1.1 Nanostructuring

The research of the Nanostructuring group is devoted to the growth of III-V semiconductor structures, ferromagnet-semiconductor hybrid structures, as well as metastable heterostructures by molecular-beam epitaxy (MBE) and to the investigation of their growth-related properties. Synchrotron x-ray diffraction is used to study the growth in-situ and in real time, while high-resolution as well as analytical transmission electron microscopy (TEM) are applied to characterize the structures with high spatial resolution and to analyze compositional variations at interfaces.

Following the in-situ x-ray diffraction measurements of Fe_3Si films on GaAs(100) at BESSY synchrotron [J. Herfort *et al.*, Physica E **32**, 371 (2006)], growth oscillations during epitaxy and their dependence on the substrate temperature were studied in detail. High-resolution measurements of the layer structure during deposition revealed characteristic variations, which are explained by the generation of inversion domain boundaries. X-ray diffraction was also used to investigate the high-temperature properties of the high-κ dielectric material Pr_2O_3 in contact with Si during growth and subsequent annealing. At high temperatures, Pr_2O_3 loses oxygen in favor of the formation of silicides.

The growth of low-dimensional heterostructures on GaAs(110) has been extended [R. Hey *et al.*, Phys. Status Solidi C **3**, 651 (2006)] to fabricate defect-free GaAs/AlAs-based Bragg reflectors and cavity structures. The structural degradation, which is particularly critical for thick AlAs layers on GaAs(110), is successfully suppressed by using short-period-superlattice stacks replacing $\lambda/4$-AlAs layers. This approach is very promising for the fabrication of high-quality quantum well cavity structures grown on GaAs(110).

The dominant crystal defect types in *M*-plane nitride layers on $LiAlO_2$(100) are stacking faults and prism plane boundaries. The formation of these planar defects during the GaN nucleation stage is clarified by high-resolution TEM demonstrating the critical role of the substrate surface morphology [A. Trampert *et al.*, J. Phys. IV **132**, 221 (2006)]. In addition, the epitaxial growth of AlN layers on *M*-plane SiC substrates has been further optimized. The MBE growth conditions for realizing single poly-type AlN films as well as for AlN-based quantum dots are established.

Quantum wells of metastable dilute nitrides (Ga,In)(N,As) emitting in the 1.55 μm wavelength range were successfully fabricated by applying extreme MBE growth conditions: a growth temperature as low as 375 °C in combination with a low beam-equivalent-pressure (BEP) flux ratio of about 5 [F. Ishikawa *et al.*, Appl. Phys. Lett. **88**, 181910 (2006)]. The low growth temperature prevents the decomposition-driven nanometer-sized compositional fluctuations, which is directly measured by spatially resolved low-loss electron energy-loss spectroscopy in the TEM [X. Kong *et al.*, Micron **73**, 465 (2006)]. The low As-pressure allows the incorporation of nitrogen with concentrations up to 4 to 5% and of indium as high as 35%.

These quantum wells are characterized by a high luminescence efficiency that is correlated with smooth interfaces including chemically sharp transitions [F. Ishikawa *et al.*, Appl. Phys. Lett. **88**, 191115 (2006)]. We applied dark-field TEM in combination with the strain analysis of high-resolution TEM micrographs to measure the In concentration profiles across the quantum wells. The result of such an analysis with monolayer resolution taken from a nominally 4 nm thin quantum well is shown in Fig. 1. We observe a rather narrow interface width as well as a remarkable segregation inside the well. The fitting curve represents a theoretical calculation that includes Muraki's segregation model and a specific interface-related part.

In the field of ferromagnet-semiconductor hybrid structures, the extensive work of the last years about the interplay of stress and magnetic properties in epitaxial MnAs films was summarized in an extended review article [L. Däweritz, Rep. Prog. Phys. **68**, 2581 (2006)]. In the case of ferromagnetic Fe_3Si epilayers grown on GaAs(001), the interface structure and the atomic ordering in the films were determined for various MBE growth conditions and for exact stoichiometry by x-ray diffraction and TEM as well as resistivity measurements. The results were discussed in relation to the well-known Fe/GaAs system [J. Herfort *et al.*, Int. J. Mater. Res. **97** 1026 (2006)]. The magnetic anisotropy and magnetic reversal were systematically studied for Fe_3Si films grown on GaAs(113)A substrates [P. K. Muduli *et al.*, J. Phys: Cond. Mat. **18**, 9453 (2006)].

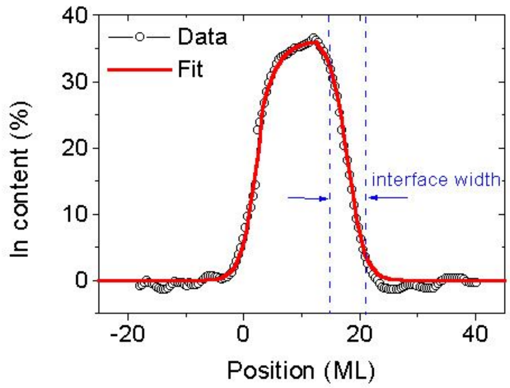

Fig. 1. In concentration profile across the (Ga,In)(N,As) quantum well. Experimental data are presented together with a fit based on Muraki's segregation model. 1 monolayer (ML) corresponds to 0.27 nm.

The recently started work on growing epitaxial half-metallic full Heusler alloys of Co_2FeSi on GaAs is extended to the analysis of their magnetic properties [M. Hashimoto *et al.*, J. Phys.: Condens. Mat. **18**, 6101 (2006)] as well as to a detailed study of the growth-temperature-dependent evolution of the interface structure [M. Hashimoto *et al.*, J. Vac. Sci. Technol. B **24**, 2006 (2006)]. The onset of solid state reactions at the Co_2FeSi/GaAs interface is estimated to be around 200 °C, which is significantly higher than the onset for Fe films on GaAs.