Fabricating semiconductor quantum dots by molecular beam epitaxy for quantum technology

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III-V-semiconductor quantum dots (QDs) have been established as promising sources for on-demand single photons and entangled photon pair generation for quantum communication applications. In this talk, I will outline the activities of my group on fabricating quantum dot heterostructures by molecular beam epitaxy (MBE). After an introductory discussion on strained vs unstrained QDs, I will give examples for both types of structures. In case of strained QDs, I will show results for the well-known InAs QDs in a GaAs matrix with emission around 930 nm. With an inhomogeneous In deposition, we can achieve low spatial densities required for optically addressing single QDs and by employing partial GaAs capping, we can adjust the emission wavelength. In addition, I will present results for InAs QDs on a metamorphic $In_xGa_{1-x}As$ buffer layer for QDs emitting in the optical C-band (1.55 µm). Here, we find a surprisingly low critical InAs thickness for QD formation and inhomogeneous spatial distribution of the QDs.

For unstrained QDs, I will discuss our results on droplet etched QDs in the $In_xGa_{1-x}As$/ $In_yAl_{1-y}As$/InP system (see Fig. 1). Nanoholes can be etched into $In_yAl_{1-y}As$ layers by In, Al and InAl droplets but not employing Ga or InGa droplets. The density of nanoholes decreases exponentially with increasing etching temperature where the nanoholes tend to become elongated for high temperatures. Under optimized fabrication parameters, one can produce circular shaped holes with a depth larger than 25 nm. Filling the nanoholes with $In_xGa_{1-x}As$ works much better under As_4 than under As_2 atmosphere and we observe also accumulation of $In_xGa_{1-x}As$ at the rings surrounding the nanoholes. Photoluminescence measurements reveal several features in the range between 900 and 1600 nm, which origins I will discuss. We can identify emission from the QDs around 1500 nm and µ-photoluminescence measurements reveal sharp lines typical for emission from individual QDs.

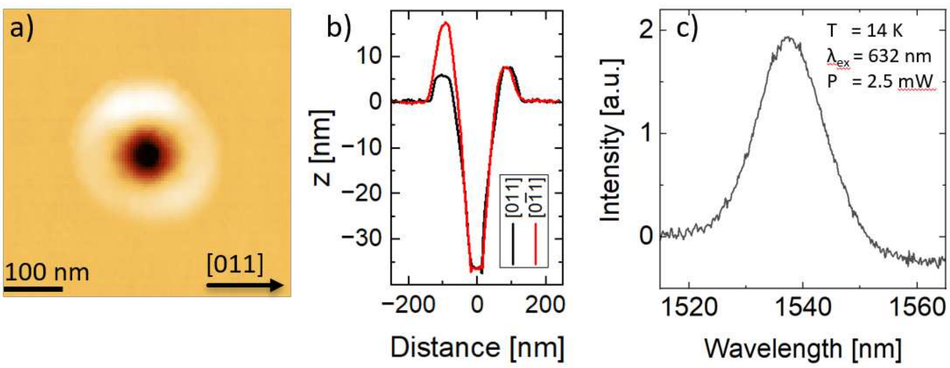

Figure 1 - a) Exemplary AFM image of a nanohole etched into an $In_{0.52}Al_{0.48}As$ layer by depositing InAl droplets. b) Corresponding line scans in the two main crystalline directions. c) Ensemble photoluminescence signal from $In_{0.56}Ga_{0.44}As$ QDs embedded in an $In_{0.52}Al_{0.48}As$ matrix, grown by filling nanoholes produced with the same parameters as in a) and overgrown with $In_{0.52}Al_{0.48}As$.