Effect of Gold Coatings on Quantum Dot Emission

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We grow tensile strained quantum dots (TSQDs) by depositing GaAs on InAlAs(111)A buffer layers lattice-matched to InP(111)A substrates. Tensile strain of 3.7% is imposed due to the difference in lattice constant between the two materials. The unusual presence of tensile strain in these GaAs QDs lowers their band gap and red-shifts their light emission further into the infrared.[1] The outcome is TSQDs that emit light at energies below the bulk band edge of GaAs.

One of the applications for these high symmetry TSQDs on (111)-oriented surfaces is as entangled photon sources. The single photon spectroscopies used to demonstrate entanglement require that the photon collection efficiency of our measurements be as high as possible. During photoluminescence (PL), our TSQDs emit photons in all directions. One way to increase photon collection efficiency is to insert a mirror below our TSQDs to reflect the photons emitted downward (towards the substrate) back to the sample surface, where they can be collected in the spectrometer.

For conventional InAs/GaAs(001) QDs, this mirror is typically a distributed Bragg reflector (DBR), consisting of a superlattice of alternating GaAs/AlGaAs layers. To create a similar DBR in our InP-based structures would be challenging for two reasons. First, the GaAs TSQDs emit light at λ = 1000–1100 nm (at 11 K). Second, our samples would require lattice-matched InGaAs and InAlAs, which do not have a particularly strong index contrast. The combination of these factors means that each period of the InGaAs/InAlAs superlattice would need to be significantly thicker than conventional GaAs/AlGaAs DBRs, with even more periods required to reach even low reflectivity. High quality InGaAs/InAlAs growth on InP(111)A requires growth rates of ~170 nm/hr, [2] which estimates a total growth time for DBRs of 8-10 hours.

A cheaper, easier, and less time-consuming approach is to take advantage of the long-wavelength emission from our GaAs TSQDs. At 11 K, the TSQD photon emission energy (<1.24 eV) is less than the band gap of either InAlAs (1.53 eV) or InP (1.42 eV), allowing us to simply use a gold reflective coating on the backs of the substrate. The InAlAs barriers and InP substrate are transparent to the TSQD emission, allowing photons to be reflected by the gold coating, back up through the sample, and into the PL collection optics.

Preliminary results on GaAs TSQDs show a clear increase in PL intensity for coated vs uncoated samples. We will present results showing how gold deposition thickness affects PL intensity and how the gold-InP interface may be optimized to maximize reflectivity.

1. Yerino *et al*. Appl. Phys. Lett. **105**, 071912 (2014)

2. Yerino *et al.*, J. Vac. Sci. Technol. **35**, 010801 (2017)

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Supplementary Page

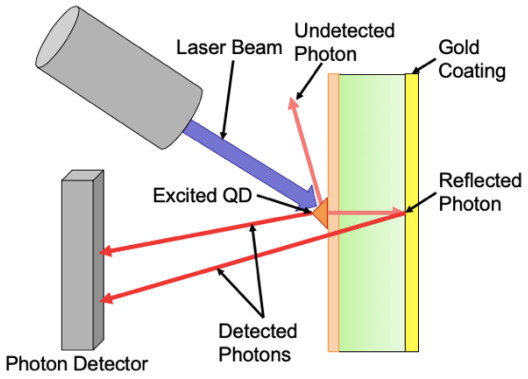

Figure 1: Diagram of our experimental set-up showing how we can use gold coatings deposited on the back of our substrates to increase photon collection efficiency.

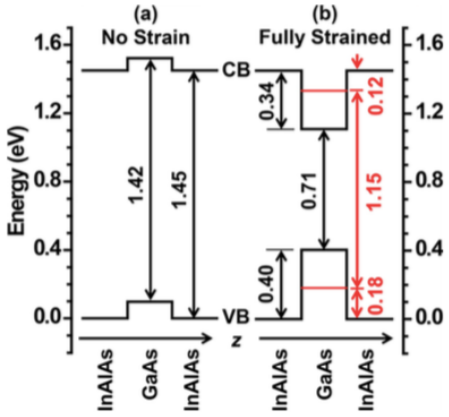

Figure 2: Tensile strain lowers QD bandgap and red-shifts light emission towards the infrared spectrum. [1]

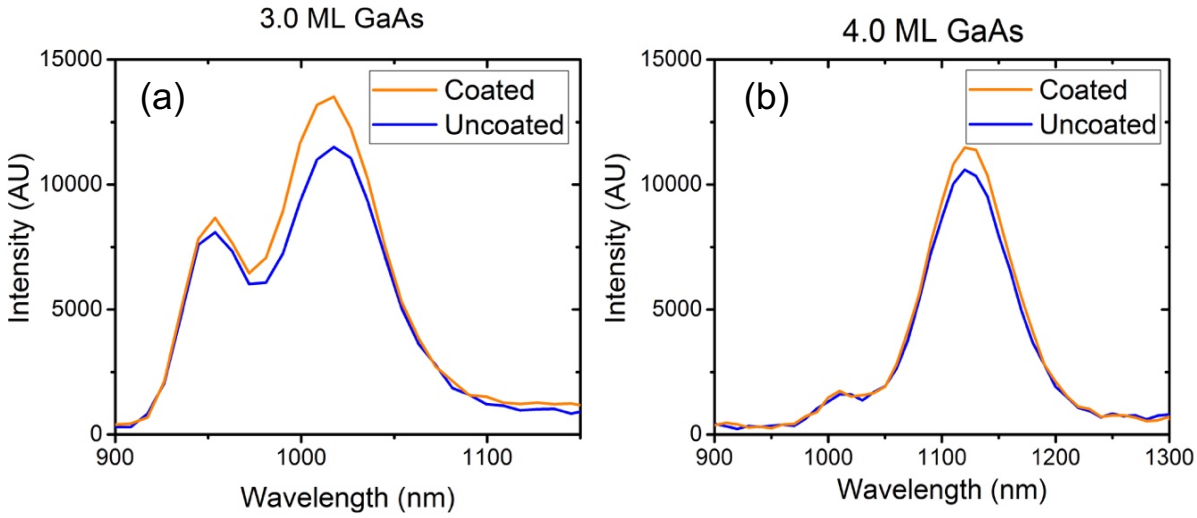

Figure 3: PL spectrum from (a) 3 ML and (b) 4 ML GaAs TSQDs at 11 K. In both cases, the wetting layer and TSQD emission peaks show an increase in intensity for the sample with the gold coating compared to a control sample. A wavelength redshift corresponding to an increased deposition amount is observed, which is consistent with quantum size effects for the TSQDS as observed in previous work. [2]

1. Yerino *et al*. Appl. Phys. Lett. **105**, 071912 (2014)
2. Schuck *et al*., J. Vac. Sci. Technol. **36**, 031803 (2018)