CdSe/ZnSe quantum dots in microcavities for single photon emission

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Semiconductor quantum dots (QDs) are very good candidates as active medium for single photon emission. The driving idea to get a single photon on demand is to spectrally filter the emission of a single QD after the excitation pulse to discriminate the last emitted photon among the deexcitation photon cascade of multiexcitons. When a single QD is located at the center of a resonant microcavity pillar the cavity effect is twofold: (i) the spectral selection requirement is fulfilled; (ii) the Purcell effect enhances drastically the spontaneous emission into the fundamental mode of the microcavity pillar and yields optimized single photon collection [1]. To elaborate such devices, three major steps have to be mastered: first the epitaxial growth of high quality QDs, then their incorporation into planar microcavities and finally the etching of micropillars. In the present study, we optimize each step using CdSe/ZnSe QDs grown by molecular beam epitaxy and TiO_2/SiO_2 Bragg reflectors for the photon confinement.

CdSe/ZnSe QDs provide blue-green emission and are promising materials to keep strongly confined excitons when increasing temperature [2]. We present a detailed study of growth condition optimization. The epitaxial structures consist of a single layer of CdSe islands encapsulated between a λ/2-ZnSe buffer layer grown on GaAs and a λ/2-ZnSe capping layer. The CdSe islands are formed as a consequence of strain relaxation in the highly strained, initially pseudomorphic, CdSe layer. This relaxation phenomenon leading to a 2D-3D transition of the CdSe layer was previously observed [3] after a thermal annealing of the sample. We propose here a new approach to induce the island formation. After the growth of 3 mono-layers of CdSe on a ZnSe buffer layer we check by Reflective High Energy Electron Diffraction (RHEED) that the diffraction pattern is characteristic of a perfectly 2D-surface. The sample is then cooled down below room temperature and amorphous selenium is deposited on the surface. The RHEED pattern vanishes. The amorphous selenium overlayer is evaporated by heating the sample back to growth temperature. When the RHEED pattern reappears, very clear spotty 3D RHEED features can be observed. Using thermal annealing instead, we also obtained some intensity modulation of the RHEED pattern due to 2D-3D surface reorganization, but the signature of this effect was rather weak. The second point to enhance the optical quality of the samples is to grow the CdSe thin layer as well as the ZnSe barriers entirely by atomic layer epitaxy. Applying the above processes, we obtain relatively intense photoluminescence (PL) emission up to room temperature. The study of the PL decay times versus temperature shows that the 0D confinement into the dots fully holds up to 170K. Above 170K non-radiative channels are activated but the PL emission is still observed at 300K.

To enclose the CdSe QDs into a hybrid microcavity we have developed TiO_2/SiO_2 Bragg reflectors. An almost total reflection is observed on a 8.5 period's TiO_2/SiO_2 structure.

Such a mirror is deposited on top of the CdSe/ZnSe epitaxial active layer. Then the GaAs substrate is removed by selective chemical etching before deposition of a 4.5 period's second mirror. Micropillars are then etched by reactive ion etching technique to provide the lateral optical confinement. Optical characterization are now under process to demonstrate the Purcell effect and the high potential of those complex, high quality quantum structures as single photon emitters.

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[1] J.M.Gérard and B. Gayral, J. of Lightwave Technology **17** (1999) 2089.
[2] K. Sebald, P. Michler, T. Passov, D. Hommel, G. Bacher and A. Forchel, Appl. Phys. Lett. **81** (2002) 2920.
[3] M.Rabe, M.Lowisch and F.Henneberger, J. of Crystal Growth **184/185** (1998) 248.