Weak anti-localization and universal conductance fluctuations in mesoscopic sample patterned from SnTe 3D topological crystalline insulator

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It is known that the SnTe epitaxial films and quantum wells are members of a new class of materials — the so-called 3-dimensional topological crystalline insulators (3D TCI) [1]. In particular, it is predicted that the SnTe/CdTe interface carries 2D electrons with the gapless energy spectrum, which are protected against backscattering by the symmetry of atomic lattice. The transport studies of 2D surface states in this system are, however, difficult because of p-type conductivity of intrinsic holes occupying states within quantum well. In order to separate both contributions, the weak anti-localization (WAL) effect is usually studied, which occurrence is reserved for the topological surface states by symmetry arguments. Therefore, plausible modeling of WAL in 3D TCI materials is of paramount importance.

Recently, WAL has been measured for macroscopic samples made of SnTe/CdTe quantum well in the temperature range 14 to 3.8 K [2]. Obtained data have been analyzed using 2D theory of weak anti-localization referred as Hikami-Larkin-Nagaoka (HLN) model [3]. Furthermore, it has been assumed that $l_\varphi \ll l_{\rm SO}$ and $l_\varphi \ll \ell$, where l_φ is the phase coherence length, $l_{\rm SO}$ is the spin relaxation length and ℓ is the transport mean free path for electrons. It is known, however, that even for materials with strong spin-orbit coupling, $l_{\rm SO}$ may be of the same order as l_φ [4]. Furthermore, the reliable estimations of ℓ in SnTe quantum wells are in fact unavailable. Here, we extend our studies by expanding the temperature range down to 0.250 K and by investigating WAL effect also for mesoscopic samples of width $W = 0.6$ μm and length $L = 2.0$ μm, in order to justify assumptions of WAL modeling. The devices have been prepared from the 20 nm thick SnTe epilayer which was grown on [100] GaAs substrate with CdTe buffer and then covered by 100 nm cap of undoped CdTe. The macroscopic and mesoscopic multi-terminal structures have been patterned using the low-temperature electron beam lithography method. The separating grooves have been wet etched down the CdTe substrate and the macroscopic electrical connections were made with silver paint.

We have studied the quantum transport using the low-frequency lock-in technique, the measurements have been performed in He3 cryostat at temperatures $\geqslant$ 250 mK and magnetic field B up to 7 T. We have observed weak anti-localization effect and, for the first time, universal conductance fluctuation (UCFs) for microscopic structures. Furthermore, UCFs were used to independently determine l_φ by the analysis of so-called correlation field $B_{\rm c}$. Data obtained for mesoscopic sample were analyzed using 1D WAL theory [5], with l_φ and $l_{\rm SO}$ taken into account.

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