

# A REVIEW ON THE TYPES, PREPARATION TECHNIQUE AND APPLICATIONS OF FERRITE

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## **ABSTRACT**

*Ferrite materials are gaining importance due to its vast applications. There is an ever increasing demand with improved properties. In order to meet the demands one must turn to novel materials processing methods. An approach was made herein to review the concept of ferrite nanoparticles, processing methods and application explored in various fields. Emphasis is paid to the processing of ferrite by self propagating high temperature synthesis (SHS) technique, sol-gel method, chemical co-precipitation and citrate precursor method. Novel applications of ferrite are discussed.*

**Keywords:** *Ferrites, Spinel Structure, Processing Methods, Sintering Temperature*

## **I. INTRODUCTION**

Ferrites are engineering materials giving useful magnetic, electrical and structural properties [1-5]. Based on the magnetic properties ferrites are classified as hard and soft. Hard ferrites are those having a high coercivity and high remanence after magnetization. Eg. Permanent ferrite magnet. Soft ferrites are those having a low coercivity. This means the magnetisation of the materials can reverse the direction easily without dissipating much energy. Eg. Transformer, electromagnetic cores. Under soft ferrite there is a type of material called spinel ferrite which crystallizes in spinel structure. The spinel crystal structure is being made up of the closest possible packing of oxygen ions forming f.c.c lattice. Metallic cations, magnetic and nonmagnetic; reside on the interstices of the close-packed oxygen lattice. In the spinel structure these cations have either four- or six-fold coordination and form tetrahedra (A) and octahedra (B) sub-lattices that are in themselves arranged in a close-packed arrangement. Spinel ferrite is again classified into three types.

*Normal spinel ferrites:* In such ferrites all tetrahedral (A) sites are occupied by  $\text{Me}^{2+}$  whereas all the octahedral sites are occupied by trivalent  $\text{Fe}^{3+}$  ions. Symbolically,  $\text{Me}^{2+}[\text{Fe}^{3+}]$  where  $\text{Me}^{2+}$  occupy A site and that inside the bracket is in B site.

*Mixed spinel ferrite:* In such ferrite  $\text{Me}^{2+}$  and  $\text{Fe}^{3+}$  occupy both A and B site.

Symbolically,  $\text{Me}_{1-a}^{2+}\text{Fe}_a^{3+}[\text{Me}_a^{3+}\text{Fe}_{2-a}^{3+}]\text{O}_4^{2-}$  where 'a' is the degree of inversion,  $\text{Me}_{1-a}^{2+}\text{Fe}_a^{3+}$  occupies A site and  $\text{Me}_a^{3+}\text{Fe}_{2-a}^{3+}$  occupy the B site.

*Inversed spinel ferrite:* In such ferrite  $\text{Me}^{2+}$  occupy octahedral site and  $\text{Fe}^{3+}$  ions are distributed between tetrahedral and octahedral site. Symbolically,  $\text{Fe}^{3+}[\text{Me}^{2+}\text{Fe}^{3+}]\text{O}_4^{2-}$  where  $\text{Fe}^{3+}$  occupies A site and  $\text{Me}^{2+}\text{Fe}^{3+}$  occupies B site.

The ferrites are tailored for its various applications by changing their physical and chemical properties. The properties is manipulated by changing the synthesis method, processing temperature and also substitution [6-8]. Efforts when made to achieve a fine tuning of the size give rise to ferrite nanomaterials. There is a growing interest in ferrite nanoparticles because of their wide applications in various fields.

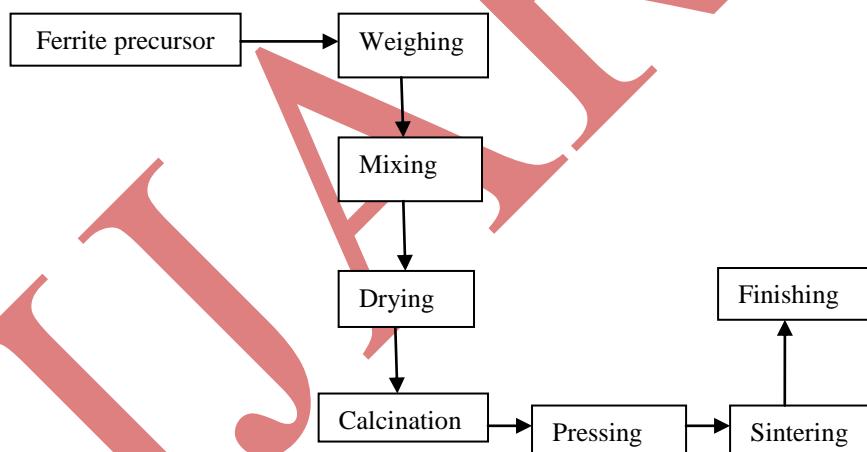
The review gives some general processing method and applications on spinel ferrite nanomaterial which is found to be useful due to their electronic, optical, electrical, magnetic and catalytic properties.

## II. PROCESSING METHOD OF BULK FERRITES

Bulk ferrites are prepared by using different types of processing method. Some few method such as standard ceramic co firing route [9-10], i) self propagating high temperature synthesis (SHS) technique [11], (ii) sol-gel method [12-13], (iii) chemical co-precipitation [14], (iv) citrate precursor method [15] etc. are being discussed.

### 2.1 STANDARD CERAMIC CO FIRING ROUTE

The starting materials such as oxides/carbonates/chlorides are stoichiometrically mixed to yield homogeneous powders followed by drying for removing water. After this calcinations process is carried out to make the reaction. After calcinations, the heavily agglomerated lump is milled to homogenize their composition for obtaining a more uniform and small particle size. At the end inorganic binders are added to facilitate particle packing during shape forming. The ferrites are given final sintering for densification.



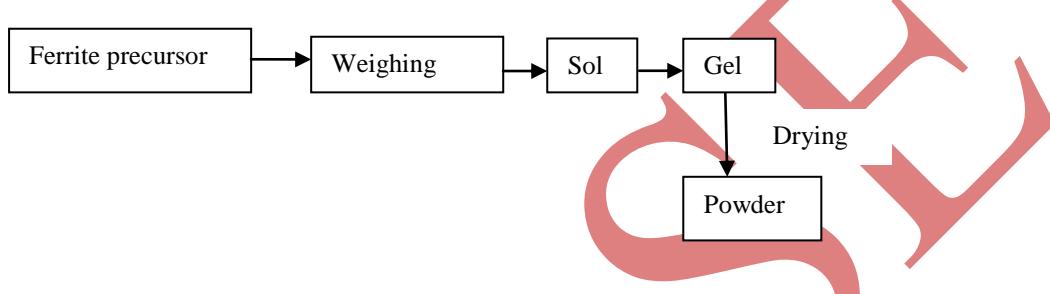
**Fig. 1. Block diagram of ceramic processing of ferrite materials.**

### 2.2 SELF PROPAGATING HIGH TEMPERATURE SYNTHESIS (SHS) TECHNIQUE

In these methods, precursor is taken using an organic acid in aqueous solution. The solution contains all necessary cations and combustible anions in the desired product. After dehydration the precursor becomes dry gel that is amorphous in nature. The dry gel directly yields the required materials upon calcination in presence of air/oxygen. Here the starting materials are mixed in the atomic scale. The phase formation occurs at lower calcination temperature as compared to ceramic route. The entire process completes within 5 minutes, giving ultrafine powders.

### 2.3 SOL-GEL METHOD

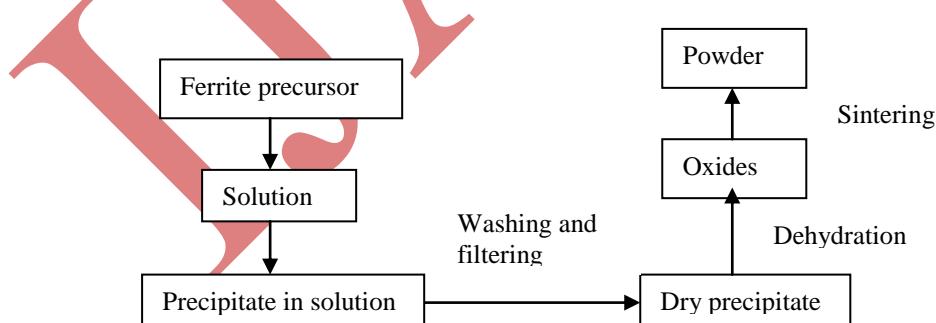
The sol-gel process involves the transition of a solution system from a liquid sol into a solid gel phase. A sol is a dispersion of the solid particles in a liquid where only the Brownian motions suspend the particles. The sol is heated to form a gel. A gel is a state where both liquid and solid are dispersed in each other, which presents a solid network containing liquid components. The starting materials used in the preparation of the sol are usually inorganic metal salts or metal organic compounds such as metal alkoxides. The precursor is subjected to a series of hydrolysis and polymerization reactions to form a colloidal suspension, or a sol. With further drying and heat treatment, the gel is converted into dense materials.



**Fig. 2. Block diagram of sol-gel method.**

### 2.4 CHEMICAL CO-PRECIPITATION

In the chemical co-precipitation an aqueous solution of suitable salts of iron, lithium, manganese and other desired, suitable materials is mixed with a precipitating agent which causes the precipitation of the other metals present in the solution. The precipitate represents a substantially uniform mixture of precursor compounds of the ferrite metals on an atomic scale. In this formation of ferrite it is important to prevent agglomeration; Ostwald ripening etc. The precipitate is filtered and dried. The dry precipitate is heated in air at an elevated temperature to dehydrate the precipitate and to burn out carbonaceous matter leaving a residue of the oxides of the respective metals.



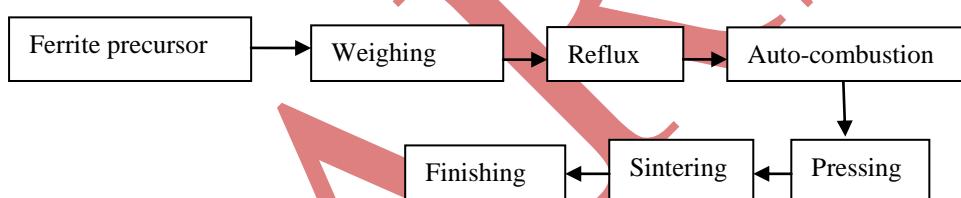
**Fig. 3. Block diagram of chemical co-precipitation method.**

The particles are then given final sintering. The sintering operation results in some grain growth. It is to be noted that the grain size is significantly smaller than that obtained in conventionally prepared lithium ferrites. The method does not work well in cases where two reactants have very different solubilities in water and the

reactants do not precipitate at the same rate. However the co-precipitation process takes a very long duration to obtain the required materials and is often not suitable for preparation of high purity, accurately stoichiometric phases. Therefore other methods such as citrate precursors are used.

## 2.5 CITRATE PRECURSOR METHOD

In this method, the metal ions from the starting materials such as nitrates are complexed in an aqueous solution with  $\alpha$ -carboxylic acids such as citric acid. The pH of the solution is controlled at 7 by adding ammonium hydroxide. The pH controlled solution is refluxed with continuous stirring using magnetic bar agitator and dried. A highly viscous mass is then formed by the evaporation of the solution resulting from metal nitrates and citric acid making a redox reaction to occur. The underlying idea for the reaction is that the metal nitrates react with water. Then the carboxylic acid functionalities from the citric acid chelant are deprotonated with ammonium hydroxide and the metal hydroxide by removing protons. It results in production of metal ions having a positive valency and carboxylic ions with negative valency together with water molecules. After this co-ordinate bonds are formed to produce the metal and acid complex which is the ash-synthesized powder obtained. Finally auto-combustion or the ignition process takes place. The powder is pressed into pellets and toroids according to its specific requirements and then given final sintering for densification. Processing of the material prior to firing has a significant effect on the prepared samples. However during firing, microstructure and hence the engineering properties of the final product is developed.



**Fig. 4. Block diagram of citrate precursor method.**

## III. PROCESSING METHOD OF FERRITES FILMS

Inorder to prepare ferrite films several methods such as spin spraying, pulsed laser deposition (PLD), plasma vapour deposition (PVD) etc. are used. PLD technique is mostly used to deposit a variety of oxide films with good magnetic and dielectric properties. It has been used successfully by optimizing preparation conditions, such as pulse rate, cooling rate and substrate surface.

Pulsed laser deposition (PLD) is a method for growing ferrite films. In conventional PLD, laser pulses from a high energy laser ablate a homogeneous target forming a molecular flux. The substrate intercepts the plume allowing for film growth on selected, often lattice-matched, substrates. PLD has been used in the deposition of garnet, spinel, and hexaferrite ferrites. As industry demands high frequency devices investigations are focussed on low temperature synthesis of ferrites. Also high power operations require enhanced instability threshold of ferrite above the power specification and good spreading of energy.

#### IV. APPLICATIONS

Depending on type of applications there are various forms like biomedical applications, permanent magnets, magnetic fluids, magnetic drug delivery, and high density recording media etc. The widely used magnetic nanoparticles for biomedical applications are magnetite ( $\text{Fe}_3\text{O}_4$ ) and related oxides which are chemically stable and have attractive magnetic properties. It shows considerable promise for applications as targeted drug delivery, hyperthermic treatment for malignant cell, and magnetic resonance imaging (MRI). They are useful in biomedical application because magnetic nanoparticles can have controllable size ranging from a few nanometers up to tens of nanometers, and are smaller than comparable in sizes to a cell. They can get close to the cell or gene and they can be coated with biomolecules to make them interact or bind with biological entity. They can be used to deliver a package, such as an anticancer drug to a targeted region of the body such as a tumor. Better control of particle size and properties will be necessary to use these particles in biomedical application, in which uniformity of the properties will ensure accurate dosing and delivery. Ferrites are also largely used for practical applications like magnetic components, phase shifters, microwave devices etc.

Ferrites are primarily used as sensor, power applications, EMI suppression etc. Layered samples of ferrites with piezoelectric oxides can lead to a new generation of magnetic field sensors. The basis of their performance is the capability of converting magnetic fields into electrical voltages. Power applications of ferrites are dominated by the power supplies for a large variety of devices such as computers, TV and video systems, and all types of small and medium instruments. The main application is in the systems known as switched-mode power supplies (SMPSs). In this application, the mains power signal is first rectified it is then switched as regular pulses (typically rectangular) at a high frequency to feed into a ferrite transformer, and finally it is rectified again to provide the required power to the instrument. An increase in power delivery and efficiency can be obtained by increasing the working frequency of the transformer. A recent approach to increase efficiency of the ferrite cores is based on the decrease of eddy currents, by increasing resistivity. Beside the use of nonconducting additives that locate preferentially on grain boundaries MnZn and NiZn are combined as  $\text{Mn}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$  and obtained through a citrate precursor method [34]. The significant increase in the amount of electronic equipment such as high-speed digital interfaces in notebooks and computers, digital cameras, scanners, and so forth, in small areas, has seriously enhanced the possibility of disturbing each other by electromagnetic interference (EMI). Hexaferrites represent an interesting alternative to cubic ferrites as EMI suppressor components; they possess higher resonance frequencies, relatively high permeabilities (at microwave frequencies), and high electrical resistivities. Metallic ferromagnets, in contrast, show a larger saturation magnetization, but, as frequency increases, they exhibit a strong decrease in permeability due to eddy currents. However, in combination with hexaferrites, they have shown a strong potential for EMI suppressor devices [45]. Notably spin spray ferrite plating, allows the coating of IC components with ferrite films and coatings fabricated in a low-temperature process. This is a significant advance to eliminate or significantly reduce EMI by the use of ferrite coatings.

## V. CONCLUSIONS

Bulk ferrites remain a key group of magnetic materials, showing a dramatic promise for applications in even significantly wider fields. There are various synthesis methods. Various processing methods have been summarized for important ferrite systems along with some applications. Considering the complicated chemical compositions of ferrites, it is noted that special attentions must be paid to (a) careful selection of chemical precursor, (b) possible decrease of the sintering temperature by doping, (c) development of ceramic consolidation routes that target a high compact density, a fine grain size, and a homogeneous microstructure.

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