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Effect of annealing on structural and magnetic properties of $NiFe_2O_4$/$ZnFe_2O_4$ nanocomposites

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ABSTRACT

Nanocomposites of Ni-ferrite (NF) and Zn-ferrite (ZF) were prepared by mixing them at different ratio and were subsequently annealed at different temperatures. Structural studies showed the appearance of NiZn-ferrite along with the constituent ferrites in the nanocomposite samples with the increase in annealing temperature. Magnetization value increased and the coercivity showed a peak around 750 °C with the increase in annealing temperature. Both the magnetization and coercivity decreased with the increase in ZF concentration in these samples annealed at temperatures lower than 900 °C. The highest magnetization value of 52 emu/g and the lowest coercivity of 40 Oe were observed at 300 K in the nanocomposite sample with NF:ZF = 3:2 and annealed at 900 °C. The observed magnetization value was higher than the expected values whereas the observed coercivity was lower than the expected values in the annealed samples. Grain growth, intergranular interactions, formation of NiZn-ferrite and cation distribution in the spinel structure explain the observed magnetic behaviour in these nanocomposites.

1. Introduction

Magnetic nanocomposites of core-shell structures [1,2], bilayered thin films [3,4], and solid mixtures [5,6] of different materials are of great scientific interest to understand the coupling between the constituent materials and to tune the magnetic properties for their possible applications in technology, biomedical and environmental fields [7–11]. These composites are made by the combination of ferromagnetic, ferrimagnetic or antiferromagnetic material with any other material. Magnetic behaviour of the nanocomposites of bimagnetic systems depends on the grain size and their distribution, packing density, intergranular interactions and composition of these materials. Depending on the type and strength of magnetic interactions magnetic properties like exchange bias [12,13], exchange spring behaviour [14,15], enhanced remanence, coercivity and high energy product [16,17] are observed in these bimagnetic nanocomposites.

Nanocomposites consisting of spinel ferrite have been studied for their possible applications in different fields. $NiFe_2O_4/SiO_2$/graphene oxide, $NiFe_2O_4/MnO_2$/ graphene, $ZnFe_2O_4$/graphene/TiO_2, $BaFe_{12}O_{19}$/$ZnFe_2O_4$/carbon nanotubes, $BaFe_{12}O_{19}/NiFe_2O_4$ nanocomposites were studied for microwave device applications [18–22]. The nanocomposites of $NiFe_2O_4/MnO_2$ and Fe_3O_4/carbon have been reported for water purification by removal of heavy metal like Pb(II) and Cr(VI) respectively from waste water [23,24]. $CoFe_2O_4/CoFe_2$ nanocomposites were studied by Prabhakaran et al. for magnetic refrigeration applications [25]. Wu et al. studied the influence of stochiometric ratio of $SrFe_{12}O_{19}$ to $ZnFe_2O_4$ on magnetic and photocatalytic properties of $SrFe_{12}O_{19}/ZnFe_2O_4$ nanocomposites [26]. Lorenz et al. reported exchange bias and magnetodielectric coupling in $ZnFe_2O_4/BaTiO_3$ composite thin films [27]. Bimagnetic nanocomposites consisting of two spinel compounds have also been studied by many researchers. Song et al. reported that by varying the core and shell materials, and volume fraction of soft and hard phase one can control the blocking temperature, coercivity and switching of moments in $CoFe_2O_4/MnFe_2O_4$ core/shell nanoparticles [2]. Oberdick et al. studied spin canting in $Fe_3O_4/Mn_xFe_{3-x}O_4$ core/shell nanoparticles [1]. Magnetic coupling in nanocrystalline $CoFe_2O_4/ZnFe_2O_4$ bilayered thin films was studied by Sahoo et al. [4]. Thickness dependent exchange spring behaviour in epitaxial $Fe_3O_4/CoFe_2O_4$ magnetic bilayers was reported by Lavorato et al. [3]. In the present work we studied the effect of annealing on the magnetic properties of $NiFe_2O_4/ZnFe_2O_4$ nanocomposites.

$NiFe_2O_4$ (NF) shows grain size dependent ferrimagnetic behaviour in nanoscale [28,29]. $ZnFe_2O_4$ (ZF) though antiferromagnetic in bulk shows ferrimagnetic behaviour depending on grain size and their distribution in the nanomaterials [30,31]. In the present study we mixed these two spinel ferrite nanoparticles and investigated their magnetic

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