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Original Research

Study of the Effect of Acidity on the Nanosized Size of Ferrite

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Abstract:

In many electrical devices, such as transformers, motors, and generators that rely on magnetic fields generated by electrical currents, which always contained iron or one of the iron compounds within their crystalline structure, the importance of this was to increase the magnetic flux and confine it to the desired place. All materials of different types, whether they are gases, liquids, or solids, have magnetic properties as a result of their influence by the magnetic field, but to varying degrees, as some materials have weak magnetic properties, some medium, and others strong. As for temperature, it has a major impact on magnetic properties, and there are materials Others have reversible magnetic properties, meaning that the direction of the field in them is opposite to the direction of the external field (the projected field). In view of the use of magnetic materials in many electronic applications and devices such as microphones, headphones, and wireless means of communication, as well as in computer memory, logic circuits, and high-speed opening and cutting applications in the circuits themselves, it has become important to study the basic properties of these materials and know their physical properties. Many studies have been conducted on These materials are used to know the magnetic properties of the materials and are understood in detail, whether theoretical or experimental, as some of these studies depend on quantum mechanical theory, and this is outside the framework of our current study.

Key words: Acidity, Nanosized Size, Ferrite

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Introduction:

The science of physics witnessed a remarkable and important development at the beginning of the twentieth century regarding the concepts of nature, energy and radiation, which led to the division of physics into two parts: first - classical physics and second - contemporary physics. The great development in industry has become a need for materials that have special mechanical or electrical properties. Or thermal or optical [1]. Ferrites have been studied since 1936, and they are one of the magnetic ceramics that have developed due to their use in the manufacture of high- and low-frequency electrical circuits. They are considered solid and brittle iron oxides, like other types of ceramics. The general formula of spin ferrite is (MFe2O4), where M is one of the divalent transition elements or a mixture between them, such as (Mg+2, Co+2, Cu+2, Ni+2, Fe+2, Mn+2, Cd+2). Ferrites are characterized by their high magnetic permeability and high electrical resistance of up to (109Ω), as well as their dielectric constant ranging from (10 to 15), and these quantities change with changes in the electric and magnetic field applied to them. Ferrites are classified as ferromagnetic materials [2]. Spinal ferrites are one of the types of ferrites widely used in many electronic and magnetic devices because of their high magnetic permeability and low magnetic losses, in addition to their high thermal stability, which makes them highly capable of withstanding thermal temperatures [3]. Ferrites are prepared in the form of powders, then pressed and sintered to take the desired shape. They are cheap materials and easy to prepare and form compared to other materials.

The properties of ferrites depend on the size and shape of the nanoparticles, the method of preparation, the sintering temperature, and also depend on the type and quantity of elements that make up the ferrite [2, 3]. There are several methods for preparing ferrite, including the ceramic method, co-chemical precipitation, and the solution-gel method with auto-combustion. It is one of the distinctive methods because of its ease of preparation, short time, and does not require high temperature.

As a result of the physical properties possessed by ferrite, it has been widely used as an alternative to previously used materials (iron sheets) in the manufacture of electrical transformer cores and magnets, due to its effective role in reducing energy dissipation as a result of reducing the magnetic hysteresis cycle and its possession of high electrical resistance that distinguishes it from other metals, which causes eddy current losses. Very small compared to the large eddy currents when using other metals as cores of electrical transformers. It is also used in communications devices (receiving and broadcasting circuits) and as filters in radars, antenna bars, magnetic amplifiers, digital cameras, computer memories and other electronic applications. It is also used as microwave attenuation materials to hide flying targets from radar, and its applications are still increasing nowadays. [4, 5].

Nano science:

It is the science that is concerned with studying the properties of materials at the atomic and molecular level, as it links material sciences with physics, such as bioengineering, chemical and mechanical engineering, and these sciences form several branches, all of which are related to studying the properties of matter at the nanoscale level, which is the unit of measurement for the length of very small things. As for the forms of nanomaterials They are materials with structural components, at least one of whose dimensions is in the nanospace, and the properties of these materials determine their composition in the nanospace. Materials whose diameter is the size of a nano are called nano particles, and they have new and improved properties that depend on their size compared to larger particles of the same material. When the distance is equal between one atom and another, or one molecule and another, for elements and compounds within the nano scale, they are known as nano crystals, and it can be Its crystal structure must be different or similar to its equivalent in large sizes.

The Ferrites:

It is one of the types of magnetic materials that have found widespread use in the electrical industries. The reason is due to the distinctive magnetic and electrical properties of these materials, as it is considered an insulating material with a high electrical resistivity higher than (104 cm.Ω), meaning that the electrical resistance of these materials exceeds the resistance of permeable materials. High magnetism (108 - 1014) times, because its losses resulting from eddy currents constitute a small amount when they are present in oscillating magnetic fields, and this property makes them used in transformer cores [9].

Ferrites are non-metallic substances, but rather complex ionic oxide compounds of different minerals, which are derived from macintite (iron oxide) and whose chemical formula is Fe2+3O3, Fe2+2O by replacing the binary ion Fe2+2 with divalent ions such as Cu+2, Mn+2, Mg+. 2, Zn+2 and other divalent ions, or the trivalent ion Fe+3 may be replaced with trivalent ions such as Cr+3, Al+3, Mn3+. In these replacements, the radii of the replacement ions must be taken into account, which must range between (0.5 –1 A˚) in order to create the compound's chemical formula A+2B2+3O4+2, as B+3, A+2 represent the binary and ternary ions, respectively, so that the compound crystallizes in the spinel structure.

Ferrite is used in many industries, including:

1- In the manufacture of electrical transformer cores

2- In the manufacture of electrical mechanical transmission Transducer

3- In the manufacture of some microwave equipment

4- In the manufacture of electronic storage devices (Electronic memory equipment).

Magnetic fields in the vicinity of the atom:-

First: The orbital motion of the electron

It is the rotation of the electron around the nucleus, which results in a current with a magnetic moment, as happens when an electric current flows in a circular ring, which creates a magnetic dipole perpendicular to the plane of the ring.

Second: The spin movement of the electron

It is the movement of an electron around itself and is called electron spinning. It is the result of the electron's intrinsic magnetic moment, that is, the rotation of the electron around its axis, just as the Earth rotates around its axis. Therefore, the result of these two movements is what determines the magnetic properties of each atom or ion, as shown in Figure (2). 1), As for the effect of these movements on the magnetic [5, 6] properties, the orbital movement has a secondary effect, while the spin is fundamental in changing the magnetic properties of materials.

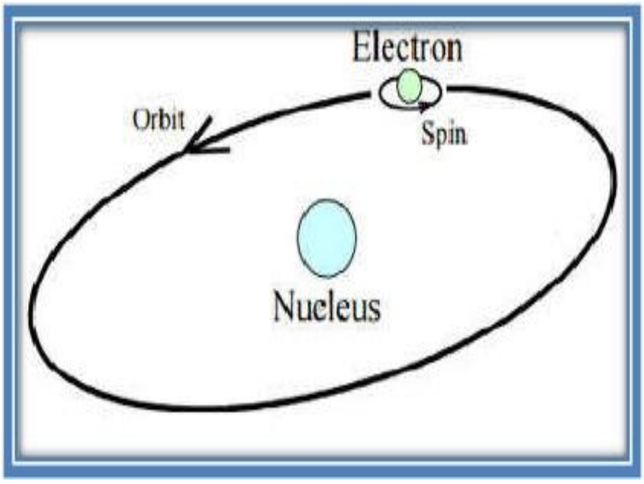

Figure (2-1) is a model of the movement of an electron around the nucleus [35]

Classification of materials

Materials of all kinds are affected by the external magnetic field, but to different degrees. To simplify them, we can divide them in terms of magnetic properties into the following: -

Paramagnetic materials

They are materials that have a positive magnetic influence when there is an external magnetic field, as the magnetic influence disappears when the external field is removed, and this condition results when the individual moments of atoms, ions or molecules are aligned in the direction of the influential magnetic field, as shown in Figure (2-2), but when the field disappears The external influence is that the moments of atoms and molecules are random and irregular and their result is zero. Therefore, they possess a permanent magnetic moment resulting from the directional summation of the spin moments of the electrons. The degree of alignment and direction of the moments of the para materials depends on the strength of the applied magnetic field and on the temperature. This characteristic of the materials appears at degrees The temperature is higher than the Curie temperature, Tc. The Curie temperature varies from one material to another, and the total spin of the para materials is not equal to zero, and the magnetic susceptibility to them is positive and much less than one $(1>\chi)$, while the permeability is slightly greater than one.

It has been found that magnetic susceptibility decreases when the temperature increases in such materials because thermal energy disperses the directions of the magnetic field. As for the value of the magnetic permeability of the para materials, it is greater than one $(1 < \mu)$, and the susceptibility ranges between (10-3 - 10-5), meaning that they are attracted to the magnet. Examples of these are salts of transition elements such as chlorides, sulphates, chromium carbonates, iron, cobalt, salts, and oxides. Trace elements such as dysrosium.

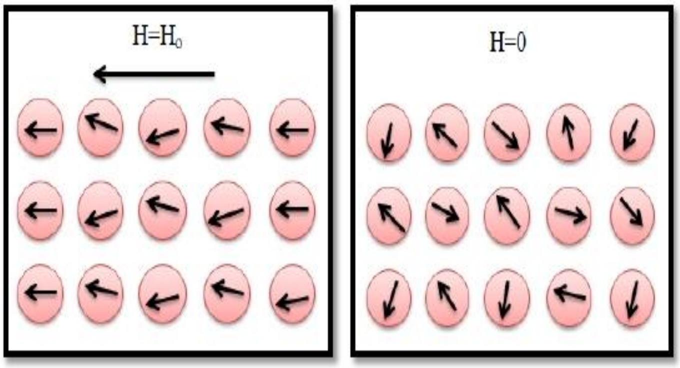

Figure (2-2) The effect of paramagnetic matter on the magnetic field [38]

Diamagnetic materials:

Diamagnetic materials go back to their discoverer, the scientist Michael Faraday, in 1846 AD, through the repulsion of bismuth Bi when placed in a strong magnetic field. Therefore, it was called diamagnetic materials. They are materials that generate a magnetic field within their atoms that is opposite to the direction of the external field applied to them, that is, they are not attracted to the magnet. [These materials tend to To move away from the applied magnetic field, regardless of its direction, and if it is allowed freedom to rotate, it makes the lengths of its axes perpendicular to the lines of force.] Since its orbital electrons are random and poorly balanced, the resultant of the magnetic moments of all the atoms' electrons is equal to zero. The magnetic moments of their outer electrons are one in the opposite direction to the other. Within the electronic double, the magnetic susceptibility of the DIA materials is very small and is estimated at (10-5). This leads to the fact that the resultant magnetic flux density of the material is less than that in free space (H◦μ) and for the same field, and that this effect will disappear with the disappearance of the external field. Al-Musalat: These materials are characterized by having a permeability of less than one and a very weak (negative) magnetic effect on temperature. Examples of these materials are silver, copper, zinc, and bismuth, as shown in Figure (2-3).

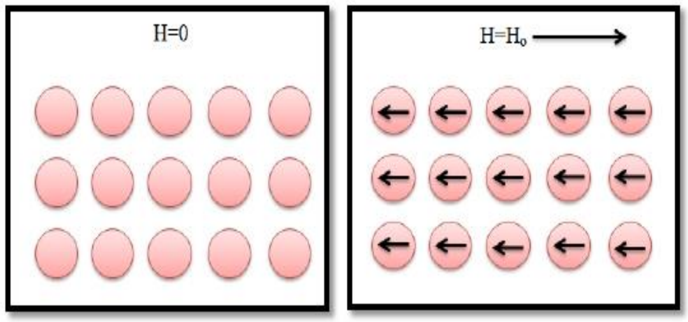

Figure (2-3) The effect of demagnetic matter by the magnetic field [34]

Ferromagnetic materials:

In ferromagnetic materials such as iron (Fe), cobalt (Co), and nickel (Ni), there is a strong interaction between the magnetic moments of neighboring atoms, meaning that the atomic moments can move towards the magnetic field applied to them, even if it is weak. Therefore, they have a high magnetic permeability and retain their magnetism after the disappearance of the external field applied to them. To be permanently magnetized, while the value of magnetic saturation can be easily reached at small values of magnetic intensity because the moments are all in one direction once a magnetic field is applied. Therefore, the relationship between the magnetization M and the applied magnetic field H is a non-linear relationship M as it is a constant of proportionality, and it is called By the molecular field coefficient, this means that the magnetic susceptibility of ferro materials is not constant, but rather changes with the intensity of the field applied to it, H. Ferro materials can transform into para materials when the temperature is increased to a limit higher than the Curie temperature (Tc), and this increase makes the material gain thermal energy. It leads to a change in the arrangement of the magnetic moments, which leads to a decrease in their magnetism, and Figure (2-4) shows this.

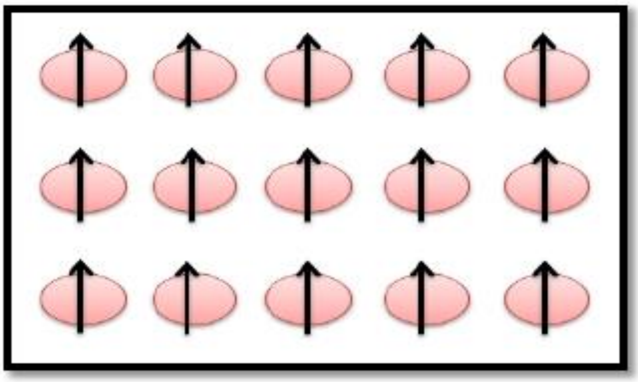

Figure (2-4) Ferromagnetic matter[38]

The ferrimagnetic meterials:

It is a special case of antiferromagnetic materials, as the moments are opposite in direction and different in magnitude, meaning that the moments are unequally aligned, as shown in the picture (2-5). This makes it possess a spontaneons magnetic moment, meaning that it is self-magnetic even when the external field is removed. Influencing it.

As for the susceptibility □ and the magnetic permeability rμ of ferritic materials, they are relatively high, but they are less or do not reach ferromagnetic materials because all their moments are aligned in the direction of the field applied to them. Ferri materials are good conductors of electrical and thermal current, but their specific resistance is very high compared to ferromagnetic materials. The chemical formula for Ferri materials is expressed as MQ2X4, where the letter]

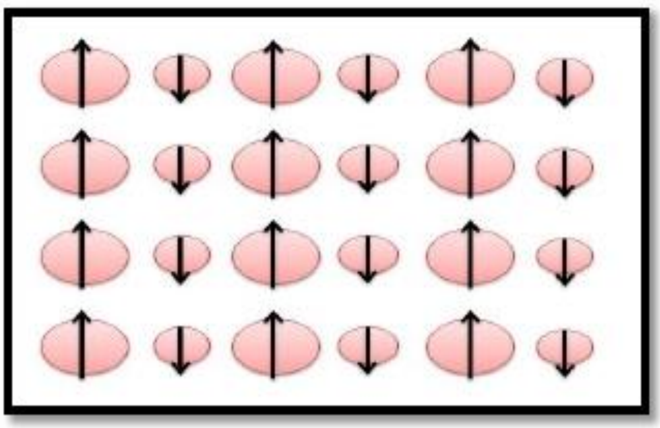

Figure (2-5) Ferrimagnetic material [38]

Anti-ferromagnetism meterials:

Exchange coupling between neighboring atoms is known as a binding force between the first atom and the second atom and vice versa. This bonding works to direct the moments parallel to each other, equal in magnitude and opposite in direction in the basic lattice. This material is known as antiferromagnetic, as in Figure (2-6).

When a magnetic field is applied to anti-ferro materials, the dipole moments of the atoms will align and move opposite to the direction of the applied field. Therefore, the generated magnetism will cancel the effect of the external field, and this makes the resultant magnetic moments of the primary lattice equal to zero, because the moments of the adjacent secondary lattice are parallel and opposite, just like nickel oxide. And manganese oxide.

These materials also increase in their magnetism with increasing temperature until they reach a maximum at a certain limit known as the Neel temperature (Tn) or (the Neel point), and when the temperature continues to increase beyond the Neel point, the material turns into a magnetic bar.

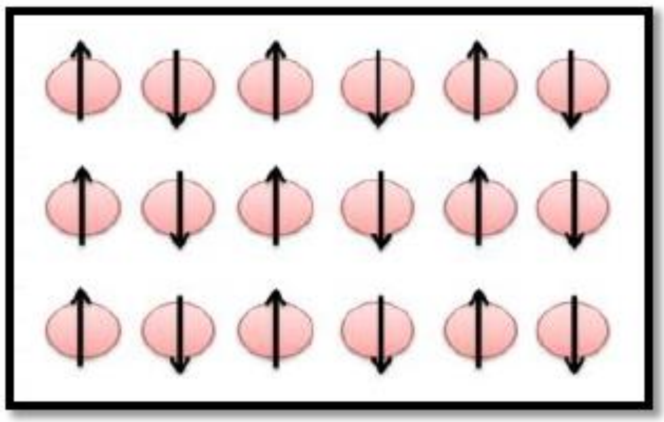

Figure (2-6) Antiferromagnetic matter[38]

Types of ferrite according to the crystal structure

Garnet Ferrite:

The structural formula for this type of ferrite is (M3c Fe2a Fe3d O12), where the (M) represents one of the rare elements such as yttrium (Y) or rare earth, while the lowercase letters (a, c, d) represent the weights of the prepared materials.

Hexagonal ferrites:

These ferrites are characterized by having a very complex structure, as they consist of spindle-like sections that are interconnected in some way to form a crystalline structure with hexagonal symmetry. As for its structural formula, M+2Fe12O19, the M is a divalent metal ion such as (Sr, Ba, pb). There are four types of ferrites. Hexagonal ferrites are (M, W, Y, Z).

Spinel Ferrites:

It is one of the types of ferrites with a cubic crystal structure, and its general formula is MFe2O4, as M represents a divalent transition metal such as Mg, Zn, Mn, Cd, Ni. We can obtain more than twenty types of compound ferrites that take the same general formula, except The M can be replaced with different elements such as (Ni-Zn) because the M represents a mixture of positive ions.

As for the effect of the radius of the positive ion, it is important in forming the crystalline structure of spin-shaped ferrite. This type of ferrite can be formed when the radius of the positive ion replacing M+2 is less than 1A°, and when the radius is greater than 1A°, the Coulomb force is not Sufficient to ensure the stability of the crystal structure. Therefore, it is difficult to form spindle crystals from binary calcium ions (Ca+2) because the radius of the ion is greater than one (Ca+2 = 1.05 A°). As for cadmium ions, for example, their ion radius is less than one (Cd). +2=0.99A° This indicates the possibility of forming a spin-ferrite from this element. The following table (2-1) shows the radii of some positive ions.

First: The structure of the tetrahedral, from which a group of A-sites is formed:

Secondly - the octahedral structure, which consists of a group of B-sites. As for the sub-lattice, the secondary alloys are formed from different groups that interfere with each other, and the result of one of them is opposite to the other, and the structure of the A groups, which number (8), are groups consisting of four oxygen ions surrounding the positive ion. For one group, while group B, which has 16 groups, consists of six oxygen ions surrounding the positive ion.

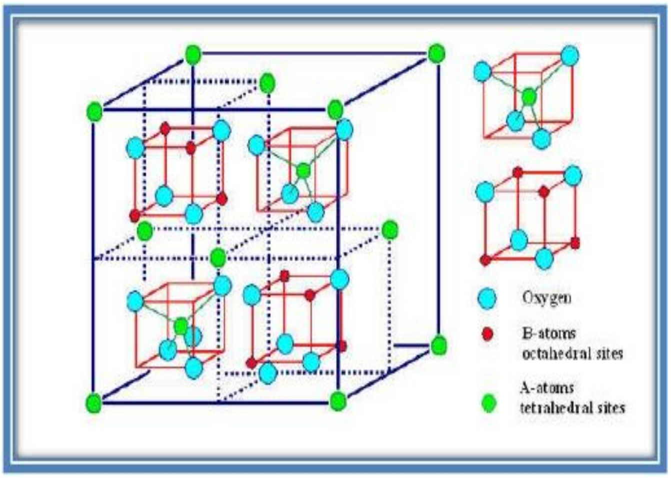

Figure (2-7) Structure of spin-ferrite and the locations of the groups (A-site), the groups (B-site), and the oxygen sites[46]

Classification of ferrites according to their magnetic properties:

Ferrites are classified according to their magnetic properties into two types: hard ferrite and soft ferrite, depending on their ability to magnetize or not.

Hard Ferrite:

It is one of the types of ceramics and is permanently magnetized, as it has a high magnetic flux density and also a high magnetic reluctance, so it is difficult to magnetize or demagnetize it compared to other permanent magnets.

These materials are first manufactured in the form of powder, then pressed in special molds to take specific shapes. After pressing them, a sintering process is carried out on them, and then they are exposed to a very high magnetic field in order to give them great magnetic strength.

The hysteretic ring for this type of solid ferrite is wide and large, an example of which is barium ferrite BaFe12O19.

The thing that makes it commonly used is its low cost and its ceramic nature. It is hard and brittle and takes on the color of coal gray [8, 9]. It is used in many industrial applications such as loudspeakers, medical treatment, mining, oil industries, and in the field of electricity and the automobile industry.

Soft Ferrites:

Soft ferrites are classified as a type of ceramic and differ from hard ferrites by being easily magnetized and losing their magnetism after the disappearance of the external magnetic field.

As for the hysteretic loop, it is completely opposite to the previous type. It is narrow, long, and has a low coercive force (magnetic reluctance). This indicates that the energy loss in this type is very small, so it is used in microwaves, transformer cores, and induction coils. One of the important properties that makes this type Ferrite is used in many applications due to its high resistance and very low eddy current losses over a wide range of frequencies. It has high magnetic permeability, and Figure (2-8) shows this.

It has thermal stability over a wide range of temperatures, an example of which is cobalt ferrite $CoFe_2O_4$ and nickel $NiZnFe_2O_4$.

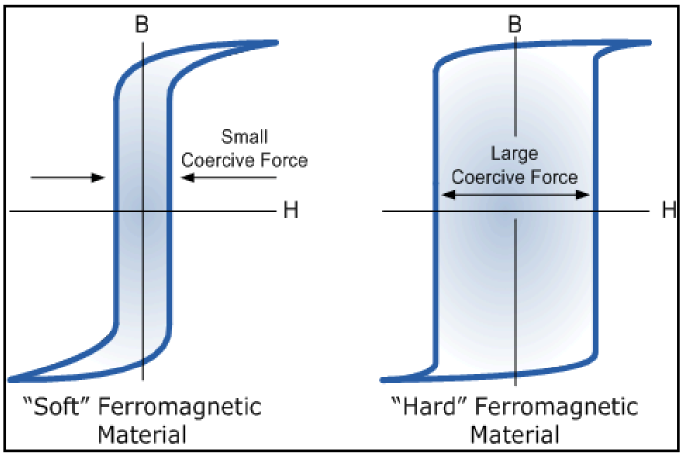

Figure (2-8) The two hysteresis rings for (soft) ferrite and (hard) ferrite [50]

Magnetic permeability:

It is the ability of magnetic field lines to penetrate and flow into the material. The ease of flow of field lines increases with the increase in the permeability of the material and vice versa. This depends on the external magnetic field applied to the material and to the dipoles because the dipoles are affected by the internal force of attraction and repulsion between them in addition to the random force that they gain from energy. Heat from its external surroundings, as the diodes are arranged randomly and each diode is in a different direction from the other, and the sum of the external effect of these diodes is zero. This effect is due to the random alignment of the dipoles that are not affected by the external magnetic field. However, if the dipoles are affected by the external field, it attempts to align the moments (dipoles) in the direction of the applied field. If the moments are not aligned, an internal magnetic field may be generated in addition to the external field, and this depends on the property of the material. Because in some materials the internal and external random force is much greater than the external field, so the internal and total magnetic field resulting from the dipoles remains equal to zero, and in this case these materials are called non-magnetic materials.

Methods for preparing nanomaterials:

Conventional ceramic method:

When manufacturing nanomaterials, the raw materials involved in their preparation must be determined, which are in the form of oxides or salts of elements such as carbonates, chlorides, or nitrates [10-14]. After determining the weights accurately, the mixing process begins. The goal of this is to make the materials a homogeneous mixture in order to prevent aggregation and agglomeration. One of the components in a specific location.

The mixing process is carried out either dryly or by adding water or any of the alcohols whose components do not interact chemically with the mixed materials. It is an essential step in homogenizing the components of the reacting materials. After completing the mixing process, the drying stage comes and is done either by filtration or heating to a temperature of (100ºC), and its purpose is Dispose of the solvent liquid. After the drying stage, the calcining process takes place at 700°C for three hours, then the material is crushed well using steel balls or an agate pestle until it turns into small particles.

Then comes the forming process, in which the crushed particles are compressed using a hydraulic piston to take the shape of the mold used. The samples in this stage are characterized by weak mechanical properties and can be transformed into powder under the influence of a small amount of force. To improve their mechanical and physical properties, the material is sintered [15, 16] and alcohol is often used. Polyvinyl chloride (PVA) or carbon tetrachloride (CTC) is a binder that helps distribute nucleation centers.

The pressed samples need a heat treatment called the sintering process, which is to raise the temperature of the material to less than the final sintering temperature, about (200°C), in order to allow room for some reactions and to reduce the resulting shrinkage in the final sintering stage. The first sintering time is estimated at (8). -12h); Then the samples are left in the oven until they cool.

Co-precipitation method:

It is one of the methods of preparing and manufacturing magnetic materials. It begins with adding alkaline bases such as sodium hydroxide (NaOH) or ammonia to solutions containing metal ions involved in the composition of ferrite, such as the oxides of these metals, their carbons, sulfates, or chlorides. There are several parameters through which the speed of ferrite deposition can be controlled. The PH value should be between (8-14) in the hydroxide solution.

The metals begin to precipitate depending on the PH value, which affects the shape and size of the precipitated particles. The precipitation process takes place at a temperature higher than (50°C). Precipitation can also occur in (30 minutes) at a temperature of (90°C), and the oxidation process takes place with or without ventilation. The solution is then filtered using filter paper or using a centrifuge to complete the sedimentation process. It is washed with water or alcohol several times to get rid of the remaining precipitated material until the acidity is neutralized (PH = 7). Then the resulting powder is dried by raising its temperature to get rid of the normal water and the rest of the solution. Carbonates [17-19].

One of the advantages of the co-precipitation process is that it is an easy and direct process for preparing metal powders and oxides. The homogeneous mixing of the reacting precipitates reduces the reaction temperature and the resulting powders do not need high temperatures when sintering [20]. The disadvantages of this method are that it is an inappropriate method for obtaining pure and accurate phases, and this method may not work well if the reacting materials have different solubility or different sedimentation rates.

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