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# Susceptibility and curie temperature study in $Cr^{3+}$ substituted Mg-Cd ferrites

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## ABSTRACT

Temperature dependence normalized AC susceptibility and Curie temperature of spinel ferrites $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ (x=0, 0.2, 0.4, 0.8 and 1.0; y=0, 0.05 and 0.1) study reveals that $MgFe_2O_4$ exibits multi domain (MD) structure with high Curie temperature On substitution of $Cd^{2+}$, MD to Single Domain (SD) trasitions takes place and Curie temperature decreases due to decrease in A-B intraction. On substitution of $Cr^{3+}$ in Mg-Cd ferrite system peak obtained in $MgFe_2O_4$ 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 Cr-Fe interaction at B-site 

## KEYWORDS

Normalized AC susceptibility;
Domain structure;
Curie temperature;
Magnesium ferrites.

## INTRODUCTION

Susceptibility, a magnetic property of ferrites was found to depend upon grain size, grain boundary and domain structure[1]. Ferrites consists of Multimomain (MD), single domain(SD) and superparamagnetic (SP) particles. The transition from one domain to another mainly depends on substitutions[2]. These domain states can be studied by the technique of low field AC sussceptibility[3]. The MD particles contain domain walls (DW)[4] and DW motion are responsible for magnetic changes. Formation of domain mainly depend on particle size. As particle size decreases, formation of domain walls becomes energitcally unfavorable, then it is said to be single domain (SD) particle. In such a ferrites magnetic changes do not takes place through DW motion but require the rotation of spins resulting in larger coersivity. If 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 the present investigation the efforts are made to understand the domain nature in $Cr^{3+}$ substituted and unsubstituted Mg-Cd ferrite system using low field AC sussceptibility measurements.

## EXPERMENTAL DETAILS

Polycrystalline spinel ferrite with general formula $Cd_xMg1-_xFe_{2-y}Cr_yO_4$(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,

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CdO and $Cr_2O_3$ (LOBA Chem. India). These pure oxides were accurately weighed accordingly to weight ratio required in the final proportions on single pan microbalance. The powders of each sample were mixed together and wet milled using acetone base. Dried powder of samples was prisintered at 700 $^0$ C for 12 hours and then sintered at 1050 $^0$ C for 24 hours. The pellets of samples were formed by applying $10^6$ Kg $cm^{-2}$ using hydrolic press. The pellets 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 was used to measure temperature of the powder sample. The Curie temperature of all the pelletized samples was measured by using modified Lorria-Sinha method.

## RESULTS AND DISCUSSION

### Characterization

A 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 Figure 1. It is found that lattice constant increases with $Cd^{2+}$ 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 $Cd^{2+}$ ion (1.03A$^0$) and $Fe^{3+}$ion (0.67A$^0$). On substitution on $Cr^{3+}$ ion, the lattice constant found to decrease. This was also attributed to the difference in ionic radii of $Cr^{3+}$ ion (0.63A$^0$) and $Fe^{3+}$(0.67A$^0$).

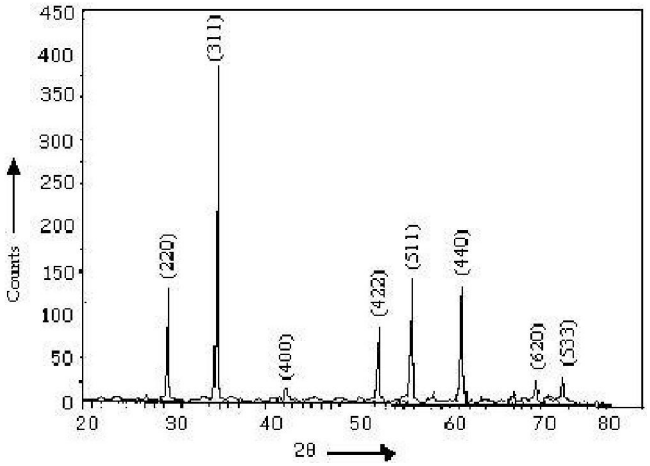


**Figure 1 : Typical X-ray diffractogram of $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ ferrite with x = 0.6 y = 0.00.**

### Normalized susceptiblity

The plots of normalized susceptiblity ($\chi/\chi_{RT}$) verses temperature are presented in the Figures.2-3. From these figures it can be seen that for magnesium ferrite, the susceptibility slowly increases and reaches peak value with temperature and suddenly drops to zero. The sudden drop of $\chi/\chi_{RT}$ curve shows the formation of single phase cubic spinel[8]. The incresase in sussceptibility with peak values suggests there is existance of multidomain particles in the material[9]. The peak is found to suppresed with substitution of $Cr^{3+}$ in $MgFe_2O_4$ and also Curie temparature (Tc) decreases with $Cr^{3+}$ 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 sys-

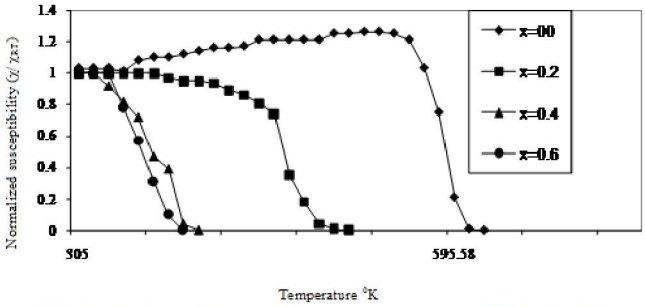


**Figure 2 :The plots of normalized susceptibility ($\chi/\chi_{RT}$) verses temperature $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ Ferrite with y = 0.05.**

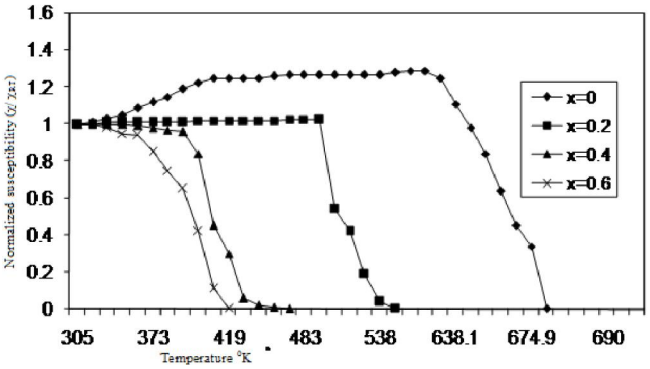


**Figure 3 : The plots of Normalized susceptibility ($\chi/\chi_{RT}$) verses temperature $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ Ferrite with y = 0.10.**

**TABLE 1 : Curie temperature data from susceptibility measurement and Loria-Sinha method for the composition $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$.**

| Conc.$Cd^{2+}$(x) | Conc.$Cr^{3+}$(y) | $T_C$ from AC susceptibility measurement $^0K$ | $T_C$ from Loria-SinhaMethod.$^0K$ |
|---|---|---|---|
| 0.00 | 0.00 | 715 | 720 |
| 0.20 | | 600 | 590 |
| 0.40 | | 495 | 490 |
| 0.60 | | 450 | 445 |
| 0.80 | | ----- | ---- |
| 1.00 | | ----- | ---- |
| 0.00 | 0.05 | 669 | 670 |
| 0.20 | | 550 | 555 |
| 0.40 | | 445 | 435 |
| 0.60 | | 420 | 425 |
| 0.80 | | ---- | ---- |
| 1.00 | | ---- | ---- |
| 0.00 | 0.10 | 613 | 600 |
| 0.20 | | 520 | 520 |
| 0.40 | | 430 | 425 |
| 0.60 | | 395 | 390 |
| 0.80 | | ---- | ---- |
| 1.00 | | ---- | ---- |

tem. 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, y = 0, 0.05 and 0.1 shows paramagnetic behaviour at and above room temperature. Curie tempratures (Tc) obtained from susceptibility plots are presented TABLE 1.

The Curie temparature measurement of all the samples was also been carried out by the method suggested by Lorria-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 $Cd^{2+}$ in $MgFe_2O_4$, Curie temperature was found to decrease. This is because substituted $Cd^{2+}$ ion 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 $Cr^{3+}$ ion, Curie temperature of each composition is found to decrease. This is attrbuted to dilution of B-B interaction[12]. On substitution $Cr^{3+}$ ion occupies B-site replacing equivalent $Fe^{3+}$ ions and so also decrease in magnetization at B-site.

## CONCLUSIONS

Temperature dependent normalized susceptibility measurements reveals that $MgFe_2O_4$ exhibit MD particle and on substitution of $Cd^{2+}$, domain structure changes from MD to SD and for higher concentration SD to SP. Curie temperature was found to decrease on substitution of $Cd^{2+}$, which is attributed to the dilution of A-B interaction. On substution of $Cr^{3+}$, peak obtained in the graph of normalized susceptibility of $MgFe_2O_4$ is suppresed may be attributed to the decrease in grain size. Further decrease in Curie temperature in Mg-Cd ferrite system due to substitution of $Cr^{3+}$ is attributed to the dilution of B-B site.

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