REVIEW OF RESEARCH
IMPACT FACTOR : 5.7631(UIF) UGC APPROVED JOURNAL NO. 48514 ISSN: 2249-894X

VOLUME - 8 | ISSUE - 4 | JANUARY - 2019

MAGNETIC BEHAVIOR AND ELECTRICAL RESISTIVITY OF SOL-GEL SYNTHESIZED FERRITE NANOPARTICLES

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ABSTRACT:

Nanocrystalline magnetic materials are promising materials due to their wide range of applications in the field of electronics and telecommunication industry such as in microwave devices, memory core applications, power transformers etc. Magnetic behavior and d.c. electrical resistivity studies were made on ferrite nanoparticles synthesized via sol-gel auto-combustion technique and finally sintered at 600^{0}C for 4 hrs. Sol-Gel auto combustion method was used for synthesis of Cr^{3+} doped Co-Zn-Ni ferrite nanoparticles. The structural characterization of the samples was carried out by X-ray diffraction technique. All the samples were crystallized in single phase cubic spinel structure. The magnetic behavior was studied by using room temperature vibrating sample magnetometery. The typical hysteresis loop indicates the ferromagnetic nature of samples. High coercivity values specify the nanocrystalline nature of newly prepared samples. The saturation magnetization, remnant magnetization and coercivity decreases as the Cr concentration increases in composition. Two-probe technique is used to study the d.c. electrical resistivity. Transition temperature and activation energy was calculated by using d.c. resistivity graphs.

KEY WORDS: *Magnetization, coercivity, d.c. resistivity.*

INTRODUCTION

The multiferroic materials increase the interest of researcher due to their unusual properties in different field of modern technology. Magnetoelectric composite consists of a suitable combination of ferroelectric material with ferromagnetic material. Magneto-electric effect in these composites is the result of mechanical coupling between piezoelectric (ferroelectric) and magnetostrictive (ferromagnetic) materials. Under applied magnetic field a strain is developed in ferromagnetic (piezomagnetic) material through magnetostriction, which passed to ferroelectric (piezoelectric) material results into stress in it. Thus extra charges are developed across multiferroic composite when magnetic field is applied which in turn generates induced voltage due to the piezo- electric effect. Nanocrystalline magnetic materials are promising materials due to their wide range of applications in the field of electronics and telecommunication industry such as in microwave devices, memory core applications, power transformers etc. [1-4]. In the recent years many workers have been reported on the structural, electrical and magnetic properties of substituted spinel ferrites due to their technological importance in various fields [5-11]. Cobalt ferrite and Nickel ferrite are the examples of inverse spinel ferrites and Zinc ferrite is the example of normal spinel. Ni-Zn ferrites, Co-Zn ferrites and Ni-Co-Zn ferrites are the soft ferrimagnetic materials having cubic spinel structure belongs to Fd3m space group [5]. They are commonly used in high frequency transformer cores, inductors, microwave devices, radars, antenna rods, magnetic recording tapes etc. due to their high resistivity, low eddy current losses, high Curie temperature, mechanical hardness and chemical stability [11].

The structural, electrical and magnetic properties were controlled by changing the amount and nature of dopant in ferrites. Method of preparation plays an important role to achieve the desire properties of ferrite materials. By using various physical and chemical methods ferrites can be synthesized. The properties of ferrites are depends on method of preparation, sintering temperature, sintering time and amount and type of cation doped in it. Among the various chemical methods of preparation, sol-gel autocombustion method is one of the best methods to synthesis ferrites at low temperature. In the present paper we report the results on magnetic and electric properties of Cr^{3+} doped Ni-Co-Zn ferrite system by changing the Cr concentration. The magnetic properties such as saturation magnetization, remnant magnetization, magneton number and coercivity and electric properties such as d.c. electrical resistivity, transition temperature and activation energy was studied.

EXPERIMENTAL:

By using various physical and chemical methods ferrites can be synthesized. The properties of ferrites are depends on method of preparation, sintering temperature, sintering time and amount and type of cation doped in it. Sol-Gel auto combustion method was used for synthesis of Cr^{3+} doped Co-Zn-Ni ferrite nanoparticles. The concentration of Cr^{3+} ions was changed in the step of 0.2 from 0.0 to 1.0 in the series having general chemical formula $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_{2-x}Cr_xO_4$. Nickel nitrate, cobalt nitrate, zinc nitrate, chromium nitrate, ferric nitrate and citric acid was mixed in distilled water and the solution was continuously stir and heated at constant temperature of 90^0. pH of the solution was maintained at 7 by adding liquid ammonia in the solution. The final powders obtained by self ignition of dried gel were finally sintered at 600^0 for 4 hrs. The morphological study and crystal structure of the samples was confirmed by X-ray diffraction patterns. In order to study the magnetic properties such as saturation magnetization, magneton number, remnant magnetization and coercivity, the room temperature vibrating sample magnetometry was used. d.c. electrical properties were studied by using two probe technique as a function of temperature in the range 300K – 800K.

RESULTS AND DISCUSSION:

Method of preparation plays an important role to achieve the desire properties of ferrite materials. By using various physical and chemical methods ferrites can be synthesized. The properties of ferrites are depends on method of preparation, sintering temperature, sintering time and amount and type of cation doped in it. Among the various chemical methods of preparation, sol-gel autocombustion method is one of the best methods to synthesis ferrites at low temperature. Typical room temperature magnetic hysteresis loops of the series $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_{2-x}Cr_xO_4$ (x = 0.0 sintered at 600^0C) using vibrating sample magnetometer technique (VSM) is shown in Fig. 1.

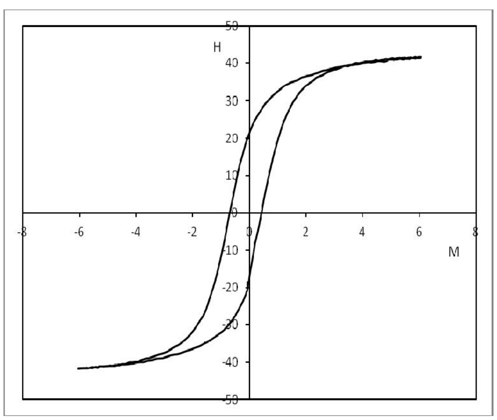

Fig. 1: Typical magnetic hysteresis loop for $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_{2-x}Cr_xO_4$ (x = 0.0)

The shape of the loop depicts that the sample possess a nature of soft magnetic material. The values of coercivity are less than 1 kOe which indicates the properties of soft ferrites. The magnetic properties such as saturation magnetization, remnant magnetization, ratio of saturation magnetization and remnant magnetization and coercivity obtained from hysteresis loops for all samples are summarized in Table 1.

Table 1: Saturation magnetization, remnant magnetization, remnant to saturation magnetization ratio, coercivity, transition temperature and activation energy for $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_{2-x}Cr_xO_4$

x	Ms	Mr	Mr/Ms	Hc	T_C (K)
0.0	41.56	23.05	0.555	664	689.5
0.2	39.48	20.15	0.510	628	625.8
0.4	37.40	18.07	0.483	589	588.2
0.6	36.16	14.96	0.414	536	555.5
0.8	34.91	12.21	0.350	486	540.5
1.0	33.25	9.14	0.275	408	526.3

As the Cr concentration increases in $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_{2-x}Cr_xO_4$ the saturation magnetization decreases from 41.56 to 33.25 emu/gm. Also the remnant magnetization and coercivity also decreases as the Cr substitution increases in the composition. Magnetic properties of ferrites are sensitively dependent on the structure of ferrite, chemical composition, particle size, amount and type of dopant, cation distribution, density, anisotropy etc.[12]. Cation distribution over tetrahedral – A, and octahedral B- sites strongly affected the magnetic properties. In the present case Ni, Co and Fe ions shows strong preference towards octahedral B sites, where as Zn and Cr ions shows strong preference towards tetrahedral A sites. As Cr^{3+} ($3\mu_B$) ions replaces Fe^{3+} ($5\mu_B$) ions decreases the net magnetic moment. The variation of saturation magnetization and coercivity with Cr concentration in the series is shown in Fig. 2.

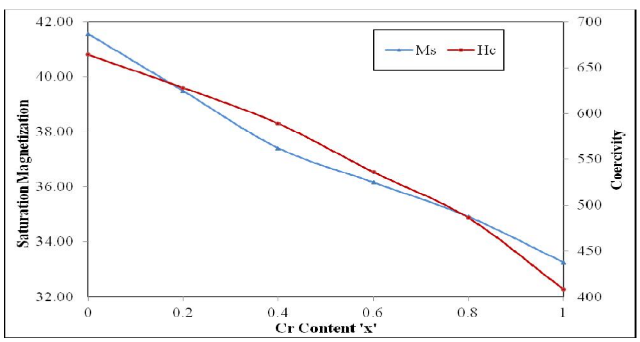

Fig. 2: Varition of M_S and H_C with Cr contnet 'x' for $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_{2-x}Cr_xO_4$

Fig. 3 shows the plots of log ρ versus 1000/T for all the samples of Cr doped Ni-Co-Zn mixed ferrites.

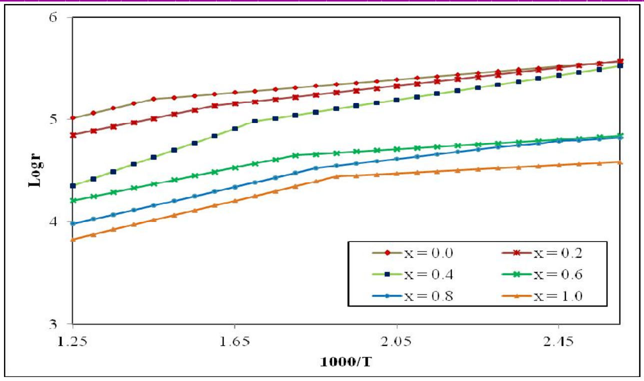

Fig. 3: Variation of log ρ versus 1000/T for $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_{2-x}Cr_xO_4$

The temperature dependent d.c. electrical resistivity have been studied for all the samples in the temperature range 300K to 800K. From fig. 2; it is clear that the values of log ρ linearly increase upto a certain point at which the graphs bend called as knee point. After knee point the slope of graph changes, which indicates that the knee point is nothing but the transition point at which the ferrimagnetic nature of ferrites changes to paramagnetic. This transition temperature is also called as Curie temperature. The values of Curie temperature obtained from resistivity graphs are given in table 1. By using the slopes of para and ferri region, activation energy of the samples were calculated.

CONCLUSIONS:

The typical hysteresis loop indicates the ferromagnetic nature of samples. Hysteresis loop of $Ni_{0.2}Co_{0.6}Zn_{0.2}Fe_2O_4$ indicates the nature of ferrites is of soft magnetic materials. High coercivity values specify the nanocrystalline nature of newly prepared samples. Due to replacement of Fe^{3+} ions by Cr^{3+} ions decreases the saturation magnetization, remnant magnetization and coercivity of the samples. The d.c. resistivity plots shows the kink nearby the Curie temperature. The Curie temperature obtained from d.c. resistivity plots shows decreasing nature as the concentration of Cr increases in the composition.

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