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# The Effect of the Introduction of $Ni^{2+}$ Ions on the Electrical and Magnetic Properties of InSe Layered Crystals

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Influence intercalation ions of $Ni^{2+}$ on the electrical and magnetic properties of indium selenide crystals was investigated. It is shown that intercalates $Ni_{0.15}InSe$ that was received introduction of $Ni^{2+}$ at constant magnetic field generated magnetic impurity clusters of domain structure; dependence of the magnetic moment of nickel intercalates InSe of the magnetic field at room temperature has the form of the hysteresis loop. Found that increasing the concentration $Ni^{2+}$ ions specific conductivity and mobility of indium selenide crystals tends to decline.

**Keywords:** Indium selenide, Intercalation, Nickel, Conductivity, Mobility, Ferromagnetism.

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Indium monoselenide (InSe) is a semiconductor of the $A^3B^6$ group of layered compounds [1]. The energy gap of InSe is about 1,3 eV at room temperature. The basic unit consists of two planes of metal atoms sandwiched between two planes of chalcogen atoms. The atoms are bound by a mixture of covalent and ionic bounds within a layer, while the interlayer bonding is due to the weaker Van der Waals forces. Therefore, indium monoselenide have highly anisotropic electrical and optical properties. Particular interest in the study of layered crystals associated with the possibility to change their physical properties through a process of intercalation [2, 3].

The van der Waals surface of InSe layered crystals allows their use as substrates for growing nanostructures and creating heterojunctions based on semiconductor materials with different symmetry and lattice period.

Single crystals of indium monoselenide were grown by the Bridgman modified method. Intercalation of nickel ions was performed by the electrochemical method in the course of the anodic reaction of intercalation from saturated aqueous solution $NiNO_3$.

Investigation of magnetic properties of intercalated $Ni_xInSe$ ($0 \le x \le 1$) was performed on a vibration magnetometer «Vibrating Magnetometer 7404 VSM» in magnetic field intensity of 3000 Oe. The weight of intercalated nickel ions to InSe defined by Microscales AB135-S/FACT (sensitivity $10^{-5}$ m).

Intercalation was performed in galvanostatic mode currents, the density of which does not exceed 0.4 mA/sm2. The concentration of embedded Ni (x) is calculated according to Faraday's law.

The basic samples of indium monoselenide are paramagnetic. Introduction nickel ions using electrochemical intercalation in a magnetic field in InSe causes a change in the magnetic properties of intercalated $Ni_{0,15}InSe$.

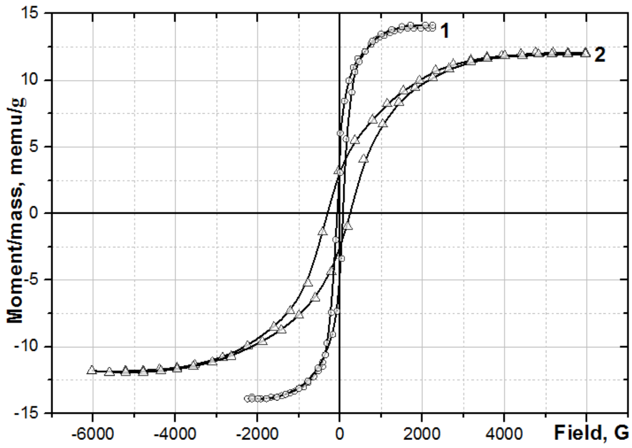


**Fig. 1** – The dependence of the magnetic moment of the magnetic field at T = 300 K for $Ni_{0,15}InSe$

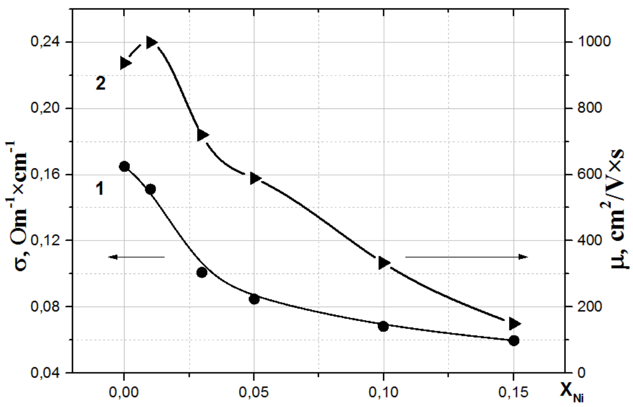


**Fig. 2** – The dependence of conductivity (1) and mobility(2) of majority carriers along the crystallographic axis c of concentration of intercalated ions $Ni^{2+}$ at a constant magnetic field

It is shown that intercalates of $Ni_{0.15}InSe$ that were received by introduction of $Ni^{2+}$ at constant magnetic field generated magnetic impurity clusters of domain structure; the dependence of the magnetic moment of nickel intercalates of InSe of the magnetic field at room temperature has the form of the hysteresis loop (Fig. 1). It was found that at the increase the concentration of $Ni^{2+}$ ions the specific conductivity and mobility of indium selenide crystals tends to decline (Fig 2.).

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