CdSe/ZnCdSe quantum dot heterostructures for yellow spectral range grown on GaAs substrates by molecular beam epitaxy

S.V. Gronin[1], S.V. Sorokin[1], D.R. Kazanov[2], I.V. Sedova[1], G.V. Klimko[1], S.V. Ivanov[1]

[1]*Ioffe Physical-Technical Institute of RAS, St.-Petersburg, Russia*
[2]*St.Petersburg State Polytechnical University, St.-Petersburg, Russia*

II-VI wide-gap semiconductor heterostructures still attract great attention due to prospects of using in optoelectronic devices emitting in green and yellow-green ranges of visible spectrum, such as II-VI/III-N laser diode (LD) converters [1], BeZnCdSe-based quantum well (QW) LDs [2], and electron-beam-pumped lasers [3]. Different approaches were employed to extend the laser wavelength of II-VI heterostructures lattice-mathced to GaAs to the "true" yellow (570-590 nm) range, which is of importance for expanding the color space (CMYK) in the printing and projection devices. Among them LDs with ZnCdSSe (560 nm) [4] and BeZnCdSe (570 nm) [2] strained QWs, as well as a micro-chip LD converter comprising a CdSe/ZnSe quantum dot (QD) laser structure with CdSe nominal thickness enhanced beyond 3.1 monolayer (ML) (567 nm) [5]. However, the latter demonstrated reduced luminescence efficiency and output power (90 mW) in comparison with the green prototype (165 mW) due to partial plastic stress relaxation in the CdSe QD plane when its thickness exceeded the critical one (~3ML [6]). An alternative way we proposed previously - to embed CdSe QDs into a strained ZnCdSe QW - resulted in the emission wavelength of 565 nm [7], while λ~576 nm has been achieved in such a structure after optimization of the ZnCdSe QW composition and thickness [8].

This paper presents detailed calculations of the luminescence wavelength in the CdSe/ $Zn_{1-x}Cd_xSe$/Zn(S)Se QD system (x=0.3-0.5, t_{CdSe}=2.8-3.0 ML) using the envelope-function approximation. The following data and assumptions were utilized: (i) the CdSe QD layer is considered as a Gauss-like ZnCdSe QW with maximum Cd content of 85-95%, (ii) the broadening of CdSe layer is taken as (5-7) ML [9,10], (iii) the ~40% elastic stress accommodation at the QDs formation is taken into account for the CdSe/ZnCdSe band-gap and band offsets calculations. The calculations predict rather narrow range of the ZnCdSe QW thickness suitable to obtain the yellow emission (t_{QW}=2.5–4 nm). The larger ZnCdSe QW width has been found to have no significant effect on emission wavelength, whereas at t_{QW} below 2.5 nm the emission wavelength steeply decreases regardless of the Cd content in QW. To avoid defect formation in such QD system we employed the tensile strained ZnSSe/ZnSe superlattice barriers to compensate the compressive stress induced by the ZnCdSe QW only. A series of 2.8 ML-CdSe-QD/ZnCdSe-QW heterostructures has been grown by molecular beam epitaxy on GaAs(001) substrates, with the Cd content in ZnCdSe QW being varied in the 0.3-0.5 range as monitored by using RHEED oscillations technique. The experimental data demonstrate reasonable agreement with calculations. The maximum achieved emission wavelength at T=300K is as high as 600 nm, whereas the intense PL is observed up to λ=590 nm only. Further steps for improvements of the nanostructures as well as first results on laser heterostructures with such an active region will be discussed.

[1] S.V. Sorokin et al., Electron. Lett. 48, 118 (2012); [2] J.-I. Kasai et al., Appl. Phys. Express 4, 082102 (2011); [3] M.M. Zverev et al., Phys. Stat. Sol. (b) 247, 1561 (2010); [4] M. Klude et al., Appl. Phys. Lett. 79, 2523 (2001); [5] E.V. Lutsenko et al., Quantum Electron. 43, 418 (2013); [6] S. Ivanov et al., Appl. Phys. Lett. 74, 498 (1999); [7] I.V. Sedova et al., J. Korean Phys. Soc. 53, 3012 (2008); [8] S. Gronin et al., Abstr. 16th Int. Conf. II-VI compounds and Related Materials, Nagahama, Japan, September 9-13 (2013),p 28; [9] R. Kyutt et al. Appl. Phys. Lett. 75, 373 (1999); [10] N. Peranio et al., Phys. Rev. B 61, 16015 (2000).