

# **Synthesis and Characterization of M-type Hexaferrite**

A dissertation

Submitted

By **VIVEK KUMAR**

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Of

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## **CERTIFICATE**

This is to certify that **Mr. Vivek Kumar** has completed the dissertation report entitled **“Synthesis and Characterization of M-type Hexaferrite”** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study.

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## **DECLARATION**

I hereby declare that the dissertation report entitled, “**Synthesis and Characterization of M-type Hexaferrite**” submitted for **M.Sc. (Hons) Physics** degree is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma at any university.

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## ABSTRACT

$\text{Ba}_{0.7}\text{Er}_{0.3}\text{Fe}_{11.7}\text{Al}_{0.3}\text{O}_{19}$  which is an M-type hexaferrite synthesized by the sol gel auto combustion method and then exposed to different temperature 750, 850, 950 °C. The sample formed is of pure phase of M-type after the 700 °C and this was confirmed by the X-ray diffraction spectroscopy patterns for the heat treated.

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The properties of Nano materials, made up of Nano particles square measure totally different from bulk materials. Now–a-days the chief attention is on the development of Nano particles. There’s good importance for the preparation of solid solution in nonorange to fulfil the nanotechnology: applied science will be outlined as style, manufacture and application of nanomaterials, and it additionally offers the vital accretive of the connections between the physical belongings and measurements of particles. It agreements with materials in micro millimeter scales ( $10^{-9}$  m). This technology additionally offers the chance of making nanostructures of stability stages with belongings like electrical conduction and magnetism. There’s additional significance of applied science.

One of the foremost advances within the field of applied sciences that the development of solid solution materials, that attributable to their outstanding magnetic behavior influence be helpful in several modern-day applications like solid solution cores, solid solution magnets and in microwave devices. Researchers, over an amount of your time are keenly curious about the sphere of solid solutions and lots of booming tries tare created to synthesize ferrite materials that show improved magnetic properties like saturation magnetic polarization material, property constants critical temperature. For higher use in applications. Ferrites square measure deliberated abundant improved than the opposite magnetic tools as they need little eddy current losses and have high electrical resistance. M –type hexaferrite having formula  $MFe_{12}O_{19}$ , wherever M will be Sr, Pb, Ba area matter of attention because of these compounds are the work mount of durable magnet honest. Metal hexaferrite has been studied for magneto-optical recording and magnetic recording media. They are magnetic force as they’ll be attractable or hooked up to a magnet additionally they’re electrically nonconducting. Ferrites are divided into 2classes supported magnetic confrontation of a magnetic physical to changes in attractive polarization is the vector field that expresses the density of permanent or induced magnetic dipole moments in a magnetic material, equivalent to the field power needed to demagnetize the fully magnetized material, resistance to being demagnetized.

Now a day’s hexaferrite of M-type have drawn attention of people working the nono-technology particle sciences because of its magnetic properties along with low cost. Hexaferrite exhibits in many from like U, V, M, X, Y, Z, W-Types, they all are blessed with magnetic property but M-type Hexaferrite has magneto-Plumbite structure having P63/mmc space group, shows better properties among all the hexaferrites. The M-type hexaferrite

(BaM) is a family of oxide containing ferromagnetic compound with easy axis of magnetization. These types of hexaferrite adopted because of its dielectric, magnetic, and chemical properties. On the account of these properties they can be used as super capacitor. These M-type of hexaferrite have vast area of application in microwave technology, permanent magnets, high frequency devices, sound device, fridge magnet, reading tape and many more area we are using the BaM hexaferrite. The property is in RF and microwave application, for that one's must require high electrical resistivity ferrite coupled with low magnetic loses for maintain the low insertion loses. The Curie temperature is very high for these material which is 503°C.

Block of S and S\* of oxygen layer having spinel block of these layers and then linked to block R having Barium ion. The Barium layer is closely packed in form of hexagonal structure w.r.t the 2 oxygen layer at each site. M-type Hexaferrite structure have 4 oxygen layers packed cubically in between those contains Ba<sup>2+</sup>. One unit cell is made up of 2 molecules and one molecule consists of 5 oxygen layers. The total number of ion in a unit cell are 2 barium, 24 iron, 28 oxygen. The RSRS\* describes the crystallographic structure and having space group P6<sub>3</sub>/mmc (D<sub>64</sub><sup>4</sup>). These ferrite have good magnetic property because of presence of 24 Fe<sup>3+</sup> ion. The spin, geometry and surrounding of ion is represented in the below tables.

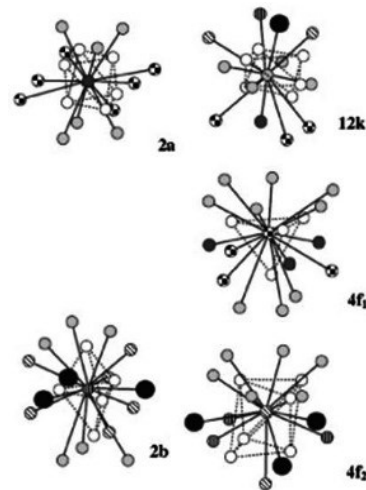
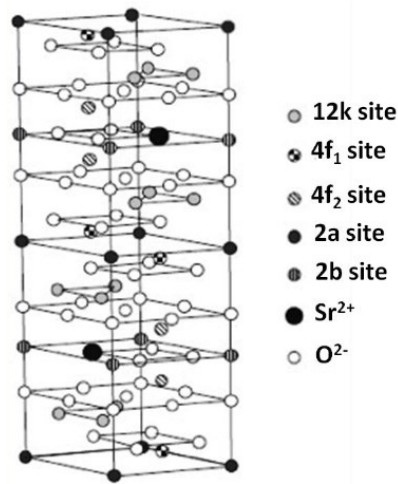


Fig. 1.1 Crystal structure of M-type Hexaferrite      Fig. 1.2 surrounding of 5 Fe ion site



Table 1.3 Number of Fe<sup>3+</sup> in sublattice of hexaferrite and their spin

Site	Geometry	No. of Fe <sup>3+</sup> ions	Spin
12K	Octahedral	6	Up
2a	Octahedral	1	Up
4f <sub>1</sub>	Tetrahedral	2	Down
4f <sub>2</sub>	Octahedral	2	Down
2b	Trigonal bipyramidal	1	Up

As the advancement in technology is going on the researcher are trying to enhance the property of these M-type ferrite, for that they are trying to make different configuration by substituting the cations like La-Na, Bi, Eu and many more. The ferrite and barium ion may be replaced by transition metal ion and rare earth metal respectively because of these have small ionic radii.

We can prepare hexaferrite in many different ways out of them some are citratre precursor, milling method, micro emulsion method, microwave induction method and sol-gel method, out of these above mentioned method sol-gel is method is best suitable for synthesis of hexaferrites, because it requires low temperature which results in lowering the cost of material and powder forms have uniform grain size.

In this article we have studied the M-type barium hexaferrite (BaM) Ba<sub>1-x</sub>Er<sub>x</sub>Fe<sub>12-x</sub>Al<sub>x</sub>O<sub>19</sub>. We took x=0.3 which refers to the compound Ba<sub>0.7</sub>Er<sub>0.3</sub>Fe<sub>11.7</sub>Al<sub>0.3</sub>O<sub>19</sub> (BaErAlM) and prepare it using the method sol-gel auto-combustion. After synthesis of BaErAlM we want to study the changes that goes in the material when we heat it on different temperatures, we also want to study the dielectric and structural properties with the variance of temperature.

### 1.1: SOFT FERRITES

These ferrites have low confrontation of a magnetic physical to changes in magnetic polarization, equivalent to the field strength necessary to demagnetize the fully magnetized material states that the materials magnetic polarization in polarization will effortlessly reverse direction while not dispersing considerably energy although the materials nice electrical phenomenon avoids eddy current loss within the core. RF transformers and inductors uses the soft ferrites. Examples: zinc ferrite, Nickel ferrite.

**1.2: HARD FERRITES** :- Hard ferrites are units that have high resistance of a magnetic material to changes in magnetic polarization. This is the vector field that expresses the density of permanent or induced magnetic dipole moments in a magnetic material, equivalent to the field intensity necessary to demagnetize the fully magnetized material and its remanence. Permanent magnets that are units equipped with hard ferrites, as hard ferrites have good resistance of a magnetic material to changes in magnetic polarization equivalent to the field intensity necessary to demagnetize the fully magnetized material & great remanence once magnetized. In the main Iron, chemical compound and metal carbonate are units used to manufacture the hard ferrite solid solution. The good resistance of a magnetic material to changes in magnetic polarization equivalent to the field intensity necessary to demagnetize the fully magnetized material funds that the materials are units that are terribly robust to changing into demagnetized. It's associated degree necessary unambiguous for a static magnet. They even have permeabilities. Examples: strontium ferrite, barium ferrite.

#### **TYPES OF HEXAFERRITES:**

##### **(i) THE W FERRITES**

General formula of W kind ferrites is  $BaMe_2Fe_{16}O_{27}$ , wherefore that the D block parts or the actual bivalent ion and the Ba that would get replaced by further cluster parts. All W kind ferrites guarantee uniaxial property, exception is  $Co_2W$  primary solid solution having formula ( $BaCo_2Fe_{16}O_{27}$ ), and the molecular mass of 1581 g and the density  $5.31g\text{-cm}^{-3}$ . It's a cone of informal magnetic polarization in polarization at steady angle  $70^\circ$  to c-axis from the  $-273^\circ\text{C}$ , at that the purpose, its property revolves to the c-axis with the growing temperature until it converts uniaxial at the temperature of  $280^\circ\text{C}$ , and the magnetic polarization in polarization becomes constant within the c-axis with further rise within the temperature.

##### **(ii) THE M FERRITES:**

General formula of M kind solid solution is  $BaM$ ,  $BaFe_{12}O_{19}$ . The freezing point of M kind solid solution is  $1390^\circ\text{C}$  confirmed within the year of 1936. Though, the structure of M kind solid solution had not established as existence of isomorphous with the polygon magneto electric machine - plumbite until it had been thought of and characterized magnetically by Philips in 1950. It absolutely was deliberated because the strange ferrites as per it absolutely was confined with no nickel and metallic element, but this was beautifully firm with the resistance of a magnetic material to changes in magnetic polarization equivalent to the field intensity necessary to demagnetize the fully magnetized material of  $160\text{-}255\text{kA/m}$ . They were terribly cheap to yield and had nice electrical electric resistance of  $10^8\Omega\text{cm}$  and conjointly

it's great magnetic uniaxial property beside the c-axis. BaM having molecular mass of 112 g and therefore the determined density is of  $5.295\text{gcm}^{-3}$ , even though within the certainty a ceramic material repeatedly that had a density less than ninetieth of theoretic density. Rigidity of the BaM within the c-axis had been measured to be 5.9 GPA and dignified as 6.0Pa.

### **(iii) THE X FERRITE:**

The X solid solutions were first represented within the year of 1952 as that they had varied section of M and W ferrite. The overall statement of X ferrites is  $\text{Ba}_2\text{Me}_2\text{Fe}_{28}\text{O}_{46}$ , during which Pine Tree States that the D block component or the sure powerfulness ion. First represented X solid solutions that the  $\text{Fe}_2\text{X}$ ,  $\text{Me} = \text{Fe}^{2+}$  and this was established that it had the uniaxial magnetic property beside a c- axis. The density is of  $5.3\text{gcm}^{-3}$  all X ferrites have the uniaxial property at RT, exception is that the  $\text{Co}_2\text{X}$ , it had cone of magnetic polarization in polarization (at  $74^\circ$ ) to the c- axis. Alike W solid solution they seem like, the cone varies to implement associate degree alignment parallel to the c-axis at the bigger temperature,  $143^\circ\text{C}$  during this situation.

### **(iv) THE Y FERRITES:**

The first ferrites to be exposed, is Y solid solution and presently known as most Y ferrites had the favored plane of magnetic polarization upright to the c-axis at RT. General formula for the Y ferrites is that the  $\text{Ba}_2\text{Me}_2\text{Fe}_{12}\text{O}_{22}$ , wherever Me is that the tiny bivalent ion, and  $\text{Zn}_2\text{Y}$  and  $\text{Co}_2\text{Y}$  were the primary created for ferrites.  $\text{Co}_2\text{Y}$  have molecular mass of 1410 g, and having density  $5.40\text{g}\cdot\text{cm}^{-3}$ . At RT, the  $\text{Co}_2\text{Y}$  has plane property however it fluctuates to cone of magnetic polarization in polarization below  $58^\circ\text{C}$ . The temperature from  $-580^\circ\text{C}$  to the Curie point, the property rests in favored plane. The  $\text{Cu}_2\text{Y}$  is that the single Y ferrites that were initiated to had a desired the uniaxial manner of the magnetic polarization.

### **(v) THE Z FERRITES:**

The general formula of Z ferrites is  $\text{Ba}_3\text{Me}_2\text{Fe}_{24}\text{O}_{41}$  they have exposed at that amount because the ferro plane Y ferrites were found. Molecular mass of  $\text{Co}_2\text{Z}$  is 2522g and its  $5.35\text{g}\cdot\text{cm}^{-3}$  density. Entirely Z primary solid solution have the uniaxial property parallel to the c-axis, exception is that the  $\text{Co}_2\text{Z}$ , because it may be a placid at RT then again, it's the composite magnetic property, at least four dissimilar anisotropic positions. At little temperatures, the  $\text{Co}_2\text{Z}$  had informal cone of magnetic polarization, at the angle of  $65^\circ$  to the c-axis, and it perpetually constant up to  $-103^\circ\text{C}$ . Between  $1030^\circ\text{C}$  and  $-53^\circ\text{C}$  angle rises to the  $90^\circ$ , and the desired magnetic polarization remnants within the basal plane until this changes to the c-axis at a warm temperature sandwiched between  $206^\circ$  and  $242^\circ\text{C}$ .

**(vi) THE U FERRITES:**

The general formula of U ferrites area unit  $Ba_4Me_2Fe_{36}O_6$  thoughts recognized at the similar time as extra polygonal shape ferrites. The U ferrites had been not characterized greatly each magnetically or structurally. 5.44 is that the density of  $Co_2U$  and the density of the  $Zn_2U$  is  $5.31 \text{ g cm}^{-3}$ . The U ferrites area unit having uniaxial property exception is that the  $Co_2U$ , that area unit having coplanar property at RT, and molecular mass of the  $Co_2U$  is 3622 g.

**1.5 : APPLICATIONS OF HEXAFERRITES**

1) The hexaferrites have several applications, like in motors, transformers, generators, sensors, data storage, mobile communications, and security, and transport, region and to focus the negatron beams. The magnetic attraction materials square measure the largely used magnetic material. Alloys or magnetic attraction ceramics also are used largely permanent magnet

2) Number of applications like Medical devices, Microwave ovens, laptops, telecommunications like Phones and T.V

Devices of Gyromagnetic electronics: Filters, Absorbers for computers and alternative physics as in Circulator and Power meters.

The synthesized compounds are often utilized in several applications like permanent magnets, medical devices, microwave ovens, computers, native communications, phones and T.V, circulator, filters, power meters, absorbers for computers and physics.

[1] **C. Dube et al.** have studied Zn-Ti substituted element hexaferrite crystalline samples. Solid state reaction is used in making these types of hexaferrite. The sophisticated permittivity and porousness measurements are dispersed on the  $\text{BaFe}_{(12-2x)}\text{Zn}_{(x)}\text{Ti}_{(x)}\text{O}_{19}$  ( $0.3 \leq x \leq 0.7$ ) samples at intervals the microwave frequency vary of 9-14 rate by hole disquiet method. Discovered nonstandard stuff behavior is associate cumulative propensity for stuff continuous through occurrence consumes remained accredited to the varied transmission. The influence of Zn-Ti replacement on the permittivity and stuff harm takes been examined at intervals the occurrence varies of one kHz-one megahertz additionally. The upsurge in attentiveness of Zn-Ti impurity added monotonically can upsurge the permittivity and thus the porousness at intervals the examined frequency ranges, which can be credited to raised polarizability and unpinning of the area walls, severally.

[2] **C. Herme et al.** have studied the physical examination of metallic element hexaferrites  $\text{SrFe}_x\text{O}_{19}$  (for  $x = 10, 11$  and  $12$ ) and relieved examples  $\text{Sr}_{0.7}\text{Nd}_{0.3}\text{Fe}_{12y}\text{Co}_{0.3}\text{O}_{19}$  (for  $y = 2.3, 1.3$  and  $0.3$ ) ready done the change state substance from which another is formed, especially by metabolic reaction methodology is studied by the researcher. Nd and Co replacement modifies fullness attractive division (MS) and will rise fighting of an attractive material to changes in magnetic polarization, equivalent to the field intensity necessary to demagnetize the fully magnetized material ( $H_c$ ) in samples heat-treated at  $1100^\circ\text{C}$  for 2 hours. Mossbauer examines completely dissimilar iron tenancy and therefore the inspiration of the  $\text{Fe}^{3+}$  gratifiedis especially emphasised. Hematite separation is ascertained for a few arrangements. Examples by little  $\text{Fe}^{3+}$  gratified show the finest magnetic possessions with no subordinate part isolation.

[3] **M. Iqbal et al.** have studied putting of ions having positive charge in M-type hexaferrites is considered, can really be an extremely useful tool in molding the electric property of synthesized material. They have studied the combination of two or more entities that together form something new transform the electrical and physical properties of Sr-Ba hexaferrite Nano-particles and characterization of Neodymium–nickel doped Sr-Ba hexaferrite nanomaterials of nominal composition  $\text{Sr}_{0.5}\text{Ba}_{0.5-x}\text{Nd}_x\text{Fe}_{12-y}\text{Ni}_y\text{O}_{19}$  ( $x = 0.00-0.11, y = 0.00-1.2$ ). Impurities added to the material is that of the simple ideal mixture, electrical and structural properties of the simultaneous precipitation of more than one compound from

a ferrite solution unit of measurement of a systematic or formal inquiry to discover and examine the facts of exploitation progressive techniques. The study of optical phenomenon observation allows us to see that the physical dimension of unit cells in a crystal lattice and cell volume of a unit, measurement reciprocally associated with the impurities added level. the resistance offer to the direct current which depend upon the temperature measurements proves that electrical phenomenon of Sr-Ba hexaferrites reduced to  $1.9 \times 10^{10}$  to a combine of  $2.0 \times 10^8$   $V_{cm}$  whereas the drift quality, material constant and material as the relation (or viewpoint in a multifaceted plane) of the loss reaction to the electrical pitch E in the curl calculation to the lossless response part of measurements straight away proportional to the Neodymium–nickel extend. The study of the observation sets up a bridge between the modification of chemical properties of doped Ba-Sr material and the behavior of positively charged ions an occupancy of their website.  $V_{cm}$  whereas the drift quality, material constant and material as the relation of the loss reaction to the electric field E in the curl equation to the loss response unit of measurement remains connected to the Nd–Ni extent. Observation of this research act as a bridge in between the modification of chemical possessions of doped ferrites and nature of cations and their crystal web site filling.

[4] **B. Kaur et al.** have studied the dielectric behavior of flux mature relieved minerals manner arrangement  $SrGa_xIn_yFe_{12-(x+y)}O_{19}$  ( $y = 0.8, 1.3, 1.0$ ;  $x = 5, 7, 9$ ) is described. Difference of non-conductor constant non-conductor damage then ac physical phenomenon ( $\sigma_{ac}$ ) through fever within the vary 30-500°C beneath the regularity of the functional ac ground within the vary 1-104 kHz for altogether the various arrangements square measure analyzed and clarified. Summary significant particle radioactivity belongings on these limits square measure examined. Arranged irradiation, the minerals demonstration vicissitudes within the principles of non-conductor continuous, non-conductor loss ( $\tan \delta$ ) and ac physical phenomenon ( $\sigma_{ac}$ ). The incidence difference of  $\sigma_{ac}$  and  $\tan \delta$  is enlightened by Koop's phenomenological philosophy and springing frequency of electrons amid  $Fe^{2+}$  and  $Fe^{3+}$  on octahedral places for each exposed and irradiated mineral.

[5] **B. Kaur et al.** have used moving sample magnetometer (VSM) fifty MeV  $Li^{3+}$  particleradioactivitybelongings on attractive belongings of one crystal of  $SrGa_xIn_yFe_{12-(x+y)}O_{19}$  (where  $x=1, 6, 7, 8$ ;  $y=0, 0.9, 1.4, 1.0$ ), are reportable. The replacement of In and GA hip metal hexaferrite mineral seductions the worth of course pitch that couriers the density of permanent or induced magnetic dipole moments in a magnetic material sharply,

that is attributed to shifting of superficial magnetic command to a non-collinear one. Discount of magnetization is additionally explained to be because of the occupation of the point regularity of a specific site in three dimensions (x, y, and z) within the unit cell of  $\text{Fe}^{3+}$  by  $\text{Ga}^{3+}$  and  $\text{In}^{3+}$ . The  $\text{Li}^{3+}$  particleradioactivityreductionsthe worth of magnetization, no stuff whether the crystals are Ga-In replaced or unrelated crystals of  $\text{SrFe}_{12}\text{O}_{19}$ . Results understood in footings of the prevalence of a magnet jacket in quartzes substitution magnetic size because of treatment. Substitution of Ga-In in metal hexaferrite decreases the worth of stuff constant. Radioactivity with  $\text{Li}^{3+}$  ions will increase the standards of property turf for each substituted yet as unsubstituted crystals. Substitution with Ga-In conjointly decreases the temperature at which convince resources misplace their perpetual magnetic properties, to be replaced by induced magnetism (Critical temperature) however the irradiation with  $\text{Li}^{3+}$  ions don't influence the fever at which some resources lose their permanent magnetic possessions, to be substituted by encouraged magnetism of either Ga-In doped or ideal  $\text{SrFe}_{12}\text{O}_{19}$  sample.

[6] **T kaur et al.** have studied M-type metallic element hexaferrite  $\text{Ba}_{0.7}\text{La}_{0.3}\text{Fe}_{11.7}\text{Co}_{0.3}\text{O}_{19}$  (BaLCM) dust, manufactured mistreatment sol-gel motor car burning methodology, heat treated at 750, 900, 1150 and 1250°C. X ray optical phenomenon (XRD) precipitate designs of warmth preserved examples show the creation of unadulterated section of M-type hexaferrite when 750°C. Thermal quantitative examination (TGA) discloses that the damage of BaLCM develop send less when 680°C. The attendance of two outstanding peaks, at  $444\text{m}^{-1}$  and  $597\text{cm}^{-1}$  in Fourier remodel Infrared chemical analysis (FT-IR) spectra, provides the thought of formation of M-type hexaferrites. The M–H curve obtained from moving Sample meter (VSM) were accustomed calculate saturation magnetic polarization in polarization(MS), retentiveness ( $M_r$ ), oblongness ration (SR) and battle of a magnetic solid to changes in magnetic polarization, equivalent to the field intensity necessary to demagnetize the fully magnetized material ( $H_c$ ). The most worth of resistance of a magnetic material to changes in magnetic polarization, equal to the field strength necessary to demagnetize the completely magnetized physical (5602Oe) is originate at 950°C. The need of crew gap on infection was studied mistreatment UV–vis NIR chemical analysis. The insulator constant has been found to be tall at little frequency however it decreases with increase in frequency. Such reasonably sound proofing behavior is elucidated on the premise of Koop's phenomenological philosophy and Maxwell Wagner model.



[7] **T. Kojima et al.** placed compound collected of ceria-stabilized zirconia oxide polycrystals (Ce-TZP) and  $\text{LaO}_{19}$  remained manufactured from a dust combination of Ce-TZP,  $\text{Al}_2\text{O}_3$ ,  $\text{La}(\text{Fe}_{0.9}\text{Al}_{0.1})\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{CoO}$ . The thick Ce-TZP spread by placid  $\text{LaO}_{19}$  crystals as a second part were shaped once sintering from 1260 degrees to 1360 degrees C. The saturation magnetic polarization in place composite Ce-TZP/ $\text{LaO}_{19}$  was relative to the figure fraction of the hexaferrite additional innovate Ce-TZP. The resistance of a magnetic material to changes in magnetic polarization equal to the field strength needed to demagnetize the completely magnetized material of the composite with a twenty-one huge of second part stonewashed from 9.15 to 2.51 kOe (from 729 to 202 kA/m) once the maceration of the composite. The condition augmented by 16%-25% beneath uniaxial stress on the composite. The modification of the condition price increased with lessening mass fraction of the second innovate the composite.

[8] **L. Lechevallier et al.** have studied  $\text{Sr}_{(1-x)}\text{Y}_x\text{Fe}_{(12-x)}\text{Co}_x\text{O}_{19}$  and  $\text{Sr}_{(1-x)}\text{RE}_x\text{Fe}_{12}\text{O}_{19}$  ( $x = 0-0.5$  and  $Y = \text{Nd, Pr}$ ) the approaches for initial dusts of earthenware raw materials into multifaceted figures are needed in countless areas of knowledge is used to synthesis the M-type of hexaferrite. The XRD method is used to analysis the structure leads the investigator to the that ability for a given substance, the solute, to dissolve in a solvent of slightly of a group of chemically alike metallic rudiments including the lanthanide series and (usually) scandium and Yr linked to the M-type sector depends on with the material that exist in nature very rare, because they have tendency to combine so the Co is used. The tendency to dissolve of Nd in less than the dissolving capacity of Pr in M-type, and the dissolving capacity will increase due to presence of Pr in the material that found in earth are very rare. Literature review is framed using these observations It appears that entirely light-weight sporadic ground scan enters the M-type structure, with a dissolving tendency that is connected to the distribution of 4f electronic configuration then to shield the crystal construction. The element's that exists very rare on due to their combining tendency ions unit of measurement placed among the  $\text{Sr}^{2+}$  computing machine, whose shielding associate with electronic charge scattering flattened at the poles.  $\text{Co}^{2+}$  ions modify the atmosphere of the  $\text{Sr}^{2+}$  computing machine, up the introduction of rare earth ions with electronic charge scattering flattened at the poles.

[9] **K. Maillik et al.** have studied highly ratio and part pure metal hexaferrite has remained manufactured by co-precipitation likewise as a solid-state propaedeutic methodology victimization high purity nitrates, oxides and carbonates of iron (III), barium

(II) and ammonia. Isochronous and isothermally unrushed advanced permittivity and non-conductor damage tangents ended 1MHz–1GHz in incidence remained comparatively steady till a heat action applied to a powder compact to impart strength and integrity. Heat is supplied by some treatment to a dust solid in instruction to communicate forte and integrity is underneath the tender point of the main basic of the Dust Metallurgy substantial between 1155 and 1320 °C. A tall value of comparative permittivity of thirty-one and low cost curve of 0.0322 designate appropriate high incidence physiognomies for metal hexaferrite. The leisurely apparent thicknesses before and once every gunfire cycle showed it is strictly increasing on the left and right while just non-decreasing in the middle. The mineral construction determined from X-ray diffraction studies tells us the presence of single part happiness to the theoretical area cluster P63/mmc with designed cell parameters of  $a=b=5.885 \text{ \AA}$  and  $c=24.199 \text{ \AA}$ . additionally the DTA hexaferrite creation fever was originate to be 1070 °C.

**[10] E. Pashkova et al.** have studied the need for the synthesis of  $\text{CuCO}_3$  substance from which another is formed, especially by metabolic reaction were put under observation's impact on the chemical, physical, shape and structure properties of another substance formed. The researcher made the study of the change occurring at every step of metal hexaferrite of M-type. The primary suggestion for a structure containing branching and crosslinking to form a 3D network, the relation between crystal dimension's and a substance from which another is formed, especially by metabolic reactions activity all time to the synthesis material were introduced. Parameter for the something to come with the best dimension and crystal formula was found. This information allows an improvement of the action or process of filtering something, constant of the precipitates by an element of 46, getting significant reduce within the heat needed for cartelization of the material and plate having uniform mass, size and shape resembles to the particle at Nano-scale (32.5 nm radius) with the form property and saturation magnetic polarization in division ( $M_s$ )=70.8 emu/g and the pitch strength necessary to demagnetize the completely magnetized material ( $H_c$ )=5441 Oe).

**[11] V.K Sankaranyanan et al.** have studied nanoscale particles of  $\text{BaFe}_{12}\text{O}_{19}$  within the size vary 10-21 nm are ready at a considerably cold of 425°C using a rotation a material from which additional is shaped, particularly by metabolic response method. The technique which uses low-temperature involved inside a substance after which additional is shaped, especially by metabolic reaction synthesis are compared and studied with the processes

complicated in several biological ways that and ancient ceramic ways that to point but primary solid solution formation becomes potential at relatively lower temperatures inside for the substance from which another is formed, especially by metabolic reaction technique. At 435°C for making the constancy usual spinel structures are usually cubic close-packed oxides with dual tetrahedral and single octahedral sites per formula unit that undergoes temperature/time-dependent changes to reform to the ultimate hexangular shape. Victimization X-Ray Diffraction and Infrared knowledge it's used to see that the normal spinel structures are usually cubic close-packed oxides with two tetrahedral and one octahedral sites per formula unit is truly a 'masked' structure of hexaferrites wherever  $Ba^{2+}$  particle, within the hexangular layer of the building block is engaged owing to the presence of carbon at very small scale. The hexaferrite structure is formed when the  $Ba^{2+}$  were freed by extraction of carbon. They have studied however numerous sub lattice sites step by step grow with increasing heat treatment temperature and particle size to complete the advanced chemical element primary solution structure. It has been seen by measurement by magnet on top of changes in structure are reflected as changes in magnetic polarization and as will increase in Critical temperature. The rise in Critical temperature is caused to potential variation within the variety of effective reciprocal action or influence of magnetic strength.

[12] **W. Zhao et al.** they have studied tendency to gift an adapted precipitation methodology toward urge single-phase non-stoichiometric M-type hexaferrite with atomic number fifty-six  $Ba_{1+x}CoTiFe_{10}O_{19+x}$  ( $x=0.20, 0.15, 0.10$ ). It can be proved by X-ray examination that the mineral construction of  $Ba_{1+x}CoTiFe_{10}O_{19+x}$  did nonfailures a result of the  $x$  augmented at intervals the vary 2.0-2.21. The nonlinear differences of c-axis and a-axis distances proved that the excess number fifty-six is at intervals the large holes on axis called a-axis for the  $Ba_{1+x}CoTiFe_{10}O_{19+x}$ . Mineral formation and mineral kind alteration after flat toward having one optic axis, as in the hexagonal, trigonal, and tetragonal systems related by the  $x$  price was found with a skimming magnifier and broadcast magnifier. Grain size varies accordingly to the number fifty-six with error ( $x$ ) shows that a discrete region of magnetism in ferromagnetic material structure of  $Ba_{1+x}CoTiFe_{10}O_{19+x}$  is usually merely remodeled from a discrete region of magnetism in ferromagnetic material to multinomial with dynamical the  $x$  price. The dusts of  $Ba_{1+x}CoTiFe_{10}O_{19+x}$  for  $x=0.06$  have a most resistance of a magnetic material to changes in magnetic polarization, equivalent to the arena strength essential to demagnetize the fully magnetized substantial price of  $H_c=567.13Oe$  and a most remnant magnetic polarization price of  $r=20$  emu/g, every are

ascribed to an extreme or excessive amount or degree of number fifty six and extra grain boundaries on the coherent magnetic polarization rotation reversal mechanism of randomly single-domain packed particle ranging from one hundred fifty to three hundred nanometer. Magnetic polarization in polarization values of  $Ba_{1+x}CoTiFe_{10}O_{19+x}$  area unit unaltered intervals the x vary 0.05-0.08 but bated having very little inflection at intervals, x vary 0.06-0.0625, and this could be explained in terms of the reduced in strength results of excess number fifty-six on the  $Fe^{3+}$  with magnetic property due to the increase of unit volume. The act of diluting and additionally the magnetic polarization reversal mechanism by the domain wall motion of arbitrarily crowded multi-domain construction atoms cause the continual discount of confrontation of a magnetic physical to vicissitudes in magnetic polarization equivalent to the field intensity necessary to demagnetize the fully magnetized material and remnant magnetic polarization worth's of  $Ba_{1+x}CoTiFe_{10}O_{19+x}$  as a result of the x worth can increase at intervals the vary 0.06-0.0625.

**[13] T. Robinson et al.** comparative study has been dispensed of the magnetic and insulator losses between 95 and one hundred and five gigacycle for metal hexaferrite single crystals freely nucleated in different fluxes and force from a metallic element solid solution flux. The crystal growth conditions are described and the results of X-ray and impurity analyses of the crystals given. To accurately compare the magnetic losses, the influence of the surface structure of the measuring sphere on the measured line-widths has been evaluated. No vital distinction was found between the losses of crystals obtained from metallic element solid solution and metallic element chemical compound fluxes. Slightly higher losses for a chemical element chemical compound flux might be because of the presence of powerfulness iron or a second section.

**[14] I. Junliang et al.** have studied Quasi-single magnetic domain M-type atomic number 56 hexaferrite dusts are manufactured through sol-gel auto-combustion route, shadowed by subordinate boiler action at 850 °C for 3 h, exploitation atomic number 56 nitrate, solid solution nitrate, nitrate, acid, and ammonia answer because the beginning resources. The auto-combustion manufacturing dusts were  $Fe_2O_3$  and  $BaCO_3$  with assistance of further nitrate to extend the burning temperature. The inspirations of the cutting to metallic ions (CA/M) and pH scale standards on the gel auto-combustion, the part arrangements of the manufacture dashes and their magnetic properties are deliberate. The consequences showed that the chelation of atomic number 56 and solid solution ions was necessary for the part creation of atomic number 56 hexaferrite the part arrangements of the manufactured dusts

modified from a multi-phased combination to one part of  $M\text{-BaFe}_{12}\text{O}_{19}$  for the bit by bit whole complexing of atomic number 56 and iron ions with change state because the pH scale values and CA/M inflated. The ensuing dusts incontestable that varied magnetic properties chiefly relied on the difference in part arrangement, sintering bond between grains and grown-up of crystalline sizes. With CA/M=1.6, pH 7.2, the manufactured dusts had a particle size distribution within of 100–200nm and a saturation magnetic polarization of 58.0 emu/g at 12kOe.

[15] **Y. Tokunaga et al.** have studied magnetic (electric) polarization by smearing an outside electric (magnetic) field (ME) for single crystals with added impurities of M-type Barium hexaferrites. Magnetic polarization in (M) and optical phenomenon of nucleon was discovered by which standardization  $S_c$  attentiveness a longitudinal cone like national is steady up to end of space temperatures. It has been seen that by measuring the magnetic (electric) polarization by put on an exterior electric (magnetic) field photo electromagnetic field design of radiation measured in a flat vertical (i.e., transverse) to the broadcast way of the beam will introduce to magnetization of a dielectric material (P). The projection of the angular momentum onto the direction of momentum is non-volatile as well as bearable up to close the cone like magnetic transition temperature at low temperature. It completely was together exposed that the response (reversal or retention) of the P vector upon the reversal of M varies with fever. In turn, this feature permits America to switch the relation between the spin projection of the angular momentum onto the direction of momentum and conjointly the H vectors with M and temperature.

[16] **T Kikuchi et al.** have Synthesized of La-Co relieved M-type metallic element hexaferrite remained studied. Samples were ready by polymerizable advanced technique. High cleanliness chemical agent of metallic element, iron (III) nitrate monohydrate, atomic number 27 (II) nitrate hexahydrate and atomic number 57 compound were rummage-sale as beginning resources. Ready solution was animated for dehydration and crystalizing. Current transmutation was distributed by heating the gel. The obtained a substance from which another is formed, especially by metabolic reaction ashes were crushed with an aluminum oxide grout and compressed by uniaxial persistent into floppy specimens and then frenzied at temperature vary between 1173 K and 1573 K in mid-air. Section ID and willpower of lattice parameters were distributed by powder diffraction (XRD). Scanning microscope (SEM) was used to research the microstructure of the polycrystalline ferrites. Magnetic properties were mentioned by magnetic polarization capacities by measuring of M-H curve

with poignant sample gauss meter (VSM). Single-phase of M-type hexaferrite was got at lower temperature comparative to by standard mixture.

[17] **M. Mohebbi et al.** have studied magnetic (electric) polarization by smearing an outside electric (magnetic) field observation output in hexaferrite of M- type, skinny films are introduced before this effort, the Main result in hexaferrite resources was determined solely in unpackaged crystalline resources. Lean films of  $\text{SrCo}_2\text{Ti}_2\text{Fe}_8\text{O}_{19}$  were full-grown on sapphire (0001) mistreatment periodical optical maser deposition. For making wafer films characterization XRD, SM, magnetic force resonance and moving sample gauss meter. They tend to put the saturation magnetic polarization of 1255 G with g-factor of 2.76, and powerful arena of 21 Oe for these magnetic (electric) polarization by smearing an outside electric (magnetic) field skinny films of hexaferrite of M-type. By keeping a constant watch of the formation rate of residual magnetism is the magnetization left behind in a ferromagnetic material (such as iron) after an external magnetic field is removed can be verified with the appliance of DC voltage at fever and it gave increase to vicissitudes in residual magnetism is the magnetization left behind in a ferromagnetic material (such as iron) after an outside magnetic field is detached within the order of 13.9% with the appliance of solely 2.2 V (DC voltage). They wanted to deduce a magneto electric coupling, alpha of  $6.08 \times 10^9 \text{ sum}^{-1}$  in  $\text{SrCo}_2\text{Ti}_2\text{Fe}_8\text{O}_{19}$  skinny film.

[18] **P. Brasov et al.** have studied the M-type hexaferrite, wafer of  $\text{BaFe}_{10.2}\text{Sc}_{1.8}\text{O}_{19}$ , square measure grownup on  $\text{Al}_2\text{O}_3$  (00.1) substrates by periodic a device that creates, manipulates, or measures electromagnetic radiation deposition. The crystal linking quality is increased by post deposition by optical method and produces entirely stable skinny flicks. The post-annealed films demonstration magnetic behavior wanted a stable conic magnetic construction, that is needed to work out the magnetic (electric) polarization by applying an outside electric (magnetic) field impact in hexaferrites. The magnetic section diagram has been obtained from taxing vector field that expresses the density of permanent or iatrogenic dipole moments during a magnetic material curves. Finite-size effects because of the scale is confined to a limit in the magnetic helix justify variations in magnetic properties amid skinny films and put together the unpackaged.

[19] **Jicheng Feng et al.** have studied a sequential formation nickel or carbon Nano compounds containing the porous of Nano scale for high efficiency are made by a mix of IWI and by the action of heated water in the earth's crust for the primary time), XRD, a plan of qualified weight vs. capacity adsorbed obtained by gaging the quantity of  $\text{N}_2$  gas that

adsorbs onto the surface of interest the following amount that desorbs at a continuous temperature and a microscopy technique in which a beam of electrons is communicated through an ultra-thin example, interacting with the specimen as it passes through it, are won't to synthesize the composites derived at the action of heated water in the earth's crust temperature of 125, 160, 180, 225, and 325°C. Nickel compounds was formed using the Nano-technology, totally within the material containing pores with diameters between 2 and 50 nm, was confirmed with X-ray Deflection and Broadcast electron microscopy (TEM). A plot of relative weight vs. volume adsorbed obtained by gaging the amount of N<sub>2</sub> gas that adsorbs onto the surface of interest the following quantity that desorbs at a constant fever is still make recognized for the host/guest compounds. It's was noted that anomic/inorganic compound Ni (NO<sub>3</sub>)<sub>2</sub> composite (OMCN-150) gives a lot of wonderful performance. Supported the assorted hydrothermal temperatures of the composite, the capacitance of Associate in Nursing OMCN-155 delivering the simplest chemical science performance is regarding 2.2 (6 mV s<sup>-1</sup>) and 3.5 (50 mV s<sup>-1</sup>) times of the pristine OMC. The capacitance holding of associate in Nursing OMCN-150 is 95.6.1%, it gives the proof of the efficiency of the supercapacitor was increased many times, and can be used in the vast field of the charge storing devices.

[20] **J. Qiu et al.** have studied the Aluminum and chromium-substituted metal primary solid solution particles with a magnetic atom that breaks in a single domain state for all magnetic fields is called a single area atom were ready victimization) is a method for producing inorganic compounds by exothermic reactions (SHS)technique. The crystalline size, structure, confrontation of a magnetic material to vicissitudes in the vector field that expresses the density of permanent or induced magnetic dipole moments in a magnetic material, equivalent to the field intensity necessary to demagnetize the fully magnetized material and heat absorption property of the particles were explored by proposes that of XRD, TEM, moving taster magnetometer and vector network analyzer. The observation proved that the shape of crystal BaFe<sub>12</sub>xAl<sub>x</sub>O<sub>19</sub> remains hexangular however, once the metal substitution quantity y exceeds zero.6, the extra metal ions cannot arrive the lattice of BaFe<sub>12</sub>.Cr<sub>y</sub>O<sub>19</sub>. Once Fe<sup>3+</sup> is part substituted with Al<sup>3+</sup> and Cr<sup>3+</sup>, the microwave absorption properties of metal primary solid solution are improved. Most absorption reaches 35.76 dB. The magnetism resonance is a vital channel of metal primary solid solution to soak up microwaves with high frequency. Metallic element and metal substitutions modification the magnetism resonant incidence of metal primary solid solution. The multi-peak development

of the magnetism resonance will increase the heat absorption capability of metal primary solid solution.

[21] **F.F.M Pereira et al.** have done this work is according associate in Nursing new and arithmetical study of attractive resonator antennas (MRA) of magnetic the blend  $\text{Ba}_x\text{Sr}_{1-x}\text{Fe}_{12}\text{O}_{19}$  obtained in an exceedingly new procedure within the solid-state methodology. The new and theoretic characteristics of the feeler like come back damage, bandwidth, contribution resistance, and energy designs area unit in smart agreement. Arithmetical authentication is finished, taking under consideration the air gaps between the insulator resonator and therefore the bimetal electrodes. Occurrence answer information measure within of 10–11% was obtained for occurrence action around four rate. The blends  $\text{Ba}_x\text{Sr}_{1-x}\text{Fe}_{12}\text{O}_{19}$  presented an insulator constant around 9, with loss within the vary  $10^2$ – $10^3$ . The temperature constant of resonant frequency (sf) was furthermore slow for attractive blends  $\text{Ba}_x\text{Sr}_{1-x}\text{Fe}_{12}\text{O}_{19}$ . The values obtained were within of 45.90–87.83 ppm/°C. These results obtained ensure the possible use of these resources for tiny insulator.



- **X- ray Diffraction:**

X- ray diffraction (XRD) technique is that the best operative technique to outline the crystal structures of the materials. Diffraction also can determine the chemical compounds. However, it cannot determine the compound from their compositions.

- **Fourier Transform Infrared Spectroscopy:**

Fourier rework Infrared spectrographic analysis conjointly referred to as FT-IR, is that the best used and largely undulation spectrographic analysis technique. It uses the infrared spectrum analysis is rework technique referred to as Fourier rework that is employed to amass a spectrum during an entire vary of the wavenumbers instantly. The chief part within the FTIR system is that the Albert Michelson measuring system.

- There is a vital facet regarding Nano ferrites that their behavior like magnetic properties depends normally on the grain size and part purity that area unit abundant tormented by the synthesis techniques. There are a unit several ways to synthesize Nano Ferrites that embody the standard ceramic sintering route, mechanical grinding, the macro emulsion technique, the hydrothermal reaction, and the glass crystallization technique like sol-gel technique, salt-melt technique critical temperature. Nowadays the foremost normally used technique is that the sol-gel technique. It's been used for the preparation of Nano grained hexaferrites. Main blessings of this technique are:

Low cost

Energy efficiency and

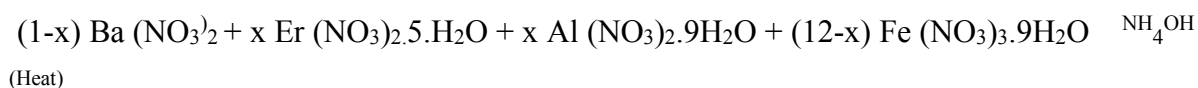
High production rate.

Lower calcination temperature

Ultrafine resultant particles

### Synthesis Method

Powder of M-type barium hexaferrite  $Ba_{1-x}Er_xFe_{12-x}Al_xO_{19}$  ( $x=0.3$ ) is made by using the sol-gel auto combustion method. The chemical used are in the synthesis of above mentioned hexaferrite are Erbium (III) Nitrate (AR/ACS)  $Er(NO_3)_2 \cdot 5H_2O$  (LOBA Chemie., 99% purity), Barium Nitrate  $Ba(NO_3)_2$  (LOBA Chemie., 99% purity), Ferric Nitrate AR/ACS (Nanohydrate)  $Fe(NO_3)_3 \cdot 9H_2O$  (LOBA Chemie.), Aluminium Nitrate (Nanohydrate)  $Al(NO_3)_2 \cdot 9H_2O$  (LOBA Chemie., 98% purity), citric acid (LOBA Chemie., 99.5% purity). The all metal nitrate and hydrated solution of iron are mixed together in stoichiometric ratio in the double distilled water and then put on a magnetic stirrer. After 1 hour of time passage the all chemical are mixed together then aqueous solution of citric acid is added to reduce the pH by 8.82. Then solution is again placed of on magnetic stirrer with heating temperature of  $80^\circ C$  for 4-5 hours.



After 4-5 hours the water evaporate resulting the solution get converted in the brown colour homogenous solution. Then we put the solution after removing the magnetic bid on the hot plate at  $300^\circ C$  for 2-3 hour until we get the powder form of material. During this process the

brown gases are evaporated in the atmosphere. After this we heated the formed powder at 500°C for 5 hours, this removes the impurities in the material. Then we divide the sample three parts and heated them on 750°C, 850°C, 950°C for 5 hours.

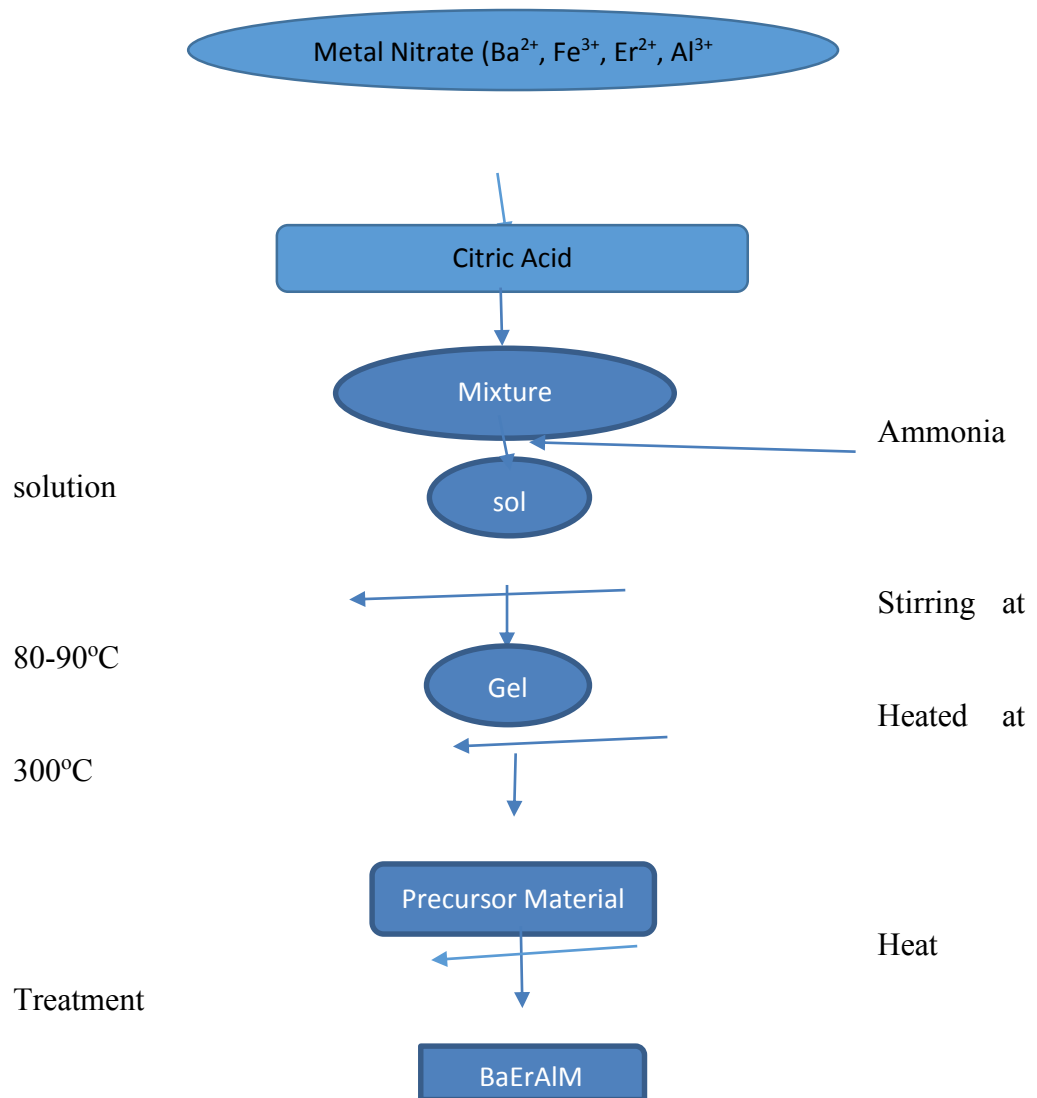


Fig. 1.3 Synthesis technique for M-type hexaferrite

### 6.1 FT-IR Study

Study of FT-IR spectroscopy gives us the information about the functional group attached in the material that remains from the chemical used in synthesis process and which can be recognised. We saw that two major peak in the result of FT-IR spectroscopy at  $420\text{ cm}^{-1}$  and  $580\text{ cm}^{-1}$  which means that the formation of hexaferrite has been taken. These peak corresponding to the stretching vibration of metal-oxygen bond. The peak  $420\text{-}480\text{ cm}^{-1}$  and  $550\text{-}590\text{ cm}^{-1}$  arises due to crystallographic octahedral and tetrahedral site of iron ion. We doesn't find any peak at  $3200\text{-}3700\text{ cm}^{-1}$  which reveals absence of carboxylic group. The peak near  $1714$  corresponding to presence of stretching of  $\text{C}=\text{O}$  bond. Other peak near  $2850$  arises due to presence of moisture, which remains at time of synthesis. We see the area swept is less by the major peak above the  $700^\circ\text{C}$ , which means that the cation have been occupied the ferric sites and held there by strong force of interactions. The plot for different sample is show in the below figure 6.4

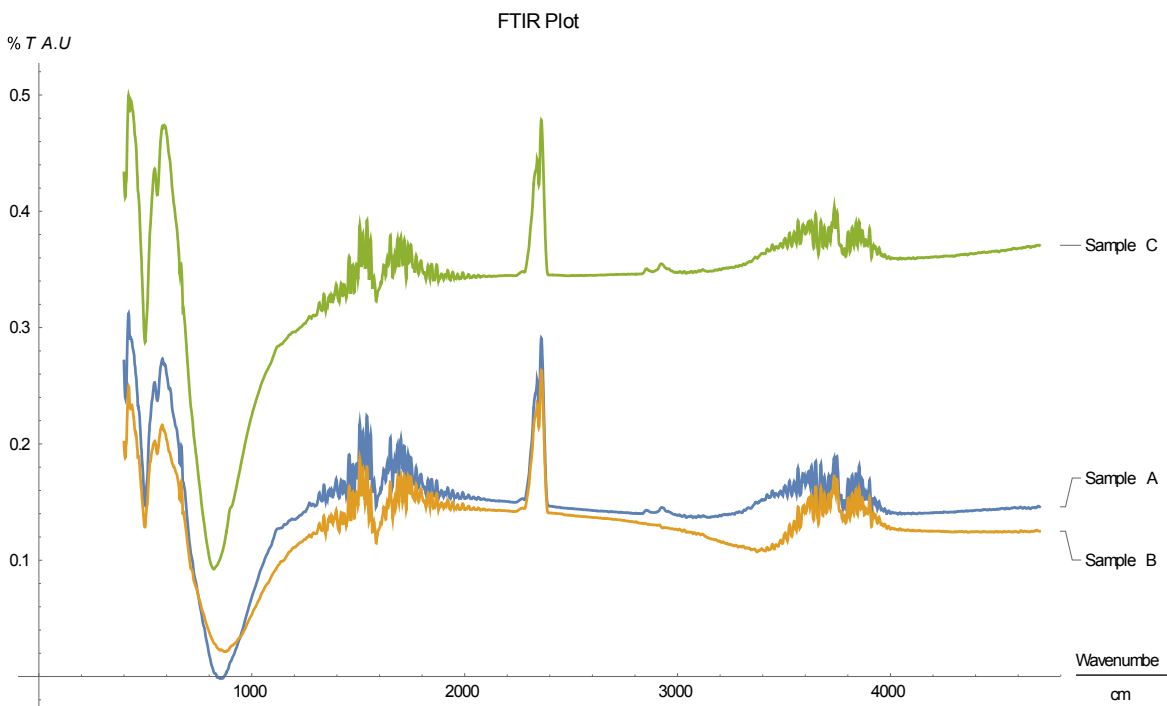


Fig.6.4 plot of FTIR

## 6.2 X-ray Diffraction Study

### 6.2.1 Study of phase change of BaErAlM

We exposed the sample of BaErAlM at different temperature of 750, 850, 950°C for 6 hours, and study have been made of non-destructive X-ray powder diffractometer which is show in the fig. presented in this section. We have found that all are sample are free from impurity and in crystalline phase above 750°C. By analyzing the peak present in the result when plotted on graph conforms that the sample prepared has hexagonal structure and peaks matches to the standard powder diffraction file (PDF) for all the temperature which are taken in consideration in this paper which are 750, 850, 950°C. Which proves that ion which we have substituted have occupied the crystallographic sites. Some peak are absent above 700°C temperature which point out formation of homogeneous mixture and synthesis of pure substituted BaM. Plot of X-ray diffraction is shown in fig. 6.5

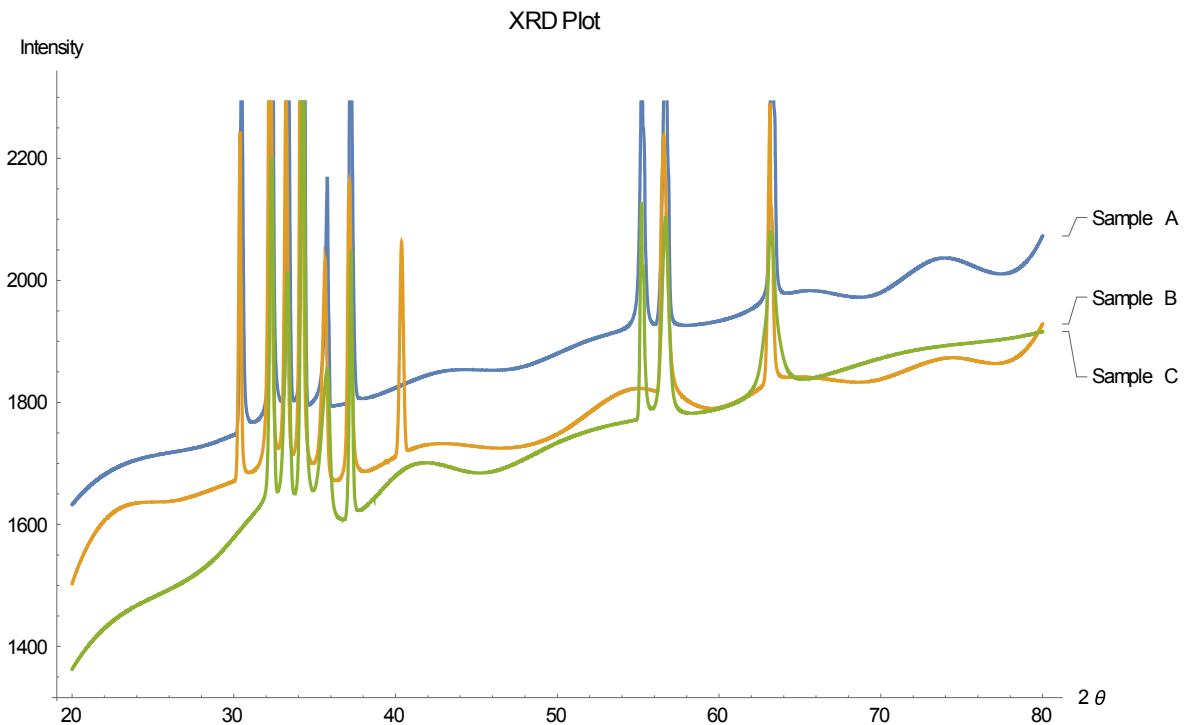


Fig 6.5 plot of XRD

### 6.2.2 Study of crystal size of BaErAlM:-

To investigate the crystalline size ( $D$ ) we used the Scherer formula  $D = k\lambda/\beta \cos\theta$ , where  $\lambda$  is 1.54056 Å which is the wavelength for x rays,  $\theta$  called Bragg angle,  $\beta$  is for full width at half maxima (in radian) and  $k$  is for space factor having unit value for hexagonal structure. Using this formula we found increase in size with increase in temperature.

### 6.2.3 Lattice parameter

Using the x-ray diffraction pattern we find the value of lattice constants 'c' and 'a' and forms the table is given below (Table 3.2.3). To encounter the table we use the formula which is

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

Where  $d^2$  is used to represent the d spacing corresponding to the hkl which are known as miller indices for a peak in X-ray diffraction pattern. We saw that the value of c is continuously decreasing from 23.2246 Å to 23.0871 Å and the value of 'a' is nearly remains constant during the course that is 5.9034 Å. The volume of unit cell depends upon the value of 'a' and 'c' so 'a' is constant and 'c' is decreasing hence there has been seen decrease in volume with the increase in temperature i.e.  $V_{\text{cell}} = 0.8666a^2c$ . This may happen due to rare earth metal presence, the binding energy of Erbium Oxygen octahedral in rare earth substituted oxide material is known to be much higher than the transition metal ion oxygen octahedral.

Table 3.2.2 for lattice parameter and volume of cell

T °C	A(Å)	c(Å)	D(nm)	V <sub>cell</sub> (Å <sup>3</sup> )
750	5.89136	23.38	43.5	703.225 0
850	5.87368	23.50	35.5	702.598 3
950	5.832	23.49	26.66	589.642 9

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