Control of electrical types in the P-doped ZnO thin film by Ar/O_2 gas flow ratio

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Abstract : ZnO has a very large exciton binding energy (60 meV) as well as thermal and chemical stability, which are expected to allow efficient excitonic emission, even at room temperature. ZnO based electronic devices have attracted increasing interest as the backplanes for applications in the next-generation displays, such as active-matrix liquid crystal displays (AMLCDs) and active-matrix organic light emitting diodes (AMOLEDs), and in solid state lighting systems as a substitution for GaN based light emitting diodes (LEDs). Most of these electronic devices employ the electrical behavior of *n*-type semiconducting active oxides due to the difficulty in obtaining a *p*-type film with long-term stability and high performance. *p*-type ZnO films can be produced by substituting group V elements (N, P, and As) for the O sites or group I elements (Li, Na, and K) for Zn sites. However, the achievement of *p*-type ZnO is a difficult task due to self-compensation induced from intrinsic donor defects, such as O vacancies (V_O) and Zn interstitials (Zn_i),or an unintentional extrinsic donor such as H. Phosphorus (P) doped ZnO thin films were grown on *c*-sapphire substrates by radio frequency magnetron sputtering with various Ar/ O_2 gas ratios. Control of the electrical types in the P-doped ZnO films was achieved by varying the gas ratio with out post-annealing. The P-doped ZnO films grown at a Ar/ O_2 ratio of 3/1 showed *p*-type conductivity with a hole concentration and hole mobility of $10^{-17}cm^{-3}$ and $2.5cm^2/V{\cdot}s$, respectively. X-ray diffraction showed that the ZnO (0002) peak shifted to lower angle due to the positioning of P^{3-} ions with a smaller ionic radius in the O^{2-} sites. This indicates that a *p*-type mechanism was due to the substitutional P_O. The low-temperature photoluminescence of the *p*-type ZnO films showed *p*-type related neutral acceptor-bound exciton emission. The *p*-ZnO/*n*-Si heterojunction LED showed typical rectification behavior, which confirmed the *p*-type characteristics of the ZnO films in the as-deposited status, despite the deep-level related electroluminescence emission.

Key Words : P-doped ZnO, *p*-type, Sputtering, Light emitting diode