A deterministic process for fabricating quantum devices with self-assembled quantum dots.

J. Lapointe, D. Dalacu, S. Frédérick[a], D. Kim[b], J. Lefebvre, W.R. McKinnon, P.J. Poole, M.E. Reimer[a] , G.C.Aers, and R.L. Williams[a]

Institute for Microstructural Sciences, National Research Council, Ottawa, Canada, K1A 0R6
[a] also at Dep. of Physics, University of Ottawa, Ottawa, Canada, K1N 6N5
[b] also at Dep. of Materials Science Engineering, University of Toronto, Toronto, Canada, M5S 3E4

Devices for quantum information applications were fabricated using a combination of site-selective growth on a patterned substrate as well as standard micro and nano-fabrication processing. Their optical and electrical properties were also measured. Self-assembled InAs/InP quantum dots are excellent candidates for quantum information applications as they emit strongly around 1.5 µm but the random nature of the nucleation process makes them difficult to integrate efficiently into any device. A solution to this problem consists in using a template to control with nanometer precision the location of the nucleation sites of InAs dots on InP[1]. In this directed self-assembly process, a SiO_2 mask is used to confine the growth by chemical beam epitaxy of InP to some well defined areas and leads to the formation of InP pyramids or ridges under appropriate growth conditions (fig. 1-2). InAs quantum dot(s) are then introduced near the apex of the structures.

Electrostatic gates defined by electron beam lithography were deposited on InP ridges containing a single row of self-assembled InAs quantum dots (fig. 2). The gates are used to select a probing area for photoluminescence measurements and to apply an electric field on the dots. Optical transitions were measured for single dots and coupled dots as a function of the applied electric field and compared with theoretical predictions. InP pyramids with 4 separate gates were also fabricated to better control the charge and wavefunction states of the quantum dots (fig. 1).

A single quantum dot can also be used to create an efficient single photon source by coupling it to a high finesse microcavity. Tuneable high finesse microcavities were first fabricated in InAs/InP membranes using a defect cavity in a photonic crystal structure[2] (fig. 3-4). Simulations were used to optimize the defect geometry and a dipole mode with a Q-value exceeding 28,000 was obtained. Devices were then fabricated by using a second selective growth step to planarise the InAs/InP pyramidal structures and incorporate them to the membrane. High finesse microcavities were then formed with the InP-based pyramids at their center.

1 D. Chithrani, R.L. Williams, J. Lefebvre, P.J. Poole, and G.C. Aers, Appl. Phys. Lett. **84**, 978 (2004)
2 D. Dalacu, S. Frederick, P.J.Poole, G.C. Aers, R.L.Williams, Appl. Phys. Lett. **87**, 151107 (2005)

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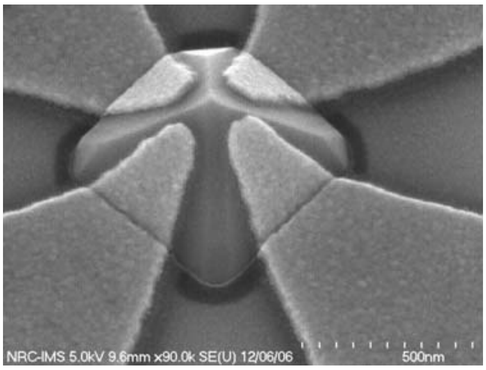

Figure 1: SEM image of a grown InP pyramid with InAs quantum dot(s). Gold gates were later deposited and are used to manipulate the charge and wavefunctions in this system.

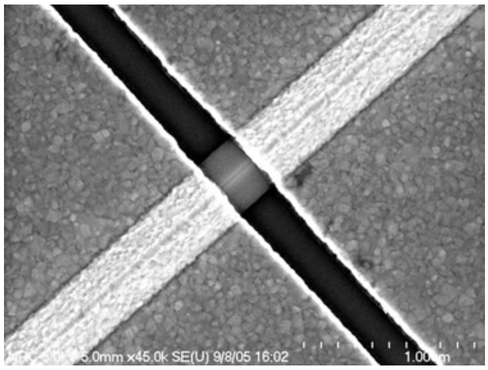

Figure 2: SEM image of metal gates covering an InP ridge with InAs quantum dots grown on the apex.

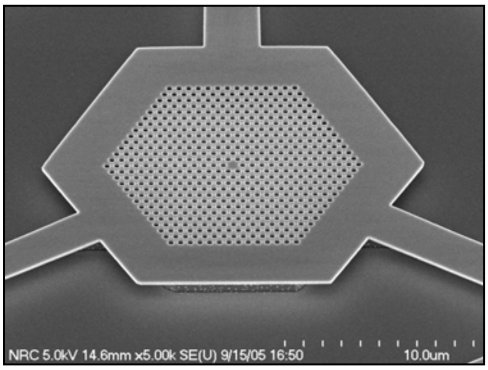

Figure 3: SEM image of a photonic crystal microcavity fabricated using an InP membrane containing InAs self-assembled quantum dots.

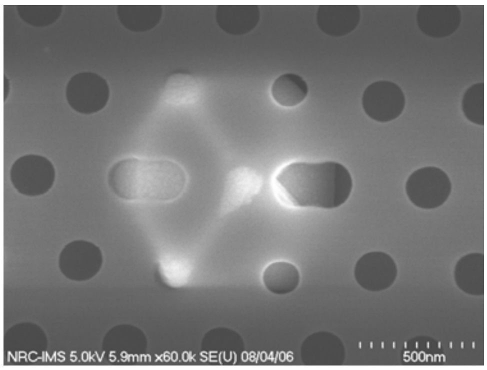

Figure 4: SEM image of the resist pattern used to create the photonic crystal microcavity. In this case, the InP pyramid was not planarised and its effect on the resist can be observed.