Synthesis and Characterization of Ni-Cd-Cu Ferrites

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Abstract
The Ni-Cd-Cu ferrites having the composition $Ni_{0.95-x}Cd_xCu_{0.05}Fe_2O_4$, in which x varies as 0.2, 0.4 and 0.6 were synthesized by standard double sintering ceramic method. The X-ray diffraction (XRD) and FTIR spectral analysis confirms the formation of single phase cubic spinel structure of ferrite phase. The lattice parameter was found to increase with increase in cadmium content and was due to the large ionic radius of cadmium. The structural parameters such as lattice parameter, X-ray density, cation distribution, ionic site radii, oxygen positional parameter, theoretical lattice parameter, bond length, jump length of tetrahedral (A) site as well as octahedral (B) site, tetrahedral edge length, shared and unshared octahedral edge length was estimated. The estimated cation distribution of ferrite was verified by comparing the observed and theoretical lattice parameters. The elastic parameters of ferrites such as longitudinal modulus, rigidity modulus, young's modulus, bulk modulus and Debye temperatures was estimated by using FTIR technique.

Keywords: X-ray diffraction: Structural Properties; Elastic properties

1. Introduction:

The Ni-Cu ferrites are technologically important materials as it possess high saturation magnetization, high resistivity, high stability and low loss energy over a wide range of frequency[1,2]. Infact, Cd substituted Ni-Cu ferrite are the subject of intensive investigations in the field of fundamental and applied research due to their wide applications in electronic industry. The physical properties of spinel ferrites depend on the distribution of cations over the tetrahedral (A) and octahedral (B) sites [3,4]. In electronic materials the elastic moduli are of much importance because they shows the nature of binding force in polycrystalline materials and also helps to understand the thermal properties of these materials.

2. Experimental:

The ferrite with composition $Ni_{0.95-x}Cd_xCu_{0.05}Fe_2O_4$ (x = 0.2, 0.4 and 0.6), were synthesized by standard double sintering ceramic method. The ferrite powders was well grounded and prisintered at 800 ^oC for 8 hrs in a furnace. The prisintered powders were again grounded and pellets were prepared by using hydraulic press and were final sintered at 1150 ^oC for 12 hrs.

The powder sample was characterized by XRD measurements (Philips model PW-1710) with Cu-Kα radiation (λ= 1.5405 Å). FTIR measurements were carried out by using FTIR spectrometer (Nicolet; Model – *Impact*, 410, America) in the range of 400 to 800 cm^{-1}.

3. Results and Discussion:

The peaks appeared in the XRD pattern (fig.1) of the ferrites are identified. However, the non-appearance of extra peaks reveals the formation of single phase cubic spinel structure of ferrite. The increase of observed lattice parameter 'a_o' and X-ray density 'd' with increase of the cadmium content was due to the difference in ionic radii and atomic weight of the component ions in the ferrite system[5]. The distribution of cations in the tetrahedral (A) and octahedral (B) sites can be expressed as[6],

$$(Cd_xFe_{1-x})^{A}[Ni_{0.95-x}Cu_{0.05}Fe_{1+x}]^{B}O_4^{-2}$$

The theoretical lattice parameter of ferrite samples estimated using the relation[7] were listed in table 1. The good agreement between experimentally estimated and theoretical lattice parameters confirms the assumed cation distribution of the ferrites. The mean ionic radius of the tetrahedral 'r_A' and octahedral 'r_B' sites are found to increase with Cd ion content. The increase of ionic radii of tetrahedral site with Cd ion content was due to the larger ionic radii of Cd ions. But the values of oxygen positional parameter are almost same in the ferrite systems.

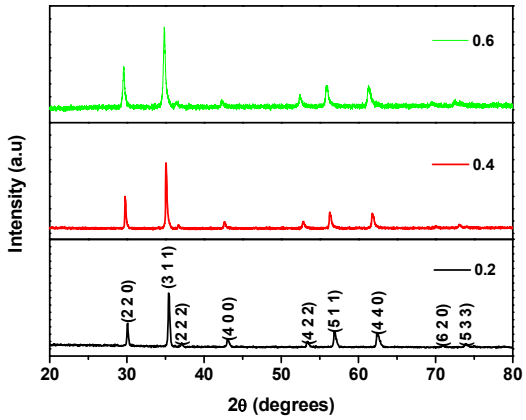

FIGURE 1. XRD patterns of $Ni_{0.95-x}Cd_xCu_{0.05}Fe_2O_4$ (x = 0.2, 0.4 and 0.6) ferrites.

TABLE 1. Structural and elastic parameters of ferrites.

Parameters	x = 0.2	x = 0.4	x = 0.6
a_o (Å)	8.402	8.480	8.533
ρ x 10^3 (kg/m^3)	5.4950	5.5790	5.7070
d x 10^3 (kg/m^3)	4.7770	4.8760	5.0480
f	0.1307	0.1260	0.1157
r_A (Å)	0.709	0.774	0.839
r_B (Å)	1.392	1.365	1.338
a_{th} (Å)	8.346	8.399	8.539
u	0.4004	0.4034	0.4069
υ_1 x 10^2 (m^{-1})	598	584	576
υ_2 x 10^2 (m^{-1})	440	443	433
k_t (N/m)	1.829	2.039	2.269
k_o x 10^2 (N/m)	1.174	1.184	1.128
k x 10^2 (N/m)	1.501	1.611	1.698
V_l (m/s)	5702	5835	6279
V_s (m/s)	3292	3369	3625
L x10^9 kg $m^{-1}s^{-2}$	178.69	189.96	199.06
G x10^9 kg $m^{-1}s^{-2}$	59.56	63.32	66.35
B x10^9 kg $m^{-1}s^{-2}$	99.27	105.53	110.59
σ	0.25	0.25	0.25
E x10^9 kg $m^{-1}s^{-2}$	148.9	158.3	165.9
V_m (m/s)	3655	3740	4025
θ (ºK)	495	502	515

The band positions of FTIR spectrum are listed in table 1. The shift of band position υ_1 towards lower wavelength side was due to the substituted Cd ion, preferably it occupies the tetrahedral (A) site[8]. The octahedral (B) site was occupied by Ni^{2+}, Cu^{2+} ions, where Fe^{3+} ions occupy both tetrahedral and octahedral sites. The force constant for tetrahedral 'k_t' and octahedral 'k_o' sites, longitudinal 'V_l' and transverse 'V_s' elastic wave velocities, elastic moduli and Debye temperature 'θ' for ferrite samples were estimated using the relations[6] and are listed in table 1. The decreases of octahedral force constant with increase of the Cd ion content, was due to the substitution of Cd ion content, which decreases the amount of Ni and increases the amount of Fe ions in the octahedral (B) sites. The increase of longitudinal modulus 'L', rigidity modulus 'G', bulk modulus 'B' and young's modulus 'E' with increase of the cadmium content, may be due to the strengthening of inter atomic bonding between various atoms continuously. The values of poisson's ratio are found to be 0.25 for all the ferrites. The present estimated values of poisson's ratios are lying in the range of -1 to 0.5; which reveals the theory of isotropic elasticity.

4. Conclusions:

The XRD pattern confirms the formation of cubic spinel structure of ferrite phase. The lattice parameter and X-ray density are found to increase with Cd content. The estimated cation distribution of ferrites has been verified by comparing the observed and theoretical lattice parameters. The structural parameters estimated through X-ray diffraction were affected with Cd content. The elastic parameters are found to increases with increase of Cd content and was explained in terms of inter atomic bonding between various atoms and is being strengthened continuously. The estimated elastic parameters of the present results are in good agreement with the earlier reports.

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