


| | | |
|---|--|--|
|  ROBL-CRG | Experiment title: Spinodal decomposition and formation and structural properties of transition metal clusters | Experiment number: 20-02/663 |
| Beamline: BM 20 | Date of experiment: from: 03.05.2008 to:05.05.2008 | Date of report: 22.10.2008 |
| Shifts: 8 | Local contact(s): Dr. Nicole Martha JEUTTER | <i>Received at ROBL:</i> |
| <p style="text-align: center;"> G. Talut*, D.Bürger*, A. Shalimov* and J. Grenzer* Forschungszentrum Dresden-Rossendorf e. V. Institute of Ion-Beam Physics and Materials Research 01324 Dresden, Germany </p> | | |

Report:

One of the challenges in the engineering of ferromagnetic diluted magnetic semiconductors is the determination of their microstructure. We have investigated wurtzite gallium nitride (GaN) layers on sapphire implanted with 200 keV Fe ions and fluences of $8 \cdot 10^{16} \text{ cm}^{-2}$ and $1.6 \cdot 10^{17} \text{ cm}^{-2}$ at room temperature. The samples were subsequently annealed by using the flash lamp method for 3 ms, 20 ms and 2×20 ms in Ar-flow. In order to investigate a possible spinodal decomposition as well as the formation and structural properties of transition metal clusters or other secondary phases structural investigations were carried out with a 10 keV monochrome x-ray radiation in the ω -2 θ geometry.

In as implanted samples no secondary phases like bcc-Fe or iron nitrides were detected using x-ray diffraction techniques (Fig. 1). However, a clear ferromagnetic response was found by SQUID magnetometry in these samples. This behavior is a clear indication of a spinodal decomposition.

In the sample implanted with $8 \cdot 10^{16} \text{ cm}^{-2}$ a broad peak at about 35.2° was detected after 3 ms flash lamp annealing. This peak could be attributed to nanometer sized clusters of $\epsilon\text{-Fe}_{2.4}\text{N}$ (221-reflection). This peak disappears for longer annealing

times. For 20 ms annealing a peak at 34.7° appeared. This one has to be assigned to $\varepsilon\text{-Fe}_3\text{N}(200)$ because the sample has turned to be strong ferromagnetic. Longer annealing times (2x20 ms) lead to an additional peak at about 33.9° . This cannot be assigned to a certain phase and could be related to some nonstoichiometric iron nitride.

For a higher Fe fluence ($1.6 \cdot 10^{17} \text{ cm}^{-2}$), i.e. higher Fe concentration, already a 3 ms annealing lead to an elevation at about 34.7° , that is $\varepsilon\text{-Fe}_3\text{N}$. It grows to a broad peak after annealing for 20 ms. An intensive broad peak at about 35.5° was detected upon annealing for 2x20 ms and was related to bcc-Fe what was supported by Mössbauer spectroscopy.

Therefore, the following process during annealing can be suggested. During the implantation Fe is randomly distributed in the GaN lattice. For high fluences ($\geq 8 \cdot 10^{16} \text{ cm}^{-2}$) spinodal decomposition may occur. Short annealing times cause short diffusion lengths. Furthermore they enable the formation of metastable iron nitrides. The increase of annealing times results in a higher Fe content in the forming iron nitrides. Finally, for large Fe fluences and/or highest annealing times ($>40\text{ms}$) metallic bcc-Fe clusters are formed that have an epitaxial relationship with the GaN matrix. Further annealing would result in the growth of that bcc-Fe as it is known from the literature [1].

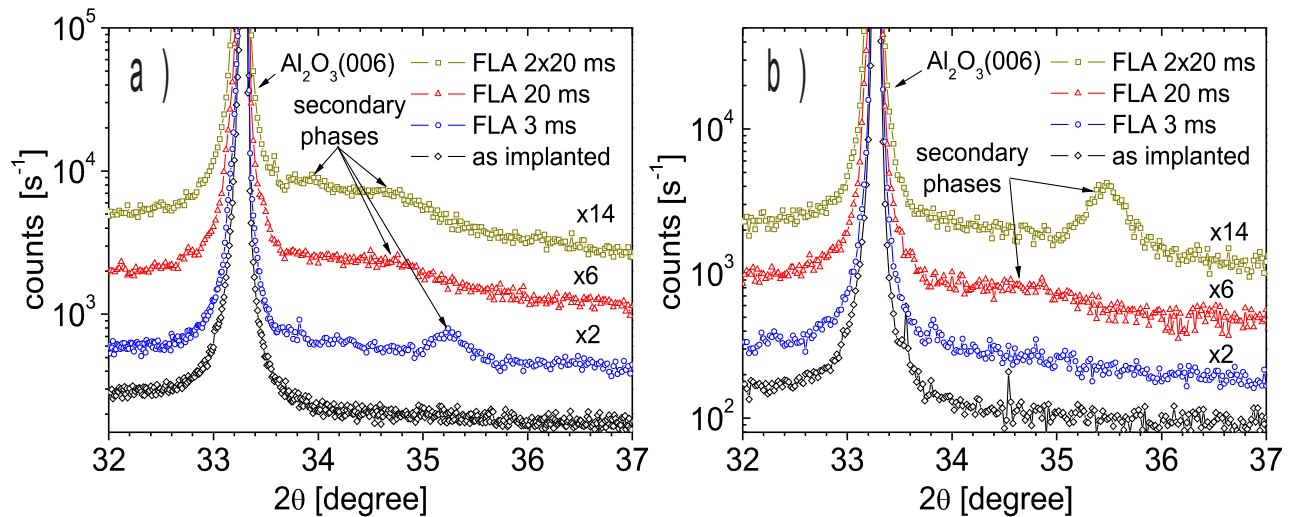


Fig. 1: Coplanar ω -2 θ scans of samples implanted with a) $8 \cdot 10^{16} \text{ cm}^{-2}$ and b) $1.6 \cdot 10^{17} \text{ cm}^{-2}$ Fe and subsequently flash lamp annealed. Scans are shifted along the ordinate.

[1] G. Talut, H. Reuther, A. Mücklich, F. Eichhorn, and K. Potzger, *Appl. Phys. Lett.*, **89**, 161909 (2006).