Structural investigation of GaAs/AlGaAs quantum dots

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Quantum Dots
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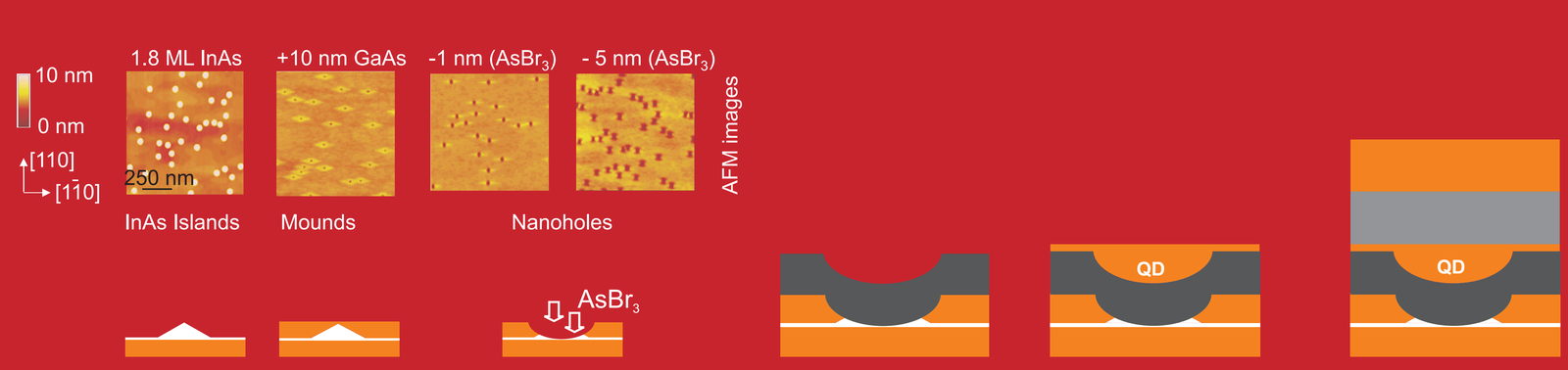
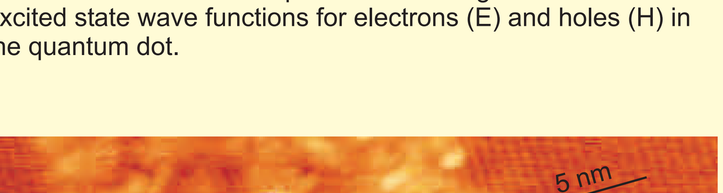
Formation of unstrained quantum dots

- A combination of Stranski-Krastanov growth mode and in situ etching technique leads to unstrained GaAs/AlGaAs quantum dots.
- Low temperature photoluminescence spectra show that GaAs/AlGaAs quantum dots are optically active at ~700-780 nm wavelength.
- An inverted quantum dot shape is assumed.
- Cross-sectional scanning tunneling microscopy (XSTM) is used for structural investigation of these buried nanostructures.

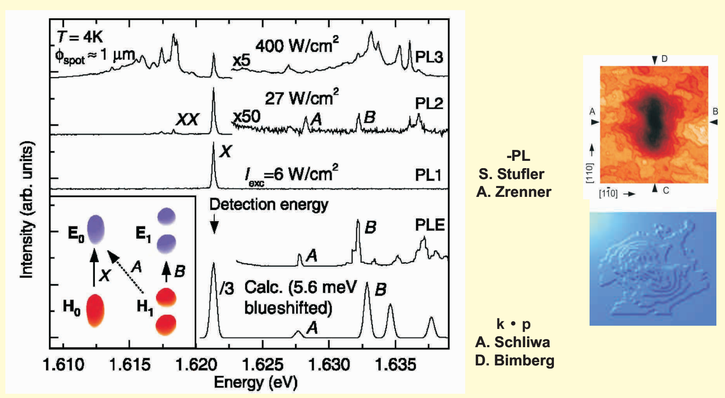


Top-view AFM and STM

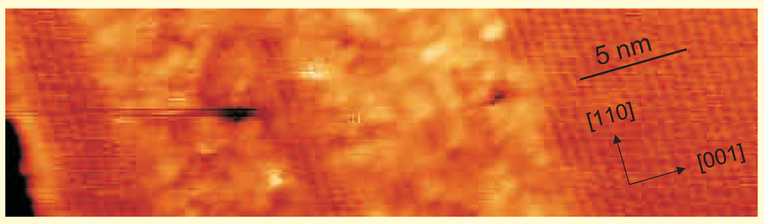
- Atomic force microscopy (AFM) and STM images are taken to control the new technique and characterize the surface morphology before deposing the GaAs QD material.
- AFM image after 5 nm etching and therewith after forming the nanohole.
- STM image of the AlGaAs nanohole and height profile.



Photoluminescense spectra



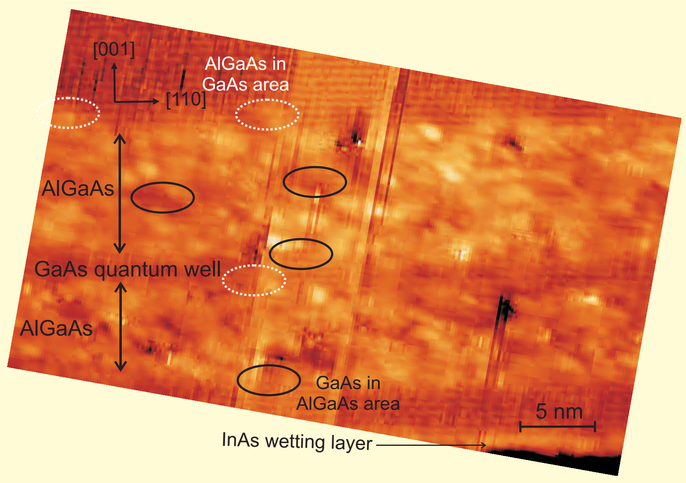
- PL and PLE spectra of a single GaAs/AlGaAs quantum dot.
- The bottom graph is a calculated excitonic absorption spectrum and the inset shows 3D representations of ground and first excited state wave functions for electrons (E) and holes (H) in the quantum dot.



XSTM image of a GaAs quantum well taken at -2.5 V.

- The observed decomposition of the AlGaAs layer can explain the blueshift, since it is known from annealing experiments that the decomposition of a formerly abrupt interface leads to a blue-shift of the photoluminescence.

Cross-sectional scanning tunneling microscopy (XSTM)



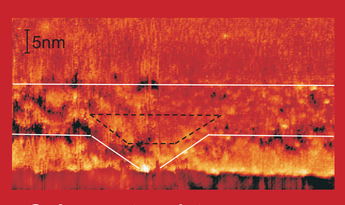
- The GaAs quantum well thickness varies between 0.5 and 2.5 nm. Furthermore a decomposition of the AlGaAs is observed. Therefore the interfaces of GaAs and AlGaAs layers are not abrupt.
- The observed thicknesses of the other layers fit well to the nominal growth parameters.

Conclusion

First XSTM images of unstrained, inverted GaAs/AlGaAs QDs grown by a combination of SK growth mode and an in situ etching technique by $AsBr_3$ are shown.

From atomically resolved images we found thickness variations of the GaAs quantum well between 0.5 and 2.5 nm and a decomposition of the AlGaAs layers.

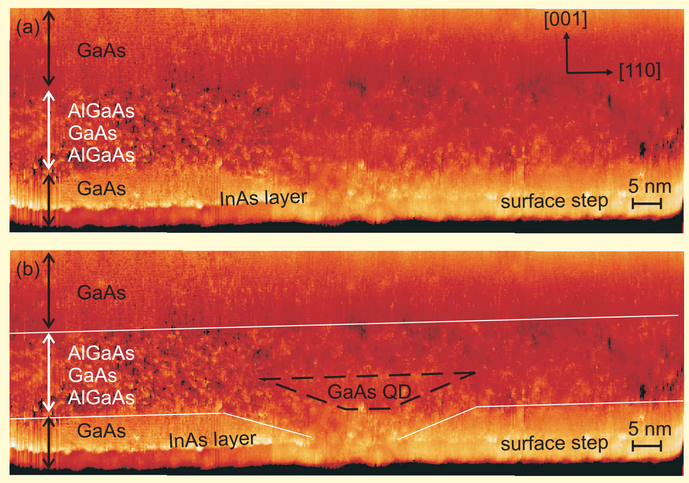
GaAs QDs were observed with base lengths of about 35 nm, heights of 5-6 nm and a reversed truncated cone shape.



GaAs quantum dot

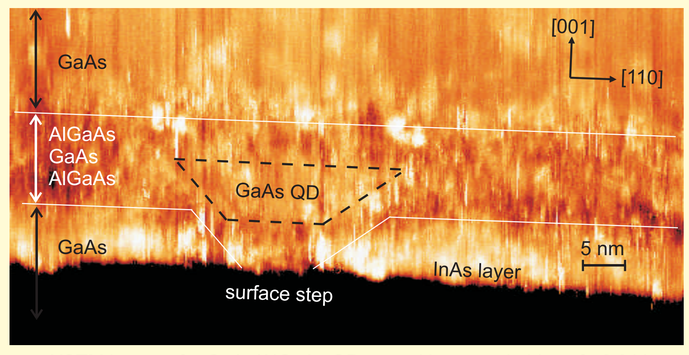
GaAs quantum well

- The GaAs/AlGaAs quantum dots have a low density of 4×10^9 cm^{-2}, which is directly correlated to the density of the former InAs QDs.
- To locate GaAs/AlGaAs QDs, XSTM images have to be examined for regions were the lower AlGaAs layer reaches down to the InAs wetting layer.



XSTM images of (a) a GaAs/AlGaAs QD at negative sample bias of -2.0 V, and (b) the same QD, but the AlGaAs/GaAs interfaces are marked.

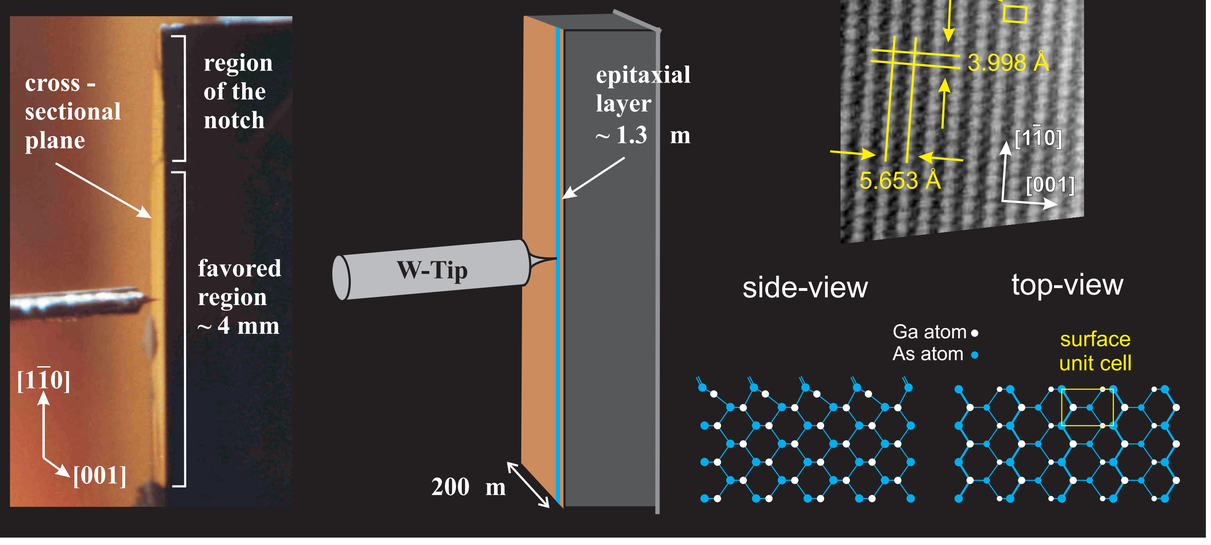
- The lower AlGaAs interface reaches down to the InAs wetting layer, and exactly above this position the GaAs/AlGaAs QD is located.
- This unstrained GaAs/AlGaAs QD has the shape of a reversed truncated cone, a base length of about 35 nm, and a height of about 5 nm.



XSTM image of a GaAs/AlGaAs QD at positive sample bias of +2.3 V.

- This quantum dot base length amounts to 35 nm, while the height of about 6 nm is slightly larger.

XSTM Experiment



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