The project is focused on nanowire heterostructures consisting of topological crystalline insulator (TCI) nanowire (NW) cores encapsulated by the shells of magnetic (ferro and antiferro; FM and AFM, respectively) and superconducting (SC) materials. Topological crystalline insulators exhibit unique physical properties. Due to the distinct symmetries of their crystalline lattices (cubic, rock-salt structure) and specific feature of bulk electronic bands some materials from the rich family of narrow bandgap IV-VI semiconductors, e.g. PbSnSe and PbSnTe ternary alloys undergo so-called topological protection, which results in the occurrence of immune to back-scattering charge carriers at the border of material (surface or edge in the case of bulk crystal, or thin crystalline film, respectively). Such topologically protected charge carriers have similar properties to those occurring in graphene – they behave like massless Dirac fermions and are characterized by very high mobilities. Moreover topologically protected charge carriers have distinct spin orientation (which does not occur in the charge carriers in graphene), i.e. their spin is perpendicular to the wave-vector k).

Above mentioned features of TCIs lead to the occurrence of unique physical phenomena at the hetero -interfaces of TCI with, long-time investigated ferro/antiferro –magnetic (FM/AFM) and superconducting (SC) materials. This is due to the mutual interactions between spin-oriented charge carriers and local magnetic moments in both types of materials, namely TCI-FM and TCI-AFM. In the case of TCI-SC hetrostructures the local superconductivity can be induced in a TCI material by the SC one placed in the close vicinity.

These effects enable modifications of the properties of one material (TCI) by another one (FM/AFM or SC). These phenomena may be potentially applied for design of new dissipationless electronic (spintronic) devices. The combination of TCI and SC material (in heterostructures, with one material grown on-top of another) leads to the emergence of so called Majorana fermions – the composite quasiparticles, which due to their unique properties, are potential candidates for quantum computing applications.

In this project we propose to fabricate and investigate the quasi-one-dimensional nanostructures (NWs) in which, due to their high surface-to-volume ratio the effects associated with topological protection at the border are much stronger than those occurring in the bulk crystals or thin films of topological materials. The entire NW heterostructures will be crystallized in a molecular beam epitaxy (MBE) growth system. The MBE setup produces ultra-pure materials - both single crystalline layers and heterostructures combining dissimilar materials with e.g. different lattice parameter, crystallographic structure, and/or chemical composition. The MBE growth of structures occurs in the ultra-high-vacuum conditions, which is mandatory to fabricate high quality materials enabling detection of the effects associated with topological protection.

The hetreostructures fabricated during realization of the project will be investigated in the Institute of Physics Polish Academy of Sciences in Warsaw, with use of advanced experimental setups such as scanning and transmission electron microscope, superconducting quantum interference device, and others.