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# Magnetic Iron Oxide Nanoparticles: Various Preparation Methods and Properties

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## ABSTRACT

This review shows the research on magnetic nanoparticles on their types of production, specific methods for preparing magnetic nanoparticles and properties. Substantial progress has been made for the preparation of magnetic nanoparticles, a major challenge is to find out the most efficient and economical one. At present ferrite nanoparticles and oxide nanoparticles are the most employed one.
**Keywords:** Magnetic Nanoparticles, Preparation, Properties

## I. INTRODUCTION

In recent years, the research and development for nanotechnology has attracted significant interest and it is still the subject for investigation on its application. Since the past three decades a series of new journals are devoted particularly to the nanotechnology. Magnetic nanoparticles are commonly composed of magnetic element, such as iron, Nickel cobalt and their oxide like magnetite $Fe_3O_4$, Magnetite $\gamma Fe_2O_3$, cobalt ferrite $Fe_2CoO_4$ chromium dioxide. Magnetic Nanoparticles displays the phenomenon of super paramagnetic nanopowder are used as conductive materials, catalysts activation and sintering materials high dense recording material.

Usually, the magnetic nanoparticles tend to aggregate due to their large surface area by volume ratio and due to magnetic dipole–dipole attraction between particles. The nanoparticles are at least ($10^{-7}$ - $10^{-9}$ m) in dimension. As size decrease the properties nanoparticles change this is due to decease in particles size result in increase in fraction of surface energy in its chemical potential. The magnetic properties of nanoparticles are determined by many factors key including chemical composition.

Nanoparticles and materials based on them (classification, definitions)

First, it is necessary to consider the general concepts related to the Nano-sized objects. A Nano-object is a physical object differing appreciably in properties from the corresponding bulk material and having at least one nanometre dimension (not more than 100 nm). Nanotechnology is the technology dealing with both single Nano-objects and materials and devices based on them and with processes that take place in the nanometre range. Nanomaterials are those materials whose key physical characteristics are dictated by the Nano-objects they contain. Nanomaterials are classified into compact materials and Nano dispersions. The first type includes so-called `nanostructured' materials, i.e., materials isotropic in the macroscopic composition and consisting of contacting nanometre-sized units as repeating structural elements. Unlike nanostructured materials, Nano dispersions include a homogeneous dispersion medium (vacuum, gas, liquid or solid) and Nano-sized inclusions dispersed in this medium and isolated from each other.

## II. METHODS FOR PREPARATION OF MAGNETIC NANOPARTICLES

### A. Chemical Methods

Diverse metal containing compounds including metal carbonyls metal carbo oxalates, organometallic compounds etc., are used as the precursors in the synthesis of magnetic Nano-particles. Most often, precursors decompose on heating or UV irradiation; other types of treatment of MCC.

**B. Thermolysis of Metal Containing Compound**

Metal organic chemical decomposition technique is used to obtain nanoparticles. In CVD synthesis, of monodispersed Fe oxides has been proposed as MCC. When reaction is carried out in liquid medium in the presence of polymer surfactants it is possible to stabilise the nanoparticles diameter up to 10nm. Two stage thermolysis of $Fe(CO)_5$ has been reported. First, an iron oleate complex is formed from $Fe(CO)_5$ and oleic acid at100◦C; at 300◦C, the complex decomposes to give primary `loose' nanoparticles (4 ± 11nm).

**C. Decomposition of Metal Containing Compounds on Ultrasonic Treatments**

Here metal carbonyls and their derivative are used as metal containing compound. Co nanoparticles were synthesized by ultrasound-induced decomposition of a solution of $Co_2 (CO)_8$ in toluene. For the synthesis of Fe-containing magnetic nanoparticles, $Fe(CO)_5$ is used most often.

**D. Reduction of Metal Containing Compounds**

Magnetic metallic nanoparticles can be prepared from metal salts using reducing agents, namely alkali metal dispersion in hydrocarbons. The general method for preparation of metallic nanoparticles is done by reducing metal salts in aprotic solvents. The reduction of $CoCl_2$ with $LiBEt_3H$ in the presence of trialkylphosphines yield Nanoparticles of pure cobalt e-phases with 2 ± 11 nm size (depending on the alkyl chain length in trialkyl phosphine).

**E. Synthesize in Reverse Micelles**

Recent years were marked by recent development and wide use of synthesis nanoparticles in Nano sized reactors the size of nanoreactor can be controlled within certain limits. Co Nanoparticles were synthesized by mixing two colloid solutions of reverse micelles with the same diameter (3 nm), one containing. $CoCl_2$ and the other containing sodium tetra hydroborate of the same concentration.

**F. SOL-GEL Method**

This method is widely used in nanotechnology field. It is applicable to the synthesis of Nano sized metals and fused bimetallic hetero element particles. reduction of $Ni^{2+}$ and $Fe^{2+}$ ions inserted in silica gel in 3: 1 ratio with hydrogen at 733 ± 923 K resulted in $Ni_3Fe$ nanoparticles (4 ± 19 nm) within the $SiO_2$ matrix.

**G. Novel Arc discharge Method**

This method is the cheapest and most economical method for the preparation of magnetic nanoparticles. This method is similar to electrolysis process. In this we require 2 beakers, 2 electrodes, ice, variac, transformer, voltmeter, ammeter, connecting wires and power supply. We arrange these equipment in particular order and synthesize nanoparticles by melting the electrodes.

## III. PROPERTIES

The Bulk properties present in magnetic nanoparticles are physical, structural, thermal, electrical, and magnetic.

**A. Physical properties**

Natural and synthesized magnetite micro-scale crystals exhibit metallic luster and opaque jet black color. Magnetite's density is established at 5.18 $g/cm^3$, slightly lighter than reddish-brown hematite ($\alpha$-$Fe_2O_3$; 5.26 $g/cm^3$) and somewhat heavier than yellowish-orange ferrihydrite ($\alpha$-FeOOH; 4.26 $g/cm^3$); pure iron ($\alpha$-Fe) has a density of 7.87 $g/cm^3$. At ambient temperatures, magnetite particles exhibit hardness of 5.5, identical to glass. Effective surface areas of magnetite vary according to synthesis method as certain procedures generate coarser/finer particles; however, typical micro-scale particles with approximate diameters of 0.2 μm exhibit surface areas of approximately. Magnetite particles are not porous.

**B. Structural Properties**

Magnetite's crystal structure follows an inverse spinel pattern with alternating octahedral and tetrahedral octahedral layers. From Figure 1, ferrous species are observed to occupy half of the octahedral lattice sites due to greater ferrous crystal field stabilization energy; alternatively, ferric species occupy the other octahedral lattice sites and all tetrahedral lattice sites. This preponderance allows for application of the chemical formula Y[XY]O4, where brackets represent octahedral sites while the absence of brackets represents tetrahedral sites; consequently, X and Y symbolize ferrous and ferric, respectively. Additionally, magnetite unit cells adhere to the facecentered cubic pattern with crystal lattice parameter, $a$ = 0.8396 nm (Cornell and Schwertmann, 1996). Moreover, Figure demonstrates the presence of eight formula units ($z$ parameter) within each magnetite unit cell.

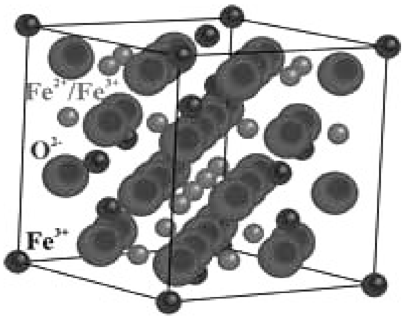


**Figure 1.** Structure and Unit Cell of Magnetite

### C. Thermal Properties

Magnetite melting/boiling points are observed at 1590 and 2623 °C, respectively. Heats of fusion, decomposition, and vaporization are 138.16, 605.0, and 298.0 kJ/mol (at 2623 °C), respectively.

### D. Electrical Properties

Octahedral sites in the magnetite structure contain ferrous and ferric species. The electrons coordinated with these iron species are thermally delocalized and migrate within the magnetite structure causing high conductivity exchange constants: ranging from -28 J·K to 3 J·K between tetrahedral/octahedral sites and octahedral/octahedral sites, respectively (Cornell and Schwertmann, 1996). Magnetite's Verwey transition temperature (VTT) (118 K) exhibits an ordered arrangement of ferrous and ferric ions on octahedral sites, inhibiting electron delocalization when temperatures fall below VTT. Furthermore, due to electron delocalization effects magnetite can be slightly metal deficient on octahedral sites; such deficiency allows for n- and p-type magnetite semiconductors.

### E. Magnetic Properties

Magnetite's Curie temperature is observed at 850K. Below the Curie temperature, magnetic moments on tetrahedral sites, occupied by ferric species, are ferromagnetically aligned while magnetic moments on octahedral sites, occupied by ferrous and ferric species, are antiferromagnetic and cancel each other; such combined behavior is termed ferromagnetic. Therefore, at room temperature, magnetite is ferrimagnetic.

Figure 2 illustrates the ferro-magnetic behavior of tetrahedral sites and mentions the antiferro-magnetic behavior of octahedral sites. As temperatures increase to the Curie temperature, thermal fluctuations destroy the ferromagnetic alignment of magnetic moments on tetrahedral sites; hence, ferromagnetic strength is diminished. When the Curie temperature is attained, net magnetization becomes zero and superparamagnetic behavior is observed.

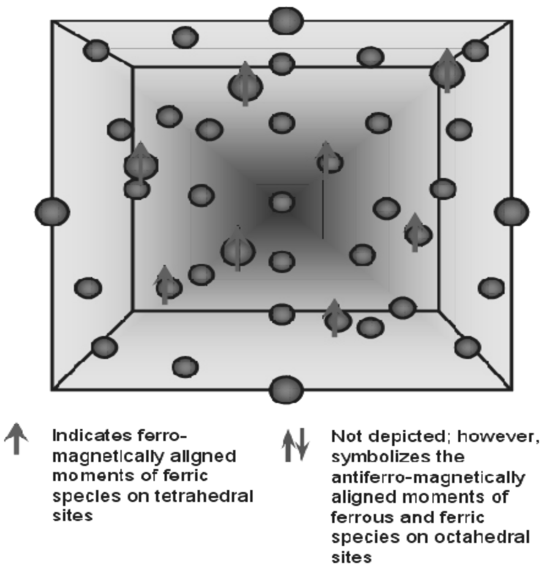


**Figure 2.** Ferrimagnetic behavior of magnetite

## IV.CONCLUSION

Magnetic nanoparticles play an important role in the rapidly developing branches of science specialising in the study of objects (existing in nature or, more often, artificially produced) with Nano-sized structural blocks. Magnetic Nanoparticles display the phenomenon of super paramagnetic. At the end bulk and nano-scale properties of magnetite have been documented and discussed; methods of synthesizing magnetite nanoparticles have been described at length.

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