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INFLUENCE OF GROWTH CONDITIONS ON OPTICAL PROPERTIES OF ZnCdSe/ZnSe QUANTUM WELLS GROWN BY MOLECULAR BEAM EPITAXY

M. Godlewski[a], J.P. Bergman[b], B. Monemar[b], E. Kurtz[c] and D. Hommel[c,d]

[a]Institute of Physics, Polish Academy of Sciences
Al. Lotników 32/46, 02-668 Warsaw, Poland
[b]Dept. of Physics and Meas. Technol., Linköping Univ., 581 83 Linköping, Sweden
[c]Exp. Physik III, Würzburg University, Am Hubland, 97074 Würzburg, Germany
[d]Institute of Solid State Physics, Bremen University, 28334 Bremen, Germany

The results of investigations of photoluminescence, time-resolved photoluminescence, photoluminescence kinetics and their temperature dependencies are discussed for two types of ZnCdSe/ZnSe multi quantum well structures — for pseudomorphic and for strain relaxed structure. Densities of 2D localized states and averaged localization energies, as seen by excitons, are determined from the photoluminescence kinetics measurements. We show distinct differences between exciton properties in two multi quantum well structures studied.

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1. Introduction

ZnCdSe based quantum well (QW) structures are intensively studied due to their use in blue colour laser devices [1–4]. In this communication we compare the optical properties of two ZnCdSe/ZnSe multi QW (MQW) structures grown by molecular beam epitaxy (MBE) on GaAs (001) substrates — pseudomorphic structure grown on a thin ZnSe buffer layer and strain relaxed structure grown on a thick ZnSe buffer layer deposited on top of GaAs substrate and buffer. The present paper was motivated by the recent observation of a strong temperature dependence of photoluminescence (PL) intensity in partly strained structures. It was observed that PL of the widest QW (11.4 nm thick), closest to the GaAs/ZnSe interface, was rapidly deactivated with increasing temperature [5]. It was also reported that thermal stability of QWs under annealing depends on a distance between QW and GaAs/ZnSe interface, i.e., on strain conditions in a QW [6].

2. Experimental

All samples studied were grown by MBE on (100) GaAs substrate using a multi chamber RIBER 2300 system. Prior to the II–VI growth a GaAs buffer layer was deposited in the interconnected III–V chamber. The sample labelled ZQ29 was a lattice relaxed ZnCdSe/ZnSe (23% of Cd) MQW structure with 4 ZnCdSe QWs (7.5 nm, 4.5 nm, 3 nm and 1.5 nm thick — listed in order from buffer to cap layer) grown on 1500 nm thick ZnSe buffer with QWs separated by 50 nm thick ZnSe barriers and with 30 nm thick ZnSe cap layer. The sample labelled ZQ31 was a pseudomorphic ZnCdSe/ZnSe (23% of Cd) multi QW structure with 2 ZnCdSe QWs (7.5 nm and 4.5 nm thick — listed in order from buffer to cap layer) grown on 50 nm thick ZnSe buffer with QWs separated by 50 nm thick ZnSe barrier and with 30 nm thick ZnSe cap layer.

The PL, PL excitation (PLE) and PL kinetics measurements were performed at 2 K on experimental setups described elsewhere [5].

3. Results and discussion

Distinctly different PL emissions were observed for two MQW structures studied. The PL of the ZQ29 sample had much narrower emission lines (full width at half maximum (FWHM) 5 meV for the 7.5 nm QW and 7 meV for the 4.5 nm QW) and showed a weak temperature dependence of PL intensity. All PL lines were observed up to 70 K. Then the PL of 1.5 nm QW was deactivated (at about 100 K) followed by deactivation of PL from 3 nm QW (at about 200 K). In contrast, for the strained pseudomorphic ZQ31 sample wide PL lines were observed (FWHM 8 meV for the 7.5 nm QW and 15 meV for the 4.5 nm QW) with a strong temperature dependence of the PL intensity. Moreover, the decrease in the intensity with increasing temperature was faster for the 7.5 nm QW being closer to the GaAs/ZnSe interface. Also the spectral position of the relevant emissions was shifted by about 90 meV towards lower energies compared to the positions in the ZQ29 sample.

PL kinetics and its temperature dependence were measured to evaluate more quantitatively optical properties of two structures studied. Mobile excitons were observed at 2 K in the 4.5 nm thick QW in the ZQ31 sample. We observed drift of PL maximum towards lower energy during excitons decay time and energy dependent decay time (60 ps at high energy wing and 85 ps at the maximum). For the 7.5 nm QW in the same sample 100 ps excitons decay time was observed at 2 K. In Fig. 1 we show temperature dependence of decay times of excitons in these two QWs. The observed difference in this dependence indicates a more localized character of excitons in the 7.5 nm QW. The PL decay time for this QW increases only slightly with increasing temperature, which is a property expected for localized excitons [7].

Quasi-mobile (4.5 nm QW) and localized (7.5 nm QW — 75–80 ps decay time) excitons were observed at 2 K in the ZQ29 structure. In the former case the decay time was energy dependent and was 90 ps at high energy wing and 145 ps at the PL maximum. Figure 2 shows temperature dependence of excitons decay time in the 4.5 nm QW. The PL decay time increases with increasing temperature,

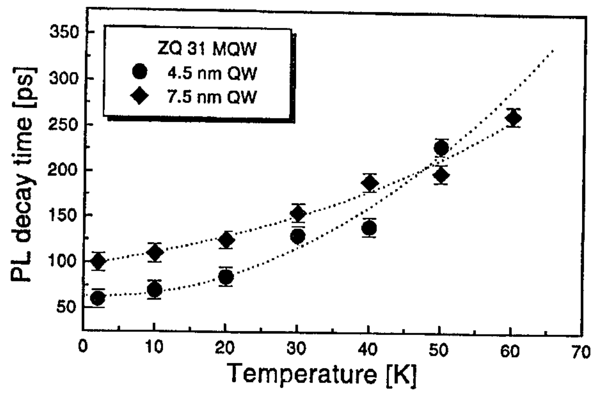

Fig. 1. Temperature dependence of PL decay times for the 4.5 nm and the 7.5 nm thick QWs in the pseudomorphic ZQ31 ZnCdSe/ZnSe structure. The dotted lines represent the fit to the experimental results with the Citrin theory.

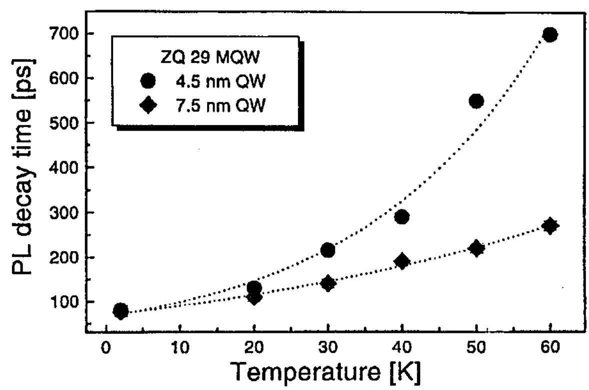

Fig. 2. Temperature dependence of PL decay times for the 4.5 nm and the 7.5 nm thick QWs in the strain relaxed ZQ29 ZnCdSe/ZnSe structure. The dotted lines represent the fit to the experimental results with the Citrin theory.

as is expected for mobile or quasi-mobile excitons [7]. For the 7.5 nm QW decay time of PL increases very slowly with increasing temperature indicating a localized character of excitons in this QW.

We applied the Citrin theory [7] to analyze the observed temperature dependencies of PL decay times in two MQW systems. From the fit of the Citrin theory we estimated the density of 2D localized states and averaged, as seen by excitons, localization energy in studied QWs in the pseudomorphic and in the strain relaxed sample. The dotted lines in Figs. 1 and 2 represent the fit to the experimental results with the Citrin theory describing excitons properties in QW systems with rough interfaces. The densities of 2D localized states obtained from the fit (between 10^{12} cm^{-2} and 10^{13} cm^{-2}) are one–two orders in magnitude larger than those for contemporary GaAs/AlGaAs structures reported by Colocci w et al. [8].

These densities were about 2–4 times (2 times for the 7.5 nm QWs and 4 times for the 4.5 nm QWs) larger in the pseudomorphic structure. However, the averaged localization energies, as seen by excitons, are larger in strain relaxed sample accounting for more localized nature of excitons in this MQW structure.

We indicate further that the localization energies derived from the fit to temperature dependencies of the PL decay times (ZQ29: 4.5 nm QW — 4.6 meV, 7.5 nm QW — 1.7 meV; ZQ31: 4.5 nm QW — 2 meV, 7.5 nm QW — 1.4 meV) agree well with the shifts of PL maxima observed in the PL kinetics and time-resolved PL experiments (ZQ29: 4.5 nm QW — 4–5 meV, 7.5 nm QW — about 1 meV; ZQ31: 4.5 nm QW — about 3 meV, 7.5 nm QW — about 2 meV). These results allow us positively verify the model of Zachau et al. [9], who have related the shift of PL maxima to a slow in-plane drift-diffusion of excitons between sides of different energy related to potential fluctuations in a QW width and composition. We can thus exclude the model which relates shift of PL maxima to differences in PL decay times of QW regions of varying width [10].

Concluding, the present results indicate a different morphology of interfaces in two types of MQW structures. The strain relaxed structure has less rough interface, however the planar extent of regions of different QW width becomes comparable with an exciton radius resulting in excitons localization. The averaged localization energies, as seen by excitons, are larger in this structure. The estimated densities of 2D localized states are still 1–2 orders in magnitude larger than those in contemporary GaAs/AlGaAs samples indicating still inferior morphological quality of II–VI QW systems. Finally, the present results relate the observed drift of PL maxima during excitons decay to a statistical distribution of QW states of different potential energy and to a slow exciton drift-migration between these states.

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