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Structural and magnetic properties of Zn-Mg-Ti ferrite system

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ABSTRACT

Polycrystalline spinel ferrites of $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ (where t=0.05 and x=0.2, 0.4, 0.6) series are prepared with traditional double sintering ceramic method. The structural and surface morphological studies are carried out by using X ray diffraction and scanning electron microscope. An IR studies shows the absorption bands at around 600 cm^{-1} (v_1) and 400 cm^{-1} (v_2); this indicate the presence of tetrahedral and octahedral group complexes, respectively. Magnetization curves taken at room temperature showed that saturation magnetization increases with increase in Zn content. The value of magnetic moment per formula unit increases up to x=0.4 and the sample become nonmagnetic for x=0.6   © 2011 Trade Science Inc. - INDIA

INTRODUCTION

None other than soft ferrites have been found to be an appropriate choice of magnetic cores in transferring energy effectively with minimum losses over a wide frequency range from kilohertz to gigahertz because of their high saturation magnetization coupled with high electrical resistivity. The studies of electric and dielectric behaviour are equally important as those of the magnetic properties, from both the applied and fundamental research points of view[1]. It is well known that the intrinsic properties of ferrites largely depend on chemical composition and preparation conditions[2]. By introducing relatively small amount of divalent metal ions, the structural, magnetic and dielectric properties of ferrites can be modified[3,4]. $MgFe_2O_4$ is a partially inverse ferrite and is n-type of semiconductor. $ZnFe_2O_4$ is also n-type semiconductor so addition of Zinc in Magnesium is expected to retain n-type conduction[5]. The magnetization in Manganese ferrite is enhanced by addition of Zinc. Recent data reports an increase of resistivity of ferrite with the tetravalent ion substitution (like Ti^{4+}, Sn^{4+} and Ge^{4+})[6] Focusing on these objectives, the $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ (where t=0.05 and x=0.2, 0.4, 0.6) series is prepared and their structural, magnetic and electric properties are reported.

EXPERIMENTAL DETAILS

Sample preparation

All the compositions of $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ (where t=0.05 and x=0.2, 0.4, 0.6) system were prepared by double sintering ceramic method. The AR grade starting materials such as ZnO, MgO, TiO_2 and Fe_2O_3 were taken in the required stoichiometric ratio and milled for 3 hrs. in an agate mortar. The milled powders were pre-sintered at 700 °C for 8 h. These powders were uniaxially pressed in a die to form pellets (thickness of 2–3mm and diameter of 15mm) using hydraulic press. Polyvinyl alcohol (10% of its weight) was used as a binder during the formation of pellets. The resulting pellets were final sintered at 1000 °C for 4 h. The heating rate of 1 °C/min and natural cool-

ing was adopted for the both heat treatments.

Characterizations

The confirmation of single-phase formation was carried out by X-ray diffractometer (XRD) (Philips Model PW-3710) using Cr-Kα radiation (λ = 1.54056 Å). For electrical measurements, all the samples were painted on both sides with silver paste to ensure good ohmic contacts.

RESULTS AND DISCUSSION

X-ray diffraction

X-ray diffraction (XRD) patterns of $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ (where t=0.05 and x=0.2, 0.4, 0.6) are shown in figure 1. The XRD patterns reveal the polycrystalline nature of the sample with cubic spinel structure, confirmed by analyzing the patterns with JCPDS cards. It observed that, the lattice parameter (a) increases with increase of Zn content, which is attributed to the replacement of smaller ionic radii Mg^{2+} ions (0.75Å) by larger ionic radii Zn^{2+} ions (0.8Å) and thus obeys the Vegards law[7,8].
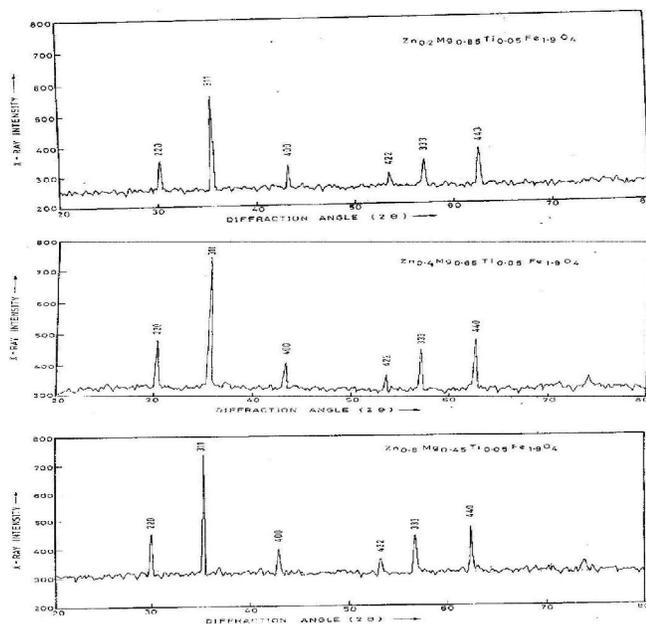

Figure 1 : X-ray diffraction (XRD) patterns of $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ system.

Theoretical density was estimated by using the relation[9],

$$D_x = \frac{8M}{Na^3} \qquad (2)$$

Where M is the molecular weight of ferrite, N is the Avogadro's number and a^3 is the volume of unit cell. It is observed that the X-ray density decreases with increase in Zn content.

Infrared (IR) spectroscopy

The IR absorption bands in ferrites (MFe_2O_4) mainly appear due to the vibrations of oxygen ions with cations. As the concentration of divalent metal ion increases in ferrites, it gives rise to structural change in spinel lattice. Figure 2 shows, the IR absorption bands for $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ compositions and the observed values of absorption bands are listed in TABLE 1. It shows that higher absorption bands are in the range from 590 cm^{-1} to 602 cm^{-1} and lower absorption bands in the range from 442 cm^{-1}- 450 cm^{-1} attributed to the stretching of intrinsic vibrations of the tetrahedral (A) and octahedral (B) sites of spinel lattice respectively. The differences in the band positions for tetrahedral site (ν_T) and octahedral site (ν_O) are expected because of the difference in Fe^{2+}- O^{2-} bond length for the tetrahedral site (0.189nm) and octahedral site (0.199nm) of the spinel lattice[10,11].

Scanning electron microscope

Scanning electron microscopy was used to study the surface morphology. Figure 3 shows SEM images for all the compositions of $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ system with heat treatment of 1000 ?C for 4 h. Figure 3 shows SEM micrographs of the $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ It is observed that samples consist of small pores with many contacts among the grains. The dense microstructure was well demonstrated by the density measurements. As the Zn content increased, sample become less denser which is in agreement with density measurements carried out by us.

Magnetic properties

Room temperature magnetic hystereses for all the compositions of $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ (where t=0.05 and x=0.2, 0.4, 0.6) system are calculeted. It is seen that the saturation magnetization *Ms* increases with increase of Zn content for Mg-Ti ferrite system up to x=0.4 and decreases after x=0.6. Actually, the *Ms* has to be decrease with the substitution of Zn^{2+} (Zero µB) for Mg^{2+} (2µB), but it is increasing with Zn showing an anomalous magnetic behaviour. This incongruity arises
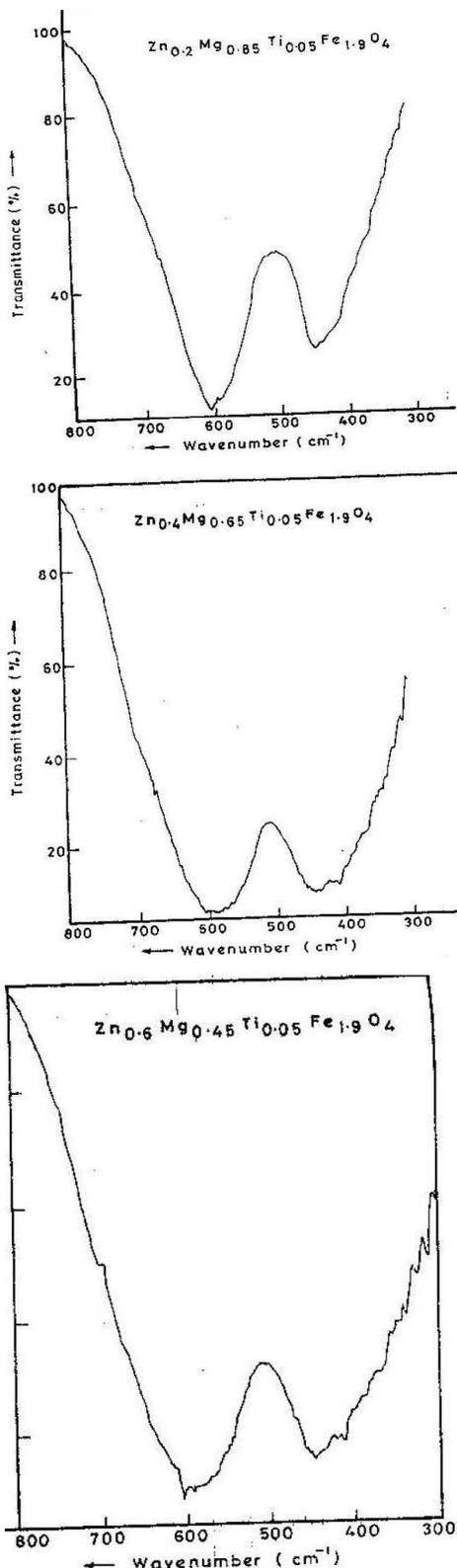
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Figure 2 : The IR absorption bands of $Zn_xMg_{(1-x+t)}Ti_tF_{2-2t}O_4$ system

mainly due to cation distribution of spinel lattice[12]. The increase in saturation magnetization can be well explained

TABLE 1 : Structural, infrared, and magnetic data of Mg-Zn-Ti ferrite system.

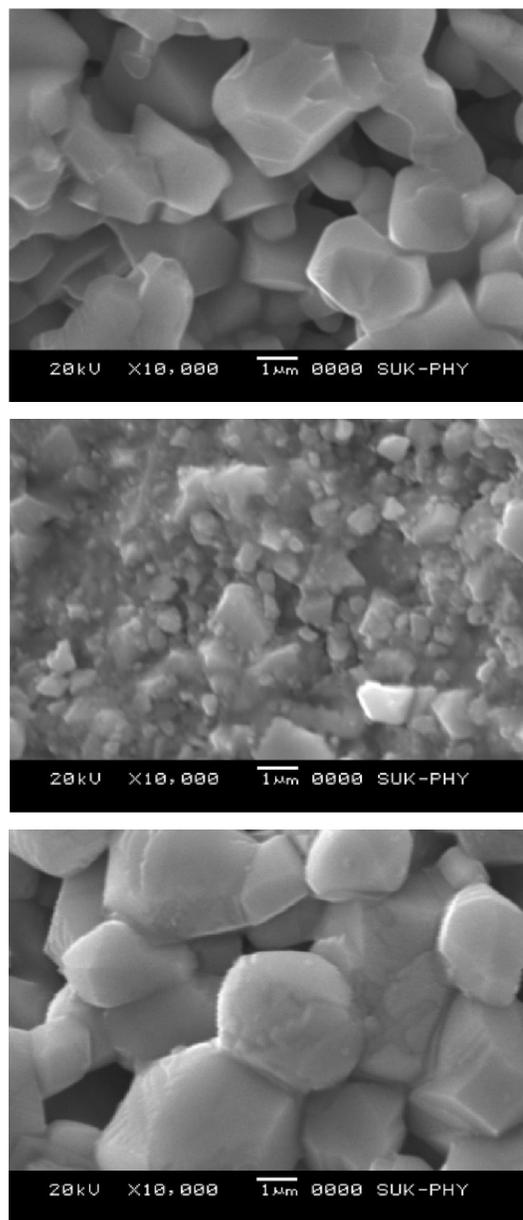| Composition (x)	A (Å)	X-ray Density Dx (g/cm³)	v_1 (cm⁻¹)	v_2 (cm⁻¹)	Hc (Oe)	Mr/ Ms (emu/gm)
0.2	8.35	4.69	590	442	291.61	0.36
0.4	8.36	4.87	604	445	211.50	0.30
0.6	8.42	3.49	602	450	-	-

Figure 3 : Scanning electron micrographs for $Zn_xMg_{(1-x+t)}Ti_tF_{2-2t}O_4$

with the help of Neel's two sublattice model according to which, saturation magnetization is given by the relation[13],

$$M_s = M_B - M_A \qquad (4)$$

Where. M_B and M_A are the magnetic moments of cations at B-site and A-site respectively. On the basis of this, we can say that magnetic moment of spinel lattice in ferrite is mainly dependent on magnetic ions present at A and B-sites. Assuming $MgTi_{0.05}Fe_2O_4$ as parent ferrite (for x = 0.0) As Zn prefers A-site it reduces the magnetic moment due to replacement of Mg ions. Thus increasing the total magnetization[14]. Magnetic moments of the formula unit are calculated by using the relation[2],

$$\mu_B = \frac{M \times M_s}{5585} \qquad (5)$$

Where M is the molecular weight of particular composition and M_s is saturation magnetization (emu/gm).

CONCLUSION

The $Zn_xMg_{(1-X+t)}Ti_tF_{2-2t}O_4$ (where t=0.05 and x=0.2, 0.4, 0.6) system have been successfully prepared by double sintering ceramic method. The X-ray diffraction and scanning electron microscope techniques confirm the phase formation and reveals the spinel cubic structure of the final product. The IR absorption spectra show the presence of two absorption bands in the Zn-Mg-Ti ferrite system which confirms the presence of two sublattices (A- site and B site). The saturation magnetization (Ms) of Mg-Ti system increases with the addition of Zn content.

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