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Research Papers

ELECTRICAL DC CONDUCTIVITY AND THERMOELECTRIC POWER OF Mg–Cd FERRITES

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Abstract

Thermoelectric power (a) and Dc electrical resistivity (ρ) of polycrystalline $Cd_x Mg_{1-x} Fe_2O_4$ (x = 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0) ferrite system is studied as a function of Temperature in the range of 300 – 800 K. The Variation of DC resistivity (ρ) and thermo-electro motive force (a) with temperature shows that the samples are of degenerate type semiconductors. The Positive sign of Seeback coefficient (a) and drift mobility (μd) of the order of 10^{-9} cm^2/Vsec indicates the compositions exhibits P- type semiconducting behaviour in the entire temperature range. P-type semi conducting behavior of the samples is attributed to the presence of Alpha lacunar phase (ρ $Fe_2 O_3$) called Superstructure having hole trapping cation vacancies in octahedral (B) site. The presence of Fe2+ takes place the $Fe^{2+} \leftrightarrow Fe^{3+} + e^-$ transition. DC conductivity mechanism is explained on the basis of thermally activated electron hopping model. Decrease in electrical resistivity with Cd^{2+} content revealed that the Conductivity arises only due to drift mobility (μd) and not due to number of charge carriers in the same sample increases hopping length increases hopping Probability results more μd. Abrupt change in the Conductivity is ascribed due to magnetic behaviour of the sample. Lower values of the activation energies in ferromagnetic region than in paramagnetic region depicts. The cooperative behavior of ordered high spins of Fe^{57} to the hopping mechanism of electron. Addition of Cd^{2+} in host lattice of $MgFe_2O_4$ results the canting of spins on B-site. Increasing in canting angles resembles more activation energy. Decreasing trend of activation energy in paramagnetic region with Cd^{2+} content is found to be contrary support to the decreasing resistivity and Increasing drift mobility (μd) and vive-versa. Close agreement of investigated values of band gap energies EF (0) of the samples with activation energies in the ferriregion is the conformity of degenerate semi conducting behavior of the sample.

Keywords: Ferrites; Thermoelectric Power; Drift Mobility; DC conductivity; Activation Energies; Curie Temperature.

1.INTRODUCTION:

Among the various oxides, the spinal Ferrites have been considered of interest owing to their interesting and magnetic properties. Ferrites have low electrical conductivity and the order of magnitude of conductivity greatly influences their dielectric and magnetic behaviour [1-3]. The reduction of Fe^{3+} to Fe^{2+} takes place without disrupting the lattice configration. Charge carries are not free to move through the crystal lattice, but jumps from ion to ion. The number of Fe^{2+} ions in the octahedral sites plays a dominent role in the mechanism of conduction [4]. Mobility of charge carriers during hopping between

$Fe^{2+} \leftrightarrow Fe^{3+}$ is studied by Tawfik [5]. The aim of present work is to study the DC conductivity & thermoelectric Power of Mg – Cd Ferrites.

2. EXPERIMENTAL

Polycrystalline samples of $Cd_x\ Mg_{1-x}\ Fe_2\ O_4$ (x= 0.0, 0.2, 0.4, 0.6, 0.8, & 1.0) ferrites were prepared by standard ceramic method using AR grade MgO, Fe_2O_3 and $CdCO_3$. The ingredients with acetone base were mixed and calcinated at 650oC in Platinum crucible. Milled power with acetone base was presintered at 800^0C for 24 hours. Fine powders of final product were sintered at 1000^0C at 48 hours. Samples were pelletised by appling pressure 7 tones per square-inch with help of hydrolic pressure cooling and heating rate of the farnace was mentained 80^0C/Hrs.

Samples were characterized by X-ray diffraction IR, AAS and Microstructural analysis by SEM of fractured surface of the samples. DC resistivity of the bulk samples was measured using the two-probe method with silver electrode and the temperature was measured using cromel alumel thermocouple.

For thermoelectric power measurements a Temperature difference of 35K was maintained across the pellet with the help of a microfurnace fitted on the sample holder assembly. The Temperature difference across the pellet was measured with the aid of chromel-alumel differential thermocouple. The thermoemf was measured with the help of Philips microvoltmeter by connecting its Positive terminal to the hot end. Galvanometer and CdS pellete as a well Known N-type semiconductor [6] was used for conformity of the sign Conventions.

3.RESULT AND DISCUSSION

X-ray powder diffractograms of the sample showed well-defined planes of allowed cubic spinal structure whose d values are very close to ASTM data of Magnesium ferrite and Cadmium Ferrite. Close inspection of diffractograms (fig.1) depicts an additional line of lower significance near 311 peak in the composition with X= 0.2, 0.4, and 1.0. This additional line indicating separate phase is identified due to [104] plane of α -Fe_2O_3 from ASTM data. Absence of alpha ferric oxide phase in other remaining compositions is insignificant under the experimental conditions.

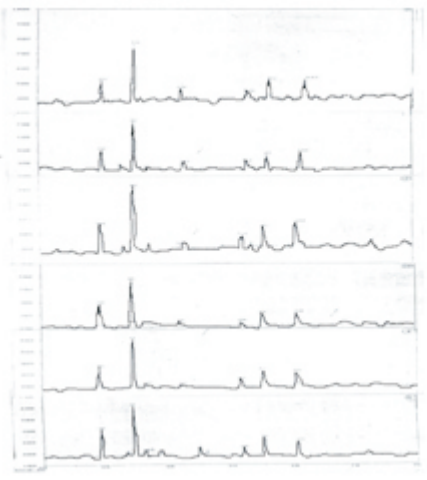

Fig.1 XRD of Mg-Cd ferrite

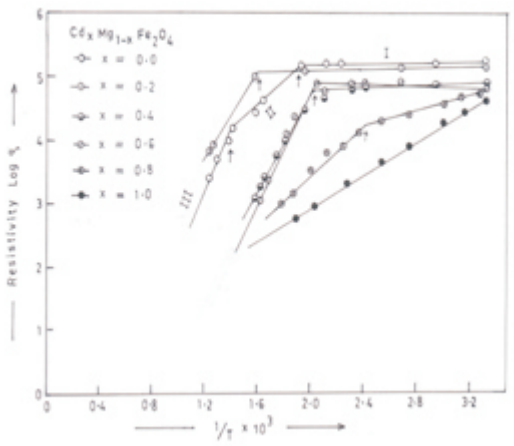

Fig.2 Variation of Log resistivity with 1/T 103

Cubic λ lacunar phased solid solution between Nickel ferrite and ρ- $Fe_2\ O_3$ is previously reported as a superstructure having cat ion vacancies in the octahedral site [7-10]. From X-ray diffractograms the values of lattice constant (a), ionic Radius (R_A) on tetrahedral (A) site and ionic Radius (R_B) on octahedral (B) site, physical density (da) and X-ray density (dρ) are calculated [11] and presented in table 1. Markedly variation of RA with Cd content suggests the tetrahedral occupancy of cadmium ion. Wolska has reported such type of results previously [12]. Average grain size of the sample is calculated

and presented in table 1. Micrographs of the sample showed that the samples are crack free and grain growth is continuous well defined at the grain boundaries. Grain size is found of the order of 3-10 μm. Particle size of the compositions is also calculated from the formula t= (0.94 ρ)/2BCosρ discussed elsewhere [13].

Variation of the log ρ with reciprocal of temperature (fig.2) showed two distinct regions expect for X= 0.0, and 1.0. Abrupt change in the resistivity at particular temperature is observed. These temperatures are the Curie temperature (Tc) of the sample. In Magnesium ferrite first break observed at phase transitions temperature (Tp) and second break is due to Curie point, while $CdFe_2O_4$ does not show any break due to its paramagnetic behaviour at the room temperature.

Activation Energy (Es) in both ferromagnetic region and paramagnetic region are calculated and presented in table 2. Activation energies in ferri-region are found very less than those of in Paramagnetic-region, shows somewhat temperature independent behaviour. The temperature independent behaviour of (a) is the conformity [15] that conductivity arises due to drift mobility and not due to number of charge carriers. Similar results are obtained in the variation of log μd with reciprocal of temperature (fig. 3).

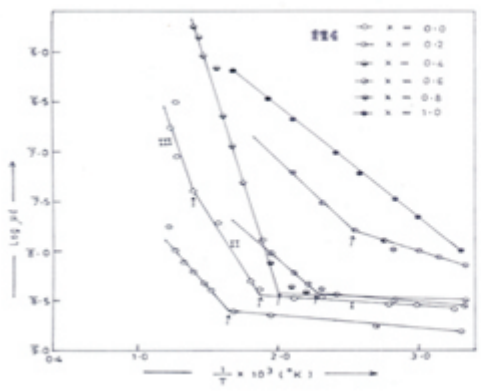

Fig. 3 Dependence of drift mobility with temperature in $Cd_xMg_{1-x}Fe_2O_4$ Ferrites

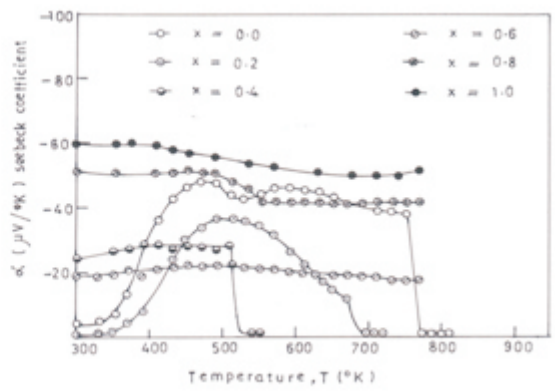

Fig. 4 Dependence of thermoelectric power α (μv/k) with temperature (k)

Fig.4 depicts increase of (a) with temperature in the sample X ≤ 0 .up to 500 K due to less mobility. In these three sample αsuddenly drops to zero due to abrupt change in μd.. Negligible positive values of (α)beyond their Curie is attributed to trapping of holes at grain boundaries. Such sharp phase transition is observed due to high spin of Fe^{57} presence in those samples. Similar sharp phase transition is observed in other experiments viz. AC susceptibility and initial permeability [16].

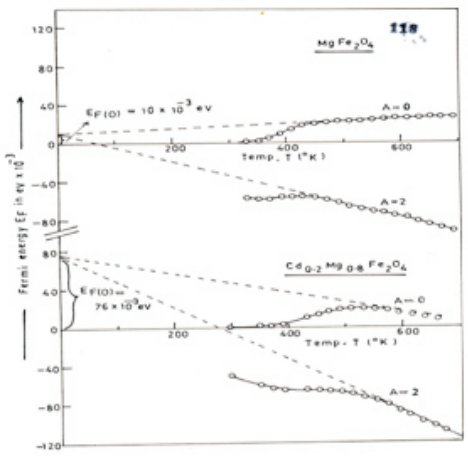

Fig. 5 Dependence of fermi energy with absolute temperature

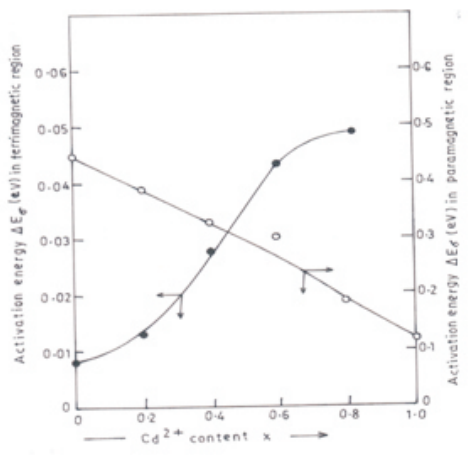

Fig.6 Dependence of activation energy in Ferri and paramagnetic region with cd^{2+} in $Cd_xMg_{1-x}Fe_2O_4$ Ferrites

Figure 5 resemblance the estimation of band gap energies Ef (0) as discussed elsewhere [17] are found to be very close to activation energies in the ferriregion. Low values of activation energy ρ E < 0.2 eV due to magnetic ordering is also reported by Ghani [18]. Increase in Activation Energy with Cd^{2+} content (fig.6) is predicted that more canted spins required more Activation Energy to turn off the order of magnetic spins ultimately magnetization . Variation of Activation Energy in Para region with Cd^{2+} content is explained on the basis of resistivity and mobility. Due to addition of Cd^{2+} content in host lattice of Mg Fe_2O_4 replaces Fe^{3+} ion from tetrahedral (A) site to octahedral (B) site. Number of Fe^{3+} ion on B site Increases with substitution of Cd^{2+}. Probability of hopping is more on B site predominant $Fe^{2+} \leftrightarrow Fe^{3+}$ transitions due to comparative smaller distance and larger in number of Fe^{3+}. More hopping frequency leads to increase the mobility. Mobility of ions in Mg Fe_2O_4 ferrite is reported 1.39 X 10-8 cm^2/V Sec with N type semi conducting behaviour [19].

CONCLUSION:

Presence of alpha lacunar phase called superstructure having hole trapping cation vacancies in octahedral site plays an important role in P type semi conducting behaviour. Temperature independent Variation of (α)revealed that the conduction occurs B. Gillot, R.M Belnlocif and A, Rousset, only due to drift mobility and not due to number of charge carriers. Conduction mechanism is explained on the basis of thermally activated electron hopping model. Increase of activation energy in ferromagnetic region with Cd^{2+} is attributed to Increasing canting angles between magnetic spins, while decrease in activation energy in paramagnetic region on the basis of resistivity and mobility vice- versa. Activation energies in ferromagnetic region satisfy the estimated values of Ef (0) and activation energies from drift mobility (E μd.) are smaller than those of calculated from resistivity (E σ) Prediction for this result satisfies the condition E σ =E μd + Ef (0) which is the conformity of degenerate semi conducting behaviour of the samples.

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Table 1 : Micro structural and Conductivity data of $Cd_x Mg_{1-x} Fe_2 O_4$ Ferrites.

Content X	Lattice Constant (a) nm	Ionic Radius		Physical Density (da) gm/cm^3	X-ray Density (dx) gm/cm^3	Average grain size μm	Resistivity ρ Ω cm X 10^{+5}	Drift Mobility μ_{d} X 10^{-9} cm/V Sec
		R_A nm	R_B nm					
0.0	83.72	5.49	6.93	3.38	4.527	3.98	1.67	0.49
0.2	84.30	5.86	6.93	3.65	4.825	4.00	1.51	1.55
0.4	85.12	6.28	6.99	3.94	5.066	4.38	0.85	3.18
0.6	85.60	6.63	6.98	4.29	5.355	5.22	0.80	3.45
0.8	86.18	7.01	6.98	4.46	5.613	6.22	0.47	7.30
1.0	86.82	7.40	6.99	4.73	5.847	9.62	0.41	9.20

Table 2:- Data of DC conductivity and thermoelectric power in $Cd_xMg_{1-x}Fe_2O_4$ Ferrites.

Content X	Phase Transition Temperature Tp K^0 From		Curie Temperature Tc K^0 From		Band Gap Energy $E_F(0)$ in eV.	Estimated activation energy in eV			
						In Ferri region		In Para region	
	DC conductivity.	TEP.	DC conductivity.	TEP.		from $E\mu_d$	from $E\sigma$	from $E\mu_d$	from $E\sigma$
0.0	528	532	714	723	0.010	0.008	0.005	0.345	0.447
0.2	-	-	632	609	0.076	0.013	0.006	0.158	0.388
0.4	-	-	505	500	0.014	0.028	0.008	0.135	0.333
0.6	-	-	490	432	0.009	0.043	0.009	0.370	0.308
0.8	-	-	413	382	0.030	0.048	0.060	0.115	0.189
1.0	-	-	-	-	0.010	-	-	0.115	0.119

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