CREATION OF MnAs NANOCLUSTERS AT PROCESSING OF GaMnAs

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Annealing of GaMnAs layers at 700-1000 K can result in the compressive strain changing to the tensile one. This effect is related to a creation of MnAs nanoclusters embedded in the GaAs matrix and indicating the preferred crystallographic orientation [1-3]. Depending on the MnAs cluster size, the granular GaAs:MnAs material exhibits a ferromagnetic/ superparamagnetic behavior at room temperature [1].

The goal of present work was determination of the effect of annealing at various conditions on the defect structure of the GaMnAs heteroepitaxial layers grown on the GaAs substrates.

Three GaMnAs samples differs by Mn concentration were studied (A66 - 2%, A831 - 6%, A832 - 7%.). GaMnAs layers were deposited on 001 oriented GaAs by the MBE method. After layer deposition, the A66 sample was annealed in Ar atmosphere for 1 h at 670 K under ambient pressure (10^5 Pa) or under enhanced hydrostatic pressure (p = 1.1 GPa). The other A66 sample processed for 1 h at T = 670 K under 10^5 Pa was subsequently treated at 920 K for 1 h, also under p = 1.1 GPa. The A831 and A832 samples were annealed for 1 h at 770 K or at 870 K under 10^5 Pa.

Structural characterization of the layers, before and after processing, was performed using synchrotron radiation at the W1.1 beamline at DESY-Hasylab. Following measurements were performed:

i) 2θ scans in the glancing incidence geometry,

ii) ω scans across the 002 and 004 GaAs reflections,

iii) 2θ-ω scans across the 224 GaAs reflection.

The phase analysis of the near surface layers was performed using diffraction synchrotron radiation in the glancing incidence geometry. In this method a sample is placed in the fixed position while the angle between the sample surface and X-ray beam is small (1° in our case). The intensity of diffracted beam was detected by the counter rotating in the plane perpendicular to the sample surface within the large 2θ angles. The described geometry of measurements has been applied for investigation of the phase composition of the thin near surface polycrystalline layers.

By an analysis of the 2θ scans, the diffraction peaks, originating from the polycrystalline orthorhombic MnAs phase, were detected for the A831 and A832 samples after their annealing at 670 K and 870 K. Also the polycrystalline hexagonal MnAs inclusions as well as the cubic Mn ones were detected in the case of A832 sample. In the case of sample A66, the hexagonal inclusions were detected only in the case of sample treated at 920 K under p = 1.1 GPa. Using the ω scan around the 002 and 004 GaAs reflections and the 2θ-ω scan around the 224 GaAs reflections, the lattice parameters of hexagonal MnAs crystallites, with a well-defined orientation relationship in respect to the GaAs matrix, were determined from the positions of the 11.0 and 03.0 reflections of hexagonal MnAs [2-4]. For the A831 and A832 samples annealed at 870 K, the lattice parameters were: a = 3.710 Å and c = 5.785 Å. In the case of A66 sample, annealed at 870 K, the a and values were 3.765 Å and 5.648 Å, respectively. The reflections originating from the hexagonal MnAs clusters with preferred orientation were not detected for samples annealed at 670 K/770 K under ambient pressure or at 670 K under enhanced pressures. An influence of defects on the structural changes in the temperature-pressure treated samples will be discussed.

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