Investigations of ZnO/ZnMgO multiple quantum wells in ZnMgO nanocolumns grown on Si (111) by MBE

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One dimensional (1-D) ZnMgO/ZnO nanostructures have great potential for applications in the fields of optoelectronic and sensor devices. The high quality ZnMgO nanocolumns can be employed for fabrication of high performance devices including field-effect transistors (FETs), Schottky diodes, logic circuits and light emitting devices. ZnMgO is regarded as an ideal semiconductor for ZnO-based optoelectronic devices. Ternary $Zn_{1-x}Mg_xO$ alloys present a 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 $Zn_{1-x}Mg_xO$ occurs. Using this alloy system the exciton binding energy can be increased in ZnMgO/ZnO/ZnMgO quantum well structures from 60 meV in bulk ZnO up to ~100 meV in quantum wells. ZnMgO has also another great advantage, as the lattice mismatch with ZnO is on the order of 1% only for a wide range of ZnMgO compositions.

We report on the growth conditions and structural properties of ZnO/ZnMgO multiple quantum wells (MQWs) in nanocolumns grown on Si (111) substrates by molecular beam epitaxy without employing a catalyst. The ZnMgO nanocolumns with different diameters were obtained at different growth temperatures. The structures were grown either without any buffer layer or with a thick ~300 nm ZnO buffer layer. The growth temperature of these layers ranged between 450-550^{o}C. For the growth of the nanocolumns, the temperature was set to 840^{o}C. During the growth the RF power of oxygen plasma was fixed at 350 W.

Ten periods of ZnO/ZnMgO MQWs (with well widths of 1.7 and 3 nm) were sandwiched between thick ZnMgO cap and buffer layers or substrate. The barriers have different widths (2 nm and 15 nm). When the distance between the two QWs is small enough, the wave functions of charge carriers overlap and tunneling is possible through the barrier. The problem of finding the treshold thickness for this barrier (for which the electrons in double quantum wells become separated), predicted by theoretical calculations, still has not been confirmed experimentally.

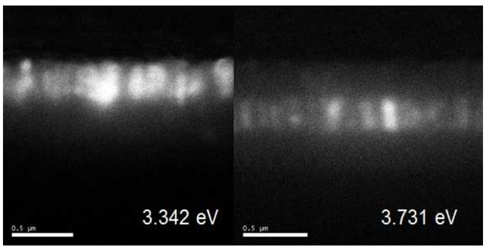

Fig.1. The cross-sectional SEM image - monochromatic CL mapping images

For the characterization of these samples scanning electron microscopy (SEM), photoluminescence (PL) and cathodoluminescence (CL) were used. SEM shows that ZnMgO nanorods with various density and diameter could be controlled by growth temperature of nanocolumns and the temperature of buffer layers grown. The cross-sectional SEM-CL mapping was collected for panchromatic as well as for monochromatic light. The CL spectra mapping measurements performed on a cross section of the sample show, emission from 3.342 eV comes from the ZnO QW`s and emission from 3.73 eV comes from the ZnMgO buffer layer (fig.1). It is noticed that the location of QWs in nanocolumns agrees well with the assumed for the growth.

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