DS 20: Symposium: Real Time Growth Studies I

Time: Thursday 9:30–11:00 Location: H32

DS 20.1 Thu 9:30 H32

Real-time studies of MBE growth using electron and synchrotron x-ray diffraction — •Wolfgang Braun[1], Dillip Kumar Satapathy[2], Vladimir Kaganer[1], Bernd Jenichen[1], Lutz Däweritz[1], and Klaus Ploog[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin — [2]Paul Scherrer Institut, Swiss Light Source, CH-5232 Villigen PSI, Switzerland

Using reflection high-energy electron diffraction (RHEED) and synchrotron x-ray diffraction, we can study epitaxial growth phenomena in great detail under realistic growth conditions. Whereas RHEED has a superior surface sensitivity, but is hampered by usually strong multiple scattering effects, x-ray diffraction allows a straightforward quantitative analysis using kinematical scattering theory. In addition, x-rays can penetrate deeply into the material, allowing us to follow the formation of a heteroepitaxial interface even as it is buried by continued deposition.

The growth of MnAs on GaAs(001) by molecular beam epitaxy serves as an example to demonstrate the synergy of both methods. Whereas RHEED offers a detailed view of the initial nucleation phase, x-ray diffraction allows us to follow the formation of a strongly anisotropic, periodic array of misfit dislocations at the heterointerface that is governed by the misfit and the bonding between film and substrate. A fascinatingly rich and complex sequence of growth stages unfolds, taking us beyond the standard classification of Volmer–Weber and Stranski–Krastanov growth.

DS 20.2 Thu 9:45 H32

X-ray in-situ investigations of growing SiGe nanostructures on nominal substrates and patterned templates — •Tobias Schulli[1], Marie-Ingrid Richard[1], Gilles Renaud[1], Gang Chen[2], and Guenther Bauer[2] — [1]1CEA Grenoble, DRFMC/SP2M 17 rue des martyrs, 38054 Grenoble, France — [2]Institut für Halbleiterphysik, Johannes Kepler Universität Linz, 4040 Linz Austria

A challenge for the development of nano-electronics is to elaborate semiconductor quantum dots that are homogeneous in shape, size, strain and composition, thus resulting in well-defined electronic and optical properties. Recently the growth of highly monodisperse Ge islands on prepatterned Si substrates has been obtained by a combination of lithography and self-assembly techniques [1]. The complexity of such growth modes calls for in-situ studies of the kinetics of epitaxy on patterned surfaces. On BM32 at the ESRF in Grenoble, we have developed in-situ x-ray scattering methods giving access to the evolution, of size, shape, faceting, strain relaxation and interdiffusion during the growth. Utilizing grazing incidence small angle x-ray scattering and diffraction these tools were used to track the facet size evolution for growing Ge domes on nominal Si (001) surfaces, as well as in the determination of material transport from the wetting layer during the transition form two dimensional to island growth [2,3].

References

[1] Z. Zhong et al. Appl. Phys. Lett. 84, 1922 (2004).
[2] T.U. Schülli et al., Appl. Phys. Lett. 89, 143114 (2006).
[3] M.-I. Richard et al., submitted to Phys Rev. Lett. (2006).

DS 20.3 Thu 10:00 H32

Layer-by-layer growth of thin epitaxial iron silicide films on GaAs — •Bernd Jenichen, Vladimir Kaganer, Wolfgang Braun, Jens Herfort, Roman Shayduk, Claudia Herrmann, and Klaus Ploog — Paul-Drude-Institut, Hausvogteiplatz 5-7, 10117 Berlin

The layer-by-layer growth mode during molecular beam epitaxy allows the controlled fabrication of epitaxial layer sequences with very sharp interfaces between them. The aim of the present work is the in-situ characterization of the Fe_3Si epitaxial growth process in the layer-by-layer growth mode by x-ray surface diffraction methods in order to achieve high-quality interfaces. The long range ordering in the films is monitored by measuring different Fe_3Si superlattice reflections. The Fe_3Si layers were grown under x-ray control on the As-rich GaAs surface at different substrate temperatures near 200°C which is the optimum growth temperature with respect to structural and interfacial perfection and a high degree of long range atomic order. The Si and the Fe cell temperatures were tuned in order to achieve perfect lattice match of the Fe_3Si to the GaAs substrate and at the same time full stoichiometry of the films. An anneal of the surface at 310°C for about 1 h together with the growth of one ML of Fe_3Si improved the surface quality considerably, which is determined in situ by the increasing intensity of the x-ray surface reflections. X-ray intensity oscillations were obtained after such an annealing procedure. Fe_3Si grows indeed layer-by-layer. The measured curves exhibit damping, indicating that several terrace levels contribute to the diffracted intensity.

DS 20.4 Thu 10:15 H32

In Situ X-ray Diffraction during Pulsed Laser Deposition — •Vedran Vonk[1], Mark Huijben[2], Kurt Driessen[3], Guus Rijnders[3], Dave Blank[3], Sybolt Harkema[3], and Heinz Graafsma[4] — [1]Max-Planck-Institute for Metals Research, Stuttgart, Germany — [2]University of California, Berkeley, USA — [3]University of Twente, Enschede, The Netherlands — [4]Deutsches Elektronen-Synchrotron, Hamburg, Germany

The use of in situ X-ray diffraction for the study of thin film growth enables in a straightforward way to derive the atomic structure, because the kinematical scattering approximation holds. Here we present the results of studying the heteroepitaxial growth by Pulsed Laser Deposition of complex oxides such as the High-T_c superconductor $YBa_2Cu_3O_{7-x}$ [1] and the insulator $LaAlO_3$ [2] on $SrTiO_3(001)$ substrates. A special sample chamber has been constructed to be used with synchrotron X-rays [3]. Detailed pictures of the growth kinetics and of the atomic interface structure at deposition conditions result from fitting quantitatively both the intensity growth oscillations and the crystal truncation rods. The growth of the complex oxide thin films presented here is characterized by substantial interlayer-mass transport and large deviations from the bulk room-temperature atomic structure. The results show the effects of the interplay between formation and diffusion energies on the processes of nucleation and kinetics during heteroepitaxial growth. [1] V.Vonk *et al.* ESRF Highlights 2004 (2005) [2] V.Vonk *et al.*, Phys. Rev. B (submitted) [3] V.Vonk *et al.*, J. Synchr. Rad. **12** (2005) 833

DS 20.5 Thu 10:30 H32

Pressure Dependant in-situ Investigations on the Rapid Thermal Processing of $CuInS_2$ Thin Films — •Humberto Rodriguez Alvarez, Immo Michael Kötschau, Alfons Weber, and Hans Werner Schock — Hahn Meitner Institut, Glienicker Str. 100. 14109 Berlin

The solid state transformations taking place during the rapid thermal processing (RTP) for the sulfurization of metallic precursors (Cu,In) were monitored using in-situ energy dispersive X-ray diffraction (EDXRD) experiments at the EDDI beamline of BESSY II (Berlin). The new reaction chamber allows an RTP type processes at high pressure (∼1 mbar) and short heat-up time (550°C,∼200 K/min), which is considerably different from the process conditions ($p_{max} \sim 10^{-3}$ mbar) of a complementary experiment available at HASYLAB (Hamburg). The time resolved analysis of the EDXRD spectra gives information on the reaction pathway leading to the formation of the $CuInS_2$ thin film. The first experiments show a strong pressure dependence of the formation of binary sulfides prior to the formation of the ternary chalcopyrite. The changes in the reaction pathway under variation of the maximum sulfur partial pressure will be discussed.

DS 20.6 Thu 10:45 H32

Coarsening kinetics of facetted 2D islands: theory and Monte Carlo simulations — •Vladimir Kaganer[1], Wolfgang Braun[1], and Karl Sabelfeld[2] — [1]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin — [2]Weierstraß-Institut für Angewandte Analysis und Stochastik, Mohrenstr. 39, 10117 Berlin

Two coarsening mechanisms, Ostwald ripening and dynamic coalescence, are studied by means of kinetic Monte Carlo simulations. Ostwald ripening is the leading coarsening mechanism in absence of a step edge barrier, while dynamic coalescence takes place if an exchange of atoms between islands is prohibited by a step edge barrier. We find that the coarsening laws qualitatively change at large bond energies or low temperatures, when the 2D islands become facetted. Ostwald ripening proceeds through a sequence of 'magic' sizes corresponding to square or rectangular islands and becomes attachment-limited, but the Wagner's asymptotic law is reached after a very long transient time.

The unusual coarsening kinetics obtained in Monte Carlo simulations are well described by the Becker-Döring equations of nucleation kinetics. We show that these equations can be applied to a wide range of coarsening problems. Dynamic coalescence is a result of the Brownian motion of the islands. For large bond energies, the island diffusion coefficient becomes size-independent and the size distribution becomes monotonously decreasing. The results of the kinetic Monte Carlo simulations are supported by numerical solutions of the Smoluchowski equations.