

Structural Properties of Bismuth Doped Cobalt Ferrite.

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Abstract - Bismuth doped Cobalt ferrite having chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ where ($x = 0.00, 0.05$ and 0.10) samples have been prepared by standard ceramic technique. The structural properties were investigated by X-ray diffraction technique. Lattice constant increases and reduction of crystallite size Bi^{+3} concentration increases in cobalt ferrite. The increase in lattice constant is due to replacement of larger ionic radii of Bi^{+3} ($1.03 \text{ \AA}$) by smaller ionic radii of Fe^{+3} ($0.64 \text{ \AA}$) at octahedral site and reduction of crystallite size for such materials. The values of the tetrahedral and octahedral bondlength (d_{AX} and d_{BX}) and the shared and unshared octahedral edge (d_{BEX} and d_{BXUE}) Using the value of the lattice parameter 'a' ($\text{\AA}$) and the oxygen position parameter 'u' ($u=0.381 \text{ \AA}$). The value of the bondlength of the tetrahedral and octahedral sites, hopping length (L_{A} , L_{B}) values are depended on the lattice parameter so, the lattice parameter increases with Bismuth concentration increases in chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x = 0.00, 0.05$ and 0.10) so that this value also increases.

Keywords: Cobalt ferrite, Structural properties etc.

1. INTRODUCTION

Cobalt ferrite (CFO) has an inverse spinel structure with a formula $(\text{Fe})_{\text{A}}(\text{Co Fe})_{\text{B}}$, in which, in the theoretical viewpoint, all divalent ions are at site B (octahedral) and trivalent ions are distributed evenly between site A (tetrahedral) and site B (octahedral). The variations in the distribution of cations open up opportunities to modify the physical properties of cobalt ferrite by doping other cations [1]. The cations distribution in tetrahedral and octahedral sites is responsible for novel magnetic and electrical properties of the CFO. Many researchers have drawn their attention to these materials due to its properties like high coercivity, resistivity, Curie temperature, chemical stability and mechanical hardness [2]. These properties make the material potential candidate for use in different applications like high density recording media, transformer cores, sensors, actuators, microwave devices like isolators, circulators, RF

circuit, high quality filters and as a 86 electrode materials for Li batteries and solid oxide fuels. CFO system has been studied to explore its special magnetic behavior and to enhance properties by doping. Bismuth Ferrite (BFO) is one of the most important single phases multiferroic materials due to their high electrical resistivity, low magnetic and dielectric losses [3-5]. And it is reported that on doping of bismuth in very small amount does not alter the spinal structure of Cobalt ferrite. From the literature, we found that very less people worked on doping of Bismuth ferrites [6-9]. Bismuth doped Cobalt nano ferrites are suitable for magnetic recording applications such as audio, videotapes and high-density digital recording discs. Therefore, Bi_2O_3 is a potential substitution for improving the magnetic and electrical properties of ferrites. Hence, in this paper we have focused to correlate the understandings between structural properties of Bismuth doped cobalt ferrites having chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x = 0.00, 0.05$ and 0.10).

2. EXPERIMENTAL DETAILS

The sample materials used for characterization are Bi^{+3} doped cobalt ferrites with chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x = 0.00, 0.05$ and 0.10) were prepared by standard ceramic technique using analytical reagent grade oxides compounds were accurately weighed in molecular weight percentage with a single pan microbalance [10]. The mixed powders were wet ground and pre-sintered at 950°C for 24 hours. The sintered powder is again re-ground and pelletized. Polyvinyl alcohol was used as a binder in making circular pellets of 10mm diameter and 2–3mm thickness. The pellets were finally sintered in muffle furnace for 1180°C for 24 hours and then slowly cooled to the room temperature. X-Ray diffraction patterns were taken at room temperature to confirm the crystal structure of the prepared samples. The XRD patterns were recorded in the 2θ range from 20° to 80° using $\text{Cu-K}\alpha$ radiation ($\lambda = 1.5406 \text{ \AA}$) with scanning rate 1° per/m.

3. RESULT AND DISCUSSION

Structural Analysis: Room temperature X-ray powder diffraction patterns (XRD) for series having chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x=0.00, 0.05$ and 0.10) synthesized by standard ceramic method.

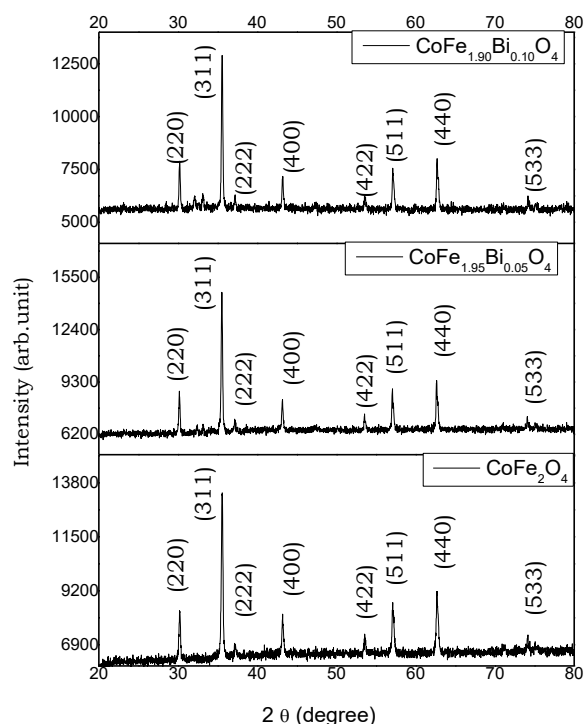


Fig 1: XRD patterns of $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x = 0.00, 0.05$ and 0.10)

The XRD pattern shows the reflections corresponding to (2 2 0), (3 1 1), (2 2 2), (4 0 0), (4 2 2), (5 1 1), (4 4 0) and (5 3 3), which are allowed peaks of the cubic spinel structure shown in Fig 1. The plane (3 1 1) is most intense whereas others are relatively low intense. The analysis of XRD pattern revealed the formation of single-phase cubic spinel structure. The increase in lattice constant is attributed to the fact that, the Fe^{3+} (0.64 Å) ions of smaller ionic radii are replaced by Bi^{3+} (1.03 Å) ions of larger ionic radii.

The variation of lattice constant 'a' increases with concentrations of Bi^{3+} increases with chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ (where $x = 0.00, 0.05$ to $x = 0.10$) is shown in Fig 2. The increase in lattice constant is due to replacement of larger ionic radii of Bi^{3+} (1.03 Å) by smaller ionic radii of Fe^{3+} (0.64 Å) at octahedral site. This causes expansion of octahedral sub lattice site which results in increase in lattice constant. The crystallite size variation with concentration of Bismuth (Bi^{3+}) in the Fig 2. shows that the crystallite size is found to decrease with increase in Bi^{3+} concentrations. The replacement of a larger ionic radii ion by smaller

radii ion creates strain in the lattice. Also, the presence of Co^{2+} ions with maximum electrostatic shielding by 3d electrons introduces an additional strain. This strain depends on different factors such as lattice defects, larger surface energy, and presence of impurities etc. The micro-strain arises due to larger surface energy involved in larger surface to volume ratio of the sample [11 -12]. It is noticed that substitution of Bi^{3+} in CoFe_2O_4 is restricted; as a result, there is a reduction in crystallite size. The reason is Bi^{3+} - O^{2-} bond energy is more than the Fe^{3+} - O^{2-} bond energy, so it required more energy to incorporate Bi^{3+} ions in place of Fe^{3+} ions into octahedral site.

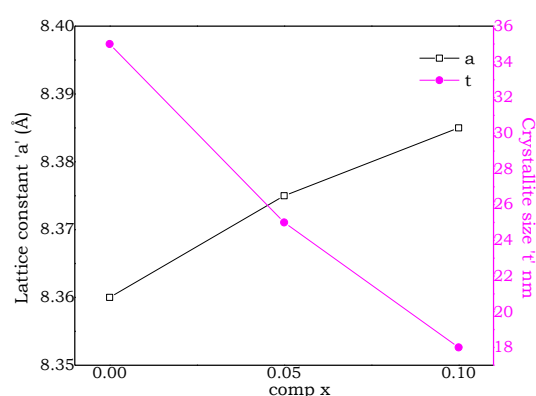


Fig 2: Lattice constant and crystallite size of $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x = 0.00, 0.05$ and 0.10)

The Fig 3. shows that, x-ray density increases with Bi^{3+} concentrations. This can be attributed to the fact that the density and atomic weight of Bi^{3+} is greater than that of Fe^{3+} .

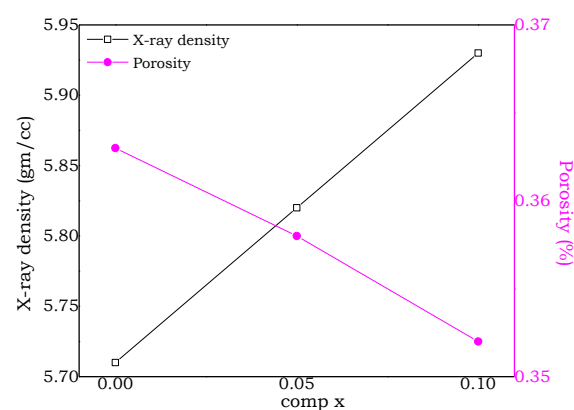


Fig 3: X-ray Density and Porosity of $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x = 0.00, 0.05$ and 0.10)

This behavior of enhancement in the X-ray density with increase in Bi^{3+} concentrations also supports effective incorporation of Bi^{3+} into $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ ($x = 0.00, 0.05$ and 0.10) chemical composition. Fig 3 shows that porosity decreases with increase in content

Bi^{+3} in cobalt ferrite. Fig 4. Shows the values of the tetrahedral and octahedral bond length (d_{AX} and d_{BX}), and Fig 5. Shows the shared and unshared octahedral edge (d_{BXE} and d_{BXUE}) can be calculated [13-14]. Using the value of the lattice parameter 'a' (Å) and the oxygen position parameter 'u' ($u=0.381$ Å). Fig 3 shows that the value of the bond length of the tetrahedral and octahedral site, It is seen that the all values are depend on the lattice parameter so, the lattice parameter increases with increases Bismuth (Bi^{+3}) concentration increases for chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ (where $x=0.00, 0.05$ to $x=0.10$), so the edge and the bondlength of the tetrahedral and octahedral sites are also increases with increases Bismuth (Bi^{+3}) doped content in cobalt ferrite.

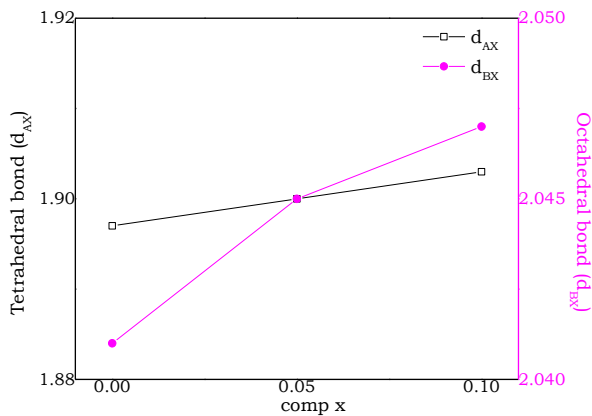


Fig 4: Tetrahedral bond (d_{AX}) and Octahedral bond (d_{BX}) of $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$. ($x = 0.00, 0.05$ and 0.10)

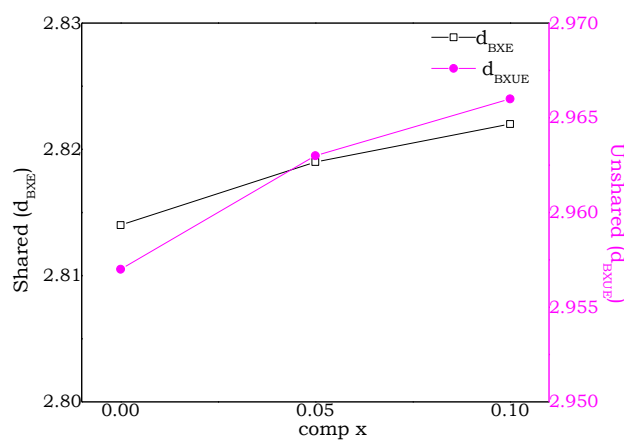


Fig 5: Shared (d_{BXE}) and Unshared (d_{BXUE}) octa edge of $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$. ($x = 0.00, 0.05$ and 0.10)

In Fig 6. shows that Hopping length (L_A , L_B) of chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ (where $x=0.00, 0.05$ to $x=0.10$), It shows that the Hopping length (L_A ,

L_B) values are depend on the lattice parameter so, the lattice parameter increases so the Hopping length (L_A , L_B) also increases doping content Bismuth (Bi^{+3}) cobalt ferrite.

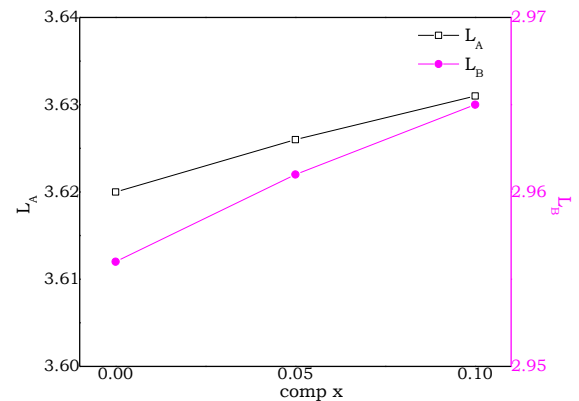


Fig 6: Hopping Length (L_A , L_B) of $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$. ($x = 0.00, 0.05$ and 0.10)

4. CONCLUSIONS

The XRD pattern shows the single-phase cubic spinel structure as concentration of Bi^{3+} substitution in cobalt ferrite matrix having chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ where ($x = 0.00, 0.05$ and 0.10) samples have been prepared by standard ceramic technique. The structural properties were investigated by X-ray diffraction technique. Lattice constant increases and reduction of crystallite size. The increase in lattice constant is due to replacement of larger ionic radii of Bi^{+3} (1.03 Å) by smaller ionic radii of Fe^{+3} (0.64 Å) at octahedral site and reduction of crystallite size for such materials. The values of the tetrahedral and octahedral bondlength (d_{AX} and d_{BX}) and the shared and unshared octahedral edge (d_{BEX} and d_{BXEU}) Using the value of the lattice parameter 'a' (Å) and the oxygen position parameter 'u' ($u=0.381$ Å). The value of the bondlength of the tetrahedral and octahedral sites, hopping length (L_A , L_B) values are depended on the lattice parameter so, the lattice parameter increases with increases Bi^{+3} (Bismuth) concentration increases for chemical composition $\text{CoFe}_{2-x}\text{Bi}_x\text{O}_4$ (where $x=0.00, 0.05$ to $x=0.10$), so that this value also increases.

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