Description for the general public

Title of the project: Transport properties of magnetic topological insulators

Institution: Faculty of Mathematics and Applied Physics, Rzeszów University of Technology, Poland

This project is aimed at detailed study of certain new materials which attract recently a lot of attention of physicists and materials scientists. It turned out that at surface of some insulators (they are called now topological insulators) appears a two-dimensional electron gas which can transfer electric charge and spin. The electronic spectrum of such surface states can be described by the relativistic model of two-dimensional particles with zero effective mass, for which the whole Fermi surface is reduced to a single point (called Dirac point). Usual impurities and defects do not change properties of the surface states, but magnetic impurities or nonzero magnetization can change substantially the corresponding electron spectrum. As a results, an energy gap appears and the surface electrons acquire a nonzero effective mass which leads to big changes of their physical properties.

This project is focused on the development of the theory of transport properties of magnetic topological insulators. For systems of certain geometry, with the electronic structure like in a dielectric material, the nonequilibrium flow of charge and spin at low temperatures is purely quantum. There appears a quantization of kinetic coefficients accompanied with the dissipationless transport of charge and spin. An example of this phenomenon is quantum anomalous Hall effect, which has been recently observed in BiSbTe-based topological insulators with Cr magnetic impurities. The interest in this effect is really huge now, which is mostly due to the possibility of its application in metrology as a natural standard of electrical resistance. But the main problem to be solved for practical realization of this idea is to raise substantially the critical temperature of magnetic ordering. It is a real challenge for physicists, that requires more theoretical and experimental research.

Several tasks will be undertaken in this project. They include the development of the theory of magnetic interaction between magnetic impurities at the surface and in the bulk of the topological insulator, modeling of the ordering of magnetic moments, and the development of the theory of quantum transport phenomena. We will also perform numerical calculations and computer modeling of the anomalous Hall effect, Seebeck and Nernst effect, spin current, spin torque, and magnetic polarization induced by electric field, temperature gradient or nonequilibrium flow of phonons and magnons. The key point of our approach is how to relate the quantization of kinetic coefficients to the edge currents, and to find the way of their control at the crystal boundary, at the domain walls and at the edges of magnetic domains. One of the tasks of this project is to study the structure of topological excitations (skyrmions and electrically induced monopoles) in the magnetic system and to control these excitations. The main result of the work done in frame of this project will be a broadening of our knowledge on the new phenomena in quantum transport, and on the optimization of materials' parameters in order to observe and to practically use these phenomena. The materials which will be in scope of our activity are, first of all, Bi_2Se_3, Bi_2Te_3, BiSb topological insulators and PbSnTe crystalline topological insulator.