Comparison of the growth conditions and optical properties of the self-organized ZnMgO nanocolumns with ZnO/ZnMgO quantum wells grown on different substrates by MBE

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ZnO is a versatile functional material. 1D ZnO nanostructures such as nanotubes, nanowires, nanorods, nanobelts and nanoribbons stimulate considerable interests for scientific research due to their importance in fundamental physics studies and their potential applications in nanoelectronics, nanomechanics, and flat panel displays. Particularly, application of 1D ZnO nanostructures in optoelectronic devices becomes one of the main directions in recent nanoscience research. An important issue in the self-organized growth of 1D nanostructures is how to control their morphology, position, orientation and crystallinity. 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).

In our work, we present the comparison of the growth conditions, structural and optical properties of ZnO/ZnMgO single, double and multiple quantum wells in nanocolumns ZnMgO grown on different substrates (Si [1], semi-polar *r*-plane [2], non-polar *a*-plane, polar *c*-plane [3] Al_2O_3, SiC) by MBE. We show that it is possible to grow self-organized ZnMgO nanocolumns without employing a catalyst. Scanning electron microscopy (SEM) shows that ZnMgO nanocolumns with various density and diameter could be controlled by growth temperature.

We have grown these structures with two different procedures: without any buffer layer, and with a thick ZnO buffer layer. We applied and optimized a low temperature ZnO buffer layer before the growth of ZnMgO nanocolumns. ZnO buffer layers were grown at different growth temperatures of 450 and 550^{o}C. The shape and thickness of nanocolumns in the samples with buffer layer are improved significantly.

QWs interactions are a very interesting topic to investigate due to vague information about the critical thickness of barrier at which the electron wave functions of two neighboring quantum wells still overlap. Although there are some theoretical attempts to calculate the values of critical distance for given Mg content, there is insufficient volume of experimental data in this field.

We also compare the luminescence spectra of ZnO/ZnMgO structures grown on the semipolar substrate with *r* orientation and on a polar *c*-oriented substrate is done. It is probably the first experiment comparing the quantum confined Stark effect for structures of different polarities, grown on Al_2O_3 substrates of different crystallographic orientations.

[1] M.A. Pietrzyk, et.al,, J. Lumin. **179**, 610-615 (2016)
[2] M.A. Pietrzyk, et.al, J. Alloys Compd. **650**, 256-261 (2015)
[3] M.A. Pietrzyk et. al, J. Alloys Compd. **737**, 748-751 (2018)

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