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Magnetic Properties of Ni-Zn Ferrites by Citrate Gel Method

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ABSTRACT

Ni-Zn ferrite with a nominal composition of $Ni_{1-x}Zn_xFe_2O_4$ (x = 0, 0.2, 0.6, 0.8, 0.9) are prepared by citrate gel method and characterized by X-ray diffraction. Magnetic properties of all samples are obtained by using VSM (Vibrating Sample Magnetometer) in the range of 10 Koe. The saturation magnetization values of the samples are carried out from the B-H loop. The effect of composition on saturation magnetization and magnetic moment are studied in this paper. The results showed that Saturation magnetization and magnetic moment values increases gradually as Zn^{2+} composition increases, it reaches maximum value 70.28 emu/gm for (x = 0.6) and decreases further with increasing Zn^{2+} composition.

Keywords: Ni-Zn Ferrites; Citrate Gel Method: Vibrating Sample Magneto Meter; Saturation Magnetization; Magnetic Moment

1. Introduction

Nickel-Zinc ferrites are considered as one of the most versatile soft ferrites because of its high resistance and low eddy current losses [1]. Mixed Ni-Zn ferrite has been commercially used in radio frequency circuits, high quality filters, rod antennas and transformer cores [2,3]. Ni-Zn ferrite is mixed spinel in which the tetrahedral (A) sites are occupied by Zn^{2+} and Fe^{3+} ions, and the octahedral sites (B) are occupied by Ni^{2+} and Fe^{3+} ions in the spinel formula AB_2O_4. The magnetic & dielectric properties depend on this distribution of these ions on tetrahedral and octahedral sites. This distribution is different when the ferrite is synthesized at low temperature [4]. It is also believed that addition of Zn^{2+} ions alter the saturation magnetization, lattice parameter and Curie temperature. Several researchers synthesized Ni-Zn ferrite by conventional methods like double sintering method, solid state reaction method, and chemical co precipitation method, hydro thermal process etc. In this context, the objective of this work is to synthesize zinc doped nickel ferrite produced by Citrate gel method and to study their magnetic properties.

2. Experimental

Five different compositions of $Ni_{1-x}Zn_xFe_2O_4$ with x = 0.0, 0.2, 0.6, 0.8, and 0.9 are prepared by citrate gel method. The citrate process [5,6] is simple, easy and doesn't require any elaborate and expensive experimental setup. The main advantages of this method is

1) Capacity to yield a homogenous mixture of the constituent ions.

2) As no ball milling is required in this process, there is a little scope of contamination of materials.

3) In case of conventional methods, there is a possibility of introducing iron impurities during milling this leads inhomogenity in sample, which affects the magnetic property.

4) This is a simple method which offers a significant saving in time and energy consumption.

The starting materials used in this preparation are nickel nitrate (Merc, India), zinc nitrate (Merc, India), iron (III) citrate (Merc, India) and citric acid (Merc India) having molar ratio of 1:3 were dissolved in deionized water. Citric acid acts as chelating agent and helps in the homogenous distribution of metal ions. The pH of the solution is adjusted to 7 by using ammonia solution. The solution was uniformly heated at 373 K with constant stirring to transform it into a gel and the dried gel was obtained by de hydration process. The dried gel was combusted with evolution of gases and resulted in formation loose powder. This powder is subjected to micro wave sintering at 1000˚C for 30 minutes to get the final product. The X-ray diffraction patterns of the ferrite powder was taken on powder X-ray diffractometer (X-rd) using Cu-K_α radiation. The Magnetic measurements was carried out by using Vibrating Sample Magneto meter (VSM) in the range of 10 Koe.

3. Results & Discussions

The X-ray diffractogram of Ni-Zn ferrite is shown in **Figure 1**, which reveals a single phase cubic spinel structure. The lattice parameter of

$$a = d\left(h^2 + k^2 + l^2\right)^{1/2} \quad (1)$$

where, a = lattice constant,
d = inter planar distance and,
(h, k, l) are the Miller indices.

The variation of lattice parameter with Zn^{2+} composition is shown in the **Figure 2**. From the figure it can be

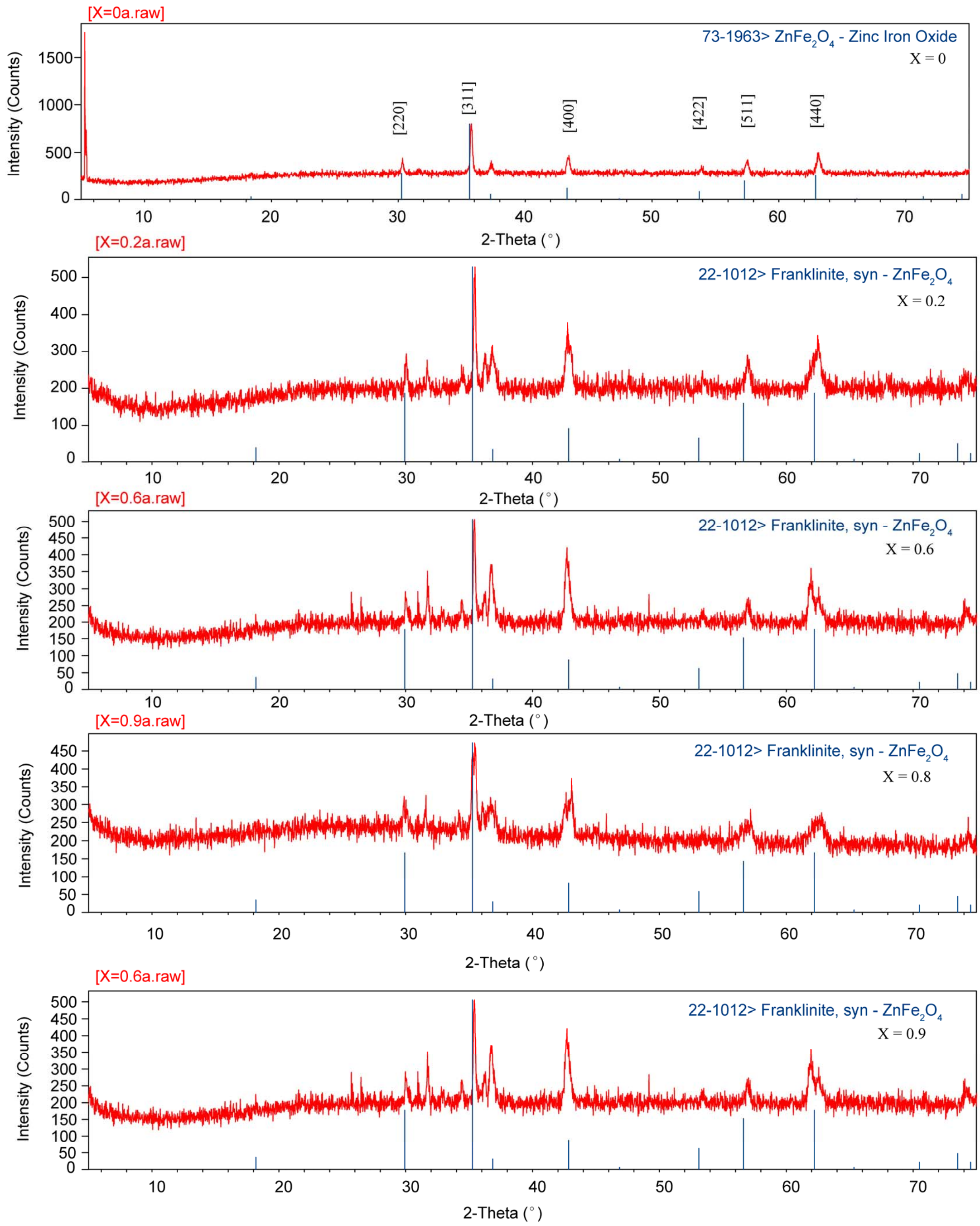


Figure 1. X-ray diffraction studies of mixed Ni-Zn ferrites.

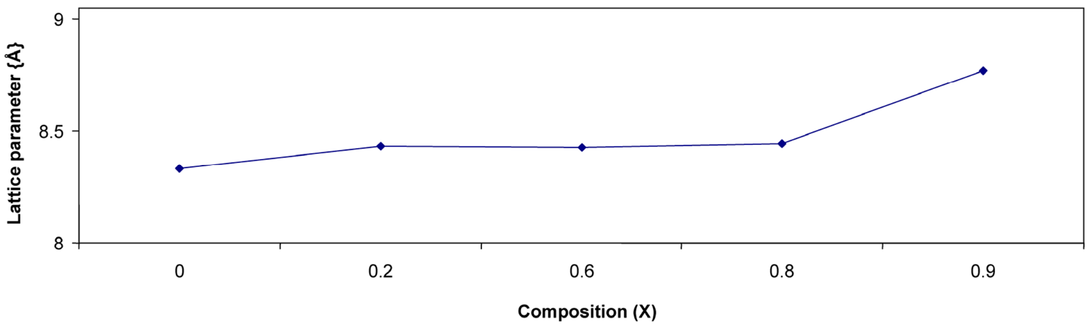


Figure 2. Variation of lattice parameter with composition.

seen that lattice parameter increases with Zn^{2+} composition. There by it indicating that the Ni-Zn ferrite system obeys Vegard's law [7]. A similar variation also observed by Ravinder in case of Cu-Zn ferrites [8]. This variation can be explained on the basis of ionic radius of Zn^{2+} (0.82 Å) is greater than Ni^{2+} (0.78 Å).

3.1. Magnetic Properties

From the VSM data, hystersis loops are plotted as shown in the **Figure 3**. The variation of saturation magnetization with composition is discussed. It can be seen from the table, that the value of saturation magnetization increases gradually from X = 0.0 to 0.6 and reaches to the maximum value of 70.28 emu/gm for X = 0.6 composition and then decreases gradually while Zn^{2+} composition increases. The behavior of this plot is similar to the [9]. The dependence of saturation magnetization is explained in terms of spin-disorder and spin-canting. In mixed Ni-Zn ferrite, the Zn^{2+} ions concentrate preferentially in the A site and the Ni^{2+} ions in *B* site in cubic spinel lattice. When the concentration of Fe^{3+} ions in the *A* site is diluted by low concentration of diamagnetic substances such as Zn^{2+}, the net magnetization increases. However magnetization decreases at higher level doping. The reason for this nature is that low Zn^{2+} concentration reduce the no of spins occupying the *A* sub lattice, causing the net magnetization increases. As the Zn^{2+} content increases the exchange interactions are weakened and the *B* spins are no longer held rigidly parallel to the few remaining *A* spins. The decrease in *B* sub lattice moment, interpreted as spin departure from co linearity causes the effect known as canting. Sattar [10] also described this effect in samples of Cu-Zn ferrite.

3.2. Magnetic Moment

Magnetic Moment is calculated in Bhor Magnetron using the following relation [11] and tabulated in the **Table 1**.

$$m_B = \frac{M \times Ms}{5585},$$

M = Molecular weight of particular composition,

Ms = Saturation Magnetization.

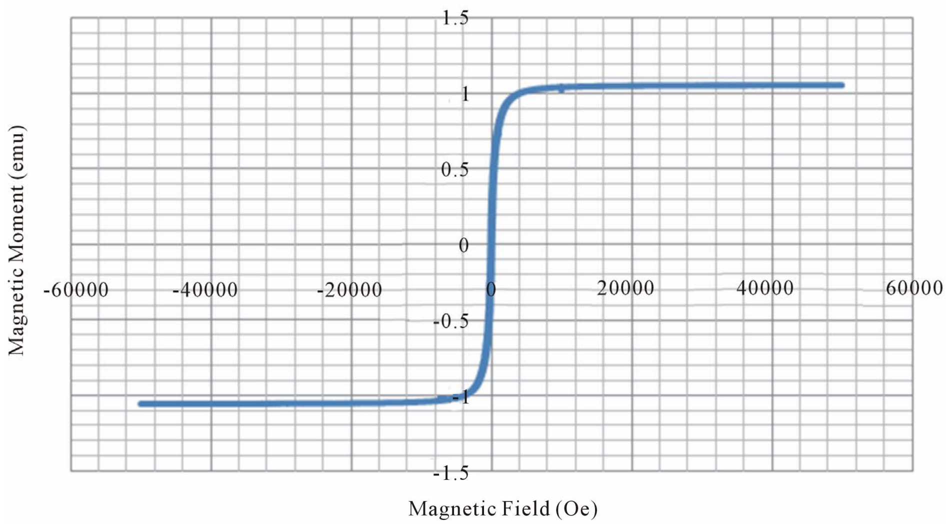
It can be seen from the table that the ferrite with composition $Ni_{0.4}Zn_{0.6}Fe_2O_4$ shows highest value of magnetic moment. It is evident from the **Table 1**, that the magnetic moment increases with Zn^{2+} composition from X = 0.0 to X = 0.6 reaches to maximum value 70.28 at X = 0.6 and then decreases. It can be concluded that as Zn^{2+} replaces magnetic ions from "*A*" sites. The magnitude of *A* site moment decreases but the difference between the *A* site and B site moment increases, as a result magnetic moment increases but the decrease in magnetic moment after X = 0.8 indicates the possibility of canted spin (non-collinear) structure in the present system. The decrease in magnetic moment with increase Zn^{2+} concentration indicating ferromagnetic behavior which decrease with increasing Zn^{2+} composition [12].

4. Conclusion

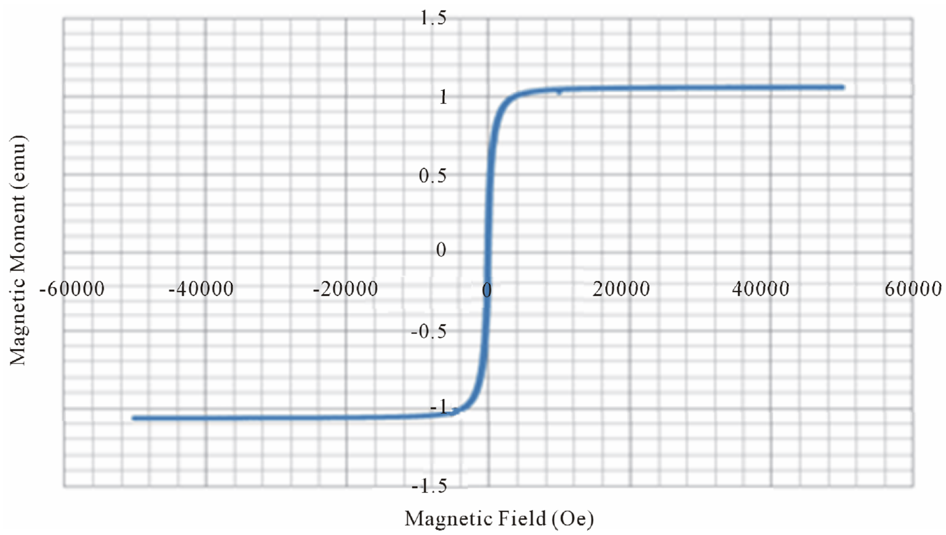
A series of Ni-Zn ferrite with the composition X = 0.0, 0.2, 0.6, 0.8, and 0.9 are prepared by using citrate precursor method. The lattice parameter increases as Zn^{2+} compositions is increases, the ferrite with X = 0.9 shows highest value of lattice parameter. The values of saturation magnetization, magnetic moment increases gradually from X = 0.0 to X = 0.6 reaches the maximum value at X = 0.6 and then decreases as Zn^{2+} composition is increases.

Table 1. Values of the Saturation magnetization and Bhor magnetron (μ_B) as a function of composition.

Composition	Saturation Magnetization (emu/gm)	μ_B (Bhor magnetron)
$NiFe_2O_4$	40.32	1.69
$Ni_{0.8}Zn_{0.2}Fe_2O_4$	42.79	1.80
$Ni_{0.4}Zn_{0.6}Fe_2O_4$	70.28	2.99
$Ni_{0.2}Zn_{0.8}Fe_2O_4$	58.26	2.55
$Ni_{0.1}Zn_{0.9}Fe_2O_4$	44.40	1.91


1.5
1
0.5
0
-0.5
-1
-1.5
-60000
-40000
-20000
0
20000
40000
60000
Magnetic Moment (emu)
Magnetic Field (Oe)

X = 0.0


1.5
1
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-1
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20000
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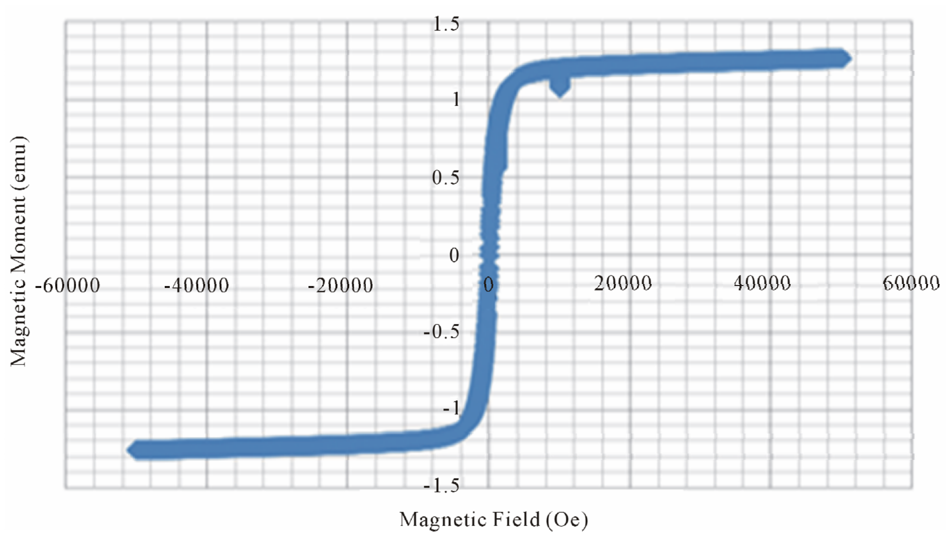
60000
Magnetic Moment (emu)
Magnetic Field (Oe)

X = 0.2


1.5
1
0.5
0
-0.5
-1
-1.5
-60000
-40000
-20000
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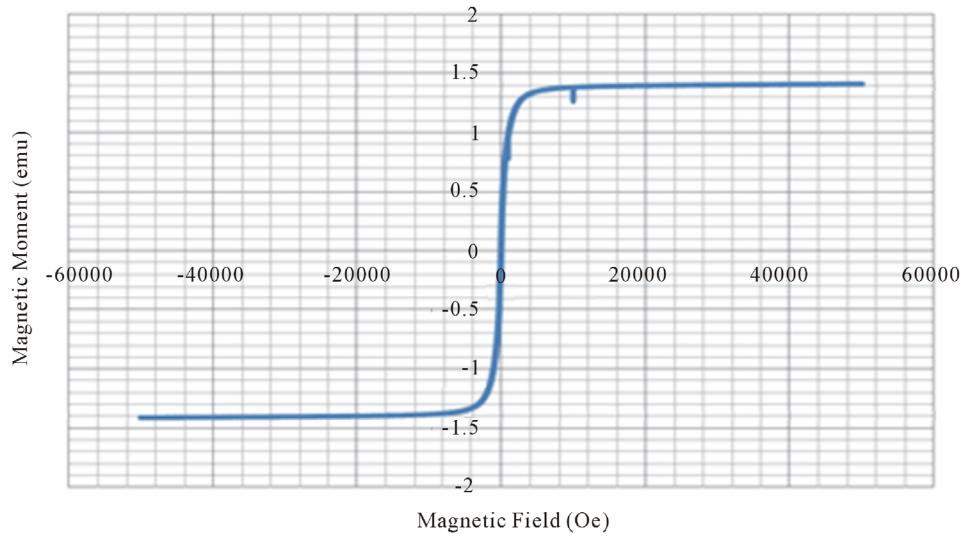
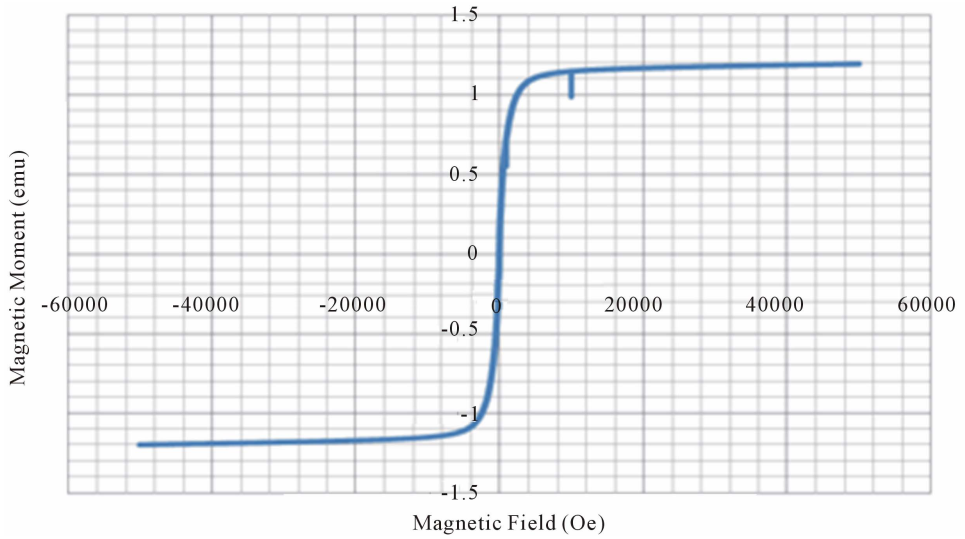
20000
40000
60000
Magnetic Moment (emu)
Magnetic Field (Oe)

X = 0.6



X = 0.8



X = 0.9

Figure 3. Magnetic hysteresis loops drawn between magnetic field and magnetic moment.

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