XMCD STUDIES OF THE MAGNETIC PROPERTIES OF NANOCLUSTERS IN GaAs MATRIX

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Keywords: granular materials, magnetic moments, spintronics, XMCD

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The failure in producing the room temperature (RT) ferromagnetic diluted magnetic semiconductors, resulted in the increasing interest in the granular materials which are ferromagnetic at room temperature. In the case of GaMnAs, granular material can be easily produced by thermal processing of the low temperature grown MBE layers. In such materials the ferromagnetic clusters which show RT magnetism are immersed in a semiconducting matrix. Recently the possibility to produce the magnetic tunnel junctions with active layer of GaMnAs with the small cubic cluster was demonstrated [1]. As a result, new questions aroused concerning the control of the nanoclusters' crystallographic structure, size distribution and magnetic properties.

In the series of our recent papers [2-5] we demonstrate that the cubic MnAs clusters do not exist. Instead the small cubic GaMnAs clusters are formed with much higher content of Mn than ever produced in GaMnAs layers with randomly distributed Mn atoms. The clusters with size larger than 8 nm already have the MnAs hexagonal structure. Moreover, the commonly accepted conditions that annealing of layer up to 500°C produces exclusively cubic clusters while annealing at 600°C or higher results in solely hexagonal clusters are not valid.

The recent studies of x-ray absorption spectra (XAS) and x-ray magnetic circular dichroism (XMCD) on the series of granular materials will be presented. From the performed studies result that the Mn position in the as grown samples (substitutional or interstitial) plays an important role in the formation of nanoclusters of given crystallographic structure. The XMCD investigation performed at the ESRF station ID08 showed the remarkable difference in the magnetic properties of cubic and hexagonal nanoclusters. Moreover, the small number of the hexagonal MnAs nanoclusters is sufficient to dominate the magnetic properties of the sample (see Fig. 1) and the shape of the XMCD signal. Nevertheless, in all granular samples the XMCD signal was observed at RT under the magnetic field while at 12 K the dichroic signal was also detected for the remanently magnetized samples.

Two detection mode were applied with different sensitivity. The surface sensitive total electron yield (TEY) and bulk sensitive total fluorescence yield (TFY). The remarkable differences in the shape of both signal were detected (Fig.1) indicating variation in the spatial distribution of clusters with different structure. The dependence of the orbital and spin magnetic moment on the structure and size of observed clusters will be also discussed.

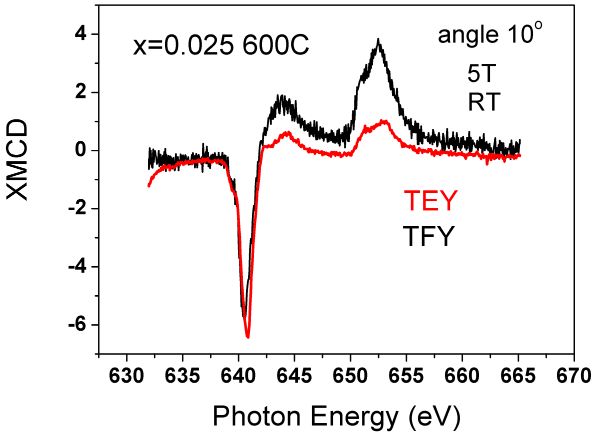

Figure 1: The XMCD at the $L_{2,3}$ edge of Mn measured at RT under field 5 T in two detection modes - total electron yield (TEY) and total fluorescence yield (TFY).The sample $Ga_{1-x}Mn_xAs$ with $x = 0.025$ after annealing at 600°C has only small fraction of hexagonal nanoclusters which dominated the XMCD bulk signal. The surface signal is still characteristic for cubic clusters.

Acknowledgments: TThe measurements performed at HasyLab have received funding from the European Community's Seventh Framework Programme (FP7/2007 – 2013) under grant ELISA agreement no. 226716. The measurement at ESRF from special project ESRF/73/2006 from the Ministry of Science and High Education. Authors thank you J. Sadowski for providing the samples.

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