Synthesis of ferrites via sol-gel route: a mini review

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Abstract

Ferrites have complex spinel structure. They are magnetic in nature because of their structure. Their magnetic nature makes them useful for several electrical and electronic applications. Sol-gel method is widely used for the synthesis of this class of compounds. Sol-gel has several positive points e.g. this is a very versatile route of synthesis, does not require very sophisticated infrastructure of the laboratory, to name a few.

Keywords: inductor, spinel, magnetic, RADAR, microwave

1. Introduction

Ferrites are oxides of iron having ferrimagnetic nature. These class of compounds have 'spinel' molecular structure with AB_2O_4 molecular formula, where A is the divalent ions and B is the trivalent ion. The term 'spinel' signifies here, that these class of materials have crystalline structure like that of 'spinel'. The molecular formula of spinel $MgAl_2O_4$. Naturally, occurring spinel are found in various colors e.g. pink, red, blue, yellow, brown etc., to name a few. Spinel i.e. $MgAl_2O_4$ has a cubic lattice structure. Magnetic properties of the ferrites are due to the distribution, arrangement of ions and structure of the lattice.

Spinel structure are cubic closed packed with tetrahedral and octahedral sites. In spinel structure A and B is anti-ferromagnetic having opposite spin which cancel each other. Depending on the magnetic properties the ferrites are classified as hard ferrites and soft ferrites. Soft ferrites are those having low coercivity and the hard ferrites are those having low coercivity. Coercivity is defined as the resistance to get demagnetized on the removal of the magnetic field which makes it as a permanent magnet [1-4]. Low coercivity is defined as the property of magnetization of materials which can be reversed comfortably beyond consuming substantial energy. On the other hand, the materials with high coercivity avoid eddy currents in the core. Eddy currents are the origin of loss of energy in the form of heat. Magnetic recording tapes also make the use of ferrite powder. Ferrite acts as the RADAR absorbing material. Nanoparticles of ferrite have the super magnetic properties. These properties demonstrate that ferrites can be used in several applications e.g. electronic and electrical devices and in power supply, to name a few. Applications of ferrites are described in the following section (see sec. 2).

2. Applications of ferrites

An inductor is an electrical element having a capacity to store energy when electric current is passed through it in a magnetic field. Most used, inductors are in the form of a wound wire around a core. Ferrites are used for the fabrication of inductors. A soft magnetic ferrite in combination of a metallic wire forms an inductor. Very efficient miniature magnetic sensors can be manufactured using these ferrites in combination with piezoelectric oxide. Telecommunications and radar systems that function in microwave region require ferrites as these materials allow total penetration of of electromagnetic radiations in microwave regions, whereas, in metallic devices, microwave energy is lost due to skin-effects. Ferrites are also used in power supply of variety of instruments e.g. computer, television, to name a few.

Electromagnets, transformers and electrical inductors make the use of ferrite cores. Here the loss in eddy current is very less because they have high electrical resistance [3]. These are usually present as a lump in the cable of computers, known as ferrite bead. It helps to restrict huge frequency electrical noise. They can be also used in the coatings of magnetic recording tapes. Iron (III) oxide is well known material of this kind. Ferrite also plays an important role as a radar-absorbing material or in the coatings of aircrafts and for electromagnetic compatibility measurements in the absorption tile lining of the rooms. Most common radio magnets, including those used in loudspeakers are the ferrite magnets. Efforts have been made by several groups of scientists to prepare these materials [5]. These materials can be synthesized using sol-gel route. A brief discussion of sol-gel route is presented in the next section (see sec. 3).

3. Sol-gel route

This is one of the most widely used method of preparation of nanoparticles. As the name says the reaction occurs in two stages having reaction mixture 'solution like stage, known as 'sol', which undergoes 'gelation' to form a 'gel'. In sol gel process first, a sol is formed. Sol is a colloidal solution which is stable. In sol the solid particles ranging in size from 1 nm to 1 micron are suspended in liquid. Metal oxides and inorganic salts by condensation polymerization and hydrolysis give rise to it. Particles of sol agglomerate on drying to form a gel. After the drying process the liquid from the gel is removed, a porous material is left behind. If the gels are dried by evaporation, then the resulting material is known as xerogel. When gel is dried by supercritical drying then the resulting material is known as aerosol. After this the material is calcinated so that the further polycondensation can occur and structural stability along with mechanical properties can be enhanced. A typical sol-gel process is represented in fig. 1.

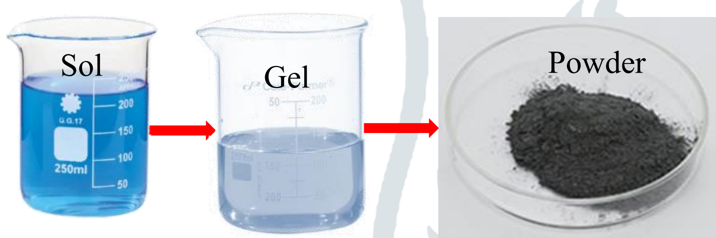

Fig. 1: Pictorial representation of different phases of sol-gel process.

This provides an opportunity to synthesize particles with various diameters and porosity. It also allows the change in composition of nanomaterials by changing reactants. It does not require any sophisticated infrastructure of the lab or high temperatures to occur the reaction. It allows homogeneity in reaction mixture because of the nature of reaction. These advantages make this route of synthesis very handy. Oxides, non-oxides, coatings, paints etc. can be synthesized via this route [6].

Few examples of preparation of ferrites via sol-gel route and the characterization techniques used to study these samples are described in the next section (see sec 4).

4. Few examples of preparation of ferrites using sol-gel route and the characterization of the products:

Chen et al. prepared nickel ferrite via sol-gel route. Aqueous solutions of nickel nitrate (0.4 M) and ferric nitrate (0.8 M) were prepared and was mixed with aqueous solution of polyacrylic acid (PAA). The mixture was stirred when phase separation was observed. Nitric acid was added to this mixture to acidify the reaction mixture. The final pH of the reaction mixture was maintained in between 1 to 3. The color of the reaction mixture turned to green. It was then heated at 50 °C for 10 hours to form a thick brown gel. It was then heated at 300 °C to 400 °C when $NiFe_2O_4$ nanoparticles formed [7].

M. Khairy and M.E. Gouda (2015) et al. synthesized nickel ferrite nanopowder from was synthesized by sol–gel using nickel nitrate ($Ni(NO_3)_2.6H_2O$), ferric nitrate ($Fe(NO_3)_3.9H_2O$ and polyethylene glycol (PEG). Chen et al. used polyacrylic acid (PAA) whereas Gouda et al. used polyethylene glycol. The reaction mixture was stirred vigorously using a magnetic stirrer and was heated at 90 °C and product was formed in 2 hours [8].

Several other research groups have adopted sol-gel method to synthesize this class of compounds. Advanced materials characterization techniques e.g. Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Thermogravimetric Analyzer (TGA), Differential Scanning Calorimeter (DSC), to name a few, were used to characterize these samples.

5. Summary

Ferrites are magnetic materials. They can be used for several electronic and electrical applications. Several methods have been adopted to synthesize this class of compound. Sol-gel method is also employed extensively as this method does not require very sophisticated infrastructure of the laboratory.

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