(S)TEM-Investigations of GaN co-doped with Iron

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Introduction

Semiconductor-based spintronics recently gained a lot of interest and represents a break-through in spintronic nanotechnology. By co-doping GaN with Fe it is possible to obtain a self-organized aggregation of nano-crystals into the paramagnetic host [1]. Therefore both the local and global magnetic behavior of the material is modified, which might lead to a suitable spintronic semiconductor. Consequently, analytical knowledge of the chemical composition of the nano-crystal is important to optimize the epitaxial growth conditions [2,3]. In this work two aspects of the III-V semiconductor GaN co-doped with Fe are shown. First the possibilities of a probe-corrected microscope (FEI TITAN) equipped with ChemiSTEM-technology (©FEI) are presented. The second aspect covers (analytical) insights into Fe co-doped GaN where 2 different doping levels were investigated (nominal: 0.25% and 0.5% doping).

GaN - Chemical and Structural Information

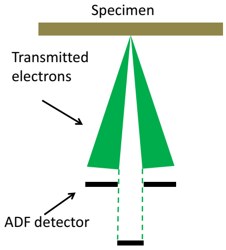
Annular Bright Field imaging:

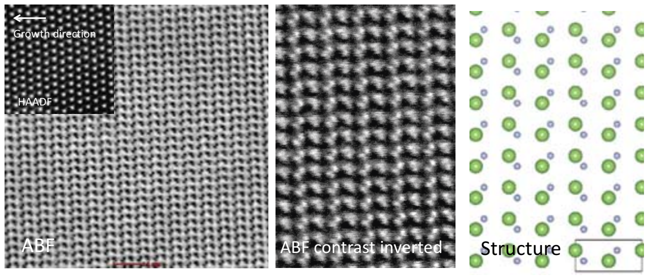
- ABF: improved sensitivity for light atoms (e.g.: N, O and C) [4]
- First CL adjusted that diameter of transmitted disc fits to inner diameter of ADF detector and then doubled
- Ga and N atoms are distinguishable; compared to structure model

Experimental Details:

- probe-corrected 300kV FEI TITAN with FEI ADF detector; ABF images correspond to an angular range of 12.1 – 67.6mrad

ABF:



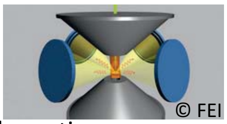


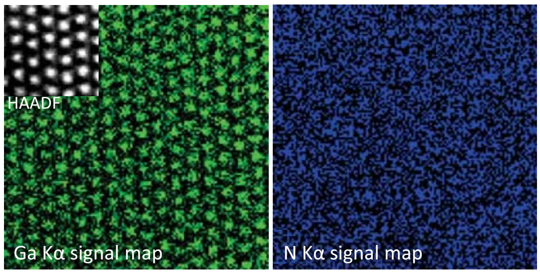
ChemiSTEM:

- 4 quadrant SSD EDXS detector
- Atomically resolved EDXS map of GaN (in [110]) with Ga Kα
- Nitrogen: lower X-ray generation; radiation damage; signal absorption

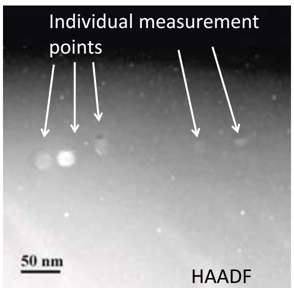
Experimental Details:

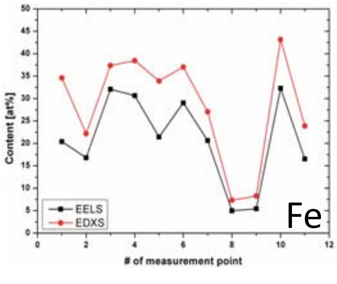
- EDXS map: 128x128 pixel, 25µsec per pixel, beam current ~150nA continuously integrating frames for 5min on 300kV probe-corrected TITAN
- Corresponding STEM image recorded with 512x512 pixel, 40µsec dwell time/pixel

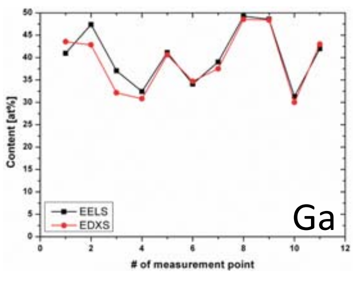


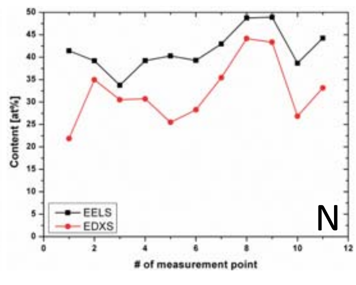


Iron doped GaN









STEM-EELS & STEM-EDXS measurement and quantification of Fe-doped GaN [5] :

- 2 specimens: 0.25% and 0.5% Fe (nominal concentration)
- Individual crystals exhibit different levels of brightness (HAADF image) → variation of chemical compositional of individual crystals
- Content of Ga, Fe and N fluctuates strongly between individual crystals (only nominal 0.5% Fe shown)
- Strong deviations of N and Fe → reflects strengths and shortcomings of respective analyses techniques (EELS and EDXS)
- Tryout of “synthesis” of chemical meaningful Fe_xN_{1-x} compound embedded in the GaN matrix
- Average value of Fe within nano-crystal increases with increasing nominal concentration: 0.25% Fe-doping: 9%
  0.5% Fe-doping: 23%

Experimental Details:

- STEM-EELS and STEM-EDXS measurements done on a 200kV FEI Tecnai
  EDXS: 400sec with 10eV/ch and 100µsec integration time
  EELS: 0.5eV/ch dispersion; collection angle: 15.9mrad; acquisition times: low-loss 0.1sec and high-loss: 200sec

Literature

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[3] A. Bonanni *et al*, Physical Review Letters **101** (2008), p. 135502.
[4] S. D. Findlay *et al*, Ultramicroscopy **110** (2010), p. 903.
[5] M. Wegscheider *et al*, Journal of Physics: Condensed Matter **20** (2008), p. 454222.

Acknowledgements

The help and work of Sorin Lazar (FEI) is gratefully acknowledged.
This work was supported by within the Austrian NANO Initiative
(project number: 819702).