Epilayers of Topological Materials Based on IV-VI Semiconductors and Sn

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Topological materials (TM) are promising candidates for future electronics and spintronics. As quantum materials, they are also of great interest for fundamental condensed matter physics. In the last decade, the discovery of various topological phases with unusual energy dispersion, the emergence of novel quasiparticles and new phenomena has greatly expanded the field of topological quantum matter research.

In this talk, we will discuss topological materials in the form of thin epilayers produced by molecular beam epitaxy (MBE) technique. This low-dimensional form is of importance due to the physical properties of such TM not achievable in their bulk. Growth, structural characterization, transport properties and angular resolved photoemission spectroscopy (ARPES) investigations will be presented.

First, we will focus on (111)-oriented topological crystalline insulators (TCIs) epilayers based on IV–VI semiconductors. Band inversion and crystal symmetry protection in TCIs make topological surface states (TSS) very sensitive to external perturbations. The polar nature of (111) surface, which is difficult to realize during bulk growth, results in the intervened Dirac-Rashba spectrum. Furthermore, we will show through ARPES studies how the Rashba effect can be induced and controlled by surface and bulk doping [1], as well as by using quantum well asymmetry [2]. Also, we will present magnetoresistance measurements for (111) TCI thin films and show through weak antilocalization effect that non-zero Berry curvature exists even for the topologically-trivial IV-VI thin films [3]. The non-zero Berry phase was also confirmed by spin-resolved ARPES measurements. For samples with trivial composition, helical spin polarization was observed.

Second, we will consider ferromagnetism (FM) that can be introduced in prototypical TCI SnTe by Mn-induced RKKY interactions [4]. It has been believed that FM order is related to filling with carriers of the heavy-hole Σ-band. We directly observed by ARPES studies the evolution of Σ-band in (111) $Sn_{1-x}Mn_xTe$ films induced by Mn doping and showed its carrier filling with an increase of Mn content. Anomalous Hall effect and SQUID magnetization measurements confirmed the presence of FM ordering in the obtained films.

Third, we will discuss gray tin (α-Sn) epilayers synthesized on (001) insulating CdTe/GaAs substrates. Gray tin is an elemental topological material in which topological insulator - zero-gap semiconductor - Dirac semimetal (DSM) transitions can be realized through strain engineering. We demonstrate how the DSM phase is revealed by combined ARPES and magnetotransport measurements and structural characterization of obtained samples.

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