Micro-Photoluminescence Studies of CdSe/ZnSe Quantum Dot Structures with and without Sub-monolayer CdTe Stressor

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In the last decade, the physics of quantum light sources, namely, the sources of single photons and entangled pairs of single photons, has become one of the leading areas of nanophotonics and nanoelectronics. Up to now, single photon emission at room temperature has been achieved in molecules and color centers in diamond, where serious difficulties exist in fabrication of the electrically driven devices. Single self-organized quantum dots (QD) grown by epitaxial techniques are good candidates for the electrically driven single photon sources, because they can be easily integrated into commercial diode structures. However, there are very few reports on single photon emission in the epitaxial QDs at room temperature, which is mainly hampered by the relatively low quantum efficiency and spectral overlap of the emission bands of different QDs due to their large density.

In this work we perform comparative studies of CdSe/ZnSe QDs structures grown by molecular beam epitaxy either with (sample A) or without (sample B) predeposition of a sub-monolayer thick CdTe layer (stressor). Both techniques using migration-enhanced epitaxy (MEE) for the CdSe QD growth [1] were developed for the purpose of improving uniformity of size and composition within the QD ensemble, while the former was intended additionally for increasing the QD density and the Cd content in the dots [2]. Both samples involve the CdSe QDs embedded between the ZnSe layers of a thickness 70 (bottom) and 7 nm (sample A), and 60 and 15 nm (sample B). Emission properties of individual QDs were investigated by micro-photoluminescence (micro-PL) spectroscopy using 500 nm apertures in a non-transparent gold mask, opened by a ball-assisted etching technique.

Spectroscopic studies revealed the smaller full width at half maximum (FWHM) of the total PL spectrum of sample A (35 meV versus 50 meV in sample B), which indicates better homogeneity of the QD ensemble in the sample with the stressor-controlled QD growth. Micro-PL spectra display in both samples a number of narrow PL lines assigned to emission of excitons, trions and biexcitons of individual QDs or certain groups including a few QDs. The overall lines number is smaller in sample B as compared to sample A. Also the average FWHM of each line in sample B is about 0.3-0.6 meV, while in sample A it has never been less than 1 meV, being typically larger than 2-3 meV. A possible reason of the spectral broadening may be the spectral diffusion induced by trapping of the charge carries in the type-II ZnSe/CdTe nanostructures formed presumably in the vicinity of the CdSe QDs [1]. Analysis of these features allowed us to conclude that MEE-grown CdSe/ZnSe QDs without stressor are better suitable for single photon applications, while the QDs grown with the CdTe stressor might be preferable for laser applications [2] due to their better homogeneity.

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