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Full Length Research Paper

Structure and Room Temperature Ferromagnetism of Ni^{2+}- doped ZnO Nanoparticles Prepared by Sol-gel Process

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Abstract
Ni doped ZnO ($Zn_{1-x}Ni_xO$, $0 \le x \le 0.05$) Diluted magnetic semiconductors (DMSs) nanoparticles are prepared by sol-gel process. Transmission electron microscopy (TEM) image shows nanoparticles with an average size of 25nm. The analysis of X-ray diffraction (XRD) identified that the impurity phase is observed when the Ni content x reaches 0.05. With the increment of x, wurtzite structures degrade gradually. The magnetic properties are measured using superconducting Quantum interference device (SQUID) at room temperature; the $Zn_{1-x}Ni_xO$ ($x \le 0.02$) nanoparticle shows ferromagnetism, however, for the sample of $Zn_{0.95}Ni_{0.05}O$ paramagnetism is observed.

Keywords : *ZnNiO nanoparticle, Structure and ferromagnetism*

Introduction

ZnO has been extensively investigated due to its potentials in optoelectronic applications. It has wide band gap (3.37 ev) and a large exciton binding energy (60 mev) [1-4]. Recent predictions of ferromagnetism at room temperature in III-V and II-VI semiconductor materials have attracted renewed interest from the scientific and industrial communities [5-7]. The incorporation of ions such as Co, Ni, Fe and Cu into the structure of ZnO Could opens new possibilities involving magnetic, magneto-optic and magneto transport effects [8-10]. Among them most studies focused on Co- doped ZnO [11,12] while fewer studies on Ni-doped ZnO have been reported.

Transition metal (TM) doped ZnO can be prepared by a variety of methods such as chemical vapor deposition (CVD), Pulse laser deposition (PLD) and sol-gel process. The sol-gel process has been successfully used to obtain nanoscale material at low cost. In this work, the sol-gel process is developed to prepare ZnNiO nanoparticle, the structure and magnetism are studies in details.

Experimental Details

$Zn_{1-x}Ni_xO$ nanoparticles are fabricated by sol-gel process. First, at room temperature, tetramethyl ammonium hydroxide ($N(Me)_4OH$. $5H_2O$) was dissolved in ethanolic, then a solution (solution α) of 0.55 mol/L was formed; on the other hand, a mixture of x $Ni(OAc)_2 .4H_2O/(1-x)Zn(OAc)_2 . 2H_2O$ (where x = 0, 0.01, 0.02, and 0.05, respectively) were dissolved in DMSO to form another solution (solution β), for which the concentration was 0.10 mol/L. Then, under constant stirring, solution α was added drop wise into the solution β. Resultantly, a sol was formed and dispersed subsequently. After Ostwald ripening, the sol was iteratively washed by precipitation and resuspension in ethanol so as to remove the excess reactants (Ni^{2+} and Zn^{2+}). The resulting nanocrystals were then capped with dodecylamine. The resulting powders were then annealed at 500 ^{0}C for 30 min.

JEM-1010 transmission electron microscope (TEM) was used to study the sample morphology and size. The sample structure and composition were carried out by X-ray diffraction (XRD) using a D/MAX 2200 VPC X-ray diffractometer (Rigaku) with Cu-K_a radiation of 1.54056 A°. Magnetic measurements were performed on a superconducting quantum interference device (SQUID) magnetometer (MPMS-XL7 Quantum Design, Inc).

Results and Discussion

The sphere like morphology could be identified clearly by the TEM image (fig. 1) {TEM image of the sample $Zn_{0.99}Ni_{0.01}O$} of Ni – doped ZnO nanoparticles and average size of the nanoparticles is estimated to be about 25 nm.

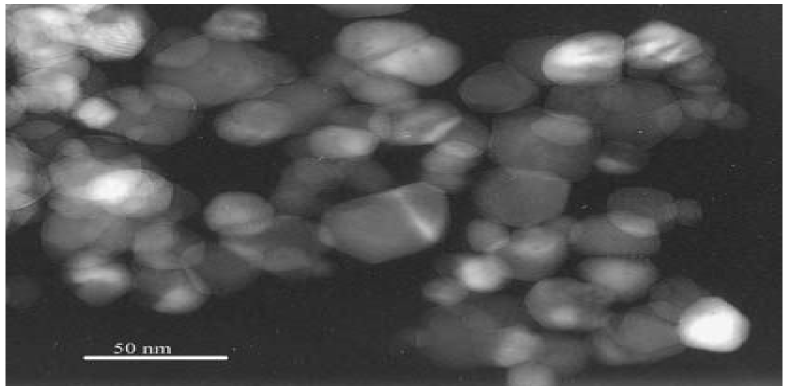

Fig.1. TEM image of the sample $Zn_{0.99}Ni_{0.01}O$.

XRD pattern (fig. 2) indicate that the synthesized sample are in wurtzite structure with all the peaks correspond to ZnO when the content of Ni (x) is less than 0.05, however, when x reaches 0.05 an additional diffraction peaks observed due to phase segregation.

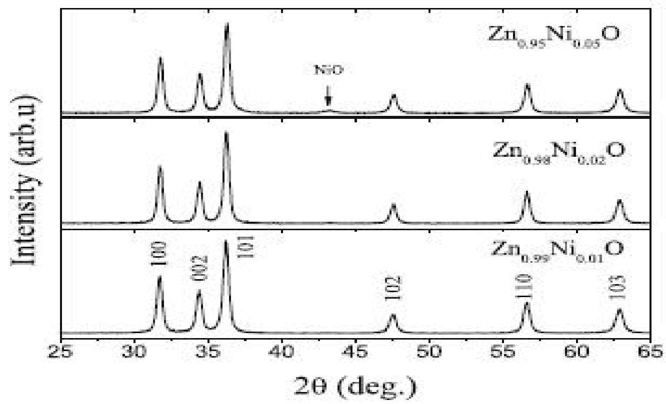

Fig. 2. XRD pattern of ZnNiO nanoparticles.

SQUID results (fig. 3) indicate weak magnetic hysteresis loop when the content Ni (x) is less than 0.05 while at x= 0.05 particles show paramagnatism (fig.4).

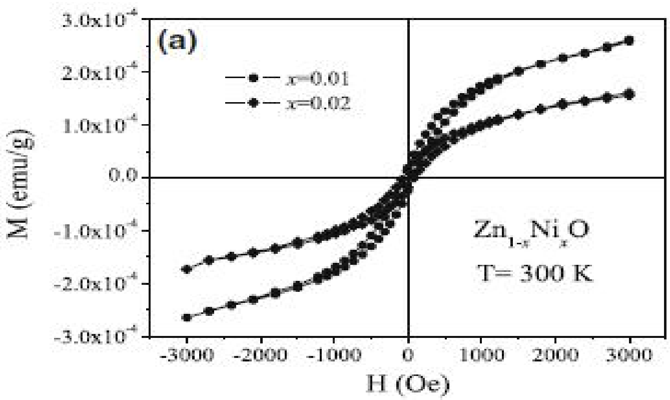

Fig. 3. M-H curves of $Zn_{1-x}Ni_xO$ nanoparticles ($x \leq 0.02$).

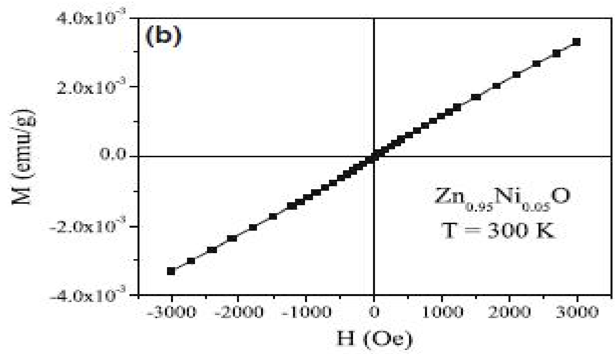

Fig. 3. M-H curve of $Zn_{1-x}Ni_xO$ nanoparticles ($x \le 0.05$).

Conclusion

In conclusion, Ni-doped ZnO ($Zn_{1-x}Ni_xO$, $0 \le x \le 0.05$) diluted magnetic semiconductors nanoparticles are prepared by sol–gel process. XRD analysis shows wurtzite structures for all the $Zn_{1-x}Ni_xO$ nanoparticles. With increasing Ni concentration, the wurtzite structures degrade gradually. FM is observed in $Zn_{1-x}Ni_xO$ ($x \le 0.02$) system, and the Curie temperature is higher than 300 K. It is probable that the RT FM might originate from long-range Ni^{2+}–Ni^{2+} ferromagnetic coupling mediated by shallow donor electrons. However, when x increasing to 0.05, antiferromagnetic NiO formed and the system turns to be paramagnetic.

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References

[1] Tang Z. K., Wong G.K.L., Yu P., Kawasaki M.and Segawa Y., (1998) “Room-Temperature Ultraviolet Laser Emission from Self-Assembled ZnO Microcrystallite Thin Films,” *Applied Physics Letters*, 72, 3270-3272.

[2] Y. B. Li, Y. Bando and D. Golberg, (2004) “ZnO Nanoneedles with Tip Surface Perturbations: Excellent Field Emitters,” *Applied Physics Letters*, Vol. 84, No. 18, , pp. 3603-3605.

[3] A. Tsukazaki, A. Ohtomo, T. Onuma, M. Ohtani, T. Mankino, M. Sumiya, K. Ohtani, S. F. Chichibu, S. Fuke, Y. Segawa, H. Koinuma and M. Kawasaki, (2005) “Repeated Temperature Modulation Epitaxy for *p*-Type Doping and Light-Emitting Diode Based on ZnO,” *Nature Materials*, Vol. 4, No. 1, , pp. 42-46.

[5] Nguyen Hoa Hong and Joe Sakai., (2005) Ferromagnetic V-doped SnO2 thin films. *Physica. B,* 358, 265-268.

[6] Nguyen Hoa Hong, Antoine Ruyter, and W Prellier**.** (2005) Magnetism in Ni-doped SnO2 thin films. *J. Phys: Condens. Matter*, 17**,** 6533-6538.

[7] Nguyen Hoa Hong, Joe Sakai, W Prellier, and Awatef Hassini., (2005) Transparent Cr-doped SnO2 thin films: ferromagnetism beyond room temperature with a giant magnetic moment. *J. Phys: Condens. Matter.* 17, 1697-1702.

[8] S. B. Ogale, R. J. Choudhary, and S. R. Shinde., (2003) High Temperature Ferromagnetism with a Giant Magnetic Moment in Transparent Co-doped SnO_2 *Phys. Rev. Lett*, 91, 077205-077208.

[9] S. J. Pearton, C. R. Abernathy, and L. A. Boatner., (2003)Optical and magnetic properties of ZnO bulk crystals implanted with Cr and Fe. *J. Appl. Phys,* 93, 1-13.

[10] T. Dietl, H. Ohno, F. Matsukura, J. Cibert, and D. Ferrand., (2000) Optical and magnetic properties of ZnO bulk crystals implanted with Cr and Fe. *Science* , 287**,** 1019-1022.

[11] Y. X. Wang, Hui Liu, and S. P. Ringer., (2006) Role of structural defects on ferromagnrtism in amorphous Cr-doped ZnO films. *Appl. Phys. Lett*, 89, 042511-042513.

[12] Zhenjun Wang, Le Dung, Leonard Spinu, and Weilie Zhou., (2003) Electrical and ferromagnetic properties of Tb-doped indium–tin oxide films fabricated by sol–gel method. *J. Appl. Phys*, 83, 518 -520.