

# CHAPTER ONE

## INTRODUCTION

### 1.1. Magnetic materials and applications

Magnet is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet a force that pulls on other ferromagnetic materials such as iron, and attracts or repels other magnets.

A permanent magnet is an object made from a material that is magnetized and creates its own persistent magnetic field an everyday example is a refrigerator magnet used to hold notes on a refrigerator door materials that can be magnetized which are also the ones that are strongly attracted to a magnet are called ferromagnetic this include iron, nickel ,cobalt. Some alloys of rare earth metals and some naturally occurring minerals such as lodestone although to a magnet strongly enough to be commonly considered magnetic.

Ferromagnetic materials can be divided into magnetically “soft” materials like annealed iron which can be magnetized but do not tend to stay magnetized and magnetically “hard” materials which do permanent magnets are made from “hard” ferromagnetic materials such as alnico and ferrite that are subjected to special processing in a powerful magnetic field during manufacture to align their internal microcrystalline structure making them very hard to demagnetize to demagnetize a saturated magnet a creation magnetic field must be applied and this threshold depends on coercivity of the respective material “hard” materials have high coercivity where as “soft” materials have low coercivity[1].

Magnetic materials encompass a wide variety of materials which are used in diverse range of applications magnetic materials are utilized in the creation and distribution of electricity and in most cases in the appliances that use that electricity. It is difficult to imagine a world without magnetic materials and they are becoming more important in the development of modern society magnetic materials are classified in terms of their uses if a materials easily magnetized and demagnetized then it is referred to as a soft magnetic material where as if it is difficult to demagnetized then it referred to as a hard magnetic material [2].

Be used for magnetic materials can magnetic recording VHS tapes contain a reel of magnetic tape the information that makes up the video and sound is encoded on the magnetic coating on the tape Common cassettes also rely on magnetic tape. Medicine Hospitals use magnetic resonance imaging to spot problems in patient's organs without invasive surgery. Magnetic levitation transport or maglev is a form of transportation that suspends guides and propels vehicles (especially trains) through electromagnetic force. Electric motors and generators Some electric motors rely upon a combination of an electromagnet and a permanent magnet and much like loudspeakers they convert electric energy into mechanical energy a generator converts mechanical energy into electric energy by moving a conductor through a magnetic field, While electric motor was magnetic field generated by electric current to induce mechanical motion [1].

## **1.2. Research problem**

There are not enough experimental studies explaining the effect of nano size on magnetic permeability of the diamagnetic materials.

### **1.3. Literature review**

Low pressure chemical vapor deposition device is used to synthesize carbon nanotubes (CNTs) of iron nano clusters [3].

Investigated the self-magnetization for Iron filling samples the experimental shown that the self-magnetization increasing dependent on size nanoparticles for the samples  $c(x^1, x^2$  and  $x^3)$  which  $x^1$  denote the hard sample  $x^2$  is the mid-size and  $x^3$  is soft one for Iron filling the magnetization of sample  $x^3$  was greater than sample  $x^2$  and sample  $x^1$  [4].

Two types of highly ordered  $TiO_2$  nanotubes were grown by anodic oxidation on titanium foil and titanium films deposited by rf-sputtering onto transparent conducting glass. Highly ordered  $TiO_2$  nanotubes were grown by anodic oxidation on titanium foil and titanium films deposited by rf-sputtering onto transparent conducting glass ( $TiO$ ) and their photo-electrochemical parameters were characterized and compared to each other [5].

### **1.4. Aim of work**

The aim of the work is to study the effect of the difference nano sizes of Copper which is diamagnetic material on the magnetic permeability.

### **1.5. Thesis layout**

The thesis consists of four chapters chapter one is the introduction chapter two is concerned with magnetic properties of matter while chapter three is devoted for nano science. the contribution is in chapter four

## CHAPTER TWO

### MAGNETIC PROPERTIES OF MATERIALS

#### 2.1. Introduction

This chapter is concerned with the magnetic properties of matter this includes magnetic susceptibility magnetic classification of materials langevin equation and quantum paramagnetic.

#### 2.2. Magnetic moment and susceptibility

The magnetic moment  $P_0$  is defined in terms of the current  $i$  and area  $A$  enclosed by it to be in the form

$$P_0 = iA \quad (2.1)$$

But the current generated by the electron of charge  $-e$  moving around a nucleus in a circular orbit of radius is given by

$$i = -efZ = \frac{e\omega Z}{2\pi} \quad (2.2)$$

Where,  $f$  is the frequency and  $Z$  is the atomic number.

Where the area is given by

$$A = \pi r^2 \quad (2.3)$$

One the other hand the orbital angular  $L$  is given by

$$L = mvr = m\omega r^2 \quad (2.4)$$

Where,  $m$  is the mass of electron and  $v$  is the electron speed.

Inserting equations (2.2) , (2.3) and (2.4) in (2.1) yields the magnetic moment in the form

$$P_0 = iA = -\frac{e\omega Z}{2\pi}(\pi r^2) = \frac{-eZ\omega r^2}{2}$$

$$P_0 = \frac{-emZ\omega r^2}{2m} = -\frac{Ze}{2m}L \quad (2.5)$$

Similarly the spin magnetic moment  $P_s$  is related to the spin angular momentum according to the relation

$$\vec{P}_s = -\frac{e}{m}\vec{S} \quad (2.6)$$

The total magnetic moment  $P_m$  resulting from spin and orbital motion is given by

$$\vec{P}_m = \frac{e\hbar}{2m}g_J\vec{J}$$

$$\vec{P}_m = -\mu_B g_J\vec{J} \quad (2.7)$$

$J$  is the quantum number,  $g_J$  is the g factor and  $\mu_B$  is the susceptibility hence

$$\vec{P}_m = -\mu_B \langle \vec{L} + 2\vec{S} \rangle \quad (2.8)$$

Where

$$g_J\vec{J} = \langle \vec{L} + 2\vec{S} \rangle \quad (2.9)$$

$$\mu_B = \frac{e\hbar}{2m} \quad (2.10)$$

The parameter  $g_J$  can simply be given by

$$g_J = \frac{\frac{3}{2}\vec{J}^2 + \frac{1}{2}\vec{S}^2 - \frac{1}{2}\vec{L}^2}{\vec{J}^2} = \frac{3}{2} + \frac{S(S+1) - L(L+1)}{2J(J+1)} \quad (2.11)$$

$$\vec{J} = \hbar\sqrt{J(J+1)} \quad (2.12)$$

This relation can be found by setting

$$\vec{J} = \vec{L} + \vec{S} \quad (2.13)$$

$$J^2 = L^2 + S^2 + 2\vec{L} \cdot \vec{S} \quad (2.14)$$

$$\langle \vec{L} + 2\vec{S} \rangle = \vec{L} + 2\vec{S} \quad (2.15)$$

To get

$$g_J \vec{J} \cdot \vec{J} = (\vec{L} + 2\vec{S}) \cdot (\vec{L} + \vec{S}) = L^2 + 2S^2 + 3\vec{L} \cdot \vec{S} \quad (2.16)$$

Then

$$g_J J^2 = L^2 + 2S^2 + 3L \cdot S \quad (2.17)$$

Form equation (2.14) on found that

$$L \cdot S = \frac{J^2 - L^2 - S^2}{2} = \frac{1}{2}J^2 - \frac{1}{2}L^2 - \frac{1}{2}S^2$$

$$g_J J^2 = L^2 + 2S^2 + \frac{3}{2}J^2 - \frac{3}{2}L^2 - \frac{3}{2}S^2 = \frac{3}{2}J^2 - \frac{1}{2}L^2 + \frac{1}{2}S^2$$

Hence

$$G_J = \frac{\frac{3}{2}J^2 + \frac{1}{2}S^2 - \frac{1}{2}L^2}{J^2} \quad (2.18)$$

If  $n$  atoms per unit volume align themselves along the x-ray thus the component of  $x$  is given by

$$M_x = nP_m = -n\mu_B g_J \vec{J} \quad (2.19)$$

Where  $M_x$  change from 0 to max value during a time  $t$ .

The electron revolving around a nucleus can produce a magnetic field of flux density  $B$  if the electron revolves with frequency  $f$  in circular orbit of radius  $r$  then according to Bio-Savart law it produces a magnetic field of flux density

$$B_e = \frac{\mu_0 i}{2r} \quad (2.20)$$

$$B_e = \frac{\mu_0 f e}{2r} \quad (2.21)$$

$$i = f e$$

The magnetic moment produced by such an electron is given by

$$P_m = iA = i(\pi r^2) = \pi i r^2 \quad (2.22)$$

Where  $A$  is the area enclosed by the current  $i$

$$A = \pi r^2 \quad (2.23)$$

For  $z$  electron with mean radius  $r$ , the magnetic flux density of the atom ( $B_a$ ) is given by

$$B_a = \frac{\mu_0 z f e}{2r} \quad (2.24)$$

Thus the internal atomic field generated by one electron is  $B_i = \frac{\mu_0 f e}{2r}$  and is related to the magnetic moment through the relation

$$B_e = \frac{\mu_0 P_m}{2\pi r^3} \quad (2.25)$$

Since the current for the whole atom is

$$i = z f e$$

Hence the field of the atom is related to the magnetic moment also as follows

$$B_a = \frac{\mu_0 P_m}{2\pi r^3} \quad (2.26)$$

But the magnetic moment  $M$  is defined in terms of the number of dipoles  $N$  divided by the volume  $V$  to be

$$M = \frac{N P_m}{V} \quad (2.27)$$

If the atomic radius is  $r$ , thus one atom exists in a volume  $V_a$  is given by

$$\frac{N}{V} = \frac{1}{V_a} = \frac{1}{\frac{4}{3}\pi r^3} = \frac{3}{4\pi r^3} \quad (2.28)$$

Thus



$$M = \frac{3P_m}{4\pi r^3} \quad (2.29)$$

Using (2.25),(2.27)and (2.28) in (2.29) yields

$$M = \frac{3}{4\pi r^3} \frac{B_a}{\mu_0} (2\pi r^3) = \frac{3B_a}{2\mu_0} \quad (2.30)$$

Assume the proton is affected by nuclear force  $F_e$  beside internal magnetic field  $B_i$  and a resistive force  $\gamma v_0$  thus the proton equation of motion

$$ma = F_e - B_i e v_0 - \gamma v_0$$

$$ma = \frac{mv_0^2}{r} = F_e - eB_i \omega_0 r - \gamma \omega_0 r$$

$$m\omega_0^2 r = F_e - eB_i \omega_0 r - \gamma \omega_0 r$$

$$F_e = m\omega_0^2 r + eB_i \omega_0 r + \gamma \omega_0 r \quad (2.31)$$

When an external magnetic field  $B_e$  is applied the frequency becomes  $\omega$  thus one gets

$$m\omega^2 r = F_e - eB_i \omega r - \gamma \omega r + B_e v$$

$$= m\omega_0^2 r + eB_i \omega_0 r + \gamma \omega_0 r - eB_i \omega r - \gamma \omega r + B_e \omega r$$

$$m(\omega + \omega_0)(\omega - \omega_0)r = eB_i r(\omega_0 - \omega) + \gamma r(\omega_0 - \omega) + B_e \omega r \quad (2.32)$$

If the frequency  $\omega$  is greater slightly than  $\omega_0$  it follows that

$$\omega_L = \omega - \omega_0 \approx \omega_0 \quad (2.33)$$

$$-2m\omega_0 \omega_L = eB_i \omega_L + \gamma \omega_L + B_e \omega_0$$

$$-[2m\omega_0 + \gamma + eB_i]\omega_L = B_e\omega_0$$

$$\omega_L = -\frac{B_e\omega_0}{2m\omega_0 + \gamma + eB_i} \quad (2.34)$$

The magnetic susceptibility can be found by using

$$i = -zef = \frac{ze\omega_L}{2\pi}$$

$$P_m = Ai = \pi r_0^2 ef = -ze\omega_L r_0^2 \quad (2.35)$$

Where

$$x = y = z$$

$$x^2 = y^2 = z^2$$

Thus

$$r^2 = x^2 + y^2 + z^2$$

$$z^2 + z^2 + z^2 = 3z^2$$

Hence

$$z^2 = \frac{1}{3}r^2$$

$$r_0^2 = r^2 - z^2 = 3z^2 - z^2 = 2z^2 = \frac{2}{3}r^2 \quad (2.36)$$

$$M = nP_m = -\frac{2zner^2\omega_L}{3}$$

$$M = -\frac{2ze^2nr^2\omega_0B}{3(2m\omega_0 + \gamma + eB_i)}$$

$$M = -\frac{2ze^2n\omega r^2\mu_0}{3(2m\omega_0 + \gamma + eB_i)}H = \chi_m H \quad (2.37)$$

Then magnetic susceptibility is given by

$$\chi_m = -\frac{2ze^2n\omega r^2\mu_0}{3(2m\omega_0 + \gamma + eB_i)} \quad (2.38) [6].$$

## 2.3. Classification of magnetic materials

All materials can be classified in terms of their magnetic behavior the two most common types of magnetism are diamagnetism and paramagnetism which account for the magnetic properties of most of the periodic table of elements at room temperature these elements are usually referred to as nonmagnetic whereas those which are referred to as magnetic are actually classified as ferromagnetic the only other type of magnetism observed in pure elements at room temperature is antiferromagnetic. Finally, magnetic materials can also be classified as ferromagnetic although this is not observed in any pure element but can only be found in compounds such as the mixed oxides known as ferrites from which ferrimagnetism derives its name the value of magnetic susceptibility falls into a particular range for each type of material.

### 2.3.1. Diamagnetism

In a diamagnetic material the atoms have no magnetic moment when there is no applied field under the influence of an applied field (H) the spinning electrons process and this motion which is a type of electric current produces a magnetization (M) in the opposite direction to that of the applied field all materials have a diamagnetic effect however in nono diamagnetic material another effect

makes the diamagnetic contribution insignificant the value of susceptibility is independent of temperature[7].

### **2.3.2.Paramagnetism**

When materials have unpaired electrons a net magnetic moment due to electron spin is associated with each atom when a magnetic field is applied the dipoles align with the field causing a positive magnetization because the dipoles do not interact extremely large magnetic fields are required to align all of the dipoles in addition the effect is lost as soon as the magnetic field is removed this effect called Paramagnetism is found in metals such as aluminum titanium and alloys of copper the magnetic susceptibility ( $X_m$ ) of paramagnetic materials is positive and lies between  $10^{-4}$  and  $10^{-5}$  ferromagnetic and ferrimagnetic materials above the Curie temperature also exhibit paramagnetic behavior [8].

### **2.3.3.Ferro- antiferro- and ferrimagnetism**

The simple theory of Paramagnetism in materials assumes that the individual magnetic moments (ionic shells of non-zero angular momentum in insulators or the conduction electrons in simple metals) do not interact with one another in the absence of an external field the individual magnetic moments are then thermally disordered at any finite temperature they point in random directions yielding a zero net moment for the solid as a whole. In such cases an alignment can only be caused by an applied external field which leads to an ordering of all magnetic moments at sufficiently low temperatures as schematically however a similar effect could also be obtained by coupling the different magnetic moments by having an interaction that would favor parallel alignment for example Already quite short-ranged interactions for example only between nearest neighbors would already lead to an ordered structure Such interactions are often generically denoted as magnetic

interaction although this should not be misunderstood as implying that the source of interaction is really magnetic in nature materials that exhibit an ordered magnetic structure in the absence of an applied external field are called Ferro magnets (or permanent magnets) and their resulting magnetic moment is known as spontaneous magnetization  $M_s$  the complexity of the possible magnetically ordered states exceeds the simple parallel alignment case in another common case the individual local moments sum to zero and no spontaneous magnetization is present to reveal the microscopic ordering such magnetically ordered states are classified as antiferromagnetic and one possible realization. If magnetic moments of different magnitude are present in the material and not all local moments have a positive component along the direction of spontaneous magnetization one talks about ferrimagnetism  $M_s \neq 0$  a few examples of possible ordered structures however the complexity of possible magnetic structures is so large that some of them do not rigorously fall into any of the three categories those structures are well beyond the scope of this lecture and will not be covered here [9].

## 2.4. Langevin equation

The diamagnetic susceptibility can be found by using langevin equation

The magnetic moment of atom is given by

$$U_m = iA = \frac{-e\omega}{2\pi} \times \pi r^2 = -\frac{e\omega r^2}{2} \quad (2.39)$$

For electron moving with velocity  $v_0$  the centrifugal force is given by

$$F_c = \frac{mv_0^2}{r} \quad (2.40)$$

Where

$$v_0 = \omega_0 r \quad (2.41)$$

Then

$$F_c = m\omega_0^2 r \quad (2.42)$$

When only electric force  $F_e$  and centrifugal force act on electrons

$$F_e = F_c = m\omega_0^2 r \quad (2.43)$$

But when magnetic force act on electrons

$$F_c = \frac{mv^2}{r} = m\omega^2 r = F_e + Bev = m\omega_0^2 r + Be\omega r \quad (2.44)$$

Thus

$$\omega^2 - \omega_0^2 = -\frac{eB\omega r}{m} \quad (2.45)$$

By adopting the approximation one found that

$$\omega - \omega_0 = \Delta\omega$$

$$\therefore \omega \approx \omega_0 \quad (2.46)$$

Hence

$$\omega^2 - \omega_0^2 = (\omega + \omega_0)(\omega - \omega_0) = (2\omega)(\Delta\omega) \quad (2.47)$$

From equations (2.45) and (2.47)

$$\therefore \Delta\omega = \frac{eB}{2m} \quad (2.48)$$

Thus the Larmor frequency is given by

$$\omega_l = \Delta\omega = \frac{eB}{2m} \quad (2.49)$$

Therefore the current take the form

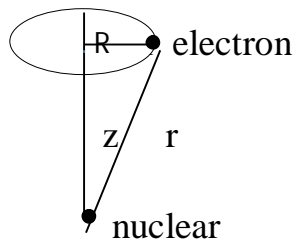
$$i = -ef = -\frac{\omega_l e}{2\pi} = \frac{\left(-\frac{eB}{2m}\right)e}{2\pi} \quad (2.50)$$

Thus the atomic magnetic moment is given by

$$M_a = iA = -\frac{\omega_l e}{2\pi} \pi R^2 = -\frac{\omega_l e R^2}{2} \quad (2.51)$$

$$M_a = \Delta M = -\frac{eR^2 \Delta\omega}{2} \quad (2.52)$$

$$M_a = -\frac{e^2 R^2 B}{4m} \quad (2.53)$$



When

$$r^2 = x^2 + y^2 \quad (2.54)$$

Hence

$$R^2 = \frac{2}{3}r^2 \quad (2.55)$$

Thus

$$M_a = -\frac{e^2Br^2}{6m} \quad (2.56)$$

Where

$$r^2 = x^2 + y^2 + z^2$$

$$\therefore x = y = z$$

$$\therefore R^2 = \frac{2}{3}r^2 \quad (2.57)$$

But the magnetic moment per unit volume is given by

$$M = nzM_a = -\frac{nze^2r^2B}{6m} = -\frac{nze^2r^2\mu_0H}{6m} \quad (2.58)$$

Where

$$B = \mu_0H$$

Where,  $n$  is number of atoms per unit volume.

The diamagnetic susceptibility is given by

$$X_D = \frac{M}{H} = -\frac{\mu_0nze^2r^2}{6m}$$

Or

$$X_D = \frac{\mu_0nze^2R^2}{4m} \quad (2.59) [10].$$



## 2.5. Quantum Paramagnetic

If a magnetic field of strength  $H$  causes the energy  $E$  to change by an amount

$$\Delta E = g\beta H m_s \quad (2.60)$$

Where,  $g$  is Lande factor,  $\beta$  is Bohr magneton and  $m_s$  is Magnetic spin quantum number.

The energy split into two sub states  $E_1$  and  $E_2$  where the number of particles in them is given by

$$n_1 = e^{\Delta E/kT} \quad (2.61)$$

$$n_2 = e^{-\Delta E/kT} \quad (2.62)$$

Thus

$$\therefore n = n_1 + n_2 = e^{\Delta E/kT} + e^{-\Delta E/kT} \quad (2.63)$$

$$\frac{n_1}{n} = \frac{e^{\Delta E/kT}}{e^{\Delta E/kT} + e^{-\Delta E/kT}} \quad (2.64)$$

And

$$\frac{n_2}{n} = \frac{e^{-\Delta E/kT}}{e^{\Delta E/kT} + e^{-\Delta E/kT}} \quad (2.65)$$

The magnetic moment is given by

$$M = g\beta m_s (n_1 - n_2) \quad (2.66)$$

$$M = g\beta m_s \left( \frac{e^x - e^{-x}}{n} \right) n = \frac{e^x - e^{-x}}{e^x + e^{-x}} g\beta m_s n \quad (2.67)$$

Setting

$$x = \frac{\Delta E}{KT} \quad (2.68)$$

Inserting equation (2.60) in equation (2.68) yields

$$x = \frac{g\beta m_s H}{KT} \quad (2.69)$$

For small  $x$  one gets

$$\therefore e^x \approx 1 + x, \quad x \ll 1$$

$$\frac{e^x - e^{-x}}{e^x + e^{-x}} = \frac{(1+x) - (1-x)}{(1+x) + (1-x)} = \frac{2x}{2} = x \quad (2.70)$$

Inserting equation (2.70) in equation (2.67) yields

$$M = x g \beta m_s n \quad (2.71)$$

Inserting equation (2.69) in equation (2.71) yields

$$M = g \beta m_s n \times \frac{g \beta m_s H}{KT}$$

$$M = \frac{n g^2 m_s^2 \beta^2 H}{KT} \quad (2.72)$$

When  $g = 2$ ,  $m_s = \frac{1}{2}$

$$M = \frac{n \beta^2 H}{KT} \quad (2.73)$$

Thus the paramagnetic susceptibility takes the

$$X = \frac{M}{H} = \frac{n \beta^2}{KT} \quad (2.74)[11].$$

## CHAPTER THREE

### NANO SCIENCE

#### 3.1. Introduction

Recent development in physics shows that nanoscience is one of the most recent branches of science that can change radically material properties. This chapter exhibits some nano world mysteries. In 1959 Richard Feynman gave a talk to the American physical society in which he laid out some of the consequences of measuring and manipulating materials at the nanoscale this “talk there is plenty of room at the bottom” is reproduced in its entirety in appendix B it does a far better job than ever I could of laying out the consequences of a technology that allows us to carry out routine manipulations of materials at the nanoscale the remarkable technological implications laid out in Feynman’s talk form the basis of most people’s impression of nanoscience but there is more to nanoscience than technology nanoscience is where atomic physics converges with physics and chemistry of complex system quantum mechanics dominates the world of the atom typical nanosystems may contain from hundreds to tens of thousands of atoms

Nano is a Greek word which means very small thing. Nano meters is the part which is produced one meter is divided into thousand million equal parts. Thus 1 nano meter (nm) is equal to  $10^{-9}$  meter [12].

*Nanoscience* is the study of phenomena and manipulation of materials at atomic molecular and macromolecular scales where properties differ significantly from those at a larger scale.

*Nanotechnologies* are the design characterization production and application of structures devices and systems by controlling shape and size at nanometer scale [13].

### **3.2. Nano materials**

Basically nanomaterial's have always existed and have been applied by humans we remind of colloidal gold and silver particles which served as pigments in stained glass church window and ceramics since the 10th century AD .nano-particles have been created for thousands of years as cooking combustion volcanic activities and more recently from vehicle exhausts nevertheless the past decades have seen a large progress in synthesizing and tailoring nanomaterial's to order.

One of the main points to take care of is the nanomaterial's are always thermodynamically unstable relative to materials consisting of macroscopic entities this mean that they have to be produced at sufficiently low temperatures where their growth is controlled kinetically and not thermodynamically there has been great progress in the ability to control structures at smaller and smaller scales the strength and the durability of structural materials strongly depend on the structure and properties of grain boundaries therefore grain boundaries will often have to be protected by thin passivating layers of oxides or organic molecules furthermore interfaces usually act as barriers to dislocation motion and therefore strengthen materials with decreasing grains size Qualitatively described by the well-known Hall –petch relation this leads to special mechanical properties of Nano crystalline metals. Nanomaterial's are to a large extent reality but more detailed understanding of some basic principles is expected to extend greatly their potential for practical applications [14].

### **3.3. Disadvantages of nano materials**

Nano particles suffers from instability of the particles - Retaining the active metal nanoparticles is highly challenging as the kinetics associated with nanomaterial's is rapid in order to retain nano size of particles, they are encapsulated in some other matrix nanomaterial's are thermodynamically met stable and lie in the region of high-energy local-minima Hence they are prone to attack and undergo transformation these include poor corrosion resistance high solubility and phase change of nanomaterial's this leads to deterioration in properties and retaining the structure becomes challenging. Because nanoparticles are highly reactive they inherently interact with impurities as well. In addition encapsulation of nanoparticles becomes necessary when they are synthesized in a solution (chemical route) The stabilization of nanoparticles occurs because of a non-reactive species engulfing the reactive nano-entities thereby these secondary impurities become a part of the synthesized nanoparticles and synthesis of pure nanoparticles becomes highly difficult. Formation of oxides nitrides etc. Can also get aggravated from the impure environment/ surrounding while synthesizing nanoparticles hence retaining high purity in nanoparticles can become a challenge hard to overcome

Biologically harmful nano materials are usually considered harmful as they become transparent to the cell-dermis Toxicity of nano materials also appears predominant owing to their high surface area and enhanced surface activity nano materials have shown to Cause irritation and have indicated to be carcinogenic If inhaled their low mass entraps those inside lungs and in no way they can be expelled out of body their interaction with liver/blood could also prove to be harmful (though this aspect is still being debated on). Difficulty in synthesis isolation and application it is extremely hard to retain the size of nanoparticles once they are synthesized in a solution hence the nano materials have to be

encapsulated in a bigger and stable molecule/material. Hence free nanoparticles are hard to be utilized in isolation and they have to be interacted for intended use via secondary means of exposure Grain growth is inherently present in nano materials during their processing. The finer grains tend to merge and become bigger and stable grains at high temperatures and times of processing. Recycling and disposal - There are no hard-and-fast safe disposal policies evolved for nano materials Issues of their toxicity are still under question and results of exposure. Experiments are not available Hence the uncertainty associated with effects of nano materials is yet to be assessed in order to develop their disposal policies [15].

### **3.4. Nanoshapes**

Nano particles can be have different geometrical shapes. It can be in the form of isolated spheres or in the form of isolated two dimensional layer. Sometimes they arrange themselves as rods or tubes forming the so called nano rods and nano tubes. It can form other shapes in two or three dimensional space. Surely the shape geometry or arrangement change the physical properties of nano material

[16].

### **3.5. Quantum Dots**

Quantum dots are fabrical nanostructures in which charge carriers such as few electrons are confined in a small spatial region in host crystal in many cases the confinement potential of the electron the quantum dot region is quasi partial and the number of trapped electrons varies from few to thousands of electrons.

Quantum confinement profoundly affects the behavior of the systems electrons great by I flouncing their interaction such as a magnetic field quantum confinement of electrons Is just one of several ways quantum mechanics reveals itself another

pure quantum phenomena associated with electrons is their spin generally the Bohr radius (size) of quantum dot's much larger than the Bohr radius of real atoms this impels that ordinary magnetic field (on the order of T ) control magneto-transport properties of N-electron 2D quantum dots subject to a magnetic field  $\vec{B} = (0,0, B)$  perpendicular to the dot plane are generally calculated by considering the following Hamiltonians :

$$\hat{H} = \sum_{i=1}^N \left\{ \frac{1}{2m} [\vec{p}_i + e\vec{A}(\vec{r}_i)]^2 + V(\vec{r}_i) \right\} + \frac{1}{4\pi\epsilon_0\epsilon_r} \sum_{i>j}^N \frac{e^2}{|\vec{r}_i - \vec{r}_j|} + g\mu_B B_z S_z \quad (3.1)$$

Where, the first term is one-electron term, the second term is coulomb potential energy and the last term is the Zeeman energy.  $V(r)$  is the one electron confinement potential. The vector potential in a symmetric gauge is written as follows

$$\vec{A}(\vec{r}) = \frac{B_z}{2} (-y, x, 0) \quad (3.2)$$

Where:

$\vec{r} = (x, y)$  is the 2D position vector,  $-e (e > 0)$  is electron's charge,  $m$  is electron's mass,  $g$  is electron's  $g$ -factor,  $\mu_B$  is Bohr's magneton,  $\epsilon_r$  is the dielectric constant and  $S_z$  is the  $z$ -component of the total spin.

To obtain the mang-electron energy spectrum and wave function one must solve the station Schrodinger equation for the Hamiltonian given by

$$\hat{H}\psi(\vec{r}_1, \dots, \vec{r}_n) = E\psi(\vec{r}_1, \dots, \vec{r}_n) \quad (3.3)$$

$$V(r) = \frac{m}{2}\psi_0^2 r^2 \quad (3.4)$$

Where

$\hbar\omega_0$  Is the parabolic confinement energy

$$r^2 = x^2 + y^2$$

$$\frac{V(r)}{\hbar\omega_0} = \frac{1}{2} (\alpha r)^2 \quad (3.5)$$

Where

$$\alpha = \sqrt{\frac{m\omega_0}{\hbar}} \quad (3.6)$$

Is the inverse quantum oscillator length.

If we neglect the coulomb interaction between electron's the Hamiltonian in equation (3.5.1) without the Zeeman term can be written:

$$\hat{H}(\vec{r}) = \frac{1}{2m} [\hat{p} + e\vec{A}(\vec{r})]^2 + \frac{m}{2} \omega_0^2 r^2 \quad (3.7)$$

The Fock-Darw in states is written as follows

$$\psi_{nm_z}(r, \varphi) = N_{nm_z} \exp\left(-\frac{r^2}{4l_\Omega^2}\right) \left(\frac{r}{\sqrt{2}l_\Omega}\right)^{|m_z|} L_n^{|m_z|}\left(\frac{r^2}{2l_\Omega^2}\right) \times \exp\frac{(-im_z\varphi)}{\sqrt{2\pi}} \quad (3.8)$$

Where,  $l_\Omega = \sqrt{\frac{\hbar}{2m\Omega}}$  is an effective magnetic length,  $n = 0, 1, \dots$  is the radial quantum number and  $m_z = 0, \pm 1, \dots$  is the z-angular moment quantum number.

$L_n^{|m_z|}(z)$  Are associated laguerre's polynomials the normalization constant is

$$N_{nm_z} = \sqrt{\frac{n!}{l_\Omega^2 (n+|m_z|)!}}$$

the frequency  $\Omega$  appearing in the expression for the effective magnetic length is defined as follows

$$\Omega^2 = \omega_0^2 + \frac{\omega_c^2}{4} \quad (3.9)$$



Where  $\omega_c^2 = \frac{eB_z}{m}$  is the well-known cyclotron frequency

The discrete allowed energies without Zeman energy are written as:

$$E_{nm_z} = \hbar\Omega(2n + 1 + |m_z|) - \frac{\hbar\omega_c}{2}m_z \quad (3.10)$$

$$\varepsilon = \frac{E_{nm_z}}{\hbar\omega_0}$$

When  $\omega_0 = 0$  or  $\omega_c \gg \omega_0$  is effective magnetic length  $l_\Omega$  becomes the electronic magnetic length

$$l_\Omega \rightarrow \sqrt{\frac{\hbar}{m\omega_c}} = \sqrt{\frac{\hbar}{eB_z}}; \frac{\omega_c}{\omega_0} \rightarrow \infty \quad (3.11)$$

If  $\omega_0 \neq 0$  the effective magnetic length  $l_\Omega$  can be written

$$\frac{1}{l_\Omega^2} = 2\alpha^2 \sqrt{1 + \frac{1}{4} \left(\frac{\omega_c}{\omega_0}\right)^2} \quad (3.12)$$

One is the dimensionless coulomb correlation parameter

$$\lambda = \frac{e^2\alpha}{(4\pi\varepsilon_0\varepsilon_r\hbar\omega_0)} \quad (3.13)$$

And the other is dimensionless magnetic field parameter:

$$\gamma = \frac{\omega_c}{\omega_0} \quad (3.14) [17].$$

## CHAPTER FOUR

# THE EFFECT OF NANO SIZE ON MAGNETIC PERMEABILITY

### 4.1 Introduction

In this chapter one measured the magnetic flux density of Cu powder of different size and saw the changing of magnetic permeability due to changes of nano size particles.

### 4.2 Instruments

Testometer , Am meter , Copper powder with coarse grain ,medium grain and fine grain sizes , Power supply , Copper wire , glass tubes , Wires .

### 4.3 Theory

$$B = \frac{\mu n}{r} I \quad (4.1)$$

$$\mu = \frac{Br}{nI} \quad (4.2)$$

Where,  $B$  is the magnetic flux density,  $\mu$  is the magnetic permeability ,  $n$  is the number of turns,  $r$  is the radius and  $I$  is the electric current.

### 4.4 Methodology and experimental procedures

Three tubes were prepared the tubes are made of glass.

The copper wires is wounded around each tube and

The diameter of the tube and the number of turns are found.

The three powder samples were put inside three tubes.

Each tube wire were connected to an electric power source.

The electric current and magnetic flux density were measured where 5

Readings were taken finly The flux density is given by equation (4.1) and

Magnetic permeability calculated by equation (4.2)

## 4.5 Results

Table (4.1): magnetic flux density change with current for fine grain powder (small spacemen)

$I/A$	$B/mT$	$\mu \times 10^{-7}$
0	0.03	0
0.4	0.09	0.131
1.6	0.27	0.0983
2.8	0.45	0.0936
3	0.60	0.116

Table (4.2) magnetic flux density change with current for medium grain powder

$I/A$	$B/mT$	$\mu \times 10^{-7}$
0	0.03	0
0.4	0.06	0.0873
1.6	0.19	0.0691
2.8	0.32	0.0665
3	0.56	0.108

Table (4.3) magnetic flux density change with current for coarse grain powder

$I/A$	$B/mT$	$\mu \times 10^{-7}$
0	0.03	0
0.4	0.05	0.0728
1.6	0.08	0.0291
2.8	0.13	0.0270
3	0.20	0.0388

Where,  $\mu_r$  is the relative permeability and  $\mu_0$  is the vacuum permeability.

Table (4.4) magnetic permeability for different nano sizes

$\mu_{r_{\text{soft}}}$	$\mu_{r_{\text{medium}}}$	$\mu_{r_{\text{rough}}}$
0	0	0
0.104	0.00695	0.00579
0.00782	0.00550	0.00231
0.00745	0.00529	0.00214
0.00923	0.00859	0.00308

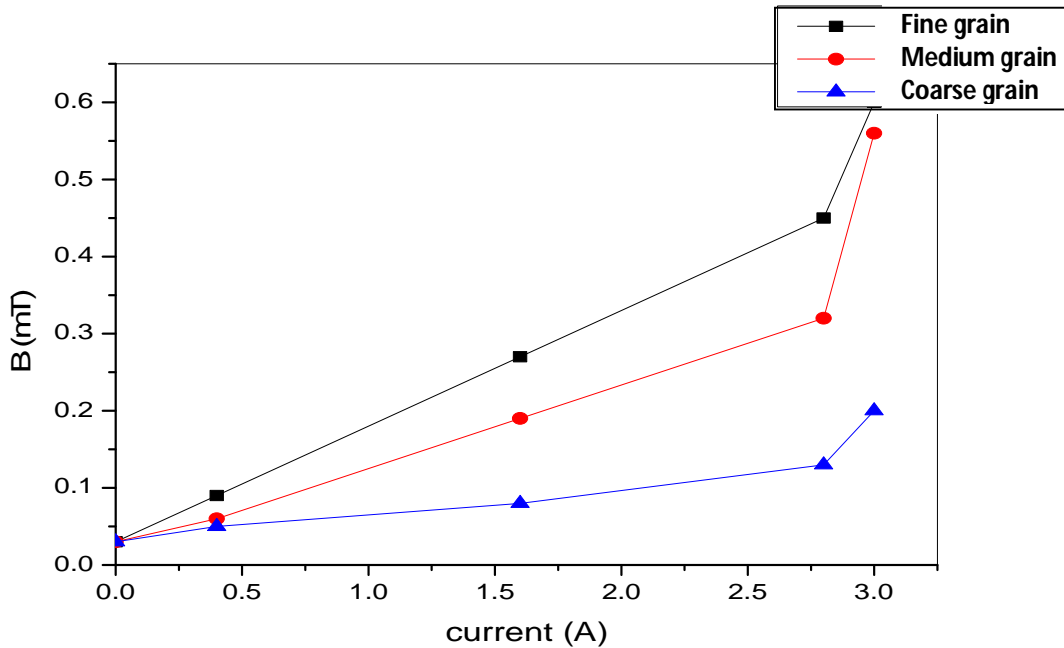


Figure (4.1) explains magnetic flux density versus current for three different nano Copper sizes.

## 4.6 Discussion

It is very interesting to note that according to figure (4.1) and table (4.4) the magnetic permeability of copper which is a diamagnet increases when the nano size decreases this may be attributed to the fact that decreases nano size increases the number of particles which act as a diamagnet which increases in turn the internal medium field which increases magnetic permeability according to figure (4.1). It is clear that for certain current value the internal field increases by decreasing the nano size while the rate of magnetic flux density change increases by increasing current and external field this means that external field increases permeability.

## 4.6 Conclusion

The change of nano size changes of the magnetic permeability copper (diamagnet) where it increases permeability up on decreasing nano size.

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