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MAGNETIC PROPERTIES OF 4f ELEMENT DOPED SnO_2 DILUTED MANETIC SEMICONDUCTOR

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ABSTRACT

The magnetic properties of 5 at% lanthanide magnetic ions (Gd, Dy and Er) doped SnO_2 matrix have been studied. The moments of the doped samples are found to be lower (0.27 - 0.32 μ_B/RE-ion) at room temperature in the applied magnetic field of 1 T. It was seen that at low temperatures the rare earth substituted samples exhibits an upturn in ac magnetic susceptibility, which depends on the nature of the rare earth ions. The temperature of this upturn is found to be the highest for the Gd doped compound (116 K) and lowest for the Er doped compound (54 K) with the Dy doped compound exhibiting it at (74 K). Very low field hysteresis was observed at room temperature for the earth-doped samples.

Keywords: Dilute magnetic semiconductor, Magnetic susceptibility, Hysteresis

1. INTRODUCTION

Dilute Magnetic Semiconductors (DMS) obtained by doping magnetic impurities into host semiconductors, mostly III-V and II-VI compounds, are key materials for spin electronics in which the correlation between charge and spin of electrons is used to bring about spin-dependent electronic functionality.[1] Wide and direct band-gap semiconductors are great interest in optical industries including blue and ultraviolet (UV) optical devices, such as light emitting diodes and laser diodes. Tin oxide SnO_2, a very important n-type semiconductor with a wide band gap (E_g= 3.6 eV at 300 K), is potentially suitable for such applications.[2] On the other hand, Rare earth metal ions have been investigated most frequently because of their unique fluorescence properties due to their stability and high emission quantum yields. Cobalt-doped TiO_2 is one such material, where Matsumoto.et.al.[3]showed that epitaxially grown films of single-crystal $Ti_{1-x}Co_xO_2$, with doping levels rising to $x = 0.08$, are electrically conductive and display ferromagnetic hysteresis at room temperature. This motivated us to study the effect of rare earth ions in SnO_2 to check its potential applicability as a room temperature ferromagnet.

2. EXPERIMENT

Polycrystalline $Gd_{0.05}Sn_{0.95}O_{2-\delta}$, $Dy_{0.05}Sn_{0.95}O_{2-\delta}$ and $Er_{0.05}Sn_{0.95}O_{2-\delta}$ samples were prepared using conventional solid-state method. High pure (99.9 %) oxides of rare earths Gd_2O_3, Dy_2O_3, Er_2O_3 and SnO_2 were weighed stoichiometrically, mixed thoroughly and calcined at 1200 °C for 24 h. This procedure was repeated thrice and the resultant powder was pressed into pellets and sintered at 1350 °C. The phase formation was confirmed by X-ray diffraction. The room temperature moment up to a field of 1 T was measured using a Varian vibrating sample magnetometer and ac magnetic susceptibility studies in the temperature range 300 – 20 K were carried out at low temperatures using a commercial ac-susceptometer.

3. RESULTS AND DISCUSSION

The X-ray diffractograms of $Gd_{0.05}Sn_{0.95}O_{2-\delta}$, $Dy_{0.05}Sn_{0.95}O_{2-\delta}$ and $Er_{0.05}Sn_{0.95}O_{2-\delta}$ are shown in Fig.1. The samples could be indexed to a tetragonal structure with lattice constants as listed in Table 1. The lattice constants were found to be remain almost a constant for all three samples possibly due to the very low concentration of the rare earth ion present in the host lattice. It is seen that all the three samples exhibit a paramagnetic behaviour with a very low field hysteresis at room temperature.This shows that the samples are not in a complete paramagnetic state but have some short-range correlations present leading to a weak ferromagnetic behaviour.

Upon further cooling, the samples exhibit an upturn (~150 K) followed by saturation at low temperatures, which is indicative of ferromagnetic behaviour. The temperature at which the upturn occurs (T_C, Curie temperature) is found to be the highest for the Gd doped compound (116 K) and lowest for the Er doped compound (54 K) with the Dy doped compound exhibiting it at 74 K. This can be explained as follows. Bulk SnO_2 system is devoid of charge carriers due to the stoichiometric oxygen concentration. .
Since the dopants are randomly spread out in the lattice, the probability of a rare earth ion placed next to each other may be small. Hence, the spins form islands of isolated spin clusters, and do not interact with each other leading to the short range correlations as seen through the weak hysteresis. However, as the sample temperature is lowered, the thermal fluctuations decrease and hence the magnetic RE-moments may show an increase in the existing short-range magnetic interaction and hence exhibit a very low and broad T_C. The moments of the doped sample are found to be lower (0.27 - 0.32 μ_B/RE-ion) than the theoretical spin only moment and possibly require higher fields to saturate the moment.

4. CONCLUSIONS

The effect of rare earth ions on the magnetism in the semiconducting oxide SnO_2 was studied. It was seen that at low temperatures the rare earth substituted samples exhibits an upturn, which depends on the nature of the rare earth. The temperature of this upturn is found to be the highest for the Gd doped compound (116 K) and lowest for the Er doped compound (54 K) with the Dy doped compound exhibiting it at 74 K. This was attributed to the devoid of carriers in stoichiometric $SnO_{2,}$ which hinders the itinerant exchange leading to the absence of long range ordering at high temperature.

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REFERENCES

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TABLES

Table 1**:** Lattice constants of rare earth doped SnO_2 compounds

Compound	Lattice Constants (Å)
$Gd_{0.05}Sn_{0.95}O_{2-\delta}$	a=4.719, c=3.177
$Dy_{0.05}Sn_{0.95}O_{2-\delta}$	a=4.717, c= 3.175
$Er_{0.05}Sn_{0.95}O_{2-\delta}$	a=4.703, c=3.173

FIGURES

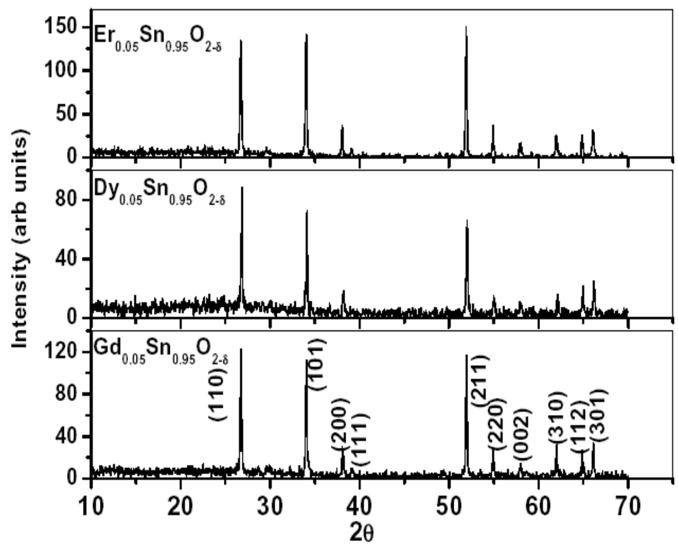

Fig. 1: The X-Ray diffractograms of rare earth doped SnO_2

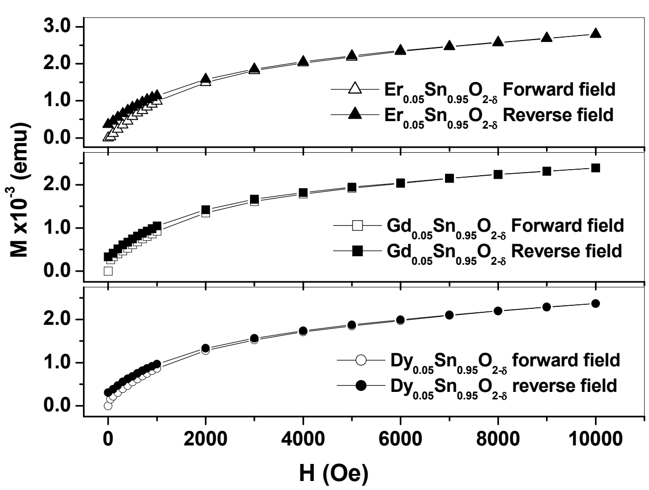

Fig. 2: The magnetic hysteresis curves of rare earth doped SnO_2 at room temperature

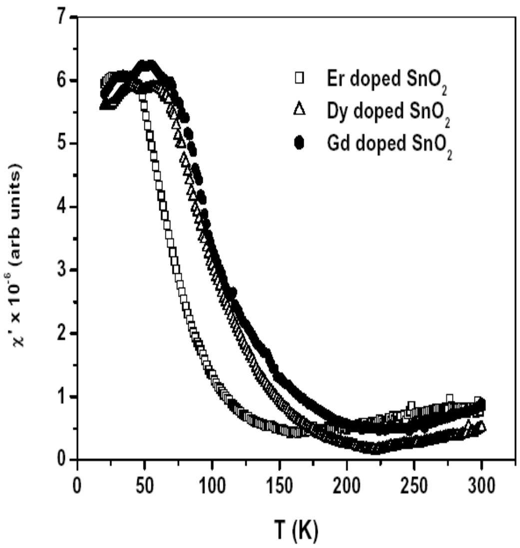

Fig. 3: Temperature variation of magnetic susceptibility of RE-doped SnO_2