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Sudan University of Science and Technology

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The Effect of Nano- particles on the magnetic field Induction for Iron fillings crushed for different time of crush

Thesis submitted for the degree M.Sc Complementary

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الاية

قال تعالى:

{وقال الذين اوتوا العلم ويلكم ثواب الله خير لمن ءامن وعمل صالحا ولا يلقاها الا الصابرون }

(القصص الاية 80)

Dedication

I Dedicate these studies for a lot of people whom has a major roal in my studying live and I mean by them:-

- ✓ My dear's parents.
- ✓ My brothers and my sisters.
- ✓ My teachers' in all levels of education.
- ✓ My friends in all levels of my live.

I dedicate this little effort and ask Allah success me to be addition in the field of knowledge.

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I want to send my thanks and assessment to those people that help me in prepare this studies and associate me to make it by this finale shape and I mean by them :-

✓ Professor Mubarak Dirar Abdullah.
✓ All staff in the college of science of Sudan University of science and technology.

Abstract

Three different coils (100, 150 and 200 turns) were prepared using U-shape test tubes and raw material of iron was brought from Sudan minster of miner and meteorology (Fe_2O_3 purity 80 % investigated in chemical laboratory).

The samples were crushed four different intervals of times (2, 6 and 10 minute), the samples placed in magnetic field induction through the different coils and the relation between current I and magnetic field induction four different times of crush was investigated.

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Chapter one

1.1 introduction

Nanoscience or nanotechnology deal with very small objects [1]. But what is meant by nanoscience and nanotechnology. However, as the term 'nanotechnology' encompasses such a wide range of tools, techniques and potential applications, we have found it more appropriate to refer to 'nanotechnologies'. Although there is no sharp distinction between them, in this report we differentiate between

nanoscience and nanotechnologies as follows. Nanoscienceis the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale. Nanotechnologiesare the design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometer scale [2].Indeed, this branch of science and technology deals with materials having at least one spatial dimension in the size range of 1 to 100 nm [1].

The prefix 'nano' is derived from the Greek word for dwarf. One nanometre (nm) is equal to one-billionth of a metre, 10^{-9}m. A human hair is approximately 80,000 nm wide, and a red blood cell approximately 7000 nm wide, Atoms are below a nanometre in size, whereas many molecules, including some proteins, range from a nanometre upwards. The conceptual underpinnings of nanotechnologies were first laid out in 1959 by the physicist Richard Feynman, he delivered a lecture entitled "There's Plenty of Room at the Bottom", in this lecture Feynman talked about writing twenty four volumes of the Encyclopedia Britannica on the head of a pin, and miniaturizing the computer. He also suggested that it would be possible to arrange the atoms the way we want [2][1].

The term 'nanotechnology' was not used until 1974, when Norio Taniguchi, a researcher at the University of Tokyo, Japan used it to refer to the ability to engineer materials precisely at the nanometre level. The primary driving force for miniaturisation at that time came from the electronics industry, which aimed to develop tools to create smaller (and therefore faster and more complex) electronic devices on silicon chips. Indeed, at IBM in the USA a technique called electron beam lithography was used to create nanostructures and devices as small as 40–70 nm in the early 1970s. The size range that holds so much interest is typically from 100 nm down to the atomic level (approximately 0.2 nm), because it is in this range (particularly at the lower end) that materials can have different or enhanced properties compared with the same materials at a larger size. The two main reasons for this change in behaviour are an increased relative surface area, and the dominance of quantum effects. An increase in surface area (per unit mass) will result in a corresponding increase in chemical reactivity, making some nanomaterials useful as catalysts to improve the efficiency of fuel cells and batteries. As the size of matter is reduced to tens of nanometres or less, quantum effects can begin to play a role, and these can significantly change a material's optical, magnetic, or electrical properties. In some cases, size-dependent properties have been exploited for centuries. For example, gold and silver nanoparticles (particles of diameter less than 100 nm) have been used as coloured pigments in stained glass and ceramics since the 10th century. Depending on their size, gold particles can appear red, blue, or gold in colour. The challenge for the ancient chemists was to make all nanoparticles the same size (and hence the same colour), and the production of single-size nanoparticles is still a challenge today. At the larger end of our size range, other effects such as surface tension or 'stickiness' are important, which also affect physical and chemical properties. For liquid or gaseous environments Brownian motion, which describes the random movement of

larger particles or molecules owing to their bombardment by smaller molecules and atoms, is also important. This effect makes control of individual atoms or molecules in these environments extremely difficult. Nanoscience is concerned with understanding these effects and their influence on the properties of material. Nanotechnologies aim to exploit these effects to create structures, devices and systems with novel properties and functions due to their size. In some senses, nanoscience and nanotechnologies are not new. Many chemicals and chemical processes have nanoscale features – for example, chemists have been making polymers, large molecules made up of tiny nanoscalar subunits, for many decades. Nanotechnologies have been used to create the tiny features on computer chips for the past 20 years. The natural world also contains many examples of nanoscale structures, from milk (a nanoscale colloid) to sophisticated nanosized and nanostructured proteins that control a range of biological activities, such as flexing muscles, releasing energy and repairing cells. Nanoparticles occur naturally, and have been created for thousands of years as the products of combustion and food cooking [2].

Nanomaterials and Nanotechnologies attract tremendous attention in recent researches [3]. It is likely to have a profound impact on our economy and society and hence it may lead to the next industrial revolution, because nanotechnology is essentially a set of techniques that allow manipulation of properties at a very small scale, it can have many applications, such as materials and manufacturing, electronics, medicine, energy and its environment, biotechnology, and information technology [4].

1.2 Significance of the nanoscale

Ananometre (nm) is one thousand millionth of ametre. For comparison, a single human hair is about 80,000 nm wide, a red blood cell is approximately 7,000 nm wide and a water molecule is almost 0.3nm across. People are interested in the nanoscale (which we define to be from 100nm down to the size of atoms (approximately 0.2nm)) because it is at this scale that the properties of materials can be very different from those at a larger scale. We define nanoscience as the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale; and nanotechnologies as the design, characterisation, production and application of structures, devices and systems by controlling shape and size at the nanometre scale. In some senses, nanoscience and nanotechnologies are not new.

Chemists have been making polymers, which are large molecules made up of nanoscale subunits, for many decades and nanotechnologies have been used to create the tiny features on computer chips for the past 20 years. However, advances in the tools that now allow atoms and molecules to be examined and probed with great precision have enabled the expansion and development of nanoscience and nanotechnologies. The properties of materials can be different at the nanoscale for two main reasons. First, nanomaterials have a relatively larger surface area when compared to the same mass of material produced in a larger form. This can make materials more chemically reactive (in some cases materials that are inert in their larger form are reactive when produced in their nanoscale form), and affect their strength or electrical properties. Second, quantum effects can begin to dominate the behaviour of matter at the nanoscale - particularly at the lower end - affecting the optical, electrical and magnetic behaviour of materials.Materials can be produced that are nanoscale in one dimension (for example, very thin surface coatings), in

two dimensions (for example, nanowires and nanotubes) or in all three dimensions (for example, nanoparticles) [2].

1.3 The problem

The properties of Nano sized particles has wide application in technology so it is important to conduct the effect of change bulk material to small size

1.4 Aim of the Work

Studding the change of magnetic properties for iron samples crushed for different interval of times

1.5 Methodology

Preparing coils with different turns crush samples for different interval of times

1.6 Theses lay out

Chapter one Introduction, chapter two Nano – Material and application, chapter three magnetic properties for Nano-Material and chapter for Material and method

Chapter Two

Nano - Material and its application

1.1 Nanomaterials

Nanotechnologies are concerned with producing new or enhanced materials. Manipulating matter at the nanometer scale, using building blocks with dimensions in the nano-size range, makes it possible to design and create new materials with unprecedented functionality and novel or improved properties. Nanostructured materials are made of nanosized grains or nanoparticles as building blocks, have a significant fraction of grain boundaries with a high degree of disorder of atoms along the grain boundaries (or particle surfaces), and a large ratio of interface (or surface) area to volume. Chemical composition of the phases and the interfaces, between nano-grains, must be controlledas well [5].

Nanomaterials are used as additives to enhance the properties of base materials. When it is added to the fluid, the produced mixture is denoted by nanofluid; while by adding the nanomaterials to phase change material (PCM), the produced mixture is denoted by nanocomposites [4].

Nanomaterials can be constructed by 'top down' techniques, producing very small structures from larger pieces of material, for example by etching to create circuits on the surface of a silicon microchip. They may also be constructed by 'bottom up' techniques, atom by atom or molecule by molecule. One way of doing this is self-assembly, in which the atoms or molecules arrange themselves into a structure due to their natural properties. Crystals grown for the semiconductor industry provide an example of self-assembly, as does chemical synthesis of large molecules. A second way is to use tools to move each atom or molecule individually. Although

this 'positional assembly' offers greater control over construction, it is currently very laborious and not suitable for industrial applications [1].

Nanotechnology based solutions are being developed for a wide range of energy problems such as, solar electricity, hydrogen generation and storage, batteries, fuel cells, heat pumps and thermo electrics. Organic nanomaterials consist of fullerenes, carbon nanotubes (CNT), single-walled carbon nanotubes (SWCNT), multi-walled carbon nanotubes (MWCNT), graphite and nanofibers. Most of the organic nanomaterials are carbon based nanomaterials [5]. While, metal and metal oxide based nanomaterials such as aluminium, zinc, copper, iron, aluminium oxide, iron oxide, titanium oxide are categorized as inorganic nanomaterials [6]. Quantum dots, such as CdSe, ZnS, ZnO etc are metalloid nanomaterials and are also categorized as inorganic nanomaterials . Hybrid nanomaterials are the combination of organic – organic nanomaterials, organic - inorganic nanomaterials and inorganic – inorganic nanomaterials through synthesis such as chemical vapor deposition (CVD), Electro spinning, atom transfer radical polymerization (ARTP) etc.[5].

1.1.1 Structure

One of the most important characteristics of nanostructured materials is the dependence of certain properties upon the size in nanoscale region.For example, electronic property, with quantum size effects, caused by spatial confinement of delocalized valence electrons, is directly dependent on the particle size. Small particle size permits conventional restrictions of phase equilibrium and kinetics to be overcome during the synthesis and processing by thecombination of short diffusion distances and high driving forces of available large surfaces and interfaces. A wide range of materials, including metals and ceramics in crystalline, quasi-crystalline, or amorphous phases have been synthesized as

nanosized or nanostructured materials [5]. The structure of nanomaterials can be classified by their dimensions. The zero -dimensional nanostructures are nanoparticles. The one-dimensional nanostructures are whiskers, fibers (or fibrils), nanowires and nanorods. In many cases, nanocables and nanotubes are also considered one-dimensional structures. Thin films are considered as two-dimensional nanostructures. Colloids bearing complex shapes have three-dimensional nanostructures [1]. Engineered nanomaterials are designed with specific properties in mind. Engineered nanomaterials encompass nano-objects and nanostructured materials. The former are defined as materials with one (nanoplate), two (nanorod) or three (nanoparticle) external dimensions in the nanoscale (i.e. between approximately 1 and 100 nm). Examples of nanostructured materials are nanocomposites composed of nano-objects embedded in a solid matrix or nano-objects bonded together in simple random assemblies as in aggregates and agglomerates or ordered as in crystals of fullerenes or carbon nanotubes [7].

Self-assembly

Self-assembly is the autonomous organization of components into patterns or structures without human intervention. Self-assembling processes are common throughout nature and technology. They involve components from the molecular (e.g., crystals) to planetary (e.g., weather systems) scale and many different types of interactions. Self-assembly is a fundamental principle which creates structural organization from the disordered components in a system. The principles of self-assembly was conceptualized long time ago (circa400 BC). The ancient Greek philosopher Democritus expounded the idea that atoms and voids organized in different arrangements constitute all matter. He explained the growth of the universe from the minutest atomistic building blocks to the stars and galaxies. This is perhaps the oldest recorded vision of matter undergoing self-assembly over all

scales. The basic principle of nanochemistry lies in the self-assembly of a target structure from the spontaneous organization of building blocks. The building blocks can be molecules or nano-scale clusters. There are five important factors that need to be taken into consideration for selfassembly:

- Building blocks, scale, shape and surface structure.
- Attractive and repulsive interactions between the building blocks.
- Association, dissociation and adaptable motion of the building blocks in the assembly to attain the lowest energy structure.
- Interactions of the building blocks with the solvents, interfaces and templates [1].

The building blocks are usually not monodisperse (unless they are single atom or molecules). The poly dispersity present in the building blocks in terms of size and shape dictates the achievable degree of structural perfection of the assembly, and the defects in the assembled system. The making of building blocks with a particular surface structure, charge and functionality is a challenging task. The surface properties control the interactions between the building blocks and their interactions with the environment as well. This determines the geometry and the equilibrium separation between the building blocks in a self-assembled system. The aggregation and de-aggregation processes, and the corrective movements of the self-assembled structure allow it to attain the most stable form [1].

The driving forces for molecular organization can be as varied as ionic, covalent, hydrogen bonding or metal ligand bonding interactions. The chemistry of self assembly of materials transcends the chemistry of molecular assembly. It is distinct solid state materials chemistry where the building blocks and their assemblages are unconstrained by scale, and they are not restricted to just chemical bonding forces. At length scales higher than molecular length scales, other forces such as capillary, colloidal, elastic, electric, magnetic and shear forces can all influence the self-

assembly of materials. An important feature of self-assembly is hierarchy, the primary building blocks associate into more complex secondary structures, which are integrated into the next size level in the hierarchy [1].

The self-assembly of molecules and materials can be directed by templates. The template can be constituted of molecules, molecular assemblies or additive materials which serve to fill space, balance charge and direct the formation of a specific structure. For example, mesoporous zeolites are templated by block copolymers or lyotropic liquid crystals. A template patterned at the nanoscale can direct the assembly process. The structure-directing templates which can make, organize and interconnect the building blocks can be porous hosts, lithographic patterns, and channels in polymer, alumina and silicon membranes. Some of these templates are widely used to make nanowires, nanorods and nanotubes. A well-known templating method is the use of surfactant micelles and liquid crystals. Many microporous and mesoporous inorganic solids have been prepared by this templating mechanism [1].

1.1.2 Synthesis

The first discovered nanomaterials was prepared by vacuum evaporation of iron in inert gas and condensed in cooled substrates. After then many methods to fabricate nanoparticles including inorganic ceramics and organic compound are developed, such as arc plasma torch to produce metallic powder laser induced chemical vapor deposition method (CVDM) to produce special compounds, and microwave plasma enhanced CVD to produce hard and brittle materials. Instead of chemical vapor, the liquid co-precipitation can produce single-phase compounds and the solid-state thermal decomposition can produce single-phase oxide metals [3]. The different synthesis methods of preparation and the characterization of nanofluid, suspension, and the convection and conduction heat transfer in nanofluids have been reported by many authors [4].

The methods of synthesis of nanoparticles are well known for a long time as compared to the other nanomaterials. For the synthesis of nanoparticles, the processing conditions need to be controlled in such a manner that the resulting nanoparticles have the following characteristics:

- Identical size of all particles,

- Identical shape,

- Identical chemical composition and crystal structure,

- Individually dispersed with no agglomeration [1].

Nanoparticles can be synthesized by both top-down or bottom-up approaches. Two well-known top-down approaches are milling (or attrition) and thermal cycling. Attrition produces nanoparticles of a wide range of diameter ranging from 20 nm to several hundred nanometers. The shape of the particles varies as well. They may contain impurities from the milling medium. The nanoparticles made by this process are usually used in the fabrication of nanocomposites and bulk materials having nano grains where perfections in size and shape, and presence of impurities do not matter significantly [1]. Moreover, some of the defects can get annealed during the sintering process. A bulk material having very small thermal conductivity but a large coefficient of thermal expansion may be subjected to repeated thermal cycling to produce very fine particles. However, this technique is difficult to design and the control of particle size and shape is difficult [1]. The bottom-up methods are more popular than the top-down methods. There are several bottom-up methods such as homogeneous and heterogeneous nucleation processes, microemulsion based synthesis, aerosol synthesis, spray pyrolysis and template-based synthesis [1]. Various methods in preparation metallic nanoparticles invoke different properties with desired purposes. The widely exploited methods are:

The sol–gel method: Silver nanoparticles, for example, is prepared by mixing the AgNO$_3$ solution with tetraethylorthosilicate (Si (OC$_2$H5$_4$, TEOS)), ethanol and water then with a few drops of HNO$_3$as a catalyst. The mixed solution was dispersed and dried. The dried gels were reduced at a temperature of 400 C for 30 min in hydrogen gas. The Ag particles have a size of about 5to10 nm with a profile distribution in the form of lognormal distribution. The nanoparticles are embedded in silica glass in wellseparated and protected matrix. The preparation of iron nanoparticles embedded in glass can be prepared with the same method by substituting FeCl$_3$ for the silver salt.

The sol–gel method has advantages of yielding high purity, isotropic, and low temperature annealing while with shortage of cracking after dried by heavy doping. The free water absorbed in the porous gel and the H O·bonds desorbed on the porous surface or the chemical absorbed hydroxyl groups which affects the optical absorption within the wavelengths of 160 to 4500 nm can be removed by high temperature sintering.

Hydrosol/magnetic fluid method: The pure metallic suspension particles such as noble metals can be prepared by hydrosol method by using reducing agent to embed in protective gelatin. The advantage of the hydrosol method is that relatively narrow size distribution with average diameter of 20Å can be achieved.

Vacuum deposition method: The presence of inert gas in vacuum chamber and lowering down the substrate temperature to liquid nitrogen temperature during thermal evaporation can reduce the momentum of the evaporated metallic atoms or clusters by collision with gas to obviate their further aggregation on the substrate. The evaporated metal atoms condensed just at where they reached without migration to the potential minimum thereby lose vander attraction between particles. The resulting smokes can be collected from the substrate or walls of the evaporation chamber with the particle sizes can be easily controlled between 30 to

1000 Å depending on the gas pressure, the evaporation speed, the type of gas used, and the substrate temperature. Direct (DC) or radio frequency (RF) sputtering with the structure of deposited films mostly to be amorphous without substrate heating can successfully deposit refractory metals and alloys.

Ball milling method: Hard and brittle ceramic materials can be ball-milled into nanoparticles to produce nanocrytals, noncrystals, and pseudocrystals. Powders of 500 nm sizes can be milled into several nm by strong vibrations when mixed with tungsten-carbide (WC) spheres. The shortages of ball milling are the surface contamination of the products and nonuniformity of the structure but is a simple method. Sometimes an addition of 1 to 2% of methanol or phenol can prevent diffusion and solid reaction of the nanoparticles [3].

1.2 Applications

Nanotechnology is considered to be one of the most important future technologies involving several disciplines of science including solid state physics, solid state chemistry, solid state ionic, materials engineering, medical science and biotechnology [5].

Nanomaterials are expected to have a wide range of applications in various fields such as electronics, optical communications and biological systems. These applications are based on factors such as their physical properties, huge surface area and small size which offers possibilities for manipulation and room for accommodating multiple functionalities [1]. general applications on materials with a reduced particle size into the sub-micrometer range and that the results provide important parameters for the thermal characterization of nanomaterials [5]. A very promising and rapidly-growing field of application of nanotechnology is in medicine. One interesting application involves the use of nano-scale devices which may serve as vehicles for delivery of therapeutic agents and act as detectors

or guardians against early disease. They would possibly repair the metabolic and genetic defects. They would seek out a target within the body such as a cancer cell and perform some functions to fix it. The fixing can be achieved by releasing a drug in the localized area. The potential side effects of general drug therapy can be reduced significantly in this manner. As nanotechnology becomes more sophisticated, gene replacement, tissue regeneration, or nanosurgeries are the promising future developments. The possible benefits that can be obtained from nanoscience and technology seem to be almost endless [1].

Current applications of nanoscale materials include very thin coatings used, for example, in electronics and active surfaces (for example, self-cleaning windows). In most applications the nanoscale components will be fixed or embedded but in some, such as those used in cosmetics and in some pilot environmental remediation applications, free nanoparticles are used. The ability to machine materials to very high precision and accuracy (better than 100nm) is leading to considerable benefits in a wide range of industrial sectors, for example in the production of components for the information and communication technology (ICT), automotive and aerospace industries [1].

Applications of nanoscience and nanotechnologies are also leading to the production of materials and devices such as scaffolds for cell and tissue engineering, and sensors that can be used for monitoring aspects of human health.

Applications of nanotechnologies in medicine are especially promising, and areas such as disease diagnosis, drug delivery targeted at specific sites in the body and molecular imaging are being intensively investigated and some products are undergoing clinical trials. Many of the applications may not be realised for ten years or more (owing partly to the rigorous testing and validation regimes that will be required). In the much longer term, the development of nanoelectronic systems that can detect and process information could lead to the development of an

artificial retina or cochlea. Progress in the area of bionanotechnology will build on our understanding of natural biological structures on the molecular scale, such as proteins. Industrial applications So far, the relatively small number of applications of nanotechnologies that have made it through to industrial application represent evolutionary rather than revolutionary advances. Current applications are mainly in the areas of determining the properties of materials, the production of chemicals, precision manufacturing and computing. In mobile phones for instance, materials involving nanotechnologies are being developed for use in advanced batteries, electronic packaging and in displays. The total weight of these materials will constitute a very small fraction of the whole product but be responsible for most of the functions that the devices offer. In the longer term, many more areas may be influenced by nanotechnologies but there will be significant challenges in scaling up production from the research laboratory to mass manufacturing. In the longer term it is hoped that nanotechnologies will enable more efficient approaches to manufacturing which will produce a host of multifunctional materials in a cost-effective manner, with reduced resource use and waste [2].

It is rarely possible to predict accurately the timescale of developments, but we expect that in the next few years nanomaterials will provide ways of improving performance in a range of products including silicon-based electronics, displays, paints, batteries, micro-machined silicon sensors and catalysts. Further into the future we may see composites that exploit the properties of carbon nanotubes – rolls of carbon with one or more walls, measuring a few nanometres in diameter and up to a few centimetres in length – which are extremely strong and flexible and can conduct electricity. At the moment the applications of these tubes are limited by the difficulty of producing them in a uniform manner and separating them into individual nanotubes. We may also see lubricants based on inorganic nanospheres; magnetic materials using nanocrystalline grains; nanoceramics used for more

durable and better medical prosthetics; automotive components or high-temperature furnaces; and nanoengineered membranes for more energy-efficient water purification [1]. World energy crisis has triggered more attention to energy saving and energy conversion systems with high efficiency. There is a growing awareness that nanoscience and nanotechnology can have a profound impact on energy generation, conversion, and recovery [5].

Chapter Three

Magnetic Material and properties

3.1 Magnetic Materials

The orbital motion and spinning motion of electrons in an atom give rise to the magnetic moment in a material. Therefore, each atom represents a tiny permanent magnet in its own domain. The revolving electron generates its own orbital magnetic moment, measured in Bohr magnetons (μB) and also a related spin magnetic moment due to the electron spinning by itself like the earth, on its own axis. Every two electrons in an atom will form a pair such that they have opposite spins with the resultant spin magnetic moment as zero. Unpaired electrons are present in the 3d orbital of magnetic materials like iron, nickel, cobalt, etc.

A high spin magnetic moment can be observed in the magnetic materials due to the interaction between the unpaired electron spin magnetic moment and the electrons from the adjacent atom. Magnetic behavior of materials are therefore dependent on these unpaired electron spins. The spin magnetic moment of an electron is much larger than its relative orbital magnetic moment. Every magnetic material can be defined in terms of their magnetic behavior, and depending on their bulk magnetic susceptibility. Magnetic susceptibility measures the degree of magnetization of a material under the influence of an applied magnetic field. Its value is positive for ferromagnetic and paramagnetic material and negative for a diamagnetic material [12]. Generally, Magnetic Materials classified into:

3.2 Diamagnetism

When a material produces a magnetization effect (M) opposing the direction of applied field magnetic field due to a change in motion of the spinning electrons in the material then the material is classified as a diamagnetic material. The measurement of the ability of a material with which it can be magnetized under the influence of an external magnetic field is called its susceptibility. The susceptibility value does not depend upon the temperature and is always negative.

3.3 Paramagnetism

In an atom, the unpaired electrons result in a net magnetic moment in relation with electron spin. But the bulk material does not show any magnetic property in absence of an external magnetic field because these magnetic moments are randomly oriented. With the application of magnetic field, these magnetic dipoles can align in the field direction. Since these moments do not interact, a very large magnetic field is needed to align all of them. However, the above condition prevails only in the presence of external field. When the external field is removed, the dipoles return to their random orientation. This magnetic property is classified as the Paramagnetism and is found in many materials like calcium, titanium and alloys of copper [12].

3.4 Ferromagnetism

The phenomenon by which the atoms are arranged in such a way that their atomic magnetic moments align parallel to each other is known as ferromagnetism. The presence of an internal field elucidates this phenomenon. The internal field considered to be strong enough to magnetize the material to saturation. The Heisenberg model of ferromagnetism describes the parallel alignment of magnetic moments in terms of an exchange interaction between neighboring moments. The

presence of magnetic domains within the material, which are the regions where the atomic magnetic moments are aligned [12].

3.5 Antiferromagnetism

Antiferromagnetism is differing from ferromagnetism as in antiferromagnetic material there is antiparallel alignment of the atomic magnetic moment due to the exchange interaction between the neighboring atoms. These materials resemble the paramagnetic behavior as the antiparallel alignment of the atomic magnetic moment cancels out the magnetic field. There exists a transition temperature called Neel temperature (T_N), above which these materials become paramagnetic. The only exceptional element is Chromium (Cr: T_N = 37 ºC) exhibiting antiferromagnetism at room temperature. Antiferromagnetic materials have positive and very small susceptibility value [12].

3.6 Ferrimagnetism

Ferrimagnetism occurs in solids which have unequal numbers of both parallel aligned (as in ferromagnetism) and anti-parallel aligned (as in antiferromagnetism) magnetic moments. This is due to the presence of different types of atomic composition of atoms or ions in the solids. These different kinds of atoms or ions respond differently to an external magnetic field. Hence, the magnetic moment corresponding to a particular kind of ions may align in the field direction while the moments of a different kind of ions can align in the opposite direction. These different forms of alignment of magnetic moments result in a spontaneous magnetization of the material. Ferrites are the ceramic material which exhibits this type of magnetic behavior. Some ferrimagnetic materials are YIG (yttrium iron garnet) and ferrites composed of oxides of iron, aluminum, cobalt, nickel, manganese, and zinc [12].

3.7 Magnetic properties of Nanoparticles:

Nanoparticles with nanoscale dimensions are found to exhibit novel properties. The exceptional behaviour exhibited by nanoparticles is due to two main reasons, finite size effects, and surface effects. nanoparticles are also influenced by the feature of single domain nature. it is observed that when a particle is smaller than about 100 nm, a domain wall simply can't fit inside it, resulting in single domain particles. The single domain particle has only one magnetic direction and it is uniformly magnetized to its saturation magnetization. A single domain particle has high magnetostatic energy (magnetic potential energy generated in the presence of a magnetic field) but negligibly low domain wall energy compared to the multi domain particle [12]. Magnetic nanoparticles, which exhibit a variety of unique magnetic phenomena that are drastically different from those of their bulk counterparts, are garnering significant interest since these properties can be advantageous for utilization in a variety of applications. An examples of these magnetic properties such as [13]:

3.8 Superparamagnetism

Superparamagnetism exhibited by small ferromagnetic or ferrimagnetic nanoparticles is referred to as. This is observed in magnetic nanoparticles with sizes close to few nanometers to couple of tenth of nanometers, depending on the material. These nanoparticles are single domain particles and their magnetization randomly flip direction under the influence of temperature. The time between two flips of magnetization direction is called as Neel relaxation time. Magnetic nanoparticles are considered to be in superparamagnetic state, when the time used to measure the magnetization of the nanoparticles is much longer than the Neel relaxation time and their magnetization appears to be in average zero in the absence of an external magnetic field. Similar to the paramagnets they can be

magnetized under the influence of an external magnetic field but their magnetic susceptibility is much higher than the paramagnets. One of the most crucial factors responsible for the paramagnetic behavior of magnetic oxides like ferrites is the finite size effect. Due to this effect, the thermal energy is sufficient to change the direction of magnetization of the entire crystallite even when the temperature is below the Curie or Neel temperature. The magnetic field is zero when the resulting fluctuations are in the direction of magnetization. In superparamagnetic materials the magnetic moment of the entire crystallite tends to align with the magnetic field, whereas in paramagnetic materials each individual atom is independently influenced by an external magnetic field. The crystalline anisotropy energy is the energy required to change the direction of magnetization of a crystallite, and it depends both on the material properties and the crystallite size [12]. Ferromagnetic materials are subdivided into areas known as domains. In an unmagnetized sample, the moments of these domains are randomly orientated, but tend to align themselves in the direction of an external applied magnetic field. As the particle size approaches a certain minimum critical size, often in the nanoscale range, the formation of domain walls becomes energetically unfavorable [14].

Changes in magnetization occur through the rotation of spins rather than through the motion of domain walls. Particles exhibiting these properties are called single domain. As particle size is decreased further, spins are affected by thermal fluctuations and the particles become super paramagnetic. This superparamagnetic property of materials is useful in that individual particles become magnetized only when exposed to an external magnetic field, but exhibit no remanent magnetization when the field is removed. In addition, the particle size provides a large surface area for functionalization which lends itself to applications of small dimensions of interest [14].

3.9 saturation magnetization

Saturation magnetization is when all domains of a material are aligned. The saturation magnetization forms the basis of comparison between different ferromagnetic materials. The saturation magnetization decreases upon heating because the thermal agitations of the atoms lead to the misalignment of the atomic moments. With large thermal agitation the material becomes paramagnetic, and this transition temperature is called Curie temperature, TC (Fe: TC = 770°C, Co: TC = 1131°C and Ni: TC = 358°C). Ferromagnetic material has positive and high magnetic susceptibility [12]. When a ferromagnetic particle is very small, a high fraction of the atoms would be involved in a domain wall. The energy cost for forming the domain wall can then be larger than the reduction in the magnetostatic energy. In this case, it is energetically unfavorable to form a domain wall and the particle therefore will consist of a single magnetic domain. For particles with uniaxial anisotropy, the critical particle diameter below which a particle consists of a single magnetic domain is approximately given by:

$$d_c \approx \frac{18\sqrt{A_{ex}K}}{\mu_0 M_s^2}$$

Where (M_s) the saturation magnetization and (μ_0) the permeability of free space. When magnetized, such particles can maintain the magnetization direction for years, whereas particles with dimensions above the critical size spontaneously form domains in zero applied field and the stored information will be lost [15]. Saturation magnetization of nanoparticles is also strongly dependent on their size. Intrinsically, magnetic materials possess magnetically disordered spin glass like layers near the surface due to the reduced spin–spin exchange coupling energy at the surface [13]. In bulk cases, since the disordered surface layer is minimal

compared with the total volume of the magnet, such surface spin canting effects are negligible. Upon reduction of the size of magnetic materials to nanoscale regime, however, the surface canting effects are dramatically pronounced in the saturation magnetization value. For very small nanoparticles less than 5 nm, such size effect on saturation magnetization is more noticeable, since internal spins of the nanoparticle also start to be canted as well as the surface spins due to increased interactions between the surface and internal spins [13].

3.10 Coercivity

The coercivity of nanomagnetic systems is an important quantity that plays a crucial role as far as the stabilization of a magnetic system is concerned. At room temperature, a maximum in the coercivity curve is observed at a critical diameter D_c, so that two different regimes can be distinguished. This indicates two different mechanisms of magnetization reversal as a function of particle size. The behavior of the coercivity as a function of particle size is a well-studied and various theoretical models have been published on the particle size dependence of coercivity, the increase in coercivity with an increase in particle size at room temperature in the single domain region has been clarified [16].

The variation in coercivity with particle diameter when the particle size is reduced, increases to a maximum value and then declines toward zero. The coercivity reaches a maximum when the particle size reduces below a critical value D_c, and become single domain. The particles with size less or equal to D_c, change their magnetization by spin rotation. The coercivity decreases with the decrease in particle size below D_c, because of thermal effects. Below a critical diameter D_c, the thermal effects are strong enough to spontaneously demagnetize a previously saturated assembly of particles, this results in the reduction of coercivity to zero [12]. Above the critical size ($D>D_c$), multi domain magnetism begins in which a

smaller reversal magnetic field is required to make the net magnetization zero. In the case of Co nanoparticles, the magnetic coercivity increases from 370 to 1680 Oe in a single-domain regime as the size of the Co nanoparticles increases from 4 to 8 nm [13]. However, the magnetic coercivity decreases to 1600, 1100, and 250 Oe as the size of the Co nanoparticles further increases to 10, 12, and 13 nm by forming multimagnetic domains . Therefore, the critical single-domain size of Co nanoparticles is expected to be around 8–10 nm [13]. Magnetic properties are strongly influenced by the nanoscaling laws, and as a result, these scaling relationships can be leveraged to control magnetism from the ferromagnetic to the superparamagnetic regimes, at the same time, they can be used in order to tune magnetic values. For example, life time of magnetic spin is directly related to the magnetic anisotropy energy and also the size and volume of nanoparticles. Therefore, the nanoscaling laws of magnetic nanoparticles are important not only for understanding the behavior of existing materials but also for developing novel nanomaterials with superior properties [13].

3.11 Effect of Different Parameters on Magnetic Properties

Magnetic properties of nanoparticales depend on the size of the nanoparticles, magnetic behavior is complicated and cannot be defined with respect to one parameter, and there are many factors influence key magnetic properties such as:

3.11.1 Size

It has been shown that many of the unique magnetic properties of nanoparticles can be attributed to their high surface-to-volume ratio [17], large surface area to volume ratio in magnetic materials develops a substantial proportion of atoms having a different magnetic coupling with neighboring atoms, leading to differing magnetic properties [12]. Saturation magnetization (M_s) varies with size until it reaches a threshold size beyond which magnetization is constant and is close to the

bulk value. The linear dependence of M_s on size below this threshold has been demonstrated in several studies, however, the tunable property of size is subtractive with respect to M_s and superparamagnetism: for example, when the size decreases, the nanoparticle moves toward superparamagnetism but may have a reduced M_s. Depending on the targeted application, we might choose to tailor the size of the nanoparticles to tune these parameters (e.g., to favor superparamagnetism or high M_s). The size of the nanoparticle helps define the nanoparticle regime and hence its magnetic behavior. As the size of the Magnetic nanoparticles (MNPs) decreases, the magnetic anisotropy energy per nanoparticle decreases. Magnetic anisotropy energy is the energy that keeps the magnetic moment in a particular orientation. At a characteristic size for each type of MNP, the anisotropy energy becomes equal to the thermal energy, which allows the random flipping of the magnetic moment. The flipping occurs at sizes below ro, and the nanoparticle is then defined as being superparamagnetic. MNPs possess a disordered spin layer at their surfaces, and when the size of the nanoparticle is small than (5 nm), the ratio of disordered layer to the radius of the MNP is significant. Surface spin disorder thus leads to reduced M_s for smaller nanoparticles as defined here:

$$M_s = M_{s_b}[(r-d)/r]^3$$

Where r is the radius, d is the thickness of the MNP surface exhibiting disordered spins, and M_{s_b} is the bulk M_s. Recent studies have demonstrated that the surface functionalization of MNPs can reduce the level of surface spin disorder observed in small nanoparticles, thus increasing their measured M_s. Some studies compared the magnetic properties of iron oxide (Fe_3O_4) MNPs of diameters 6, 10, and 17 nm and observed that the M_s of eachunexpectedly reached the bulk value. They attributed this decrease in surface spin disorder (and hence increased

magnetization) to covalent bonding of oleic acid to the nanoparticles. However, so other studies observed no such phenomenon when they examined 10 nm Fe_3O_4 MNPs that were dopamine-stabilized and oleic acid-stabilized.

3.11.2 Shape

Substantial efforts are dedicated toward understanding the relationships between nanoparticle shapes and magnetic properties; there is remarkably little researches on going to study the effect of shape on the magnetic properties of nanoparticles having the same volume or related size parameter. There are many studies on the synthesis of unique shapes of MNPs: for example, ferrite nanocubes , maghemite nanorods, NiFe nanowires, cobalt nanodiscs, magnetite tetrapods, and Au-MnO nanoflowers.

3.11.3 Composition

Composition is the most commonly cited parameter responsible for determining the specific magnetic properties of a material, all materials classified based on their magnetic properties, these magnetic properties arise in the presence or absence of unpaired valence electrons located on the metal atoms or metal ions found in MNPs [17]. When the composition of an atomic cluster is less than 30 atoms, its magnetic moment would then be close to the atomic magnetic moment. However, when the number of atoms increased to 700, the magnetic moment of the particle would approach that of the bulk material [18]. The orientation of the magnetic moment μ, associated with the electrons defines the magnetic behavior. Using the magnetic moment of a single electron, 1.73 Bohr magnetons (BM), we can estimate the magnetic moment in a MNP. For example, with five unpaired electrons, Fe^{+3} has a moment of ~8.5 BM, which underlines the strong dependence of the composition (atomic state) on the magnetic behavior of a specific element. Additionally, the distribution of cations within the octahedral (O_h) and tetrahedral

sites (T_d) of the commonly found spinel or inverse spinel crystal structures is another critical determinant of μ.

3.12 Shell-Core Architecture

Nanoparticles are often coated with a selected material either to make them biocompatible and stable in physiological fluids or to provide a modified surface that can be used for further functionalization; or to alter the magnetic properties of the core nanoparticle in a favorable manner. The coating can be either non-magnetic or magnetic (antiferromagnetic, ferromagnetic, or ferrimagnetic). Regardless of the type of coating, there is usually some effect on the magnetic properties of the core. One effect is akin to the disordered spin layer that reduces the M_s of small nanoparticles (vide supra); since saturation magnetization isdefined on a per gram basis, a non-magnetic coating (shell) will necessarily decrease its value. In the case of a magnetic coating, the core-shell interface interaction might lead to a change in anisotropy and a shift in the hysteresis loop. The shift of the hysteresis loop is "exchange bias" and it mainly arises due to interface coupling between two different types of layers (e.g., ferromagnetic and ferrimagnetic) [17].

This means fundamental magnetic properties such as coercivity and susceptibility are no longer permanent material characteristics and are susceptible to variations in their size, shape, and composition, nanoparticle size effects can also be observed in changes in magnetic coercivity. In contrast to the bulk magnet, which possesses multiple magnetic domain structures [13].

3.13 Applications of magnetic nanoparticls

The applications of nano-magnetic particles have expanded rapidly, for fields including ferrofluids, data storage, biomedicine, etc [18]. Nanoparticles possessing magnetic properties offer great advantages in that they can provide selective attachment to a functional molecule, confer magnetic properties to the target, and allow manipulation and transportation to a desired location through the control of a magnetic field produced by an electromagnet or permanent magnet. Magnetic nanoparticle carriers consist of three functional parts: a magnetic core, a surface coating, and a functionalized outer coating. At the center of the carrier is the super paramagnetic core, which allows for the magnetic manipulation of the particle in the presence of an external magnetic field. The composition of the magnetic core is dependent on the application. For example, magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_3) with high oxidative stability are currently the only accepted nontoxic magnetic materials for medical applications [14]. Magnetic nanoparticles have variety of applications such as in nanoelectronics, biomedical sensors, drug delivery, magnetic resonance imaging, data storage, color imaging, bioprocessing, magnetic refrigeration and ferrofluids [12].

The use of magnetic nanoparticles in medical applications is a novel and highly interdisciplinary field offering great potential in therapeutic and diagnostic testing, in vitro and in vivo. Initial medical applications used iron powder or magnetite directly in treatment methods. In this form, however, particles are recognized by the macrophages of the mononuclear phagocyte system and are eliminated from the body. In order to improve biocompatibility, to reduce toxicity and to ensure non-immunogenicity, particles have been encapsulated (e.g., with chitosan, dextran, poly(lactic acid), starch, carbon, polysaccharides, gelatine, and proteins) to yield "stealth" particles . One of the main envisaged therapeutic applications of

coated magnetic nanoparticles is for targeted chemotherapeutic drug delivery to tumors. Particles coated with a drug could be injected intravenously, transported to a site of action (e.g., cancerous tumor or arterial blockage) and be retained at the site by application of a magnetic field gradient. This form of drug delivery, is advantageous in that a specific site in the body, can be targeted by the magnetic field gradient. The doses required for systemic drug delivery are reduced, localized drug levels can be increased significantly with reduced potential toxic side effects at nontargeted tissues, and a prolonged release of high localized drug concentrations at a required site can be obtained. An interesting extension of this technique is the use of implanted magnetized stents, which can be used as capture sites for magnetic particles carrying therapeutic agents and offer the possibility of reapplication of a tailored drug and optimum dosage. A second important therapeutic application is in the field of hyperthermia, which involves heating organs or tissues to between 41 and 46 °C to obtain tumor cell necrosis. The application of an external alternating magnetic field to nanosized magnetic particles causes heating via hysteresis energy losses.

Superparamagnetic particles are used as magnetic resonance imaging (MRI) contrast agent in diagnostics applications. MRI may be used to enhance the image contrast between normal and diseased tissue and/or indicate the status of organ functions or blood flow. Small superparamagnetic iron oxides (SPIOs) have been developed for imaging liver metastases and to distinguish loops of bowel from other abdominal structures. Medical applications require particles with high saturation magnetization, exhibiting superparamagnetic behavior and small enough to interact in the region of interest, e.g., to promote tissular diffusion. (Large particles may irritate surrounding tissue or embolize small blood vessels and capillaries) [14].

3.14 BIOMEDICINE APPLICATION

Magnetic nanoparticles offer some attractive possibilities in biomedicine. First, they have controllable sizes ranging from a few nanometres up to tens of nanometres, which places them at dimensions that are smaller than or comparable to those of a cell (10–100μm), a virus (20–450 nm), a protein (5–50 nm) or a gene (2 nm wide and 10–100 nm long). This means that they can 'get close' to a biological entity of interest. Indeed, they can be coated with biological molecules to make them interact with or bind to a biological entity, thereby providing a controllable means of 'tagging' or addressing it. Second, the nanoparticles are magnetic, which means that they obey Coulomb's law, and can be manipulated by an external magnetic field gradient. This 'action at a distance', combined with the intrinsic penetrability of magnetic fields into human tissue, opens up many applications involving the transport and/or immobilization of magnetic nanoparticles, or of magnetically tagged biological entities. In this way they can be made to deliver a package, such as an anticancer drug, or a cohort of radionuclide atoms, to a targeted region of the body, such as a tumor. Third, the magnetic nanoparticles can be made to resonantly respond to a time-varying magnetic field, with advantageous results related to the transfer of energy from the exciting field to the nanoparticle. For example, the particle can be made to heat up, which leads to their use as hyperthermia agents, delivering toxic amounts of thermal energy to targeted bodies such as tumors. In addition, many other potential applications are made available in biomedicine as a result of the special physical properties of magnetic nanoparticles [12].

Chapter Four
Material and Methods

4.1 Introduction:

In this chapter the experimental work that carried out in this thesis introduced, in addition to material and methods that used to prepare the samples.

4.2 Material:

Three different coils (100, 150 and 200 turns) were prepared using U-shape test tubes and raw material of iron was brought from minster of miners and meteorology (Fe_2O_3 purity 80 % investigated in chemical laboratory).

4.3 Method:

The samples were crushed for different times (2, 6 and 10 minute), and putted in the plastic tubes and then the electric circle was maked and the tables with relation between the current and magnetic field in different values and different sizes of samples were recorded, then the curves for this relation were drawn.

4.4 Results:

Table (4-1): Different time crush sample in 200 turn coil:-

I(A)	B(mT),2minute	B(mT),6minute	B(mT),10minute
0	-1.12	-1.09	-1.12
0.3	-1.05	-0.91	-1.05
0.6	-0.88	-0.79	-0.92
0.9	-0.64	-0.50	-0.74
1.2	-0.52	-0.33	-0.30
1.5	-0.30	0.00	0.04
1.8	-0.04	0.27	0.53
2.1	0.15	0.60	0.66
2.4	0.50	0.86	1.29

Table (4-2): Different time crush sample in 150 turn coil:-

I(A)	B(mT),2minute	B(mT),6minute	B(mT),10minute
0	-0.09	-1.23	-1.15
0.3	-0.03	-1.09	-1.1
0.6	0.00	-0.87	-0.90
0.9	0.15	-0.77	-0.64
1.2	0.21	-0.54	-0.48
1.5	0.30	-0.43	-0.30
1.8	0.47	-0.19	-0.27
2.1	0.58	0.26	-0.13
2.4	0.67	0.31	1.07

Table (4-3): Different time crush sample in 100 turn coil :-

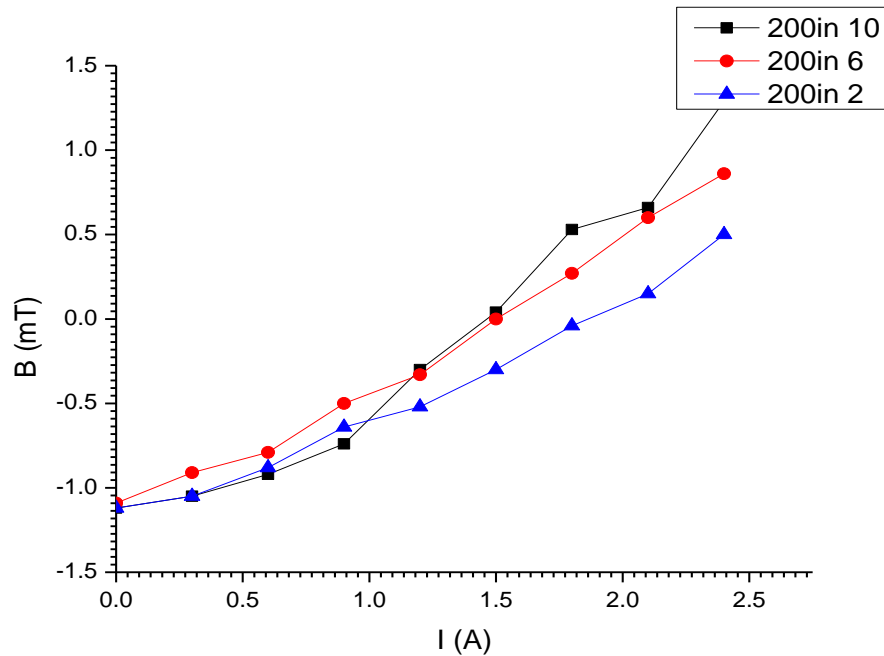| I(A)	B(mT),2minute	I(A)	B(mT),6minute	I(A)	B(mT),10minute
0	-1.23	0	-1.18	0.023	-1.14
0.3	-1.07	0.27	-1.09	0.27	-1.1
0.61	-0.93	0.6	-0.89	0.7	-1.02
0.89	-0.79	0.83	-0.87	1.11	-0.93
1.16	-0.63	1.08	-0.73	1.44	-0.87
1.53	-0.41	1.34	-0.60	1.78	-0.80
1.90	-0.20	1.86	-0.33	2.05	-0.78
2.35	0.084	2.18	-0.097	2.33	-0.74
2.74	0.32	2.38	0.009	2.72	-0.72

Figure (4.1) shows the relation between magnetic field induction B (mT) and current I (A) for different crushing time in 200 turns coil
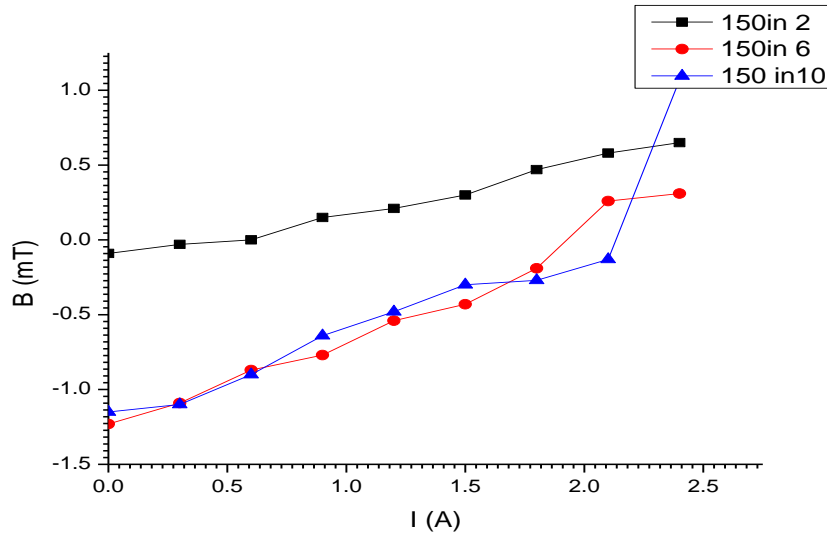
Figure (4.2) shows the relation between magnetic field induction B (mT) and current I (A) for different crushing time in 150 turns coil
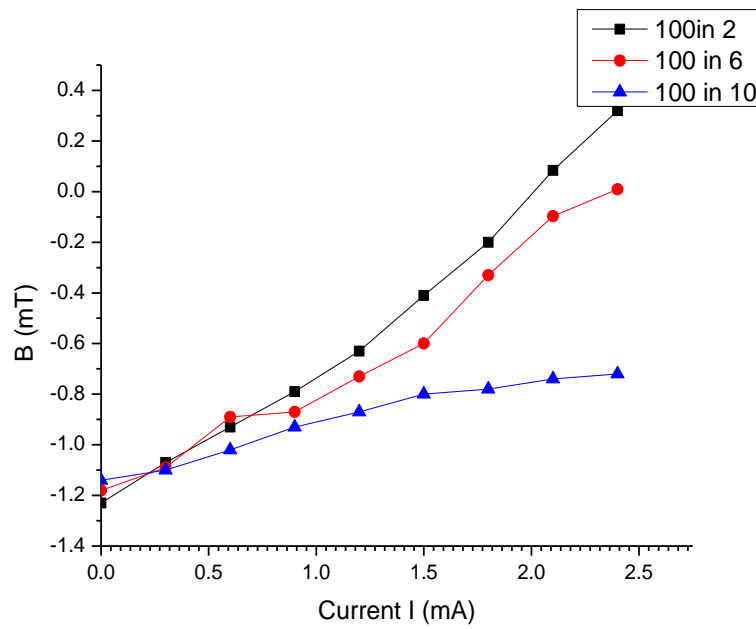

Figure (4.3) shows the relation between magnetic field induction B (mT) and current I(A) for different crushing time in 100 turns coil

4.5 Discussion:

Figure (4-1) show that the same number of turns(200turns) with different size particles according to the time of crush (2,6and10) which indicate the time of crush increases the magnetic field induction due to reduces of the volume for the iron filling , but in figure (4-2) and figure (4-3) by using coil with 150 turns and 100 turns the effect of crush time revealed that the magnetic field induction is higher in the lower time of crush (largest sized).

4.6 conclusions:

The sized of nano particles affect the magnetic field induction and its properties so the different nano sized particle can be used in different applications.

4.7 Recommendation:

In future studies in this field I recommend that use the more number of samples, coil with more different number turns and more number of finale tables in order to arrive to the new and different properties of iron in its nano size particles.

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