Structural and magnetic properties of $MgFe_2O_4$: effect of fuel and annealing

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Sol gel auto-combustion technique was employed to synthesize $MgFe_2O_4$ powders with various organic fuels such as aloe vera, lemon juice, ginger, honey, and citric acid. The fuel, pH, annealing temperature, and time influenced the magnetic behaviour. Ginger yielded the maximum saturation (M_s = 25.9 emu/g) and aloe vera yielded the minimum (7.90 emu/g). The coercivity (H_c) ranged between 112.4 Oe (ginger) – 40.9 Oe (aloe vera). Magnetic behaviour was altered by increasing annealing temperature, time. Magnetic property change can be correlated to crystallinity, particle size, and inversion degree.

Keywords: Spinel ferrites; Magnetic properties; Cationic distribution

1. Introduction

Synthesis of crystalline magnesium ferrite ($MgFe_2O_4$) nanoparticles is of great interest because of its potential use in drug delivery, transformer cores, and high-frequency microwave devices [1]. The crystal structure of magnesium ferrite, a partially inverted spinel, is represented by $(Mg_{1-\delta}Fe_{\delta})_A[Mg_{\delta}Fe_{2-\delta}]_BO_4$, δ: – inversion parameter range between 0 to 1 [2]. Magnetic, electrical, and structural properties of $MgFe_2O_4$ are determined by how metal ions are distributed on A, B sites. The preparation method, process conditions employed also affect properties [2]. One of the common, and low-cost methods used for synthesizing oxide compounds is combustion synthesis [3], where a self-sustaining exothermic reaction is employed in combustion synthesis, and the generated heat is enough to continue the process [4].

This study highlights the significant influence of synthesis conditions, including fuel type, annealing temperature, time on the structural, magnetic properties of $MgFe_2O_4$ powders.

2. Results and discussion

Hysteresis loops, remanence (M_r), coercivity (H_c) of $MgFe_2O_4$ powders prepared with various fuels show significant differences, as shown in Fig. 1 (a-c). The saturation magnetization (M_s) is the highest for ginger (25.9 emu/g), followed by lemon juice (24.8 emu/g), honey (22.3 emu/g), citric acid (18.7 emu/g), and aloe vera (7.90 emu/g). For the studied samples, highest to lowest remanence (M_r) the following trend is obtained: honey→ ginger → lemon juice → citric acid → aloe vera. Lower M_s , M_r values for aloe vera can be associated with a low crystallinity of the prepared $MgFe_2O_4$ powder. In addition, type of fuel also influences the coercivity (H_c) of the powders; the highest H_c is that of ginger (112.4 Oe), followed by citric acid (108.2 Oe), lemon juice (106.2 Oe), honey (92.8 Oe), and aloe vera (40.9 Oe). H_c modification is ascribable to particle size variation. H_c usually increases with particle size to a maximum value prior to reducing as a result of the creation of multidomain structures in large particles [5]. Fig. 2 (a, b) respectively illustrate the effect of annealing temperature, and time on the hysteresis loops of $MgFe_2O_4$ powders. M_s, and M_r of spinel ferrites are very sensitive to cation distribution between tetrahedral (A), and octahedral (B) sites. The magnetic spins of A-site cations are antiparallel to those of B-site cations. Greater the difference in magnetic moment between A, and B sites, an indicator of low level of inversion, higher are the M_s, and M_r values [6]. The differences in M_s observed in Figs. 1, 2 can be linked to the inversion degree. Additionally, higher annealing temperatures, and longer annealing times may lead to the formation of multidomain structures in larger particles, which could explain the observed decrease in M_r (see Fig. 2).

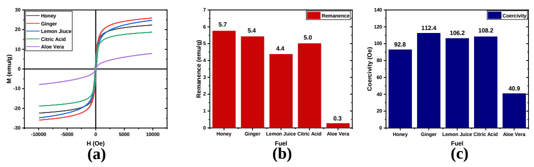

Figure 1: (a) Hysteresis loops, (b) Mr, (c) Hc of MgFe2O4 powder prepared using dry gel method, different fuels and maintaining pH 7.

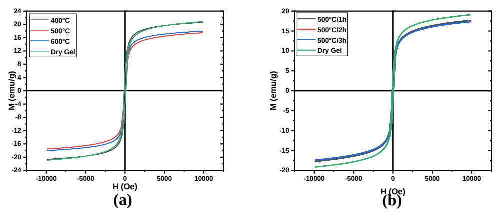

Figure 2: (a) Effect of annealing Temperature and (b) time on MgFe2O4 powder prepared using citric acid as fuel and maintaining pH 7.

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