Chapter 1: Introduction

1.1 Introduction

Presently the science and technology of materials is in an advanced phase as to allocate the application of physico-chemical theories for the design of preferred new materials in ceramic, single crystal and/or amorphous classes. This advancement of science and technology of bulk is primarily because of the cognizance that structures and properties are associated at the molecule level. The major part of many solid state devices that are having wide applications belongs to semiconductors, magnetic garnets, ferrites, solid state lasers, , ferroelectric, piezoelectrics, magnetic bubbles, ultraviolet and infrared sensitive crystals etc.

Today technology expects the great reduction in size of the devices of the range of nanometer when their ultimate performance is significantly enhanced. Nanophase and nanostructured materials, the new branches of material science are appealing various possible fields viz, properties related with light, electronic devices, special materials which accelerates the chemical reactions and special non-metallic and nanocomposites. The special characteristics and the improved functioning of nanomaterials are estimated by their size, surface structures and mutual action among the particles. The behavior shown by particle dimension is related to materials constitution, mixing of some other factor that defines a system and determines its performance.

Nanomaterials are categorised into nanostructured materials as well as Nanophase/nanoparticle materials. The earlier refers to condensed mass materials that are built of relatively small granular particle of a substance with granulate shapes in nanometer size interval, while the later are normally the dispersive nanoparticleces. The nanometer size covers a broad interval which may be as long as 100-200 nm.

Nanostructured materials are also distinguished based on the relation among their morphology and magnetic nature.

Figure 1.1 depicts applications of nanotechnology. Majority of the processes and products shown here could be considered as nanomaterials.
Fig. 1.1: Applications of Nanotechnology

Other most challenging applications of nanomaterials are pointed out viz usage of nanomaterials for polluted environment. The speedy development of nanoscience indicates a progress in diversity of noble electronic, medical and variety of new progressive application of nanomaterials was encountered. The growing of novel nanostructure is a fastly developing area of research.

For categorizing nanoparticle, particles structure is mainly exploited according to their material proportion, morphology and the areas of applications. Jorter and Rao (2002), have classified nanoparticles as shown in Table 1.1.
<table>
<thead>
<tr>
<th>Nanostructure</th>
<th>Example material or application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanotubes</td>
<td>Carbon</td>
</tr>
<tr>
<td>Fullerenes</td>
<td>Carbon</td>
</tr>
<tr>
<td>Nanowires</td>
<td>Oxides, Metals, Semiconductors, Nitrides, Sulfides</td>
</tr>
<tr>
<td>Quantum Dots,</td>
<td>Metals, Non-conductors, Semiconductors, Magnetic</td>
</tr>
<tr>
<td>Nanocrystals</td>
<td>Materials</td>
</tr>
<tr>
<td>Other Nanoparticles</td>
<td>Metals, Ceramic oxides</td>
</tr>
</tbody>
</table>

Table 1.1: Nanoparticle classes and applications

1.1.1 Nanotubes
In 1991 Lijima, describes a peculiar type of fullerenes known as Carbon nanotubes (CNT). CNTs are alike in microstructure to C60 merely stretched to form 1-2 nm tubular structures. Normally nanotubes consist of single layer of carbon atoms in cylindrical form known as single –wall carbon nanotubes (SWCNTs). Various shapes of carbon nanotubes are developed by researchers with greater strength even hundred times more substantial than steel but its weight is 1/6th. Maynard et al (2004) reported few worthy properties as electrical behavior, good conductivity, eminent surface area etc.

1.1.2 Fullerenes
In 1985, Kroto et al. reported that fullerenes are of four kinds of natural existing forms of carbon. The particles were constituted totally of carbon which poseess the form of a tube. Fullerenes are alike in structure to graphite which are framed from a piece of six sided carbon chains but consist of diagonal pentagons. The Buckyballs are the most common fullerene C60. Their natural occurrence is observed in lightening strikes and in fires, but they were developed in laboratories with the help of soot which is obtained from ablation of graphite with lasers. A variety of fullerenes are obtained now a days by various methods as mentioned else where.

1.1.3 Nanowires
It is typical form of single crystal structure having a diameter of few nanometers and a conducting or semi-conducting nano microstructure. They are having wide applications
in nanoelectronic equipments. The metals like gold, copper etc are used to formulate nanowires.

Semiconductor industry has established a set up for microchip fabrication. This technique is utilized in fabrication of nanowires.

1.1.4 Quantum dots

A typical nanostructure consisting of 1000 -100000 atoms form a quantum dots. This structure has resulted into formation of quantum dots of metal, metal oxide and semi-conductors. Many techniques have been developed to control the formation of quantum dots as they exhibit quantum size effect.

1.1.5 Other Nanoparticles

This is a typical class of nano particles consisting spherical or compact form of elementary particle and prepares chain like or branching shapes. This class involves nano particles of fumed silica and ultrafine carbon black. The material which is used in fabrication of such types of nano particles are ceramics, metals, oxide etc. Wet chemical methods are normally used for production of these nano particles in greater amount. Normally, nanomaterials are prepared by two methods. The first method is known as Top-Down method in which larger mass substances are broken into tiny ultrafine materials by various techniques. The another method called bottom-up method where nano-sized particles are analyzed by properly controlled chemical techniques. The Table 1.2 summarizes the detail of each method.
| TOP-DOWN | 
| --- | --- | 
| **Process** | **Nanomaterials Produced** | **Maturity** |
| Mechanical Mining | Alloys & composites, Mixtures of elemental and prealloyed powders | Common |
| Etching (Chemical) | Arrays of nano-scale shapes | Ordinary |
| Electro-explosion (Thermal/ Chemical) | Fullerenes, metallic nanopowders, nanotubes, metallofullerenes | Usual |
| Sputtering (Kinetic) | Similar to vapor phase techniques | Ordinary |
| Laser Ablation (Thermal) | Wide range of nanoparticles | Usual |

| BOTTOM-UP | 
| --- | --- | 
| **Process** | **Nanomaterials Produced** | **Maturity** |
| Sol-gel | Oxide nanoparticles, colloidal nanoparticles, composite nanopowders | Common |
| Aerosol based process | Industrial production of nanoparticles such as titania pigment, titania &fumed silica, carbon blacks, optical fibres, CdS nanoparticle, some metal | Ordinary |
| Chemical vapor deposition | Broadly used to produce carbon nanotubes | Usual |
| Atomic or molecular condensation | Metal comprising particles | Common |
| Supercritical Fluid Synthesis | Diverse nanoparticles | Ordinary |
| Spinning | Thin polymer fibres | Usual |
| Use of Templates | Zeolites, Porous alumina, di-block co-polymers, proteins and other molecules containing regular nano-sized pores or voids, dendrimers | Common |
| Self-Assembly | Different biological and organic compounds, inorganic oxides, semiconductors and metals | Ordinary |

Table 1.2: List of top-down and bottom-up approaches to nanomaterial production (Luther, 2004).
1.2 Introduction to Magnetic Materials

Magnetism as its origin is in the circulating electron in an atom. In an atom, every individual electron has magnetic moment which originates from two routes. Out of these one is associated to its orbital revolution about the nucleus which generates a little electromagentic area and bearing a magnetic moment by axis of revolution. The magnetic moment originates from electron spin which is spinning around an axis.

The materials like iron, nickel, cobalt etc. get magnetized when placed in magentic fields. Carbon steel was common material used as permanent magnets for the long time, but now days other materials have been developed that are more efficient as permanent magnets, involving certain ferroceramics and Alnico, an alloy containing aluminum, iron, cobalt, nickel and copper. Permeability is one of the important properties for classification of magnetized substances. Important types of magnetic materials fall into categories as described below.

1.2.1 Types of Magnetism

(a) Diamagnetism

When the applied external magentic field is absent, magnetic moment does not exist, but when field is applied, magnetic moment gets induced and they are aligned face to face to the field way. When other types of magnetism are completely absent, then only diamagnetism can be detected otherwise it is very weak to observe [1].

(b) Paramagnetism

In case of substantial materials, every atom has a lasting magnetic moment due to the uncomplete negation of electron spin and/or orbital revolution of electromagnetic moments. In case, applied magnetic field is absent then atomic magentic moments are randomly oriented in such a way that, material does not posseses any net microscopic magnetization. These formed atomic dipole moments are free way to go around and paramagentism ensues when the atomic dipole align [2].

(c) Ferromagnetism

In such class of materials the individual moment of the atom or ions are strongly coupled and are more or less parallel one to another even in the absence of magentic field, so called positive exchange interaction. It is spontaneous magnetization of small regions of materials that be there when external magnetic field is away. Ferromagnetism, occurs
when paramagnetic ions in a solid lock together in a small region in which all magnetic moment are along the same direction. Such region is called domain. Domain is the self alignment of atoms carrying permanent moments in the same direction. There are number of domains present in the ferromagnetic materials. The limits among domains with dissimilar orientation are referred as domain walls. In case of ferromagnetic material, if applied external magnetic field is absent domains are arbitrarily pointed in such a way that net magnetic moment becomes null. Now if sample is arranged, applied external magnetic field incline to adjust domain along the direction of the subject field. Iron, cobalt, Nickle are the examples of ferromagnetic substances [3].

(d) Anti-Ferromagnetism.

It is seen that ferromagnetism is due to the exchange interaction or exchange field which rises when the wave functions of the two atoms overlap [4]. Thus gives rise to exchange energy. This change of energy is more if side by side spins are not intersecting which directs to a ground level where adjacent spins becomes not parallel and thus exist a cooperative alternating alignment below a specific temperature $T_N$ called as the Neel temperature. In such crystals, the atoms one after another have their spins parallel to each other but not the adjacent atoms. Such crystals can be regarded to be composed up of two inter-penetrating sub-lattices A and B. One sub-lattice gets aligned in one direction, whereas the second in the other direction. These substances are known as anti-ferromagnetic.

When the external magnetic field not available, underneath Neel temperature net magnetic moment becomes zero. The phenomenon of anti-ferromagnetic can be examined by presuming that alternate lattice points are filled by atoms A and B with anti-parallel spins. Suppose the average magnetic moment field at the sites of atoms A and B will be

$$B_A = B_0 - \lambda_A M_B$$

and

$$B_B = B_0 - \lambda_B M_A$$

where $B_0$ is the external applied magnetic field, $\lambda_A$, $\lambda_B$ constants independent of temperature and $B_A$ and $B_B$ the total magnetic field for A and B sets of atoms respectively. For temperature above $T_N$, the Neel temperature, according to Curie law, we have
\[ x = \frac{c}{T + T_N} \]  (2)

Where \( T_N \) is the Neel temperature. Thus in the case of anti-ferromagnets \( X_m \) is inversely proportional to \( T + T_N \). A small amount of magnetization is produced in existence of magnetic field. This magnetization rises as the temperature of the specimen is increased. With further increase of temperature, the interaction between sub-lattices become less effective and the susceptibility enhances. For a typical temperature the susceptibility becomes highest and above this temperature it starts decreasing. This critical temperature at which the susceptibility is highest known as Neel temperature. Above the Neel temperature spins are free and thus anti-ferromagnetic become paramagnetic. The top arriving in the graph at \( T = T_C \) is most characteristic feature of anti-ferromagnetic. At \( T = T_N \) the susceptibility of anti-ferromagnetic is not limited.

It implies that at temperature below \( T_C = T_N \), the sets of atoms A and B are spontaneously magnetized in the opposite direction and the net magnetization is zero. This is why such materials are known as anti-ferromagnetic. In anti-ferromagnetic, the crystal filed aligns the magnetic moments along a opted way under \( T_C \). A field applied perpendicular to this direction is linked with a susceptibility \( \chi_\perp \) which is independent of \( T \) \((T<T_C)\) while a field applied parallel to this direction is connected with a susceptibility \( \chi_\parallel \) which is equal to \( \chi_\perp \) at \( T = T_C \) but limits to zero as \( T \to 0\)K.

**Ferrimagnetism**

The substance in which magnetic moment coupling among neighbouring ions or atoms takes place is identified as ferromagnetism. Due to uncompleted cancellation of spin moments there exists a possibility of permanent magnetization in ferric magnetic materials [5].

1.1.2 **Single Domain Particles**

Domain is radical of spins having uniform direction fragmented by domain boundaries and behaving cooperatively. The change in position of domain walls is a elementary cause for opposing magnetic nature. Practical observation of the coercivity dependence on particle size dimension indicated a tendency represented in fig. 1.2 [6].
The graph indicates the value of $H_c$ reduces grain dimension $D$ below to 40 nm. The coercivity is inversely proportional to particle diameter. The dependence of grain size on $D$ is specific for every substance in which the poly-domain transfers to single domain matter. Due to this coercivity enhances as magnetization in this case doesn’t takes place by mere changing the domain boundaries. The change from ferromagnetic to supermagnetic nature takes place when the size of magnetic matter measures underneath 20 nm.

1.3 Characteristics Of Magnetic Materials
1.3.1 Saturation magnetization
The highest quantity of electromagnetic field which produced by a substance is known as saturation magnetization $M_s$. The magnitude of $M_s$ is based on the force of the dipole
moment which forms the material and also density of the materials. The important parameter which affects the atomic dipole moment is behavior of the atom and electron configuration. The crystal microstructure and occurrence of any non-magnetic elements in the structure helps to obtain the packing density of the atomic moments, it may decrease due to the thermal shaking of the atoms which causes change in alignment of the moments. The value of $M_s$ is a function of relative alignment of the moments and temperature since in case of ferromagnetic substances all moments are not intersecting still at zero Kelvin.

### 1.3.2 Curie point

In ferromagnetic materials, at specific temperature, ferromagnetic ability is lost, which is known as Curie point. When the temperature is underneath the Curie point, the magnetic moments are partly arranged in magnetic domain region for ferromagnetic materials. Below the Curie point thermal vibration rapidly vanishes magnetic alignment as further temperature is increased the total magnetization approaches null. The complete paramagnetic state of a substance is observed at and above the Curie point. The $T_N$ is the degree of hotness at which an anti-ferromagnetic material becomes paramagnetic where, the thermal energy becomes large adequate to destroy the macroscopic magnetic sequence in the material.

### 1.3.3 Magnetic anisotropy

In case of magnetic substances where electromagnetic nature changes and based on crystallographic path as well as alignment of electromagnetic dipoles. The field $H_a$ is a assess of the magneto crystalline anisotropy to straightforward path of magnetization. It is the intensity used to move every moment by $90^\circ$ at a time in unique crystal. In the lattice the conjugation of the electron orbit induces field $H_a$ and in the simple path of magnetization, these electron orbitals occupy minimum energy level. The simple path of magnetization for a lasting magnet, depends on rare earth alloyed and ferrite, ought to be having single axis.

### 1.3.4 Hysteresis loop

According to the thermodynamics the free energy of a solid tends to reach a minimum value. As a consequence, the actual pieces of ferromagnetic materials are normally found in demagnetized state. Weiss explained this fact by assuming the existence of little areas
named ‘domains’ contained by which the material is magnetized to saturation. The focus of magnetization, however, changes from domain to domain and thus the net macroscopic magnetization may vary between null and saturation.

When a ferromagnetic substance is submitted similar to an increasing external magnetic subject field, the magnetic area start growing by moving their walls and the magnetization vector starts aligning along the field direction. Above a certain critical field (OA) (fig. 1.3) the domain walls move faster and the brighter domains overfrow the smaller ones. The stage viz. AB is irreversible. At higher fields, the magnetization vector of overgrown domains rotates along the field direction and the materials get saturated(OC).

When an external field is decreased, the magnetization lags behind the field exhibiting the phenomenon of ‘hysteresis’. The residual magnetization at zero external field is called as ‘retentivity(M)’ (fig 1.3). When the direction of the field is reversed, the retentivity goes on decreasing and becomes zero at a certain value of magnetic field called as ‘coercivity (H_c)’ or ‘coercive force’. The variation of magnetization over one complete cycle of external magnetizing field is called as ‘hysteresis loop’. The loss of energy per unit volume per cycle of hysteresis is equivalent to the area of the loop. The slope of the tangent to the B-H curve at the origin gives the magnitude of initial permeability($\mu_i$).The maximum permeability occurs near knee of the magnetization curve.

Neel, Gorter and Guillaud have done extensive work on the magnetization of ferrites through hysteresis measurements. The outline of hysteresis graph provides the valuable selective information for the domain state of matter of grains inside the material under testing. Bean on the basis of hysteresis phenomenon has classified the magnetic particles into ‘singledomain’(SD), ‘multidomain’(MD) and ‘supermagnetic’(SP). The hysteresis graphs of these particles are represented in fig 1.3.

On basis of magnitude of coercive field($H_c$), ferrites are classified into two groups. Ferrites with low $H_c$ are called as ‘soft ferrites’ and are mainly used as core materials in the manufacture of transformers, motors and generators. This type of ferrites has low retentivity but high saturation magnetization and initial permeabilities, which are more worthy for low frequency applications. Ferrites with high $H_c$ are called as ‘hard ferrites’.
They possess high retentivity and are used as permanent magnets for electric motors, loud speakers, telephones and TVs etc.

1.3.5 Remanence
As external magnetic field is removed, the magnetization left behind in a substance is known as remanence and is shown by $M_r$. The remanence magnitude can be obtained from a hysteresis curve at the intersections of the curve with the vertical magnetic field.

1.3.6 Coercivity
When the direction of the field is reversed the retentivity goes on decreasing and become zero at certain value of magnetic field called as coercivity and is denoted by $H_c$. The requirement of permanent magnet is that the coercivity of ferromagnetic substance must be high.

1.3.7 Magnetostriction
If the material is kept in magnetic field it causes dimensional changes which lead to magnetostriction [7]. The partial deviation in length $\Delta L/L$ is a strain and to differ it with strain induced due to applied stress, it is denoted by $\lambda$

$$\lambda = \frac{\Delta L}{L}$$  \hspace{1cm} (3)

The magnitude of $\lambda$ computed at magnetic saturation is known as saturation magnetostriction. $\lambda$ as well as its value based on level of magnetization and on used field.

1.4 Structure of Ferrites
Ferrites are magnetic ceramics containing iron oxide as a major constituent in it. It has been around 75 years since ferrites introduced as an important new category of magnetic materials. Nowadays, these are very well established group of magnetic materials. Presently ferrites are used in a broad range of applications, and have contributed materially to the improvement in electronics. The commercially available ferrites have permeabilities up to 30,000 and power ferrites for frequencies up to 10 MHz[8]. Even though, improvements and innovations continue to take place; many new practical application, modern theories and preparation technologies are currently under development in field of ferrites. The smallness trends of electronics equipment result in the production of latest device multilayer ferrite chip inductor (MLFCI) components. The usual shielding of this wire wound component contributes to the development of MLFCI.
There are plenty of applications in modern electronic appliances such as video cameras, cellular device, hard and floppy drives, notebook computers etc [9]. The chip inductor is produced by coating ferrite films and inner metallic device designed to transmit electricity, heat, etc one after another and then simultaneously firing to develop the unique layer microstructure [10]. Now a days, NiCuZn ferrites are the prevailing candidate for MLFCI as they have lower calcining degree of hotness ($< 950^\circ$C) as well as good magnetic nature [11-12]. The NiCuZn ferrites have improved high frequency properties equated to that of Magnesium Zinc ferrite and lesser compaction temperatures as compared to Nickle Zinc ferrites [12-13]. Since, this work is related to NiCuZn ferrite, a brief description about it is given below. NiCuZn ferrite is a spinel ferrite. Ferrites are chemical substances with the formula $\text{AB}_2\text{O}_4$, here A as well as B stand for different cations of metals; generally Iron[14]. The term ferrites is used to mean magnetic oxide containing iron oxide as their main component, regardless of their crystal structure. It consists of cubic closed pack magnetic oxides where cations of A position occupy $1/8^{th}$ of the octahedral voids and cations of B position occupy half of the octahedral voids. In case of inverse spinal class of ferrite divalent metal ions go to B position and trivalent iron ion are equally distributed over A and B sites e.g. Fe, Zn, Mg, Cr, Al, Mn, Si etc.

![Hysteresis loop for hard and soft ferrite](image)

**Fig. 1.3: Hysteresis loop for hard and soft ferrite**
1.4.1 Soft Ferrite
These are characterized by a small value of coercivity so they cause low hysteresis loss at high frequency owing to which they are widely used in electromagnetic cores of switching circuits in computers, RF inductors and transformers, e.g., Lithium ferrite, Nickel ferrite and Mn-Zn ferrite.

1.4.2 Hard Ferrites
These are characterized by a large value of retentivity and coercivity after magnetization. Hence, they find applications as permanent magnet in radios, e.g., Strontium and Barium ferrite. Ferrites are ferromagnetic materials that are typically oxides of mixed transition materials involving iron. For example, MnFe₂O₄ and Mg-Zn ferrite is Mn₁₋ₓZnxFe₂O₄ they are usually insulator in nature, unlike other ceramics, hard and fragile. They were having variety of applications like magnetic components in microelectronics. Majority of the ferrite particles used in synthesis of magnetic fluid posses a crystallographic structure.

1.4.3 Structure of Unit Cell of Spinel Ferrite
It includes 8 divalent metal ions, 32 oxygen and 16 trivalent ion. The most important feature of the unit cell is that array of oxygen ions leave two kinds of interstices open, which can be filled by the metal ions. These interstices are denoted as tetrahedron A position and octahedron B position. The crystallographic combination of unit cell ferrite is shown in fig 1.4. It has two groups of four cubes (octants). The ionic locations are separate in two octants distributing a face or a corner and the same in two octants sharing an edge. Thus, to give a complete picture, it is necessary only to show the positions of the ions in two adjacent octants. Note that each octants contains, in the center, a metal ion (small green sphere) surrounded by the tetrahedral of oxygen ions. This ion is said to occupy an A site. The right hand octant shows four metal ions (small red spheres) each surrounded by an octahedran (one of which is shown) consisting of six O₂ ions. Such ions occupy B position. In case of unit cell, out of 64 A position, 8 are engaged, as well as out of 32 B position, 16 are engaged. Bivalent metal subatomic particle commonly used in ferrites can be grouped into those favoring B sites Fe, Ni, Co and those preferring A sites Mn and Zn. In the normal spinel structure the eight bivalent metal ions stick towards the A sites and the sixteen trivalent iron ions stick to B sites. They will displace eight of the trivalent iron ions which will go over into the A sites. This
results in an inverted spinel. As two ionic species are the distributed over the octahedral sites a certain number of randomness may be present, contributing to the line width (loss) of the materials. These are however, limiting cases [15].

Fig. 1.4: Structure of unit cell of spinel ferrite.

1.4.4 Substitution In Spinels

The substitution is further complicated in the cases of substituted ferrites. In these materials, some of the ferrite iron ions are replaced by trivalent ions of different metal. The result on the magnetization based on the site favored by the substituent, e.g. Al prefers octahedral coordination and hence lowers the magnetization of the substituent ferrite, at least for low Ga concentration. It is not easy to predict the ion distribution in advance [9].
1.4.5 Spinel Structure
In case of spinel structure the oxygen ions form an fcc lattice and the $A^{+2}$ valence and $B^{+3}$ valence ions absorb tetrahedral and octahedral interstitial sites, depending on the specific type of spinel.

1.4.6 Normal Spinel Structure
In case of spinel structures unit cell, there are eight $MO.Fe_2O_3$ molecules. In the structure, the eight $M^{+2}$ ions engage eight tetrahedral sites and the sixteen $Fe^{+3}$ ions engage sixteen octahedral sites [10]. The negative BB interaction makes its existence felt and the trivalent iron ions side with themselves in an anti-parallel way, producing zero net magnetization [16].

1.4.7 Inverse Spinel Structure
In case of inverse spinel structure there are eight $M^{+2}$ ions which absorb eight octahedral positions as well as the sixteen $Fe^{+3}$ subatomic particle which is separated into eight octahedral sites as well as eight tetrahedral positions as represented in Table 1.3 [10].

<table>
<thead>
<tr>
<th>Interstitial site</th>
<th>Number usable</th>
<th>Number filled</th>
<th>Normal Spinel</th>
<th>Inverse spinel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octahedron</td>
<td>64</td>
<td>8</td>
<td>$8M^{+2}$</td>
<td>$8Fe^{+3}$</td>
</tr>
<tr>
<td>Tetrahedron</td>
<td>32</td>
<td>16</td>
<td>$16Fe^{+3}$</td>
<td>$8Fe^{+3}8M^{+2}$</td>
</tr>
</tbody>
</table>

Table 1.3: Metal ion arrangement in spinel ferrite unit cell for $MO.Fe_2O_4$

The inverted structures of the nonmagnetic ions occupy eight B sites, whereas the iron evenly divided into two lattices sites. The AB interaction, overriding the AA and BB interactions, leads to as parallel arrangement within each secondary lattice. Since magnetic moment of bivalent subatomic is zero, the resultant magnetization vanishes [16].
1.4.8 Partially Inverted Structures
Here the trivalent iron is un-symmetrically distributed between the two types of sites and if the AB interaction is dominant, there will be a net magnetization [17].

1.4.9 Nano-Magnetic Material
Now a days, the synthesis of nano-magnetized substance is a reason of powerful investigation as a consequence of new microscopic characteristics exhibited by the tiny particles of quantum sizes situated among the transition area along with atoms and mass solids [18]. Quantum dimensional special effects as well as the big surface field of electromagnetic particles considerably changes magnetic nature and demonstrate superparamagnetic physical process and quantum tunneling of magnetic induction, since each nano particle is measured as unique magnetic domain area. Magnetic nanocrystalline particles have concerned increasing interest both in fundamental science and in industrial practical application because of its various valuable characteristics. A variation in particle size can also modulate the physical properties, even without varying the composition. In case of nanomaterials, the domain edge microstructure found in the mass ferrites is substituted using unique domain edge structure characteristics of every nanoparticle, which results into novel processes e.g. supreparamagnetism, spin canting and extra anisotropy contributions [19].

The analysis and magnetic structure characterization of ferrites widely studied [19-21] and a keen interest is taken for the formulation as well as analysis of metal oxide nanocrystal particles of magnetic oxide with chemical formula, MeFe$_2$O$_4$ (where Me= Mn, Mg, Zn, Co etc.) [22-27].

Nanostate substances having a normal grain dimension of the order of 1 to 50 nm had appealed researchers[28-29]. This is latest category of materials which is being utilized in modern scientific and technological applications[30-31].

The grain size is the dominant factor for existence of atoms within the grain edges as majority of the atoms are available at grain edges, the nanomaterials display improved diffusivity.

The nonmagnetic substances may be investigated with changing grain dimensions by methods like sol gel method, laser ablation method, mechanical milling, oxidation...
method, co precipitation method and reverse micelle polyol process etc. The co precipitation method is utilized for analysis of zinc ferrite, cadmium ferrite, nickel zinc ferrite and magnesium ferrite by different researchers. In the present study, NiCuZn nano ferrite particles are analyzed by formal sol-gel self propagation way[32].

1.5 Organization of Thesis
The thesis is furcated into six chapters. Chapter 1 presents a brief background of nanomaterials, introduction to NiCuZn ferrite and organization of thesis. Chapter 2 deals with the detailed literature review. A brief introduction of application of ferrites is given. Chapter 3 describes various synthesis techniques of ferrites. The details of sol-gel auto-combustion technique processes are elaborated at the end of the chapter. The fundamental material characterization for preparation of sample is given. Chapter 4 explains the results and discussion on optimization of Cu concentration in $\text{Ni}_{0.8-x}\text{Cu}_x\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ ferrite, which has been divided into 5 sections. These sections describe structural aspects, cation distribution, morphological study, FT-IR spectroscopy and magnetic attributes of the prepared samples in detail. Chapter 5 narrates about the impact of Zn$^{2+}$ addition on structural and surface studies of $\text{Ni}_{0.8-x}\text{Cu}_x\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ ferrite. The sixth chapter summarizes the work presented in the thesis and emphasizes on the possible further research in this area.
References


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