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Growth evolution of superlattice morphology

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During growth of short-period superlattices, spontaneous lateral composition modulation can occur leading to a quasiperiodic modulation of the thicknesses of individual layers; resulting one-dimensional nanostructures (quantum wires) have potential applications in optoelectronics. Theoretical description of the modulation process is based on two different models. If there is a high density of monolayer steps on the vicinal surface a step-bunching instability occurs [1], but if the density of the the monolayer steps is low, a self-organized growth of two-dimensional or three-dimensional islands takes place. The latter process occurs, if the reduction of the strain energy due to an elastic relaxation of internal stresses in the islands outweighs the corresponding increase of the surface energy (morphological Asaro-Tiller-Grinfeld (ATG) instability [2]).

The dependence of the lateral composition modulation on the number of layers was investigated using grazing incidence x-ray diffraction. The series of four samples of InAs/AlAs superlattices grown by molecular beam epitaxy (MBE) on an InP(001) substrate was studied; the substrate was prepared without any nominal miscut. The samples have 2, 5, 10 and 20 superlattice periods; the InAs and AlAs thicknesses were nominally 1.9 monolayers in all samples. For all samples, we have measured the intensity distribution of the grazing-incidence 400 and 040 diffraction in the plane parallel to the sample surface. The x-ray measurements have been carried out at the beamline ID01 of the European Synchrotron Radiation Facility (ESRF, Grenoble).

From the experiment follows that the modulation amplitude increases with the number of layers, the lateral modulation period L=(267 ± 15) Å remains constant during the growth, while the width of the lateral satellites decreases [3].

From this behavior it follows that the first stages of the spontaneous modulation of the average chemical composition of a short-period superlattice cannot be explained as a result of the bunching of monolayer steps at the interfaces. Most likely, this behavior can be ascribed to the ATG instability, in which the critical wavelength of the surface corrugation, L_{crit} depends on the stress in the growing layer, elastic constants and its surface energy. The evolution of the surface morphology of multilayers has been studied only in a linearized approach so far [4]. We have simulated a full nonlinear time evolution equation of the spontaneous lateral modulation and we have obtained the critical wavelength L_{crit}=300 Å. The particular values of diffusion rate have only weak influence on the resulting interface morphology. We have also found that the nonlinear dependence of the strain energy on the layer thickness (wetting effect) has a crucial influence on the resulting interface morphology [5].

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Metallic films on polymer foils characterized by in-situ WAXS coupled with mechanical tests

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The new tensile stage TS600 from Anton Paar GmbH was used for in-situ synchrotron X-ray scattering investigations on Cu and Ag thin films with the thickness in the range of 50-1000 nm. The films were deposited on uniaxial oriented PET foils of 50 µm thickness. The metal/polymer structures were cyclically strained in the tensile stage and the structural response of the metal film as well as of the polymer were simultaneously monitored using a 2D detector. The experiments were performed at synchrotron sources HASYLAB (beamline A2) and ELETTRA (SAXS beamline).

By performing in-situ SAXS and WAXS experiments on the metal/polymer composites it was possible to determine a variety of structural parameters. In the case of metallic films elastic strains and stresses, flow stresses and the size of coherently diffracting domains were evaluated. For the polymer material, orientation factors and internal strain of crystals and amorphous phase were evaluated from the scattering signal. The parameters were correlated with the actual state of the cyclic tensile experiments. Since the plastic deformation in the metal film occurs at smaller strains then in the polymer, the setup allowed to test the film also in compression. The characterization of the metallic films demonstrated a strong dependence of the flow stresses on the film thickness. For the films below 400 nm thickness, the flow stresses increase dramatically up to few hundreds MPa.

The polymer material was fully elastic in the tested regime. The strain in the amorphous and in the crystalline phase was approximately in the same order of magnitude. No dependence of the metallic film thickness on the mechanical response of the polymer could be assessed.

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X-Ray Diffraction by the One-dimensional Superlattice with a Stacking Fault

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Superlattices (SL) are multilayered crystalline structures, in which electrons are affected by, besides the periodic lattice potential, an additional periodic potential with period considerably exceeding the lattice parameter.