Pis'ma v ZhETF, vol. 109, iss. 7, pp. 479 – 480

To the intrinsic magnetism of the $Bi_{1.08}Sn_{0.02}Sb_{0.9}Te_2S$ topological insulator

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Submitted 11 December 2018
Resubmitted 4 February 2019
Accepted 12 February 2019

DOI: 10.1134/S0021364019070014

Topological insulators (TI) belong to a class of quantum materials [1–3] which are characterized by gapless surface states with Dirac-like dispersion. Their nontrivial topology is protected by time-reversal symmetry (TRS). The violation of this symmetry gives rise to different topological states corresponding to new quantum materials. One of the most promising ways to study the effects of TRS violation is the external doping of TI with magnetic ions. While at low doping TI remain stable to such perturbations, at higher doping a kind of ferromagnetic ordering takes place [4] and the TRS is broken due to appearance of the spontaneous magnetization. The magnetic ordering of the doped ions is driven by their indirect Ruderman–Kittel–Kasuya–Yosida (RKKY) coupling via the charge carriers. Among the important consequences of such ordering is realization of the quantum anomalous Hall effect, associated with the breaking of TRS by magnetic ions doped into Bi_2Te_3 family of TI. In addition, Bi_2Te_3 is predicted to serve as a platform for novel Majorana fermions detection once magnetism is introduced [5].

The emergence of magnetism in TI has largely relied upon the doping of external magnetic ions. Therefore the intense studies of extrinsic magnetic moments were carried out with a help of Electron Spin Resonance (ESR) of the doped Mn ions serving as a sensitive spin probes in the Bi_2Te_3 structure, where they occupy the positions of Bi ions. The critical behavior of the ESR signal in the vicinity of 10 K at cooling of $Bi_{2-x}Mn_xTe_3$ compound for $x = 0.05$ confirmed the magnetic ordering of Mn ions at this temperature [6, 7]. The similar spectrum was observed for $Bi_{1.91}Mn_{0.09}Te_3$ with higher T_c of 12–13 K [8]. These studies confirming the violation of the time reversal symmetry of TI were restricted by the external magnetic moments. In the current paper we discuss another origin of magnetism in the topological insulators, that is the creation of magnetic moment due to intrinsic nonmagnetic defects.

The recent first-principles calculations [9, 10] demonstrate that for basic TI compounds Bi_2Te_3 and Bi_2Se_3 such local moments may be induced due to the antisite substitutional defects in Te(Se) layer of the typical quintuple structure when some of the Te(Se) atoms are replaced by the Bi atoms. The corresponding local magnetic moment's value is about $0.6\mu_B$ and it originates from the p-orbital of the guest Bi atom. Such a mechanism, which is different from that of a vacancy defect, provides new insights into the origins of magnetism. Quite recently the intrinsic magnetic moments were found [11] in newer representative of bismuthates' family – $Bi_{1.08}Sn_{0.02}Sb_{0.9}Te_2S$ (BSSTS) [12], which is recognized to be one of the best 3D topological insulators. The current paper is aimed on the ESR spectroscopy and the Superconducting Quantum Interference Device (SQUID) magnetometry of the intrinsic magnetic phase of TI basing on the example of this compound.

Using ESR spectroscopy together with the SQUID magnetometry we found that the intrinsic magnetic moments, originating from the nonmagnetic structural defects of $Bi_{1.08}Sn_{0.02}Sb_{0.9}Te_2S$ topological insulator form the superparamagnetic state. It represents an array of nanoscale single domain ferromagnets randomly distributed in the nonmagnetic media. Their net magnetic polarization in the absence of external magnetic field is completely averaged out and the time-reversal symmetry is not violated. Single domain ferromagnetic particles at elevated temperatures behave magnetically in a manner analogous to the Langevin paramagnetism of moment bearing atoms. The main distinction is that the moment of the particle may be 10^2–10^3 times the atomic moment.

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The preparation of single crystals for TI studies and modernization of experimental equipment was supported by the Russian Academy of Sciences in a frames of the Program “The fundamental properties of High-Tc superconductivity”.

Full text of the paper is published in JETP Letters journal. DOI: 10.1134/S0021364019070014

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