Nanocomposite magnetic compounds based on layered semiconductors synthesized by electrochemical intercalation in gradient magnetic field

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In recent years many efforts are directed to implant magnetism into the semiconductor architecture of modern electronic devices. One of the approaches for solving this problem consists in the preparation of materials able to combine properties of a ferromagnetic and a semiconductor [1]. Because of the progress in the technology and methods for preparation of semiconductor materials, along with investigations of single crystals (ferromagnetics and diluted magnetic semiconductors) the growing attention is concentrated on nanocomposite and granular semiconductor systems, films, layered structures and quasi-one-dimensional systems. One of the methods having being used for the formation of systems with reduced dimensionality, including magnetic ones, is intercalation of various impurities into the interlayer spaces of the compounds with layered crystal structure. Layered semiconductor crystals InSe and In_2Se_3 belong to the binary III-VI compounds and are characterized by the existence of two types of chemical bond – strong covalent within a separate layer and weak Van der Waals between the layers. As a result, there is a possibility to insert foreign atoms and even molecules into the interlayer spaces forming thereby layered structures with new properties. Intercalates are appropriate model objects to study physics of two-dimensional states and find applications as accumulators, thermoelements, solar cells, detectors and sources of IR radiation, etc.

In this paper, we propose a method of intercalation of layered single crystals in a magnetic field gradient. We report on structure properties of Co_xInSe and $Co_xIn_2Se_3$ layered crystals intercalated by cobalt. In addition, morphology of the van der Waals surfaces of the crystal layers was studied as well. We investigate self-organisation of Co magnetic nanostructures on the van der Waals surfaces of layered semiconductor crystals during electrochemical intercalation in the presence of external magnetic field. It is shown that the application of a gradient magnetic field at the interface (intercalation front) during electrochemical intercalation of the layered semiconductors with ions of 3d transition metals, in particular Co^{2+} ions, leads to the formation of various intercalant nanostructures on the Van der Waals surfaces of the layers. These nanostructures are formed due to self-organization of the intercalant on such surfaces. Similarly to epitaxy techniques, this makes it possible to fabricate magnetic nanocomposite structures consisting of a layered semiconductor matrix and interlayer planar inclusions of magnetic impurities normal to the crystallographic ***c*** axis by using intercalation along with an applied magnetic field. The interaction between the substrate and nanoparticles by means of Van der Waals forces and the exchange magnetic interaction between Co atoms are the determinative factors in the formation of such structures.

[1] H. Kronmuller, S. Parkin (Eds), Handbook of Magnetism and Advanced Magnetic Materials, John Wiley & Sons, Ltd, New York, 2007

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