11th International Conference on Advanced Materials
ICAM2009
Rio de Janeiro Brazil
September 20 - 25

ZnO:Co Diluted magnetic Semiconductor or hybrid nanostructure for Spintronics?

F. Golmar[(1)], M. Villafuerte[(2,4)], A. Mudarra Navarro[(3,4)] C. E. Rodríguez Torres[(3,4)], J. Barzola-Quiquia[(5)], S.P. Heluani[(2)*], and P. Esquinazi[(5)]

(1) Lab. de Ablación Láser, Dto. Física, Facultad de Ingeniería, Universidad de Buenos Aires, Argentina.
(2) Lab. de Física del Sólido, Universidad Nacional deTucumán, Argentina.
(3) Dto. Física-IFLP, Facultad de Ciencias Exactas, Universidad Nacional de La Plata, Argentina.
(4) Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).
(5) Division of Superconductivity and Magnetism, Institut für Experimentelle Physik II, Universität, Leipzig, Germany
* Corresponding author.

Abstract - We have studied the influence of intrinsic and extrinsic defects in the magnetic and electrical transport properties of Co-doped ZnO thin films. X ray absorption measurements show that Co substitute Zn in the ZnO structure and it is in the 2+ oxidation state. Magnetization (M) measurements show that doped samples are mainly paramagnetic. From M vs. H loops measured at 5 K we found that the values of the orbital L and spin S numbers are between 1 and 1.3 for L and S=3/2, in agreement with the representative values for isolated Co 2+. The obtained negative values of the Curie-Weiss temperatures indicate the existence of antiferromagnetic interactions.

Transition metal atoms introduced into the cationic sites of semiconducting host lattices have recently attracted increasing attention because of their potential use in spintronic devices. Since the theoretical prediction of ferromagnetism in Co-doped ZnO [1] this material is being intensively studied. However, contradicting results concerning magnetic properties have been reported. Some groups observe room temperature ferromagnetism, while others report no ferromagnetism at room temperature or the observed ferromagnetism comes from metallic cobalt clusters. Also, the role of defects such as O- and Zn-vacancies, Zn- and N-interstitials or due to an inhomogeneous dopant distribution in the ferromagnetism remains still unclear. Recently, it has been proposed another model for ferromagnetism in DMS materials based on a spin-split donor impurity band. The impurity band can interact with local magnetic moments through the formation of bound magnetic polarons (BMP). This mechanism was applied to understand the magnetism in ZnO:N[2]. The latter suggest us to start a study on electric and magneto transport mechanism, and the effect of the interaction between defects and dopants on these mechanisms.

In this work, 15% and 10% cobalt doped ZnO films were grown on SiO2/Si and sapphire substrates in N_2 or O_2 atmospheres by pulsed laser deposition. XRD patterns corresponded to the wurtzite structure for all films showing a double peaks at the 0002 and 0004 wurtzite reflection (not observed in pure samples growth in similar conditions) probably corresponding to ZnO structure with different lattice parameter due to dissimilar Co distribution. X ray absorption spectroscopy showed that Co ions are in 2+ state, substituting Zn in the ZnO structure. Electron Microscopy results, Fig.1b, shows Co rich regions inside the semiconductor matrix revealing a phase separation (spinodal nano-decomposition). This results suggest us to consider the system ZnO:Co as an hybrid nanostructure.

The M vs. H loops taken at 5 K showed paramagnetic behaviour, from which we obtain L = 1.3 and S=3/2 in agreement with the values expected for Co 2+ (Fig.2.a). The negative values of the Curie Weiss temperature obtained from the extrapolation of the high temperature range of the inverse moment vs. temperature indicate the existence of antiferromagnetic interactions. Positive magnetoresistance at low and high fields applied parallel to the current suggests an antiferromagnetic local order. This behaviour may be ascribed to the antiferromagnetism of CoO clusters.

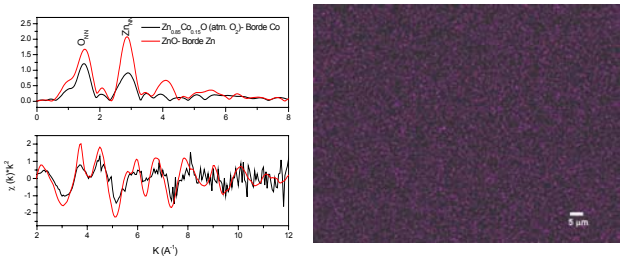

Figure1: a) Oscillation extracted from X rays spectrum of a representative samples and the corresponding Fourier transformed. Data of pure ZnO are included for comparison. b) SEM image showing a non homogeneous Co distributions.

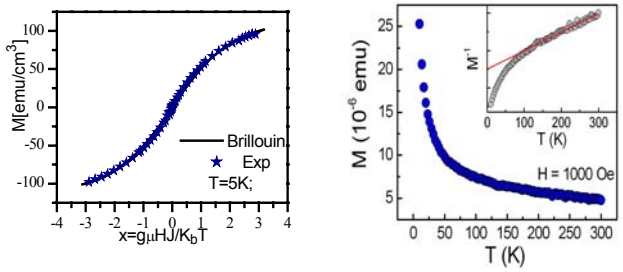

Figure 2: M vs. H and the M vs. T curves suggesting paramagnetic behaviour with antiferromagnetic interactions.

[1] T. Dietl, H. Ohno, F. Matsukura, J. Cibert, D. Ferrand, Science, **287**, 1019-1022, 2000.
[2] Chang-Feng Yu, T. J. Lin and H. Chou, J. Phys. D: Appl. Phys. **40,** 6497-6500, 2007.