

An Overview on Preparation Techniques for Magnetic Ferrites

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Abstract : Owing to their electromagnetic characteristics, pure and doped ferrites have been used for many applications in modern electronic industry. The use of these materials in bulk form, where the size of grains is in micrometer scale, is only confined to a few megahertz frequencies due to their higher conductivity and domain wall resonance. On the other side, ferrite nanoparticles show novel magnetic properties such as single domain behavior and ferrimagnetism which are not observed in bulk material. The properties of ferrite depend mainly on the technique and conditions of preparation, which, in turn, affect the the microstructure features, i.e., grain sizes and porosities. In the present work, various methods used for the ferrite synthesis have been reviewed.

Key words: Ferrites, magnetic properties, preparation, microstructural properties.

1. INTRODUCTION

Ferrite with spinel structure (Fig. 1) can be depicted as cubic close packed arrangement of oxygen atoms in which 32 oxygen ions forms a unit cell. Layers of oxygen ions contain 64 tetrahedral (A) sites and 32 octahedral (B) sites. To provide electrical neutrality of the lattice the 8 tetrahedral and 16 octahedral sites are occupied by divalent or trivalent ions, so unit cell contains eight formula AB_2O_4 units [1].

Ferrites have been observed as better magnetic materials than pure metals due to their ease of preparation, low cost processing and high resistivity. Also, a small addition of dopant ions can improve their magnetic properties. The properties of the ferrite materials, which decide their application in the respective fields, are governed by the chemical compositions and the procedures applied for their preparation. Therefore, the molecular engineering of ferrite composition and employment of appropriate process parameters play a significant role in tailoring the material properties for a specific need. The properties of the ferrites can be modified and upgraded by substituting the optimum amount of various metal ions in the basic compositional formulae. In this way, ferrites provide a wide range of properties and are useful for a variety of applications. It is, therefore, desirable to investigate and understand the dependence of composition on magnetic/electric behavior of these ferrites. Ferrite nanoparticles show unusual magnetic properties such as single domain behavior and ferrimagnetism which are not observed in bulk material [2,3]. Therefore, chemical aspect has become the most important factor in the design and preparation of ferrite materials. Solution combustion method has been found to be the most suitable technique for the synthesis of a particular mixed ferrite composition. The properties of the final product (particle size, surface area, and porosity) depend on the way combustion is conducted. The release of gases during combustion favours the desegregation of the product (increasing the porosity) and heat dissipation (inhibiting the sintering of the products). The exothermicity of the combustion is controlled by the nature of the fuel used and the ratio of oxidizer to fuel.

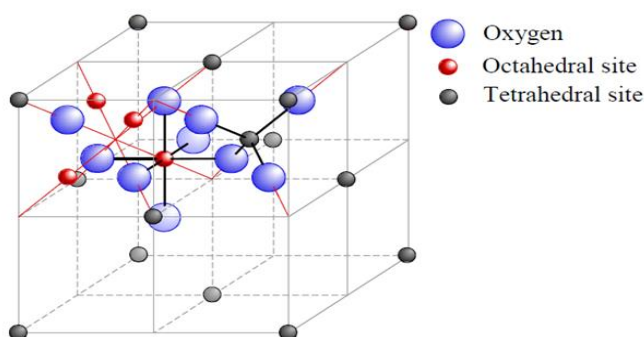


Fig. 1 Schematic representation of spinel structure.

2. PREPARATION METHODS

Different chemical synthesis techniques have been used by the researchers for the ferrite nanoparticle synthesis with a common feature that all reagents are mixed in atomic or molecular level. Most popular methods are Solid state ceramic [4], co-precipitation [5], sol– gel method [6-7] and precursor method [8].

2.1. Solid state ceramic Method

The term solid-state reaction route is often employed to explain interactions where neither controlled vapor-phase interactions nor a solvent medium is carried out. As these reactions usually engage extreme states (high pressure and/ or high temperature), solvothermal methods are often regarded as part of the solid-state tool kit. Eventually, the solid-state route was employed where other methods are not useful: the fabrication of refractory ceramics, glasses and bulk crystals. This route is also applied to produce advanced materials with unique compositions like piezoelectrics. Many researchers involving but not restricted to the following [9–11] have performed this technique to produce nanocrystalline spinel ferrites. The solid-state method is known as the simplest route to synthesize various materials even with only a little knowledge about the chemical science. Performing this technique enables one to produce desired products by mixing high-purity oxide materials with certain proportion. This blending is being carried out by dry or wet milling media for long durations. Some disadvantages of the method may also be encountered such as sintering at higher temperatures for long times (needs expensive furnace) and long milling time, and sometimes, it is difficult to control the process due to the formation of unwanted phases.

2.2. Co-precipitation method

The precipitation is the settling down by a precipitate of substances normally soluble under the conditions employed. It includes the simultaneous precipitation of required hydroxides from a solution so that the precipitate contains the required metals in the desired proportion. The prepared solution is the mixture of dissolved precipitation agent like ammonium hydroxide or ammonium oxalate or oxalic acid to precipitate the blended hydroxide or oxalate as well as the combined hydroxide or oxalate out of solution. By heating the precipitates at higher temperatures, the final crystalline oxide is attained [4]. It has been revealed that by using this method, spinel ferrite can be fabricated at shorter duration than that required in the conventional route.

2.3. Sol–gel auto-combustion method

This method involves exothermic and self-sustaining thermally-induced anionic redox reaction of xerogel, which is obtained from aqueous solution containing desired metal salts (oxidizer) and organic complexant (reductant) [6]. Combustion reaction of reactant mixtures is shown in Fig. 3 [5]. Proportions between complexant and salts are usually calculated according to the valences of the reacting elements in order to supply the relation of oxidizer/reductant equal to 1 [7]. The nitrate salts are favored as precursors, because they serve as water-soluble low temperature NO_3^- oxidant source for synthesis [8].

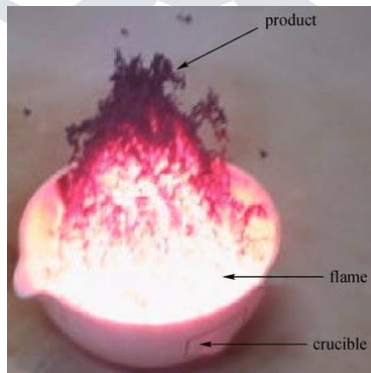


Fig. 2 Combustion reaction of reactant mixture in sol-gel method

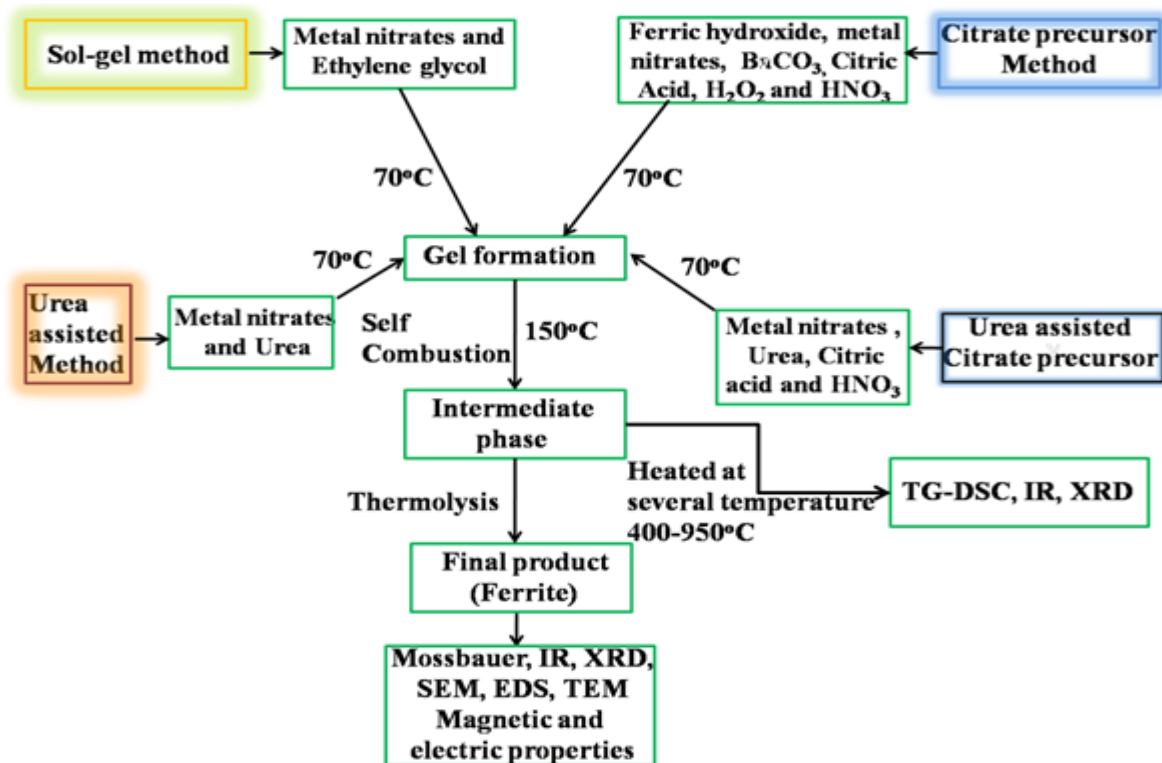


Fig. 3 Schematic representation of various routes employed for preparation of ferrites.

In some cases, metal nitrates and complexant are directly mixed together by intensive stirring and heating without adding water. Metal nitrates possess hygroscopicity; consequently, they easily absorb moisture and become slurry. This variety of the sol-gel auto-combustion is called flash-combustion method [9-10]. Rapid evolution of a large volume of gases accompanying by a great mass loss during the xerogel combustion leads to the formation of ferrite nanopowders. Evolution of gases limits the occurrence of agglomeration [10-11].

2.4. Precursor method

A precursor of mixed oxides is obtained by dehydration from solutions containing the required metal salts and organic polyfunctional hydroxy-acids. Metal salts generally used are nitrates, acetates or oxalates and organic acids as citric, malic, tartaric, glycollic or lactic acid. The important step in the preparation of amorphous precursor is the rapid dehydration of the solution at low temperature in a revolving evaporator in sufficiently high concentration and then completely drying in a vacuum oven. This precursor is then heated very rapidly at its pyrolysis temperature in air or oxygen to get the finely divided ferrite powders. This method yields highly dispersed oxide mixtures of ferrites or ferrite solid solutions containing many cations. Nearly all compositions have been achieved with the exception of phases containing silver or in some instances titanium.

3. CONCLUSIONS

Different chemical methods explained have been found to be capable of producing homogeneous and uniform fine powders without the mechanical grinding. The product is as pure as the raw materials from which it is processed. The methods are particularly useful for studies of the effect of additives on densification and grain growth because by these methods uniform distribution of even a very small amount of additives is assured. Each method has its particular advantages and limitations and the choice of a preferred process depends upon the application in view and the scale of operations. All the chemical methods discussed have considerable flexibility and hold great promise for future. A judicious selection of a specific process for a particular grade of ferrite will enable the manufacturer to prepare in a more reproducible manner, products with improved properties.

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