Hematene: a unique tool for understanding of magnetism in non van-der-Waals two-dimensional systems

Since the discovery of graphene with its exceptional properties the family of two-dimensional (2D) materials has grown into enormous field of nanostructures revealing various novel phenomena and potentially new applications. Due to the nature of the bonding these materials can be divided into two basic groups: van-der Waals (vdW) and non-van-der Waals (nvdW) materials. The latter group which includes metal oxides, nitrides, phosphides, and metallic chalcogenides is more challenging to obtain in the 2D form due to the strong bonding in all directions. However, such materials in bulk often exhibit a "layered" structure that allows the fabrication of ultrathin films. It turns out that nvdW materials with reduced dimensionality are also characterized by interesting properties significantly different from those observed in their solid counterparts.

Promising candidates in this field are 2D iron oxides that show significant changes in magnetic behaviour when going from bulk to low dimensional structures, only a few layer thick. Such changes have been observed in the transition from hematite to hematene (hematite with a thickness of several layers), where hematite is antiferromagnetic and hematene can be ferro- or antiferromagnetic. In addition, it turns out that the deposition of single atoms and metal clusters on the surface of ultrathin oxides, apart from increasing number of active sites, can significantly modify the magnetic anisotropy and local magnetic properties of such materials.

The aim of the project is to learn and understand magnetic properties of ultrathin quasi-2D iron oxides and their derivatives modified with single atoms and metal clusters Mn, Co, Ni, Cu deposited on their surface.

The project will include optimization of the procedure for obtaining hematene sheets with controlled thickness and in the next stage, the preparation of appropriate 2D iron-based materials including other oxides, metallic iron, iron carbides and nitrides from the prepared hematene precursor. A comprehensive study of the structural, morphological, electronic and magnetic properties of the obtained 2D materials will be carried out through the use of various experimental and theoretical research methods.

Understanding the basic magnetic properties of emerging 2D systems other than van-der-Waals materials is critical to their potential applications. These materials may push the limits of current technologies in the field of magnetic storage media, and in addition, a large surface combined with single atoms and metal clusters may expand their application potential in the field of catalysis and photocatalysis.