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Magnetic Properties of Ni-Zn Ferrite Prepared with the Standard Ceramic Method

Rohini Manikrao Mahindrakar

Abstract:

The effect of Si^{4+} substitution on the magnetic properties of $Ni_{0.7+x} Zn_{0.3} Si_x Fe_{2-2x} O_4$ with x = 0,0.1,0.2,0.3,0.4, 0.5, 0.6 was investigated. The ferritesamples are magnetically characterized by its saturation magnetization andBhormagneton. The saturation magnetization and Bhormagneton can be obtained using hysteresis loop technique. The values of saturation magnetization (σ_s) and Bhormagneton (n_B) are obtained at room temperature for all the samples. the increase in saturation magnetization s_s up to x = 0.2 has been satisfactorily explained on the basis of Neel's theory of two sub-lattice model while the decrease in magnetization for x ≥ 0.3 by three sub-lattice model of Yafet-Kittle theory.

1.1 Introduction:

Magnetic oxides are used in many technological applications such as permanent magnets, microwave absorbers, chemical sensors etc. [1, 2]. They possess both magnetic and electrical

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properties, which depend on several factors such as method of preparation, chemical composition, sintering temperature, sintering atmosphere and distribution of cations at tetrahedral (A) and octahedral [B] sites [3]. Spinel ferrites are known to be materials, extremely sensitive to the manufacturing process. Soft ferrite crystallizes in spinel structure in which cations can be found in tetrahedral (A) and octahedral [B] site. The method of preparation plays an important role in governing the basic properties of ferrite. Spinel ferrites are usually prepared by ceramic technique.

Nickel ferrite is an inverse spinel in which the tetrahedral sites (A) are occupied by Fe^{2+} ions and the octahedral sites [B] by Fe^{2+} and Ni^{2+} ion. Nickel and Nickel substituted ferrites have been studied by several workers [4,5]. Nickel Zinc ferrites are having many technological applications particularly in the high frequency fields, due to their reduced magnetic losses. Nickel ferrite is largely used in electric and electronic devices. Nickel ferrite is one of the most important magnetic materials extensively used in high frequency application via microwave devices due to high resistivity and low losses. The substitution of non-magnetic ions brings the variation in the properties of spinel ferrite. In the present work, the magnetic properties of Si^{4+} substituted Ni-Zn ferrite system were investigated by means of magnetization measurements. No reports are available in the literature on the magnetic properties of Si^{4+} substituted Nickel-Zinc ferrite. Therefore, an attempt has been made to synthesize $Ni_{0.7+x}Zn_{0.3}Si_xFe_{2-2x}O_4$ spinel ferrite system by standard ceramic technique.

Experimental:

Nickel Zinc ferrites of the formula $Ni_{0.7+x}Zn_{0.3}Si_xFe_{2-2x}O_4$ withx = 0,0.1,0.2,0.3,0.4, 0.5, 0.6 were prepared by employing a standard ceramic technique. The appropriate quantities of Ferric oxide (Fe_2O_3), Nickel Oxide (NiO), Zinc Oxide (ZnO) and Silicon dioxide (SiO_2) all 99.9% pure, were thoroughly mixed in stoichiometric proportions. This mixture was then ground in agate mortar for about two hours. Mixture was then heated at 500°C for 24 hours and cooled in the furnace to room temperature. The temperature of furnace was measured with the help of Platinum-Rhodium thermocouple. The presintering powder of samples was again ground for minimum two hours. The powder was then palletized without any binder in a die of 10mm diameter by applying a hydraulic pressure of 6 tons per square inch for about 10 minutes. The final sintering is made for 24 hours at 950°C. The saturation magnetization, coercivity, remanance magnetization etc. magnetic properties are measured using pulse field magnetic hysteresis loop tracer supplied by Magenta Company (Mumbai). The measurements were carried out at room temperature.The magnetic moment per formula unit in Bohr magneton (n_B) is calculated by using the relation,

$$n_B = \frac{M_W \times M_S}{5585} \quad 1.1$$

Where M_W is molecular weight of the composition and M_S is saturation magnetization.

Result and Discussion:

The ferrite samples are magnetically characterized by its saturation magnetization, Bhormagneton and Curie temperature. The saturation magnetization and Bhormagneton can be obtained using hysteresis loop technique. The values of saturation magnetization (σ_s) and Bhormagneton (n_B) are obtained at room temperature for all the samples. The curves are shown in fig 1.1 (a,b,c). The values of both saturation magnetization (σ_s) and Bhormagneton (n_B) are presented in Table 1.1. The variation of Bhormagneton (n_B) with the Si^{4+} content x is shown in fig 1.2. From Fig. 1.2 it is observed that Bhormagneton n_B initially increases up to x = 0.2 and thereafter it decreases with increase in Si^{4+} content x. The decrease in Bhormagneton is linked with the decrease in A-B interaction. In spinel ferrite three kinds of interaction exist viz. A-A, B-B and A-B interaction. Among the three interactions A-B is dominant over A-A and B-B interaction. From the cation distribution it is clear that Si^{4+} replaces the magnetic ions Fe^{3+} from A-site, the magnitude of A-site magnetic moment decrease but the difference in M_A and M_B increase as n_B increases. Therefore initial increase in n_B with Si^{4+} content x can be explained on the basis of Neel's theory [6]of two sub-lattice; but decrease in n_B after x>0.2 indicates the possibility of non-colinear spin structure of the system. According to Neel's model the Neel magnetic moment n_B^N is given by

$$n_B^N = M_B - M_A \qquad 1.2$$

Where, M_B and M_A denotes the magnetic moment of octahedral [B] site and tetrahedral (A) site respectively. M_B and M_A can be independently calculated by assuming the magnetic moments of the cations present at B and A site.

In the present system $Ni_{0.7+x}Zn_{0.3}Si_xFe_{2-2x}O_4$, Zn^{2+}, Si^{4+} [7] and a tiny part of Ni^{2+} ions are occupied in A-site. Remaining part of Ni^{2+} and tiny part of Zn^{2+} are occupied in B-site [8]. Fe^{3+} occupies both A and B site. Taking into account the magnetic moments of Ni^{2+}, Zn^{2+}, Si^{4+}, Fe^{3+} as $2.85m_B$, $0m_B$, $0m_B$ and $5.92m_B$ respectively, the Neel's magnetic moment was calculated and the values are given in Table 1.1. Comparing the observed and calculated values of Bhormagneton it is clear that observed and calculated values are not in good agreement with each other for all the samples under investigation. This suggests that structure is non-collinear throughout the range studied, which is due to the presence of non magnetic Zn^{2+}, Si^{4+} ions in A-site. On account of similarities of present system and other Zn^{2+} substituted system [9, 10, 11] and Si^{4+} substituted [7], it is reasonable to assume Yafet-Kittle [12]type of magnetic ordering in the present system.

It is clear that the magnetization of the present system for x = 0 to x = 0.2 can be explained on the basis of Neel's theory. And the magnetization for x > 0.2 can be explained on the Y-K angle theory. The Y-K angle exists from x = 0.2. It increases with increases in Si^{4+} content x. This variation of Y-K angle with content of Si^{4+} is in good agreement with the literature [13]. Table 1.1 also shows the values of molecular weight of samples.

Conclusions:

From magnetization studies, it may be concluded that the increase in saturation magnetization s_s up to x = 0.2 has been satisfactorily explained on the basis of Neel's theory of two sub-lattice model while the decrease in magnetization for x $\geq$ 0.3 by three sub-lattice model of Yafet-Kittle theory.

Table 1.1

Molecular Weight(M), Magnetization saturation (σ_s)and magneton number (n_B) of the system $Ni_{0.7+x}Zn_{0.3}\,Si_xFe_{2-2x}O_4$

Comp. X	Molecular Weight M gms	Saturation Magnetization (σs or Ms)	Magneton Number (η_B) Obs.	Magneton Number (η_B) Cal.	Yafet-Kittle Angle (degree)
0.0	236.39	164.93	3.789	4.779	----
0.1	233.90	145.56	3.488	5.238	----
0.2	231.41	168.65	5.289	5.578	14.715
0.3	228.91	145.28	4.197	5.984	37.720
0.4	226.42	104.13	2.906	6.390	42.616
0.5	223.93	97.15	2.539	6.796	58.399
0.6	221.40	67.58	1.839	7.203	71.747

Fig. 1.1.: (a, b, c) Hysteresis loop for the system $Ni_{0.7+x}Zn_{0.3}\,Si_xFe_{2-2x}O_4$

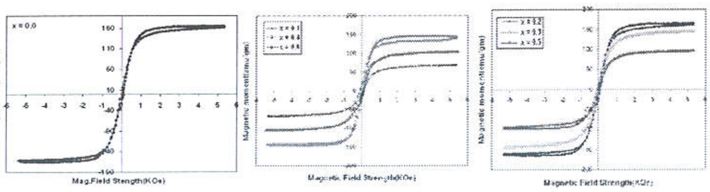
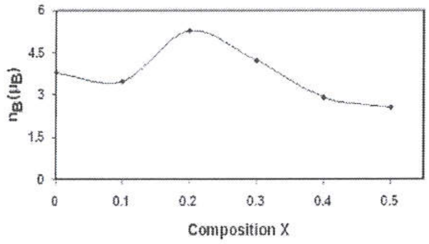


Fig. 1.2: Variation of ' ì$_B$ ' with Si^{4+} Content x of the System $Ni_{0.7+x}Zn_{0.3}Si_xFe_{2-2x}O_4$



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