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Study of Effect of Gadolium and Zinc substitution on susceptibility Magnesium ferrites

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ABSTRACT

Ferrites with general formula $Zn_xMg_{1-x}Fe_{2-y}GdyO_4$ were prepared by usual solid state standard ceramic method. Characterizations were made by X-ray diffraction method and temperature dependence normalized AC susceptibility and Curie temperature of spinel ferrites was also studied. This study reveals that $MgFe_2O_4$ exhibits multi domain structure with high Curie temperature On substitution of Zn^{2+}, 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 interaction. On substitution of Gd^{3+} in Mg-Zn ferrite system peak obtained in $MgFe_2O_4$ is suppressed 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

Keywords: Ferrites, Ceramic method, susceptibility, domain structure, Curie temperature.

Introduction :

In ferrites, magnetic properties like Curie temperature and susceptibility are more important properties for the best application of the materials in various devices. These

properties are found to depend on grain size, grain boundary and domain structure [1]. Generally soft ferrites consists of three types of domains like, Multidomain (MD), single domain(SD) and super paramagnetic(SP) particle, which mainly depends on substitutions [2]. These domain states can be distinguished by using the technique of low field AC susceptibility [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 energetically unfavorable, then it is said to be single domain (SD) particle. In these magnetic changes do not takes place through DW motion but require the rotation of spins resulting in larger coercivity. 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 substitution in the spinels [5]. Addition of Cr^{3+} in $NiFe_2O_4$ the domain structure changes from MD to SD [6]. Al^{3+} substituted mixed Cu-Cd ferrites exhibit mixture of SD and MD particles [7]. In this paper we investigated the domain nature in Gd^{3+} substituted and unsubstituted Mg-Zn ferrite system using low field AC susceptibility measurements.

Experimental details

Spinel ferrites with general formula $ZnxMg_{1-x}Fe_{2-y}GdyO_4$ (with 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 °C for 10 hours and sintered at 1050 °C for 24 hours, cooled and powdered. The pellets of samples were formed by applying 106 Kg cm-2 using hydraulic press. The pellets were again sintered at 1050 °C for 24 hours for better compaction. The powdered samples were characterized by XRD on Philips computerized X-ray diffractometer (PW 3710) using Cuká radiation. The AC susceptibility measurements of polycrystalline 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.

Results and discussion

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 From this figure it is confirmed that there is completion of solid state reaction and formation of ferrite phase from (311) peak which is characteristic of ferrites.

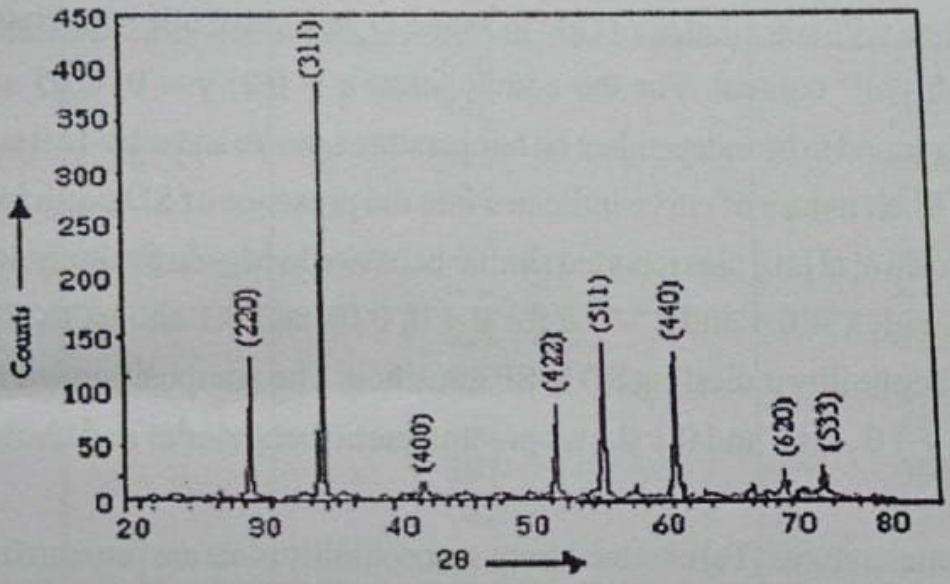

Fig.1 Typical X-ray diffractogram of $Zn_xMg_{1-x}Fe_{2-y}GdyO_4$ ferrites with x= 0.2 and y= 0.05.

Normalized susceptibility

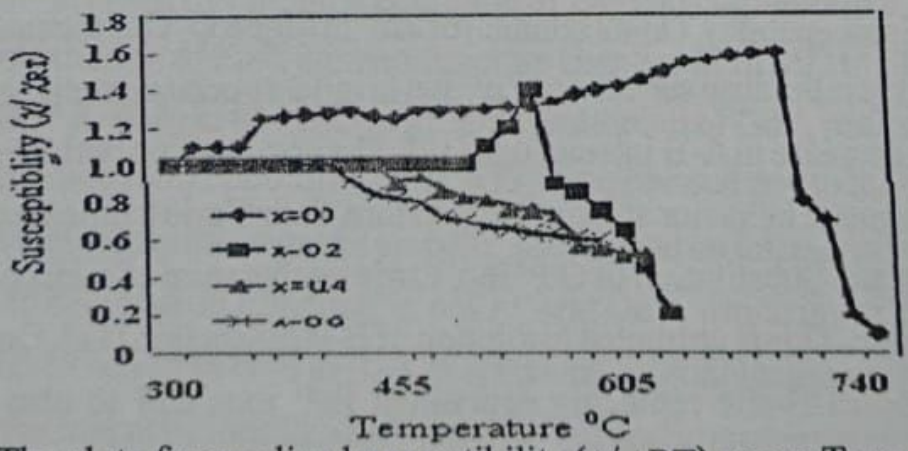

Figure 2. The plot of normalized susceptibility (÷/ ÷RT) verses Temperature of $Zn_xMg_{1-x}Fe_{2-y}GdyO_4$ ferrites with y = 0.05.

To study the property susceptibility, we measured the susceptibility at various

Table 1. Experimental data of Curie temperature of samples under investigation.

Conc. Cd^{2+}(x)	Conc. Gd^{3+}(y)	Tc from AC susceptibility measurement ^0K	Tc from Loria-Sinha Method ^0K
0.00	0.00	700	711
0.20		615	602
0.40		475	490
0.60		435	455
0.80		----	----
1.00		----	----
0.00	0. 50	659	670
0.20		540	565
0.40		455	435
0.60		410	415
0.80		----	----
1.00		----	----
0.00	0.10	623	620
0.20		527	527
0.40		440	433
0.60		397	390
0.80		----	----
1.00		----	----

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 shows 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 substitution of Gd^{3+}, peak obtained in the graph of normalized susceptibility of $MgFe_2O_4$ is suppressed due to the decrease in grain size. Curie temperature a magnetic property also depend 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 magnetic ions like Zn^{2+} and Gd^{3+} magnetic properties decreases and also particle size decreases.

FIG2. THE PYROLYSIS PRODUCT YIELD AS A RESPONSE OF PROCESS TEMPERATURE

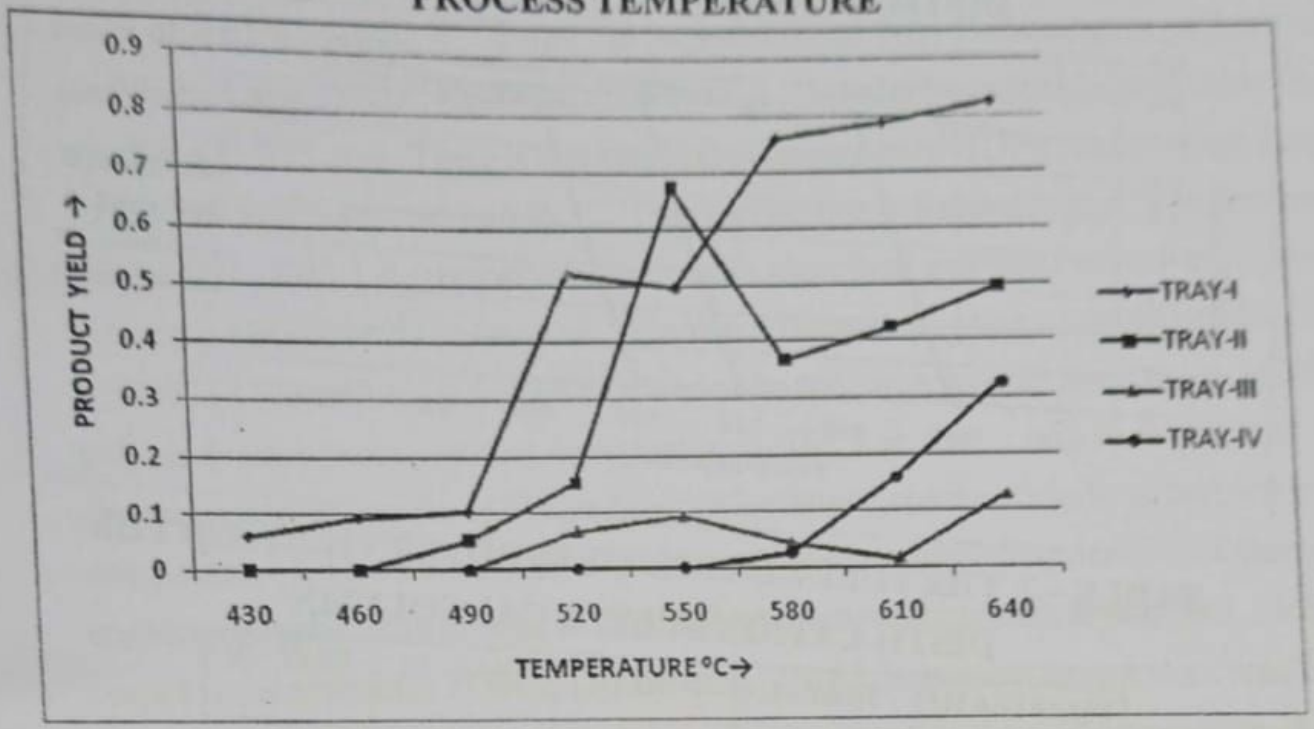

TABLE – 1. THE PRODUCT OF DISTILLATION BUBBLE CAP COLUMN OF EACH TRAY.

TEMPERETURE	TRAY-I	TRAY-II	TRAY-III	TRAY-IV
430	0.061	0	0	0
460	0.093	0	0	0
490	0.103	0.053	0	0
520	0.522	0.153	0.067	0
550	0.496	0.676	0.092	0
580	0.761	0.367	0.044	0.026
610	0.787	0.423	0.016	0.158
640	0.824	0.494	0.128	0.325

has its own characteristic modes of degradation and resistances to heat , light and chemicals. Polymers are degraded by using photoinduced degradation , thermal degradation , chemical degradation [solvolysis ,ozonolysis , oxidation , galvanic action , chlorine induced cracking], biological degradation , stabilizers [Hindered Amine Light Stabilizers HALS] [3].

The physical degradation process in nature occurs through pressure , humidity and heat from the sun. Physical methods are referred to as reduction , reuse and recycling. [4]. Physical method is inappropriate because plastic waste returns to the environment and will later on end up as waste plastic. However, the chemical process through the pyrolysis method is a more efficient and economical of recycling because it can restore the energy contained in plastic. [Zadegaonkar-2006]. Pyrolysis is the process of thermally degrading long chain polymer molecules into smaller (Monomers) less complex molecules through heat. The process requires intense heat (430 °C – 640 °C) with shorter duration and in absence of oxygen [5] generating products in the form of carbon as residues and volatile hydrocarbons which can be condensate as fuel and non condensable as gaseous fuel [6]. The reaction of this polymer as a weak bond chain and is damaged by increasing temperature, followed by formation of the free radical propagation stage . These free radicals will then separate again to form smaller ones which produce more stable compounds [Scheirs-2006]. These smaller fre radicals produce stable compounds in the form of paraffin compounds , isoparaffin , olefins, naphthenes and aromatics [Tadmor-2006]. An analysis of the derived gases and oils indicated that pyrolysis gave a mainly aliphatic composition consisting of a couple of hydrocarbons (alkanes and alkenes).

The liquid fuel obtained from the pyrolysis process can not be directly used as fuel due to the presence of impurities ash and wax from the feedstock [Mburu-2016]. Hence the pyrolysis product is used in reducing the ash and wax content in the fuel product. The purification of the pyrolysis products was conducted using distillation bubble cap tray column which reduces the ash and wax content in the fuel products[7]. Moreover, used for separate the pyrolysis product has based on different boiling points. This review therefore focuses on the effect of temperature on the pyrolysis results which have been integrated with the bubble cap distillation column. This is carried out by utilizing the heat

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