Gallium-assisted Deoxidation for Spatially and Spectrally Controlled InAs Quantum Dot Molecules

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InAs quantum dots (QDs) have long been considered as possible qubits and numerous proof-of-concept quantum operations have been performed [1, 2]. However the random nucleation for these self-assembled QDs and the spectral inhomogeneity that arises from variations in size, composition, and shape have made it impossible to produce arrays of identical QDs that are desired for scalable production of devices. Other material platforms for quantum device technologies face similar problems with inhomogeneity [3, 4]. To overcome these challenges we are engineering a new, molecular beam epitaxy (MBE) grown III-V QD material platform with built-in spectral tunability and site control. We present on using improved gallium-assisted deoxidation [5, 6] of patterned GaAs substrates for InAs QD growth used in photonic crystal cavities.

Typical patterned growth of QDs produces low optical quality structures [7]. To address this we are implementing a column of QDs in between the patterned GaAs surface and the optically active QD. This maintains the spatial location but creates a buffer layer away from defects at the growth interface. However in the fabrication of the patterned substrates surface oxide forms. Conventional thermal deoxidation leaves the surface pitted due to the stable surface oxide Ga_2O_3 reacting to form a volatile oxide Ga_2O. These surface pits compete with the fabricated nano-holes of the pattern for QD nucleation. A previous study by Atkinson et. al. successfully investigated gallium-deoxidation for patterned nano-holes [5, 6]. The nano-holes were spaced 500 nm apart and used a gallium deposition rate of 1 ML per minute to deposit 6 to 8 ML in 30-second intervals with 30-second growth interrupts. This study achieved 60% doubly and 40% singly occupied QDs in nano-holes. For implementation into our photonic crystal cavities we require a 10-µm spacing of nano-holes for the devices, single QD occupancy in nano-holes, and higher gallium flux for continued growth of the QD column in a GaAs matrix. We have shown 89% single QD occupancy in our pattern using a 12 ML per minute gallium deposition rate to deposit 4 to 6 ML in 1-second intervals with 30-second growth interrupts. The growth parameters and oxide removal for this system will be discussed.

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