IJCPS Vol. 6, No.6, Nov-Dec 2017 ISSN:2319-6602
www.ijcps.org International Journal of Chemical and Physical Sciences

Exploration of Synthesis Techniques to Tailor Properties and Applications of Nano Iron Based Metal Oxides: A Review

SANDHYA S. BHARAMBE[1], PUSHPINDER BHATIA[2]

[1]Department of Humanities and Applied Sciences, S.I.E.S Graduate School of Technology,Navi-Mumbai,
[2]Department of physics, Guru Nanak College of Arts, Commerce and Sciences, Mumbai,India
Corresponding Author: Email: pushpindergb@gmail.com

Abstract

Literature about current research on synthesis, properties environmental and biomedical applications of nanoscale iron based material is reviewed and summarized in this article. The role of adsorbents and the desirable properties of various classes of adsorbents for use in environmental remediation are discussed. Nano-spinel ferrites which are stable and non-toxic in nature are found to be potential adsorbents for removal of contaminants from polluted water. Chemical routes are observed to be most preferred for synthesis of nanoparticles. The important use of nanoparticles in biomedical applications is also discussed.

Keywords: *Environmental and biomedical applications, Toxic metals, Heavy metals, Properties, Nanoparticle*

Introduction

Globalization, rapid developments in industrialization, urbanization have largely contributed to the severe pollution of water, air and soil. Among these, safe drinking water has become a major concern for practical utility. The most significant water problems include: (i) groundwater depletion, (ii) contamination of fresh water resources (rivers, lakes, wells and ponds), and (iii) a high demand for fresh water .Major industries are producing wastewater that contains harmful toxic metal ions. Heavy metal ions are among the major harmful contaminants in water and to counteract it, various chemical, physical and biological processes have been developed. Among these processes, adsorption is one of the most widely used processes for the removal of heavy metal ions and is considered to be easy to operate and cost-effective. Nanoparticles (NPs) as adsorbents for heavy metal ions are an emergent area of research. Nano-phase spinel ferrites are stable and non-toxic in nature. Their insolubility in water and high surface area can make them potential adsorbents for the removal of contaminants from polluted water [1].

Synthesis of novel adsorbents is of great interest in water treatment technology. Graphene is one of the promising materials with a two dimensional structure and having high surface to volume ratio. Functionalized graphene has been used in the past for the adsorption of lead and cadmium ions. Though graphene is a good adsorbent for removing the metal ions, the difficulty is the recovery of graphene adsorbent from water sample. The use of magnetic nanoparticles as adsorbate overcomes this problem[2].

In the local context, lead and mercury, the potentially obnoxious heavy metals, have increased manifold in water due to the idol immersion and other waste disposal. Thus lead and mercury are magnified in their concentration at different levels, including in fishes and birds inhabiting the lake, which finally reach the humans through food. Organic compounds of mercury, for example Methyl mercury, when it enters the human body destroys the brain cells, damaging the central nervous system, and also causes corrosion and ulceration of the digestive tracts [3].Excess of these elements causes skin diseases. An ideal adsorbent for commercial application should have following characteristics: (i) cost-efficient, (ii) rapid adsorption, (iii) high performance,(iv) environmentally non-toxic, (v) reusability, and (vi) ease of separation.

In recent years, spinel ferrites (SFs) have been the first choice for water treatment applications because not only are they nanometer-sized, but they also have super paramagnetic properties and a high surface to volume ratio[4].An understanding of the adsorption mechanism and, other parameters are necessary for the development of these particles as useful adsorbents. Our aim with this review is to recap relevant issues such as: (i) synthesis methods/features of spinel ferrites and their composites (ii) applications (iii) characteristics (iv) mechanism of adsorption, (v) magnetic recovery and utilization as an adsorbent, and (vi) the toxicity.

SYNTHESIS METHODS

Method 1

The methods of preparation are determining factors in producing different sizes and shapes of nanoscale particles.CFO nanoparticles were synthesized by hydrothermal method using ferric and cobalt nitrate as precursors and oleic acid as surfactant named as OA-CFO. For synthesizing citric acid coated CFO nanoparticles CA-CFO from the oleic acid coated CFO nanoparticles, ligand exchange method was used. It is found that these citric acid coated $CoFe_2O_4$ nanoparticles make a good colloidal solution in water in a wide range of pH. The average crystallite sizes for OA-CFO and CA-CFO nanoparticles are found as~5.9 nm and 5.4 nm respectively [5].

Method 2

Nickel-substituted cobalt ferrite nano-particles are reported to be synthesized using a self-combustion method. Aqueous metal nitrates ($Fe(NO_3)_3.9H_2O$, $Ni(NO_3)_2.6H_2O$ and $Co(NO_3)_3.6H_2O$) are taken in stoichiometric ratio, form the precursor material. Citric acid used as chelating agent added into it and fuel for self-combustion. For preparing the sample powders, aqueous ferric nitrate solution taken in a beaker is placed on a hot plate with magnetic stirrer. The solution temperature is maintained at 80^oC and stirred for about half an hour. Nickel nitrate solution, cobalt nitrate solution and citric acid solution are added one after the other, with a gap of half an hour to the ferric nitrate solution. The complex solution of metal nitrate and citric acid is stirred further for evaporation of water molecules and gelation of the solution. The viscous gel is transferred to a porcelain dish. The temperature of the dish is maintained at about 200^oC for half an hour in the open air. The gel starts combusting and the combustion continues for half an hour. After combustion a puffy solid remains. Before using for characterization, the puffy solid is grinded to powder and sintered at 600^oC for 2h with a heating rate of 10^o C per minute. Results showed that the particle sizes of the samples fall in a very small range from 38 nm to 50 nm.[6].

Method 3

$MgFe_2O_4$ (MFNPs) and nanocomposite (NC) MFNPs and NC were synthesized by the solgel method. Magnesium nitrate and ferric nitrate with molar ratio1:2 were dissolved in deionized water , then four moles of citric acid was added to the reaction mixture keeping oxidizer (O) fuel (F) ratio i.e. O/F=1. For synthesis of NC 100 mg of activated charcoal was added along with metal nitrates. The mixture was magnetically stirred at 60^oC and ammonium hydroxide was added into the mixture to adjust its pH to7.0 and the mixture transformed into so. After stirring for 8h, the sol turned into blackgel. It was dried at

100^{o}C for 8h. Finally, the dried gel was calcined at 500^{o}C for 3h to get the final thermolysis product. Result shows that the particles are spherical in shape and their average size is 25 nm[7].

Method 4

The obtaining of manganese ferrite as very fine nanoparticles, by thermal decomposition of the precursor formed between metal nitrates and polyvinyl alcohol (PVA). Thermal analysis has been used to characterize the precursor and the powders annealed at different temperatures, in order to evidence the evolution of the oxidic system with the annealing temperature. In a typical synthesis, the necessary amount of manganese nitrate is dissolved in a 4 % PVA aqueous solution, calculated for a molar ratio PVA (monomer) : NO3- = 1:1.The solution was kept under stirring for an hour, then was slowly heated up to 100^{o}C, and kept at this temperature until it became a gel. The temperature was finally increased up to 140^{o}C where the sample was kept for 8 h, in order to complete the redox reaction between PVA and metal nitrates. The obtained fine spherical particles have an average particle size of 15nm[8].

Method 5

Nanosize nickel-substituted cobalt ferrites were prepared using aerosol route. Aerosol method has the potential of producing multicomponent materials. The particle size of as obtained samples was found to be 10nm which increases upto 80nm on annealing at 1200^{o}C. The unit cell parameter ‘a’ decreases linearly with the nickel concentration due to smaller ionic radius of nickel. The saturation magnetization for all the samples after annealing at 1200^{o}C lies in the range 47.6–84.5 emu/g. Room temperature MÖssbauer spectra of as obtained samples exhibit a broad doublet, suggesting super paramagnetic nature of the sample. The broad doublet is further resolved into two doublets corresponding to the iron atoms residing at the surface and internal regions of the particle. The samples annealed at 1200^{o}C showed broad sextet, which is resolved into two sextets, corresponding to tetrahedrally and octahedrally coordinated Fe cations. Cation distribution calculated using XRD and MÖssbauer data indicates a decrease in Fe3+(oct.)/Fe3+(tet.) ratio with increasing nickel concentration . Each aerosol contains the precursor in the exact stoichiometry as desired in the product. Particle size, degree of agglomeration, chemical homogeneity can be controlled with relative ease. Furthermore, production of powder and film by this method is commercially favorable.[9].

Characterization

Sample (Nickel-substituted cobalt ferrite) was prepared by self-combustion method without altering the pH value of the precursor solution. The particle sizes of the samples fall in a very small range from 38 nm to 50 nm. The saturation magnetization values for pure cobalt and nickel ferrite samples determined from findings are 60.5 and 25 emu/g respectively .Electrical properties show that increase in nickel substitution is continuously reducing the dielectric properties. Pure nickel ferrite dielectric constant value is less than that of pure cobalt ferrite. The ferrites consist of grains, conducting because of hopping between 2þ and3þ valence states so f Fe ions, which are separated by non- conducting grain boundaries. The hopping charges get accumulated at the surface of the grain boundaries and this in turn leads to the polarization of the grains at their boundaries. At lower frequencies, for all the samples, the net polarization is a combination of electronic, ionic, dipolar and interfacial charge polarization. As the frequency of the applied field increases, the polarization because of the interfacial polarization lags behind and so we see as teep fall in the dielectric constant value with the applied frequency. At higher frequencies the polarization is mainly because of electronic and ionic contributions and so the dielectric constant value at tains almost a constant value at high frequencies. The substitution of nickel in cobalt ferrite initially increases the dielectric constant and then the dielectric constant value is decreasing with high ernickelconcentrations. As the Niconcentration increases further the structure comes closer to invers espineltype that in turn reduces the contribution of hopping and decreases the polarization[6].

Graphene magnetic hybrids were synthesized for removal of heavy metal ions from water using adsorption process. Among the magnetic nanoparticles, cobalt ferrite and nickel ferrite occupy an important place due to their physical properties such as high saturation magnetization and high coercivity cobalt and nickel ferrites with graphene (CoFe2O4–G and Ni Fe2O4–G) nanocomposites are synthesized by a simple solvothermal process and further tested for adsorption of heavy metal ions viz. Pb and Cd ions from aqueous water. The as-synthesized materials were having large surface area which was observed from the BET surface area analysis. Adsorption of Pb and Cd ions onto to the as-prepared materials GCF and GNF surfaces follows that the experimental data analysis were well fitted to the Langmuir isotherm model. Thermodynamic properties signify that the adsorption reaction was spontaneous and exothermic. The synthesized materials show good adsorption capability of heavy metal ions with an easy separation from aqueous water[2].

Cobalt substituted Ni-Cd ferrites have been prepared using solution combustion method. The dielectric constant and loss tangent are found to decrease with increase in frequency and Co substitution in Ni-Cd ferrites and it shows that dielectric dispersion at lower frequencies attains constant value at higher frequencies. The small polaron type of conduction was confirmed by the ac conductivity measurements. Saturation magnetization, retentivity, coercivity and magnetic moment are found to be increase with increase in cobalt content[10].

The powder obtained at 400 oC, which contains manganese ferrite as single crystalline phase was tested asa catalyst for the oxidative degradation of phenol. In case of the powder scalcined at 300oC and 400oC, fine spherical particles have been obtained, with diameters up to 15 nm, smaller in case of the powder obtained at 300oC. Due to the fine nature of the particles, the sintering starts even with 500 oC, where a porous mass is obtained. The sintering process is more advanced at 1000oC. The magnetic behavior of the obtained MnFePVA powder showed a significant decrease in saturation magnetization with the increase in annealing temperature above 400 oC, due to the decomposition of manganese ferrite into nonmagnetic phases. The powder obtained at 400oC exhibits super paramagnetic behavior [8].

Observations

SEM images shows that, the $CoFe_2O_4$ and $NiFe_2O_4$nanoparticleswere actually the aggregation of a great number of smaller nanoparticles with an average size of 10–15 nm and exhibits porous structure. $CoFe_2O_4$ and $NiFe_2O_4$spheres were decorated on flake like graphene nanosheets with an average diameter of150 nm. Hence it shows that the solvothermal route offered a homogeneous synthesis of the nanocomposites[2].

Typical SEM images of Co, Ni and Co–Ni mixed oxides heat treated at 650^oC where observed. It can be seen from the image that Co oxide particles are not well-distributed and more than 80% particles have the size in nanometer range. Although the average size of the particles of Ni oxide is similar to that of Co oxide, the surface of the Ni oxide particle seems to be rough as compared to those of Co and Ni–Co mixed oxides. On the other hand, the Co–Ni mixed oxide particles are spheroidal. Further it can also be seen from the SEM result that in addition to the larger particles (5–50 mm), the surface contains smaller particles as small as1 mm or less. It is, indeed, interesting to obtain smaller size, particularly nano-sized, mixed oxide particles by preventing aggregation. This might be possible by using some capping agent, e.g., poly(vinyl acetate) during the synthesis of the mixed oxide[11].

XRD analysis evidenced the presence of $MnFe_2O_4$ as single crystalline phase in the powder calcined at 400°C. The magnetic powder obtained at 400°C showed good catalytic activity for the oxidative degradation of phenol in aqueous solutions, in the presence of peroxydisulfate anion as oxidant, so it might be considered promising nanomaterialfor environmental applications [8].

The surface morphology of $MgFe_2O_4$ nanoparticles shows the presence of nanoparticles in the form of clusters, which indicates the basic nature of pristine magnetic nanoparticles to coagulate in the absence of any surfactant coating or functionalization. The SEM image of NC shows separation of NPs due to presence of flaky structure of amorphous carbon which inhibits the clustering of NPs by reducing the irbinding with one another and thus increases the available surface area of NPs, which further enhances the iradsorption capacity[7].

The total chromium removal and adsorption capacities of manganese ferrite ($MnFe_2O_4$) naonoparticles were calculated by means of Eqs. (1) and (2), respectively.

$$\text{Removal efficiency} = \left(\frac{Co - Ce}{Co}\right) \times 100$$

$$q = \frac{Co - Cv}{m} \times V$$

where C_0 represents the initial concentration of metal in the wastewater (mg/L); C_e is metal concentrations in the solution after the experiment (mg/L); q is the equilibrium adsorption capacity (mg/g); V is the sample volume (L) and m is the amount of $MnFe_2O_4$ NPs used (g)[12].

Properties

The magnetic properties of the nanoparticles can be tuned by controlling its size, composition, shape and strain/defects. By carefully reducing its size below to artifical diameter, the magnetic nanoparticles can be turned to super paramagnetic nanoparticles. Iron oxide magnetic nanoparticles such as Fe_3O_4 and $\gamma-$ Fe_2O_3 have been widely explored for biomedical applications. The saturation magnetization and hysteresis losses of these iron oxide nanoparticles are small compared to pure metals(Co, Fe, or CoFe etc.),but the metallic nanoparticles are highly toxic and very sensitive to oxidation and hence are not useful for biomedical applications. Another alternative can be spinel ferrites such as

M Fe_2O_4 (M $\cong$ Co, Mn,Ni) [9–11].

Among these ferrites, Co Fe_2O_4 is interesting due to its large curie temperature, high effective anisotropy and moderate saturation magnetization [5].

The physical characteristics of the adsorbents, such as, surface area, porosity, size distribution, density and surface charge have high influence in the adsorption process. As a result, there has been a great interest in developing new adsorbent materials with diverse compositions, properties and functionalities. Mixed metal oxides, i.e., oxides of more than one metal system, are of particular interest because the opportunity exists for generating materials intermixed at atomic level. Such systems have the potential for exhibiting chemical properties that differ notably from those of the corresponding single component oxides Transition metal oxides, viz., Co and Ni oxides are known to be important for the current technologies[11].

Table 1: Comparisons of various physicochemical processes used for the removal of heavy metals from wastewater [13]

Physical and/or chemical methods	Advantages	Disadvantages
Chemical precipitation	Low capital cost, simple operation	Sludge generation, extra operational cost for sludge disposal
Membrane filtration	Small space requirement, low pressure, high separation selectivity	High operational cost due to membrane Fouling
Adsorption	Low-cost, easy operating conditions, having wide pH range, high metal binding capacities	Low selectivity, production of waste Products
Electro dialysis	High separation selectivity	High operational cost due to membrane fouling and energy consumption
Photo catalysis	Removal of metals and organic pollutant simultaneously, less harmful by-products	Long duration time, limited applications

As shown in Table 2 the absorption capacity values obtained are larger or comparable to other adsorbents reported in the literature

Table 2: Adsorption capacities of different adsorbents for chromium[12]

Adsorbents	Cr(VI)	Cr(III)	Total Cr
Plum tree bark	100–105 mg/g	_	74.4 mg/g
α-Fe_2O_3 nanofibers	16.7 mg/g	_	_
Magnetic natural zeolite–polypyrrole (MZ-PPy) composite	434.78 mg/g	_	_
Schinus molle bark	97.56 mg /g	_	73.18 mg / g
Magnetite nanospheres with hollow interiors	9 mg/g	_	_
Agroforestry wastes (fern (FE), rice husk (RI), and oak leaves)	19.25 mg/g	_	_
Core–shell polyaniline/polystyrene nanocomposite	19 mg/g	_	_
Coconut shell activated carbon	1.99 mg/g	_	_
Activated carbon was prepared from longan seed	35.02 mg/g	_	_
A highly mesoporous melamine–formaldehyde resin (MMF	66.65 mg/g	_	_
Sunflower stem carbon−calcium alginate beads (SSC-CAB) (adown flow fixed bed column)	53.4 mg/g	_	_
Nanoparticles of $MnFe_2O_4$			89.18 mg/g

Applications

Due to the rapid development of industries and increased pesticide consumption for agricultural yield, heavy metals are directly or indirectly getting accumulated in soil and are ultimately discharged into the environment through waste water. Adsorption techniques for wastewater treatment have become more popular in recent years owing to their efficiency in the removal of pollutants too stable for biological methods. Adsorption can produce high quality water while also being a process that is economically feasible [14]. Adsorption of dyes on various adsorbent matrices has previously been extensively investigated; these include—activated carbon, peanut hull, rice husk, zeolites, clay, silicates, water hyacinth, guava seeds, perlite, algae and soon.

Hydroxyapatite (HAp) [$Ca_{10}(PO_4)_6(OH)_2$] nano-ceramic material, is used for removal of lead (Pb) particles. Such Pb impurities cause various unwanted effects such as brain damage and diminished learning abilities in children. HAp material, treated with Pb containing water. X-ray diffraction studies of the HAp sample mixed with Pb containing water solutions showed the presence of Pb incorporated in HAp matrix as evidenced by its standard peaks and other additional peaks due to mixed phase of Pb and HAp. Atomic Force Microscopy is used to visualize surface of HAp in the nano scale which exhibited high porosity and nano grain size, providing increased "Area to Volume" ratio facilitating in larger adsorption of Pb particles and efficient exchange with calcium present in HAp. It is concluded that impurities like Pb metal can be removed by means of ion exchange process with HAp matrix. This work provides inexpensive solutions to remove Pb from contaminated soil and rejuvenate the soil for better crop yield.[15].

Magnetic cobalt and nickel ferrites (Co Fe_2O_4& Ni Fe_2O_4) with graphene nanocomposites ($CoFe_2O_4$–G &Ni Fe_2O_4–G) are reported to be used as an adsorbent for the removal of lead (Pb(II)) and cadmium (Cd(II)) ions from aqueous solution. To probe the nature of the adsorbent, various experiments were investigated like contact time, adsorbent dose, solution pH and temperature were optimized. Excellent magnetic performance is necessary for a material to be a good magnetic adsorbent. Field dependent magnetization of the synthesized composite was measured at 27°C at an applied field of $-10\,000 \leq H \leq 10\,000$ Oe. The magnetic hysteresis loop of the GCF and GNF in the presence and absence of graphene, indicates their super paramagnetic nature. A saturation magnetization of 32.79 and49.55 emu $g^{-1}$was observed for $CoFe_2O_4$–G (GCF) and bare $CoFe_2O_4$respectively and for $NiFe_2O_4$–G (GNF) and bare $NiFe_2O_4$ was observed as 24.28 and 36.10 emu g^{-1} respectively. As compared to bare $CoFe_2O_4$ and $NiFe_2O_4$, the saturation magnetization decreases due to the contribution of grapheme layers[16].

In recent years magnetic nanoparticles have been extensively explored for their potentiality in many biomedical applications such as for targeted drug delivery[17] as contrast enhancement agents in magnetic resonance imaging(MRI)[18], and in hyperthermia treatments as heat mediator[19]. The main advantage of magnetic nanoparticles for biomedical applications is its larger surface area for easy ligand attachment, better tissue diffusion and reduced dipole–dipole interaction. For biomedical applications the magnetic nanoparticles should be of small sizes with narrow size distribution. These nano- particles should be coated with some organic or inorganic material which ensure their biocompatibility, nontoxicity and colloidal stability in biophase

Biomedical applications

CoFe2O4 & NiFe2O4 magnetic nanoparticles for various biomedical applications: cell viability and cell death evaluations

Recently, spinel ferrites like $CoFe_2O_4$ and $NiFe_2O_4$ nanoparticles with different coatings have been widely investigated, due to their desirable magnetic properties in biomedicine and bioengineering fields. Also, these materials should have low toxicity and high biocompatibility. Toxicity of nanoparticles on the human health is one main limiting feature for successful application.

Analysis of cytotoxicity was carried out by examining their effect on cell viability of human peripheral blood lymphocytesso as to assess biocompatibility for various biomedical applications. This work describes the successful preparation of amine functionalized Co Fe_2O_4 and Ni Fe_2O_4superparamagnetic MNPs with high aqueous stability. The size of MNPs varies from 8-10 nm. Owing to their high saturation magnetization and superparamagnetism at room temperature and with high surface area can be used as promising materials in drug delivery. Cytotoxicity evaluations of $CoFe_2O_4$and $NiFe_2O_4$MNPs were investigated using human lymphocytes. The results showed that $CoFe_2O_4$ MNPs at 0.1 mg/ml were not cytotoxic, and did not cause cell death, indicating that these nanoparticles can be safely used as drug delivery vehicles and at increasing concentration of$CoFe_2O_4$ it induces slightly cytotoxic effect but found to be less toxic than Ni Fe_2O_4 MNPs. On the other hand $NiFe_2O_4$ as increasing concentration were found to cause high toxic effect on cells and increase cell death. In this regard, $NiFe_2O_4$ MNPs might be considered promising in treatment of tumors cells and call for further detailed studies.[20]

The successful preparation of aminefunctionalized$CoFe_2O_4$, $NiFe_2O_4$, and $MnFe_2O_4$superparamagnetic describes NPs with high aqueous stability. The size of the MNPs varies from 8 to 10 nmand hydrodynamic size is in the range of 55–75 nm. Owing to their high saturation magnetization and superparamagnetism at room temperature, spherical structure, and high surface area, they can be used as promising materials in drug delivery. In vivo effect of the NPs on angiogenesis in CAM assay was investigated for $CoFe_2O_4$, $NiFe_2O_4$, and $MnFe_2O_4$NPs. These NPs can enhance angiogenesis activities in the CAM model. The results showed that $CoFe_2O_4$MNPsat 0.1 mg/ml showed the highest increase in hemoglobincontent and the optimum angiogenesis effect. Co Fe_2O_4 MNPs at 1 mg/ml are more significant than the positive control VEGF (Vascular endothelial growth factor).Ni Fe_2O_4 NPs show increased hemoglobin content at different concentrations and Mn Fe_2O_4 NPs shows angiogenesis for all the concentrations, though there is as lightly decreased hemoglobin level in terms of score of blood vessels. However, an increase in angiogenesis activity is observed as the concentration increases. The stimulation of angiogenesis and variations in the activity can beattributed to the metallic composition of the NPs. All of these nanoparticles are shown to stimulate the angiogenesis activity in CAM significantly more than the control (saline)[21]

Conclusion

Review has shown that the Co–Ni mixed oxide can be a promising surface material to remove organic dyes from water over a wide range of dye concentrations. Spheroidal particles of Co–Ni mixed oxide and surface behaves as a charged adsorbent in the acidic and alkaline media. The anionic dye PR can be adsorbed onto the oxide surface to a much greater extent than that of MB(methylene blue) suggesting that the Co–Ni mixed oxide could be an effective adsorbent for the PR removal by adsorption. The adsorption most likely occurs via electrostatic interaction between the ionic dyes and the charged Co–Ni mixed oxide surface.

Calcium Hydroxyapatite (HAp) has been found to beneficial for removal of heavy metal such as Pb from an aqueous solution by means of ion exchange process. HAp can be used for purification and rejuvenation of Pb containing soil.

It was observed that self-combustion is less polluting as it produces lesser amount of pollutant gases during synthesis. It shows that the magnetic and electrical properties can be tuned by varying the nickel concentration.

Nickel substitution into the cobalt ferrite allow us to tune the magnetic and electrical properties of the ferrite material from the hard magnetic and lower resistivity cobalt ferrite to soft magnetic and high resistivity nickel ferrites. Result shows the formation of single-phase crystalline structure without any trace of impurity. Lattice constant is decreased due to the difference in ionic radii of Ni2+ and Co2+ ions.

Increase in coleads to shows increase in ac conductivity with increase in frequency, which is the normal behavior of ferrites. The conduction in ferrites mainly due to exchange of electrons between Fe3+ and Fe2+ ions. The increase in frequency of the applied field increases the hopping of charge carriers resulting in increase of conductivity and decrease of resistivity.

It is also observed that ac conductivity decreases with increase in cobalt content in Ni-Cd ferrite. The ac conductivity is proportional to dielectric constant and dielectric loss of the material. The decrease in dielectric constant and loss tangent is responsible for decrease in ac conductivity with increase in cobalt content in Ni-Cd ferrite.

Manganese NPs would be a potential candidate as a high efficient and inexpensive adsorbent for the total chromium removal from real industrial wastewater.

Though graphene is a good adsorbent for removing the metal ions, recovery of graphene adsorbent from water sample is a main drawback. To overcome this issue, magnetic nanoparticles as adsorbate are used, signify that the adsorption reaction was spontaneous and exothermic. Excellent magnetic performance is necessary for a material to be a good magnetic adsorbent As compared to bare CoFe2O4 and NiFe2O4, the saturation magnetization decreases due to the contribution of grapheme layers.

The OA-CFO nanoparticles are not dispersible in water so this nanoparticle cannot be used in biomedical applications but the CA-CFO magnetic nanoparticles are suitable. These CA-CFO nanoparticles exhibit very small coercivity, moderate saturation magnetization and a high degree of dispersibility in water.

Iron oxide magnetic nanoparticles such as Fe3O4 and γ− Fe2O3 have been widely explored for biomedical applications. The saturation magnetization and hysteresis losses of these iron oxide nanoparticles are small compared to pure metals(Co, Fe, or CoFe etc.),but the metallic nanoparticles are highly toxic and very sensitive to oxidation and hence are not useful for biomedical application.

The sorption capacity of NC (Nanocoposite) for Cr (VI) is higher than all other adsorbents. It combines the adsorption features of activated charcoal with the adsorptive and magnetic properties of MFNPs. Eco-friendly methods should be preferred.

REFERENCES

[1]. A.Khaleel, et al.P.N.Kapoor, K.J.Klabunde, Nanocrystalline metal oxides as new adsorbent for air purification, Nanostruct. Mater.1999,11,459–468.
[2]. Chella Santhosh, Pratap Kollu, Sathiyanathan Felix, Venugopal Velmurugan,
[3]. Soon Kwan Jeong and Andrews Nirmala Grace, RSC Adv., 2015, 5, 28965
[4]. A Bajpaiz, A.Vyas, N.Verma and D.D.Mishra,Poll Res. 2008,27(3),517-522

[5]. D. Harikishore Kumar Reddy Yeoung-Sang Yun,Coordination Chemistry ReviewsS0010-8545(15)30053-9

[6]. Sandeep Munjal Neeraj,Khare Chetan Nehate , VeenaKoul J. Magn. Magn.Mater.,2016,404,166–169

[7]. Uday Bhasker Sontu, Vijayakumar Yelasani, Venkata Ramana Reddy Musugu J. Magn. Magn. Mater., 2015,374,376–380

[8]. Manpreet Kaur, Navneet Kaur, Kiran Jeet, Pervinder Kaur ,Ceramics Internal, 2015.08.040 0272-8842

[9]. Marcela Stoia ,Cornelia Muntean ,Bogdan Militaru ,J Therm Anal Calorim DOI 10.1007/s10973-015-4510-7

[10]. T4 Sonal Singhala, J. Singha, S.K Barthwalb, K. Chandraa, Journal of Solid State Chemistry ,2005,178,3183–3189

[11]. N. D. Patil, N. B. Velhal, N. L. Tarwar, Vijaya R. Puri , International Journal of Engineering and Innovative Technology, 2014,3,8 ISSN: 2277-3754

[12]. Al-Nakib Chowdhury , Abdur Rahim , Yusuf Jamal Ferdosi ,Md. Shafiul Azam, M. Mufazzal Hossain,Applied Surface Science2010, 256,3718–3724

[13]. Naim Sezgin, Arzu Yalçın & Yüksel Köseoğlu , Desalination and Water Treatment, 2015,DOI: 10.1080/19443994.2015.1088808

[14]. M.A. Barakat,, Arab. J. Chem.2010, 4, 361–377.

[15]. K.K.H. Choy, G. McKay, J.F. Porter, Resour. Conserv. Rec. 1999,27, 57.

[16]. Vijaykiran N. Narwade, Megha P. Mahabole, Kashinath A. Bogle and Rajendra S. Khairnar, International Journal of Engineering Science and Innovative Technology (IJESIT),2014,Volume 3, Issue 3.

[17]. H. Deng, X. L. Li, Q. Peng, X. Wang, J. P. Chen and Y. D. Li, Angew. Chem., Int. Ed., 2005, 44, 2782–2785.

[18]. M. Arruebo, R. Fernández-pacheco, M.R. Ibarra, J. Santamaría, Nano Today 2007,2, 22.

[19]. Y.M. Wang, X. Cao, G.H. Liu, R.Y. Hong, Y.M. Chen, X.F. Chen, H.Z. Li, B. Xu, D. G. Wei, J. Magn. Magn. Mater. 2011,323, 2953.

[20]. M.E.F. Brollo, J.M. Orozco-Henao, R. López-Ruiz, D. Muraca, C.S.B. Dias, K. R. Pirota, M. Knobel, J. Magn. Magn. Mater.2016 397, 20.

[21]. Nooris Momin, Aparna Deshmukh,b, Radha S.,Journal of Nano Research Vol.2015, 34 , pp 1-8

[22]. Momin Nooris· Deshmukh Aparna · S. Radha, Eur Biophys J. 10.1007/s00249-015-1083-0