$Zn_{1-x}Mg_xO$ ($0 \leq x \leq 0.49$) 박막과 $ZnO/Zn_{1-x}Mg_xO$ 양자우물구조의 발광 특성

Photoluminescent properties of $Zn_{1-x}Mg_xO$ ($0 \leq x \leq 0.49$) thin films and $ZnO/Zn_{1-x}Mg_xO$ multi-quantum wells

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ZnO, a wide-gap semiconductor oxide, has attracted a considerable attention due to its large exciton binding energy (~60 meV) and bond strength, which make reliable high efficiency photonic devices based on ZnO.[1,2] Moreover, the fundamental band-gap energy of the material increases from 3.3 eV to 4.0 eV by alloying ZnO with MgO, depending on the Mg content. Recently, Othomo et al. reported that $Zn_{1-x}Mg_xO$ films using pulsed laser deposition (PLD) contained Mg maximally up to 33 at.% without phase separation and showed the blue shift of luminescence energy from 3.36 to 3.87 eV.[3] However, in the view of thermodynamics, $Zn_{1-x}Mg_xO$ contenting MgO over 4 at.% is in the metastable state. These results indicate that the solubility limit of Mg in ZnO depends on the growth mechanism as well as the growth condition. This paper reports on the vapor phase epitaxial growth of $Zn_{1-x}Mg_xO$ films with the Mg content up to 49 at.% without any phase separation. Furthermore the films showed the blue shift in the bandgap energy.

The $Zn_{1-x}Mg_xO$ ($0 \leq x \leq 0.49$) were grown on $Al_2O_3(00 \cdot 1)$ substrates using low pressure MOVPE system. For the reactants, diethylzinc (DEZn) and bis-cyclopentadienyl-Mg (cp2Mg) were employed. Details of the film growth have been previously reported.[2]

For the investigation of the crystal structure and film orientation of the as-grown films, X-ray diffractometry (XRD) were employed. As shown in Fig. 1, up to 49 at.% of Mg content in $Zn_{1-x}Mg_xO$, θ-2θ scan data exhibited only $Zn_{1-x}Mg_xO(00 \cdot 2)$ peaks at 34.36° (x=0.0)-35.11° (x=0.49) depending on the Mg concentration. The observation of only $ZnMgO(00 \cdot 1)$ peaks indicates that the single phase $Zn_{1-x}Mg_xO$ ($0 \leq x \leq 0.49$) films were grown without the formation of a separated MgO phase. The incorporated Mg concentration is even higher than that of the PLD grown films, 33-36 at.%.[3-4] As shown in Fig. 2, the c-axis lattice constant of the $Zn_{1-x}Mg_xO$ ($0 \leq x \leq 0.49$) films decreased with increasing the Mg content. When 49 at.% of Mg was incoporated, the c-axis lattice constant of the $Zn_{1-x}Mg_xO$ decreased by 1.34 %.

The band-gap energy of $Zn_{1-x}Mg_xO$ depends on the Mg content, which result in a blue shift of a band-edge emission peak. Fig. 3 shows photoluminescence spectra of $Zn_{1-x}Mg_xO$ ($0.0 \leq x \leq 0.49$) films measured at 15 K. In ZnO film, the dominant emission peak was observed at 3.364 eV, which

is tentatively attributed to the exciton transition (I_2) bound to neutral donors. As increase with Mg content (x) to 0.09, 0.29, and 0.49, the near band-edge (NBE) emission peaks showed at 3.462 eV, 3.805 eV, and 4.05 eV, respectively. Considering stokes shift observed in alloy semiconductors, the band gap of $Zn_{1-x}Mg_xO$ (x = 0.49) is estimated to be 4.3 eV or so.

Furthermore we fabricated ZnO/ZnMgO multiple quantum well structures and observed the blue shift from photoluminescence spectra of the ZnO layers in the quantum wells, which presumably results from the quantum confinement effect.

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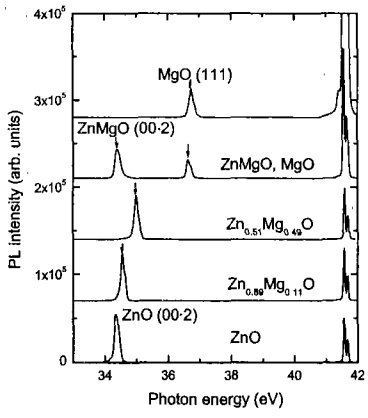

Fig. 1. XRD θ-2θ scan results of ZnO and ZnMgO, MgO films.

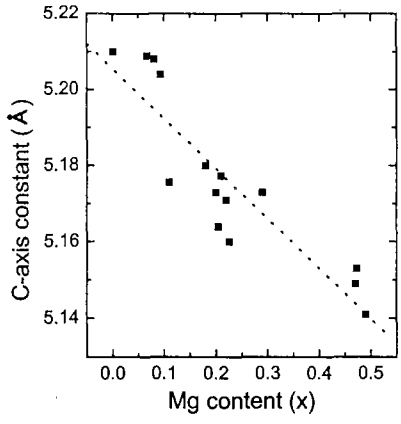

Fig. 2. Mg content dependence of c-axis constant in $Zn_{1-x}Mg_xO$ ($0.0 \leq x \leq 0.49$) films.

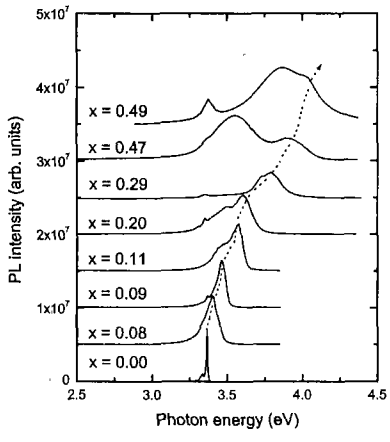

Fig. 3. PL spectra of $Zn_{1-x}Mg_xO$ ($0.0 \leq x \leq 0.49$) films measured at 15 K.