MgZnO/ZnO Heterostructures for UV Light Emitters and Spintronic Applications: Material Growth and Device Design.

(Invited Talk)

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Wurtzite ZnO is attracting more attention recently as a wide-bandgap semiconductor material rivaling with GaN and SiC. ZnO superior optoelectronic properties, e.g., free-exciton binding energy of 60 meV [1], makes ZnO material an ideal candidate for UV light emitting devices (LEDs). $Mg_xZn_{1-x}O$ alloys with low Mg-content are perfectly lattice matched to GaN that makes this material even more attractive for building high quality device structures. Due to it's high band gap, ZnO-based alloys doped with some magnetic impurities, such as Mn and Co which can incorporate in the lattice to form dilute magnetic semiconductor, hold promise for application in spin electronic.

In this paper we present our recent research results on growth of high quality epitaxial MgZnO/ZnO heterostructures on GaN using reactive molecular-beam epitaxy (MBE). We also report on simulation, fabrication and testing of double heterostructure (DHS) $Mg_xZn_{1-x}O$/ZnO/AlGaN p-n junction test devices designed for demonstration of efficient UV LEDs. Material growth and device design issues for ZnO-based light emitters as well as spintronic structures will be discussed.

Utilization of a RF-plasma source developed at SVT Associates for producing active oxygen species allowed controllable and reproducible process for $Mg_xZn_{1-x}O$ epitaxial growth. To obtain high crystal quality and expand utilization of this material into deeper UV spectrum, $Mg_xZn_{1-x}O$ films were grown on GaN/Sapphire structures. Structural analysis of $Mg_xZn_{1-x}O$ layers presented in Fig. 1 confirmed high crystalline quality and wurtzite nature of ZnO crystals grown on hexagonal GaN. ZnO epitaxial layers show strong RT exitonic emission at ~377.5 nm with FWHM of ~ 17 nm. A weak deep-level emission band was observed for some ZnO and ZnMgO epitaxial layers. Higher Mg content in $Mg_xZn_{1-x}O$ leads to a spectral blue shift of the emission band (see Fig. 2). $Mg_xZn_{1-x}O$ epitaxial layers with x<0.3 crystallize in wurtzite structure, whereas the layers with x>0.45 form a metastable cubic alloy, as confirmed by analysis of X-ray diffraction data. To utilize advantages of a strong exitonic emission in ZnO-based crystals for efficient light emission, various DHS p-n junction diodes of $Mg_xZn_{1-x}O$/ZnO/AlGaN were designed and fabricated. Since p-type doping of ZnO is not a reliably developed technology yet, p-$Al_xGa_{1-x}N$ (x~0.15%) hole injection layers were utilized in the DHS diodes. Prior to growth and fabrication of the devices, a bandgap lineup simulation was carried out using a Poisson equation solver. This enabled us to optimize the DHS design for efficient carrier injection into the ZnO active region. The application of MgZnO layers doped with magnetic impurities for spin electronics will be discussed.

This work has been supported by DoD contract #FA9550-04-C-0010, monitored by Todd Steiner.

Reference:

[1] D.C. Look, Mater. Sci. Eng. B **80**, 383 (2001).

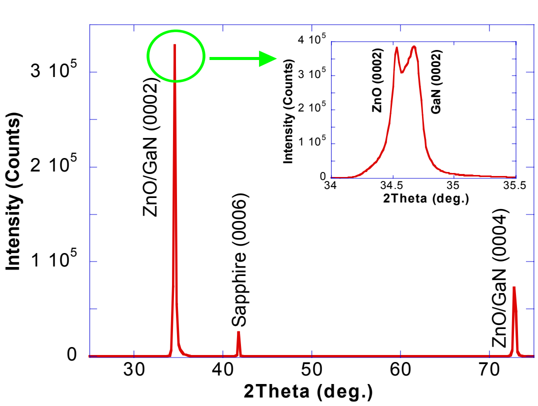

Fig. 1. XRD results from ZnO/GaN/c-plane sapphire.

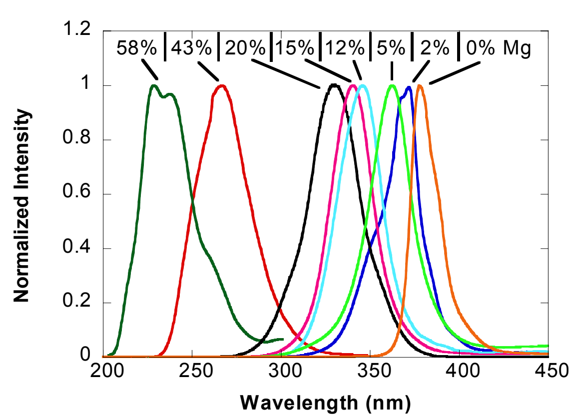

Fig. 2. RT normalized CL spectra of $Mg_xZn_{1-x}O$ films grown by MBE.