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Effect of Fe Doping on Magnetic Behavior of SnO_2 Nanoparticles for Spintronics Applications

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Abstract. Doping of magnetic ion (Transition metal) in oxide based semiconducting material at nanoscale level serves a variety of spintronics based applications. In order to understand the influence of doping concentration of Fe ions on the magnetic behavior of semiconducting oxides, we have synthesized Fe doped tin oxide nanoparticles with 1 and 2% doping concentration via chemical co-precipitation method and then magnetic measurements have been taken through Superconducting quantum interference device (SQUID) at 5K and 300K temperatures for both the samples. Various magnetic quantities such as coercivity (H_c), saturation magnetization (M_s), remanent magnetization (M_r) have been extracted from the obtained hysteresis loops and found reduction in their values with increasing doping concentration which might corresponds to the tuning of oxygen defects created due to the substitution of dopant ions in the host lattice. In this way, our study can contribute to fulfill the necessity of ferromagnetism based applications such as data storage devices, gas sensors, communication, quantum computation etc.

Keywords. Dilute magnetic semiconductors, Transition metals, Spintronics, SQUID, Ferromagnetism, etc.

1. Introduction

Spintronics technology is one of the current areas of curiosity and has attracted enormous efforts of the researchers to enhance the efficiency of electronic devices for high speed information processing and in supplement to enrich the spin degree of freedom in order to enlarge data storage capacity [1]. To accomplish this multi-functional requirement, a new class of materials has come into sight, usually known as dilute magnetic semiconductors (DMS) which offers immense technical opportunities due to their possible utilizations in spin transport electronic devices [2-7]. Practically, DMS are alloys of semiconducting crystal lattice consist of small (dilute) substitution of magnetic dopants, such as $Pb_{1-x}Eu_xTe$, $Ga_{1-x}Mn_xAs$, $Zn_{1-x}Fe_xSe$ etc. The nature of DMS makes them suitable to tune their electrical, structural, magnetic and optical properties simply by altering the composition(x).

A lot of work has been performed in this field in order to understand the actual motivation present behind the performance of DMS materials. Few literatures reported that pristine SnO_2 is diamagnetic, while few other reveals that annealing treatment plays an important role in magnetic polarization means sometimes Ni-doped tin oxide films exhibits paramagnetic behavior and achieve ferromagnetism after annealing treatment in nitrogen ambient atmosphere. Also, significant increment in magnetic moment has been noticed with rise in annealing time [8, 9]. Some of the metal oxide nanostructured materials like CeO_2, TiO_2 and ZnO behaves ferromagnetically even without dopant magnetic ions which also supports the importance of surface defects like oxygen (ligand) holes instead of the magnetic doping ions of TM elements [10]. One

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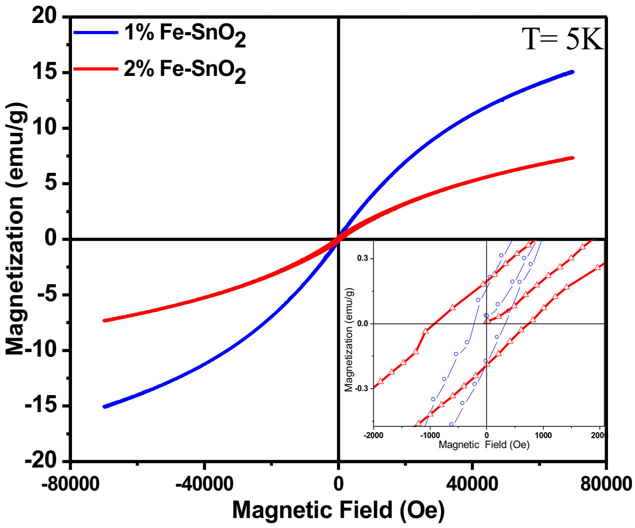
of the literatures reported magnetic study of Fe doped tin oxide prepared through simple chemical co-precipitation technique and claimed that anti-ferromagnetic alignment decreases with increment in doping concentration [11]. Hence, occurrence of room temperature ferromagnetism in DMS based materials, which is a key requirement for spintronics based applications, is still an unclear issue, whether it is intrinsic property of material or doping is responsible for it.

2. Experimental Details

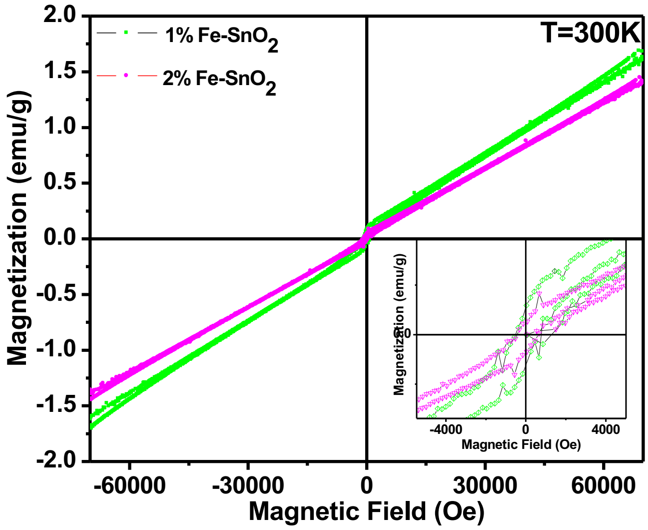
$Sn_{1-x}Fe_xO_2$ (x=0.01 and 0.02) samples have been successfully synthesized using chemical co-precipitation method. The chemicals used for synthesizing of samples were of analytical grade and no further purification is required. Synthesis includes tin (IV) chloride pentahydrate and iron (III) chloride (AR grade). The chemicals were weighed accurately as per the proportions required by using microbalance. Prepare a clear solution of $SnCl_4.5H_2O$ and $FeCl_2.6H_2O$ by dissolving them into deionized water with the help of magnetic stirrer. Now add 0.1M NH_4OH solution drop by drop into the prepared solution of tin (IV) chloride and iron (III) chloride with constant stirring until its pH value raised upto 7 and then aged the solution for half an hour. The obtained white precipitate was filtered with the filter paper and washed it 2-3 times with deionized water in order to remove ionic impurities. Afterwards the wet colloidal solution was kept at 40^{o}C in air to remove moisture and the dried powder was collected. The prepared samples have been characterized through SQUID in order to investigate the magnetic behavior of Fe doped SnO_2 having two different doping concentration.

3. Result and Discussion

Fig 1(a) and (b) represents magnetization (M) vs. applied magnetic field (H) curves for 1% and 2% Fe doped SnO_2 nanoparticles recorded at 5K and 300K temperatures.



(a)



(b)

Fig.1 Curves of magnetization (M) vs. applied magnetic field (H) (a) at 5K and (b) at 300K temperatures for 1% and 2% Fe-SnO_2 nanoparticles.

At 5K, saturation magnetization (M_s) reduces from 15emu/g to 7.45emu/g while the width of the hysteresis behavior enhances with increase in the concentration of dopant ions from 1% to 2% with the coercivity (H_c) of 239.85 Oe and 922.572 Oe respectively. These observations might correspond to the charge imbalance of dopant ions with the host ion due to the substitution of Fe^{3+} ion at the Sn^{4+} sites which creates oxygen vacancies as a result of formation of Fe^{3+}-Vo^{2-}-Fe^{3+} clusters in the host lattice sites. Thus, when an electron caught in these oxygen vacancies will interact with two neighboring irons through F-centers and leads to ferromagnetic ordering. While at higher temperatures i.e. at 300K (room temperature), the magnetic response gets drastically modified. Both the samples show ferromagnetic response at lower magnetic fields which becomes nearly paramagnetic at higher applied fields.

4. Conclusion

$Sn_{1-x}Fe_xO_2$ (x=0.01 and 0.02) nanoparticles were prepared using chemical co-precipitation method and then SQUID measurements have been taken to study the influence of dopant ion on the magnetic properties of the host SnO_2 nanoparticles. A considerable ferromagnetism has been observed at low temperature (5K) with wider hysteresis loops which could be attributed to the presence of dopant ions and the defects produced at the grain boundaries while at room temperature (300K), small ferromagnetism has been attained with increasing magnetization. Thus, Fe doped SnO_2 nanoparticles could be considered as a promising candidate from the practical applications point of view especially in data storage devices.

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References

[1] Ashutosh Tiwari, V. M. Bhosle, S. Ramachandran, N. Sudhakar, J. Narayan, S. Budak, and A. Gupta, "Ferromagnetism in Co doped CeO_2: Observation of a giant magnetic moment with a high Curie temperature", Applied Physics Letters 88, no. 14 (2006): 142511.

[2] J.K. Furdyna, "Diluted magnetic semiconductors", Journal of Applied Physics 64.4 (1988): R29-R64.

[3] H. Ohno, "Making nonmagnetic semiconductors ferromagnetic", science 281.5379 (1998): 951-956.

[4] A.H. MacDonald, P. Schiffer, and N. Samarth, "Ferromagnetic semiconductors: moving beyond (Ga, Mn) As", Nature Materials 4.3 (2005): 195-202.

[5] T. Dietl, "A ten-year perspective on dilute magnetic semiconductors and oxides", Nature Materials 9.12 (2010): 965-974.

[6] Mayuri Sharma, Shalendra Kumar, and P. A. Alvi, "Electronic structure and magnetic properties of Ni-doped SnO_2 thin films",AIP Conference Proceedings, 1953, 120010 (2018).

[7] Pradeep Kumar, Kavita Kumari, Mayuri Sharma, P. A. Alvi, and Shalendra Kumar, "Structural, magnetic and surface morphological study of Ni doped SnO2 thin films", AIP Conference Proceedings 2006, 030039 (2018).

[8] N.H. Hong, A. Ruyter, W. Prellier, J. Sakai and N. T. Huong, J. Phys. Cond. Mat., 17 (2005) 6533.

[9] P.I. Archer, P.V. Radovanovic, S.M. Heald and D. R. Gamelin, J. Am. Chem. Soc., 127 (2005) 14479.

[10] P. Sharma, A. Gupta, K.V. Rao, F.J. Owens, R. Sharma, R. Ahuja, J.M. Osorio Guillen, B. Johansson, and G. A. Gehring, Nat. Mater. 2 (2003) 673.

[11] Adhikari, R., A. K. Das, D. Karmakar, TV Chandrasekhar Rao, and J. Ghatak. "Structure and magnetism of Fe-doped SnO_2 nanoparticles." Physical Review B 78, no. 2 (2008): 024404.