Anomalous Hall conductivity in 3D magnetic topological insulator based nanostructures

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Our work shed light on the possibility for achieving a control of electron properties in the 3D magnetic topological insulator based nanostructures. We demonstrate that the anomalous Hall effect in the 3D magnetic topological insulator thin film sandwiched between normal insulator slabs is more complicated than it was thought before. The phase diagram of this system contains altered regions of normal and quantum anomalous Hall regime. So, experimental and theoretical explorations of the finite size and interface effects in studied nanostructures remain to be a challenging task.

Semiconductor nanostructures comprising three-dimensional (3D) magnetic topological insulator (MTI) thin films interfaced with 3D normal insulator (NI) materials are considered to be highly promising for spintronic device applications [1]. Indeed, a boundary between 3D MTI and 3D NI can host «chiral» electron states with spin-momentum locking [2]. On the one hand, the NI/MTI/NI trilayer can be considered as a fundamental building block of a layered MTI/NI magnetic heterostructure. On the other hand, such the trilayer can serve as a basic model unit for a study of the peculiar electronic properties of such heterostructures. When the thickness of the MTI film is comparable with the penetration length of the interfacial «chiral» electron state into the film, the boundaries would significantly affect the electronic structure of the 3D MTI film. This creates opportunities to design desirable magnetic and transport properties in MTI/NI nanostructures.

In this work, in the framework of an effective functional approach [3] based on the 3D **kp** method, we study the combined effect of an interface potential (IP) and a thickness of 3D MTI thin film on the anomalous Hall conductivity in layered nanostructures comprising MTI and NI materials. We derive an effective 2D Hamiltonian of a 3D MTI thin film sandwiched between two NI slabs and define the applicability limits of approximations used. The energy gap and mass dispersion in the 2D Hamiltonian, originated both from the magnetic order inside MTI and hybridization between MTI/NI interfacial bound electron states at the opposite boundaries of a 3D MTI film, are demonstrated to change sign with the MTI film thickness and the IP strength. We also argue that anomalous Hall conductivity can efficiently be tuned varying the MTI film thickness and the IP strength. We obtain a phase diagram of the system and predict a quantization of anomalous Hall conductivity at the large region of IP strengths and MTI thicknesses. Comparison with experimental results is also performed

References

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