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Photoreflectance investigation of InAs/InP Quantum Dash energy structure

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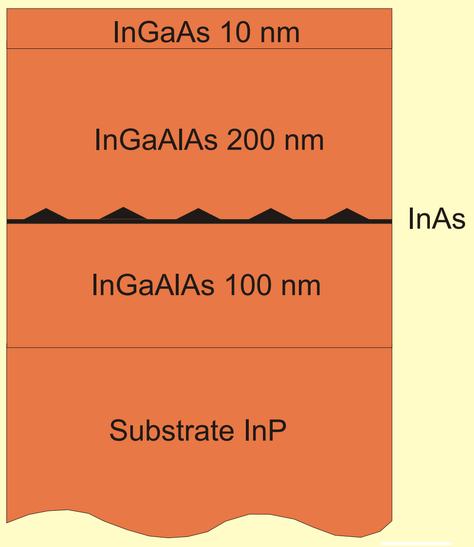
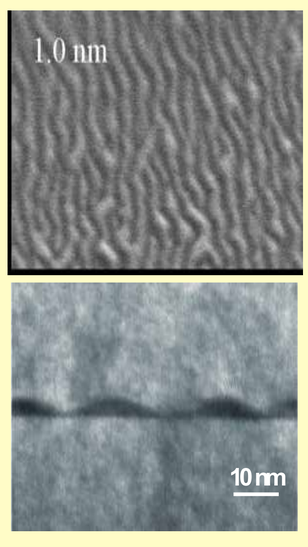
Motivation

1. Quantum Dashes have similar advantages for laser applications to quantum dots. Additionally, the emission from Qdashes may be easily tuned by changing growth conditions to wavelengths exceeding 1.55 micron
2. Photoreflectance is an absorption-like modulation technique, thus it is highly sensitive to all optical transitions in low-dimensional semiconductor heterostructures (including Qdots and Qdashes [1-3]) even at room temperature.

Layer structure

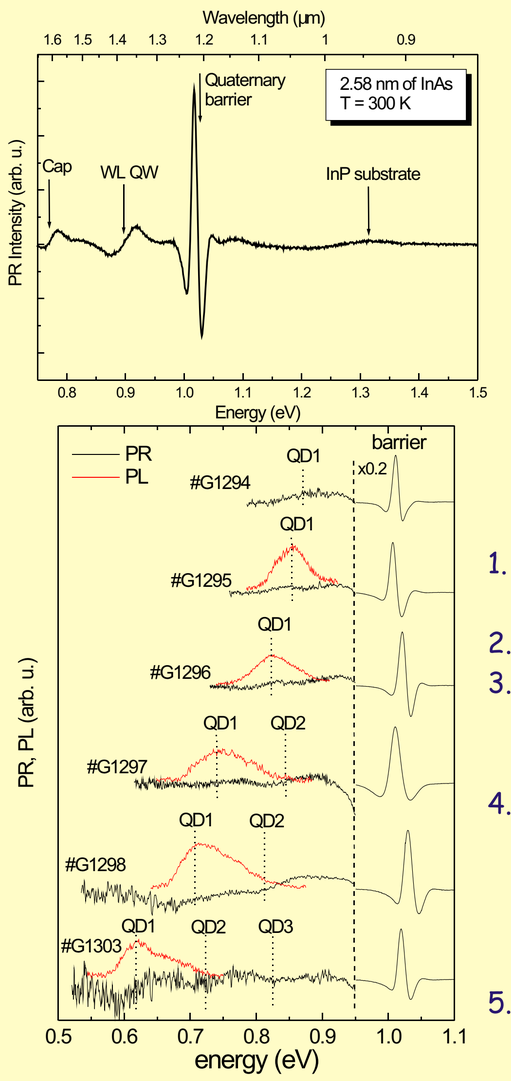


Electron microscopy images

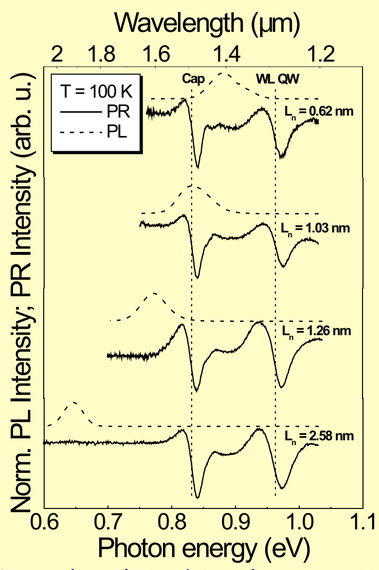


InAs/InGaAlAs/InP Quantum Dash structures

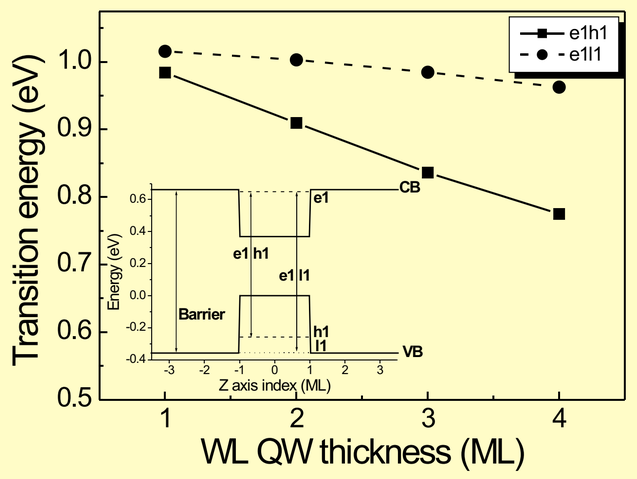
Example of RT PR spectrum



Comparison of PL and PR spectra measured at 100 K



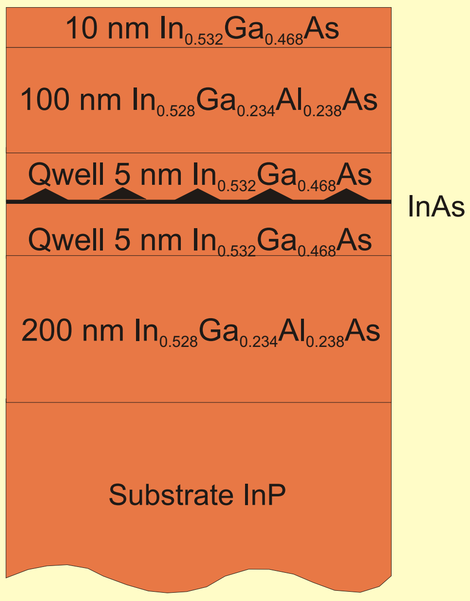
Calculations of optical transitions in a thin QW formed of WL

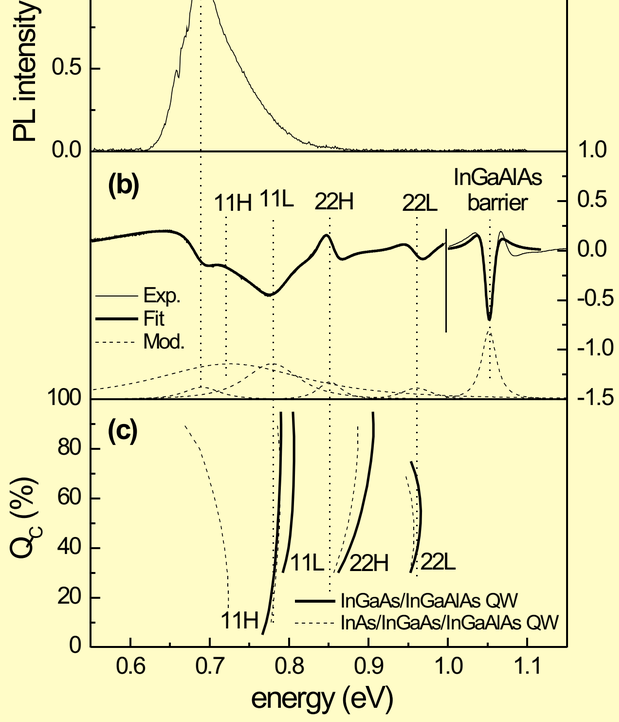


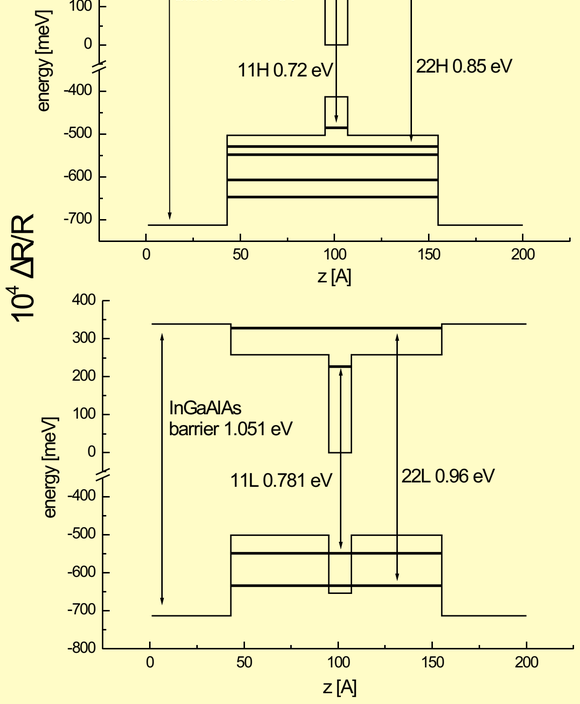
1. The PL peak related to the emission from QDashes shifts to the red with the increases of InAs nominal thickness (average size of the dash)
2. Lines connected with InGaAs cap and InGaAlAs barriers are visible.
3. Additional feature at 0.955 eV, showing constant inhomogeneous broadening (30 meV) and energy position, is observed for all samples. It is related to the transition in a thin InAs/$In_{0.528}Ga_{0.234}Al_{0.238}As$ QW formed of the WL [4].
4. The best agreement between envelope function calculations (with strain effects and nonparabolicity included) with the thickness of the well treated as a semi-free parameter and measured energies of 1h1e transition has been obtained for WL thickness of about 2 ML, which is in agreement with structural study predictions.
5. Samples with etched out InGaAs cap show PR feature related to the Qdash transition. Although signal to noise ratio is not very good, indications of transitions from excited states can be seen.

InAs Quantum Dashes embedded in InGaAlAs/InP Quantum Well

Layer structure







Conclusion

Photoreflectance can be succesfully used to study the electron levels of low-dimensional structures. The possibility of measuring the energy of all optical transitions supported with numerical calculations provides the means to determine important parameters, such as band offset.

Embedding the InAs Quantum Dash layer with additional narrow InGaAs layer, which constitutes the Quantum Well, allows to shift the emission towards red, even up to 2 microns, which is favourable for some applications

Energy level structure of Qdashes in a QW is very complex. Photoluminescence measurement can probe only the lowest state, whereas Photoreflectance gives information on energies of all transitions

PR results supported by numerical calculations allowed to determine the electron and hole level energies and conduction band offset

References

[1] G. Sek, J. Misiewicz, K. Ryczko, M. Kubisa, F. Heinrichsdorff, O. Stier, D. Bimberg, "Room temperature photoreflectance of MOCVD-grown InAs/GaAs quantum dots", Solid State Commun, 110, 657-660, (1999)
[2] G. Sek, K. Ryczko, J. Misiewicz, M. Bayer, F. Klopf, J. P. Reithmaier, A. Forchel, "Photoreflectance spectroscopy of vertically coupled InGaAs/GaAs double quantum dots", Solid State Commun, 117, 401-6, (2001)
[3] W. Rudno-Rudzinski, K. Ryczko, G. Sek, J. Misiewicz, M. J. da Silva, A.A. Quivy, "Photoreflectance study of energy level structure of self-assembled InAs/GaAs quantum dots emitting at 1.3 mu", Solid State Commun, 135, 232-236, (2005)
[4] W. Rudno-Rudzinski, G. Sęk, K. Ryczko, R. Kudrawiec, J. Misiewicz, A. Somers, R. Schwertberger, J. P.. Reithmaier, A. Forchel, "Optically probed wetting layer in InAs/InGaAlAs/InP quantum-dash structures", Applied Physics Letters, 86, 101904-1-3, (2005)