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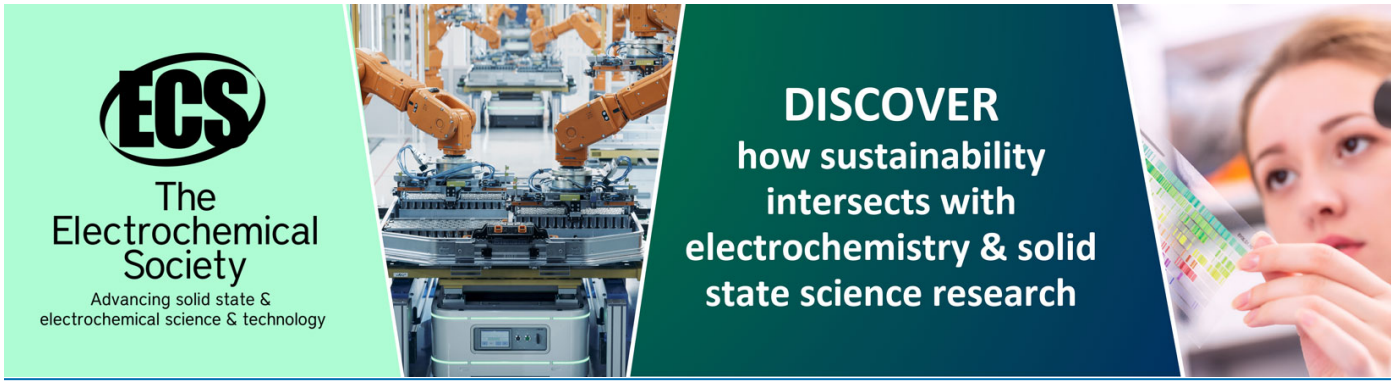

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Effect of addition on the structure and magnetic properties of $Ni_{1-x}A_x Fe_2O_4$ prepared via sol-gel method

Ahmed M. Hameed[1*], Zainab Raheem Muslim[2]
[1,2]Depatment of physics, College of science, University of Baghdad,
Jadiriya, Baghdad, Iraq
[*]Corresponding Auther: ahmediraq427@gmail. com

Abstract

The $Ni_{1-x}A_x Fe_2O_4$ (A=Co, Mg; x= 0, 0.5) spinal ferrite were compact in chemical "sol-gel" process. The structure and magnetic properties of the samples were done by XRD and VSM. The heat treatment for the samples was performed at 700℃ for 2 hours. The crystalline size of $NiFe_2O_4$, $Ni_{0.5}Co_{0.5} Fe_2O_4$ and $Ni_{0.5}Mg_{0.5} Fe_2O_4$ were 34.7 nm, 26.8 nm and 29.8 nm, respectively and magnetic measurements showed that the saturation magnetization of these materials were 48.1 emu/g, 34.4 emu/g and 20.36 emu/g, respectively. The values of coercivity (H_c) of the $NiFe_2O_4$, $Ni_{0.5}Mg_{0.5} Fe_2O_4$ and $Ni_{0.5}Mg_{0.5} Fe_2O_4$ are 182 Oe, 460 Oe and 85Oe.

Introduction

Spinel ferrite ($NiFe_2O_4$) and compounds have a good magnetic and electrical properties [1], ferrofluids, catalysts, microwave devices and gas sensors [2]. Amongst the ferrites, the inverse spinel is especially impressively because of its high magnetocrystalline anisotropy, high saturation magnetization (M_S) and unique structure of magnetic [3].

Nickel ferrite nanoparticles have high electrical conductivity and high permeability at high frequencies. It is also used as anode electrode for lithium ion batteries, and catalysts for the preparation of halogen derivatives of aromatic hydrocarbons [4].

If the two materials are combined into a single CoNiFe_2O_4 unit, they will be producing new materials with crystal structures and different properties which have been potential to be a signal rectifier oscillator device [5]. Different procedure are used to synthesize ferrite nanoparticles, like: mechanochemical method, combustion, forced hydrolysis, redox process, co-precipitation, hydrothermal, spray drying, sol-gel, solid state reaction, sonochemical, thermal decomposition method and electrochemical [6].

Experimental

The obtained $NiFe_2O_4$, $Ni_{0.5}Co_{0.5} Fe_2O_4$ and $Ni_{0.5}Mg_{0.5} Fe_2O_4$ are denoted as sample A, B and C respectively. All the samples prepared via a sol-gel method. The materials used to prepared Sample A, nitrates (nickel and iron) were mixed with distilled water (20 ml), and then citric acid added into solution (1:1:2). The materials used to prepared Sample B, nitrates (nickel, iron and cobalt) were mixed with distilled water (30 ml), and then citric acid added into solution (1:1:1:3). The materials used to prepared Sample C , nitrates (nickel, iron and magnesium) were

mixed with distilled water (30 ml), and then citric acid added into solution (1:1:1:3). All these mixtures were continuously stirred for one hour at 80℃ until water is evaporated and converted into sticky gel. The gel was dried at 150 ℃ in oven for four hours. The resulting powder were calcined at 700 ℃ for two hours in air to obtain the pure crystalline stage. The samples were then characterized by XRD and VSM, finally.

Result and discussion

Structural characterization: The structural information for the prepared all the samples were determined by XRD as shown in **Figure 1**. The samples were worked at voltage and current 40 kV and 30mA, respectively. The XRD of the samples are identical to standard values of sample A , sample B and sample C (ICSD No. 98-020-1149, 98-016-6741 and 98-004-0672), respectively, which can be easily as the cubic structure (space group of $Fd\bar{3}m$). The lattice parameter of all the samples calculated from highest peak of XRD are shown in **Table 1**. The crystalline size of these samples calculated from Scherrer's equation.

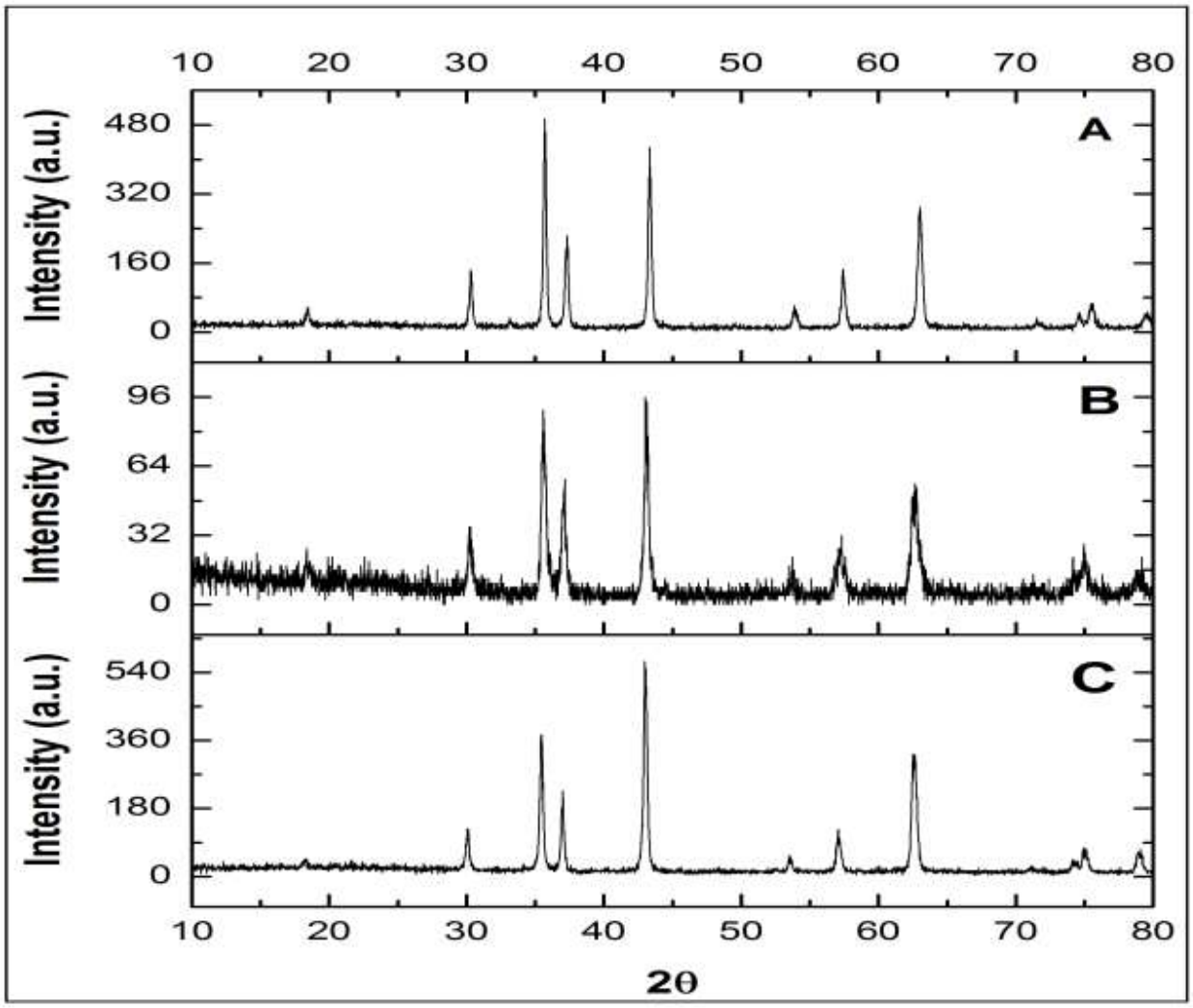

Figure. 1: XRD pattern for; A-$NiFe_2O_4$, B-$Ni_{0.5}Co_{0.5}\ Fe_2O_4$ and C-$Ni_{0.5}Mg_x\ Fe_2O_4$.

Table 1. Structure parameter of the all the samples.

Cell parameter	Sample A	Sample B	Sample C
α (Å)	8.339	8.37	8.381
b (Å)	8.339	8.37	8.381
c (Å)	8.339	8.37	8.381
Cell volumes ($Å^3$)	579.885	586.376	588.691
Lattice structure	cubic	cubic	cubic
Crystalline size (nm)	~ 34.7	~ 26.8	~ 29.8

Magnetic studies: The magnetization versus applied field were done by using VSM at room temperature where the magnetic field applied was -15 kOe≤ H ≤15 kOe. The results of magnetic properties are shown in **Table 2** and **Figure 2** signalize that all the samples are soft ferromagnetic materials. The largest value of saturation magnetization was 48.1 emu/g for the sample A and the lowest value was 20.36 emu/g for the sample B, while the saturation magnetization value of the sample C was 34.4 emu/g.

The approximately in ionic radius of cobalt ions and iron ions can substitute in nickel ions, the high saturation magnetization was due the structural uniformity [7]. The increase in saturation magnetization was approximately probably due to the smaller grain size the saturation magnetization was increase due to thermal disorder which oppose the alignment of applied magnetic field and it happened due to an increase in applied magnetic field which cannot increase the magnetization of material and the coercivity value increased with decrease of the grain size, so the sample A has M_s greater than sample B and H_c of sample A smaller than sample B, agree with [8]. There two unpaired electrons in the valence shell for Ni^{2+}, while no unpaired electron for Mg^{2+}, so that the saturation magnetization of sample C was decrease. Considering only spin contribution, the magnetic moment of Ni^{2+} is two μB and Mg^{2+} is zero μB. Both Mg^{2+} and Ni^{2+} was chosen to fill the empty sites. When Mg^{2+} ion was filled to enhance the magnetic moment into nickel ferrite. Coercivity (H_c) in the ferrite is controlled by many factors such as magnetocrystalline, crystalline size, exchange anisotropies, surface and canting. When Mg^{2+} doping to nickel ferrite, magnetocrystalline anisotropy decrease in the sample. Consequently, the H_c value decrease in the sample C [9].

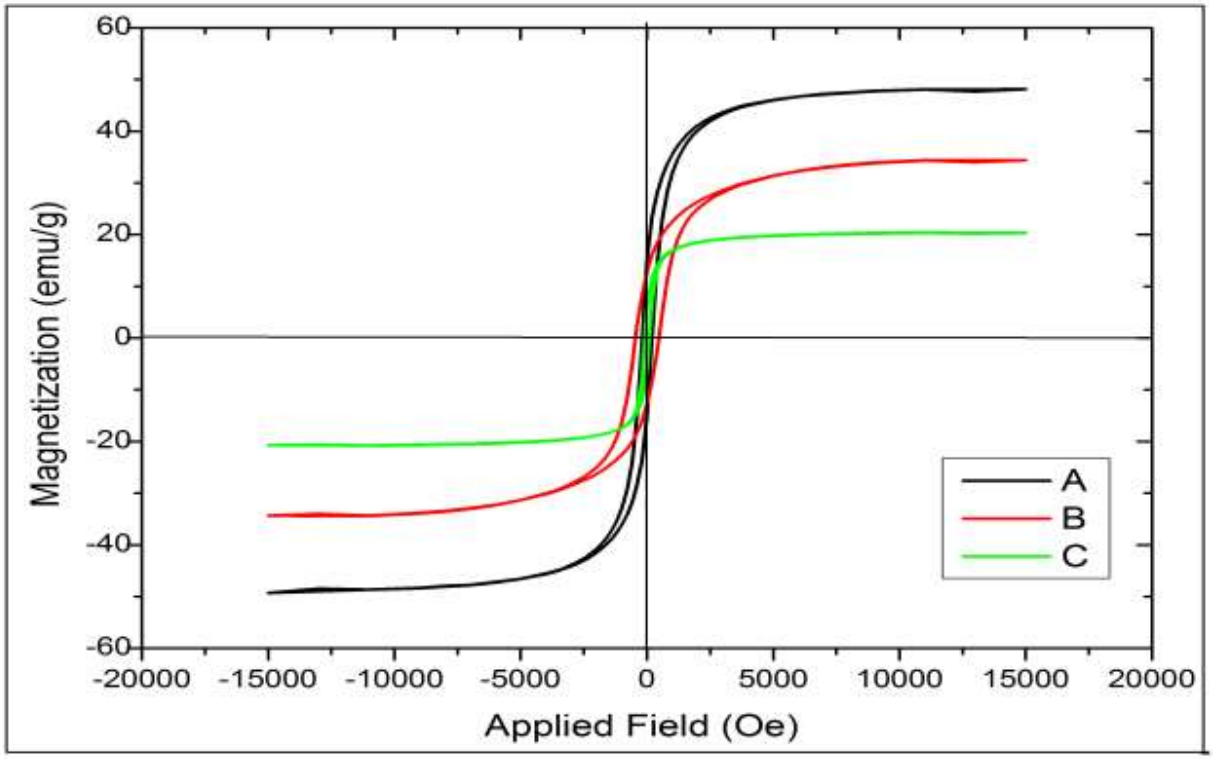

Figure 2: Hysteresis loop (magnetization as a function of applied magnetic field) for ; A-$NiFe_2O_4$,B- $Ni_{0.5}Co_{0.5}\ Fe_2O_4$ and C-$Ni_{0.5}Mg_{0.5}\ Fe_2O_4$.

Table 2: The characteristics magnetic parameters for the samples.

magnetic parameters	**Sample A**	**Sample B**	**Sample C**
$\boldsymbol{M_s}$ (emu/g)	48.1	34.4	20.36
$\boldsymbol{M_r}$ (emu/g)	17.5	12.8	6.8
$\boldsymbol{H_c}$ (Oe)	182	460	85

Conclusion

Show all samples are ferromagnetic materials due to the values of the magnetic properties. The effects of doping (Co and Mg) on the crystalline size, magnetic properties and hysteresis loop of the prepared samples were studied. The lattice parameter value of nickel ferrite increased with doping by Co and Mg whereas the crystalline size decreased. The values of the M_s and M_r of nickel ferrite decreased with doping by Co and Mg, while the H_c values increase by doping with Co and decrease with doping by Mg.

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