SL16

STRUCTURAL ANALYSIS OF GAAS/SI NANOWIRES

P. Klang[1], H. Detz[1], A. M. Andrews[1], D. Kriegner[2], J. Stangl[2], G. Bauer[2],
A. Lugstein[3], W. Schrenk[3], G. Strasser[1,3]

[1]Institute for Solid State Electronic, TU-Wien, Vienna, Austria
[2]Institute of Semiconductor Physics, Linz University, Linz, Austria
[3]Center for Micro- and Nanostructures, TU-Wien, Vienna, Austria
pavel.klang@tuwien.ac.at

Semiconductor nanowires have been intensively studied as a potential structure to merge Si-based technology with the field of III-V optoelectronics. The structural properties of ensembles of GaAs nanowires grown on Si nanowire templates are studied non-destructively by X-ray diffraction to determine epitaxial orientation, crystalline quality, and crystal structure.

The GaAs nanowires were grown using molecular beam epitaxy on Si nanowire templates. The templates were prepared by the vapor-liquid-solid growth mechanism in a low pressure chemical vapor deposition reactor [1]. The GaAs nanowhiskers formed tree-like structures with a 6-fold radial symmetry (Fig. 1) on the side facets of the Si nanowires trunks [2].

We identified both wurtzite and zinc-blend structure of GaAs in the samples from measured reciprocal space maps with a large Q_z range. Additional to the maps, we investigate pole figures to find the epitaxial relationship between GaAs and Si crystal structures. The peak positions in the pole figures for Si 111 and GaAs 111 diffraction are the same, therefore we can conclude that the GaAs nanowires are grown hetero-epitaxially on Si nanowires. The six-fold symmetry of the nanowire trees is observed also in the pole figure measurements. In this measurement for the GaAs 111 diffraction, we should obtain only four peaks corresponding to the o directions for pure zinc-blend GaAs. In the measured pole figures, there are additional peaks not expected for bulk GaAs. These peaks can be explained by considering the effects of twin defects in {111} planes in the Si and GaAs nanowires (Fig. 2). Due to the high intensity of these additional peaks a significant fraction of the Si and GaAs nanowires contain twin defects. This is in a good agreement with high resolution transmission electron microscopy analysis.

We recorded three grazing incidence diffraction reciprocal space maps to determine the wurtzite content of the nanowires. We chose the cubic (-1-11) and (311) reflections and the cubic/hexagonal (-220)/(-1-120) reflection because they are accessible in the grazing incidence geometry. We compared the measured integrated intensity with the theoretical reflection strength of GaAs for these reflections. The high intensity of the wurtzite allowed reflection implies 80-90% wurtzite in the sample, but this also includes the GaAs that did not incorporate into the nanowires.

Hetero-epitaxially grown GaAs nanowhisk and their positions in the pole figure diagrams. We include the twins to the model of GaAs nanowires grown along o or direction on the {112} side facets of the [111] Si nanowires trunks. Using grazing incidence diffraction, we measured the wurtzite content of the GaAs nanowires.

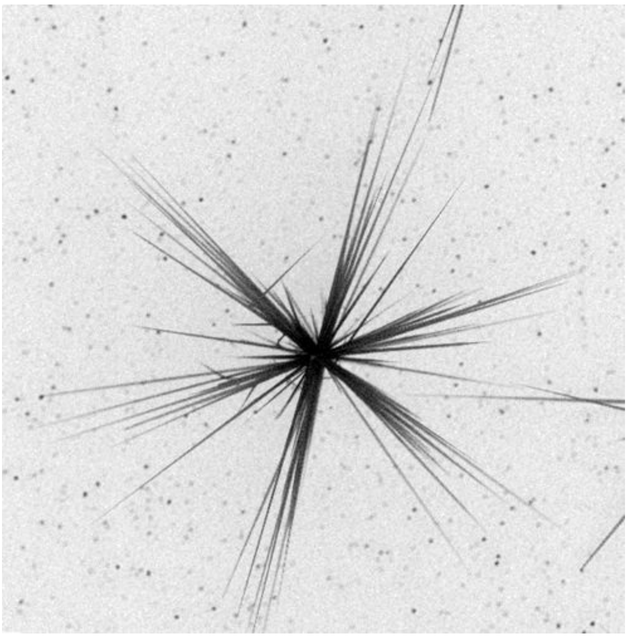

Figure 1. SEM picture of GaAs nanowhiskers on Si nanowire forming tree-like structure with a 6-fold symmetry.

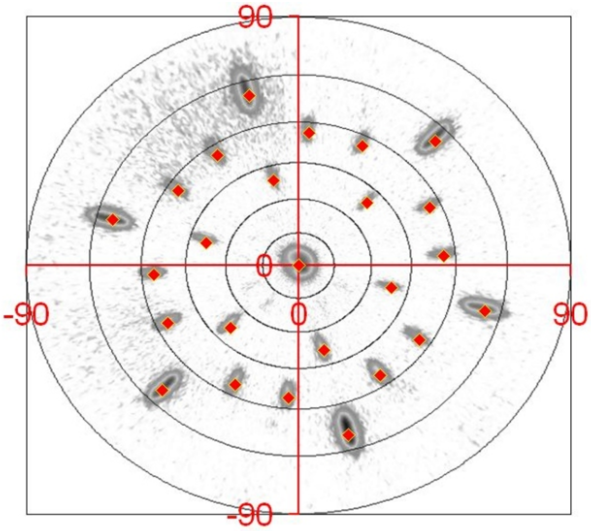

Figure 2. Measured X-ray pole figure for GaAs 111 diffraction and calculated o peak positions taking account twin defects in {111} planes.

References

1. A. Lugstein, A.M. Andrews, M. Steinmair, Y. Hyun, E. Bertagnolli, M. Weil, P. Ponratz, M. Schramböck, T. Roch, G. Strasser, *Nanotechnology*, **18**, (2007), 355306
2. H. Detz, P. Klang, A.M. Andrews, A. Lustein, M. Steinmair, Y.J. Hyun, E. Bertagnolli, W. Schrenk, G. Strasser, *Journal of Crystal Growth*, **311**, (2009), 1859

Acknowledgements

The authors would like to gratefully acknowledge the support of the Austrian SFB project IR-ON and Society for Micro- and Nanoelectronics (GMe).

SL17

PERIODIC MODULATION OF STRAIN FIELDS AND MAGENTIC ANISOTROPY IN (Ga,Mn)As/InAs/GaAs STRUCTURES

T. Čechal[1], X. Martí[1], L. Horák[1], V. Novák[2], K. Hruška[2], Z. Výborný[2], T. Jungwirth[2,3], V. Holý[1]

[1]*Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 121 16 Prague 2, Czech Republic*
[2]*Institute of Physics ASCR, v.v.i., Cukrovarnická 10, 162 53 Prague 6, Czech Republic*
[3]*School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom*
cechal@mag.mff.cuni.cz

Thin layers of (Ga,Mn)As magnetic semiconductor exhibit magnetic anisotropy which is strongly influenced by lattice-matching strains introduced into these layers during epitaxial growth. Laterally homogeneous strains can be induced by growing these layers on top of GaAs (compressive strain) or (In,Ga)As (tensile strain) buffers [1]. Lithographic techniques can be used to create complicated strain patterns leading to spatially varying magnetic anisotropy [2-4]. We combined e-beam lithography and dry etching with molecular beam epitaxy to create ordered fields of InAs quantum dost on GaAs(001) substrate which were subsequently covered by a $Ga_{0.95}Mn_{0.05}As$ capping layer.

High-resolution X-ray diffraction reciprocal-space mapping is conventionally used to explore the strains in similar cases. However, the low growth temperature required to incorporate Mn atoms into (Ga,Mn)As layers causes that the crystal quality of such heterostructures is often not as good as in the case of continuous epitaxial layers and previously reported approaches to characterize the strain fields using the X-ray data are therefore not directly applicable. Further complications arise from the combined effects of strain and chemical roughness. Here we report on a simple fitting-free methodology to evidence the presence of periodic strain fields from the measured X-ray data and show how kinematical theory of X-ray scattering coupled with the solution of elasticity equations can be used to determine the main features of these strain fields.

The proceedings are organized as follows: first we present the calculations of the strain fields in the case of (Ga,Mn)As layers grown on top of periodic arrays of InAs quantum dots. Then we discuss the evaluation of the intensity profiles along the satellites stemming from lateral periodicity and we show that the presence of strain can be evidenced from the comparison of the relative intensity of the first pair of satellites. Finally, we present the results of X-ray diffraction experiment.

The strain in (Ga,Mn)As/InAs/GaAs structures originates in different intrinsic lattice parameters of the constituent materials. We used a combination of Fourier and finite

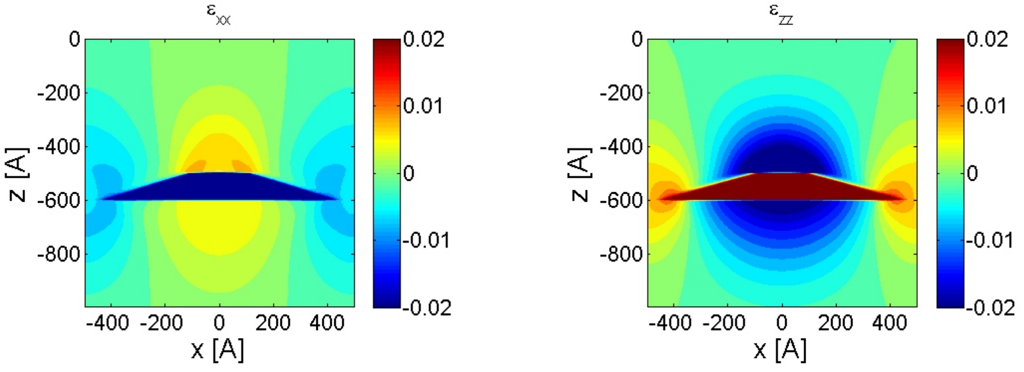

Figure 1. Calculated $_{xx}$ and $_{zz}$ components of the strain tensor in a sample containing periodic array of quantum dots. The dots have the shape of a 10nm high truncated cone with 40nm bottom radius and 10nm top radius and are assumed to be composed of pure InAs.