Ferromagnetic MnAs inclusions in InMnAs layers

A.V. Kudrin, A.V. Shvetsov, Yu.A. Danilov, D.A. Pavlov

Physics Department, N.I. Lobachevsky State University, Nizhny Novgorod, Russian Federation

In III-Mn-V layers the second-phase inclusions may appear during technology processes. In particular, nanosize ferromagnetic MnAs particles can be embedded in a semiconductor GaAs matrix as result of high dose implantation of Mn ions with subsequent rapid thermal annealing at 700 - 800ºC [1].

The InMnAs layers were grown by the pulsed laser sputtering of semiconductor InAs and metallic Mn targets placed in the quartz reactor with flows of hydrogen (the carrier gas) and arsine (the arsenic source). Semi-insulating GaAs (100) was used as a substrate. The layers were grown at 320ºC. The content of Mn was characterized by the technological parameter $Y_{Mn} = t_{Mn}/(t_{Mn} + t_{InAs})$, where t_{Mn} and t_{InAs} are the ablation times of the Mn and InAs targets. Structural properties were investigated by high-resolution cross-sectional transmission electron microscopy (TEM). The distribution of constituent elements was obtained by the energy-dispersive x-ray spectroscopy (EDS). The dc magnetotransport measurements were carried out in a van der Pauw geometry from 10 to 300 K in a closed-cycle He cryostat.

It was shown by the TEM and EDS that InMnAs (Y_{Mn} = 0.2) layers contain MnAs clusters of 20–50-nm size. Galvanomagnetic measurements demonstrated anomalous Hall effect (AHE) with hysteresis loop (Fig. 1). To change the carrier concentration in the InMnAs layer, the proton implantation was carried out with an energy of 50 keV and a fluence in the range of 1×10^{13} – 6×10^{14} cm^{-2}.

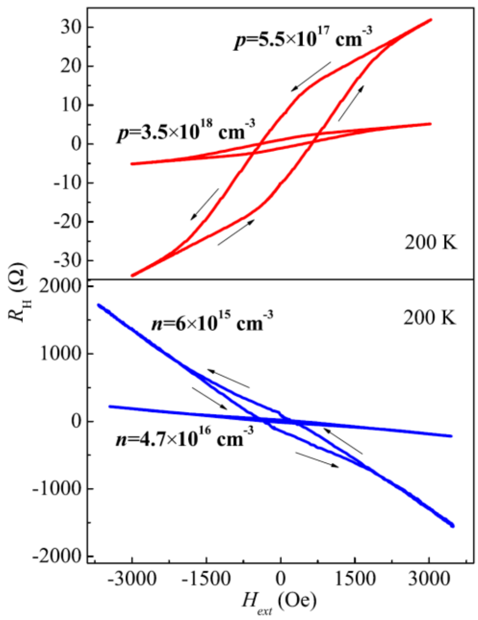

Fig. 1 Magnetic field dependences of Hall resistance for InMnAs layer for the different carrier concentration values The arrows indicate the magnetic-field scan direction.

Proton implantations with fluences of 1×10^{13} and 3×10^{13} cm^{-2} lead to a decrease in the concentration of carriers (holes) as a result of the partial compensation of the Mn acceptor impurity by radiation-induced donor-type defects. The conversion of the conductivity type from *p* to *n* is observed after the implantation with a fluence of 1×10^{14} cm^{-2}. With a further increase in the proton fluence to 6×10^{14} cm^{-2} the concentration of the majority carriers (electrons) rises. We suppose that the proton implantation with this relatively low fluence does not lead to a significant modification of properties of the MnAs inclusions, and the magnetic properties of the inclusions remain invariable. The anomaly in the Hall effect persists for the p-type and n-type conductivity of matrix. On the basis of performed study we can conclude that the apparent AHE in thin conductive InMnAs layers with ferromagnetic MnAs inclusions can be related to the influence of local magnetic fields produced by the inclusions of charge carriers.

1) O.D.D. Couto, Jr., *et al*., *Appl. Phys. Letters*, **2005**, *86*, 071906.