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REVIEW ARTICLE

A Review on Synthesis Methods, Potential of Magnetic Nanoferrites as Photo catalyst in Purification of Contaminated Water

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ABSTRACT

Researchers are very interested in synthesis and characterization of the magnetic ferrite nanoparticles due to their wide range of applications in many fields. In last few decades ferrites have received immense attraction due to their unique catalytic, structural, magnetic and high adsorption capacities. As a result some recently published studies on ferrite nanoparticles are worth considering. This study is focused on different synthesis methods and application of nanoferrites in the removal of dyes and toxic pollutants from the waste water. In this review synthesis methods of ferrites and their application in water treatment have been discussed in detail. The latest development in terms of ferrite utility in purification of contaminated water has been discussed in detailed.

Keywords: *Ferrites, magnetic nanoparticles, nanocomposite, adsorption*

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INTRODUCTION

Material science is a broad field of research that involves the study of various scientific disciplines such as chemistry, engineering, physics, biology etc. Due to increasing number of applications of material science the goal of material scientists has been broadened. The synthesis of new material and its applications has become the main focus of the material scientists. The field of material synthesis has also gained interest due to the potential of materials size to affect its properties [1,2,3].

Nanotechnology is the study of the properties of nanoparticles and their nanostructures. It mainly concerned with the size of materials and synthesis of materials with a diameter of 100 nm or less. Ferrites are the chemical compounds that can be obtained as powders or as ceramics. They have ferromagnetic properties and are mainly composed of iron oxides [4,5]. It consist of iron in the form of iron oxide which has various phases such as magnetite, hematite, iron oxide beta phase and maghemite [6,7,8,9,10]. Due to numerous properties of ferrites such as electrical, structural, magnetic and surface reactivity they have been widely studied in the past decade[10,11,12,13].Through different routes, nano crystalline ferrites can be synthesized to obtain materials with properties that are desired. Thus synthesis of nano crystalline ferrite has become an essential component of research and development in the field of materials. Researchers are involved in the development of new synthetic strategies for the production of ferrite nanoparticles. The quest for effective synthesis of ferrite materials with high purity, high homogeneity and tunable electrical properties has led to development of several preparatory methods.

Ferrites magnetic nanoparticles are versatile and can be used in various industries such as high density storage, magnetic drug delivery, MRI enhancement, catalysts and gas sensors [14,15,16,17,18].Ferrite

magnetic nanoparticles are eco-friendly and are used as catalyst for different organic reactions[19]. They have high performance due to their high surface area and are recyclable [20].This review aims to provide an overview of technology of ferrites. It highlights the various synthetic routes that are used to make ferrites and it also discusses the applications of ferrites in water treatment.

SYNTHESIS METHODS OF FERRITE NANOPARTICLES:

The properties of ferrites like optical, structural, magnetic, electrical etc. are dependent on the various factors such as preparative methods, sintering temperature, sintering rate duration and sintering environment [21,22]. The prime goal of researchers is to improve the properties of ferrite nanoparticles by producing desired structure and stoichiometry. The complexity of this process requires the use of various strategies and techniques. The physico-chemical properties of ferrite materials are strongly influenced by their crystal structure. The various micro structural properties such as grain size, porosity and phase purity are affected by the preparation methods and synthetic conditions when it comes to ferrite materials [23].

Top-down or bottom-up approach are usually used to synthesize nanoparticles. In the former a bulk material is broken up to get nanoparticles. This method mainly involves the use of high temperature to achieve the reaction. Also it has many limitations such as high temperature requirement, inhomogeneous composition, surface imperfection and presence of impurities [24].In the bottom-up approach atomic building blocks are arranged in a way that enables them to be assembled to produce nanoparticles25. This method is very efficient for the production of nanoparticles. Basically ferrite synthesis methods fall in to two main categories namely solid state methods and wet chemical methods.

Solid state method:

Solid state method is widely used for the preparation of mixed metal oxides and other solid materials. High temperature is the crucial parameter for the formation of the desired product. The process begins by mixing various pure constituent oxides/carbonates in stoichiometric manner followed by grinding of mixture. It is then subjected to pre-sintering at suitable temperature for few hours. After pre-sintering, powder is pressed in to pellet followed by final sintering at high temperature [26,27,28,29].

Advantages: Require less solvent**,** Furnish high yield of products**,** Cheaper and convenient technique

Drawbacks: a) Monitoring the reaction progress is difficult task .b) Effect of high temperature on surface area and crystal growth.

Wet chemical Methods:

Wet chemical methods are widely used since they provide reproducible results and are cost effective. Also it gives better homogeneity for small grains and low porosity.

Co-precipitation Method:

The co-precipitation method is well known process utilized for the preparation of various ferrites. This process involves the precipitation of a desired product from an aqueous solution containing various metal ions. In this method the precipitation is initiated by the reaction of metal ions with the precipitating agents like alkaline solution of hydroxides, oxalates, ammonia etc. The precipitate is then heated to required temperature to get a final product [30,31].

Advantages:

The method is useful for the preparation of metal oxide powders. It has good control over size and homogeneity.

Drawbacks:

The gelatinous precipitate formation may cause the product to have poor magnetic properties.

Micro-emulsion method:

This process involves the formation of nano particles by introducing two components, which are oil and water soluble. The resulting medium is known as emulsion. A surfactant is added to the emulsion to make it easier to perform the reaction on small scale. This helps in controlling the size of water droplets. Droplets are known as reverse micelles, which on combination with other reactants forms nano ferrite particles [32,33].

Advantages: Method is eco friendly due to use of less toxic salt

Drawbacks:

Higher annealing time, high production cost and requirement of large quantity of liquids are the major drawbacks of the process.

Hydrothermal Method:

This process involves crystallization of materials at elevated temperature and pressure in presence of aqueous solution. Hence it is known as hydrothermal process. The crystal growth of compound is achieved in a closed container (autoclave) under pressure with water as a solvent. The role of solvent is to act as transmitting medium of pressure both in vapor and liquid state [34,35].

Advantages: Does not require sophisticated processing, economical

Drawback:

Reaction proceeds at slow rate hence to increase rate of reaction electric field, microwaves or ultrasonic waves are required for heating.

Sol-gel Method:

In this method mostly the precursors were taken as metal nitrates due to their solubility in water. Generally citric acid is used as chelating agent which helps in the homogeneous distribution of metal ions. The precursors and chelating agents were taken in to suitable molar proportion. Initially, the nitrates were dissolved in distilled water followed by the addition of chelating agent. The solution is then stirred to get clear liquid. The PH of the solution is then adjusted at alkaline range by adding ammonia. The entire solution is then placed on the magnetic stirrer with hotplate to evaporate it until the gel is formed. The gel then undergoes combustion to create solid powder which is then annealed in a furnace at different temperature. The various synthetic conditions such as annealing temperature, PH and solution composition play a major role in determining the particle size [36,37,38].

Advantages:

1) Economical method 2) high purity of products 3) needs low operational temperature 4) Provides good control over morphology and size of particles

Applications of nano ferrites in water and waste water treatment:

Ferrite as a photo catalyst:

Due to the rapid industrialization and increasing population, the quality of life has become severely affected39. The improper processing of organic dye products has led to acute contamination of water and land. Various industries such as plastics, cosmetics and leather are known to produce harmful pollutants like organic dyes, hydrocarbons, gasoline that have deadly effects on human and the environment [40].

Different techniques such as ion-exchange [41,42], coagulation [43,44], precipitation [45,46], osmosis [47,48], adsorption [49,50], ozonation [51,52] are utilized to remove or minimize the pollutants from the water. In most cases, the above mentioned waste water treatment processes are not enough to remove or minimize the harmful pollutants from the environment. Usually, the use of advanced oxidation techniques (AOP) is the most effective way to accomplish this53.Advanced oxidation processes are used to treat industrial waste water. One of these is photo catalysis, these methods involves generation of hydroxyl radicals (.OH) which is one of the strong oxidizing agent54.Spinel ferrite nano composites are very stable and can be regenerated and reused without losing their properties. This makes them an ideal choice for water and waste water treatment [55,56].

In photo catalysis a reaction is initiated by the presence of photo catalyst. The band gap of the material plays crucial role in selection of photo catalyst since it decides the wavelength of light that can be absorbed. In this context ferrites are being widely studied for their chemical composition and their potential as photo catalyst. Their stability, low band gap, non-toxicity, magnetism and ease of synthesis make them suitable for photo catalysts [57,58,59].Researchers are currently working on new compounds that can be used for making visible light based photo catalysts. There are two ways in which photo catalyst can be made visible light active. One involves doping a UV active photo catalyst with various elements that can make them visible light active60. Dopant reduces the band gap in ferrites and enables them to absorb visible light [61]. The second method is the design of material with a narrow band gap, which allows photo catalyst under visible light [62].

Factors affecting photo catalytic reactions:

There are various parameters which can affect on the performance of the photo catalyst or the photo catalytic process. These factors have either positive or negative impact on the performance of the process. In detailed information about these parameters is given below.

a) Effect of doping:

When ferrite material is doped with various metal ions it will result in decrease of band gap for the doped material as compared to their bulk counterpart. Thus dopant will assist the photo catalyst to absorb in visible region63,64.

b) Catalyst loading:

An increase in the concentration of catalyst helps in the photo catalytic degradation process. However the performance of the photo catalyst can be affected when the loadings were beyond the optimum limit [65,66].

c) Irradiation time:

The photo catalytic reaction rate decreases with time as it progresses via pseudo first order kinetics [67,68].

d) PH effect:

PH affects the pollutants elimination and degradation. It can also have impact on the sorption capacity and electric charge distribution of the nano composite materials [69,70].

e) Effect of dye concentration:

The concentration of dye sorbed on the catalyst surface affects the hydroxyl radical formation. As a result up to optimum concentration degradation increases but further increase leads to decrease in process because sorbed dye molecules saturates the catalyst surface [71,72].

CONCLUSION

The researchers have been studying the different type of ferrite nonmaterial's to determine their application in the removal of hazardous contaminants from the water and waste water by virtue of their effective and efficient adsorption properties. The presence of pollutants in drinking water can lead to various health threats. It is therefore important that the concentration of these pollutants in the water should be reduced. These materials are also known to have excellent catalytic activity and are easy to recycle. Although the present review helps in understanding the various synthesis methods and use of different types of ferrite nanomaterials in the removal of Contaminants but still further research is needed. Thus use of ferrite nanoparticles in the treatment of waste water and water not only has potential to address various issues related to the standard of water but also it can provide safer and more sustainable alternative to treat the water than the conventional methods.

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