

### Structural transformations of GaMnAs layer annealed under enhanced hydrostatic pressure

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Granular GaAs:(Mn,Ga)As structures are currently thoroughly investigated, because such material exhibits a ferromagnetic/superparamagnetic behavior at room temperature depending on cluster size (see e.g. [1]). Specific ferromagnetic precipitates are fairly easily produced in effect of annealing of III–V semiconductors at 400–700°C, yielding the multi-phase materials. The formation of nanoclusters and strains created in the GaAs:(Mn,Ga)As layers correlate with their structure and ferromagnetism existing up to room temperature. Depending on annealing temperature of GaMnAs, small cubic, of the zinc-blende type (ZB), or larger, of the NiAs-type, MnAs nanoclusters are formed [2].

The goal of present work is determination of the influence of annealing under enhanced hydrostatic pressure (*HP*) on strain state of the GaMnAs/GaAs heteroepitaxial system exhibiting, due to different Mn concentrations in the GaMnAs layer, also the different initial strain state. Ga<sub>1-x</sub>Mn<sub>x</sub>As layers with nominal Mn contents  $x = 0.025, 0.03, 0.04, 0.05$  or  $0.063$  were grown by MBE on the (001)-oriented GaAs substrates at 230°C. Nominal thickness of the layers was 0.8 nm.

After deposition each sample was cut into three pieces. One of them was left untreated, the others were reintroduced into the MBE growth chamber and annealed under As<sub>2</sub> flux or under  $HP = 1.1$  GPa in argon atmosphere for 30 min. at  $T = 500^\circ\text{C}$ . X-ray diffraction measurements were performed using a synchrotron radiation as well as a standard laboratory source of Cu K $\alpha$  radiation.

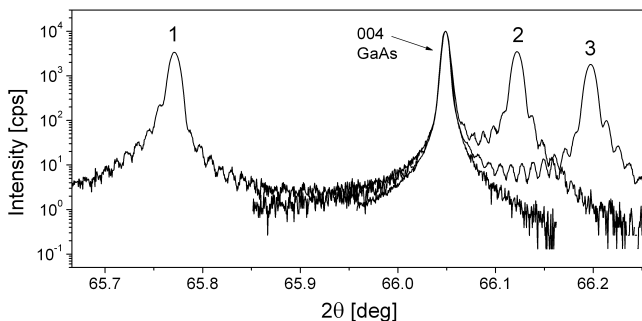


Figure 1.  $2\theta/\omega$  scans of 004 reflection for Ga<sub>0.96</sub>Mn<sub>0.04</sub>As: 1 – as-grown, 2 – annealed at 500°C under  $10^5$  Pa, 3 – processed at 500°C under 1.1 GPa are compared with the (004) substrate reflection.

Enhanced hydrostatic pressure applied during annealing of the MBE grown GaMnAs layers at 500°C results in increasingly strained layers (Fig. 1). This *HP*-induced strain is definitely dependent also on

the layer composition. The creation of additional strain within nanoclusters under the *HP-T* conditions results in the increasingly strained granular layer state.

#### References:

- [1] A. Kwiatkowski, D. Wasik, M. Kaminska, R. Bozek, J. Szczytko, A. Twardowski, J. Borysiuk, J. Sadowski, J. Gosk, *J. Appl. Phys.* **101** (2007) 113912.  
 [2] K. Lawniczak-Jablonska, J. Bak-Misiuk, E. Dynowska, P. Romanowski, J.Z. Domagala, J. Libera, A. Wolska, M.T. Klepka, P. Dłuzewski, J. Sadowski, A. Barcz, D. Wasik, A. Twardowski, A. Kwiatkowski, *J. Solid State Chem.* (2011) in press.

