



Effect of cation distribution on structural and magnetic properties of Dy substituted magnesium ferrite

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ABSTRACT

Magnesium ferrite and dysprosium (Dy^{3+}) substituted with composition $\text{MgDy}_x\text{Fe}_{2-x}\text{O}_4$ ($x=0.00-0.07$) was prepared by solid state reaction technique. Spinel phase formation was identified using x-ray diffraction technique, thus establishing the cubic spinel symmetry. The morphology was seen through scanning electron microscopic technique, from where the grain size was calculated using average intercept line method. The elemental composition of pure and dysprosium substituted magnesium ferrite was calculated from energy dispersive x-ray analysis spectrum which is then correlated with the experimentally obtained values. Magnetic hysteresis loop of the various compositions establishes it to be soft ferrimagnetic material. The magnetic parameters such as saturation magnetization, coercivity, and retentivity were also calculated. Temperature dependence of saturation magnetization was done to find the Curie temperature of different compositions.

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1. Introduction

Magnesium ferrite (MgF) is a typical spinel structure of the type AB_2O_4 in which cation distribution in the lattice is sensitive to heat treatment due to high diffusibility of Mg^{2+} ions [1]. In the normal spinel structure, divalent cations (A) normally occupy 8 tetrahedral sites out of 34 in a unit cell, whereas trivalent cations (B) occupy 16 octahedral sites among 32 sites in a unit cell. Thus, AB_2O_4 type of compounds with spinel structure show interesting structural, electrical and magnetic properties, which vary with the nature of the ions, their charge and site distribution amongst tetrahedral and octahedral [2]. Contrarily, in an inverse spinel, the tetrahedral sites are occupied by trivalent cations (B) and the octahedral sites are occupied by both divalent cations (A) and the remaining trivalent cations [3]. Magnesium ferrite belongs to the partially inverse spinel and it can be considered as a collinear ferrimagnet whose degree of inversion depends on the thermal history of the material and the preparation method [4]. Transition metal oxides with iron oxides as their main component have attracted the attention of the researchers because these are magnetic semiconductors suitable for use in microwave devices [5].

MgFe_2O_4 is a soft magnetic n-type semi conducting material, which finds number of applications in heterogeneous catalysis,

adsorption, sensors and magnetic technologies [6]. The transition metal (Mg^{2+}) ion is in an inverse spinel distribution at room temperature such as $(\text{Fe})_A[\text{MgFe}]_B\text{O}_4$ [7]. It is known that the magnetic behavior of the ferromagnetic oxides is largely governed by the Fe–Fe interaction (the spin coupling of the 3d electrons) and by introducing rare earth (R) ions into the spinel lattice, the R–Fe interactions may start to have an appreciable effect (3d–4f coupling), which can lead to small change in the magnetization and curie temperature. However, the R–R interactions are very weak since their results form the indirect mechanism 4f–5d–5d–4f [8,9]. The effect of metal ion substitution such as Al [10,11], Ge [12], Cu [13], Ni [14], Cr [15], Sm–Gd [16], Ce–Gd [17] on the magnetic properties of MgFe_2O_4 has been reported in the literature. The effect of dysprosium substitution in various ferrites such as NiFe_2O_4 [18], Mn–Zn ferrite [19], Li–Co [20] and manganese ferrite [21] has also been reported in the literature. To the best of author's knowledge, there is no such report on the effect of Dy^{3+} cation distribution on the structural and magnetic properties of $\text{MgDy}_x\text{Fe}_{2-x}\text{O}_4$ where ($x=0.0, 0.01, 0.03, 0.05, 0.07$).

2. Experimental

2.1. Synthesis

Magnesium ferrite (MgF) and dysprosium (Dy) substituted magnesium ferrite (DyMgF) with composition $\text{MgDy}_x\text{Fe}_{2-x}\text{O}_4$ ($x=0.0, 0.01, 0.03, 0.05, 0.07$) were prepared using the solid state reaction technique. Stoichiometric mixtures of the powdered

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reactants MgO, Dy₂O₃ and Fe₂O₃ were mixed in agate mortar. The mixed powder was then homogenized and wet-milled in a ball mill. The dried powder was pressed into circular pellets and pre-fired at a temperature of 800 °C for 2 h with a heating rate of 2 °C/min in order to bring about the initial chemical reaction between the constituent and then slowly cooled to room temperature. To produce a chemically homogeneous material, the pre-fired powder was again intensively milled and mixed. This powder after the addition of PVA (polyvinyl acetal) as binder is again remixed, ground and pressed into the required pellets using hydraulic press under a pressure of 120 kg/cm² in order to obtain a high degree of compaction. These were finally sintered in an electrical furnace at 1200 °C for 2 h with a heating rate of 4 °C/min. The temperature of the furnace was then cooled down at the rate of 7.5 °C/min upto 900 °C and after this stage, the furnace was left to cool at room temperature.

2.2. Characterization technique

The crystalline phase and the structural parameters were analyzed by using a Rigaku powder x-ray diffractometer at 40 kV and

Table 1

Variation of grain size with different composition of Dy i.e., MgDy_xFe_{2-x}O₄ (where x=0.00, 0.01, 0.03, 0.05, 0.07).

Composition	Size (μm)
MgF	3.99
Dy1%	2.26
Dy3%	1.69
Dy5%	1.50
Dy7%	1.17

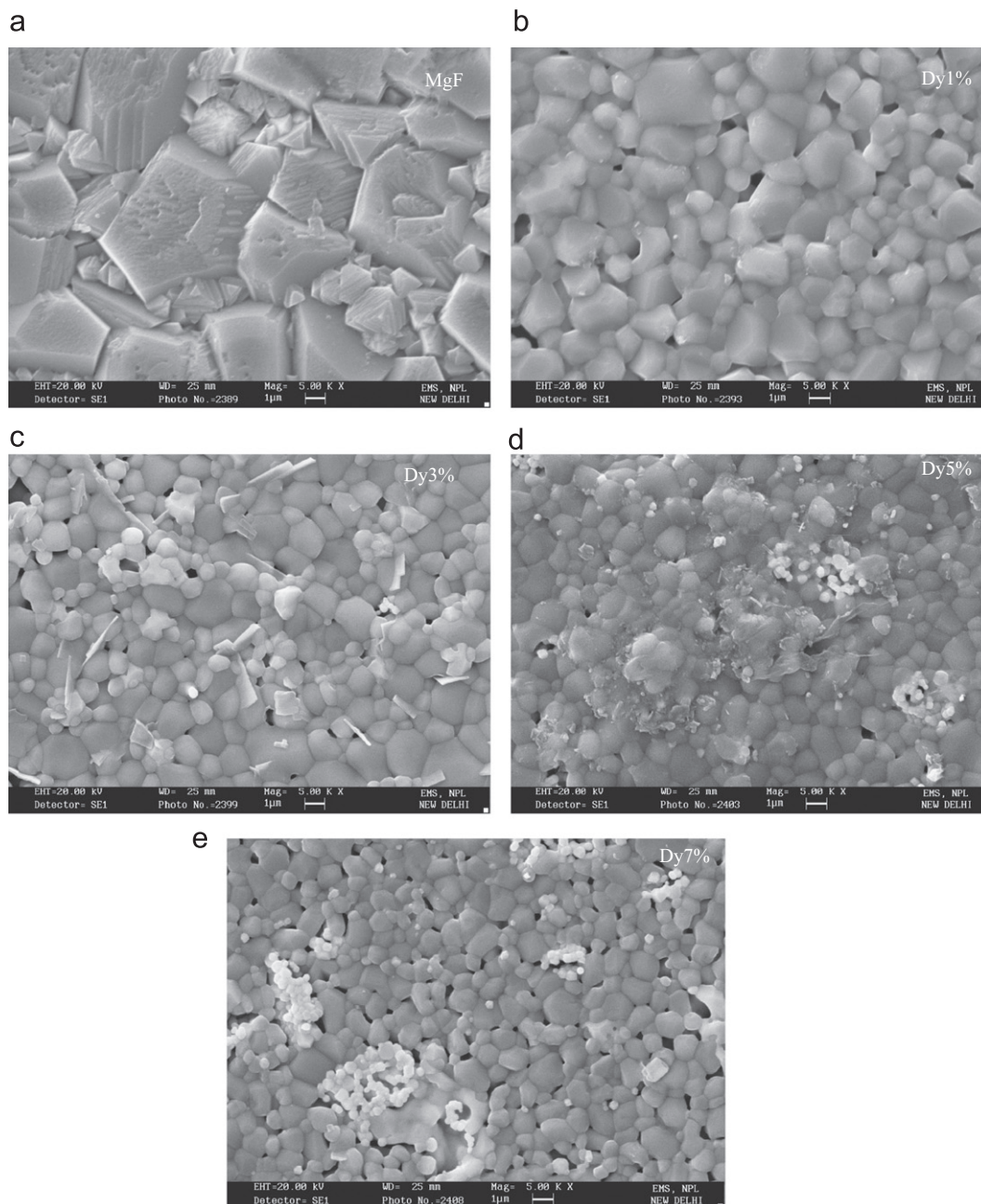


Fig. 1. Scanning electron microscopic (SEM) photographs showing (a) pure MgFe₂O₄ (MgF), (b) 1% Dy substituted MgF, (c) 3% Dy substituted MgF, (d) 5% Dy substituted MgF, and (e) 7% Dy substituted MgF. The agglomeration of particles increases with increase in Dy concentration.

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