Magnetic Properties of Tin Substituted Magnesium - Zinc Ferrites

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Abstract: ***The polycrystalline samples of mixed ferrites $Mg_{0.7+x}Zn_{0.3}Sm\cancel{x}Fe_{2-2x}O_4$ with x = 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5 were prepared by ceramic method. Single phase formation is confirmed by x-ray diffraction. It is seen that, for all samples the lattice constant increases with increase in Sn content. This is due to larger ionic radii of magnesium and Tin compared to that of Fe^{3+}. In the Sn substituted Magnesium Zinc ferrite system magnetic moment value increases with increasing Sn. The variation of ac-susceptibility with temperature shows that the present studied samples represent MD states.***

Keywords: Ferrite, x-ray diffraction, lattice constant, magnetic moment, magnetisation, susceptibility an multi domain

1. Introduction

Ferrites are magnetic oxides. They play an important role in the electronic industry. For high frequency applications, high magnetization, high resistivity and low loss ferrites are required. The magnetic parameters like saturation magnetization (M_s), Coercive field (H_c), remanence ratio and Permeability (μ) are related with its Hysteresis behavior. Hysteresis study of ferrites therefore provides an important data related to these magnetic properties. Nichel-Zinc ferrites show good magnetic properties for technical applications [1]. Reztescu and Rezlescu reported the influence of additives on the properties of Ni-Zn ferrites [2]. Studies have shown that addition of tetravalent ions like Sn increases the resistivity and modifies the microstructure in Mg-Zn ferrites. However these substituents will show canting and super paramagnetic behavior. The magnetization study on tetravalent substitution has been carried out by many workers on Magnesium mixed ferrites. [3] The canting is also observed from these studies. Khan an Misra [4] were use Mossbaur results for the interpretation of the anomaly. The aim of present work is to study the effect of Sn substitution on magnetization and Permeability on Magnesium-Zinc Ferrites.

2. Experimental Details

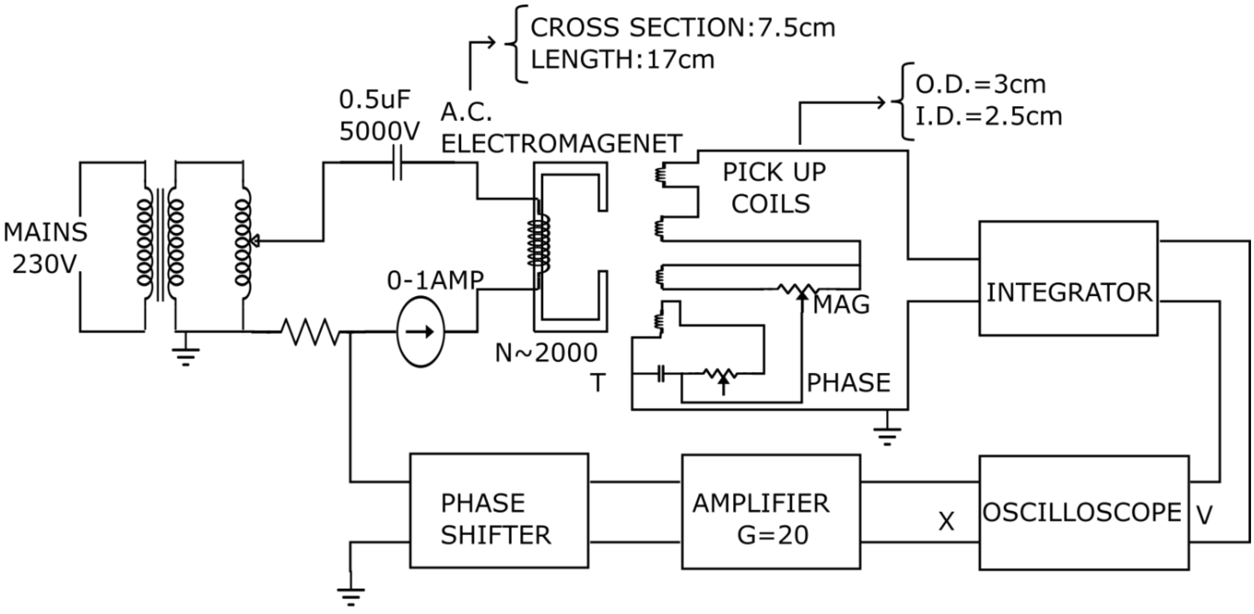
The ceramic method is the simplest of all an widely accepted as it is economical also. Hence this method is preferred in the present work. AR grade ferric oxides, Zinc oxide, Magnesium oxide, Tin oxide are use as raw materials. They are weighed accurately to require proportions using single pan semi micro balance having a least count of 0.001 gm in order to prepare the ferrite system with general formula $Mg_{0.7+x}Zn_{0.3}Sm\cancel{x}Fe_{2-2x}O_4$ with x = 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5 The mixtures were pre sintered at 700°C for 10 hour. Pre sintered powder was ground and pellets were formed under a pressure of about 10000 kg applied for 4 – 5 minutes each and subjected to final sintering at 1100°C for 24 hr.

Confirmation of single-phase formation was ensured by X – ray diffraction studies. Magnetic measurements were made on a high field loop tracer and on low field ac-susceptibility set up. The initial permeability as a function of temperature at 1 kHz was measured in the temperature range from room temperature to 500°C.

3. Instruments and Measurements

X – Ray diffraction patterns were obtained with the Philips PW1830 X-ray diffractometer using Nickel – filtered Cu – Kα radiation. XRD patterns were taken at room temperature in the 2Θ range of 10° to 80° . the step size and the scan were set at 0.1 and 0.2° per minute respectively.

The Hysteresis loop tracer consists(as shown in figure 1) of an ac electromagnet operating on 50 Hz main supply with the help of which a sinusoidal magnetic field of maximum peak value 3500 oersted is produced. The signal from the balancing coil after integration is proportional to the magnetic moment of the specimen. A signal proportional to the magnetic field is fed to the



BLOCK DIAGRAM OF HYSTERSIS LOOP TRACER USING A.C. ELECTROMAGNET

horizontal plates of the oscilloscope and magnetic moment is fed to vertical plates of an oscilloscope. Thus, CRO displays magnetic moment versus field which is a Hysteresis loop. The vertical deflection can be calibrated in terms of magnetic moment in emu and horizontal scale in oersted per division.

A specimen kept at the center of a balanced double coil which itself is at the center of Helmoltz coil system producing an alternating magnetic field behaves like an alternating dipole and induces a differential emf in the double coil. The current to the Helmoltz coil is supplied by a oscillator and a high quality power amplifier. The signal induced in the double coil, which is proportional to the rate of change of magnetic moment of the specimen is amplified and read out on a digital voltmeter. The sample was enclosed in a glass jacket containing the platinum – rhodium thermocouple to sense the temperature. The measurements were taken from room temperature up to 500^{o}C. the magnetic moments were observed for different constant temperature.

4. Results and Discussion

X -Ray Diffraction

The single phase formation of the samples is confirmed by X-ray diffraction. In an x-ray diffraction pattern of any spinel ferrite the peak (311) is very prominent and can be identified easily. The corresponding values of 2ϴ is noted from the diffraction pattern. Using the values of 2ϴ, (hkl) and λ and using the equations

$2d \, Sin\Theta = n\lambda$

and $d = \frac{a}{\sqrt{h^2+k^2+l2}}$

Lattice parameter ‘a’ can be calculated and using these a values ‘d’ values can be calculated.

In case of the system $Mg_{0.7+x}$ $Zn_{0.3}$Sm~~x~~$Fe_{2-2x}O_4$ from table.1 it is observed that lattice constant increases with increase of Sn content. The ionic radii of Mg^{2+}, Sn^{4+} an Fe^{3+} 0.75 A^o, 0.69 A^o an 0.67 A^o respectively. In present system the two ions of Fe^{3+} are substitute by one Mg^{2+} an another by Sn^{4+}. Therefore the increase in lattice constant can be ascribed to larger ionic radii of magnesium and Tin compared to that of Fe^{3+}.

Magnetization

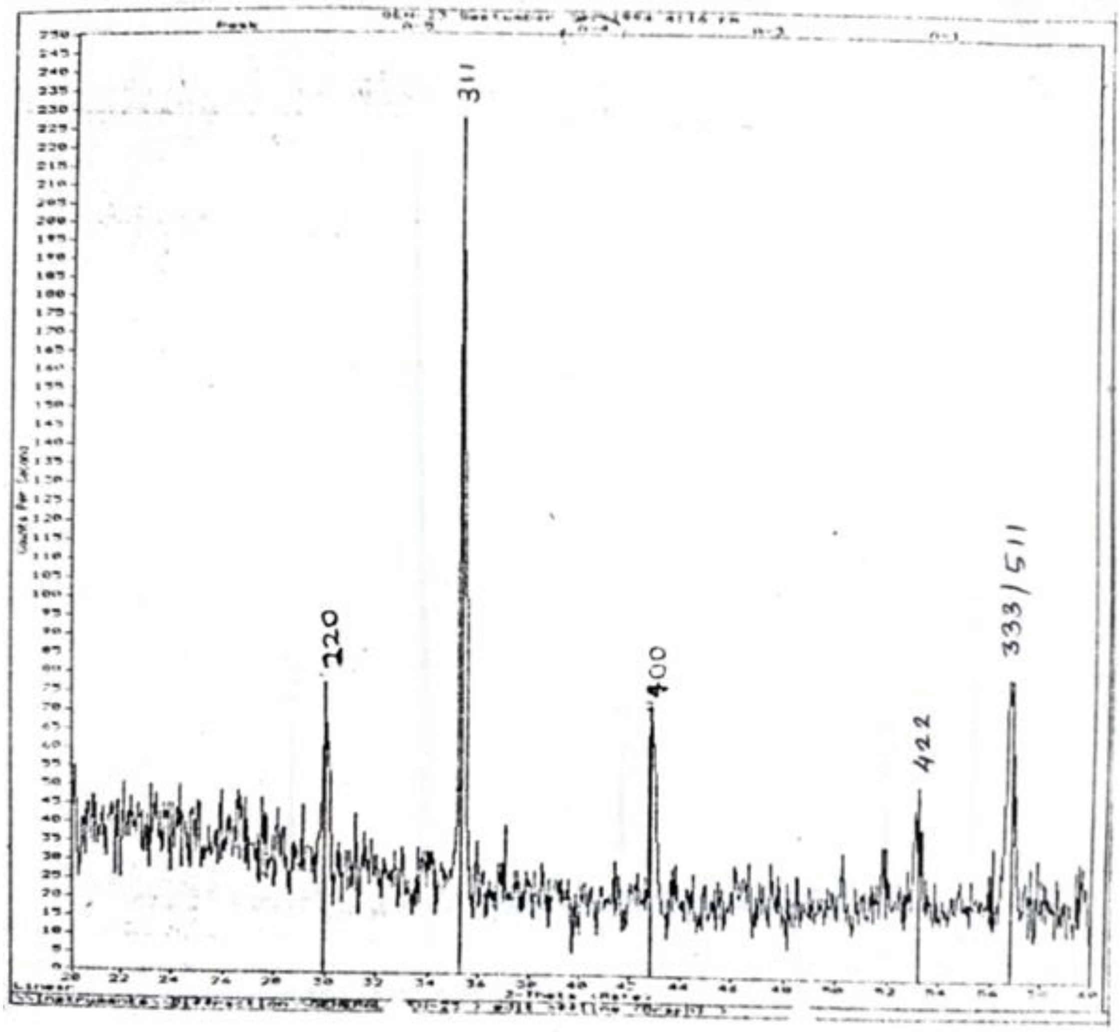
The values of saturation magnetization and magnetic moment at room temperature are noted in table.2. in the Sn substituted Mg-Zn system magnetic moment value increases with increasing Sn. Similar results are observed in many ferrites containing Zinc and tetravalent ions.

The variation of magnetization in ferrites can be understood in terms of cation distribution. There are three kind of exchange interaction exists in Spinel, namely A-A, B-B and A-B interaction. Out of these A-B interactions is more effective and stronger. The net magnetic moment of lattice is given by the vector sum of the magnetic moment on A and B sublattices. The magnetization behavior and cation distribution in ferrites is explained by Verway and Hillman, Gorter, Good enough and LocbDunitz and Orgel and Miller [5, 6, 7, 8,9,]. Miller has observed that, tetravalent ions such as Sn would occupy B site. Therefore, by considering the site preference energies and calculated cation distribution for Mg-Zn ferrite is suggested as below.

$[Zn_{0.}Mg_yFe_{0.7-y}]$ $[Ni_{0.5+x}Fe_{1.3-2x+y}Mg_{0.7-y+x}Sn_x]$

The cat ion distributions of Magnesium ferrite can be change with temperature as well as composition, spatially Cu an Mg ferrites are temperature sensitive.

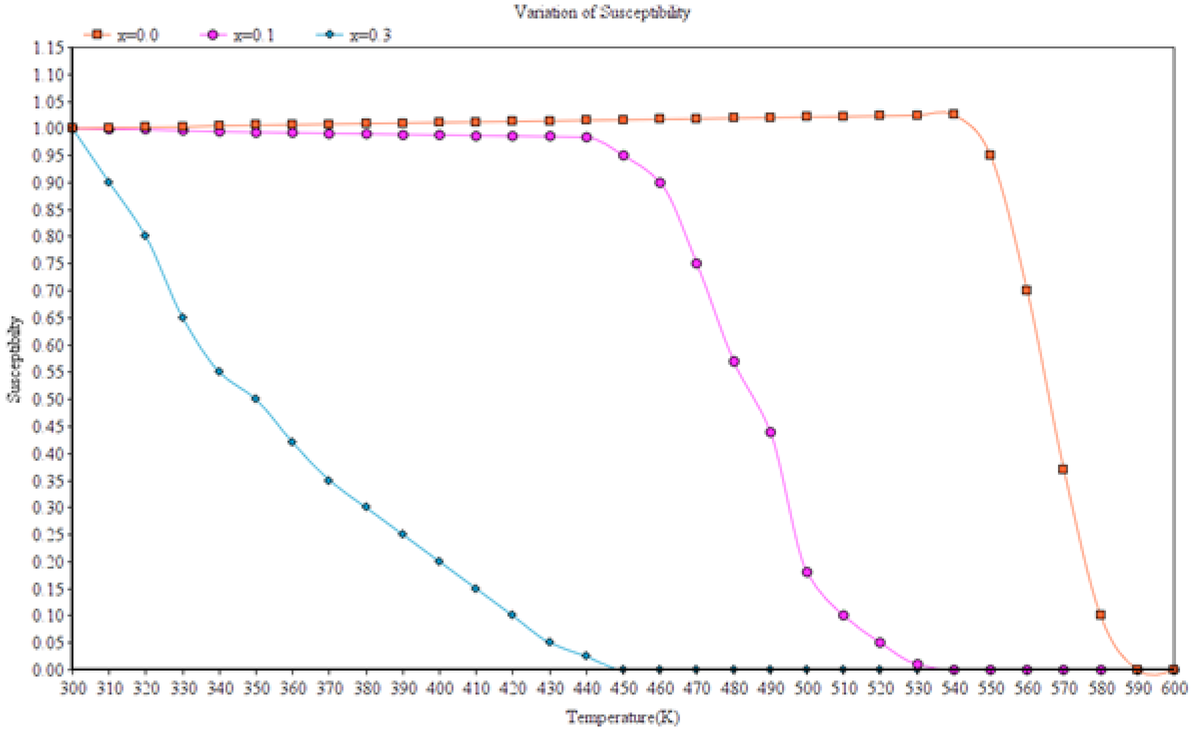
The proposed cat ion distribution is taken for the further analysis with the help of neutron diffraction study. Reitveld profile of neutron diffraction, accurately determines the cat ion distribution and the magnetization behavior of these ferrites [11]



X-ray diffraction pattern of $Mg_{0.7+x}Zn_{0.3}SmxFe_{2-2x}O_4$

AC-Susceptibility

The variation Normalized ac-susceptibility with Temperature is as shown in figure.2 and Curie temperature is determined from these plots and noted in table.2. from the nature of the plots following observations are made



1) Ac-susceptibility remains almost constant in all the samples until temperature reaches near to curie temperature.
2) Ac-susceptibility drops suddenly to zero at curie temperature.
3) No peak in ac-susceptibility plot is observed in the range of temperature studied.
4) A tailing effect is observed for higher contents of substitution.

A polycrystalline ferrite may consist of three types of domain states such as MD (multidomain) SD (single domain) and SP (superparamagnetic). It has been shown that the susceptibility for MD samples does not change with temperature and drops at curie temperature. For SP samples susceptibility decreases with temperature and becomes zero at curie temperature. In the case of SD particles susceptibility increases and shows a maximum near curie temperature.

Based on the above concepts and nature of variation of ac-susceptibility with temperature. It can be concluded that the present studied samples represent MD states.

Radhakrishnamurthy et. Al [10] have explored the magnetic behavior of ferrites, from the observations it is concluded that the tailing effect in ac-susceptibility with temperature plot may be due to impurity phases or due to canting effect. In general, the decrease in curie temperature values is observed with increasing concentration of Ti. Curie temperature of ferrites have closely related to number of Fe-O-Fe linkages. In the present case 2Fe is replaced by Mg + Sn which ultimately decreases the number of Fe-O-Fe linkages. In case of nonmagnetic substitutions there is no contribution from A-B interaction in the spinel. Hence curie temperature decreases with increase in Sn.

Table 1: Physical constants of the system $Mg_{0.7+x}Zn_{0.3}Sm\cancel{x}Fe_{2-2x}O_4$

Composition	Molecular weight gm/mole	Measured density (g/cc)	X-ray density (g/cc)	Lattice parameter
$Mg_{0.7}Zn_{0.3}Fe_2O_4$	212.30	4.04	4.77	8.390
$Mg_{0.8}Zn_{0.3}Sn_{0.1}Fe_{1.8}O_4$	215.43	4.06	4.79	8.413
$Mg_{09}Zn_{0.3}Sn_{0.2}Fe_{1.6}O_4$	218.56	4.10	4.86	8.432
$Mg_{1.0}Zn_{0.3}Sn_{0.3}Fe_{1.4}O_4$	221.69	4.21	4.88	8.452
$Mg_{1.1}Zn_{0.3}Sn_{0.4}Fe_{1.2}O_4$	224.82	4.24	4.89	8.479

Table 2: Magnetization, magnetic moment and curie temperature for the system $Mg_{0.7+x}Zn_{0.3}Sm\cancel{x}Fe_{2-2x}O_4$

Composition	Magnetization emu/gm	Magnetic moment in Bohr magneton	Curie Temperature K
$Mg_{0.7}Zn_{0.3}Fe_2O_4$	137.18	1.72	590
$Mg_{0.8}Zn_{0.3}Sn_{0.1}Fe_{1.8}O_4$	122.93	1.55	520
$Mg_{09}Zn_{0.3}Sn_{0.2}Fe_{1.6}O_4$	100.95	1.12	490
$Mg_{1.0}Zn_{0.3}Sn_{0.3}Fe_{1.4}O_4$	57.30	0.68	450
$Mg_{1.1}Zn_{0.3}Sn_{0.4}Fe_{1.2}O_4$	38.48	0.55	425

5. Conclusion

These ferrites substituted with Sn exhibit high permeability and multi domain states. obse It is concluded that the tailing effect in ac-susceptibility with temperature plot may be due to impurity phases or due to canting effect.

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