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STUDY OF BEHAVIORAL CHANGES IN MAGNETIC PROPERTIES OF NICKEL ZINC FERRITE IN RESPONSE OF VARIATION IN ZINC CONTENT.

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Abstract: To study, $NiFe_2O_4$ samples prepared by air oxidation of an aqueous suspension containing Ni^{2+}, $Zn^{2+}$and Fe^{3+} in proper proportions. The wet samples of Ni-Zn system were annealed at a 800^0C for 12 hrs. and were characterized by X-ray diffraction (XRD). The magnetic properties of soft ferrite like saturation magnetization (σ_s) and magneton number (n_B) have studied using the high field hysteresis loop technique. The magnetization data was recorded at room temperature.

Keywords: Ferrite, hysteresis loop, magnetization.

1. Introduction

Magnetic oxides are naturally occurring minerals. Magnetic oxides, Ferrites are form a class of dielectric materials. It is due to it's high resistivity and low loss properties. Among the broad classification of magnetic oxides, the spinel ferrites gain more importance because of their low cost, high magnetic permeability and low power losses which makes them suitable for high frequency applications. In order to understand their unique properties and their utilization in technological applications, one must understand the relation between structure, particle size and processing. These properties have made them to be used in many technological applications over a wide range of frequencies Although majority of ferrites contain iron oxide, there are some ferrites based on Mn, Ni, Zn and other elements. It leads ferrites to be used as a catalyst, gas sensor, super capacitor and magneto-caloric materials for future refrigeration [1–3]. The sintering temperature and sintering conditions, type and amount of dopants and method of preparation are the main factors which are responsible for obtaining changes in the properties of a ferrite material.

The method of preparation plays a vital role in governing the electrical and magnetic properties of ferrite. Soft ferrites are usually prepared by ceramic method. Recently some chemical methods have been used to synthesize soft ferrites for the reason that they produce nano-size particles. The systems made up of nano-particles are intensively studied both theoretically and practically, due to their electrical and magnetic properties that are sensibly different from those of their bulk counter [4, 5].

Ni-Zn ferrites are very important soft magnetic materials that have many applications in

both low and high frequency devices and play useful role in many technological applications because of their high resistivity, low dielectric loss, high Curie temperature and chemical stability [6, 7, 8]. Ni-Zn ferrites have been used for RF coils, transformer cores and antenna rods.

2. Experimental

The spinel ferrite system $Ni_{1-x}Zn_xFe_2O_4$ is prepared with variable composition (x = 0.0, 0.2, 0.4, 0.6) by air oxidation of an aqueous suspension containing Ni^{2+}, $Zn^{2+}$and Fe^{3+} cations in proper proportions. In preparing the solution, the molarity of Fe^{3+} is assumed as 0.5M and that of Ni^{2+} and Zn^{2+} is assumed as 0.25 M. A two molar (2M) solution of NaOH was prepared as a precipitant. In order to achieve simultaneous precipitation of all the hydroxide Ni $(OH)_2$, Zn $(OH)_2$, and Fe $(OH)_2$, the starting solution (pH≈3) was added to the solution of NaOH and a suspension (pH=11) containing dark intermediate precipitation was found. Then the suspension was heated and kept at a temperature of 60^0C, while oxygen gas was bubbled uniformly, the suspension was stirred to promote the oxidation reaction until all the intermediate precipitant changed into the dark brownish precipitate of the soft ferrite. The samples were filtered, washed several times by distilled water. The wet samples of Ni-Zn system were annealed at a 800^0C for 12 hrs.

The X-ray powder diffraction patterns were recorded on at room temperature. The magnetic data for these samples were obtained with the help of high field hysteresis loop technique [9]. The low field a.c. susceptibility measurements on powder samples were carried out in the temperature range 300-800K using double coil setup [10] operating at a frequency of 263 Hz.

3. Magnetization

The magnetic properties of soft ferrite like saturation magnetization (σ_s) and magneton number (n_B) have been studied using the high field hysteresis loop technique [9]. The magnetization data was recorded at room temperature. The values of saturation magnetization (σ_s) and magneton number (n_B) (the saturation magnetization per formula unit in μ_B) obtained from hysteresis loop technique are given in Table 1. It is clear from Table 1 that magneton number increases up to a certain value i.e. x = 0.4 and then decreases with increase in Zn-concentration x.

In the present series of $Ni_{1-x}Zn_xFe_2O_4$ magnetic Ni^{2+} ions are replaced by non-magnetic Zn^{2+} ions and magnetic Fe^{3+} ions are replaced by non-magnetic Zn^{3+} ions. Thus, A-B interaction decreases in the system. However, for $x \leq 0.4$ the difference of magnetic moment of A and B site ions increases and therefore n_B increases. For x > 0.4, n_B decreases with the increasing Ni-Zn content x.

According to Neel's two-sublattice model of ferrimagnetism, Neel's magnetic moment per formula unit in μ_B, n_B^N is expressed as

$$n_B^N = M_B(x) - M_A(x) \qquad (1)$$

where,

M_B and M_A are the B and A sublattice magnetic moments in μ_B.

There is variation of calculated values of n_B, obtained by using the cation distribution (Table 1) and Neel's eq. (1), as a function of x.

The variation of n_B with x for x > 0.4 can be explained on the basis of Yafet-Kittel model [11]. The Y-K angles were calculated by using the following formula,

$$n_B = M_B \cdot \cos \alpha_{yk} - M_A$$

and are given in Table 1.

Thus, the change of spin ordering from collinear to non-collinear shows a strong influence on the variation of saturation magnetic moment per molecule as seen in the variation of magnetization.

Table 1 Saturation magnetization (σ_s), magneton number (n_B), Curie temperature (T_C) and Yafet Kittle angle (θ_{yk}) of $Ni_{1-x}Zn_xFe_2O_4$

Composition 'x'	'σ_s' (emu/gm)	'n_B' (μ_B) Obs.	'n_B' (μ_B) Cal.	'T_C' (K)	'θ_{yk}' (degree)
0.0	54.39	2.28	2.00	---	00
0.2	65.27	2.75	3.60	839	24.50
0.4	76.15	3.23	5.20	796	45.60
0.6	59.83	2.55	6.80	704	59.45

4. Conclusions

The analysis of x-ray diffraction patterns revealed the formation of single phase cubic spinel structure. The saturation magnetization and magneton number both decreases due to the substitution of non-magnetic Zn^{2+} dopants. The observed and calculated magneton number (n_B) shows different values for x>0.4 indicating that canting exists at octahedral [B] site. Susceptibility data shows that all the samples exhibit ferrimagnetic behaviour which decreases with the substitution of Zn^{2+} dopant.

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