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A study on the magnetic properties of Mn-doped ZnO films with oxygen vacancy

S. Y. Park*, T. H. Kim, J - H. Kang***, P. J. Kim*, Y. P. Lee***

*Dept. of Physics, Hanyang Univ., Seoul, Korea

**Dept. of Physics, Ewha Woman Univ., Seoul, Korea

***Dept. of Physics, Kookmin Univ., Seoul, Korea

The ferromagnetic Mn-doped ZnO film, grown by an elaborate deposition technique, is needed because their ferromagnetic ordering is significantly sensitive to the charge carriers in a spin-split impurity band formed by the extended donor states, which is induced by native defects such as oxygen vacancy. All of $Zn_{0.96}Mn_{0.04}O_{1-\delta}$ films with a thickness of 100 nm were prepared by magnetron co-sputtering in reactive oxygen. High-purity oxygen gas (99.9995%) was introduced into the vacuum chamber for a P_{O2} range of 1.2 x 10^{-5} to 2.2 x 10^{-7} Torr during growth, were monitored with a residual gas analyzer. The crystalline structures and the compositions were determined by XRD and Rutherford backscattering spectroscopy (RBS), respectively. The magnetic properties were measured with a superconducting quantum interference device magnetometer. All the films were found to be highly oriented along the *c*-axis of hexagonal structure, and no peak from other phases has been seen. The resistivity is decreased with increasing the oxygen vacancy which is determined by RBS in the oxygen-resonance mode. These results indicate that the increment of conductivity, which might be due to the formation of donor level, could be controlled by P_{O2}. The *M-H* curves show that the film, prepared at a P_{O2} of 2.2x10^{-7} Torr, exhibits a large magnetic moment of 3.27μ_B at room temperature and a Tc above 350 K, while the films at an partial pressure of higher than 1.2x10^{-6} Torr reveal the nonmagnetic behaviors. These magnetic results suggest that the important role of oxygen vacancy is confirmed evidently for the ferromagnetic ordering in Mn-doped ZnO film, and open up another possibility for the realization of spintronic devices.