Growth and Characterization of GaAs/InAs Quantum Dots By Molecular Beam Epitaxy

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Abstract and Introduction:

Quantum dots (QD) are three-dimensional structures that have electronic properties between those of molecules and bulk materials. They can be self-assembled through molecular beam epitaxial growth or fabricated using lithography. In this work, QDs were self-assembled by molecular beam epitaxy (MBE). Growth rates for gallium arsenide (GaAs) and indium arsenide (InAs) were calibrated by reflection high-energy electron diffraction (RHEED). Doping profiles were determined for GaAs using silicon (Si) as the n-type dopant. QD devices were fabricated and compared to quantum well (QW) and quantum free devices.

Quantum dot devices had ideality factors and series resistance values of 1.34 and 61 Ω, respectively, and had enhanced currents at higher voltages when compared to quantum well and quantum free devices.

Methodology:

To characterize the MBE tool, growth rates for GaAs and InAs were calibrated, followed by doping profiles for Si. RHEED oscillations were taken at various Ga furnace temperatures. The oscillations were used to calculate the growth rate in monolayers/sec by dividing the number of oscillations (monolayers) by the elapsed time. A semi logarithmic graph was used to plot growth rates versus furnace temperature.

The doping profiles for Si were acquired by first growing a GaAs buffer layer followed by an Si-doped GaAs layer at a particular silicon furnace temperature. The process was repeated for other samples at different silicon furnace temperatures. Hall measurements were taken to calculate the carrier concentrations of the Si. A semi-logarithmic graph was used to plot carrier concentrations versus furnace temperature.

Three devices were fabricated to examine current changes versus voltage: one with only GaAs, one with a monolayer of InAs (QW device), and one with three monolayers of InAs (QD device, see Figure 1). The samples were grown on n^+ GaAs. The GaAs was grown at 580°C and at 400°C while the InAs was grown at 460°C. The Schottky contacts used in the measurements had an effective diameter of diameter of 237 μm. An I-V curve trace was used to measure the ideality

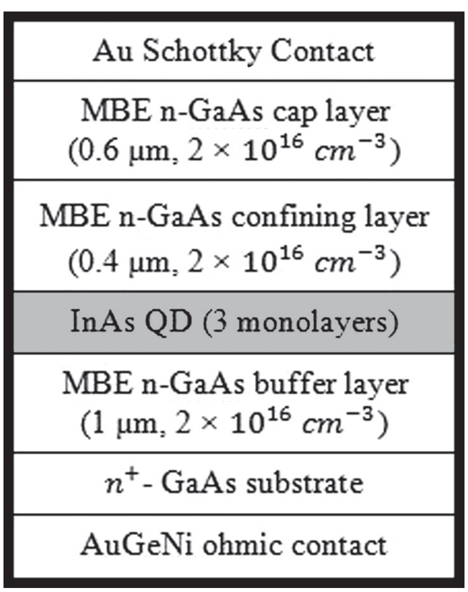

Figure 1: InAs quantum dot structure.

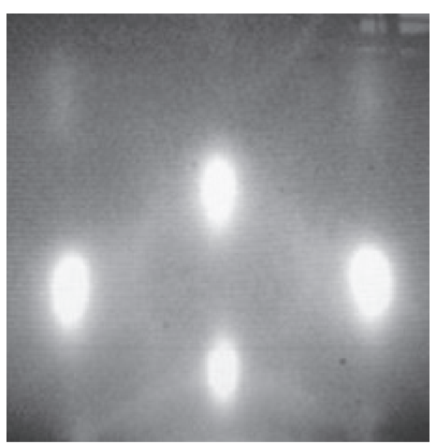

Figure 2: RHEED pattern of three monolayers of InAs on GaAs.

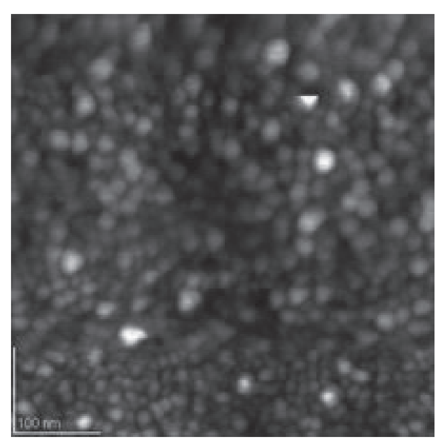

Figure 3: AFM image of InAs quantum dots on GaAs.

factor and the series resistance. A curve trace was also used to acquire current versus voltage data for the three different device structures.

Results:

RHEED images verified that the InAs structures were not two dimensional and AFM images verified that InAs QD were grown (see Figures 2 and 3, respectively). The ideality factor values for the reference, QW, and QD samples were 1.85, 2.439, and 1.134, respectively. The series resistance values were 77, 145.5, and 61 Ω, respectively.

Testing revealed that the current in the QD sample was greater than the reference sample (see Figure 4). This result was consistent with what others have found [5]. The current in the QW sample was also less than the QD sample at higher voltages. However at lower voltages the current in the QW device was higher.

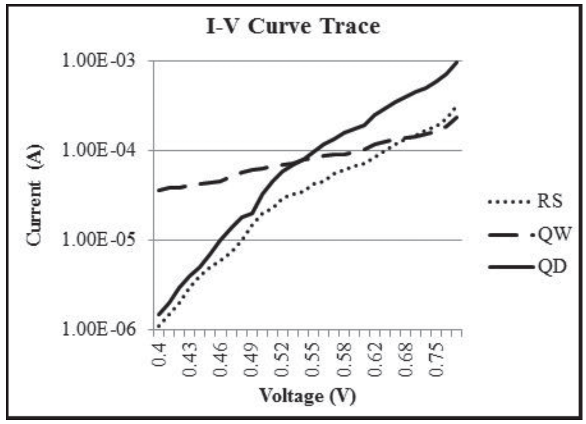

Figure 4: I-V plot of quantum dot, quantum well and reference samples.

Conclusions:

Growth rates for GaAs and InAs were calibrated up to 1 ML/s and 0.2 ML/s, respectively. Doping profiles for Si in GaAs were obtained up to 1e18cm^{-3}. Quantum dot and well samples were grown and devices were tested which revealed excess current in the QD sample relative to the QW and reference samples.

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