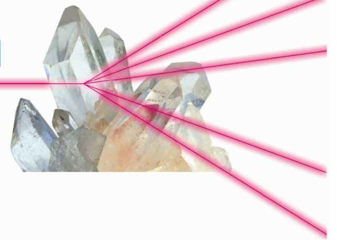
UNIVERSITÄT SIEGEN
Prof. Dr. Ullrich Pietsch
FESTKÖRPERPHYSIK



Universität Siegen ● NT Fakultät – Prof. Dr. U. Pietsch ● 57068 Siegen

Department Physik
- Festkörperphysik -

Examination report of PhD thesis of Mr. Mikhaylo Barchuk

„*Diffuse x-ray scattering from GaN epitaxial layers*"

Submitted to Math-Phys. Faculty of Charles University Prague, October 2012

GaN is a very promising semiconductor material for light emitting diodes and future solar cells. However, the material still suffers from a high number of structural defects such as edge and screw dislocations as major line defects and stacking faults as major planar defects. Besides direct but mainly destructive analysis methods as transmission electron microscopy or etch pitch density measurements via chemical treatment non-destructive x-ray diffraction methods are very promising for structural analysis as direct support for improvement of crystal growth process. Due to the large defect density X-ray diffraction beak become broaden along the radial and axial direction. The amount of this broadening and the power law of how the Bragg peak decays as function of the angular distance from the main Bragg peak position reveal the number and type of dislocations. The same yields for the determination of SF density, because they also increase the peaks width of particular Bragg reflections.

The impact of high dislocation density on the peak profile has to be treated by statistical methods. Pioneered by Krivoglaz and Kaganer there are several approaches to describe x-ray peak broadening by statistical methods. The candidate has applied an alternative concept by applying a Monte-Carlo method to simulate the whole reciprocal space map of a Bragg diffraction considering the type and the density of dislocations. He has shown that the evaluated parameters fits with the numbers obtained by alternative methods and correlate to the growth parameters.

In detail the candidate has used 3 sets of GaN samples (c-plane GaN) covered by SiNx; a-plane GaN and c-plane GaN covered by AlGaN) grown by MOPVE. The sample differ by the films thickness and/or thickness of cover layer and other growth parameters. Applying the approach mentioned above he could show for c-GaN (series S) that the evaluated number of edge dislocations scales with the thickness of the SiNx layer fairly well whereas the screw dislocation show no major variation..

POSTANSCHRIFT Universität Siegen, Fachbereich Physik, 57068 Siegen
HAUSANSCHRIFT Universität Siegen, Fachbereich Physik, Emmy – Noether - Campus, Walter – Flex - Str. 3, 57072 Siegen

Sekretariat: Kerstin Semma, Durchwahl: 3760, E-Mail: semma@physik.uni-siegen.de

The determined dislocation density agrees quantitative with the etch pitch density. For series c-GaN coverd by AlGaN (series A) edge-dislocation density scales with the thickness of the AlGaN cover layer, where the screw density is keeps rather constant again. Finally the peak widths extracted from reciprocal space maps of a-GaN layers is used to determine the SF density along the 0001 axis of wurzite structure GaN (series M). The results of the thesis are important and contribute essentially to the progress in this field of science. The candidate has demonstrated his ability to perform scientific research.

However, the written thesis suffers from many deficits. So, the samples used fro the investigation introduced in chapter 3 are not precisely described. Since all growth parameters are listed in a table for series S, such compactness is missing for samples M and A. Therefore up to the end the differences of samples M1 to M4 are not obvious, the correlation of evaluated x-ray data shown in table 10.4 with growth parameters is not possible. Few of samples are inspected by alternative methods as TEM CL and EPD. Except for series S there is no comparison of the the results of these methods with the x-ray data.

The measured reciprocal space maps are simulated by the approach mentioned above. The calculations agree with experiment fairly well as shown in figures of chapter 7. However, the fits are given without refereeing to the parameters used for calculation, a table of fit parameters listed as function of growth parameters is missing. So, the reader has no chance to compare the parameters and to understand their particular sensitivity to the final data. The same holds for the log-log plots shown in same chapter. Here the candidate shows the curves in between lines representing two decay functions without specific sample discussion. Here one expects the evaluation of decays exponent for each sample. Similar arguments holds for the presentation of results of series M in Chapter 10, a list of detailed numbers extracted from the figures are recommended.

The summary reflects the major achievements in methodical developments only but not the sample results which might be important for much broader community of semiconductor researcher. The results are partially published (3 papers in reference list).

In summary, the candidate has presented major achievement in the analysis of the dislocation and SF density in GaN epitaxial layers. I accept the thesis as dissertation and recommend awarding Mr Barchuk the PhD degree. Before final publication I recommend improvements of the dissertation.

Ullrich Pietsch
28.10.2012