Wrocław University of Technology

Centre for Advanced Materials and Nanotechnology

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Optical studies of low-density InAs/GaAs quantum dots

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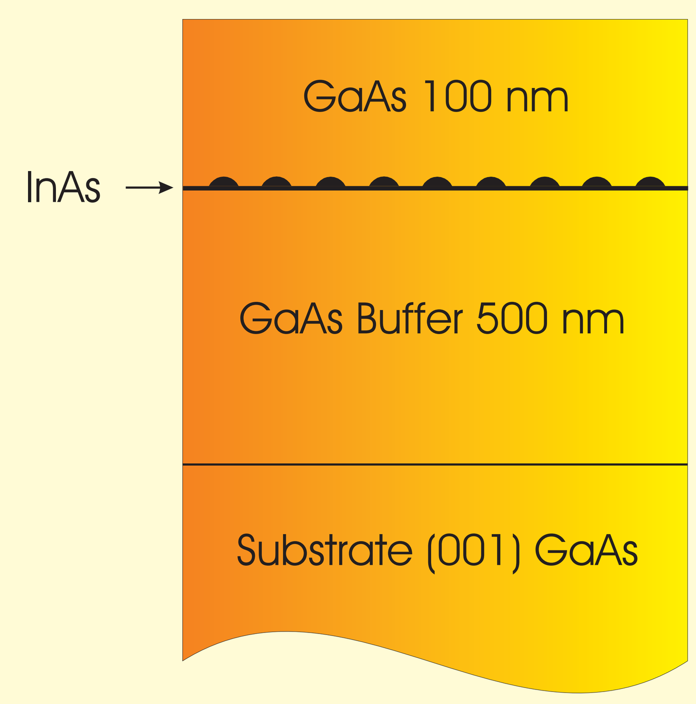
MOTIVATION

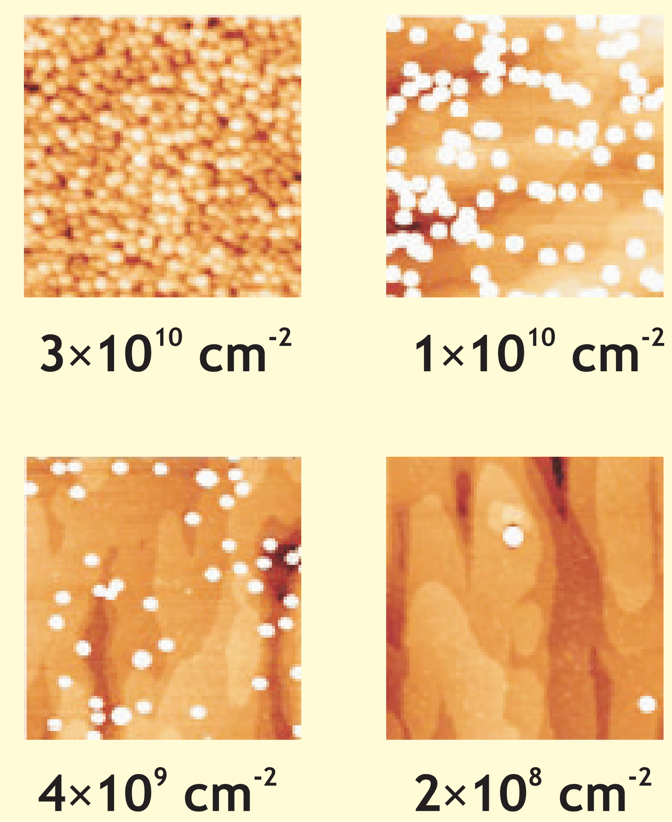
- Low density QDs emitting at 1.3 μm are candidates for single photon sources and for a realisation of quantum cryptography at fiber-based transmission windows
- Absorption-like techniques allow investigation of properties to which the emission-type methods are not sensitive, e.g. probing the real inhomogeneity, higher order states including the wetting layer related ones, oscillator strengths of optical transitions

EXPERIMENTAL DETAILS

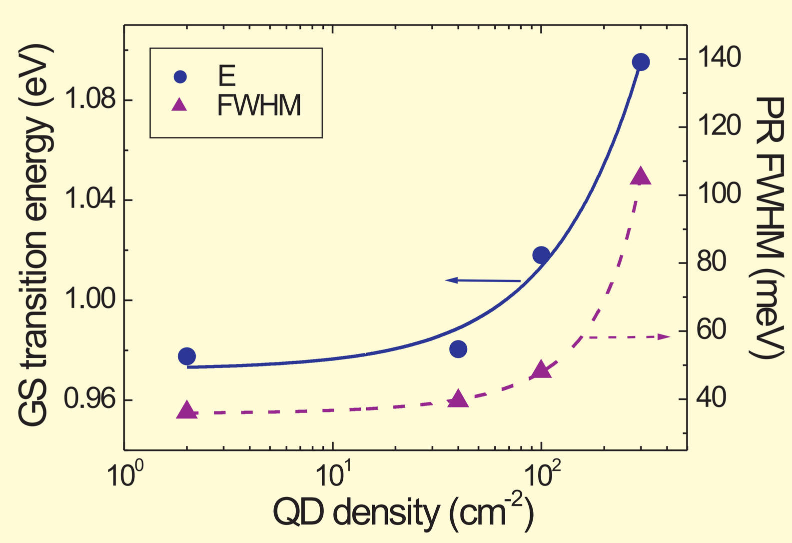
- InAs/GaAs self-assembled QDs structures grown by solid source MBE
- **various sizes and planar dots densities** (down to 2 dots/μm^2) obtained **due to significant InAs growth rate changes**: 0.16 - 0.0012 ML/s
- change in low density QDs morphology due to the increased migration distance of In atoms, which tend to decrease strains and surface energy by joining the existing dots instead of creating new ones
- average dot size increased from 7 nm (height) x 50 nm (base width) to 30 x 70 nm (basing on AFM of uncapped structures) - **QD volume increased almost 10 times**
- **Photoreflectance spectroscopy** - an absorption-like modulation technique **used to probe the QD properties**



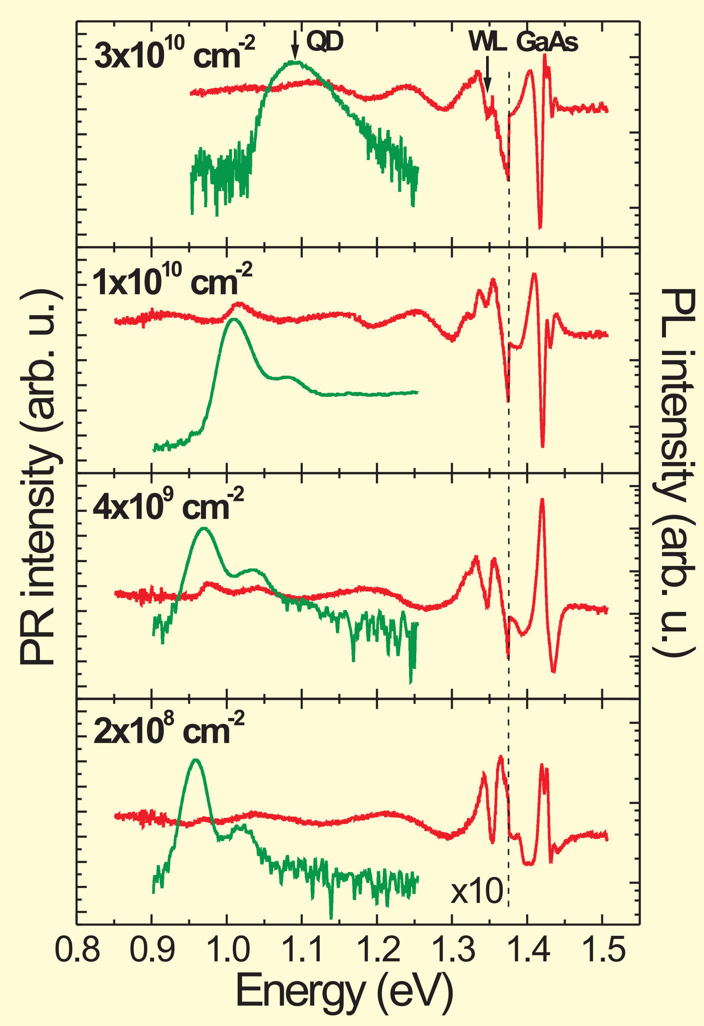
Layer structure



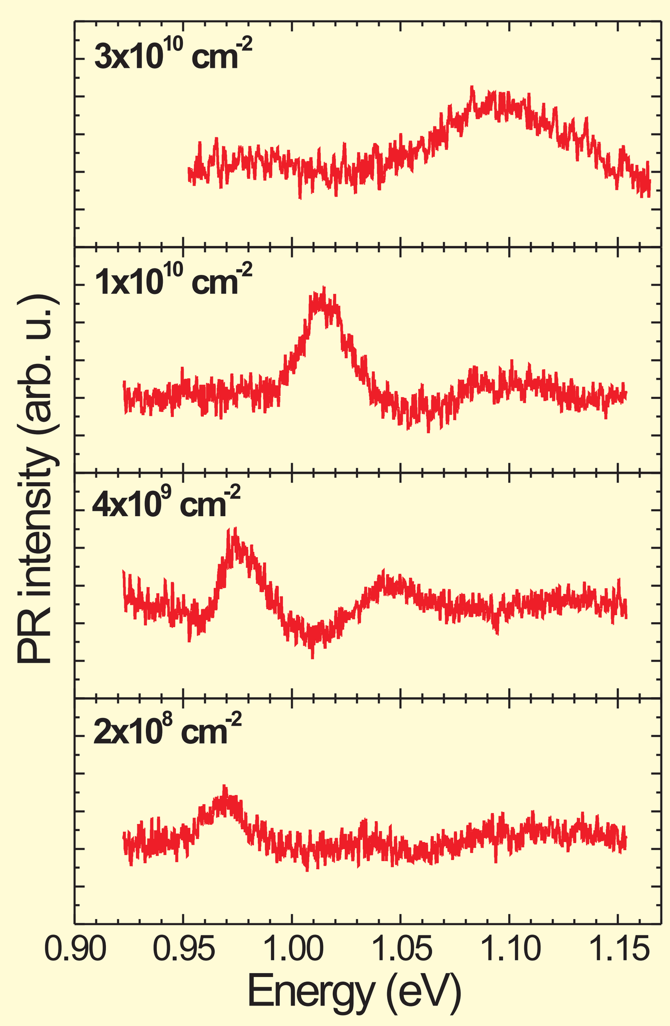
AFM pictures of uncapped structures



GS transition energy and FWHM



Comparison of PR and PL spectra at room temperature



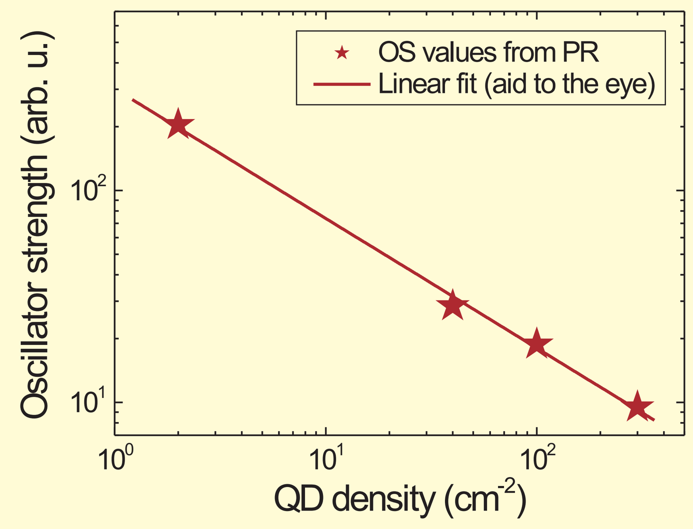
PR spectra in the QD transitions range after removing the oscillation-like feature

OBSERVATION 1

- Surprisingly strong relative intensity of PR signal observed for the low QD density structures
- increase of the QD oscillator strength and/or the PR modulation efficiency?

OBSERVATIONS 2 and 3

- increased QD size causes **ground state transition red shift down to 1.3 μm**
- decreased PR and PL line broadening suggests a possible **improvement of QDs size/shape/content homogeneity with a decrease of the dots density (i.e. for larger dots)** - confirmed by simulations assuming only QD size changes



SQD GS exciton relative oscillator strength

OBSERVATION 4

- For assumed constant modulation conditions in different QD density structures, **the single QD oscillator strength should be increased by at least one order of magnitude**, providing values never observed for InAs self-assembled QDs (?)
- If the OS effect is negligible then **the PR modulation effectiveness would differ significantly for structures with various QD density** (change of the built-in E-field distribution) (?)