left, schematic representation of the sample. Right, constant energy map (100 meV below Fermi level) measured by ARPES. Two circularly iso-energetic contours can be easily distinguished at the center of the Brillouin zone (0,0) demonstrating the presence of high Rashba effect.

This research project focuses on the study of the electronic properties of heavy metal/semiconductors alloys in the form of ultrathin films on semiconducting substrates grown with the preparation procedure described above. Our preliminary results demonstrate the possibility to develop a giant Rashba SOC in the alloy (Figure). Moreover, our preliminary transport measurements showed the possible implementation of such growth method for device fabrication. Our objectives are:

1) Identify the role of the different growth parameters in the development of Rashba-SOC
2) Implement a capping layer to protect the sample for ex-situ measurements
3) Use the alloy for device fabrication

Candidate profile:

The successful candidate should possess a good background in solid state physics and quantum mechanics. He/She should be at ease in the experimental work, be able to work in team and driven by natural curiosity for science. Experience in experimental research in physics will be a plus.