



ELECTRICAL PROPERTIES OF SAMARIUM SUBSTITUTED COBALT FERRITE

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Abstract: Samarium substituted cobalt ferrite materials with chemical formula $\text{CoFe}_{2-x}\text{Sm}_x\text{O}_4$ where $x=0.00$ and $x=0.02$ have been synthesized by standard ceramic technique using high purity analytic grade oxides (99.99 %) of CoO , Sm_2O_3 , and Fe_2O_3 . The x-ray diffraction measurements confirmed the formation of a single phase cubic spinel structure. Electrical conductivity was investigated from two probe technique in the temperature range 300K to 850K. Plots of $\log\rho(\Omega\text{m})$ vs $1000/T \text{ K}^{-1}$ reciprocal of temperature show a transition near the Curie temperature. Activation energy and D.C. electrical resistivity both are decreasing with substituted Sm^{3+} rare earth ions in cobalt ferrites and activation energy in the paramagnetic region is more than that of ferrimagnetic region.

Keywords: Cobalt ferrites; Electrical conductivity; Activation energies.

1. INTRODUCTION

Spinel ferrites with the general formula MFe_2O_4 (M is divalent metal cation) are very important material because of their wide range of applications in various technical fields due to their interesting electrical properties such as cellular phones, digital diaries, video camera, floppy drives, computer electromagnetic interference (EMI) remote control, inductors, electronics watches, TV/ computer games and audio system etc[1]. Spinel ferrites are an important class of compounds having large variety of electronic, magnetic and catalytic properties as they possess high resistivity and low eddy current losses are used as microwave devices such as isolators and phase shifters inductor memory core high frequency transformers and recording heads [2]. Cobalt ferrite possesses an inverse spinel structure in which the tetrahedral (A) sites are occupied by ferric ions and the octahedral [B] sites by ferric and cobalt ions. Thus the compound can be represented as $(\text{Fe})^{\text{A}}[\text{CoFe}]^{\text{B}}\text{O}_4$ [3-5] and the degree of inversion depends upon heat treatment (Sawataky *et al* 1968).

Spinel with rare earth ions has attracted great attention in the material science field because of their interesting properties such as infrared emission, catalytic, photoelectric and magnetic properties [6]. When the rare earth ions substitute for Fe^{3+} ions in spinel ferrite, they may enter into the lattice and

disturb grain, that is to say, rare earth ions may the make the grains fine. It is well known that rare-earth atoms play an important role in deterring the magnetocrystalline anisotropy in 4f-3d intermetallic compounds [7]. Hence, rare earth ions are substituted into spinel ferrite to break the grain. In view of their extensive applications, it is desirable to study the influence of Sm^{3+} rare earth ion substituted in cobalt ferrite on electrical conductivity. The results of such a study are presented in this paper.

2. EXPERIMENTAL DETAILS

Polycrystalline samples of Sm^{3+} substituted cobalt ferrites having the chemical formula $\text{CoFe}_{2-x}\text{Sm}_x\text{O}_4$ where $x=0.00$ and $x=0.02$ were prepared by the usual standard ceramic technique [8] using high purity analytic grade oxides (99.99 %) of CoO , Fe_2O_3 and Sm_2O_3 . Compounds were accurately weighted in molecular weight percentage with single pan microbalance and mixed together of each sample was ground to very fine powder and then pre-sintered at 950°C for 24 h. The sintered mixture was again re-ground and palletized. Polyvinyl alcohol was used as a binder in making disc shape pellets of 10 mm diameter and 3 mm thickness. The pellets were finally sintered in muffle furnace for 1180°C for 24 h and then slowly cooled to the room temperature. X-ray diffraction patterns were recorded in the 2θ range from 20° to 80° with scanning rate 2° per/m using Regaku (Miniflex-II) with $\text{Cu-K}\alpha$ radiation ($\lambda=1.5406 \text{ \AA}$).

The temperature dependence of D.C. electrical resistivity of disc shaped pellets are using two probe technique in the temperature range 300K to 850K with step of 10K and for good electrical ohmic contact the pellets were polished and silver pasted on both the surface.

3. RESULTS AND DISCUSSION

Fig 1 shows that the pure CoFe_2O_4 and Fig 2 shows that the Sm^{3+} substituted CoFe_2O_4 with composition $\text{CoFe}_{1.98}\text{Sm}_{0.02}\text{O}_4$ were prepared by standard ceramic technique. The X-ray diffraction powder (XRD) patterns were collected in the range $2\theta = 20^\circ$ to 80° . All the reflection seen in the XRD patterns are sharp clear and intense. The presence of the strong diffraction peaks corresponding to the planes (220), (311), (222), (400), (422), (511), (440) and (533) indexed using Bragg's law indicates that the presence of cubic spinel ferrite family with no extra peaks of impurities are detected when small amount of Sm^{3+} ($x=0.02$) substituted in cobalt ferrite. It indicated that the Sm^{3+} ions ($x=0.02$) can be completely solved into the Cobalt ferrite similar type of behavior of another rare earth are observed in spinel ferrites was also reported is the literature [9-11].

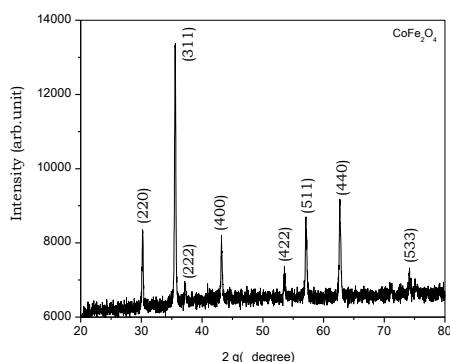


Fig.1 X-Ray Diffraction pattern of CoFe_2O_4 System.

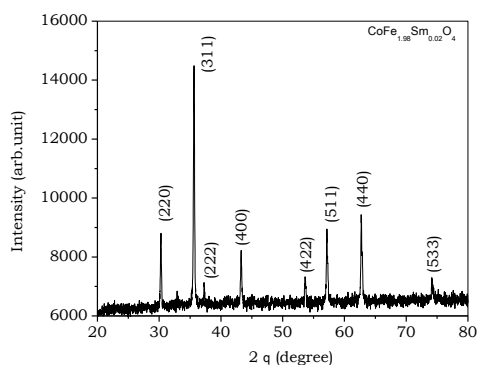


Fig.1 X-Ray Diffraction pattern of $\text{CoFe}_{1.98}\text{Sm}_{0.02}\text{O}_4$ System.

The D.C. electrical resistivity (ρ) of both the sample was calculated by measuring the resistivity of the

samples. The variations of logarithm of resistivity ($\log\rho$) with temperature for both the samples. A change in slope is observed in the resistivity curve dividing the curve in two regions corresponding to ferrimagnetic region and paramagnetic region for the pure samples CoFe_2O_4 as shown in Fig 3 and Fig 4 shows that the Sm^{3+} substituted CoFe_2O_4 with composition $\text{CoFe}_{1.98}\text{Sm}_{0.02}\text{O}_4$.

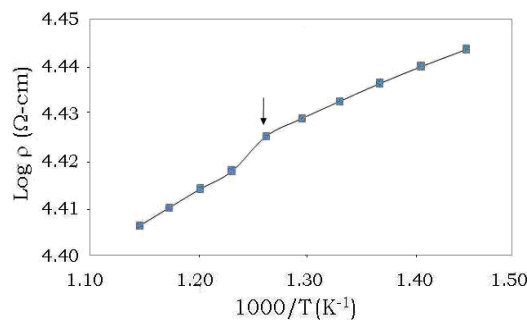


Fig.3 Variation of $\log \rho$ vs $1000/T$ (k^{-1}) of CoFe_2O_4 System.

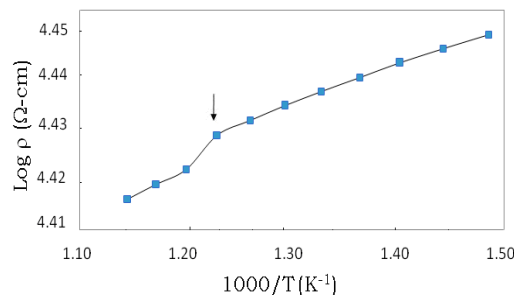


Fig.4 Variation of $\log \rho$ vs $1000/T$ (k^{-1}) of $\text{CoFe}_{1.98}\text{Sm}_{0.02}\text{O}_4$ System.

The temperature at which slope of the curve change corresponds to the Curie temperature of the sample, the resistivity plots obey the exponential relation by

$$\rho = \rho_0 \exp\left(\frac{\Delta E}{kT}\right)$$

where, ρ_0 is the temperature dependent factor,

ΔE is the activation energy,

k is the Boltzmann constant.

Taking the slope of the resistivity graphs and using above equation activation energy of both the samples corresponding to paramagnetic region and ferrimagnetic region was calculated.

The value of paramagnetic region is greater than that of ferromagnetic region as shown in Fig 5 [12, 13]. D.C. resistivity and activation energy will be changed with substituted Sm^{3+} rare earth ion in cobalt ferrite. Fig. 6 shows that the variation of D. C. resistivity and activation energy both are decreases with Sm^{3+} substituted content in cobalt ferrite. The decrease in resistivity may be attributed to the fact that the ionic

radius of Sm^{3+} (0.964 Å) is larger than that of Fe^{3+} (0.67 Å) and when the Sm^{3+} rare earth substituted substitutes for Fe^{3+} a part of Sm^{3+} will occupy octahedral sites by replacing Fe^{3+} ions.

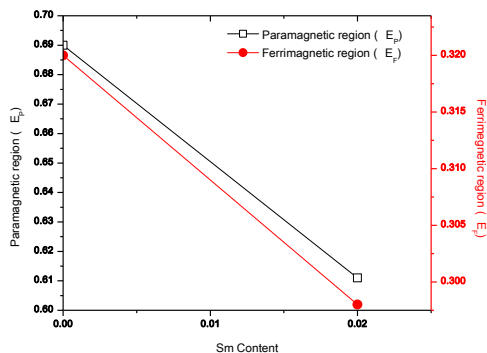


Fig 5: Activation energy in paramagnetic region (E_p) and Ferrimagnetic region (E_f), with Sm^{3+} substituted $\text{CoFe}_{2-x}\text{Sm}_x\text{O}_4$ System.

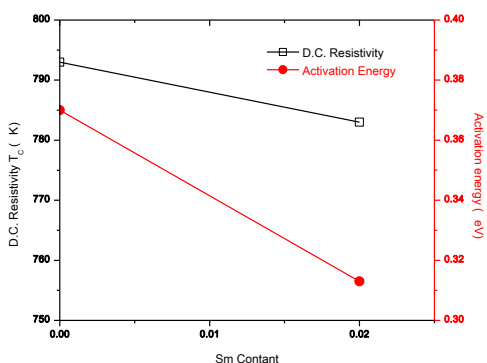


Fig 6: Variation of D.C. resistivity and activation energy with Sm^{3+} substituted $\text{CoFe}_{2-x}\text{Sm}_x\text{O}_4$ System.

4. CONCLUSIONS

The $\text{CoFe}_{2-x}\text{Sm}_x\text{O}_4$ where ($x=0.00$ and $x=0.02$) spinel ferrite system was successfully prepared by standard ceramic technique. The x-ray powder diffraction analysis of the samples revealed that the prepared sample possess single phase cubic spinel structure and the activation energy and D. C. electrical resistivity both are decreasing with substituted Sm^{3+} rare earth ions in cobalt ferrites and activation energy in paramagnetic region is more than that of ferrimagnetic region.

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