The project is focused on formation and investigations of physical properties of thin-layer heterostructures implementing two kinds of crystalline materials: (1) topological semimetals, (2) ferro- and anti-ferromagnets. Recently materials of the first kind have been extensively investigated, because of their unique properties. Topological semimetals (TSM) are three-dimensional (3D) counterparts of graphene, i.e., the dispersion relation E(k) of charge carriers in TSM is linear, and they naturally have high mobilities.

Topological semimetals belong to a broader class of materials comprising also topological insulators and superconductors. In all these types of topological materials the specific crystal lattice symmetries and relativistic effects associated with the presence of heavy element ions in the crystal lattice lead to the occurrence of so called topologically protected edge states. The topological protection is associated with prohibited backscattering at the border of material, which for two dimensional objects (e.g. thin films) consists of the sample edges, and in three dimensional (3D) case (thick layers or bulk crystals) – the surface of the sample.

Similar to the case of topological insulators, for topological semimetals topological protection of charge carriers is associated with specific crystal lattice symmetries and strong spin-orbit interactions. However, in topological semimetals conduction through topological edge (surface) states occurs always in parallel with bulk conduction. Hence in the case of thin films with a significant surface to volume ratio the conduction contribution of topological edge (surface) states is expected to be substantial. Topological semimetals consist of two main groups: (1) Dirac semimetals (DSM), (2) Weyl semimetals (WSM). In DSM both the time reversal symmetry and inversion symmetry have to occur in parallel, in WSM one of them has to be broken. External magnetic field is one of the factors breaking the time-reversal symmetry. Indeed a huge influence of magnetic field on electrical properties of topological semimetals is observed. Similar effect can be achieved by doping topological semimetals with magnetic ions (e.g. Mn, Fe, Cr, or other magnetic transition metal ions), or by proximity effect in the case when topological semimetal is adjacent to ferro- or antiferromagnet, e.g. in appropriately designed heterostructures. In such heterostructures a strong influence of magnetic material on the electronic structure and electrical properties of topological semimetal is expected.

In this project we propose to investigate: (i) single WSM layers, (ii) WSM layers doped with Sb and Bi heavy elements, (iii) WSM layers doped with magnetic transition metal ions, (iv) heterostructures (mutlilayers) comprising thin films of magnetic material (ferro or antiferromagnet) and Weyl semimetal. The samples will be grown by molecular beam epitaxy (MBE). The project will be realized at the Faculty of Physics, Warsaw University with use of a twin-chamber MBE system, with one growth chamber dedicated for II-VI, and another one to III-V semiconductors. In the first chamber thin films of $MoTe_2$ WSM and MnTe antiferromagnet will be grown; in the second one – TaAs and Ta(As,Sb,Bi) WSM and ferromagnetic (Ga,Mn)As, MnAs and MnGa layers will be deposited. The influence of magnetic layer proximity on electrical properties of WSM layers will be investigated in a broad temperature range (from 4 K to room temperature).

Topological semimetal / ferromagnet (antiferromagnet) heterostructures have not been investigated so far. Until recently only bulk crystals of WSM materials have been studied. Use of the MBE technique will enable formation of heterostructures with electronic/electrical properties of a topological semimetal significantly modified by a magnetic material. Already the MBE growth of WSM thin films will be an important achievement of the project. Heterostructures implementing WSM and magnetic materials have not been investigated so far, to our knowledge.