Nontrivial topology of Mg- and Fe-doped single-crystalline Bi_2Se_3 studied by Shubnikov-de Haas oscillations

M. Chrobak,[1,2] M. Jurczyszyn,[2] K. Maćkosz,[1,2] K. Nowak,[1,2] A. Naumov,[2] A. Kozłowski,[1] I. Miotkowski,[3] Z. Tarnawski,[1] M. Sikora,[2] and M. Przybylski[1]

[1]*AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, 30-059 Krakow, Poland*
[2]*AGH University of Science and Technology, Academic Centre for Materials and Nanotechnology, 30-059 Krakow, Poland*
[3]*Department of Physics and Astronomy, Purdue University, West Lafayette, IN 47907 USA*

Electronic structure of topological insulators is characterized by simultaneous occurrence of gapped bulk states and massless Dirac fermions at the surface. The latter are protected by time-reversal symmetry, which leads to lack of backscattering of massless fermions on impurities. It results in high efficiency of spin pumping as well as anomalous magnetotransport, both being very promising from application point of view (e.g. in modern electronic devices).
Despite the increasing knowledge of 3D topological insulators, it is not fully explained whether and how small changes in Bi_2Se_3 stoichiometry affect non-trivial topology. There are several techniques to prove it: one of them is the determination of Berry phase which can be done by analysis of Shubnikov-de Haas quantum oscillations.
In this work we present systematic study of magnetoresistance in pristine and Mg- and Fe-doped Bi_2Se_3 single crystals. The measurements were carried out by four-probe technique with a lock-in amplifier using ^{3}He/^{4}He dry dilution refrigerator "Triton" combined with the "Nanonis Tramea" system for quantum transport measurements. The measurements were performed in temperature range from 100 mK to 30 K in magnetic field up to 14 T. The results reveal that low level doping has a significant influence on the frequency and amplitude of Shubnikov-de Hass oscillations. The Berry phase obtained from Landau level fan diagram indicates that a small amount of magnetic dopant (1 % Fe) does not affect the non-trivial topology, preserving non-zero Berry phase. Charge dopant (2 % Mg) modifies topology of electronic structure leading to changes of the Berry phase from π to nearly zero.