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Can we control the process of room temperature ferromagnetic clusters formation in GaMnAs matrix?

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Since the prediction of room temperature (RT) ferromagnetic properties in diluted magnetic semiconductors (DMS) [1], in which a stoichiometric fraction of the host semiconductor atoms is randomly replaced by magnetic ions, there is a worldwide search for RT ferromagnetic DMS materials. Due to failure in producing these kind of materials, the increasing interest is devoted to the granular materials being ferromagnetic at room temperature. In the case of GaMnAs, granular material can be easily produced by thermal processing of the low temperature (LT) grown MBE layers. In such materials the ferromagnetic clusters which show RT magnetism are immersed in semiconducting matrix. Recently the possibility to produce the magnetic tunnel junctions with active layer of GaMnAs with the small cubic cluster was demonstrated [2]. Therefore, the new problem arises, how to control the nanoclusters crystallographic structure and size distribution.

In the series of our recent papers [3-5] 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 have already MnAs hexagonal structure. Moreover, the commonly accepted conditions that annealing of layer up to 500 ^{o}C produces exclusively cubic clusters and annealing at 600 ^{o}C or higher results in solely hexagonal clusters are not valid. From the performed studies we postulated that the Mn position in the as grown samples plays an important role in the formation of nanoclusters. It is known that in LT grown MBE layers part of the Mn atoms is located in the interstitial positions. It has been shown in paper [6] that in the case of samples with 5-7% content of Mn more than 50% of Mn atoms were located in the interstitial positions. In a recent paper [4] it was found that in such samples already after annealing at 500 ^{o}C significant part of Mn atoms formed hexagonal MnAs clusters. In the case of samples with content of Mn at the level of 2-3% almost all Mn atoms were located in substitutional positions already in as grown sample and after annealing even at 600 ^{o}C only cubic clusters were observed.

To check directly the influence of the Mn location in as grown samples on the structure of clusters formed during annealing procedure the special set of samples was prepared. The sample with nominal content of Mn 10% and thickness 500 Å was grown at LT and next annealed during 10 hours at 160 ^{o}C. This procedure is commonly used to remove the Mn from interstitial positions. Next part of the sample was annealed at 500 ^{o}C and part at 600 ^{o}C.

The other sample with 3% of Mn was thermal processes according to the standard procedure (500 and 600 ^{o}C). The location of Mn was investigated by X-ray absorption spectroscopy and the strain in the layers by a high resolution Philips Material Research diffractometer.

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