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FERROMAGNETIC ORDERING IN Mn-DOPED ZnO THIN FILMS

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Diluted magnetic semiconductors (DMSs) have attracted much interest in recent years due to their possibility of exploiting charge and spin degrees of freedom in a single substance. DMSs are known to be formed by partial replacement of cations of non-magnetic semiconductors by magnetic transition metal ions [1]. There have been numerous efforts [2-4] to investigate Mn-doped ZnO thin films grown under low oxygen pressure (~10^{-5} torr) [2] and at low temperature (400°C) [3,4] by a pulsed laser deposition technique. However, the results on Mn-doped ZnO thin films differ for different growth conditions and remain controversial. In the present work, we report on the magnetic and magnetotransport properties of Mn doped ZnO thin films grown as a function of substrate temperature and oxygen pressure. The effects of substrate temperature and oxygen pressure on the ferromagnetism in the Mn-doped ZnO thin films are discussed.

The Mn-doped ZnO thin films in the thickness range 30 – 50 nm were grown by pulsed laser deposition (PLD) on a single crystal sapphire substrate using various Mn concentration ZnMnO targets. The deposition time by ablating targets with Nd:YAG laser(355nm) and laser pulse energy density were 8.5min and 2J/cm^2, respectively. The films were grown at various substrate temperatures ranging from 20 – 800°C under an oxygen pressure of 10^{-1} - 10^{-3} Torr. The van der Pauw Hall and magnetoresistance (MR) measurements were performed by applying a magnetic field up to 9 T in the temperature range 4 – 300 K, in order to investigate the electrical and magnetotransport properties of the Mn-doped ZnO thin films. Hysteresis loops were measured at temperatures ranging from 4 – 300 K using a superconducting quantum interference device (SQUID).

The magnetic behavior for the Mn-doped ZnO thin films has been studied as a function of substrate temperature and oxygen pressure. Hysteresis loops for the Mn-doped ZnO thin films grown at 800°C under an oxygen pressure of 0.1 and 0.001 Torr measured at (a) 4 K and (b) 300 K. Regardless of the oxygen pressure, the Mn-doped ZnO thin films exhibit ferromagnetic ordering at 4 K, although a clear difference between two samples is found in saturation magnetization and coercivity. On the other hand, the Mn-doped ZnO film grown under 0.1 Torr is still indicative of ferromagnetic ordering at room temperature, whereas the ferromagnetic behavior in the film grown under 0.001 Torr was found to disappear.

We also confirm such a different magnetic behavior between the two samples from temperature-dependence of magnetization difference ΔM=(M_{FC}-M_{ZFC}) between field-cooled (FC) and zero field-cooled (ZFC) magnetization curves. The carrier concentration was found

to be controlled by varying the oxygen pressure. Large magnetoresistance (MR) was observed in the film grown at 700°C, especially over 10% in the positive MR, which is higher than the reported values (<5 %) [2]. Our results indicate the spin splitting caused by strong s-d exchange coupling between the conducting carriers and localized spins of Mn ions. We also found extra-ordinary Hall effect at 4 K in the Mn-doped ZnO thin film grown at 700 °C under 0.1 Torr.

The correlations between the preparation parameters, the crystalline of the thin films and carrier concentration are discussed, which leads to the clarification of the room-temperature ferromagnetic ordering in the Mn-doped ZnO thin films.

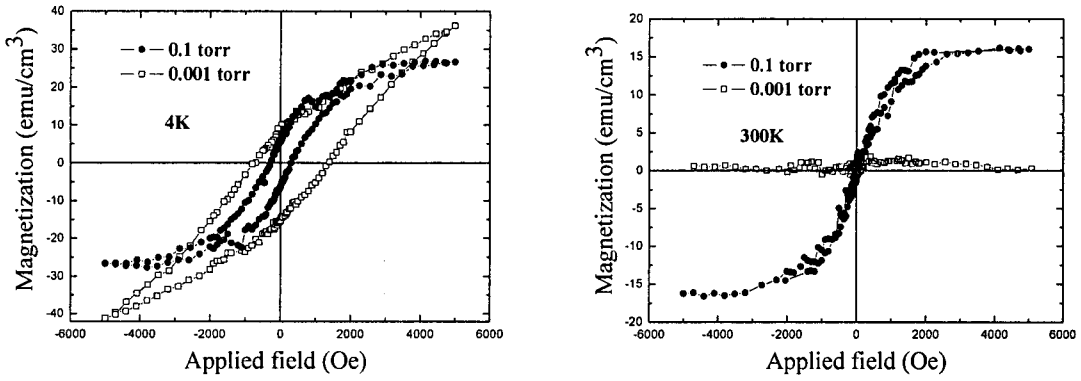

Fig. 1 Hysteresis loops for the Mn-doped ZnO thin films grown at 800°C under an oxygen pressure of 0.1 and 0.001 torr measured at (a) 4 K and (b) 300 K

References

[1] H. Ohno, *Science* **281**, 951 (1998)
[2] T. Fukumura et., *Appl. Phys. Lett.* **75**, 3366 (1999)
[3] P. Sharma et al., *Nature Materials* **2**, 673 (2003)
[4] Y.W. Heo et al., *Appl. Phys. Lett.* **84**, 2292 (2004)