Structural and optical studies of ZnO/CdO multiquantum wells grown by MBE on Si (111) substrate

M.A. Pietrzyk[1], E. Zielony[2], A. Wierzbicka[1], R. Szymon[2], E. Popko[2], A. Kozanecki[1]

[1] *Institute of Physics, Polish Academy of Sciences, Aleja Lotnikow 32/46 PL-02668, Warsaw, Poland*

[2] *Department of Quantum Technologies, Faculty of Fundamental Problems of Technology, Wroclaw University of Science and Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland*

Zinc oxide (ZnO), a direct wide band gap (3.37 eV at room temperature) semiconductor has stimulated great research interest due to its unique optical and electrical properties. Cadmium oxide (CdO) is a group of II–VI n-type semiconductor with a room temperature band gap value modulating within the range of ~ 2.18 to 2.31 eV. Alloying of ZnO with CdO leads to the gradual reduction of the bandgap, which results in tuning of luminescence from UV to VIS region. Thus, CdO/ZnO heterostructures can be used in a wide range of light emitting and laser diode sources operating from ultraviolet to green/blue wavelengths.

The subject of our investigations was 20-period ZnO/CdO multilayer that had been fabricated on a (111) Si substrate by molecular beam epitaxy (MBE) at low temperatures in oxide rich conditions. The thickness of barriers and quantum wells was kept constant at 2 nm. The ZnO/CdO/Si structure was prepared as follows: a ~20 nm thick ZnO buffer layer (grown at 380^{o}C), a ~500 nm thick ZnO barrier layer and a 20-period ZnO/CdO multilayer grown on top of the sample (at 170^{o}C). The optical properties of the structure were analyzed by photoluminescence at different temperatures (10-300 K), while the structural studies were carried out by AFM, SEM, X-ray diffraction and micro-Raman spectroscopy (using two excitation wavelengths of 514.5 nm and 325 nm).

The cross-sectional SEM picture reveals solid, planar growth without any trace of fragmentation or columnar nanostructure. The micro-Raman spectra obtained with 514.5 nm excitation wavelength show phonon modes originating from the Si substrate as well as the ZnO layer. A significant broadening of the A_1^{LO} ZnO line with comparison to the one observed for pure ZnO layers, can indicate the formation of a ZnCdO alloy. The near resonant Raman measurements (obtained with 325 nm excitation wavelength) exhibit phonon modes characteristic only for the ZnO layer, namely the A_1^{LO} peak and its two replicas. For both excitation wavelengths the Raman spectra present a significant shift of the A_1^{LO} ZnO mode towards higher frequencies. The blue shift of the A_1^{LO} Raman line has been observed in the case of $Zn_{1-x}Cd_xO$ films [1]. The shift was assigned to the inhomogeneous micro-strains as well as to fluctuations of the Cd content in $Zn_{1-x}Cd_xO$ layer [1]. Thus, based on the obtained results we can conclude about the existence of ZnCdO layer in the investigated sample, formed by incorporation of cadmium into the crystal lattice of ZnO during the growth of ZnO/CdO multilayers.

X-ray diffraction measurements reveal the structure is polycrystalline with dominant orientation in the (0001) crystallographic direction. For the lower values of 2θ angles XRD signal is coming from ZnCdO and the next one from ZnO, confirming the formation of ZnCdO layer. Obtained result is in agreement with micro-Raman experiments.

[1] O. Kolomys, et al., Semiconductor Physics, Quantum Electronics & Optoelectronics, 2014. V. 17, N 3. P. 275-283.