<table>
<tr><td>ROBL-CRG</td><td>Experiment title:

Influence of codoping on nanocrystal formation in GaFeN</td><td>Experiment number:
SI-1797</td></tr>
<tr><td>Beamline:
BM 20</td><td>Date of experiment:
from: 25/02/2009 to:03/03/09</td><td>Date of report:
30/09/2009</td></tr>
<tr><td>Shifts:
12</td><td>Local contact(s):
Nicole Jeutter</td><td>Received at ROBL:</td></tr>
<tr><td colspan="3">Names and affiliations of applicants (* indicates experimentalists):
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Report:

Transition metal doped III-V compounds offer an unprecedented opportunity to explore ferromagnetism in semiconductors. Because ferromagnetic spin-spin interactions are mediated by holes in the valence band, changing the Fermi level using co-doping, can directly manipulate the magnetic ordering**.** The Fermi energy can even control the aggregation of magnetic ions, providing a new route to self-organization of magnetic nanostructures in a semiconductor host [1].

Recent work on GaFeN samples codoped with Si has given evidence of the possibility of Fermi-level engineering in this material system [2]. The co-doping of GaFeN with acceptors is of great interest due to the fact that acceptor impurities like Mg increase the density of holes. It is believed that these holes change the charge state of the iron-ions from Fe^{3+} to Fe^{4+}. The increased electrostatic repulsion of the Fe^{4+} ions should hinder the formation of both coherent Fe-rich inclusions in the GaN lattice as well as the growth of Fe-rich precipitates. Furthermore a systematic study of the influence of growth temperature on the precipitation of the Fe-rich phases observed in GaFeN is desired. For this purpose two GaFeN samples series were measured in coplanar geometry at BM20 using a photon energy of 10 keV. Long radial scans

from 5° to 40° in $\omega/2\theta$ were performed on each sample. In first series in Fig. 1(a) only the substrate temperature during growth was varied.

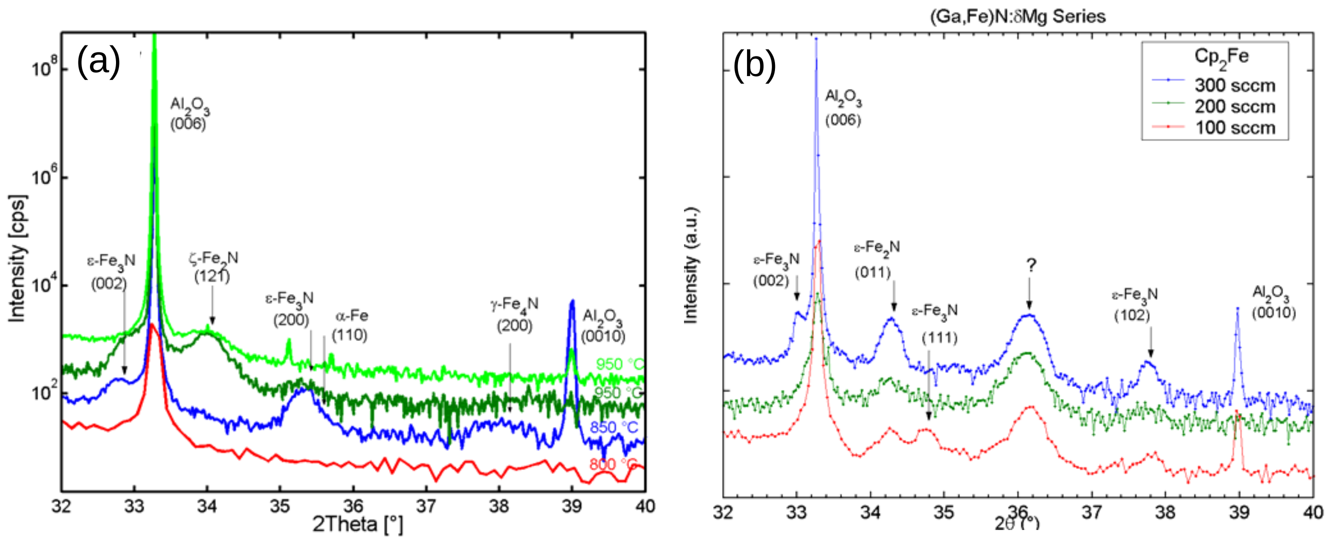

Fig. 1: (a) Radial ($\omega/2\theta$) scans of GaFeN samples as a function of growth temperature**. (b)** XRD spectra of a GaFeN:Mg sample series with constant Mg flux, but varying Fe flux.

The sample grown at 850°C shows two diffraction peaks from the ferromagnetic (FM) wurzite ε-Fe_3N, which had already been reported before [3, Exp.Rep. SI-1633]. One additional peak, however, could be detected, which can be related to the γ'-Fe_4N phase. This is an evidence that FeN precipititates can be formed in different crystallographic phases, whereas the formation process can be influenced by adjusting the growth conditions, such as the substrate temperature. At 800°C no indication of precipitate formation is observed, where as at 950°C only one precipitate peak is observed related to the ζ-Fe_2N phase. This phase had not been observed in a previous experiments.

In the second series the temperature (950°C) and the flux of the co-dopant Mg was kept constant, and only the Fe flux was altered (see Fig. 1 (b)). In this way, different Mg co-doping levels during the precipitate formation could be realised. We have evidenve that the formation of Fe precipitates is not hinderd by the co-doping with Mg as for the case of Si co-doping. Actually, Mg even *enhances* the formation of precipitates even at very low Fe source flows of 100 sccm. This will be a topic for detailed future investigations. One diffraction peak could not yet be identified, but is most probably related to an Fe-Mg alloy. The measurements on the influence of growth temperature performed during beam time SI1797 are under analysis and will soon be submitted for publication.

References: [1] T. Dietl, Nature Materials **5**, 673 (2006).
[2] M. Rovezzi *et al.* Phys. Rev. B. **79,** 195209(2009)
[3] A. Bonnani et al., Phys.Rev.Lett **101**, 135502 (2008)