Transport properties of Mn-doped ZnO films with oxygen vacancy

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To date, the ferromagnetic ordering in transition-metal doped ZnO film has been suggested to be induced by the carrier incorporation. Undoped ZnO is well-known to have n-type carriers due to a fact that the oxygen vacancies, Zn interstitials, and H interstitials make donor levels. Therefore, the magnetism in Mn-doped ZnO film could be predicted to be dependent on the oxygen partial pressure during growth. We present the dependence of oxygen pressure on the transport properties of Mn-doped ZnO film grown by co-sputtering. $Zn_{0.96}Mn_{0.04}O_{1-\delta}$ 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 the oxygen partial pressure to be in a range from 2.2×10^{-7} to 1.2×10^{-3} Torr during growth, which was monitored with a residual-gas analyzer. The crystalline structure and the composition were determined by x-ray diffraction and Rutherford-backscattering spectroscopy (RBS), respectively. Their magnetic properties were measured with a superconducting-quantum- interference-device magnetometer. The Hall measurements were carried out to determine the carrier mobility and concentration at room temperature. The hysteresis curves show that the films, prepared at an oxygen pressure of 2.2×10^{-7} Torr, exhibit the ferromagnetic behavior with a low coercivity (~ 50 Oe) at room temperature and T_c above 350 K, while the films at an oxygen pressure higher than 1.2×10^{-6} Torr turn out to be nonmagnetic. The carrier concentration is decreased with increasing the oxygen vacancy which is determined by RBS in the oxygen resonance mode. The carrier mobility drops down from around 10 to 4 cm^2/Vs in the ferromagnetic phase. These results indicate that the carrier concentration could be responsible for the long-range magnetic ordering in Mn-doped ZnO film.