Novel utilities of $ZnFe_2O_4$ nanoparticles with an assortment of modified techniques

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ABSTRACT : In this review paper, we put forth a thorough assessment of work that has already been experimented and thereafter published by various researchers on amalgamation among the zinc ferrite nanoparticles and their characterization with classic and modern synthetic pathway. The role of a variety of techniques for the formation of controlled, stable, biocompatible, and mono-dispersed nanoparticles and applications of these prepared nanoparticles in different fields has been studied. In addition, this paper also gives a summary of the advancement of the study with showing the contribution of green synthesis.

IndexTerms **- Nanoscience, Nanoparticles, Zinc ferrites, Biocompatible, Green synthesis.**

I. INTRODUCTION

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Attaining the opportunities to develop innovation in nano-systems and nano-structured materials, it's necessary to develop the novel materials, at nano-scale. There can be variations in the properties of materials at nano-scale and a larger one. There is a stepwise changes in the sizes, whenever the dimensions of a material reduces from larger size, initially the properties remains constant and thereafter, minor changes occur, until the size falls below 100 nm. This change is known as dramatic change in the properties of any material [1].

Advanced and routine developing technologies generally bring new challenges to the benefits of Science which increases the concern about health problems. There is a raising concern shown by the scientists to improve even environmental problems. Contemporary nano technology promises widespread applications of nano-particles using manifold ways of Science and Technology (S&T). Past decades has shown that nano technology has created a vast innovation of S&T. Nano technology is a combination of Science and Engineering both referring at nano-scale from 1-100nm. Metal oxides like nano-particles are inorganic. Various nano particles are accepted magnetic materials such as Fe, Ni, Co, Mn, Zn and many more. These are accepted magnetic materials so as to widespread varied range of applications such as various electronic ignition systems, vending machines, generators, recording equipment, magnetic sensors, medical implants, transformer circuits, magnetic fluids, wrist watches, telecommunications, inductor core and micro-wave absorbers etc. These are common sources of applications in different elevated-frequency [2].

Nano-particles have got implications as well as applications in a very elevated profile field of Medical Sciences where drug delivery, diagnosis and imaging can be done easily. As nano particles have got small size because of its elevated surface to volume ratio, it gives very distinctive features. Numbers of researches have taken place to prove that Zinc Oxide nano-particles contain antifungal and antibacterial property [1]. Whereas, nanoparticles named Silver also possess the same quality. We can observe many improvements in the field of nano-technology; it's all due to development of efficient methodology and different methodologies so as to engineer nano-particles of particular size and shape as per requirements. It is a serious need to develop the environmental compatible formation routes of nano-particles. This can be further processed by biological methods where toxic chemicals can be avoided. Plant leaf extract, bacterial cell extract, fungi and enzymes are environment friendly materials for the synthesis of Nano particles as they possess the quality of eco-friendly and compatibility with nature for a wide variety of medicines. As per research field of nanoparticles synthesis, the researchers have changed the custom towards biological system [3].

Ferrites in a Nano-crystalline nature found implications in new fields such as magnetic fluids, humidity and gas sensors, catalyst, magnetic resonance imaging (MRI) and magnetically guided drug delivery etc. [4],[5] Polycrystalline ferrites stay an ideal magnetic material that can't be replaced due to their significant involvement in technological advancements. According to the requirements of trending applications, modifications in the properties of such magnetic materials are being done so as to show the significance in the process of technological advancements.

Spinel ferrites are denoted by the chemical formula as MFe_2O_4 (where M is the divalent cations like Co, Ni, Zn, Cd etc.). Crystal constitution of spinel ferrite depends upon cubical closely packed ions and oxygen. Crystal structure of spinel ferrite consists of two interstitial sites i.e. for divalent ions tetrahedral site and for tetravalent ions octahedral site in which cations having various ionic radii and valence can be incorporated. The chemical composition of spinel ferrites is being given by $Me^{2+}Fe_2^{3+}O_4^{2-}$, where Me^{2+} represents a variety of divalent metallic ions, such as Zn^{2+}, Mn^{2+}, Cd^{2+} etc. It may be written as: $Me\ Fe_2O_3 = MeFe_2O_4$ In general, it is a solid solution of two such oxides [6].

The properties of a spinel material can be change to meet the needs of a particular application. Ferrites are generally synthesized by a chemical process. The particles obtained through this process are indifferent in size. As result, these indifferent

particles indicate various problems. Recently, studies have revealed that the $ZnFe_2O_4$ nanoparticles are the key for latest innovations in the technical fields. In the yestyears, the majority of materials examined were those having the magnetic behaviour because of their assuring applicability. Presently, various types of magnetic NPs are utilized for magnetic separation, drug delivery, hyperthermia treatment of tumours [7], as MRI-contrast [8], tunnelling magneto-resistance (TMR), gas sensors, magnetic data storage, ferrofluid, magnetic field assisted radionuclide therapy as well as magnetically separable absorbents. Right now the utilization of magnetic nano-particles for magnetic bioassays are most common, as their physical properties grant faster assay and in some cases, they enhance their sensitivity over currently available commercial methods [9]. Zinc ferrite nano-particles are most applicable in the field of biomedical applications and amongst materials with the magnetic properties because of their established biocompatibility [10].

II. STUDY OF $ZNFE_2O_4$ NANOPARTICLES PREPARED WITH DIFFERENT TECHNIQUES

The magnetization and electromagnetic properties of ferrites can be efficiently improved by the incorporation of Zn^{2+} [11]. Nowadays the research interest has been fascinated by different synthesis methods of zinc ferrite nanoparticles with functional applications. Structure, chemical composition, morphology and magnetization of nanoparticles can be controlled by several factors like nucleation growth, aggregation and adsorption of impurities during preparation. In recent years, diverse preparation procedures have emerged to compose controlled, stable, biocompatible, and mono-dispersed nanoparticles. Here are the corresponding formation mechanisms which briefly review the classic and modern synthetic pathway.

Co-precipitation method

Sato et al (1990) fabricated well-crystalline ultrafine $ZnFe_2O_4$ particles in nanometer sizes through co-precipitation method at different temperatures. The structural, morphological and magnetic analysis was done with the help of different techniques. In this study authors discussed the magnetization of prepared particles above and below 30K. [12]

Lopez et al (2012) fabricated cobalt zinc ferrite particles in an alkaline medium by using aqueous salt solutions ($COCl_2.6H_2O$, $FeCl_3.6H_2O$, and $ZnSO_4.7H_2O$) using co-precipitation method. In this work oleic acid was used as a surfactant. An average sized ferrofluids approximate 30nm can form colloidal solutions. EDX and XRD have been written off as the configuration of the sample. TEM technique confirmed the particle size around 10-50nm. In this study, it has been proved with the help of hysteresis loop that Hc value and size of particles are inversely proportional to the concentration of zinc as the formation of soft magnetic material. [13]

Ashok Aroraa and Yadavb Manju Panta (2013) researched the production technique of $ZnFe_2O_4$ by using co-precipitation method which is an economically efficient process. The production process used the rate of reaction and different temperature to alter the size of nanoparticles. This was all carried out by using the techniques X-ray spectrum, SEM, and TEM. The usual size of particle lied in the range of 10-14nm. [14]

Marija Milanovic et al (2016) fabricated $ZnFe_2O_4$ with the help of co-precipitation method and the changes in its surface is done with PDDA, TMAOH and PEG. This work studied the consequences of alteration technique on colloidal stability of researched nanoparticles. The alteration technique on colloidal stability of the prepared particles was examined using XRD, SEM and Raman spectroscopy. The particle size was also identified by Dynamic light scattering analysis. Thus, the experimental outcomes proved that the surfactants do not alter the constitution of the spinel nanoparticles but the morphological properties like agglomeration, size and their charge are noticeably changed. [15]

M. Augustin and T. Balu (2015) adapted co-precipitation route for the formation of Manganese ferrite and Zinc ferrite nanoparticles. The prepared particles were further treated with higher temperature up to 800^0C. Structural properties of particles were examined by XRD and morphological properties were examined by SEM analysis. Further absorption band and band gap energy were obtained by UV and FTIR. VSM studies confirmed the coercivity of particles up to 14.456 G and 50.495 G. [16]

Sol-gel Method

Chatterjee et al (1993) fabricated Ni-Zn Fe_2O_4 nanocrystals with the help of silica glass using sol-gel route. The dimensions of prepared crystals are 13-35 nm. It was observed that this dimension can be modified by changing the temperature from 973-1323 K. XRD patterns showed that the nanocrystals having spinel phase. Further Mossbauer analysis exhibited super paramagnetism in ultrafine particles. [17]

Azadmanjiri (2008) prepared nickel-zinc ferrites under sol-gel combustion route using citric acid. To ignite in air, gel is used in this method as it exhibited self-propogating behaviour. The researcher worked with this method and examined that how Zn influenced the electromagnetic properties of prepared nanoparticles. These values are inversely proportional to zinc concentration. Prepared sample demonstrated by EDX and XRD. The magnetic and electromagnetic properties of prepared sample were analysed by using VSM and impedance analyser. The average particle size was determined by XRD patterns between 73-80nm. It was claimed that the arranged nanoparticles could be used for several applications such as economical electronic materials with high performance because they have good electromagnetic properties and fine-grained micro constitutions as well. [18]

Cao et al (2009) researched over preparing magnesium and copper doped Lithium zinc ferrites via sol–gel and subsequent calcinations methods. Structural and crystalline properties of equipped particles written off as SEM, XRD and the results show that there is no difference between pure and doped sample. In this research, it was proved that microwave-absorbing attributes were enhanced by doping with copper, while doping with magnesium had little enhancement on microwave-absorbing properties of the sample. To boost low-frequency microwave absorption the doping amount of copper in already prepared sample was also examined. [19]

Farukh Iqbal et al (2016) prepared Zinc ferrite nanoparticles under Sol-Gel technique. The nanoparticles are targeted to be prepared as a low band gap semiconductor and under UV light driven photo catalyst which can be changed in to higher band gap

semiconductors. UV result confirmed the minimum wavelength of light under which the catalyst got activated. It was seen that the particles which were prepared under N_2 gas atmosphere showed higher absorption from 590nm wavelength while below this range they exhibited same absorption as the particles prepared under typical atmosphere. The weight loss analysis conducted by TGA which confirmed that the supreme weight loss obtained between 200°C-700°C. [20]

S.J. Yaghmour et al (2012) demonstrated the doping of zinc ferrite nanoparticles in acrylonitrile butadiene rubber composites with different ratio under Sol-Gel method. It was seen that the engrafting of prepared nanoparticles in rubber composites enhanced the features of the product. The increased saturation magnetization observed by magnetization measurements. The EPR spectra of synthesized particles confirmed that g-factor and line width has been increased. XRD and TEM results also supported the study and proved that the thermal stability, hardness, tear strength, and tensile stress of prepared nanocomposites are highly improved. [21]

Chemical and mechanochemical routes

Ted M. Clark and B.J. Evans (1997) studied over an improved magnetization of prepared Zinc Ferrite nanoparticles as compared to bulk. Chemical and mechanochemical routes were used to fabricate zinc ferrite nanoparticles. Magnetization technique was used to investigate the properties of nanoparticles and it was confirmed that the constitution of prepared nanoparticles is dissimilar than bulk materials. The results of conversion electron Mossbauer spectra exhibited that the cation distributions close to surface region of prepared fine crystals are similar to that of massive particles. [22]

Hydrothermal precipitation

Rath et al (1999) $Mn_{0.65}Zn_{0.35}Fe_2O_4$ nanoparticles via hydrothermal precipitation course using aqueous ammonia as a precipitant from a solution of metal chloride were prepared showing demonstration. TEM, VSM and XRD techniques were implemented to categorize them. Microscopic size of these nanoparticles was examined by XRD technique. TEM technique determines morphology and particle size. The dimension of prepared nanoparticles obtained was in the band of 9-12nm. VSM technique measured the magnetic measurements. In this work remnant, coerciveness and M_s Value enhanced by applied magnetic field of 5 Tesla. Through determining magnetization, the transition from ferromagnetic to paramagnetic state was observed. [23]

Yu et al (2003) researched using hydrothermal effect on the manufacturing of Zinc Ferrite nanoparticles, in this method they chose $FeCl_2$ and Zn sheet as reactants in NH_3 solutions at 180°C. Under this protocol nanoparticles were prepared 300nm in size with octahedral shape. By this, they found that the preparation of $ZnFe_2O_4$ nanoparticle is affected by concentration of ammonia solution, reaction time and the reaction temperature. It is also proven that for the synthesis of high quality zinc ferrite nanoparticle hydrothermal technique is a successful route. [24]

Nitrate method

Jitendra Pal Singh et al (2008) used Fe Mossbauer spectroscopy, VSM, TEM and XRD techniques to study the $ZnFe_2O_4$ particles which can be made in pure form from nitrate method with the alteration of sintering temperature from 300^0C-1000^0C. Particle size lies between the range 10-62nm and the Mossbauer hyperfine parameters remain unaltered. The spectrum of Mossbauer for all sintered samplings shows a single doublet which gives a possibility of superparamagnetic behaviour. Thus, the particle size can be stabilized by lowering the sintering temperature. [25]

Microbial method

Lucas W. Yeary (2011) used microbial method for the configuration of Zinc Ferrite nanoparticles by using enhanced magnetic properties. In this procedure ZnxFe1-xOOH precursor was incubated with Thermo-anaerobacter, metal reducing bacterium and strain TOR-39. The set nanoparticles were characterised by the help of numerous techniques like TEM, XRF, X-Ray diffraction, Neuron diffraction. After implementing XRD patterns, the mean crystalline sizes were found to be 67, 49, and 25 nm correspondingly. The crystalline sizes were found to be inversely proportional to Zn replacement while the unit cell volume and lattice parameter incremented slowly with the increase in formerly used literature ideals. To resolve the magnetic saturation of prepared nanoparticles, the superconducting quantum intrusion device magnetometer was used and further the data was checked for similarities with the values obtained in the previous literature. This research successfully concludes that Bacterial amalgamation produced Zinc Ferrite nanoparticles with improved magnetic properties. [26]

Thermal treatment method

Naseri et al (2011) studied over the preparation of nano sized particles of $ZnFe_2O_4$ using thermal treatment method. This method proved to be easy, economic and eco-friendly. By this method, pure, crystalline nanoparticles can be easily prepared. PVP i.e. Poly Vinyl Pyrrolidon stabilized nano particles which is famous and known as capping agent. It also calcined at different temperatures from 723 to 823 K. Prepared nanoparticles categorized by VSM, XRD, TEM and FT-IR. XRD and TEM techniques showed the size of nanoaprticle between 17-31nm. The nonappearance of organic bands and appearance of metal oxide bands show through FT-IR. The vibrating sample magnetometer confirmed that the calcined nanoparticles have exhibited excellent paramagnetic behaviour. It was proved that the preparation method plays an important role to change the values of Hc and Ms. [27]

Aljuraid et al (2012) Opted thermal treatment method for the fabrication of $ZnFe_2O_4$ particles under higher temperature. Prepared sample was characterized by XRD and Mossbauer technique. XRD confirmed the size between 12-48nm. This study substantiated that the annealing temperature and pH are very important factors to modify the characteristics of nanoparticles. [28]

Leng et al (2013) Used thermal treatment method using deionized water acting as a solvent to prepared particles of Ni-$ZnFe_2O_4$ in nano sizes. The XRD, TEM and VSM techniques were used to validate the formation, particle dimension and its magnetic properties of the prepared sample. With help of this study it is examined and studied that the size and magnetization

saturation are directly proportional to calcination temperature. The size and Ms value both increases by 7 to 25 nm and 11-26emu/g with the temperature from 723 to 873 K. This study also proved that thermal treatment method can be opt as a green route for nanoparticle preparation. [29]

Microwave combustion method

Kooti and Naghdi Sedeh (2012) adapted a microwave combustion method for the synthesis of three nanocrystalline ferrites which were incorporated with Mn-Zn-Fe_2O_4, $MnFe_2O_4$ and $ZnFe_2O_4$. Glycine is taken as a fuel to support sustainable combustion reaction at the time of synthesis of nanoparticles. The efficiency of particles was measured with the help of FESEM, TEM, VSM, BET and BJH. Authors substantiated that the adapted method is appropriate technique for the synthesis of small sized particles. [30]

Ceramic method

Eltabey et al (2014) elevated the magnetic qualities of Mn–Ni–Zn ferrites by the replacement of rare earth Nd^{3+} ion. This work came up with the composition dependent on the physical and magnetic properties by preparing $Mn_{0.5}Ni_{0.1}Zn_{0.4}Nd_xFe_{2x}O_4$ ferrite with the help of ceramic method. SEM and EDX technologies have given the confirmation of the average granule size that is not affected by substitution of Nd^{3+} ion. While its concentration inside the granule is quite lower than that on the grains boundaries. Saturation of magnetization augmented and reached a maximum limit with the Nd^{3+} ion concentration. [31]

Electrochemical method

Maria Rivero et al (2016) processed a combination of $Zn_xFe_{3-x}O_4$ nanoparticles by using electrochemical method which helped to alter the size and chemical composition of the particles with ease and regenerative manner by altering the magnitude of the applied current. These particles were treated with the XRD, TEM, ICP and Raman microscopy. The uniform mixture of Zn^{2+} was obtained in the form of crystals of sizes 9 to 18nm but the thermal application lead to movement of Zn ions into two separate stoichiometric Zinc ferrite and hematite. This study also confirms that the values of Ms and Hc are depending on size of the prepared sample. From the Raman analysis it is obtained that this process gives micro- regions whose magnetic properties depicted that these particles show hysteresis, saturation magnetization and the coercivity completely based on chemical composition and crystal size. [32]

III. ROLE OF GREEN SYNTHESIS FOR THE PREPARATION OF EFFICIENT $ZnFe_2O_4$ NANOPARTICLES

It is a serious need to develop the environmental compatible formation routes of nano-particles. This can be further processed by biological methods where toxic chemicals can be avoided. Plant leaf extract, bacterial cell extract, fungi and enzymes are environment friendly materials for the synthesis of Nano particles as they possess the quality of eco-friendly and compatibility with nature for a wide variety of medicines. As per research field of nanoparticles synthesis, the researchers have changed the custom towards biological system [3]. Notwithstanding, green route of zinc ferrite nanoparticles is still under research. During this study it was found that there is a very limited research performed on the preparation of $ZnFe_2O_4$ nanoparticles by using green resources. In this paper we have also include some papers of green synthesis which have been published in recent years.

Kumar et al. (2013) and Dora et al. (2014) researched nano sized Ni-Zn Ferrite and Mg-Zn Ferrite particles by adapting green route via updated sol-gel method. In this study, Aloe Vera plant extract was also used. The properties of prepared sample were characterized by several techniques like XRD, TEM, FTIR and VSM. In this research it was recognized that the Aloe Vera plant extract is not only economical and comprehensible, but it also serves high production with perfect configuration and particle size. [33], [34]

N. Namratha and Monica P.V. (2013) used neem extract for the fabrication of Silver Nanoparticles. $AgNO_3$ was reacted with *Azadirachta indica* leaf extract to develop a filtrate system for water purification. The prepared nanoparticles were categorized by different techniques to analyse the particles where UV and XRD techniques confirmed the crystalline constitution. SEM images showed that size and morphology of the particles based on several parameters during preparation like ratio of reactants, the pH of solution, temperature, mixing of precursors etc. It was determined that, to get spherical shape and size of around 50 nm the interaction time must be about 4 hours. XRD analysis also exhibited that $AgNO_3$ completely converted into silver nanoparticles with the help of neem extract as a stabilizer. In this protocol Polyurethane foams were used which were coated by prepared nanoparticles and kept in aqueous solution for overnight. After washing and drying they have got the stable Polyurethane foam with equal coating. They introduced Escherichia coli bacteria in inlet water and allowed to soak by Polyurethane foam around 10 minutes and then examined outlet water. It was obtained that the outlet water having minimum quantity of Escherichia coli bacteria. Further it was concluded that the water contamination with this bacteria is a very serious issue which can be sorted out with this green route. [35]

Palanisamy et al (2014-2015) researched over trending nanoparticles have been emerged as playing a vital role to inhibit the corrosion. There are some chemical substances which act as a corrosion inhibitor when applied on corrosive surface. The satisfactory inhibitors have many properties such as effortless production, low toxicity, low price and high inhibition efficiency. Some nanoparticles are not only exposing such properties, but they are also environmentally benign. Iron oxide nanoparticles showed high corrosion inhibition efficiency because they have superior stabilizing proficiency. Therefore, to obtain good corrosion protection, olive oils as natural stabilizing agents are taken with iron oxide nanoparticles and coated on mild steel after storage of six months at room temperature. In this work green synthesis mechanism was employed by adding olive oil as natural stabilizing agent. At the end the results indicated that the olive oil stabilized nanoparticles exhibited high inhibition proficiency with greater anticorrosion behaviour. [36]

IV. APPLICATIONS OF $ZnFe_2O_4$ NANOPARTICLES IN VARIOUS FIELDS

Drug delivery systems

Joseyphus et al (2004) studied over the ferrite nanoparticles with the facility of aqueous process for biomedical applications. This paper substantiated that due to high magnetization-temperature gradient and low Curie temperature manganese zinc ferrites can be utilised for different utilizations such as drug delivery systems, medical diagnostics with Ferro fluids. [37]

High frequency and multilayer chip inductor applications

Sattar et al (2005) studied the properties of nickel, magnesium and zinc ferrites with aluminium substitution. Due to his initiative permissibility and saturation magnetization, both the properties were improved by Al-ion substitution, porosity goes up while the lattice parameter goes down and they also claimed that for all substituted samples the DC resistivity and Curie temperatures increases. This research established that the equipped particles can be efficiently used in high frequency applications. [38]

Majid Niaz Akhtar et al (2009) demonstrated self-combustion technique for preparing $Ni_{0.8}Zn_{0.2}Fe_2O_4$ nanoparticles. These nanoparticles were further annealed at 750°C and 950°C. Prepared nanoparticles' characteristics were determined through Scanning Electron Microscopy, XRD and Raman spectroscopy. XRD spectrums confirmed the fabrication of single phase with good crystallinity. Diameter of the particle is also determined by XRD and SEM analysis between the ranges of 25-36 nm. Raman patterns confirmed the formation of spinel constitution of researched nanoparticles. It was revealed that at higher temperature, the grain size increased with cubical shape micro-constitution. The prepared nanoparticles are suitable candidates for high frequency and multilayer chip inductor applications. [39]

Energy conversion application

Arulmurugan et al (2005) Fabricated Co–Zn substituted $Co_{0.5}Zn_{0.5}Fe_2O_4$ micro particles where x varies from 0.1 to 0.5. Researchers used co-precipitation method with oleic acid as a surfactant. Various techniques were used to study the properties of prepared samples. Through TEM technique determined the size of nano particles prepared up to 50nm. As Zinc substitution increases magnetic parameters and particle size was found to decrease. In this study, it has been established that the prepared nanoparticles were used to form ferrofluid and these ferrofluids can be effectively utilize the magnetically induced convection for thermal dissipation resulting in the energy conversion application. [40]

Gas sensor applications

Rezlescu N. et al (2009) prepared $CuFe_2O_4$ and $ZnFe_2O_4$ with sol gel method. They observed the reacting behaviour of these ferrite particles against LPG, acetone and ethanol. They also confirmed the role of different parameters to control the properties of these prepared ferrite nanoparticles. In this work they substantiate that the prepared $CuFe_2O_4$ is the most sensitive to LPG and $ZnFe_2O_4$ is sensitive to ethanol. [41]

Srivastava and Yadav (2012) reported the alteration in sensitivity for a few sensing elements such as $CuFe_2O_4$, $CdFe_2O_4$, and $ZnFe_2O_4$ at various concentrations of gas with temperature. The ferrite sensors reliant on electrical resistivity exhibit wide applications with various properties. [42]

Magneto caloric pumping applications

Perales-Perez et al (2009) determined the research on preparation of pure and gadolinium doped $Mn_xZn_{1-x}Fe_2O_4$ by means of a customized co-precipitation approach. The categorization of equipped nanoparticles was carried out by a variety of methods by which it was confirmed that under most favourable conditions clean and gadolinium doped nanoparticles were enlarged from 11nm to 18nm. The prepared nanoparticles are suitable candidate materials for magneto caloric pumping applications. [43]

Highly active catalyst

Jang et al (2009a) studied on Zinc Ferrite with a spinel crystal constitution via solid-state reaction method. The prepared nanoparticles were sintered between 900-1200°C and the size were obtained at 51.9nm. Authors focused on photo catalytic properties of prepared particles under visible light (420nm). This study substantiated that as prepared nanoparticles are efficient phocatalyst under visible light for the decomposition of toxic gases. It is also proved that zinc ferrites are highly active photocatalyst as compared to recently reported $TiO_{2-x}N_x$. [44]

Papa et al (2010) fabricated zinc ferrites with and without neodymium substitution under combustion rout. Authors researched over catalytic properties of nanoparticles for oxidative coupling of methane. With the help of this experiment it was proved that for OCM response the wholly substituted Ferrite ($ZnNd_2O_4$) and the pure Ferrite ($ZnFe_2O_4$) were the most active catalysts. [45]

Mahmoodi et al (2013) worked on the concept that the zinc ferrite nanoparticles are most competent towards eradication of organic and inorganic pollutants in the water. It was examined that, the photocatalytic dye degradation and mineralization can be removed by zinc ferrite nanoparticle from wastewater. This can be used in the existence of hydrogen peroxide by using Reactive Red 120 and 198 as the model dyes. In which they analysed the dye degradation from the effects of $ZnFe_2O_4$ dosage, salt and initial dye concentration. The results stated that degraded dyes from coloured wastewater $ZnFe_2O_4$ could be efficiently used as a magnetic photocatalyst. [46]

Koleva et al (2013) researched on semiconductors, magnetic resonance, imaging, computer memory chips, and pigments are such effective applications offered by Ferrites due to their most efficient electrical, dielectric and magnetic behaviour. Alkylation of hydrocarbons, photo catalytic coronation of dyes, phenol hydroxylation (oxidation), and treatment of automobile-exhausted gases, decomposition of hydrogen peroxide, alcohols and hydrocarbon's oxidative dehydrogenation are some industrial methods

in which the catalytic description of Ferrites have been employed. The study of nanocrystalline zinc ferrites 6–45 nm sized with cubic constitution synthesised by co-precipitation technique proved the catalytic activity in methanol decomposition of CO and hydrogen. With this help it is established that ferrite materials exhibited optimum catalytic activity and selectivity to CO in the decomposition of methanol. [47]

Priya Parsoya and Suresh C. Ameta (2016) demonstrated the photo catalytic decomposition of toluidine blue dye which is the common effluent from the industrial and domestic sources, was treated under visible light in presence of $ZnFe_2O_4$, which involves superoxide anion radical as the active oxidizing chemical. Authors also studied the effect of all the parameters which were used during synthesis. [48]

Antenna construction and miniaturization process of several microwave components

Naidu et al (2011) equipped $ZnFe_2O_4$ nanoparticles via sol-gel method with Ni, and Sm. The dimension of samarium doped Zn-ferrite nanoparticles determined by SEM monographs. XRD technique has analyzed the constitution and composition of particles and the magnetic conduct of prepared particles confirmed by VSM study. It was researched by them that, if the ionic dimension is diminutive throughout the amalgamation it becomes consequently easier for the growth of particles and they in addition proved that as the samarium augmented the coercive power and Saturation magnetization also increased which caused nano size of the ferrite particles. This study established that the prepared particles can be effectively used in antenna construction and miniaturization process of several microwave components. [49]

Jacob et al (2012) decorated Ni–Zn ferrite with the doping of Terbium all the way through sol–gel technique. The categorization of equipped example by using XRD technology showed the formation of single phase FCC spinel constitution. It was demonstrated that the properties, constitution, size and AC conductivity of prepared sample influenced by the doping of Tb^{3+} [50].

T1 MRI contrast agents

Wan et al (2012) successfully worked on 6nm sized $ZnFe_2O_4$ particles through polyol process. For colloidal constancy researchers stabilized the nanoparticles by means of a layer of hydrophilic polyol and the Preliminary cytotoxicity tests incorrigibly said that the prepared particles are not toxic in nature. With the help of this exploration it was established that as novel T1 MRI contrast agents zinc ferrite nanoparticles can be efficiently replaced the conventional iron oxide particles and gadolinium chelates. [51]

Carlos Barcena et al (2008) researched mixed spinel hydrophobic zinc ferrite nanoparticles and showed its application in biomedical field. It was discovered that zinc ferrite nanoparticles can effectively reduce toxicity of Zn as compared to Mn-ferrites. Different characterization techniques were implemented to determine the various properties of nanoparticles. TEM analysis showed the uniform size of particles further alternating gradient magnetometer was involved to determine the Magnetization characteristics of the Zn- Super paramagnetic iron oxide nanoparticles. This Research proved that as the magnetization of Zn-Super paramagnetic iron oxide becomes higher it will increase the T2 relaxivity which enhanced the sensitivity of detection by MRI. [52]

Bashar Issa et al (2013) reviewed nano sized magnetic particles and stated that these nanoparticles can be utilized in biomedicine applications due to various properties. It was observed that the nanoparticles can be fabricated with different routes as well as alteration in their parameters like change in pH values and the ratio of precursors. In the arena of biomedicine exclusive study is being carried out to diagnose the various viruses and genes. In this work it is substantiated that the zinc ferrite can become desirable candidate in the field of biomedicines like MRI agents due their relevant magnetic properties adequate size distribution. [53]

Cytotoxicity on human prostate cancer cell lines

Gahrouei et al (2013) for the first time, the influence of cytotoxicity of Cobalt-Zinc Ferrite Magnetic Nanoparticles on human prostate cancer cell lines was worked upon. This study exhibited that the cytotoxicity of nanoparticles is highly being attracted for various biomedical applications. In this research DMSA coated Cobalt-Zinc Ferrite Magnetic Nanoparticles were prepared for better results. With the help of this research it is substantiated that at high concentrations DMSA coated Cobalt-Zinc Ferrite Magnetic nanoparticles exhibited some cytotoxicity on human prostate cancer cell lines. [54]

Adsorbents

Sanke Kuai et al (2013) prepared cerium-zinc ferrite nanoparticles with the help of solvothermal route. In this work researchers observed that as the concentration of cerium is inversely proportional to Ms Value. This study substantiated that the prepared nanoparticles are efficient candidates for Cr (VI) adsorption by showing the adsorption capacity up to 57mg/g. [55]

Biomedical applications

Raj Kumar et al (2014) researched over Mn-Zn Ferrite loses low power and shows high magnetic permeability. Thus, in this protocol $MnZnFe_2O_4$ nanoparticles prepared via Solution Combustion Method in the range of 10-40nm. These prepared particles can be efficiently used in various biomedical applications such as Drug Delivery Application, anti-bacterial, antifungal and conducting properties for electronic applications. [10]

Happy Agarwal et al (2017) reviewed that Zinc oxide nanoparticles can be used in biomedical applications because of its efficient properties which can be prepared by using green routes like plants, fungus, bacteria, and algae. The centre of attention of this study is the green routes for the preparation and characterisation of ZnO using different biological sources. With the help of this route nanoparticles can be used in various fields like food, cosmetic industries and pharmaceutical. [1]

Hyperthermia applications

K. Praveena and K. Sadhana (2015) reviewed an article on Zn substituted $Co_{1-x}Zn_xFe_2O_4$ and $Ni_{0.4}Zn_{0.2}Mn_{0.4}Fe_2O_4$ with the help of auto-combustion and microwave hydrothermal routes. The properties of nanoparticles determined by different tools like XRD, TEM, thermo-gravimetric differential thermal analysis and FTIR. The superparamagnetic behaviour of nanoparticle was assessed by the Zero field cooled and field cooled which exhibited poor bonding between magnetic particles. The particles size was obtained up to 17 nm by using TEM analysis. It was substantiated that as the temperature rises, the particles size also gets increased. High saturation magnetization and low coercivity were measured by hysteresis loops which also show the formation of soft ferrites. These prepared nanoparticles are highly desirable candidates for hyperthermia applications. [56]

Fumie Hirosawa et al (2017) prepared Gadolinium-substituted magnesium–zinc ferrite nanoparticles for magnetic hyperthermia applications with the help of co-precipitation method. In this protocol different metal compositions were taken where X is 0.25 to 0.75 and Y is 0 to 0.06. Due to this composition different SAR is obtained where the maximum SAR is found in case when x is 0.5 and y is 0.02 which confirmed that this composition can control the magnetic induction heating properties. Further, XRD pattern showed that the prepared particles have single-phase spinel constitution. Particle size was confirmed by SEM analysis where size was obtained between 50-200 nm. This work substantiated that by modifying metal composition, induction heating properties can be controlled which can be employed for heating mediators in magnetic hyperthermia treatments in near future. [57]

V. CONCLUSION

In this work we have studied the various methods for the preparation of zinc ferrite nanoparticles and their characterization with classic and modern synthetic pathway. The role of a variety of techniques for the formation of controlled, stable, biocompatible, and mono-dispersed nanoparticles and applications of these prepared nanoparticles in different fields has been studied. In addition, this paper also gives a summary of the advancement of the study with showing the contribution of green synthesis.

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