Characterization of ZnO/ZnMgO quantum wells in ZnMgO nanocolumns grown on polar and semi-polar Al_2O_3 substrate by MBE

M.A. Pietrzyk, M. Stachowicz, P. Dluzewski, A. Wierzbicka D. Jarosz, A. Kozanecki
Institute of Physics, Polish Academy of Sciences, Aleja Lotnikow 32/46 PL-02668, Warsaw, Poland

Zinc oxide is a promising material for optoelectronics as a stable, reliable, wide direct band-gap semiconductor. The high exciton binding energy of 60 meV is one of the properties that makes ZnO superior to other semiconductors. It is important that the high exciton binding energy is related directly to the low value of Bohr radius (a_B), which is about 1.8-2.0 nm. As a wide band-gap semiconductor ZnO is considered to be a promising candidate for solid state blue to UV optoelectronic devices, including development of lasers.

We present the synthesis of ZnO/ZnMgO heterostructures on *r*- and *c*- plane Al_2O_3 by plasma-assisted molecular beam epitaxy and investigation of their structural and optical properties. The structures were grown at oxygen-rich conditions at a temperature of 550°C. We demonstrate that it is possible to grow a good quality nanocolumns on *c*- plane Al_2O_3 substrate without employing a catalyst such as Au or Ag. We have studied also shift between polar- and nonpolar- ZnO/ZnMgO quantum wells. The non-polar (*a*-plane) ZnO/ZnMgO nanocolumns were achieved on semi-polar (*r*-plane) sapphire substrate while on polar *c*-plane substrate was used to obtain a polar *c*-orientation of the nanostructures.

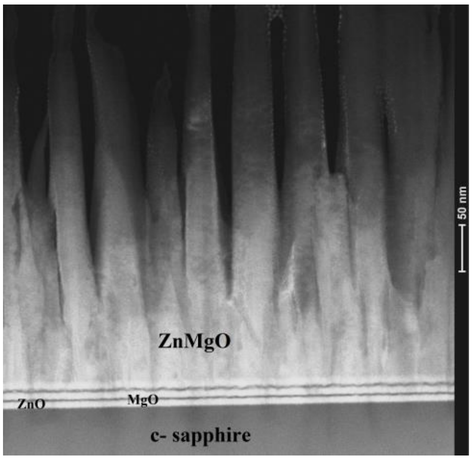

Fig. 1. TEM images of ZnMgO nanocolumns grown on Al_2O_3 substrates with ZnO + MgO layer

We present the research of ZnMgO nanocolumns with ZnO QWs located in single nanocolumns. The studied samples consist of two ZnMgO/ZnO/ZnMgO quantum wells with the wells widths of 1.5 and 4 nm. The quantum wells were separated with 15 nm ZnMgO barrier. Different experimental techniques were used to investigate the surface morphology and structural properties after the growth of samples. All samples were characterized with X-ray diffraction, photoluminescence at different temperatures (10-300K) transmission electron microscopy (TEM) and scanning electron microscopy.

The cross-sectional high resolution TEM image presents the interface between the c-plane Al_2O_3 substrate and ZnMgO nanocolumnar structure (Fig.1). We applied 3 x ZnO + 2 x MgO buffer layers at the interface and then ZnMgO nanocolumns with ZnO/ZnMgO quantum wells. The ZnO layer thickness is 8 nm and MgO 3 nm.

We measured also the effects of a piezoelectric field on the spectroscopic properties ZnO/ZnMgO QWs in the strained ZnMgO self-assembled nanocolumns. We compared the luminescence spectra of ZnO/ZnMgO structures grown on the semi-polar substrate with *r* orientation and on polar *c*-oriented substrate. 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.

Acknowledgements The project was supported by the Polish National Science Centre (NCN) based on the decision No: DEC-2013/09/D/ST5/03881.