2005

Absence of ferromagnetism and strong orbital coupling in carrier rich Zn/sub 1-x/In/sub x/Co/sub 0.075/O

Xiaolin Wang
University of Wollongong, xiaolin@uow.edu.au

Germanas Peleckis
University of Wollongong, peleckis@uow.edu.au

S X. Dou
University of Wollongong, shi@uow.edu.au

ABSENCE OF FERROMAGNETISM AND STRONG ORBITAL COUPLING IN CARRIER RICH Zn1-XInXCo0.075O

X. L. Wang, G. Peleckis, and S. X. Dou
ISEM, University of Wollongong, Northfields avenue, Wollongong, NSW 2522, Australia

Introduction

Transparent diluted magnetic semiconductors (DMS) are of great interest as the spin could be manipulated through visible light or electric and magnetic field. Extensive effort has been made on fabrication of DMS by introducing transition metal ions into well known semiconductors such as GaN, ZnO, or TiO_2. Theoretical predictions [1] of room temperature ferromagnetism (FM) ignited huge interest in ZnO oxide. Although the number of publications that describe room temperature ferromagnetism in ZnO [2,3] is increasing, still no firm conclusion can be stated, whether FM state in ZnO can be realized. If on wants to produce high quality DMS material understanding the mechanism of ferromagnetism is essential. Some blame formation of Co clusters in ZnO that makes it ferromagnetic [4], while others say that it is a lack of itinerant carriers [5] that are crucial for ferromagnetism to occur. We report on magnetic properties and Co spin state in carrier rich In co-doped $Zn_{1-x}In_xCo_{0.075}O$ oxide.

Experimental

Polycrystalline samples of $Zn_{1-x}In_xCo_{0.075}O$ $(0.010 \le x \le 0.020)$ were prepared by "rapid oxalate decomposition" technique. Phase purity analyzed by means of x-ray diffraction technique (Philips PW-1730) and structures refined by Rietveld refinement technique. Bulk conductivity of the polished pellets was measured by two point probe technique at 295 K temperature. Magnetic properties were analyzed with Magnetic Property Measurement System (MPMS XL, Quantum Design).

Results and discussion

$Zn_{1-x}In_xCo_{0.075}O$ $(0.010 \le x \le 0.020)$ samples were of single hexagonal ZnO phase with the lattice parameter c decreasing with increase of In content x.

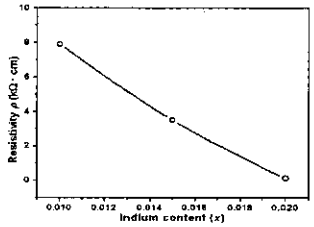

Fig. 1 Bulk resistivity (ρ) of $Zn_{1-x}In_xCo_{0.075}O$ $(0.010 \le x \le 0.020)$ samples at 295 K as a function of In doping level (x)

Figure 1 depicts dependence of bulk resistivity (ρ) of our samples on In doping content (x). It is obvious that with increasing x bulk resistivity decreases. If compared to other polycrystalline samples, such as $Zn_{1-y}Mg_yCo_{0.15}O$, they were all insulating. This leads to the fact that with introduction of In into the ZnO lattice high itinerant carrier concentration is achieved.

Magnetic properties measured, however, did not show ferromagnetic feature. In Figure 2 (a) inversed magnetic susceptibility ($1/\chi$) is plotted as a function of temperature (T) warming under applied field of 2000 Oe. Samples show paramagnetic behavior in whole range of measurement. Curie-Weiss fitting at high temperature range gives effective magnetic moment (μ_{eff}) of Co ions in our samples, *i.e.* $\mu_{eff} = 5.89\ \mu_B$/Co. This corresponds to that of tetrahedral Co^{2+} high spin ($e_g^4 t_{2g}^3$) state. Such a high calculated value of μ_{eff} suggests that in In doped samples contribution of orbitals to the effective magnetic moment of Co ion is very significant. Compared to the carrier poor Mg-Co co-doped ZnO samples, calculated μ_{eff} in linear part of $1/\chi$ curve was much lower, *i.e.* $\mu_{eff} = 3.94\ \mu_B$/Co, which indicates that orbital contribution in this case is negligible. Magnetization (M) versus applied magnetic field (H) at 10 K temperature is presented in Fig. 2 (b). No sort of ferromagnetism or hysteresis can be seen in the curves. Furthermore, variation of In content did not affect magnetic properties at all.

Despite the fact that in our samples high itinerant carrier concentration was achieved, no ferromagnetism was observed suggesting that mechanism for ferromagnetism discussed by [5] does not work in our samples.

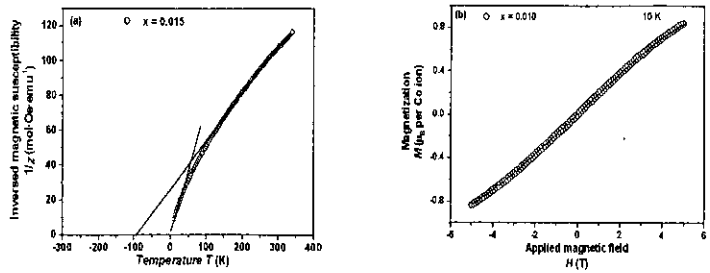

Fig. 2 Inversed magnetic susceptibility ($1/\chi$) versus temperature (T) for (a) $Zn_{1-x}In_xCo_{0.075}O$ and (b) magnetization (M) vs applied magnetic field (H) at 10 K

References:

[1] T. Dietl, H. Ohno, F. Matsukura, J. Cibert, and D. Ferrand, Science 287, 1019 (2000)
[2] L. Yan, C. K. Ong, and X. S. Rao, J. Appl. Phys. 96, 508 (2004)
[3] S. Deka, R. Pasricha, and P. A. Joy, Chem. Mater. 16, 1168 (2004)
[4] J. H. Kim, H. Kim, D. Kim, Y. E. Ihm., and W. K. Choo, J. Eur. Cer. Soc 24, 1847 (2004)
[5] W. Holting, T. Hickel, A. Ramakanth, G. G. Reddy, and M. Lipowczan, Phys. Rev. B 70, 075207 (2004)

0-7803-9009-1/05/$20.00 ©2005 IEEE