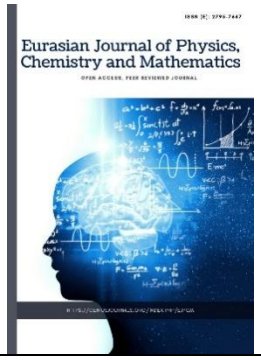

Influence of gamma radiation on the photoluminescent properties of CdZnTe/ZnTe QW

M. Sharibaev Karakalpak state univessity named after Berdakh, Nukus, Uzbekistan

A. Shamuratova Karakalpak state univessity named after Berdakh, Nukus, Uzbekistan

Saparniyazova G. Karakalpak Institute of Agriculture and agricultural technologies, Nukus, Uzbekistan

ABSTRACT

The effect of electron and X-ray irradiation on the optical characteristics of CdZnTe/ZnTe quantum-size structures has been investigated. A comparison between the results of both irradiations has shown an essential role of electron excitation in radiation enhancement of Cd diffusion that is one of the reasons for degradation of the II–VI-based quantum-size structures.

Keywords: Irradiation, quantum wells, photoluminescence

Introduction

Strained II–VI low-dimensional heterostructures are of great interest due to a possibility of efficient production of coherent and incoherent light-emitting devices that cover practically the whole visual spectral region. However, their potentialities for fabrication of such emitting devices as lasers (including those with e-beam pumping [1]) are limited by short time of operation. The reason for this lies in degradation processes occurring during lasing, structure growth process and/or post-growth treatments.

In this work the effect of electron and X-ray irradiation on the optical properties of CdZnTe/ZnTe quantum-size structures has been investigated. Electron irradiation is known to result in generation of both point defects and electron-hole pairs, while X-ray treatment produces free carriers only.

Experimental procedure and samples treatment

We studied the II–VI/GaAs structures containing both ZnTe epilayers and ZnTe epilayer with $Cd_xZn_{1-x}Te$ quantum wells (QWs) of different widths L_Z. They were MBE-grown using a KATUN' machine equipped with conventional effusion cells for high-purity elements. The residual pressure in the chamber was ~ 10^{-8} Pa. After oxygen removal the (001) GaAs substrate was cooled from 580 °C down to room temperature and then covered by an amorphous ZnTe layer 5 nm thick that was then re-crystallized by heating up to the growth temperature. The subsequent procedure was the growth of a ZnTe epilayer 1.5÷3.2 μm thick. The growth rate was about 0.6 μm/h. All the structures were sandwiched between cap ZnTe layer 4 nm thick and buffer ZnTe layer 1.5 μm thick. Details of the sample growth were described previously [2]. Photoluminescence (PL) was excited with the 488.0 nm and 514.5 nm lines of Ar^+ ion laser or the 632.8 nm line of He–Ne laser. Luminescence was detected with a photomultiplier tube in the current-flow regime

using a grating spectrometer MDR-23. The ZnTe-based structures were irradiated with 1.8 MeV-energy electrons or X-ray radiation.

Results

The effect of electron and X-ray irradiation on the low-temperature luminescence properties of QWs is shown in Figs.1 and 2.

They represent PL spectra from a sample with three tunnel-coupled QWs of both the same width (L_Z = 2 nm) and composition. In the excitonic region of the as-grown sample (Fig.1, curve 1) the following lines that are typical of ZnTe epilayer are present: I_2^{Ga} + I_{FX}^{lh} at 2.3736 eV (522.4 nm) - the line of an exciton bound to a neutral donor (probably Ga [4]) that overlaps with the light-hole component of a free exciton I_{FX}; I_1' at 2.37 eV (523.2 nm) - an exciton bound to a complex of As atoms [5] or to V_{Zn} complex [6]; I_1^C at 2.3568 eV (526.13 nm) is ascribed to dislocation-related centers [7,8].

As Figs.1 and 2 show, PL intensity after irradiation became somewhat lower. Concurrently the I_2^{Ga} + I_{FX}^{lh} band in the excitonic region of a ZnTe layer divided into two components. This was obviously due to a change in the ratio between intensities of these components (Fig.1, curve 2). Spectral positions of bands of free excitons and those bound to point defects shifted to the high-energy region after both types of irradiation. This fact is related to the residual stress relaxation after irradiation.

The spectral shifts of PL bands are confirmed by the results of measurements of reflectance spectra (Fig.2b). The value of residual stress estimated from I_{FX}^{lh} and I_{FX}^{hh} positions for as-grown sample with QWs is $\varepsilon \approx 6.4 \cdot 10^{-4}$ at a temperature of 4.2 K.

It is evident from the above results that both the electron and X-ray irradiations are capable of changing the PL spectra from the buffer ZnTe layer and QWs. As for the PL peak from the QWs, both red and blue spectral shifts were observed. Such shifts were accompanied by a decrease in the QW PL intensity. Similar results were observed in ZnSe-based quantum size structures after electron-beam irradiation [9] or charge carrier injection [10].

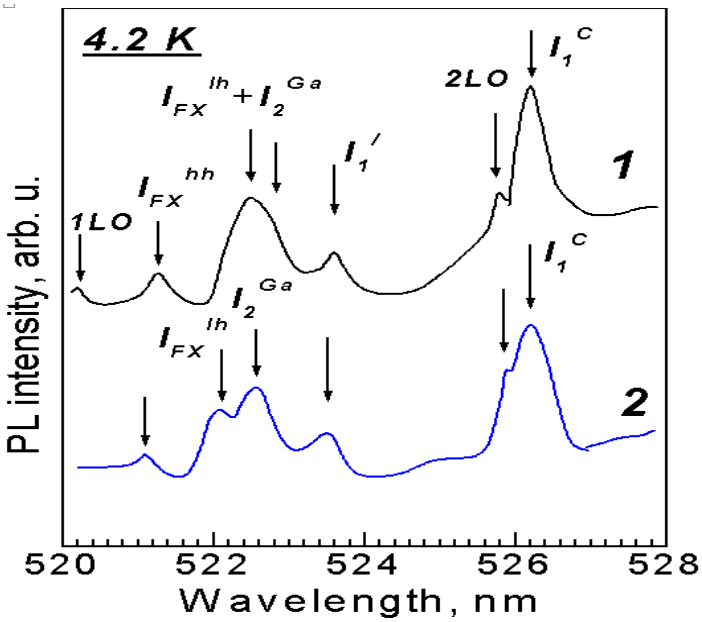

Fig.1. PL spectra in ZnTe excitonic region of as-grown (1) and electron-beam-irradiated (2) sample with three tunnel-coupled $Cd_{0.2}Zn_{0.8}Te$ QWs (see Table I); λ_{exc} = 514.5 nm, P_{exc} = 8.3 W/cm^2.

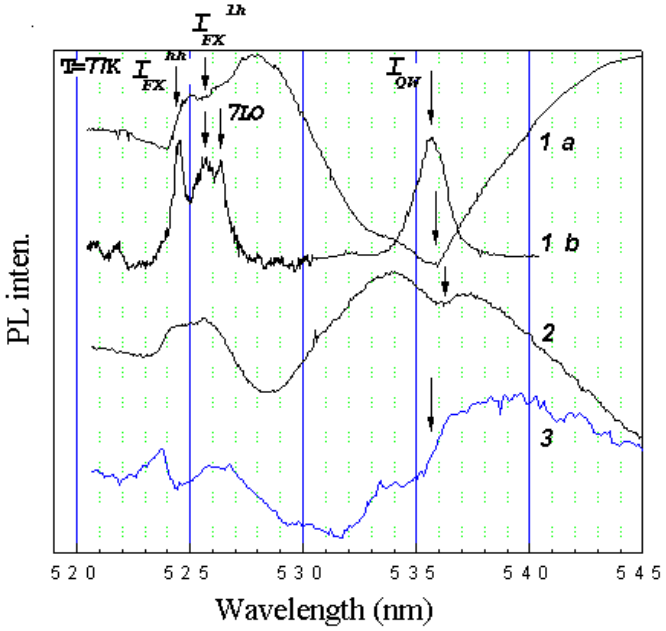

Fig.2. PL (a) and reflectance spectra (b) connected with quantum wells of sample with three tunnel-coupled $Cd_{0.2}Zn_{0.8}Te$ QWs: 1 - as-grown (open circles in inset), 2 - after X-ray irradiation (solid circles in inset), 3 - after electron-beam irradiation; λ_{exc} = 514.5 nm, P_{exc} = 8.3 W/cm^2. Inset - temperature dependence of the QW PL band intensity.

The red shift of emission was explained by the stress relaxation in the QWs, while the blue one was attributed to Cd/Zn interdiffusion and QW composition change. It seems possible that the same processes take place in our case. Indeed, the shift of PL peaks from the buffer layer under the QWs after irradiation to higher energies gives evidence of tensile strain relaxation in the buffer layer. Since the stress relaxation in single ZnTe epilayer is essentially less than in ZnTe under QWs, one may assume that this effect in the quantum-size structures takes place predominantly between the wells and adjacent layers. So the relaxation of compression stress in QW is suggested to be responsible for the observed red shift of PL peak positions under X-ray irradiation. However, the effect of QW composition change (disordering) obviously takes place in this case too because the thermal quenching of QW PL band intensity shifts to the lower temperature region (see inset in Fig.2).

It follows from our calculations that the blue shift may be connected not only to the QW depth change as it is usually supposed [9], but to the well profile change as well. This conclusion correlates with the literature data [10]. In the case of blue shift of QW PL band a comparison between the calculated and experimental results allowed us to estimate the coefficient of Cd diffusion under radiation, D_{Cd}. It turned out that its value ($D_{Cd} = (\Delta L_Z)^2/t$, where t is the duration of irradiation) was $\approx 2 \cdot 10^{-17}$ cm^2·s^{-1} for $T \approx 360$ K. This value is several orders of magnitude greater than those of the equilibrium diffusion coefficients [10]. It is important to note that radiation-enhanced changes in CdZnTe/ZnTe structures take place not only under electron irradiation when impact displacement of atoms occurs together with electron excitation, but also under X-ray irradiation when such process is absent..

Conclusions

We investigated the effect of electron and X-ray irradiation on the optical characteristics of CdZnTe/ZnTe quantum-size structures. Relaxation of compression stress in QW is suggested as being responsible for the observed red shift of QW PL peak positions under X-ray irradiation. The blue shift of the QW PL peak energy due to Cd diffusion as a function of QW widening was calculated.

References

1. N.G. Nasibov, E.M. Dianov, V.I. Kozlovskii, A.B. Krysa, A.S. Nasibov, Yu.M. Popov,

A.M. Prokhorov, P.A. Trubenko, E.A. Scherbakov, *Kvant. Electr*. *22* (1995) 756.
2. V.I. Kozlovskii, A.B. Krysa, Yu. G. Sadofyev, A.G. Turyansky, *Sov. Fiz. Techn. Poluprov*. *33* (1999) 810.
3. S. Seto, A. Tanaka, F. Takeda, and K. Matsuura, *J. Cryst. Growth 138*, (1994) 346.
4. H. P. Wagner, S. Lankes, K. Wolf, D. Lichtenberger, W. Kuhn, P. Link, W. Gebhardt, *J. Lumin*. *52* (1992) 41.
5. H. P. Wagner, W. Kuhn, W. Gebhardt, *J. Cryst. Growth 101* (1990) 199.
6. J.L. Dessus, Le Si Dang, A. Nahmani, R. Romestain, *Sol. State Comm*. *37* (1981) 689.
7. E.F. Venger, Yu. G. Sadofyev, G.N. Semenova, N.E. Korsunskaya, V.P. Klad'ko, M.P. Semtsiv, L.V. Borkovskaya, *Sov. Fiz. Techn. Poluprov*. *34* (2000) 13.
8. L.-L. Chao, G. S. Cargill, T. Marshall, E. Snoeks, J. Petruzzello, M. Pashley, *Appl. Phys. Lett 72* (1998) 1754.
9. Шарибаев М.Б.. Оптическое исследование релаксации деформаций и интердиффузии в квантовых ямах ZnSe/ZnCdSe, модифицированных γ-облучением «Илмий хаборнома» Андижан давлат университети, №2, стр. 102-105., 2020 г.