Modern technologies allow the production of new materials with atomic precision with unprecedented properties. In this project, magnetic systems containing many constituent layers, each of which is composed of only a few atomic layers, will be studied. In such structures, the contribution of atoms forming the layer boundary (interface) is significant. Because the magnetic properties of the interface atoms differ from those in the middle of the layer due to the dissimilar symmetry of the surroundings, this type of structure has different properties than the bulk material. One of the most important achievements of nanostructures research is obtaining perpendicular magnetization when the thickness of the magnetic component layer decreases below a certain critical value. In addition, if a coupling (IC) between the magnetic layers occurs, materials that are synthetic ferromagnets or antiferromagnets with parallel or anti-parallel magnetization arrangements, respectively, can be produced.

The research undertaken in this project is aimed at determining the impact of the parameters characterizing the fabricated structures on their magnetic properties. These include: the type of component layers, the sequence of their arrangement (resulting in the formation of specific interfaces), the thickness of the component layers. One of the basic properties is perpendicular magnetic anisotropy (PMA). It causes the magnetization of the layer to be perpendicular to its surface. This feature is used, for example, to increase the density of information storage on magnetic hard drives. The size of anisotropy is also responsible for the time stability of this record and determines various magnetization configurations in the material.

Nanostructures, in which another factor, called the Działoszyński-Moriji (DMI) interaction, has an additional influence on the magnetic properties, have been intensively studied for several years. This interaction causes the magnetization to be continuously twisted in the sample space. The source of DMI is a specific interaction between the atoms of the ferromagnetic layer, FM (e.g. Co or Fe) and the atoms of the adjacent non-magnetic layer made of heavy metals, HM (e.g. Pt, Ir, W, Pd) through the interface. It appears very clearly in asymmetrical sandwich structures of the HM1/FM/HM2 type, which will be studied in this project. Configurations of the magnetic structure, being a result of the collective influence of PMA, DMI and IC may evolve in the studied layers under the influence of the applied external magnetic field. Among them skyrmions – local stable magnetic whirls of very small sizes in the nanometre range – are investigated very intensively nowadays.

The described structures will be fabricated in dedicated systems under very high vacuum conditions. Their magnetic properties and magnetization configurations will be examined both in a global scale (i.e. in the scale of the entire sample) and locally (submicron areas). Numerous measurement techniques used to study the static and dynamic properties of these materials exploit the phenomenon of electric current induction (magnetometry), magnetic dipole interactions (magnetic force microscopy), light interaction (magneto-optical techniques and inelastic Brillouin scattering) or transmitted electrons (Lorentz transmission microscopy), and absorption of synchrotron radiation generated in accelerators. The experimental results will be simulated in parallel in theoretical calculations. Comparison of these results will allow for detailed interpretation of the effects observed in the conducted research and a deeper insight into the physical nature of the analysed systems.

The proposed research aims to understand magnetic phenomena appearing at the atomic level (nanomagnetism) in artificially created materials. They are implemented on several levels of complexity - from individual "blocks" to more complex systems built from an increasing number of these "blocks". Following this approach, it will be possible to produce intelligent materials with predefined properties. Nowadays, spintronics – a new branch of electronics – is developing very intensively, exploiting not only the fact that the electron has an electric charge, but also a spin. It causes the electron to behave like a magnet, whose movement can be controlled not only by the applied electric voltage, but also by an external magnetic field. Consequently, the current flow may depend on the sample's magnetization configuration. The flowing current can also modify the magnetic structure of the sample. The richness of these interactions, controlled by external factors, means that new materials can be fabricated to build electronic devices with unprecedented functionality (e.g. magnetic field reconfigured metamaterials - magnonic crystals). The skyrmions mentioned above are treated as stable objects (quasiparticles) with well-defined parameters that can be generated, annihilated or moved in the sample space by means of a flowing current. Therefore, they are also intensively tested for practical applications as magnetic information carriers or medium in devices performing logical operations.