Improved dot size uniformity and luminescence of InAs quantum dots on InP substrate

Yueming Qiu, and David Uhl

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109, Tel: (818)354-2234, Email: yueming.qiu@jpl.nasa.gov

Abstract: InAs self-organized quantum dots have been grown in InGaAs quantum well on InP substrates by metalorganic vapor phase epitaxy. Atomic Force Microscopy confirmed of quantum dot formation with dot density of 3×10^{10} cm^{-2}. Improved dot size uniformity and strong room temperature photoluminescence up to 2 micron were observed after modifying the InGaAs well.

There is growing interest in InAs quantum dots (QDs) on InP substrates for applications at wavelengths of 2 μm and beyond. InAs QDs of emission wavelength up to 2 μm has been reported on InP substrates [1], however InAs/InP QD lasing has been demonstrated only at 77K at wavelength of 1.9 μm [2]. Recently room temperature operation of InAs quantum-dash lasers were reported, but in the wavelength range of 1.60 to 1.66 μm [3]. One possible reason for the lack of room temperature lasing at long wavelengths is low luminescence efficiency from InAs QDs. We report here that improved quantum dot size uniformity and strong room temperature luminescence could be obtained from InAs QDs embedded within a modified InGaAs quantum well.

InAs QDs were self-assembled on (001) InP substrates using low-pressure metalorganic vapor phase epitaxy, which is believed to allow the formation of large dots, therefore longer wavelength. Growth conditions were carefully explored to achieve high dot density and long emission wavelength. Growth temperatures are typically in the range 500 °C~550 °C for the InAs QD layers. The QD growth starts on lattice matched InGaAs layer using atomic layer epitaxy, then uncapped samples were examined using Atomic Force Microscopy (AFM), while samples for photoluminescence (PL) measurement were embedded within InGaAs well with total thickness of 7 nm and finally capped with InP.

Figure 1 shows AFM scans of typical InAs QDs and lateral size distributions with their underlying InGaAs layers modified and non-modified. In both cases, InAs QDs have a similar area dot density of about 3×10^{10} cm^{-2}, however exhibit quite different size distribution. In the modified case, the dots are quite uniform with an average size of 60 nm in lateral and of 7 nm in height, and follow a Gaussian distribution with a standard deviation of 5 nm, however in the other case, some dot heights exceed 9 nm and the size distribution has a standard deviation of over 9 nm. Under the same growth conditions, only InAs QDs in the modified case show strong room temperature luminescence. Shown in Figure 2 are PL spectra of a typical InAs QD sample on InP substrates excited under different power, showing the ground state at peak wavelength of 1.92 μm. PL Peaks from QD excited states and InGaAs quantum well states are also observed.

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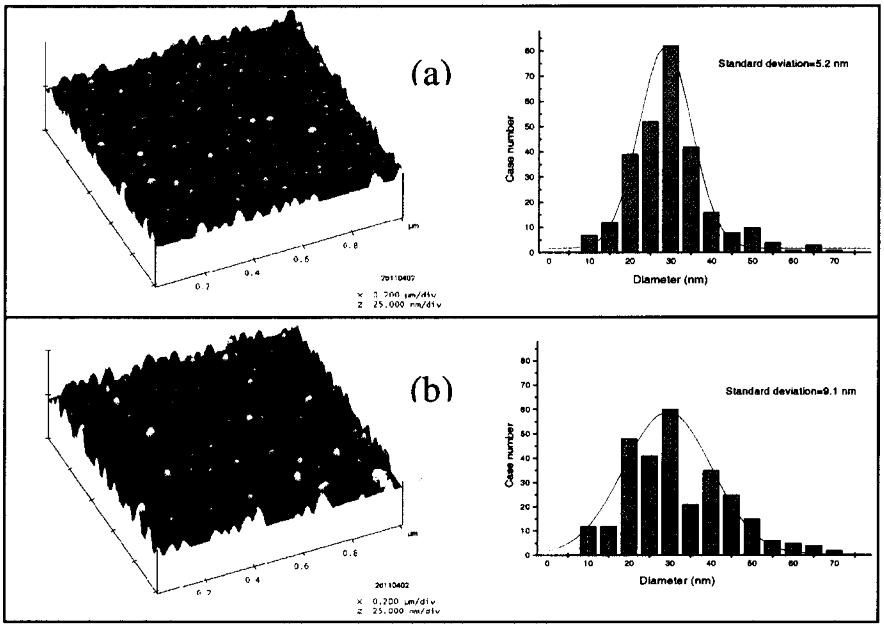

Figure 1, 1 μm x 1 μm AFM scans of typical InAs QDs on (a) modified InGaAs, (b) non-modified InGaAs layers, and their lateral size distributions.

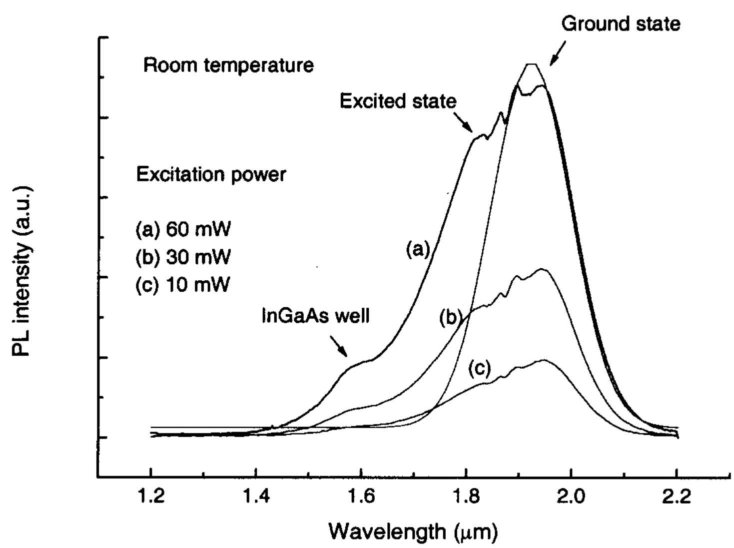

Figure 2. Room temperature PL spectra of a typical InAs QDs on InP substrates excited under different power, showing the ground state PL peak wavelength of 1.92 μm. The red curve is a Gaussian simulation for determining the peak wavelength.