Growth and characterisation of two-dimensional molybdenum disulfide layers

Recently, a relatively new research field of two-dimensional (2D) materials – starting from graphene has attracted tremendous attention. This was motivated by exceptional and unique properties of these materials, often offering very promising applications in the future. One example of these 2D materials, considered as one of the biggest competitors of graphene, is a monolayer form of molybdenum disulfide (MoS2). Due to the fact that this material is a single layer semiconductor with a layer-dependent band gap value, it is of great interest to nano- and opto- electronic. Thanks to its unique properties this materal may prove to be a milestone in development of flexible electronics.

Similar as in case of its older 2D brother graphene (Nobel Prize in Physics in 2010), in the first experiments on MoS_2, mechanical exfoliation method was used to obtain monoatomic thick layers. This method uses Scotch tape to isolate small flakes of high-quality two-dimensional crystals. While it does not require sophisticated laboratory equipment and it proved to be useful in the field of two-dimensional materials, its applications are limited. That is because of its low yield and poor repeatability, which precludes intensification and widening of research on MoS_2. Scientists and engineers interested in this material need efficient method of monoatomic thick MoS_2 layers. Mastering high quality MoS_2 growth as an efficient repetitive process that could provide samples would greatly speed up progress in research on this material. It would enable systematic research and optimalization of MoS_2 based devices.
The proposed project meets these needs. Its main objective is to **develop a scalable technology of epitaxial growth of monolayer MoS_2 on different substrates** measuring 1 cm^2. For that homemade CVD system (Chemical Vapor Deposition) will be used. It enables deposition of thin films from gaseous precursors. During such epitaxial process, when appropriate conditions are provided growth of crystalline structures with even monoatomic thick uniformity is conducted. Essential for growth mechanism is the substrate on surface of which the growth takes place. Within this project the use of entirely new hexagonal silicon carbide (SiC) substrate for MoS_2 growth is proposed to be used. SiC is well known material in semiconductors technologies, and its structure (arrangement of atoms) is in some ways similar to the structure of MoS_2. This makes it very promising substrate, on which synthesized MoS_2 layers may reach unprecedented quality.
In the project detailed characterization of obtained MoS_2 structures in planned. That will allow to understand and optimize epitaxial growth and to explore its properties (especially electrical and optical). A wide range of characterization methods, which will be used are as follows: Raman spectroscopy, photoluminescence spectroscopy, scanning probe microscopy, optical microscopy, scanning electron microscopy and most importantly electrical measurements. For the last ones, construction of devices in geometry of field effect transistors will have to be made (using nanolithography). Detailed analysis of this kind of devices will provide information of electrical transport mechanisms in MoS_2. What is more it is expected that properties of MoS_2 on SiC substrate, which are yet to be examined will shed new light on this material. That is another novelty in this project and its outcome after making a comparison with the properties on the SiO_2 substrate may significantly widen the knowledge on two-dimensional MoS_2.

Proposed research contained within the strategic research field described in the National Framework Plan: *VI. New materials and technologies: 6.1 Multi-functional nanomaterials and nanostystems* and *6.2 Advanced materials and electronic and optoelectronic devices.*