Magnetoresistance vs. electronic structure in Cu doped single crystalline Bi_2Se_3 topological insulator

M. Chrobak,[1,2] K. Maćkosz,[1,2] K. Nowak,[1,2] A. Naumov,[2] and M. Przybylski[1,2]

[1] *Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, 30-059 Krakow, Poland.*

[2] *Academic Centre for Materials and Nanotechnology, AGH University of Science and Technology, 30-059 Krakow, Poland.*

Bismuth selenide (Bi_2Se_3) is one of the 3D topological insulators (TI) that can be characterized as materials of a semiconducting volume and a conductive surface. The surface states are protected by time-reversal symmetry, which leads to a lack of backscattering of massless fermions on impurities. It results in a high efficiency of spin pumping as well as in an anomalous magnetotransport, which are both very promising from application point of view (e.g., in modern electronic devices). Unfortunately, the band gap for the volume electronic states in Bi_2Se_3 is narrow (220 meV). Thus, even a small amount of crystallographic defects leads to a shift of the Fermi level to the conduction band so that the volume is no longer semiconducting and such TIs are useless for practical applications. Moreover, the Bi_2Se_3 TI is expected to own superconducting property by Cu intercalation [1]. The aim of this work is to verify whether superconductivity can be achieved by doping, i.e., substitution of Bi with Cu (with no intercalation) and how it is related to the position of the Fermi level.

We present a magnetoresitance study that includes Shubnikov-de-Haas (SdH) oscillations, scanning tunneling spectroscopy (STS) and angle-resolved photoelectron spectroscopy (ARPES) of $Bi_{2-x}Cu_xSe_3$ (x=0, 0.05, 0.12 and 0.18) single crystals. On the basis of electronic transport measurements, we can conclude that all the tested samples reveal SdH oscillations of single frequency, which proves a good quality of the investigated single crystals as well as a high carriers mobility. The measured frequency of quantum oscillations increases with increasing content of Cu, which means that the cross section of the extremal Fermi surface increases (which is similar to the effect of Fe magnetic dopant [2]). The STS and ARPES studies confirm an occurrence of nontrivial topological surface states (forming the so-called Dirac cone) in all the tested samples. Despite obtaining good quality samples and having preserved the Dirac cone, no superconductivity is found in any of the tested samples down to the temperature of 70 mK. The results obtained from STS and SdH reveals that with Cu doping, the Fermi level is shifted towards higher energies in the conduction band reaching its final energy at around x = 0.15.

References:

[1] Y.S. Hor, *et al.*, Phys. Rev. Lett. **104**, 2010

[2] M. Chrobak, *et al.*, New J. Phys. **22**, 2020

This work was financially supported by the National Science Centre, Poland, Grant 2018/02/X/ST3/03220.

K. N. was partly supported by the EU Project POWR.03.02.00-00-I004/16.