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Preparation, Characterization and Magnetic Property Study of Gd3+ Substituted Mg-Zn Ferrites

KEYWORDS: Ferrites, Ceramic method, susceptibility, domain structure, Curie temperature

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ABSTRACT *Ferrites of ZnxMg1-xFe2-yGdyO4 (x=0, 0.2, 0.4, 0.8 and 1.0; y=0, 0.05 and 0.1) were prepared by usual solid state standard ceramic method. Characterizations were made by X-ray diffraction method and FTIR spectroscopy. Magnetic properties like temperature dependence normalized AC susceptibility and Curie temperature were studied. This study reveals that MgFe2O4 exibits multi domain structure with high Curie temperature On substitution of Zn2+ , it is found that Multi Domain (MD) structure changes to Single Domain (SD). Curie temperature also found to decrease due to decrease in A-B intraction. On substitution of Gd3+ in Mg-Zn ferrite system peak obtained in MgFe2O4 is supressed which is attributed to decrease in grain size and further decrease in Curie temperature is attributed to the decrease in B-B interaction.This is because Fe-Fe interaction is greater than Gd-Fe interaction at B-site*

1. Introduction

In ferrites, magnetic properties like permeability and susceptibility are found to depend on grain size, grain boundary and domain structure [1]. Thus to observe to changes in the internal structure of ferrites this study is more important. Soft ferrites consists of three types of domains like, Multimomain (MD), single domain(SD) and superparamagnetic(SP) particle, which mainly depends on substitutions [2]. These domain states can be distingushed by using the technique of low field AC sussceptibility [3]. The MD particles have domain walls [4] and magnetic changes takes place due to domain wall (DW) motion. As particle size decreases, formation of domain walls becomes energitcally unfavorable, then it is said to be single domain (SD) particle. In these mañgnetic changes do not takes place through DW motion but require the rotation of spins resulting in larger coersivity. As the particle size further decreases, spins are affected by thermal fluctuations and the system becomes SP particle. SP particle nature reduces magnetic character of the material. Cd^{2+} substitution is interesting substitutioin in the spinels[5]. Addition of Cr^{3+} in $NiFe_2O_4$ the domain structure changes from MD to SD [6]. Al^{3+} substitued mixed Cu-Cd ferrites exhibit mixture of SD and MD partices [7].

In this paper we investigated the domain nature in Gd^{3+} substituted and unsubstituted Mg-Zn ferrite system using low field AC sussceptibility measurements.

2. Expermental details

Spinel ferrites with general formula $Zn_xMg_{1-x}Fe_{2-y}Gd_yO_4$ (x=0, 0.2, 0.4, 0.6, 0.8 and 1.0; y=0, 0.05 and 0.10) were prepared by standard ceramic method using AR grade oxides of Fe_2O_3, MgO, ZnO and Gd_2O_3.These pure oxides were accurately weighed accordingly to weight ratio required in the final proportions on single pan microbalance. The same were mixed together and wet milled using acetone base. Dried powder of samples was prisintered at 700 ^{0} C for 10 hours and sintered at 1050 ^{0} C for 24 hours, cooled and powdered. The pellets of samples were formed by applying 10^6 Kg cm^{-2} using hydrolic press. The pellets were again sintered at 1050 ^{0} C for 24 hours for better compaction.

The powdered samples were characterised by XRD on philips computerised X-ray diffractometer (PW 3710) using Cukα radiation. The AC susceptibility measurments of ploycrystalline ferrite sample was made on Helmoltz double coil set up operated at 260 Hz with constant field of 7 0e, in the temperature range 300K to 800K. Platinum –Rhodium thermocouple is used to measure temperature of the powder sample. The Curie temperature of all the pelletized samples was measured by using modified Lorria-Sinha method.

3. Results and discussion

3.1 Characterization

Study of X-ray diffraction reveals that all the compositions under investigation were face centered cubic spinel structure. Typical X-ray diffractogram is presented in Fig.1.It is found that lattice constant increases with Zn^{2+} concentration. Such increase in the lattice constant due to addition of cadmium content was reported in the literature [5]. This increase in lattice constant is attributed to the difference in ionic radii of Zn^{2+} ion (1.03A^0) and Fe^{3+}ion (0.67A^0). On substitution on Gd^{3+} ion, the lattice constant found to decrease. This was also attributed to the difference in ionic radii.

Typical IR absorption spectrum is presented in Fig.2. IR absorption spectra of all the compositions show two dominant absorption bands one around 600 cm^{-1} (n_1) and other at 400 cm^{-1} (n_2) which are characteristic of ferrite family. The absorption band observed around 600 cm^{-1} (n_1) is due to the tetrahedral or A-sites and that of around 400 cm^{-1} (n_2) is due to octahedral or B-sites respectively. This confirms the formation of ferrites under investigation.

3.2 Normalized susceptiblity

Typical plot of normalized susceptiblity (χ/χ_{RT}) verses temperature is presented in the Fig.2. From this plot it is seen that for magnesium ferrite, the susceptibility slowly increases and reaches peak value with temperature and susddenly drops to zero. The sudden drop of χ/χ_{RT} curve shows the formation of single phase cubic spinel [8].The incresase in sussceptibility with peak values suggests there is existance of multidomain(MD)particles in the material [9]. The peak is found to suppresed with substitution of Gd^{3+} in $MgFe_2O_4$ and also Curie temparature (Tc) decreases with Gd^{3+} content. For the composition x = 0.2; y = 0, 0.05 and 0.1, susceptiblity is found to be independent on temperature upto Tc and after Tc it suddenly drops to zero. Such nature of curve indicates that the presence of SD particles in the materials [9]. Joshi et al [10] also reported similar behaviour in Mg-Zn ferrite system. The compositions with x = 0.4 and x = 0.6 for y = 0, 0.05 and 0.1 shows exponential decrease in susceptibility indicating SD to SP transition. The composition with x = 0.8 and x = 1 with y = 0 , 0.05 and 0.1 shows paramagnetic behaviour at and above room temperature. Curie tempratures (Tc) obtailned from susceptibility plots are presented table 1.

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The Curie temparature measurement of all the samples was also been carried out by the method suggested by Loria-Sinha [11] and also presented in the table 1. These valus are found to be in good agreement with the values obtained from temperature dependence of normalized susceptibility. On substitutiion of Zn^{2+} in $MgFe_2O_4$ Curie temperature found to decrease. This is because substituted Zn^{2+} ion invariably occupies tetrahedal (A) site, resulting into decrease in A-B intereaction [12]. The composition with x= 0.8 and 1.00 shows paramagnetic behaviour at room temparature, their Curie temperature lies below room tempetature. Substitution of Gd^{3+} ion, Curie temperature of each composition is found to decrease. This is attrbuted to dilution of B-B interaction[12]. On substitution Gd^{3+} ion occupies B-site replacing equivalent Fe^{3+} ions and so also decrease in magnetization at B-site.

4. Conclusions

From the study it found that $MgFe_2O_4$ exhibit multi domain structure and this structure is greatly affected by foreign substitution of Zn^{2+} and Gd^{3+} ions in it. The study shaows that on substitution of Zn^{2+}, domain structure changes from MD to SD while on substitution of Gd^{3+} it changes from SD to SP. On substution of Gd^{3+}, peak obtained in the graph of normalized susceptibility of $MgFe_2O_4$ is suppresed due to the decrease in grain size. Curie temperature a magnetic property also denpend on interactions among the ions was found to decrease on substitution of Zn^{2+} and Gd^{3+}, which is attributed to the dilution of A-B interaction as well as B-B interactions. In conclusion we can say that substitution of non magentic ions like Zn^{2+} and Gd^{3+} manetic preoperities decreases and also particle size decreases.

Fig.1 Typical X-ray diffractogram of $Zn_xMg_{1-x}Fe_{2-y}Gd_yO_4$ ferrites with x=0.4 and y=0.05.

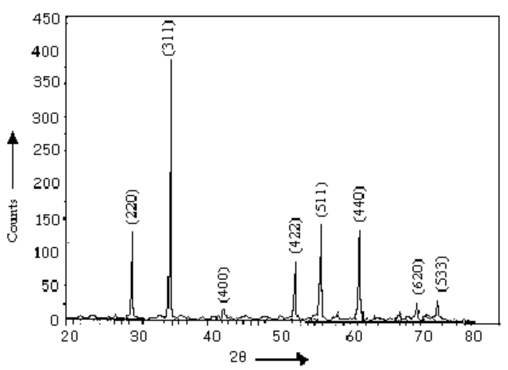

Fig.1 Typical X-ray diffractogram of $Zn_xMg_{1-x}Fe_{2-y}Gd_yO_4$ ferrites with x=0.4 and y=0.05

Fig.2 Typical IR absorption spectrum of $Zn_xMg_{1-x}Fe_{2-y}Gd_yO_4$ ferrite system with x = 0, y =0.

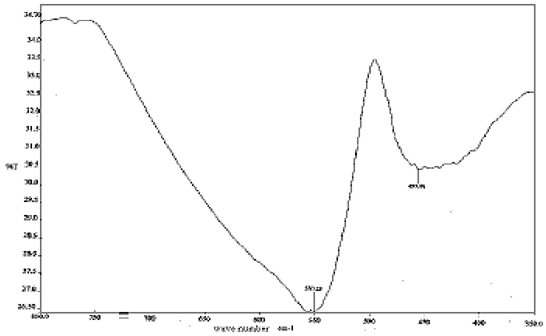

Fig. 2. Typical IR absorption spectrum of $Zn_xMg_{1-x}Fe_{2-y}Gd_yO_4$ ferrite system with x = 0, y =0.

Fig.3 Plots of normalized susceptibility (χ/χ_{RT}) verses temperature Cd_xMg1 $Zn_xMg_{1-x}Fe_{2-y}Gd_yO_4$ ferrites with y = 0.05.

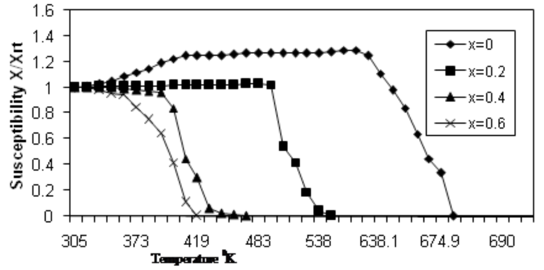

Fig.3 Plots of normalized susceptibility (χ/χ_{RT}) verses temperature Cd_xMg1 $Zn_xMg_{1-x}Fe_{2-y}$C with y = 0.05.

Table 1. Curie temperature data from susceptibility measurement and Loria-Sinha method for the composition $Zn_xMg_{1-x}Fe_{2-y}Gd_yO_4$.

Conc. Zn^{2+} (x)	Conc. Gd^{3+} (y)	T_C from AC susceptibility measurement ^0K	T_C from Loria-Sinha Method. ^0K	Frequency of vibration cm^{-1} ν_1	ν_2
0.00		700	711	571	434
0.20		615	602	575	472
0.40		475	490	550	471
0.60		435	455	563	466
0.80	0.00	-----	----	556	451
1.00		-----	----	540	441
0.00		659	670	541	434
0.20		540	565	540	431
0.40		455	435	581	470
0.60		410	415	568	465
0.80	0.05	----	----	559	437
1.00		----	----	550	457
0.00		623	620	623	423
0.20		527	527	604	425
0.40		440	433	590	471
0.60		397	390	586	467
0.80	0.10	----	----	574	456
1.00		----	----	559	439

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