Spin-orbit physics in graphene due to proximity induced effect in van der Waals heterostructures based on inversion asymmetric topological insulators and type-II Weyl semimetals

Recently, both theoretical and experimental huge interest has been devoted to topological materials in three dimensions showing amazing physical properties. Particularly, the physicist put attention on the topological insulators, topological Anderson/Kondo insulators, topological crystalline insulators, Dirac semimetals, Chern insulators and finally Weyl semimetals. To describe these materials unusual physical concepts like trivial and nontrivial topological phases, Dirac and Weyl cones, Chern number, Weyl nodes, chirality, Berry connection and curvature have been exploited. Apart from these materials still unflagging interest is devoted to graphene – the first discovered 2D material which shows very high carrier mobility among other materials. Unfortunately, graphene shows extremely low intrinsic spin-orbit coupling together with an absence of band gap, which causes a limited application of this material in spintronics. The very recent theoretical studies have been devoted to overcoming this problem by proposing new physical phenomena, which can help to induce desired spintronic properties in graphene. Commonly accepted and promising method is based on the application of proximity effect due to graphene interaction with semiconducting transition metal dichalcogenides. In our project, we initiate research on materials with much more exotic properties, which can constitute graphene heterostructures and induce spintronic properties. Particularly, we have chosen a new type of topological insulator with inversion asymmetry observed in BiTeCl compound. It possesses inequivalent surface electronic states showing n- and p-type carries conductivity, which seems to be very promising in design of heterostructures. Another material which we take into consideration is 1T'-$MoTe_2$ showing phase transition (1T'->T_d)-$MoTe_2$ from trivial to nontrivial topological phase at about 260 K. At this temperature, it becomes type-II Weyl semimetal with tilted Weyls cones. During the course of the project, we are going to answer the question whether graphene/BiTeCl and graphene/(1T'->T_d)-$MoTe_2$ heterostructures promote good spin and charge transport together with induced strong spin-orbit coupling in graphene. It is also interesting to reveal topology of the band structure of graphene close to Dirac point, which might be affected by proximity effect. The novelty of the project will arise from studies of phonon physics of BiTeCl, (1T'->T_d)-$MoTe_2$ and their heterostructures by Raman spectroscopy and tip enhanced Raman spectroscopy operated in UHV conditions at low/high temperature. Finally, we are also going to apply density functional theory and topological quantum mechanics methods to studies of Weyl semimetals and their heterostructures. In this case, a special emphasis will be put on the application of hydrodynamic approach to transfer chiral electrons including anomaly of axial current in Weyl semimetals. In this project, we are going to draw attention to the important aspects of the investigations, which are in the focus of the scientific community. This is in good agreement with the European Flagship perspective related to graphene spintronics.