Synthesis, Characterization and Applications of Ferrite Nanoparticles by Bottum up Approach

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Ferrites

Ferrites are mixed metal oxides with iron in oxidation state of +3 as the main component. Electrically, they are bad conductors and display magnetic properties. The most common ferrites have the general formulae MFe_2O_4 and $MFe_{12}O_{19}$, where M stands for a divalent metal such as Nickel(Ni), Cobalt(Co) etc. Ferrites have been receiving growing attention because of their various commercial and technological applications(1,2). Spinel and magnetoplumbite ferrites are very important and exhibit ferrimagnetism. Their hysteresis loop is almost rectangular(3). For this reason, they are used in high frequency circuits as a magnetic cores and in switching devices.

Nanoparticles

Nanoparticles are particles in the range of size 1nm to 100 nm. The understand the properties, behavior and structure of particles in this scale is Nanoscience. Nanotechnology is application of nanoscience in development of newer tools. There are two facets, one is the development of devices of very small sizes and the other is the improvement of existing materials by reduction of sizes. The size reduction increases the surface to volume ratio, free energy content, band-gap, as well as defect concentration(4). This way, nanomaterials acquire some exotic properties which are not available in Bulk materials. Quantum confinement and surface effect plays an important role in modifying the properties of nanomaterials. Because of the extremely small particle size, the continuum energy bands become quantized into discrete energy levels. Due to these reasons, the structural, electronic, magnetic and optical properties that we observe in bulk size get modified in nano size(5), which depend on size, shape, composition and method of preparation. As for examples Chalk and seashell are made of same materials, calcium carbonate. Chalk is shoft while seashell is hard. This is because the shells made of nanostructured materials.

In the **Nanocrystalline phase**, ferrites exhibited properties that are notably different from their bulk phase properties and strongly dependent on the conditions and preparation techniques (6,7). In this phase the special emergence properties such as superparamagnetism, collective magnetic excitations, spin canting is to be found.

Growth of ferrite nanoparticles

There are several routes for preparation of nanocrystalline ferrite samples. One method that has been used widely is by powdering. Ball milling are normally employed for this. Fine powders have also been obtained using chemical precipitation and annealing. Electrolytic techniques have also been used. Several other methods exists besides these. A review of the different preparation techniques has been given by M.Pal and D.Chakravorty(8). Each of these techniques has its own advantage and disadvantage. The chemical route has a number of attractive features like simplicity and low cost of preparation so that it become an attractive for preparation of nanocrystalline phase ferrite. In chemical based citrate precursor method, generally nitrates of divalent metal, Iron and citric acid are taken in stoichiometric proportions and dissolve in minimal amount of disstiled water. The aqous solutions are mixed together and stirred at 60^0c to 80^oC temperature for two hours. A Brown slurry is formed, which is then dried in an oven at a temperature of $90\,^oC$. This dried materials is the citrate precursor(Figure 01). Ferrite nanomaterials are produced by annealing of the dehydrated precursor at predetermined temperatures in a temperature controlled muffle furnace.

Figure no. 01: Citrate Precursor

Characterization:

The ferrite nanoparticles are characterized after their preparation using various characterizing tools, such as X-ray diffraction(XRD), Vibrating sample magnetometer(VSM), Transmission electron microscopy(TEM), Mossbaur spectroscopy, Scanning electron microscopy(SEM), Positron annihilation spectroscopy, Superconducting quantum interface devices(SQUID), and UV-VIS spectroscopy etc. The mean particle size,shape and phases are determined using X-ray diffraction method. Magnetic properties were measured usind SQUID and VSM. TEM gives information about particle size distribution while SEM gives particle morphology. Mossbaur spectroscopy gives information about percentage of iron content and superparamagnetic behavior. Positron annihilation spectroscopy is a powerful experimental tool for probing the electronic and defect structure of solids(9).

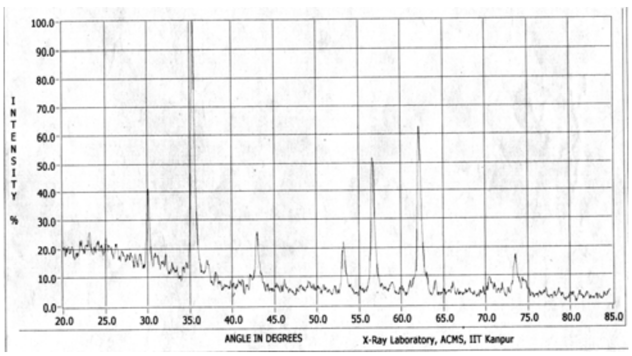

Figure no. 2: X- ray diffraction pattern of Zn Ferrite nanoparticle Annealed at 450°C (9)

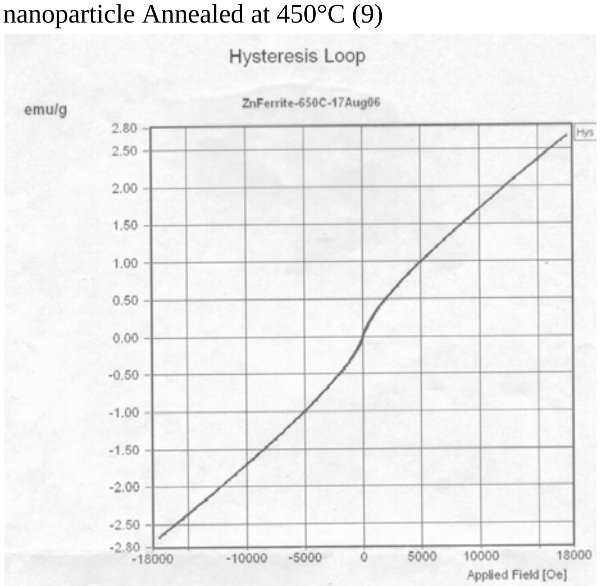

Figure no. 3: Hysteresis curve for Zn Ferrite nanoparticles (9)

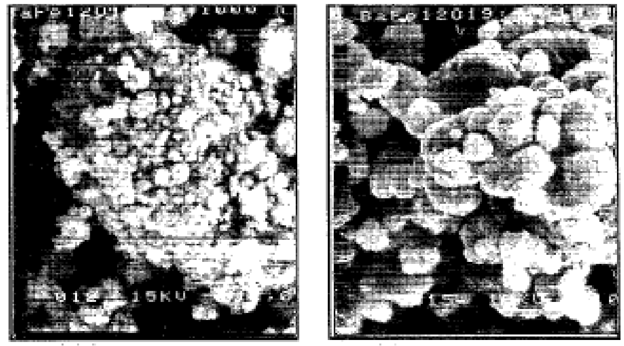

Figure no. 4: SEM Image Of Ferrite Nanoparticles (10)

For example we take zinc ferrite (10). The average particle size of Zinc ferrite sample was determined as 11.37nm using Scherrer equation ($d= k\lambda/\beta\cos\theta$)at $450^{o}C$ and 33 nm at $650^{o}C$. Where k is constant that has value 0.9 and B is full width at half maximum. For this analysis, we used the most prominent peak(Figure 02).. The average coercive field and saturation magnetization of the this nanoparticle are 2.87Oe and 3.99 emu/g. The retentivity is 1.152×10^{-3} emu/g. We find average particle size increases as annealing temperature increased. Also the magnetic parameters value changes with particle size.

Technological applications for ferrite nanoparticles.

Ferrites have a broad range of applications in many disciplines. These include products and applications such as transformer cores for power applications.[11,12,13] Multilayer ferrite chip inductors[14], Microwave ferrite devices[15,16], ferrite wave absorbers[17], Magnetic recording media[18], ferrite magnets[19], etc. In the field of medical sciences also, ferrites are finding numerous applications. Magnetic nanoparticles have unique magnetic features that can be applied to specific medical techniques[20]. These include separation, immunoassy, magnetic resonance imaging, and many others.

Drug delivery and hyperthermia are enhanced by use of appropriate magnetic particles. Magnetic cationic lipsomes (MLCs) can be used as carriers for introducing DNA into cells and heat mediators for cancer therapy.

There are other applications related to biological sciences. Applications include immobilization and modification of biologically active compounds by magnetic carriers, isolation of biologically active compounds, detection of biologically active compounds and xenobiotics, modification, detection, isolation and study of cells and cells organelles can all be effectively carried out with the help of magnetic nanoparticles.[21,22]

Ferrites and ferrites based composite materials have wide applicability in the fields of integrated electronics, microwave devices, sensors and transducers, magnetic cores, electromagnets, magnetic storage devices.

We have not come to the stage where we can suggest new technological applications. But possibility of such leads in future cannot be ignored. We will have to continue with this exploratory work.

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