Vol. 92 (1997) ACTA PHYSICA POLONICA A No. 4

Proceedings of the XXVI International School of Semiconducting Compounds, Jaszowiec 1997

PHOTOACOUSTIC INVESTIGATION OF ABSORPTION EDGE OF $Cd_{1-x}Mg_xSe$ MIXED CRYSTALS*

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The $Cd_{1-x}Mg_xSe$ crystals were grown by modified Bridgman method for x ranging from 0 to 0.44. The photoacoustic spectroscopy was employed for evaluation of the band gaps of series $Cd_{1-x}Mg_xSe$ mixed crystals with different composition. The photoacoustic spectra were measured at 300 K and 90 K using continuous wave excitation in the range from 400 nm to 800 nm. The increase in the band-gap energy with increasing Mg content is observed. The photoacoustic results are compared with photoluminescence and transmission spectra.

PACS numbers: 62.65.+k, 78.20.Hp, 78.55.Et

Recently much attention is paid to the development of visible light emitters fabricated from wide band II–VI mixed crystals [1]. These materials gain increasing interest resulting from the possibility of tuning the band gap energies and the lattice constants by adjusting their composition. Green light emitting structures using n-CdSe, p-ZnTe, $Cd_{1-x}Mg_xSe$ and $Zn_{1-x}Mg_xTe$ layers have been already fabricated [2]. The n-CdSe/p-ZnTe heterojunction structure is a very poor light emitter because the valence and conduction bands of CdSe lie 0.64 eV and 1.15 eV below those of ZnTe, respectively. It is possible to change the energy gap as well as the position of conduction band by adding Mg to CdSe and ZnTe. Recently, the room temperature ZnCdSe/ZnMdMgSe photopumped quantum well blue-green laser was fabricated [3] which implies that these new materials could be alternative to the ZnSe based ones for blue-green lasers. Until now, only a few papers concerning CdMgSe and CdZnMgSe thin films have been published but to our knowledge $Cd_{1-x}Mg_xSe$ bulk material has not been investigated as yet.

Photoacoustic spectroscopy (PAS) is a direct and sensitive method which gives information about nonradiative processes in semiconductors. This problem is very important in the context of efficiency and degradation of semiconductor

*This work is supported in part by grant no. 383-F of Nicholas Copernicus University.

laser structures and light emitting diodes. PAS can also be used to determine the optical band gap energies of semiconductors. In the case of solids photoacoustic signal is monitored by piezoelectric transducer which is in direct contact with the sample. When the incident light is scanned over the wavelength region of interest the resulting signal corresponds to the absorption spectrum of the investigated sample. In this paper we report on PAS of $Cd_{1-x}Mg_xSe$ bulk mixed crystals with various Mg content at room and liquid nitrogen temperatures.

$Cd_{1-x}Mg_xSe$ mixed crystals were grown by the high-pressure Bridgman method under argon overpressure in the range of composition $0 < x < 0.44$ using a powder mixture of CdSe and Mg as a starting material. Phase analysis was performed using a standard X-ray Bragg–Brentano powder diffractometer. It was found that $Cd_{1-x}Mg_xSe$ forms hexagonal crystal structure with the lattice constants decreasing with increasing x value in the investigated range of composition. The PA spectra were measured using an open cell with continuous wave excitation. 300 W Cermax xenon short arc lamp was used as the radiation source and its output made to pass through a prism monochromator. The monochromatic light was mechanically chopped with variable frequency in the range of 3 Hz to 1.2 kHz. The light beam was split and ten percent of it was fed to the reference detector while the rest was focused on the sample. The PA signal was detected by a PZT transducer and analysed with lock-in amplifier (Stanford SR-510) using the sine wave conversion method. All photoacoustic spectra were corrected for the spectral response of the optical system.

The Jackson–Amer model [4] of the piezoelectric detected PA effect was applied to analyse the obtained spectra. In Fig. 1, the photoacoustic spectra for pure CdSe and $Cd_{1-x}Mg_xSe$ for different x values at 300 K are presented. The dependence of the PA signal on the absorption coefficient for different frequencies calculated according to the Jackson–Amer model is shown in the insert. It can be

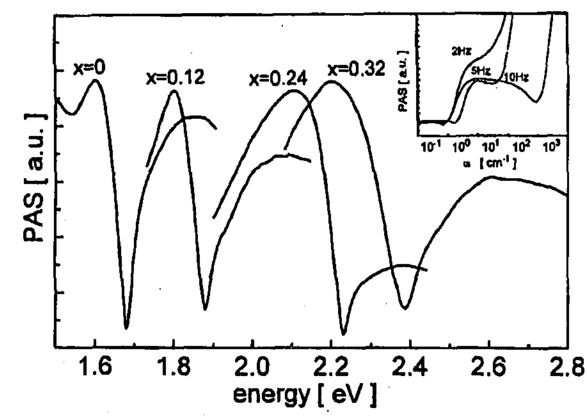

Fig. 1. Photoacoustic spectra of $Cd_{1-x}Mg_xSe$ crystals at room temperature for different Mg concentrations. The insert shows the dependence of the PA signal on the absorption coefficient for different frequencies calculated according to the Jackson–Amer model.

seen that the PA signal for energies lower than E_g is larger than that for energies higher than the energy gap. This indicates that the PA signal does not increase monotonically with the optical absorption coefficient (α). Similar anomalous dependence of the PA signal on the absorption coefficient was observed for GaAs by Ishigo and Tokumoto [5].

In order to obtain E_g values for $Cd_{1-x}Mg_xSe$, we consider the derivative of the PA spectrum. The observed PA curves exhibit well-expressed changes of the slope at some points from which these energies are determined. It was found that in $Cd_{1-x}Mg_xSe$ the room temperature band-gap energy ranges from 1.7 eV to 2.7 eV and from 1.8 eV to 2.8 eV at 90 K. With increasing Mg content a decrease in the slope and broadening in all parts of the photoacoustic spectra is observed (Fig. 1). It can be interpreted as due to increasing disorder in $Cd_{1-x}Mg_xSe$ mixed crystals.

Photoluminescence spectra of the investigated samples were measured from 40 K up to room temperature in the energy range from 1.6 eV to 3.5 eV. The typical PL spectrum at 40 K consists of near-band-edge (exciton), edge and deep-levels emission bands. The position of the highest photon energy emission line varies from 1.8 eV for CdSe up to about 2.8 eV for $Cd_{1-x}Mg_xSe$ with $x \approx 0.44$. The intensity ratio of exciton line to the edge emission increases with increasing Mg content. Figure 2a, b shows the PL and PA spectra for $Cd_{0.88}Mg_{0.12}Se$ and $Cd_{0.76}Mg_{0.24}Se$

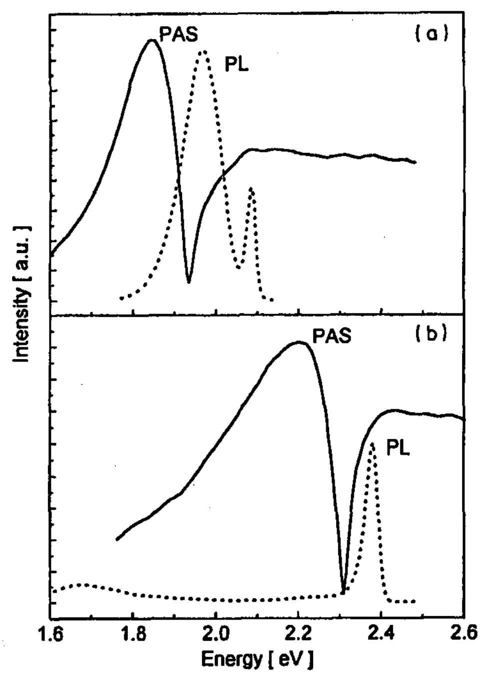

Fig. 2. Comparison of the photoacoustic spectra at 90 K and photoluminescence spectra at 40 K for $Cd_{1-x}Mg_xSe$ crystals with $x = 0.12$ (a) and $x = 0.24$ (b).

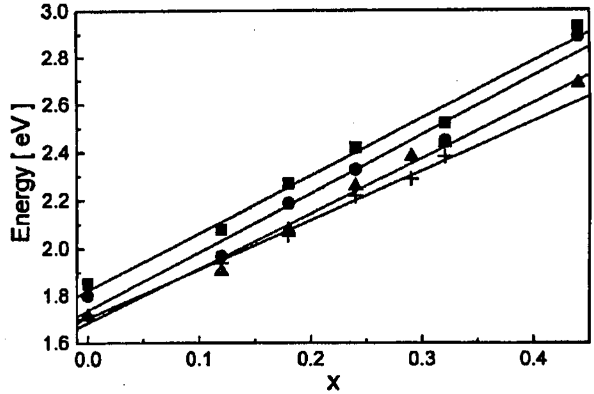

Fig. 3. The dependence of: energy gap on composition for $Cd_{1-x}Mg_xSe$ derived from PA spectra at $T = 90$ K — circles, energy gap derived from PA spectra at $T = 300$ K — triangles, exciton transition energies obtained from PL spectra at $T = 40$ K — squares, absorption edge estimated from transmission spectra at $T = 300$ K — crosses.

crystals. The PL was measured at 40 K and PAS at 90 K. The peak position which corresponds to the exciton energy in PL spectra is observed also in photoacoustic ones. The small shift observed is due to the different temperatures at which the spectra were measured.

As it was mentioned above, the PA spectrum gives also the information about nonradiative recombination processes which are correlated with the maximum of PA spectrum. It can be seen in Fig. 2a and 2b that the maxima of PL spectra correspond to minima of the PA signals.

The dependence of energy gap on x derived from PA spectra at $T = 90$ K and room temperature is shown in Fig. 3. Exciton transition energies obtained from PL spectra at $T = 40$ K and absorption edges estimated from transmission spectra at room temperature are also presented for comparison. Photoacoustic and transmission results agree very well at room temperature. The difference between these data and the results obtained from PL at 40 K and PAS at 90 K is due to the increase in the energy gap at lower temperatures.

The obtained values of energy gap and preliminary results of measurements of electrical properties of $Cd_{1-x}Mg_xSe$ solid solution indicate that this material can be also useful in construction of short wavelength photodetectors.

References

[1] A. Ishibashi, in: *Int. Symp. on Blue Laser and Light Emitting Diodes, Chiba (Japan) 1996*, Eds. A. Yoshikawa, K. Kishino, M. Kobayashi, T. Yasuda, Ohmska, Tokyo 1996.

[2] M.C. Philips, M.W. Wang, J.F. Swenberg, J.O. Mc Caldin, T.C. Mc Gill, *Appl. Phys. Lett.* **61**, 1962 (1992).

[3] Y. Guo, G. Aizin, Y.C. Chen, L. Zeng, A. Cavus, M.C. Tamargo, *Appl. Phys. Lett.* **70**, 1351 (1997).

[4] W. Jackson, M. Amer, *J. Appl. Phys.* **51**, 3343 (1980).

[5] T. Ishiguro, H. Takumoto, *Jap. J. Appl. Phys. Suppl.* **21**, 11 (1982).