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Experiment title:

Strain investigation of cleaved edge overgrown InGaAs/GaAs superlattices: a novel attempt to grow ordered InAs quantum dots

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Report:

The investigation of low-dimensional heterosystems has become an increasingly important research field in semiconductor physics. The quantum confinement of charge carriers to one (quantum wires) or zero dimensions (quantum dots) offers new applications for the development of electronic devices.

The cleaved edge overgrowth (CEO) technique can be used to fabricate quantum wires. This technique relies on the overgrowth on the cleaved edge of a previously prepared multilayer heterostructure fabricated by molecular beam epitaxy (MBE). The multilayer acts as a substrate with an in-plane modulated lattice constant, giving rise to periodic strain modulations in the epitaxial layer grown on the cleaved edge.

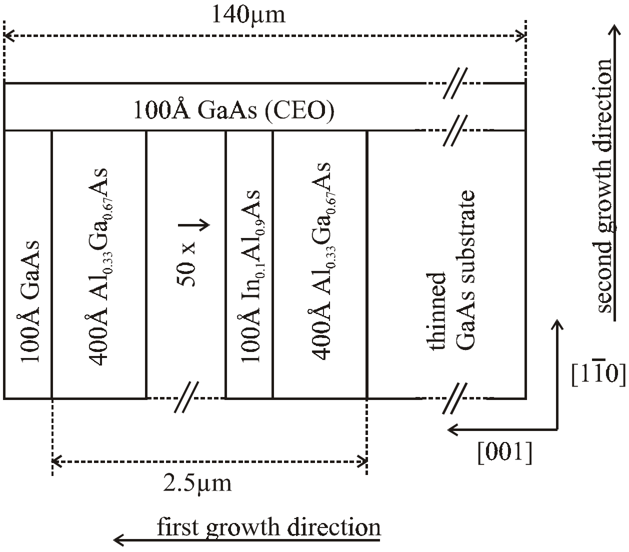

Fig. 1: Cleaved edge overgrowth: schematic diagram of the sample layout obtained after two growth steps.

This strain modulation could be used as a template for the self-organized ordering of InAs quantum dots, which represents an alternative technique to induced ordering of quantum dots by prepatterned substrates.

A detailed knowledge about the strain distribution in the overgrown layer is important and has not been studied experimentally so far.

The investigated sample (see Fig. 1) consists of a (001) oriented GaAs substrate. In a first growth step a multilayer of 50 times 400Å $Al_{0.33}Ga_{0.67}As$ and 100Å $In_{0.1}Al_{0.9}As$ is grown by MBE. After an *in situ* cleave a 100Å thick layer of GaAs is grown on the fresh (1-10) oriented edge (second growth step). An in-plane

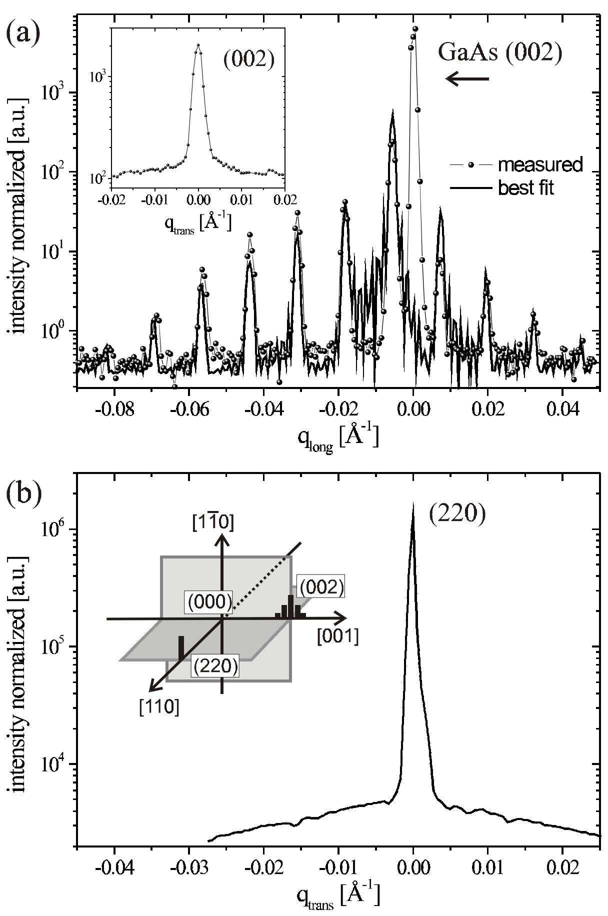

Fig. 2: (a) Strain sensitive longitudinal scan at the (002) Bragg reflection: The fit was calculated using a displacement field based on finite-element simulations. The inset shows a transverse scan at the (002) Bragg reflection. (b) Transverse scan (sensitive to composition and/or morphology) at the (220) Bragg reflection: no modulation is observed. The inset shows a sketch of the reciprocal space with the investigated reflections.

modulation of the GaAs lattice constant due to the overgrown lattice mismatched multilayer is expected within the 2.5µm of the CEO surface, which corresponds to the thickness of the multilayer (see Fig. 1).

To allow for a non destructive, surface sensitive analysis of the CEO layer the measurements were performed by means of grazing incidence x-ray diffraction (GID). By carrying out measurements at the (002) and (220) surface Bragg reflection in both the transverse and longitudinal direction (see inset of Fig. 2(b)) it was possible to distinguish between compositional/morphological and purely strain induced oscillations.

In a longitudinal scan through the (002) reflection the intensity distribution profile in the direction of the superlattice modulations is probed. The corresponding measurement is shown in Fig. 2(a). The transverse scan in [110] direction parallel to the multilayer (see inset of Fig. 2(a)) shows a single Bragg peak without any intensity modulation in satellites.
After turning the sample 90° around the [1-10] direction the measurement at the (220) reflection in longitudinal [110] direction (not shown) would be sensitive to lattice parameter changes along the wires. The transverse measurement in [001] direction (see Fig. 2(b)) would reveal changes in composition or surface morphology in the direction of the superlattice.
Both measurements do not show any satellites, thus excluding any periodic modulation in the surface morphology or in composition which could be caused by interdiffusion during the CEO. The absence of compositional or morphological oscillations in the transverse scan at the (220) Bragg reflection proofs that we are only probing the thin CEO layer and not the AlGaAs/InAlAs multilayer beneath.

The fit to the measured longitudinal scan in Fig. 2(a) was obtained using the depth depending lattice parameter distribution of a finite-element simulation (not shown). The parameters were fitted to the experimental data on the basis of a kinematical scattering model. The GaAs (002) peak (see Fig. 2(a)) originating from the unstrained part of the CEO layer was not simulated.
The best agreement between simulation and experiment is obtained for a multilayer thickness of 104Å and 386Å for the InAlAs and AlGaAs layers respectively. The GaAs lattice parameter varies between 5.649Å and 5.710Å in the probed CEO layer. These results are in good agreement with the nominal growth parameters.

In conclusion, we have shown that a periodic elastic strain modulation is induced within a homogeneous GaAs layer by using the CEO technique. No surface ripples are present and interdiffusion of In into the CEO layer can be excluded (at the growth temperature of 430°C). The strain modulation can be quantified by surface sensitive grazing incidence diffraction and results in an average lattice expansion of the CEO.