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Structural and Electrical Properties of Aluminum substituted Cobalt ferrite nano particle

A Thesis
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By

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1.1. Introduction

The history of ferrite materials can be traced back to centuries ago with the discovery of stones that attracted iron. Plentiful deposits of these stones were found in the district of *Magnesia* in Asia Minor, and hence the mineral's name became magnetite (Fe_3O_4) [1]. Ferrites, have become available as practical magnetic materials over the course of the last twenty years. During this time their use has become established in many branches of communication and electronic engineering and they now embrace a very wide diversity of compositions, properties and applications.

The naturally formed ferrites such as magnetite’s are magnetically soft, which are of technical importance and to the applications of such ferrites in devices which in the broadest sense may be described as inductors or transformers.

Ferrites are ferrimagnetic oxides consisting of ferric oxide and metal oxides. On the basis of crystal structure ferrites are grouped into three classes namely hexagonal ferrite, garnet and spinel ferrite The magnetic properties arise from interactions between metallic ions occupying particular positions relative to the oxygen ions in the crystal structure of the oxide. Ferrites with spinel structure represent the important class of magnetic materials. The combination of magnetic and electrical properties makes ferrite useful in many technological applications.

The spinel ferrite is having the chemical formula MFe_2O_4 (where M- is a divalent metal ions such as Co, Ni, Mn etc). and possess two sub-lattice namely tetrahedral A and octahedral B sites[3,4]. As an important member in the family of spinel ferrites cobalt ferrite ($CoFe_2O_4$) with inverse spinel structure are promising magnetic materials because of their moderate saturation magnetization, high electrical properties, high magneto-crystalline anisotropy, good mechanical properties and chemical stability [4]. Ferrites or Ferrimagnetics are oxides, dark grey or black in appearance , possesses the properties of ceramic materials, such as being hard, brittle and chemically inert, can be changing the electromagnetic properties of ferrites by controlling the manner of preparation and type of materials used, amount of material added and sintering temperature [2].

Ferrites have been studied since 1936. They have an enormous impact over the applications of magnetic materials. The resistivity of ferrites at room temperature can vary from 10^{-2} Ω-cm to 10^{11} Ω-cm, depending on their chemical composition [3]. They are considered superior to other magnetic materials because they have low eddy current losses and high electrical resistivity. ferrites have good magnetic properties at the same time are the insulating material's so its preferred for that material in industries which operate within the high frequency up to 10 MHz and ferrites have permeability's up to 30,000 and exhibit dielectric properties. Exhibiting dielectric properties means that even though electromagnetic waves can pass through ferrites, they do not readily conduct electricity. This also gives them an advantage over iron, nickel and other transition metals that have magnetic properties in many applications because these metals conduct electricity. Another important factor, which is of considerable importance in ferrites and is completely insignificant in metals is the Ferrimagnetisms behave similarly to ferromagnetism, in that they exhibit a spontaneous magnetization below some critical temperature, T_c Curie temperature [4,5].

1.2. Literature review

Research was conducted in different places of the world for the development of magnetic materials began in Japan by researchers V. Kato, T. Takei, and N. Kawai in the 1930 and by J. Snoek of the Philips Research Laboratories in the period(1935,1936,and1945) in the Netherlands. By Snoek in 1945 had laid down the basic fundamentals of the physics and technology of practical ferrite materials[6]. In 1948, the Neel theory of ferromagnetic provided the theoretical understanding of this type of magnetic material.

In 2000 S.S Ata-Allah and M.K. Fayek [7] prepared the composition $Ni_{1-x}Cu_xAl_yFe_{2-y}O_4$ by using the usual ceramic method, and studied the electrical properties of Cu substituted Ni–Al ferrite $Ni_{1-x}Cu_xAl_yFe_{2-y}O_4$, with ($0.0 < x < 1.0$ and $y = 1.0$). The obtained results of these materials reveal a semiconducting behavior at low concentration of Cu. A semiconducting-to-metallic transition has been observed with increasing Cu content in these compounds. This transition temperature is found to decrease linearly with increasing Cu concentration. The results of conductivity measurements are explained in the light of the cation–anion–cation and cation–cation interactions at the octahedral B-sites.

In 2000 D.R. Mane, **U. N. Devatwal, and K.M. Jadhav [8]** Polycrystalline cobalt aluminum chromium ferrites ($CoAl_xCr_xFe_{2-2x}O_4$) with Al–Cr substitution ($0 < x < 0.5$) have been prepared by standard double sintering technique and studied lattice constants, magnetization and a.c susceptibility measurements. The saturation magnetization (M_S) decreases with Al–Cr content, indicating reduction in ferromagnetic behavior. Thermal variations of a.c susceptibility at temperature in the range 300 to 860 K were exhibits almost normal ferromagnetic behavior and the Neel temperature (T_N) decreases with increasing Al–Cr content.

In 2003 R.N .Panda et al.[9] studied the magnetic properties of nano-crystalline $CoM_xFe_{2\_x}O_4$ (where M= Gadolinium (Gd), Praseodymium (Pr) and x = 0, 0.1 and 0.2) powders prepared by a citrate precursor technique . The crystallite sizes of the materials were varied by altering the synthetic conditions and are within the range of a minimum of 6.8nm and a maximum of 87.5 nm. The materials were characterized by powder X-ray diffraction (XRD) The phase identification of the materials by XRD reveals the single-phase nature of the materials. The room temperature saturation magnetization of the ferrite materials decreases with the reduction of size. This has been attributed to the presence of superparamagnetic fractions in the materials and spin canting at the surface of nano-particles. An insertion of rare-earth atom in the crystal lattice inhibits the grain growth of the materials in a systematic manner compared with that of the pure cobalt ferrite materials.

In 2003 Yeong Il Kim et al. [10] Cobalt ferrite Magnetic nanoparticles ($CoFe_2O_4$) have been synthesized in a homogeneous aqueous solution without any template and subsequent heat treatment. The average particle size could be varied in the range of (2–14) nm by controlling co-precipitation temperature of Co^{2+} and Fe^{3+} ions in alkaline solution. As the precipitation temperature increased in the range of 20–80°C, the average particle size also increased. However, there is a considerable change in XRD crystallinity and the average size of the nanoparticles at the precipitation temperature between 40°C and 60°C. While the nanoparticles prepared at temperature below 40°C show superparamagnetic relaxation at room temperature with blocking temperatures between75 and 200 K, the samples prepared at the temperature higher than

60°C consist of both superparamagnetic and ferrimagnetic nanoparticles that result in magnetic coercivity at room temperature.

In 2004 Juliana B. Silva et al. [11] nanocrystalline $CoFe_2O_4$ powders were synthesized using metallic nitrates dispersed in aqueous media precipitated by stoichiometric amount of NH_4OH. The influence of heat treatment on the texture and morphology of the cobalt ferrite powder was studied. The specific surface area varied from 150 to 1 m^2/g while the average crystallite size varied from 17 to 100 nm with the annealing temperature.

In 2005 Tal Meron et al .[12] Colloidal cobalt ferrite nanocrystals were produced using sol–gel method. This synthesis involves the single-stage high-temperature hydrolysis of the metal alkoxide precursors to obtain crystalline, uniform, organically coated nanoparticles which are well-dispersed in an organic solvent. The particles could be further manipulated to form Langmuir–Blodgett films consisting of close-packed nanocrystal monolayer. The structural and magnetic properties of these nanocrystals indicate similarity to bulk $CoFe_2O_4$ with a very high coercivity.

In 2005 J. P. Vejpravov et al. [13] Well-defined $CoFe_2O_4$ nanoparticles embedded in amorphous SiO_2 matrix have been synthesized by sol-gel method. The mean particle size was found to increase from 3 to 15 nm by varying the temperature of a subsequent annealing behavior with the blocking temperature increasing with the mean particle size. The frequency dependent AC susceptibility was found to obey the N´eel– Arrhenius law.

In 2006 Vanga S Reddy et al. [14] prepared the alkylation of phenol with methanol, by low temperature, PH controlled co-precipitation rout for composition $ZnFe_{2-x}Al_xO_4$ (x=0, 0.25, 0.5, 0.75 and 1.0) type spinel systems in a fixed bed, down flow reactor. The influence acidity, cation distribution in the spinel lattice and various reaction parameters are discussed. Characterization was made by XRD, ammonia desorption and Brunauer–Emmett–Teller (BET) surface area measurements.

In 2007 Shun Hua Xiao et al. [15] Cobalt ferrite ($CoFe_2O_4$) nanopowders was prepared by a low-temperature, auto-combustion method. The thermal evolution of the precursor, as well as the microstructure, morphology and magnetic properties of as-synthesized powder were studied. The grains observed in as-burnt powder were proved to be $CoFe_2O_4$ nanocrystallites with high dispersibility and low agglomeration. Both the saturation magnetization (*M*s) and the remnant magnetization (*M*r) were found to be highly depending upon the annealing temperature. The highest coercivity (1373 Oe) was achieved by the sample annealed at 400 °C.

In 2007 XIAO Li et al. [16] the sol-gel method was used to prepare three kinds of nano-magnetic particles, such as the nano-cobalt ferrite oxide powders and those doped by $LaCl_3 \cdot nH_2O$. The prepared magnetic particles with average diameter less than 100 nm were characterized by XRD and Transmission electron microscopy (TEM). The results show the difference between the activation energies of these particles in different thermo-decomposition stages, even not in the same stage for different samples. The cobalt ferrite doped with La^{3+} affects its saturation magnetization (M_s) and coercive force (H_c). As $CoCl_2 \cdot 6H_2O$ is partly substituted by La^{3+}, the value of H_c decrease with the increase of M_s. When $FeCl_2 \cdot 4H_2O$ is partly substituted by La^{3+}, H_c increases obviously.

In 2007 Sonal Singhal et al. [17] Aerosol route have been used to prepare the nano size ferrites $CoFe_2O_4$, $CoAl_{0.37}Fe_{1.63}O_4$, $CoAl_{0.95}Fe_{1.05}O_4$ and $CoAl_{1.36}Fe_{0.64}O_4$. A decrease in lattice parameter and saturation magnetization with the increase of aluminum concentration was attributed to the smaller ionic radius and weakening of exchange interaction respectively. Room temperature Mossbauer spectra of as obtained samples exhibited a broad doublet suggesting super paramagnetic nature. The samples annealed at 1200°C showed broad sextets which were fitted with different sextets, due to the tetrahedral and octahedral coordinated iron cation. The cation distribution calculated from the X-ray intensity and Mossbauer data indicated that Al^{3+} ions enter A and B sites in ~2:3 ratio and (oct.) / Fe^{3+}(tet.) ratio increases with Al^{3+} concentration .

In 2008 A T RAGHAVENDER and K M JADHAV [18] dielectric properties of Al-substituted Co- ferrite nanoparticles have been studied A series of polycrystalline spinel ferrites with composition, $CoFe_{2-x}AlxO_4$ ($0 \leq x \leq 1$), have been synthesized by sol–gel method. The effect of Al-substitution on structural and dielectric properties is reported in this paper. XRD revealed the nanocrystalline nature in the prepared ferrite samples. The particle size (D) decreases with increase in Al-content. The lattice parameter (*a*) and X-ray density (D_x) decreased with increase in Al-content. The dielectric constant and dielectric loss obtained for the nanocrystalline ferrites proposed by this technique possess lower value than that of the ferrites prepared by other methods for the same composition. The low dielectric behavior makes ferrite materials useful in high frequency applications.

In 2008 A.T. Raghavender et al. [19] nanocrystalline $NiAl_xFe_{2-x}O_4$ spinels have been synthesized by the sol-gel method. The particle size decreased from 29 nm to 6 nm as the non-magnetic Al content increased. The crystal structure and magnetic properties of the Al co-substituted disordered spinel series of $NiAl_xFe_{2-x}O_4$ (x = 0.0 – 1.0) have been investigated at 300 K by means of X-ray diffraction, magnetization, a.c susceptibility, and Mossbauer effect measurements. The lattice constants were determined, and the applicability of Vegard's law has been tested. Magnetization results exhibit a non-collinear ferromagnetic structure for x = 0.0 to 0.2 and Neel's collinear ferrimagnetic structure for x = 0.4 to 0.8,while the variation of the Curie temperature (T_C) obtained from the a.c. susceptibility with Al content confirms the change of spin ordering from non-collinear to collinear at x=0.4.

In 2009 Nguyen Khanh Dung and Nguyen Hoang Tuan [20] A series of cobalt doped nickel ferrite with composition of $Ni_{1-x}Co_xFe_2O_4$ with x ranges from 0.0 to 0.8 (in steps of 0.2) was prepared by using co-precipitation method and subsequently sintered, annealed at 600°C for 3h. The influence of the Cobalt content on the crystal lattice parameter, the stretching vibration and the magnetization of specimens were subsequently studied. XRD and Fourier transform infrared spectroscopy (FTIR) were used to investigate structure and composition variations of the samples. All samples were found to have a cubic spinel structure. TEM was used to study morphological variations. The results indicate that the average particle sizes are between 29-35 nm.

In 2010 A. T. Raghavender et al. [21] Studied the magnetic properties of nanocrystalline $CoFe_{2-x}Al_xO_4$ ($0\leq x \leq 1$) spinel ferrites, were prepared by the sol-gel auto-ignition method. Substitution of Al content in cobalt ferrite caused a decrease in particle size, lattice parameter, and Curie temperature. The Mossbauer and vibrating sample magnetometer (VSM) studies for these nanoparticles revealed the existence of a non-collinear spin arrangement at the surface of the $CoFe_{2-x}Al_xO_4$ nanoparticles. The saturation magnetization changes with increasing Al content due to the effect of cation distribution in tetrahedral and octahedral sites and due to a change in ferrimagnetic structure. The particle size effects on the coercivity at 290 K were studied.

In 2010 S. Abedini Khorrami et al. [22] Nano-crystalline $CoFe_2O_4$ powder was prepared by combination of sol-gel auto-combustion and ultrasonic irradiation methods from metal nitrides and glycine. The grains observed in as-burnt powder were proved to be $CoFe_2O_4$ nano-crystallites with high dispersibility and low agglomeration. The crystallite size of as-formed powders was 39.12 nm. The crystalline cobalt ferrite powders with magnetic properties having a maximum saturation magnetization (44.02 emu/g) was achieved for Fe^{3+}/Co^{2+} molar ratio 1:1 and calcination temperature 750°C for 4 h. Our results indicate that this method might provide a promising option for synthesizing high-quality $CoFe_2O_4$ nanopowder.

In 2010 Panchal N. R. and Jotania R. B. [23] Nanosized particles of Cobalt ferrite ($CoFe_2O_4$), has been synthesized from single water-in-oil microemulsion technique. The resulting $CoFe_2O_4$ was formed at temperature of around 600ºC, which is lower than that observed in the solid state reaction. The synthesized particles were characterized by XRD and VSM. These studies reveal that the formation of cobalt ferrite by using microemulsion route resulted into the finer particle size and better magnetic properties than those of the conventional routes. Magnetic investigation indicates that the sample is soft-magnetic material with low coercivity.

In 2011 P. Kumar et al. [24] $CoFe_{2-x}Gd_xO_4$; x = 0, 0.1, 0.15, and 0.2 were prepared using co-precipitation method. All the samples were sintered at 500^0C. The structure has been studied using XRD, TEM and energy dispersive X-ray analysis (EDXA). Effect of Gd doping on crystal structure has also been studied and discussed. The particle size has been estimated using Scherrer equation. All the peaks in XRD patterns are narrow which means that particles are in nano range. The structure inferred from the XRD is cubic. Gd^{3+} being larger in size prefers octahedral site.

In 2012 S. S. Madani and Muhammad Tahir Farid [25] Cobalt ferrite ($CoFe_2O_4$) powders with nanocrystalline sizes were produced by a combination of sol-gel auto-combustion and ultrasonic irradiation methods employing a mixture of urea, thiourea and glycine as the fuel with the corresponding metal nitrates. The pH in the starting solution affects the combustion process, and then determines the particle size of the as synthesized powder. The influence of the pH value on the gel auto-combustion and the phase composition of the synthesized powders have been studied with the help of (SEM) observations, (FTIR) spectroscopy and (XRD) techniques. The synthesized powders had a particle size distribution in the range of 23-43 nm.

In 2012 Ishtiaq Ahmad et al. [26] A series of Gd-substituted Cobalt based ferrites of nominal composition $CoGd_{2x}\ Fe_{2-2x}\ O_4$ for x= 0.00-0.25 in steps of 0.05 was produced by conventional ceramic technique. From XRD patterns, all samples showed single cubic spinel structure as a main phase along with small traces of second phase ($GdFeO_3$). The lattice parameter 'a' initially increases for x = 0.05 and then decreases with increasing value of x. d.c. resistivity and activation energies showed increasing trend with increasing Gd contents. The temperature dependent resistivity and activation energy decreases with increasing temperature. In all samples, saturation magnetization increases while the coercivity decreases with increasing Gd content. The increases in dc resistivity and saturation magnetization suggest that these materials are suitable for high density recording media and microwave devices. The structural, physical, electrical and magnetic properties of Gd-substituted cobalt based ferrites are discussed in the current paper.

In 2012 N. M. Deraz [27] nanocrystalline cobalt ferrite with a nominal composition of $CoFe_2O_4$ were prepared by combustion synthesis. The influence of alumina-doping on the physicochemical and magnetic properties of $CoFe_2O_4$ nano-particles were investigated by means (XRD), infrared (IR) spectroscopy, (SEM) and (VSM). XRD and IR analyses confirm that the doping with 3 wt % alumina resulted in the formation of cubic spinel phase of $CoFe_2O_4$nano-particles. Un-doped and alumina doped cobalt ferrite presented in a uniform microstructure with grain size in nano-scale. Alumina treatment led to a decrease in the coercivity (H_c) and an increase in both magnetization (M_s) and magnetic moment (n_B) of the investigated system. The maximum increase in the values of both M_s and n_B due to the treatment with 3 wt% alumina attained 29.8 %. The observed results can be explained on the basis of particle size and the Fe^{3+} concentration in the octahedral and tetrahedral sites involved in the cubic spinel structure.

In 2012 R. Lotfi et al. [28] Nanoparticles of nickel substituted cobalt ferrite have been synthesized by co-precipitation route. The average particle size varied in the range of 22-38 nm; the particle size was controlled via controlling calcination temperature which was in the range of 600 to 900°C. Their morphology structure have been determined by (SEM) and energy dispersive X-ray (EDX) analysis confirms the presence of Co, Ni, Fe and oxygen as well as the desired phases in the prepared nanoparticles. The results of SEM show that the surfactant played an important role in morphology of nanoparticles and a well crystalline single cubic structure of nickel doped $CoFe_2\ O_4$ phase was formed through precipitation precursors at pH value of 11.

In 2013 B. R. KARCHE et al. [29] Nano-particle size polycrystalline aluminum substituted cobalt ferrite samples $CoFe_{2-2y}Al_{2y}O_4$ (where y = 0.0, 0.05, 0.15 and 0.25) have been prepared by standard ceramic technique. Cation distribution is estimated on the basis of magnetic moment per unit cell of samples in Bohr magnetrons calculations. Addition of Al^{3+} replaces Fe^{3+}on A-site and hence magnetic moment per unit values decreases. Particle size of all samples is found in the range of 10-20 nm. Ionic radii and bond lengths on both sites are found decreases with Al^{3+}. Lattice constant and both physical and X-ray density of samples goes on decreasing with Al^{3+}. Curie temperature of samples goes on decreases with addition of Aluminum in the host lattice. Cobalt ferrite exhibits canting of spins of magnetic moments on B-site.

In 2014 M. M. Eltabey and N. Aboulfotoh Ali [30], Co-Zn ferrite nanoparticles were prepared using co-precipitation method. The results showed that, all the obtained samples were formed in single spinel phase. The crystallinity enhanced and the particle size increased due to the annealing process with temperatures up to 950^{o}C. Although the lattice parameter, magnetization, and blocking temperature showed minimum values at annealing temperature 350^{o}C, while the Curie temperature remained almost constant with annealing temperatures.

In 2014 Tahseen H. Mubarak, Sabah M. Ali and Laith S. Mahmood [31], Zinc substituted cobalt ferrite nanoparticles ($Co_xZn_{1-x}Fe_2O_4$, with x = 0.0, 0.1, 0.2, 0.3, 0.4, and 0.5) were prepared via sol-gel route. X-ray diffraction analysis confirms the formation of ferrites in nano phase. The results showed that the particle size decreasing from (22) to (16) nm with increasing the concentration of zinc to the (x= 0.5). The lattice constant increased from (8.36682) to (8.40943)A^0 with increasing the concentration of zinc to (x = 0.5), while the theoretical powder density decreased from (5.3225) to (5.2237) g/cm^3 by increasing zinc ion concentration to value at (x=0.5).

1.3. Nano ferrites and their applications

Nanoparticles are typically defined as solid less than 100 nm in all three dimensions. The development of uniform nanometer-sized particles has been intensively pursued in the last two decades by the fact that small size and high surface to volume ratio of nanoparticles give unique mechanical, optical, electronic, magnetic and chemical properties [32, 33, 10]. Magnetic nanoparticles are of special interest owing to their unique magnetic properties due to their reduced size (< 100 nm) Magnetic nanoparticles have potential use in many technological applications [34].

Ferrite is a polycrystalline, sintered material with high electrical resistively. The high resistance of ferrite makes eddy current losses extremely low at high frequencies. Therefore, unlike other magnetic components, ferrite can be used at considerably high frequencies .ferrites are magnetic materials, which have many applications in both low and high frequency devices and play a useful role in many technological applications because of their high initial permeability, low magnetic losses, high resistivity, low dielectric losses, mechanical hardness, high Curie temperature and chemical stability[35]. Ferrites sensitive structure materials and their properties critically depend on the manufacturing process. Because of excellent magnetic properties of spinel ferrites, it used in electronic and telecommunication industries [36].

Depending on type of applications, magnetic nanoparticles are used in varieties of forms such as surface functionalized particles in biomedical applications, as particles arrays in magnetic storage media, as compacted powders in permanent magnets and in solutions as ferrofluids [37,38].

1.3.1. Ferrofluids

A ferrofluid is a special solution of magnetic nanoparticles in a colloidal suspension whose flow can be controlled by magnets or magnetic fields[39]. Stable colloidal suspensions, a typical particle size is 10nm. A variety of materials can be used, such as Fe_3O_4,Mg , Fe, Co, and Ni,) magnetic fluids or ferrofluids are formed by the cladding of the nano-magnetic particles by the surface active agent, so that they can be stably dispersed in solution, figure(1-1) show ferrofluids attract to magnetic field. Most ferrofluids are based on hydrocarbons or other organic liquids a magnetic fluid is a kind of solution with a behavior that can be controlled by changes of magnetic field, as well as having the characteristics of both magnetism and fluid [40-41]. As a result, when fluid is not in presence of external magnetic field it has zero net magnetization. When a strong magnet is brought close to the ferrofluids, several spikes will appear, as the fluid arranges itself along the magnetic field lines of the magnet. When the field is removed, the particles again disperse randomizing their orientation [33-42]**.** Ferrofluids used in biomedical field. Biological application especially; treatment of cancer by magnetic hyperthermia, magnetic drug targeting eye surgeries are gaining much attention in recent days. The property of ferrofluids absorbing electromagnetic energy at a frequency that is different from the frequency at which water absorbs energy allows one to heat up a localized portion of a living body, where ferrofluids has been injected. Ferrofluidics corporation has been working in partnership with a major manufacturer of electrical power equipment, to develop ferrofluids for liquid-filled transformer applications. Ferrofluids have been shown to provide both thermal and dielectrically benefits to Ferrofluids can be utilized to improve cooling by enhancing fluid circulation within transformer winding [43-44] .

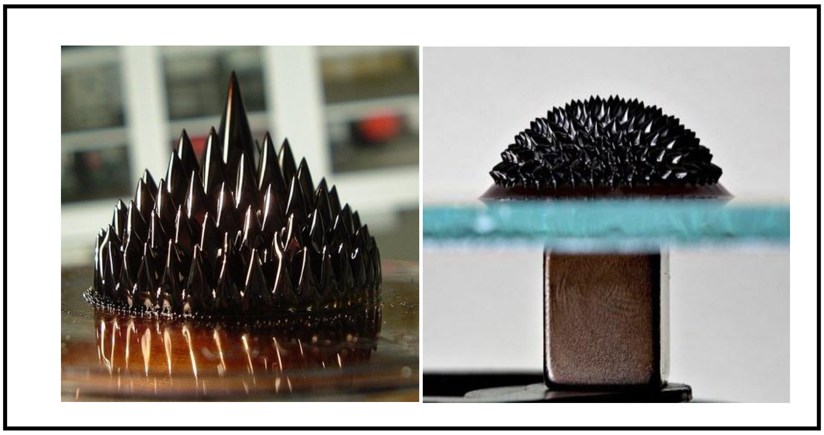

Figure (1-1): Show ferrofluids attract to magnetic field.

1.3.2. Biomedical application

Magnatic nanoparticle are use for biomedical because nanoparticles are small enough to move inside the body without disrupting normal functions, and can access spaces inaccessible by other means[45], Magnetic nanoparticles can have controllable size ranging from a few nanometers up to tens of nanometers, and are smaller than comparable in sizes to a cell (10-100μm), They can get close to the cell or gene and they can be coated with biomoleclues to make them interact or bind with biological entity. magnetic nanoparticles can be manipulated by an external magnetic field gradient. They can be used to deliver a package, such as an anticancer drug to a targeted region of the body such as a tumor [46,47].Figure (1.2) shows $CoFe_2O_4$ application in bio-medical for treatment of tumor cells.

magnetic nanoparticles must: (i) have a good thermal stability; (ii) have a larger magnetic moment; (iii) be biocompatible; (iv) be able to form stable dispersion so the particles could be transported in living system; (v) response well to AC magnetic fields. [41].

The magnetic nano practical applications in biomedical and diagnostic fields such as targeted drug delivery, hypothermic treatment for malignant cell, and magnetic resonance imaging (MRI),[48,49].

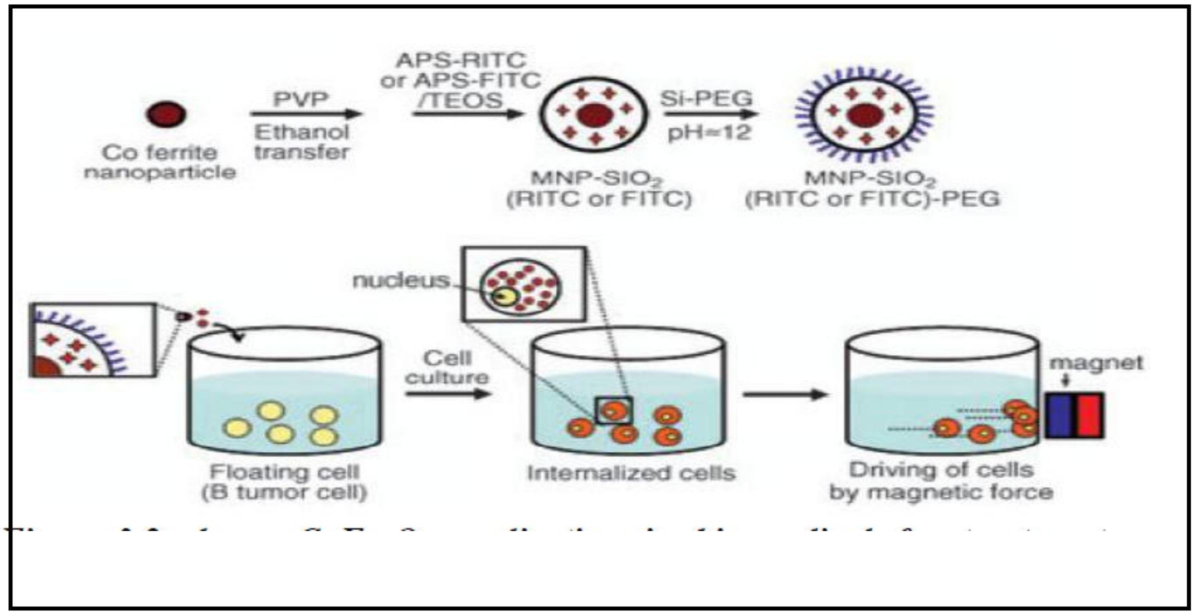

Figure (1-2) : shows $CoFe_2O_4$ application in bio-medical for treatment of tumor cells

1.3.3. Radar Absorbing Materials

Electromagnetic wave absorber in the range GHz are useful in microwave telecommunication technology to suppress electromagnetic interferences a high reflecting metallic structure disturbing radar navigation near airport can be strongly attenuated in radar spectrum by such an absorber in these application a ferrites powder is typically dispersed in resin and the mixture is applied to the structure as a paint, to increase the effective permittivity of the system use tow-layer absorber with different composition and can use metallic fiber worked as dipole antennae increasing the efficiency of the absorber Because of their excellent dielectric properties at microwave frequencies, ferrites can transmit electromagnetic waves with relatively low absorption losses. Above the absorption band mentioned earlier, significant permeability can remain in the tail of the dispersion curve with relatively small magnetic losses. For this reason, the microwave properties of ferrites have been investigated extensively and their frequency-dependent propagation in bands from 1 to 100GHz have found widespread application in communications and radar technology [50-51].

1.4. Objective of the research

- Synthesis $CoFe_{2-x}Al_xO_4$ ferrite nanoparticles with different compositions where, x takes values (from 0.2 to 1.8) using sol-gel auto-combustion method.
- Studying the structural properties depending on the XRD spectrum, AFM, FTIR and SEM for all ferrite powders calcined at deferent temperatures.
- Studying the dielectric properties (real part and tangent loss) as a function of frequency in the range 50 Hz – 5MHz for all samples with different Al-ion content in the Co-ferrites