

Determination of *In*-distribution in *InGaAs* quantum dots

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Motivation

- growth of *InGaAs* cap layer (instead of *GaAs*) to achieve the highest possible *In*-concentration in quantum dots (QDs) and maximum QD size
- determination of true *In*-distribution in QDs

Experimental techniques

Series of samples with *InAs* QD layer with a nominal thickness of 2.6 ML capped by 6 nm *In_xGa_{1-x}As* with $x = 0, 0.05, 0.1, 0.15, 0.2$ and 0.25

Photoluminescence (PL) measurements :

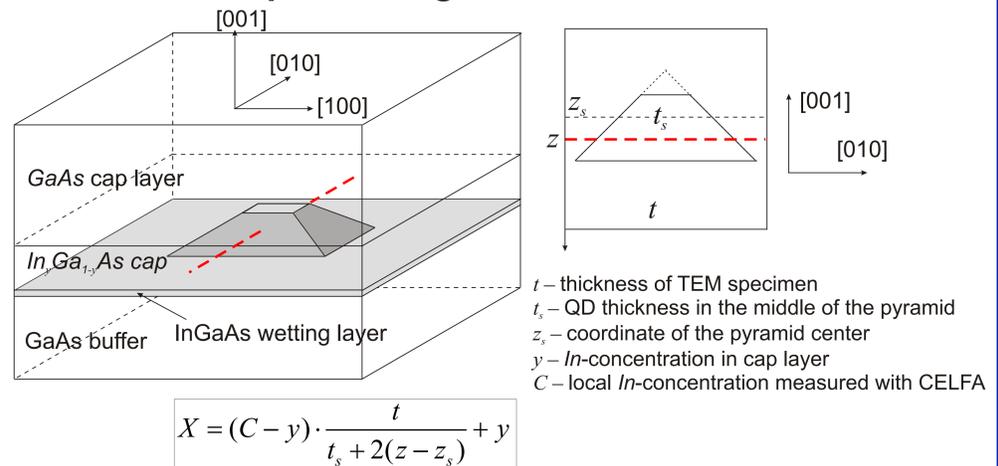
- decreasing PL peak energy with increasing x

Transmission electron microscopy (TEM):

- conventional TEM of plan-view and cross-section samples
- high-angle annular dark-field (HAADF) scanning TEM
- chemical analysis by CELFA (composition evaluation by lattice fringe analysis)*

*A. Rosenauer, D. Gerthsen, Advances in Imaging and Electron Physics 107,121 (1999)

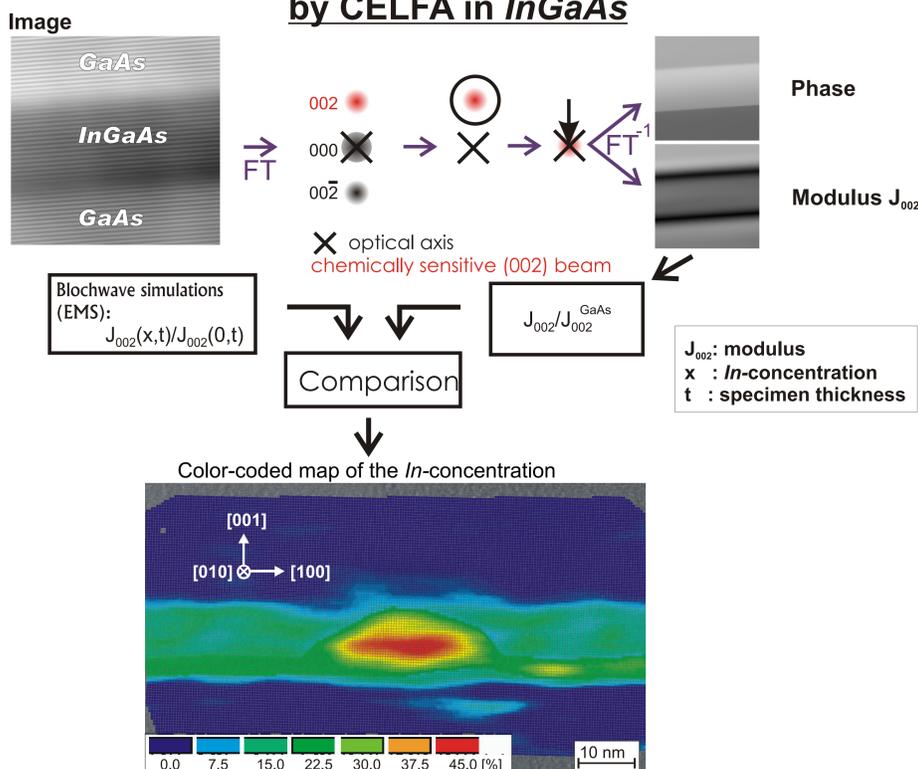
Post-processing of CELFA data



Schematic illustration of the post-processing for the determination of the real *In*-concentration X in the QD along the dashed red line.

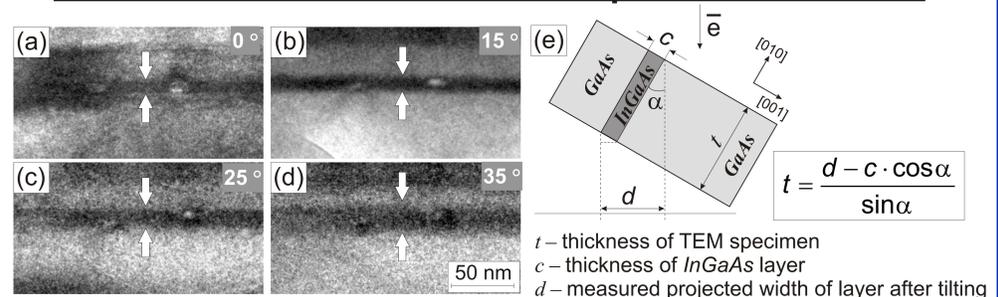
- correction of *In*-concentrations obtained with CELFA, taking into account the sizes, shape and arrangement of the island in the layer
- island shape: truncated pyramid with a square base along $\langle 010 \rangle$ and $\{110\}$ facettes

Determination of the *In*-concentration by CELFA in *InGaAs*



Problem: measured *In*-distribution in the island does not correspond to the real one due to averaging through the TEM specimen and three-dimensional morphology of the island.

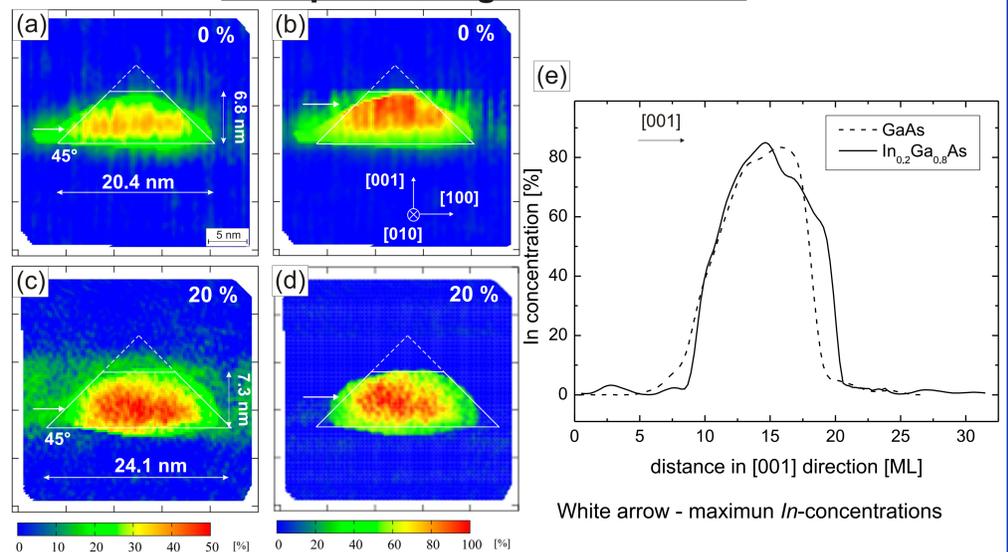
Determination of the local TEM specimen thickness



Tilt series of (002) dark-field images of the same sample region at tilt angles of (a) 0°, (b) 15°, (c) 25° and (d) 35°. (e) Schematic illustration of the determination of the specimen thickness.

- choosing for evaluation with CELFA a full island

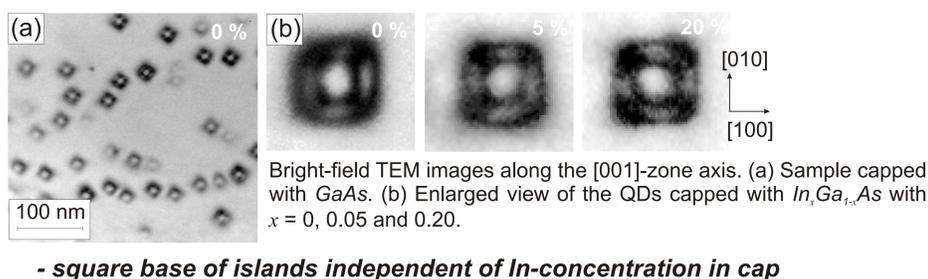
Post-processing of CELFA data



(a-d) Color-coded *In*-concentration maps obtained with CELFA using the (200) reflection in samples capped with *GaAs* (a,b) and *In_{0.2}Ga_{0.8}As* (c,d) before (left-hand side) and after post-processing of the CELFA data (right-hand side). The white triangles delineate the QD shape. (e) *In*-concentration profiles in the middle of QDs along the [001]-growth direction in samples capped with *GaAs* and *In_{0.2}Ga_{0.8}As* extracted from the thickness-corrected CELFA maps (b,d) as a function of the distance in growth direction in units of ML.

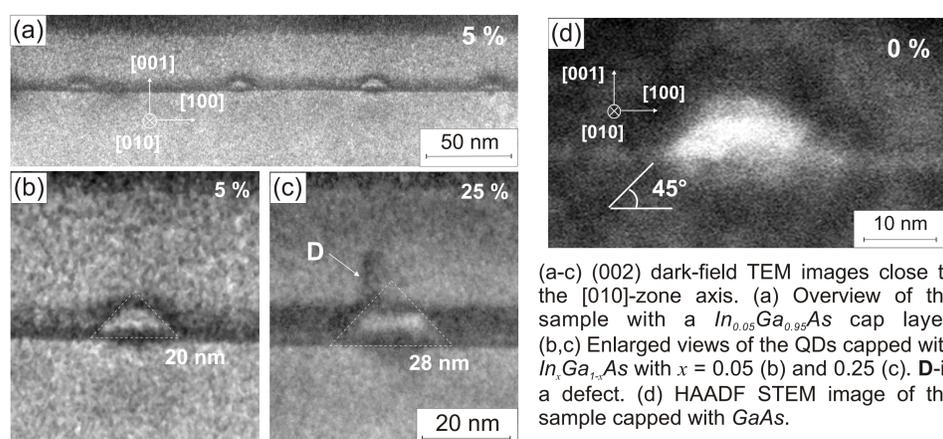
- increasing island sizes with *In*-concentration in cap layer
- increasing *In*-concentration towards the top of islands
- the maximum of *In*-concentration in islands reaches 90 %

Plan-view samples



- square base of islands independent of *In*-concentration in cap

Cross-section samples



- triangular-like shape of islands in cross-section images
- increasing size of the island base with *In*-concentration in cap layer
- defects in sample with *In_{0.05}Ga_{0.95}As* cap layer

Summary

- island shape: truncated pyramid with a square base
- increasing island sizes with *In*-concentration in the cap layer
- increasing *In*-concentration towards the top of the islands
- maximum *In*-concentration of 90 % in the islands

Acknowledgement

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