Antiferromagnetic EuTe clusters in $Ge_{1-x}Eu_xTe$ semiconductors

L. Kilanski[1], M. Górska[1], M. Arciszewska[1], A. Podgórni[1], R. Minikayev[1], A. Reszka[1], B.J. Kowalski[1], V.E. Slynko[2], and E.I. Slynko[2]

[1] *Institute of Physics, Polish Academy of Sciences, Aleja Lotnikow 32/46, PL-02668 Warsaw, Poland*
[2] *Institute of Materials Science Problems, Ukrainian Academy of Sciences, 5 Wilde Street, 274001 Chernovtsy, Ukraine*

Ternary diluted magnetic semiconductors (DMS) have been widely investigated because of an interesting mutual influence of their electronic and magnetic systems. In IV-VI DMS with rare-earth ions there is a tendency to form different types of clusters. The clusters modify significantly the properties of the materials.

We have studied structural and magnetic properties of $Ge_{1-x}Eu_xTe$ DMS with nominal x values from 0.002 to 0.021. The samples were prepared as bulk single crystals by the modified Bridgman method in the Institute of Materials Science Problems in Chernovtsy. The samples were p-type with carrier concentrations of the order of 10^{20} cm^{-3}. In the scanning electron microscopy (SEM) images of our samples we observed clusters with sizes up to 10 μm, preserving the structure of the host lattice, with the Eu content much higher than the average *x* value. We considered these clusters as spinodal decomposition. In addition to the spinodal decomposition we observed clusters with sizes of about 10 μm identified as clusters of EuTe (including a small amount of Ge) and clusters with sizes of about 20 μm, identified as clusters of Ge.

We have measured the temperature dependence of the ac magnetic susceptibility of our samples over the temperature range from 4.3 K up to 320 K and the dc magnetization as a function of magnetic field at 4.5 K, in magnetic fields up to 9 T. In the samples with $x > 0.007$ there was a cusp in the susceptibility at about 10 K. The temperature of the cusp peak did not depend on x. In the magnetic field dependence of the magnetization of the samples with the highest Eu content we saw a knee at about 7 T with approximately linear behavior below and above the knee. We attribute the cusp in the susceptibility data and the knee in the magnetization data to the presence of EuTe clusters in our samples.

The preliminary analysis of the susceptibility and magnetization data indicates a weak antiferromagnetic interaction among Eu ions, similar to that in other IV-VI DMS with rare earth ions. The Eu distribution in the samples is clearly not random. Less than 5 percent of Eu ions act as single magnetic ions. If the Eu ions were randomly distributed in the cation lattice, more than 80 percent of them should be singles.