Magnetic Nano Particles
Synthesis and Characterization

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- **Every atom behaves as magnet.**

- **The magnetism arises due to the orbital and spin motion of the electrons.**

- **When these atoms are arranged in regular and periodic manner in a crystal, different type of magnetism exhibited by the material.**

Various type of Magnetism are :

Diamagnetism

Paramagnetism

Ferromagnetism

Antiferromagnetism

Ferrimagnetisms

- Paramagnetic – Random spin orientation
  - Zero magnetic moment
- Ferromagnetic – Order spin orientation
  - High magnetic moment
- Anti ferromagnetic – order spin orientation with alternate spin of equal strength and are antiparralal
  - Net magnetic moment zero
- Ferrimagnetic – Order spin orientation with alternate spin of unequal strength and antiparralal
  - Net magnetic moment finite

Ferrimagnetic materials are usually known as Ferrite s

- **The basic magnetic parameter are**
  - **Susceptibility**
  - **Permeability**
  - **Magnetic Moment**
  - **Coercivity**
  - **Retentivity**
- **All these magnetic parameters are different for different class of magnetic materials .**
- **Experimental observations shows that the numerical values of these parameters are greatly enhanced when material goes in Nano Phase.**

This enhancement in Magnetic parameters has resulted the use of these materials manifolds.

This has also attracted the attention of we people first to synthesize and then to characterize the prepared material.

- **Out of various magnetic materials,**

  Ferrites

  has gained more importance owing to their use in memory storage properties.

FERRITE

- Ferrite is a class of ceramic-like material with magnetic properties that are useful in many types of electronic devices.
- Ferrites are hard, brittle, iron-containing, generally gray or black and are polycrystalline—*i.e.*, made up of a large number of small crystals.
- They are composed of iron *oxide* and one or more other metals in chemical combination.
- A ferrite is formed by the reaction of ferric oxide (iron oxide or rust) with any or number of other metals viz. magnesium, aluminum, barium, manganese, copper, nickel, cobalt, or even iron itself.

- **Ferrite has a cubic crystalline structure with the chemical formula $MO.Fe_2O_3$ where Fe_2O_3 is iron oxide and MO refers to a combination of two or more divalent Ions.**

  For instance Nickel ferrite $NiFe_2O_4$,

  Manganese ferrite $MnFe_2O_4$

- **The importance of Ferrites is due to their many technological applications.**

- **The important structural, electrical and magnetic properties of these ferrites are responsible for their use in various fields.**

- **When particle diameter is reduced to nanometres dimension, ferrite particles may exhibit super paramagnetic properties.**

- **Iron Ferrites Fe(Fe_2O_4) exhibit a form of magnetism called Ferrimagnetisms, which can be distinguished from the ferromagnetism Iron, Cobalt and Nickel.**

- **In ferrites the magnetic moments of constituent atoms align themselves in two or three different directions.**

- **Ferrimagnetic material possesses the combined properties:**
  --Magnetic conductors
  --Electrical insulators

- **The magnetic parameters such as magnetization and coercivity of ferrites are affected by the method of preparation and type of substitution.**
- **Synthesis of Nano sized magnetic particles proved to be one of the interesting and promising fields of material science and exhibit interesting magnetic properties.**
- **In nano size, ferrites exhibit interesting magnetic properties**

- **Synthesis of ferrites having Nano size particles is again a challenge.**

Synthesis of Ferrite Nanoparticles

- Large numbers of techniques are available for the synthesis of nano size particles of different crystalline materials.

These includes:

- **Physical methods**
- **Chemical methods.**

Physical methods

- Vacuum evaporation
- Electron beam evaporation
- Pulsed laser deposition
- Reactive evaporation
- Cathode arc deposition
- Diode sputtering
- Plasma enhanced evaporation
- Magnetron sputtering

Chemical Methods

- **Spray Pyrolysis Method**
- **Sonochemical Method**
- **Combustion Flame Synthesis**
- **Microemulsion Method**
- **Sol-Gel Method**
- **Chemical Co-precipitation Method**

Chemical Co-precipitation Method is simple and can be used in our laboratories to synthesize ferrite nanoparticles.

- Co-precipitation method has many advantages especially it is a low temperature wet chemical synthesis. Fast precipitation often takes place, resulting large particles.

- Chemical co-precipitation is widely used to synthesize ferrite nanoparticles.

- Co-precipitation reaction involves the simultaneous occurrence of

  Nucleation-- Growth -- Coarsening -- Agglomeration process.

- When precipitation begins, numerous small crystallites initially from nucleation, but they quickly aggregate together to form larger, more thermodynamically stables particles.

- To produce nanoparticles, the nucleation process must be relatively fast while the growth process remains relatively slow.

- Reaction for synthesis of oxides can generally be broken into two categories:
  - One category produce an oxide directly
  - Other category first produce a precursor. This precursor is than subjected to further processing (drying, calcinations).
- To precipitate metal hydroxides from water we add a base solution such as sodium hydroxide or ammonium hydroxide .
- The resulting chloride is washed away and the hydroxide is calcined after filtration and washing to obtain the final oxide powder.

SYNTHESIS OF FERRITE NANOPARTICLES

- The basic ingredients required for the synthesis of ferrites are :

A.R. Grade

-Nickel chloride ($NiCl_2$ $6H_2O$)
-Zinc chloride ($ZnCl_2$ $6H_2O$),
-Cupric chloride ($CuCl_2$ $2H_2O$),
-Ferric chloride ($FeCl_3$ $6H_2O$),
-Oleic acid and
-Sodium hydro-oxide(NaOH)

Initially, the required amount of ($NiCl_2$, $6H_2O$) ($ZnCl_2$ $6H_2O$), ($CuCl_2$, $2H_2O$) and ($FeCl_3$, $6H_2O$), were taken in molar ratio of 1: 2 and dissolved in suitable volume of distil water.

- Thereafter, add sodium hydroxide (NaOH) to this solution until the solution attains pH equal to 7-12.
- The pH value of the solution plays an important role in controlling the precipitation and size of the precipitate particles.
- The solution containing $NiFe_2O_4$, $ZnFe_2O_4$, $CuFe_2O_4$ and $Ni_{0.5}Zn_{0.5}Fe_2O_4$, respectively , heat up to 80-90 °C.
- There after, add specified amount of oleic acid (5ml) to the solution. This act as the surfactant and coating material.
- The solution must be kept on stirring continuously and allowed to cool down up to room temperature slowly.

- The precipitate so obtained taken out and washed with hot distilled water, so as to remove traces of sodium chloride.
- Finally water was removed by washing it with acetone. The acetone wet-slurry then dispersed in 20ml of kerosene oil and further heated this at 70 ^{o}C for 5 minutes.
- The resulting fluid , than centrifuged at 1200 rpm for about 10 minutes. After centrifuged the precipitate settled down at bottom.
- The portion of the fluid was than taken out. For getting dried particles, the precipitate were repeatedly washed with acetone and filtered six times.
- Acquired substance then dried at room temperature for 48 hours.

- The co-precipitated ferrite agglomerates were than grounded using a pestle to have very fine particles.

- These particles, subsequently heat treated in a box furnace at different high temperatures.

- The final products obtained were dark brown in colour.

- The size of the particles can be determined using XRD.

END