

1.1 Epitaxy

The research in the Epitaxy Department is based on molecular beam epitaxy (MBE) and is directed at two complementary tasks. On the one hand, our experimental contribution to the overall research of the institute is the fabrication of custom-designed nanostructured samples. On the other hand, the growth mechanisms themselves are investigated, both for their own scientific sake and in order to optimize properties that are investigated in the other departments of the institute. The long tradition for the fabrication of two-dimensional heterostructures based on III-V semiconductors has recently been extended to research on the self-organized growth of nanowires for both arsenides and nitrides. Furthermore, ferromagnet-semiconductor hybrid systems for spintronic applications such as Heusler alloys grown on GaAs and on Si are investigated. As a distinctive experimental feature, three MBE chambers are located at the Berlin synchrotron BESSY and allow in-situ, real-time analysis by x-ray diffraction for various material combinations. In general, experiments are complemented by ab initio calculations.

Quantum well and cavity structures on GaAs(110) are important for spin transport and manipulation experiments, because spin lifetimes are longer than in samples with (001) orientation. However, relaxation phenomena are different and require dedicated investigations [R. Hey *et al.*, Phys. Status Solidi C **5**, 2917 (2008)]. The critical thickness for relaxation by misfit dislocations (MD) is smaller. By using AlAs/GaAs short-period superlattices, the motion or generation of MDs is suppressed, which results in smoother interfaces for distributed Bragg reflectors. Thus, high-quality cavity structures can be fabricated for the (110) orientation.

Heterostructures composed of group III-nitrides are the basis for many commercial devices. (Al,In)N films with an In content of 18% are lattice-matched to GaN, but due to the large miscibility gap the growth of high-quality heterostructures is very difficult. The dependence of crack formation and phase separation on growth conditions in plasma-assisted MBE has been studied in detail [T. Ive *et al.*, Phys. Rev. B **78**, 035311, (2008)]. In a very narrow growth window, homogeneous and crack-free films with smooth surfaces can be reliably obtained.

Epitaxially grown semiconductor nanowires (NWs) have only a very small interface to the substrate. Due to this special geometry, heteroepitaxy for material combinations with large lattice mismatch becomes much easier. The epitaxy of both arsenide and nitride NWs on silicon substrates has been studied. The growth mechanisms are naturally much more complex than for planar films and present a new field of research. For MBE, the underlying processes are investigated in situ by line-of-sight quadrupole mass spectrometry and reflection high-energy electron diffraction (RHEED). The formation of NWs can be spontaneous or induced by catalyst seeds. Both processes are analyzed.

In the field of ferromagnet-semiconductor hybrid heterostructures, a series of Fe₃Si films on GaAs(001) with varying thickness has been studied [J. Herfort *et al.*, J. Appl. Phys. **103**, 07B506, (2008)]. Ferromagnetism at low temperatures sets in at about three monolayers and coincides with the complete coalescence of Fe₃Si islands. The uniaxial in-plane magnetic

anisotropy depends strongly on the film thickness due to the competition between a bulk and an interface contribution that have opposite sign. In addition, the growth of Co_2FeSi has been extended to the different substrate orientation GaAs(111) and to silicon substrates.

In-situ x-ray diffraction has been used to study the coarsening of islands and surface reconstruction domains on Ge(001) at various temperatures [B. Tinkham *et al.*, J. Cryst. Growth **310**, 3416 (2008)]. In both cases, the measured exponents deviate notably from what is expected according to classical theory. The same characterization technique has been applied to investigate the structure of rare-earth oxides on silicon substrates. Both Pr_2O_3 and Gd_2O_3 have the tendency to form an interface to Si with different chemical composition. As a new field, the epitaxial growth of the phase-change material system $\text{Ge}_2\text{Sb}_2\text{Te}_5$ has been started.

The understanding of surface structures is an important basis for heteroepitaxy with high-quality interfaces. The GaSb(001)-(1×3) and c(2×6) reconstructions have been prepared by MBE and characterized by RHEED azimuthal scans. Kinematic calculations of diffraction patterns showed that both reconstructions actually arise from disorder between rows of (4×3) unit cells [O. Romanyuk *et al.*, Phys. Rev. B **78**, 035311, (2008)]. This study is complemented by first-principles computations of various GaSb(001) surface reconstructions.