Name: Markel Pardo Almanza
Thesis title: Fabrication and Spectroscopic Investigation of a Tunable Magnetic Material and its Heterostructures

Research aim:

The interplay between magnetism and the spin polarized surface states of topological insulators (TIs) can open a gap and give rise to the emergence of exotic states. Such states can be realized by the selective engineering of a magnetic material (MM)/TI heterostructure, inducing magnetic ordering via proximity effects. For this purpose, a tunable layered MM, $Cr_{1+\delta}Te_2$, was fabricated and investigated in this thesis. Using the designed magnetic films, $Cr_{1.33}Te_2/Bi_2Te_3$ heterostructures were fabricated. In order to study the effective length of the magnetic proximity effect, the gap opening of the TI was investigated locally in real space.

Material and method:

$Cr_{1+\delta}Te_2$ films were fabricated by molecular beam epitaxy (MBE). The band structure of the films was visualized by in situ angle-resolved photoemission spectroscopy (ARPES) and the magnetic properties were characterized using a superconducting quantum interference device - vibrating sample magnetometer. The $Cr_{1.33}Te_2/Bi_2Te_3$ heterostructures were fabricated by MBE. The heterostructures were characterized by combining scanning tunneling microscopy/spectroscopy (STM/S) and cross-sectional transmission electron microscopy (TEM).

Result:

By a controlled post-deposition annealing process in MBE, $Cr_{1+\delta}Te_2$ films, with an amount of self-intercalated Cr_δ in the 0.3 – 0.9 range were systematically fabricated. The band structure of the $Cr_{1+\delta}Te_2$ films was unveiled by ARPES, revealing the chemical potential shift and the resulting tunable anomalous Hall effect with respect to Cr_δ. The magnetic properties were characterized, revealing increasing antiferromagnetic exchange interactions with the increase of Cr_δ and the resulting Curie temperature enhancement and magnetic anisotropy switch. $Cr_{1.33}Te_2$ films, with perpendicular magnetic anisotropy, were selected to fabricate the magnetic TI heterostructures based on Bi_2Te_3. The coexistence of two regions (5 and 6 nm-thick) of Bi_2Te_3 was observed by TEM in the fabricated heterostructures. By STM/S, these thick and thin regions were also identified, observing the magnetically induced gap opening of the TI only in the thinner ones. Based on the distinct electronic surface states of the 5 and 6 nm thick regions, ~ 5 nm is proposed as the effective length scale of the magnetic extension is studied TI heterostructures.

Conclusion:

The $Cr_{1+\delta}Te_2$ system shows complex magnetic and transport properties and has a great potential for the fabrication of van der Waals heterostructures. The observed length scale of the magnetic extension in the $Cr_{1.33}Te_2/Bi_2Te_3$ heterostructures points at the necessity of considering longer range mechanisms for magnetic proximity effects in MM/TI systems.