Effects of Stress and Confinement of a GaAsN Capping Layer on the Emission Wavelength of InAs/GaAs Quantum Dots

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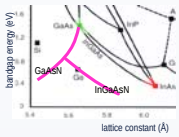
Motivation

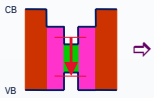
Effects of nitrogen in GaAs



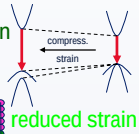
reduction of the conduction band energy ⇨ reduction of the confinement ⇨ redshift

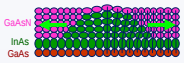
reduction of the lattice constant ⇨ change in the strain of overgrown quantum dots

GaAsN matrix around InAs quantum dots



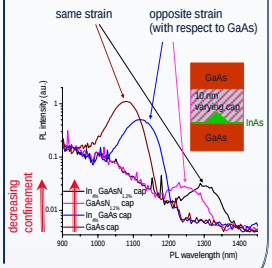
increased strain ⇨ blueshift





reduced strain ⇨ redshift

Variation of strain and confinement: Experimental results



How do the changes in confinement and strain affect the emission wavelength?

Methods

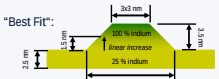
Growth equipment:
- solid-source molecular beam epitaxy (MBE)
- radio-frequency plasma source for nitrogen incorporation
- non-cracked As_4

Parameters for quantum dot growth:
- InAs growth rate: 0.05 ML/s
- growth temperature: ~ 490 °C
- reduced As pressure (compared to GaAs growth)

Photoluminescence (PL):
- measured at room temperature

Simulations*:
- tool: nextnano³
- finite difference method, strain: elasticity theory
- 6x6 k·p, excitonic binding energy: 20 meV
- $GaAsN_x$: bowing coefficient 20.4·100·x
- quantum dots: truncated pyramid

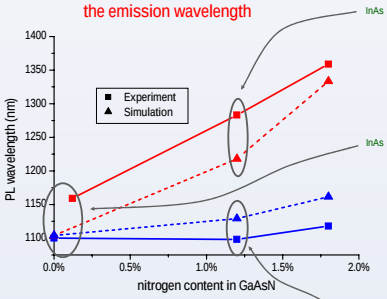
"Best Fit"*:



* http://www.wsi.tum.de/nextnano3/index.htm

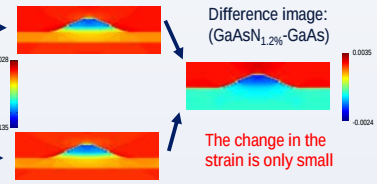
InAs quantum dots in a GaAsN matrix

GaAsN overgrowth redshifts the emission wavelength



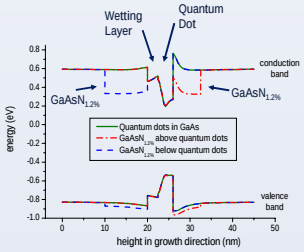
A GaAsN layer below the InAs quantum dots does not yield a strong shift of the emission wavelength

Hydrostatic strain

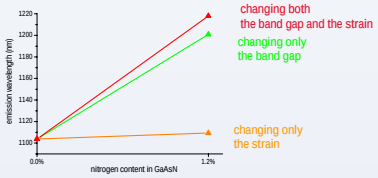


The change in the strain is only small

Band structure

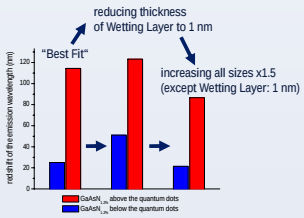


Hypothetical separation of strain and confinement by



The change in the confinement induces the redshift

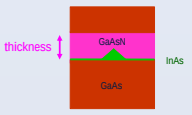
Change of the simulation parameters

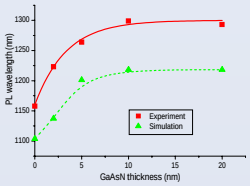


The electron wave function is screened by the wetting layer from the GaAsN layer below

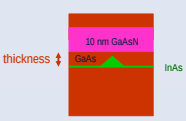
GaAsN capping layer

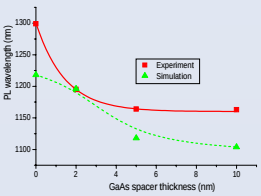
Variation of the $GaAsN_{1.2\%}$ thickness:





GaAs spacer layer between quantum dots and $GaAsN_{1.2\%}$:





Summary

- A GaAsN capping layer on top of InAs quantum dots results in a strong redshift of the emission wavelength for both experiment and simulation.
- The change in the strain of the quantum dot due to the different lattice constant of the GaAsN layer is only small.
- The redshift of the emission wavelength can be explained by taking into consideration only the change in confinement.
- The absence of the redshift for GaAsN below the quantum dots is attributed to the screening of the electron wave function from the GaAsN layer given by the potential of the wetting layer.