**Synthesis and Structural Determination of Co substituted M type Calcium Hexaferrite**

V. S. Shinde

Department of Physics, K.E.S. Anandibai Pradhan Science College, Nagothane (M.S.).

[vikasshinde4126@gmail.com](mailto:vikasshinde4126@gmail.com)

**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 ferrite 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. The important properties of Hexaferrites are high resonance frequencies, excellent chemical stability and corrosion resistivity, relatively high permeability, high electrical resistivity, good thermal durability, large magneto crystalline anisotropy, high Curie temperature, relatively large magnetization having found applications in magnetic recording devices and high-frequency applications such as telecommunications and radar systems.

Hexagonal ferrites are further classified as M, W, Y, X, U, and Z-type Hexaferrites. Unit cell of M-type hexaferrite is represented by the formula MFe12O19 where M is usually barium, strontium, lead and calcium. Two unit cells of M-type hexaferrite form the structure of M type of hexaferrite. In the structure of hexaferrite 38 oxygen ions and 24 ferric ions distributed in octahedral, tetrahedral and bipyramidal sites. In the structure of M type of hexaferrite 2a, 4f2 and 12K sites are octahedral sites containing 2, 4 and 12 ferric ions respectively; 4f1 is a tetrahedral site consisting of 4 ferric ions while 2b is a bipyramidal site consisting of 2 ferric ions.

The structural and magnetic properties of these Hexaferrites can be changed by the substitution of Fe3+ ions with some divalent metal ions such as Ni2+, Zn2+, Mn2+, Co2+ and Cu2+ .

In the current research Co substituted M type hexagonal ferrite was synthesized by sol gel auto combustion method. For structural characterization, a Panalytical X’ Pert Pro diffractometer with Cu-Kα radiation of wavelength 1.54184 Å was used.

**Materials and methods:-**

The samples of M-type Co substituted hexaferrite with formula CaCo1Fe11O19 was synthesized by sol-gel auto-combustion method.

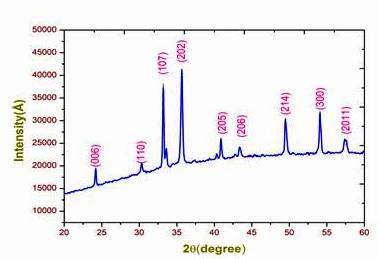
The various steps involved in sol-gel synthesis method are shown in Fig.1

C:\Users\Vikas_Shinde\Desktop\Presentation1.tif

**Fig. 1: Steps involved in sol gel synthesis of CaCo1Fe11O19 nanoparticles**

**Results and discussion:-**

XRD patterns of Cobalt doped calcium hexaferrite with composition CaCo1Fe11O19 are shown in Fig.2.



**Fig. 2: XRD Pattern of CaCo1Fe11O19**

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 (β) obtained from XRD Pattern of CaCo1Fe11O19**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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,

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

**4. Conclusions:-**

In the present study we have, prepared Co substituted Ca hexaferrite by auto combustion sol gel method and characterized by X-ray diffraction technique.  The peaks observed in the XRD pattern confirms 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.

**References:-**

1. L Li, X Zhong, R Wang and X Tu, Structural, magnetic and electrical properties of

Zr-substitued NiZnCo ferrite nanopowders, J MAGN MAGN MATER. 2017.

<https://doi.org/10.1016/j.jmmm.2017.03.073>.

1. S Shaikh, M Ubaidullah, R Mane and A Al-Enizi. Types, Synthesis methods and

applications of ferrites. Spinel Ferrite Nanostructures for Energy Storage

Devices. 2020. <https://doi.org/10.1016/b978-0-12-819237-5.00004-3>.

1. I Auwal, B Ünal, A Baykal, U Kurtan and A. Yıldız, Electrical and Dielectric

Characterization of Bi–La Ion-Substituted Barium Hexaferrites.

J, of Superconductivity and Novel Magnetism 2016.

<https://doi.org/10.1007/s10948-016-3945-9>

1. Y Yang, J Shao, F Wang, and D Huang, Structural and magnetic properties of Ni

substituted M-type Ca-Sr hexaferrites synthesized by solid-state reactions. J CERAM PROCESS RES. 2017. **18** (5), 394~398.

1. A Dairy, L Al-Hmoud and H Khatatbeh. Magnetic and Structural Properties of Barium Hexaferrite Nanoparticles Doped with Titanium. Symmetry. 2019.

<https://doi.org/10.3390/sym11060732>.

1. C Mamatha, M Krishnaiah, C Prakash and K Rewatkar. Structural and Electrical

Properties of Al Substituted Nano Calcium Ferrites.

PROC MAT SCI. 2014. <https://doi.org/10.1016/j.mspro.2014.07.328>

1. B Satone, K Rewatkar and S Satone Structural, Electrical and Magnetic Properties of La/Al Substituted Nano Calcium Hexaferrites prepared by Sol–Gel Auto- Combustion Method. International Journal of Science and Research. 2017.

6(2), 2125-2131.

1. H Nikmanesh, M Moradi, G Bordbar and R Alam. Synthesis of multi-walled carbon nanotube/doped barium hexaferrite nanocomposites: An investigation of structural, magnetic and microwave absorption properties. CERAM INT. 2016.  [https://doi.org/10.1016/j.ceramint.2016.05.089](%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20https://doi.org/10.1016/j.ceramint.2016.05.089).
2. K Rehman, X Liu, Y Yang, S Feng, J Tang, Z Ali, Z Wazir, M Khan, M Shezad, M. Iqbal, C Zhang, and C Liu. Structural, morphological and magnetic properties of Sr0.3La0.48Ca0.25n [Fe(2-0.4/n)O3]Co0.4 (n=5.5, 5.6, 5.7, 5.8, 5.9, 6.0) hexaferrites prepared by facile ceramic route methodology.J MAGN MAGN MATER 2018. <https://doi.org/10.1016/j.jmmm.2017.10.051>
3. P Shepherd, K Mallick, and R Green, Magnetic and structural properties of M-type barium hexaferrite prepared by co-precipitation. J MAGN MAGN MATER. 2006. <https://doi.org/10.1016/j.jmmm.2006.08.046>
4. T Wagner, Preparation and Crystal Structure Analysis of Magnetoplumbite-Type BaGa12O19.  J SOLID STATE CHEM. 1998 <https://doi.org/10.1006/jssc.1997.7681>.