SYNTHESIS AND STRUCTURAL DETERMINATION OF CO SUBSTITUTED M-TYPE CA HEXAFERRITE

Abstract

Co-substituted M-type Ca hexaferrite of composition CaCoFe 11 O 19 was synthesized by sol-gel auto-combustion method using metal nitrates as oxidants and citric acid as a reducing agent. The prepared sample was characterized by X-ray diffraction technology. The peaks observed in the XRD pattern confirm the M type of hexaferrite structure. No secondary peaks were observed that confirmed the purity of the sample. The calculated values of lattices parameters ‘a’ and ‘c’ were 5.9500 Å and 22.0779 Å respectively are well within the range of M type of hexaferrite. c/a ratio for the prepared sample is 3.7105 are well within the ratio range of M-type structure.

Keywords: M-type calcium hexaferrite, sol-gel auto combustion method, lattice parameters.

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I. INTRODUCTION

The composite and microstructure of the nanomaterials determines the structural, optical, electromagnetic and chemical properties of ferrites. Hence, it is necessary to determine the structure of the ferrite nanomaterials and the crystallite size of the ferrite nanoparticles. Cubic or Spinel ferrites, Garnets, Ortho ferrites and Hexagonal ferrites are four types of ferrites based on crystal structure. Out of these four ferrites Depending on coercivity value, hexagonal ferrite belongs to hard ferrite due to their high coercivity value.

Hexagonal ferrites are classified as M-type, U- type, W-type, Y- type, X-type, and Z-type. The formula $MFe_{12}O_{19}$ is used for M-type hexaferrite where M is divalent metal ions such as Ba^{2+}, Ca^{2+}, Sr^{2+} and Pb^{2+}.

Two unit cells of M-type hexaferrite form the structure of M type of hexaferrite. In the structure of this hexaferrite 38 O^{2-} ions and 24 Fe^{3+} ions are distributed in octahedral (2a, $4f_2$ and 12k) sites, tetrahedral ($4f_1$) site, and bipyramidal (2b) sites. Octahedral 2a, $4f_2$ and 12k sites consist of 2, 4 and 12 Fe^{3+} ions respectively. Tetrahedral site $4f_1$ has 4 Fe^{3+} ions and 2 Fe^{3+} ions in bipyramidal 2b site.

Substitution of divalent metal ions such as Ni^{2+}, Zn^{2+}, Mn^{2+}, Co^{2+} and Cu^{2+} against Fe^{3+} ions alter the structural, magnetic, optical and electrical properties of M-type of hexaferrite.

In the current research Co substituted M-type hexagonal ferrite was synthesized by sol-gel auto combustion method and characterized by X-ray diffractometer.

II. MATERIALS AND METHODS

Sol-gel auto-combustion method was used to synthesize sample of Co substituted M-type hexaferrite with formula $CaCo_1Fe_{11}O_{19}$

The various steps involved in sol-gel synthesis method are shown in Figure 1

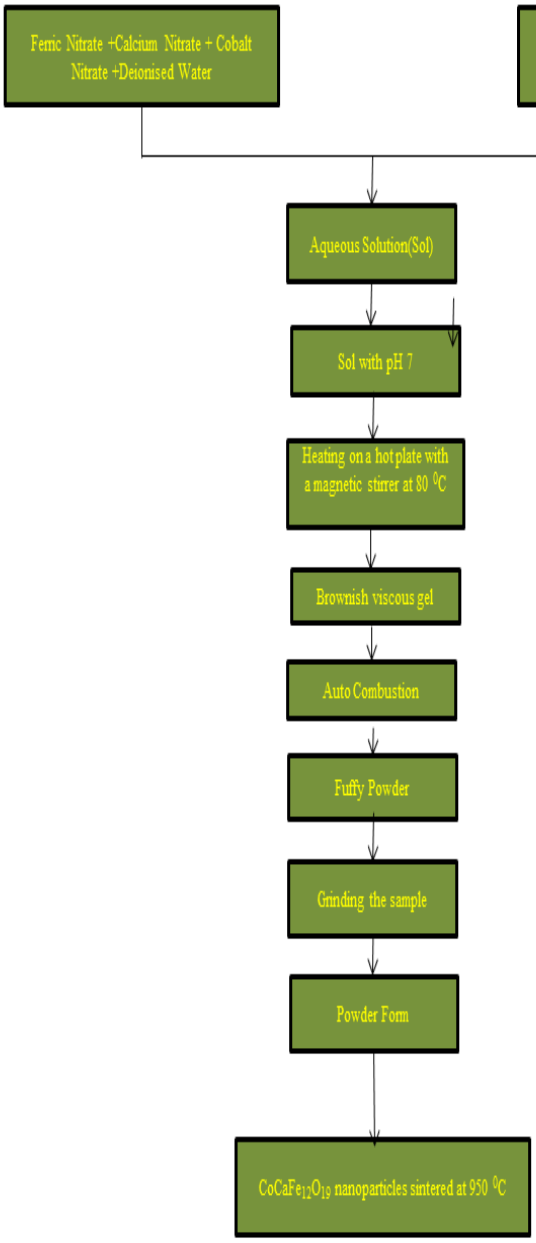

Figure 1: Steps involved in sol gel synthesis of $CaCo_1Fe_{11}O_{19}$ nanoparticles

III. RESULTS AND DISCUSSION

XRD patterns of Co doped Ca hexaferrite with composition $CaCo_1Fe_{11}O_{19}$ are shown in Fig.2.

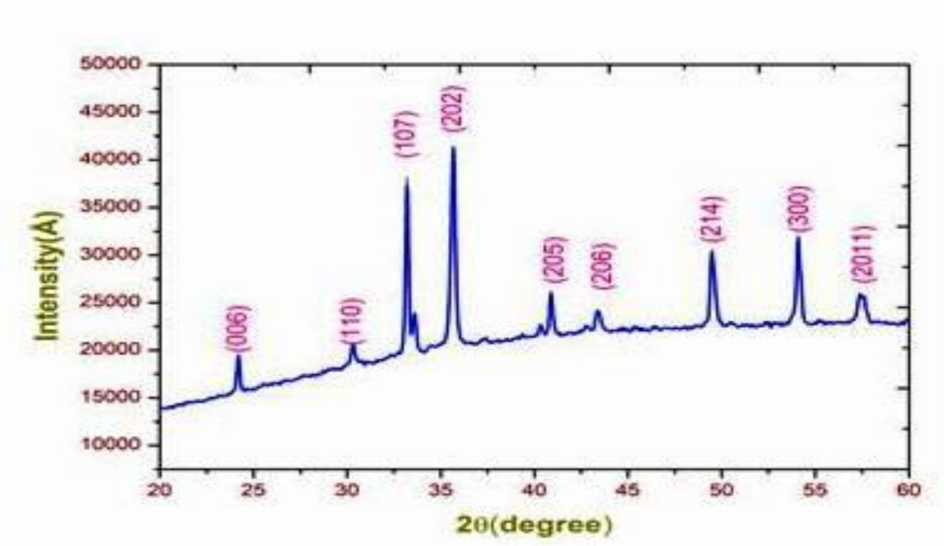

Fig. 2: XRD Pattern of $CaCo_1Fe_{11}O_{19}$

The observed XRD peak positions were indexed according to the JCPDS card number 00-007-0276 belongs to M type of hexaferrite.

The peak positions, Bragg planes, Lattice spacing's (d), Line broadening (β) are listed in the following table.

Table 1: The Peak Positions, Bragg Planes, Lattice Spacing's (D) and Line Broadening (B) Obtained from XRD Pattern of $Caco_1fe_{11}o_{19}$

Sr. No.	Peak position (2θ) degree	Bragg Plane (hkl)	FWHM (β) degree	d-spacing (Å)
1.	24.167	(006)	0.160	3.6796
2.	30.29	(110)	0.100	2.9483
3.	33.179	(107)	0.129	2.6979
4.	35.6355	(202)	0.234	2.5174
5.	40.867	(205)	0.160	2.2064
6.	43.369	(206)	0.300	2.0847
7.	49.483	(214)	0.216	1.8405
8	54.062	(300)	0.208	1.6949
9	57.422	(2011)	0.360	1.6034

In case of hexagonal ferrites there are two lattice constants a=b and ≠ c. The values of these constants depends on the lattice spacing d and the miller indices (h k l) and is given by,

$$\frac{1}{d^2} = \frac{4}{3}\left(\frac{h^2+hk+k^2}{a^2}\right) + \frac{l^2}{c^2} \quad (1)$$

For (006) plane h=k=0, l=6 and d=3.6796 Å. From these values, we get the lattice constant c = 22.0779 Å.

Putting value of 'c' in equation 1 we get the various values of 'a' for various positions of Bragg's plane and a lattice spacing (d).

The calculated values of lattice parameter 'a' are listed in Table 2

Table 2: Calculated Values of 'A'.

Sr. No.	Peak position (2θ) degree	Bragg Plane (hkl)	d-spacing(Å)	a(Å)
1.	30.290	(110)	2.9483	5.8967
2.	33.179	(107)	2.6979	6.0146
3.	35.6355	(202)	2.5174	5.9710
4.	40.867	(205)	2.2064	5.8825
5.	43.369	(206)	2.0847	5.8426
6.	49.483	(214)	1.8405	5.9642
7.	54.062	(300)	1.6949	5.8714
8	57.422	(2011)	1.6034	6.1568
			Average	**5.9500 Å**

From the above table, it is clear that the peaks were properly indexed according to JCPDS card number 00-007-0276 belongs to the M-type of hexaferrite. This confirms that our sample belongs to M type of Hexaferrite and no impurity phase is found.

IV. CONCLUSIONS

In the present study we have, used auto-combustion sol-gel method to synthesize Co-substituted Ca hexaferrite and analyzed it by X-ray diffraction technology. The peaks observed in the XRD pattern confirm the M type of hexaferrite structure. No secondary peaks were observed that confirmed the purity of the sample. The calculated c/a ratio also confirms the structure as M type of hexaferrite.

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