Confinement of Excitons in Strain-engineered Metamorphic InAs/$In_xGa_{1-x}As$/GaAs Quantum Dots for Long Wavelength (1.3 to 1.55 µm) Emission

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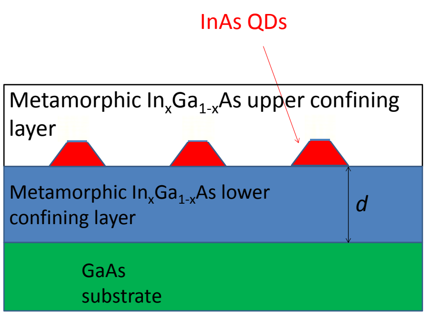
i. Introduction

Lasers with long wavelength emission (1.3 µm to 1.55 µm) are useful for telecommunications due to low attenuation in optical fibers. Although lasers based on self-assembled quantum dots (QDs) emitting at 1.3 µm are commercially available, producing longer wavelength devices has proven challenging. One possible route for achieving this is the use of strain-engineered InAs/$In_xGa_{1-x}As$/GaAs quantum dots grown on a metamorphic buffer of InGaAs, where $In_xGa_{1-x}As$ is used as upper and lower confining layers for exciton confinement.

ii. How to Control the Long Wavelength Emission?

(1) Changing the amount of indium "*x*" in the upper confining layer (UCL) and lower confining layer (LCL), which changes the band discontinuities between the QDs and confining layers and also affects the QD-CL mismatch (strain).

(2) Changing thickness "*d*" of the LCL which affects only the mismatch between the QDs and LCL.[1-2]



iii. Tool Used

We have studied thirty InAs/$In_xGa_{1-x}As$/GaAs QDs samples at 2 K and in magnetic fields up to 15 T. AFM measurements confirm that the dot morphology is independent of both *d* and *x*.

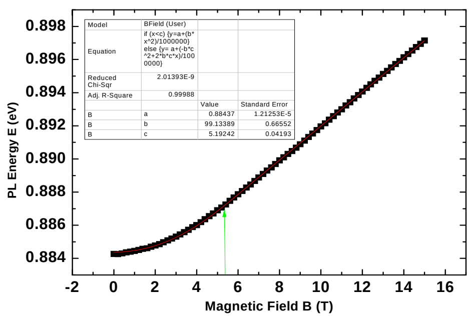
An excitonic model was used to calculate the properties of exciton, i.e, reduced mass, µ and bohr radius of exciton, a_B.

$$E = E_0 + e^2 a_B^2 B^2 / 8\mu \quad \text{for} \quad B \le 2\hbar / e a_B^2 \longrightarrow \text{Eq- 1}$$

$$E = E_0 - \hbar^2 / 2\mu a_B^2 + \hbar e B / 2\mu \quad \text{for} \quad B \ge 2\hbar / e a_B^2 \longrightarrow \text{Eq- 2}$$

where a_B and µ are the Bohr radius and reduced mass of the exciton respectively.

The transition from Eq-1 to Eq-2 occurs when magnetic length becomes smaller than the spatial confinement.



iv. Our Data

Figure1: The circle size shows value of diamagnetic shift coefficient, $\Gamma = e^2 a_B^2 / 8\mu$. The blue color represents samples for which high field regime (where the magnetic length is < a_B /√2) is reached within available fields and the red color where it is not.

Figure 2: Bohr radius of exciton, a_B, as a function of QD-CL mismatch.

Figure 3: Reduced mass of exciton, µ, as a function of QD-CL mismatch.

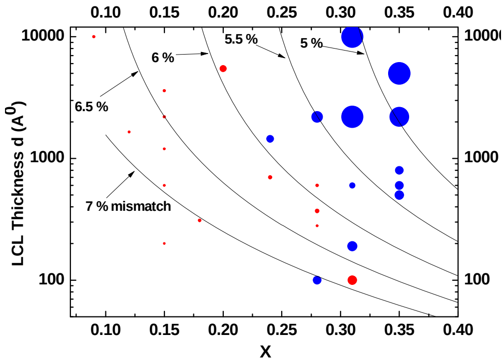


Figure. 1

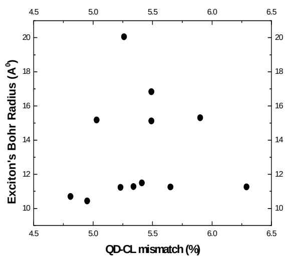


Figure. 2

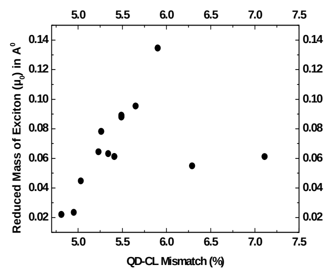


Figure. 3

v. Observation, Discussion and Conclusion

We observe in Fig. 1 that for samples where x is low (≲0.24) the high-field regime is not reached irrespective of *d*, but does when it is high (≳ 0.24 %). Γ increases with increasing *x* when *d* is constant but shows complex behaviour with increasing *d* when *x* is constant. First it decreases with increasing *d*, then increases and saturates.

Fig. 3 shows that reduced mass of exciton, µ increases with increasing mismatch for samples where the mismatch is low (5 to 6 %) and then drops dramatically, but there is no clear trend in a_B with mismatch in Fig. 2.

Further Work:

To study more samples with parameters indicated by "☺" in Figure 4 to understand the trend in Γ at constant x.

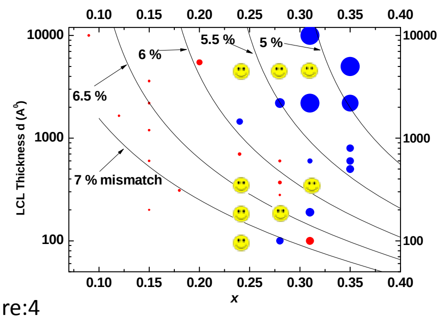


Figure:4

1 L.Seravalli et al. Journal of Applied Physics 101, 024313 (2007)
2 L. Seravalli et al. Journal of Applied Physics 108, 064324 (2010)