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CdSe quantum dot in vertical ZnSe nanowire and photonic wire for efficient single-photon emission

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We've recently demonstrated that a CdSe quantum dot (QD) in a ZnSe nanowire (NW) can emit triggered single photons up to room temperature [1]. In this contribution, we present the possibilities of enhancing the photon emission and collection in such NW-QDs structures for a realistic application as a single photon source.

We have grown vertically oriented ZnSe NWs (with typical diameter of 10 nm) by molecular beam epitaxy on a ZnSe(111)B buffer layer. The growth of a ZnMgSe passivating shell increases the (otherwise weak) ZnSe near-band-edge luminescence by two orders of magnitude. This has allowed us to observe luminescence for the first time from CdSe/ZnSe NW-QDs in the (111) direction. We managed to obtain a low NW density (~ 1 NW/4 µm2) so that single NW-QDs can be directly studied on the as-grown sample. Exciton, biexciton and charged exciton lines are clearly identified.

Then we obtained conformal dielectric coating of Al_2O_3 on the NW-QDs using Atomic Layer Deposition so that a photonic wire is formed with the CdSe QD deterministically positioned on its axis. The collection enhancement effect is studied by measuring the emission (with pulse excitation, at saturation intensity) of single vertical NW-QDs with Al_2O_3 coating thickness ranging from 20 nm to 110 nm. Decay time measurements interestingly evidence an inhibition effect of the QD emission for thin Al_2O_3 coating, indicating that the optical dipole is orthogonal to the NW axis, in agreement with our calculations.

[1] S. Bounouar et al., Nano Lett. 12, 2977 (2012)

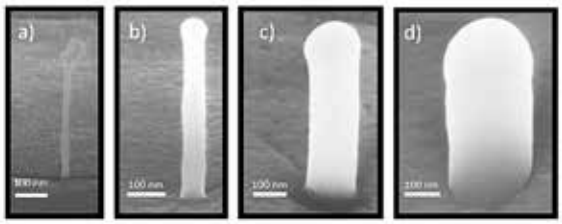

Figure 1. Scanning electron microscope images, tilted at 65°, of vertical CdSe/ZnSe NW-QDs with a thin ZnMgSe shell coated with a) no Al_2O_3 shell b) an Al_2O_3 shell of 20 nm c) 70 nm and d) 120 nm in radius.

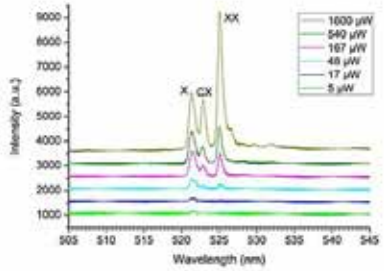

Figure 2. Photoluminescence spectra at 5K of a single CdSe /ZnSe NW-QD (on the as-grown sample) as a function of the 488nm cw laser power showing the exciton (X), biexciton (XX) and charged exciton (CX) lines.

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