Optical and structural properties of ZnO/ZnMgO nanostructures grown on r-plane Al_2O_3 substrates by MBE

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Ternary $Zn_{1-x}Mg_xO$ alloys present suitable material system which allows widening of the band-gap up to 3.9 eV for x = 0.33 before any structural phase transition to cubic ZnMgO occurs. Using this alloy system in ZnO quantum well structures the exciton binding energy can be increased from 60 meV in bulk ZnO up to ~100 meV in quantum wells (QWs).

We report on the growth conditions, optical and structural properties of ZnO/ZnMgO nanostructures grown on semi-polar r-plane sapphire substrates by molecular beam epitaxy. We show that it is possible to grow self-organized ZnMgO nanocolumns without employing a catalyst. Use of low-temperature ZnO buffer layer enables to obtain good quality planar layers. The samples consist of 10 pairs of ZnO/ZnMgO QWs of 2 nm separated by 3 nm ZnMgO barriers.

XRD pattern shows two types of peaks coming from ZnMgO nanocolumns. First $(11\bar{2}0)$ peak and the second one (0002) indicates on non-polar a-plane and polar c-plane orientation of ZnO/ZnMgO, respectively. The nanocolumn structures exhibit 62 deg tilt with respect to the sapphire substrate, which is connected with mutual placement of r-plane Al_2O_3 and a-plane ZnMgO. SEM images reveal that density and diameter of ZnMgO nanocolumns can be controlled by the growth temperature.

Optical properties of ZnO/ZnMgO MQWs using room and low temperature photoluminescence (PL) techniques were studied. The spectrum measured at 10K temperature contains of a sharp, dominant peak, located at 3.392 eV. It is recombination of excitons in the 2 nm ZnO MQW structures. One can find another weak peaks on the low energy slope of the main transition. These peaks can obviously be attributed to 1LO, 2LO and 3LO longitudinal optical phonon replicas of the NBE emission from the MQWs. At the high energy part of the spectra a weak peak with maximum at about 3.700 eV, which originates from emission in ZnMgO barrier.

The energy position of excitonic transition in the 2 nm MQWs where the barrier thickness is only 3 nm is lower than in case of quantum wells separated by thick barriers. For this width of barrier exists high probability of localized exciton wave function penetration of barrier layers and interacting or influencing with the neighboring QW excitonic wave function. In the case of MQWs it leads to lowering of the energy levels in the QW. The transition energy of the excitons localized in the single or separated 2 nm QWs is much higher than in case described above.

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