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MAGNETIC BEHAVIOUR IN ERBIUM DOPED PHOSPHATE GLASS EMBEDDED WITH COBALT NANOPARTICLES

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ABSTRACT

Considerable interest on magnetic nanoparticles (NPs) embedded rare earth doped glasses are expanding rapidly. A series of Er^{3+} doped phosphate glass with the composition of (69-x)P_2O_5-10MgO-20$ZnCl_2$-1Er_2O_{3}-(x)CoO with $0 \leq x \leq 2.0$ mol% embedded with CoO NPs are prepared using melt quenching method and the influence of CoO NPs on the glass samples are examined. Samples are characterized using X–ray diffraction (XRD) which reveals the amorphous nature of the glass. The physical and magnetic properties were investigated. The samples showed magnetic behavior, with magnetization increased with increasing the CoO concentration but decreased at 1.5% concentration. Saturation Magnetization (Mr), Remanent Magnetization (Mr), Coercivity (Hc) and Squareness (Mr/Ms) of the samples are also determined. According to the results obtained, which closely correlates with the CoO content, the glasses can be classified as antferromagnetic.

Keywords: Phosphate glass; cobalt nanoparticles; magnetic properties;

INTRODUCTION

Nanoparticles attract great scientific interest because they signify a bridge between bulk materials and molecules and structures at an atomic level [1]. From a magnetism scientist viewpoint, nanoparticles are the most interesting since their sizes are comparable with or lesser than the sizes of magnetic domains in the corresponding bulk materials [1]. Magnetic nanoparticles properties strongly dependent with the size, shape of particles, particle size distribution and interactions between nanoparticles [2]. While the field of magnetic science have been focused on superconducting ceramics, magnetic recording media and amorphous metal, the applications of glasses as magnetic materials is still in its infancy [3]. Glasses containing rare earth ions and nanoparticles with their potentials and unique properties can be explored to further contribute in materials science and technology.

A suitable transition metal-oxides nanoparticle to be used in glass would be Cobalt Oxide (CoO). Cobalt is a well-known hard magnetic material with high coactivity and moderate magnetization [4]. They are one of the magnetic nanoparticles that held the most potential for technological applications like catalyst, magnetic fluids and information storage [5]. Interestingly, K. Simeonidis had reported that it is also possible to modify oxidation products (Co_3O_4, CoO) by using oxidizing compounds or allow ambient conditions in the synthetic procedure, providing interesting hollow shape in the nanoparticles in the presence of excess of oxygen participates [5]. These properties, along with their great physical and chemical stability, make CoO nanoparticles suitable for magnetic recording applications.

EXPERIMENTAL DETAILS

Cobalt NPs embedded erbium-doped phosphate glass with composition (69-x)P_2O_5-10MgO-20$ZnCl_2$-1Er_2O_3-(x)CoO, where $0 \leq x \leq 2.0$ mol% are prepared by melt-quenching technique. About 20 g of well-mixed powders of analytical grade (99.99% purity) raw materials are weighed and mixed homogeneously before being placed in a porcelain crucible. The crucible is then transferred to a furnace (model THERMOLYNE 47900) at 1000 °C for 30 minutes under atmospheric pressure. The melt is then quenched onto a stainless steel plate mould and immediately annealed in a preheated furnace at 300 °C for 3 hours to minimize the thermal strain. Finally, the sample is cooled down to room temperature. The XRD measurements were carried out with CuKα radiation operating at 40 kV, 30mA with Bragg-Brentano geometry at room temperature using Siemens Diffractometer D5000. Archimedes method is used to estimate the density of samples with toluene as immersion liquid.

Magnetic properties of the glass such saturation magnetization (Ms), remanent magnetization (Mr), coercivity (Hc) and squareness ratio (Mr/Ms) were deduced from measurements of M-H curves was done using Lake Shore 7400 vibrating sample magnetometer (VSM) at room temperature in fields up to 15 kOe [6].

RESULTS AND DISCUSSION

XRD patterns of the (69-x)P_2O_5-10MgO-20$ZnCl_2$-1Er_2O_3-(x)CoO system is shown in Figure 1. The XRD result illustrates no sharp peaks thus confirming the amorphous nature of the host glass.

The density of samples at different concentration of CoO NPs with glass codes is listed in Table 1. The slight increase in density with the increase of CoO contents is due to the incorporation of Co^{2+} ions in the glass network that enhances the packing density of the glass. The strong dependence of density on the atomic weight of the components and associated compactness of the structural units are reported [7].

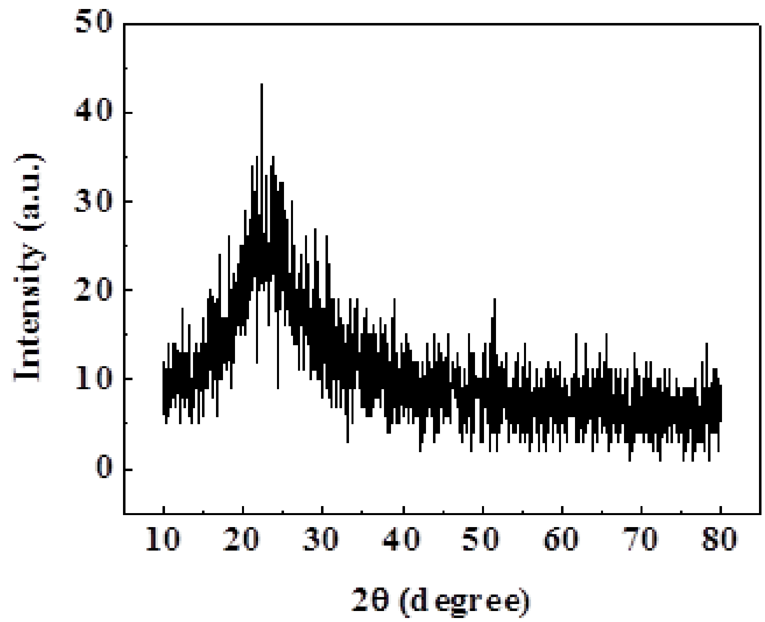

Figure 1: XRD pattern of glass system

Table 1: Density of CoO NPs embedded glass samples with their codes

Sample	CoO (mol%)	Density ($g.cm^{-3}$)
S1	0.0	2.654
S2	0.5	2.661
S3	1.0	2.672
S4	1.5	2.685
S5	2.0	2.698

The hysteresis loops of the samples at 4.2K, room temperature and a maximum field of 15 kOe are shown in Figure 2. The magnetic parameters, namely, the saturation magnetization (Ms), remanent magnetization (Mr), coercivity (Hc) and squareness (Mr/Ms) that are extracted from the graphs are listed in Table 2. The magnetization increases with the applied field sharply and tends to saturate at moderate fields for samples CoO = 0.5% and 1.0%. For samples CoO = 1.5% and 2.0% the magnetization increases slowly with the applied field and saturate at a low fields. This is probably due to the fact that the presence of oxides in magnetic materials, which form spontaneously when the metallic surface is in contact with oxygen, drastically changes the magnetic behaviour of the particles [5]. An author has reported enhanced magnetoresistance, arising from the uniform Co core size and CoO shell thickness caused by the strong exchange coupling between the ferromagnetic Co core and the antiferromagnetic CoO layer [8]. However, up to now the understanding of this effect has not been well understood. Cobalt oxides behaviour is antiferromagnetic and as a consequence CoO and Co_3O_4 nanoparticles have very weak magnetic characteristics [5].

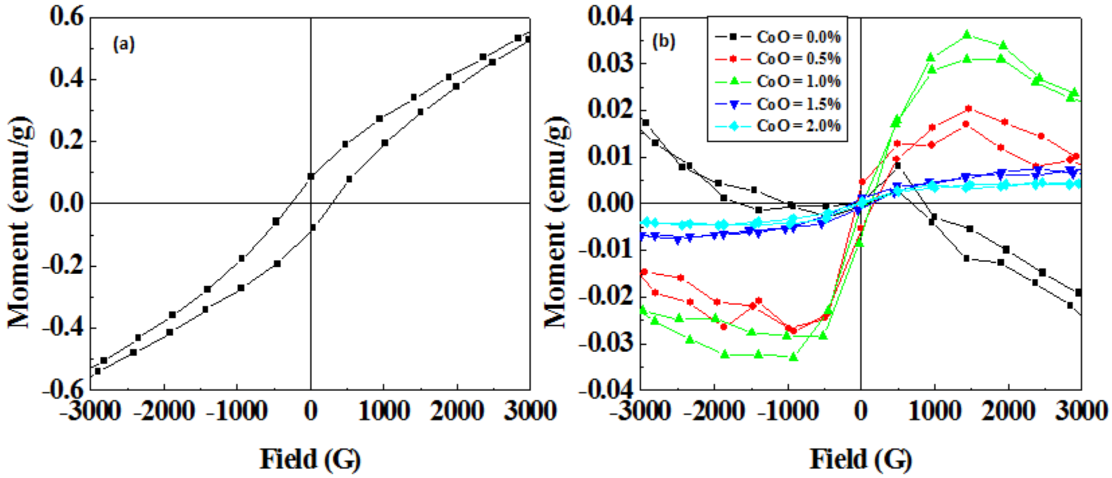

Figure 2: (a) Magnetic hysteresis loops of pure CoO NPs (b) samples of (69-x)P_2O_5-10MgO-20$ZnCl_2$-1Er_2O_3-(x)CoO with x = 0.0, 0.5, 1.0, 1.5 and 2.0

Table 2: Saturation magnetization (Ms), remanent magnetization (Mr), coercivity (Hc), squareness ratio (Mr/Ms) of (69-x)P_2O_5-10MgO-20$ZnCl_2$-1Er_2O_3-(x)CoO with x = 0.0, 0.5, 1.0, 1.5 and 2.0

Concentration of CoO (%)	CoO (Pure)	0.0	0.5	1.0	1.5	2.0
Saturation Magnetization (Ms)	2.00×10^{-3}	8.32×10^{-5}	34.34×10^{-5}	58.70×10^{-5}	61.55×10^{-5}	49.11×10^{-5}
Remanent Magnetization (Mr)	10.68×10^{-5}	0.73×10^{-5}	0.31×10^{-5}	0.39×10^{-5}	0.35×10^{-5}	0.76×10^{-5}
Coercivity (Hc)	280.13	62.77	66.42	54.12	30.01	129.31
Squareness (Mr/Ms)	53.52×10^{-3}	87.5×10^{-3}	8.94×10^{-3}	6.63×10^{-3}	5.66×10^{-3}	15.45×10^{-3}

The saturation magnetization (*Ms)*, of the magnetic dispersions give information on the concentration of the magnetic material. The magnetic behavior of the glass system is generally governed by the distribution of the rare-earth ions and nanoparticles on the crystal lattice sites [6]. From Table 3 it is found that Ms increases as the concentration of CoO increase whereas remanent magnetization (Mr) is not directly dependent on the CoO concentration. Coercivity (Hc) is the field of magnitude that must be applied in the opposite direction of the original field to reduce the B field within the specimen to zero. The result revealed that the coercively values of all samples decrease with increasing CoO contents. It is believed that the lower coercivity may be caused not only by the larger aspect ratio, but also by an incoherent magnetization reversal [9].

CONCLUSION

In the present study, the (69-x)P_2O_5-10MgO-20$ZnCl_2$-1Er_2O_3-(x)CoO where x = 0.0, 0.5, 1.0, 1.5 and 2.0 glass system produced by melt-quenching method. It is found that the samples showed antiferromagnetic behavior and the magnetization increased with the increased of CoO content and decreased at 1.5% CoO concentration. Highest magnetization was obtained at 1.0% CoO concentration.

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