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Metal Doped $SnFe_2O_4$ Composites for Efficient Organic Pollutant Degradation

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ABSTRACT

Water pollution is a major global problem that affects the health and wellbeing of humans and aquatic life. Photocatalysis is an effective way of degrading organic pollutants in water and has been widely studied in recent years. In this paper, the use of metal doped Tin Ferrite ($SnFe_2O_4$) composites as a photocatalyst for the degradation of organic pollutants in water is discussed. Titanium dioxide, Zinc oxide, Cadmium sulphide, Tin oxide, Copper oxide, ferrite chloride, and Silver are a few of the several materials employed in the photocatalysis process, In the present work Tin was used as base material in the preparation of Manganese doped Tin Ferrite & to enhance the photocatalytic activity of the $SnFe_2O_4$, Manganese was doped into $SnFe_2O_4$ by Hydrothermal technique. In the current study, scanning electron microscopy, energy dispersive X-ray spectroscopy, and X-ray diffraction were utilized to examine the structure, surface morphology, and elemental composition of the synthetic material. Finally, the produced materials photocatalytic degradative performance is investigated in the presence of UV light.

Keywords: Tin Ferrite ($SnFe_2O_4$), Scanning electron microscopy (SEM), Energy dispersive X-ray spectroscopy (EDX), X-ray diffraction (XRD)

1. INTRODUCTION

Water pollution is an alarming environmental issue that continues to pose significant threats to ecosystems and human health in the present day. As the global population grows and industrialization intensifies, the quality of our water bodies faces mounting pressure. Dye degradation methods are techniques used to break down and remove synthetic dyes from water sources, thereby reducing water pollution. Photocatalysis holds promise as a technology for addressing water pollution issues. This method is cost-effective, efficient, and scalable, making it a viable approach for remediating water pollution caused by various contaminants like organic compounds, dyes, and heavy metals. Photocatalysts, such as Titanium dioxide, Zinc oxide, Cadmium sulphide, Tin oxide, Copper oxide, ferrite chloride, which are semiconductor materials, can efficiently break down organic pollutants when exposed to sunlight. In the photocatalysis process, a catalyst, typically a semiconductor, utilizes light energy to convert contaminants into harmless substances. When the catalyst absorbs light energy, it generates electron-hole pairs, which then react with the contaminants, transforming them into safe chemicals. There is difference in efficacy of metal-doped $SnFe_2O_4$ composites for organic pollutant degradation and water pollution control, by comparing with the performance of normal $SnFe_2O_4$ with that of Mn-doped $SnFe_2O_4$.The impact of metal doping on the photocatalytic properties of $SnFe_2O_4$, review the advantages of Mn-doped $SnFe_2O_4$ for water pollution control, and provide insight into the potential of such materials for the efficient removal of organic pollutants from water. By introducing metal ions into the $SnFe_2O_4$ matrix, the material's intrinsic properties and adsorption capability can be enhanced, allowing for more efficient removal of pollutants from water. Specifically, Mn-doped $SnFe_2O_4$ materials can offer decreased recombination rates of photo-generated electrons and holes. Furthermore, the adsorption rate of organic pollutants can be improved, with the presence of Mn resulting in increased interfacial charge transfer and improved oxidation potential.

METHODOLOGY

Metal-doped $SnFe_2O_4$ composites have gained significant attention due to their diverse applications in catalysis, sensors, and energy storage devices. This concise methodology outlines the synthesis of these composites using the hydrothermal method. $SnFe_2O_4$ nanoparticles that have been Mn-doped were created using a hydrothermal method

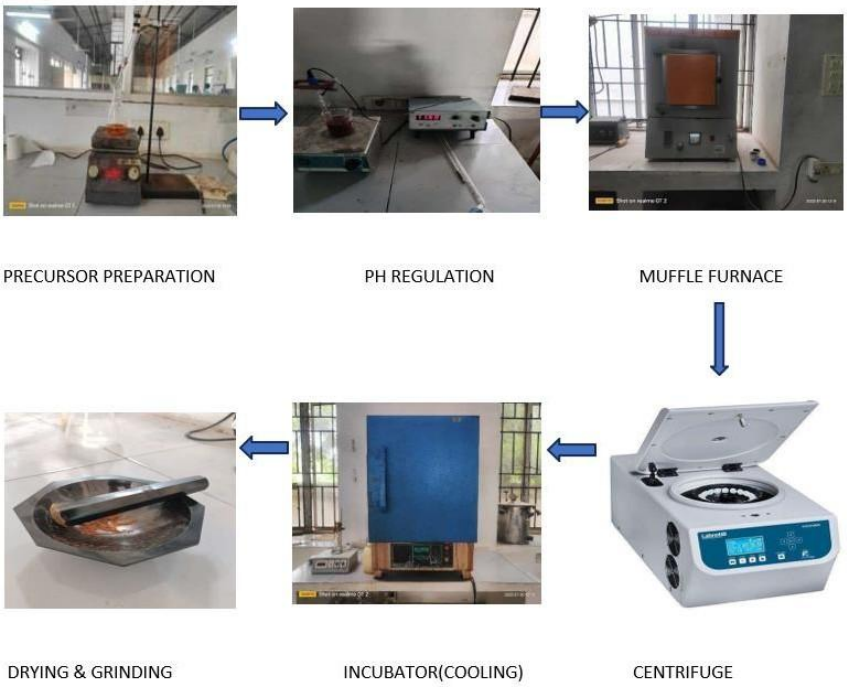

Fig: Schematic Representation of Hydrothermal method

Mn doped $SnFe_2O_4$ nanoparticles were created using sodium hydroxide of analytical grade, stannous chloride, ferric chloride, and cobalt chloride. In this typical reaction technique, 25 ml of distilled water is used to prepare a (2-X) mmol solution of stannous chloride, 4 mmol of ferric chloride, and 12 grams of sodium hydroxide in 50 ml of distilled water, all in separate beakers.In separate beakers, X = 0.02 mmol, 0.06 mmol, and 0.01 mmol solutions of cobalt chloride are made with 10 ml of distilled water. The Stannous chloride is then put into the burette and dropped into the ferric chloride solution using a dropper. For 30 minutes, this mixture was aggressively agitated using a magnetic stirrer. The previous solution is later supplemented with the doped solution (Manganese chloride). The combination was then given the proper amount of NaOH to raise the pH level to 12. The mixture was magnetically agitated for 30 minutes before being transported to an autoclave made of stainless steel with Teflon lining. The autoclave spent 12 hours in a furnace that was kept at 180 ºC. The autoclave was then left to naturally cool to ambient temperature before the precipitate it produced was centrifuged three times in distilled water. The solution is then let to dry naturally inside the tubes before being put into the incubator to finish drying completely at 100ºC for 5 hours. The powder is then manually ground for an hour using an old mortar to produce fine nano powder.

LITERATURE

Microwave-assisted chemical synthesis:

P Sakthivel et.al doped Ag+ & Al+3 ions with ZnO and mentions high degradation efficiency was obtained for the high doping concentration of Al on all irradiation times. The optical band gap values showed a blue shift, ranging from 3.54 eV to 3.89 eV, as the Al doping ratio increased. Al doping enhanced photo-degradation performance, making these NPs potential for optoelectronic and photocatalytic applications under UV/solar irradiation [14].

One-pot synthesis method

Discovered that the when the ZnO is doped with cobalt by exposing to the sunlight obtains the degradation efficiency is obtained as 99%.The band gap of co doped ZnO nano particles varies between 3.10 eV to 3.37 eV. when the cobalt is doped with zinc the Pollutants which are present in the water can be removed and make the hydrogen gas. The average particle size was found to be 5.67 nm ± 2.5 nm. The obtained sample shows the structure as hexagonal [21].

Solid state reaction method

Gurdev Preet Singh et.al Discovered that when Sm3+ is -doped with ZnO in the presence of sunlight the degradation efficiency will be of 98%. when the Sm3+ is -doped with ZnO the band gap is decreased from 3.27eV to 3.02 eV. The obtained sample shows that the structure as wurtzite hexagonal [22].

Sol gel method

Md. Naveed Iqbal Rokon et.al discovered that When copper and nickel is doped with zinc oxide (ZnO) when exposed to uv light, the obtained degradation efficiency is of 39%. The addition of Ni as a dopant to ZnO led to a decrease in the bandgap energy from 3.44 eV to 3.16 eV. The hexagonal wurtzite structure has been obtained [23].

Mohamed S. Hamdy et.al reported when copper doped with the zinc oxide (ZnO)the degradation efficiency is about 87%. UV-Vis's absorption spectra showed that Co doping resulted in increased absorption and a reduction in the band gap of ZnO. Specifically, the band gap decreased from 3.27 eV to 2.81 eV. Both pure ZnO and Co-doped ZnO samples have a hexagonal wurtzite structure [24].

Adriana Popa et.al noted that when ferrous ions in iron are doped into zinc oxide in the presence of UV light, the degradation efficiency increases to 97%. Zinc oxide has a comparatively high bandgap energy of 3.37 eV. This indicates that it takes a lot of UV light energy to excite electrons from the valence band to the conduction band. When ZnO is doped with ferrous ions, the band gap energy decreases to 2.9 eV, making electrons more easily excited for the photocatalysis reaction to occur. The morphology of the ZnO is found to be crystalline [8].

Chemical precipitation method

N. Siva et.al reported that titanium doping on photocatalyst method-activity of Zinc oxide (ZnO) nano catalyst the band gap varies 3.43eV to 3.14 eV. The TZO-4 sample has a higher degradation efficiency of 95.08%. The structural properties of the samples (Ti and ZnO) have hexagonal wurtzite structure [26].

When Tin (Sn) was doped into Zinc oxide (ZnO), the breakdown efficiency of Zinc oxide improved to 96.52% in the presence of sunshine, according to S. Ragupathy et al. Electron traps are formed as a result of tin doping. Photo-generated electrons can be trapped by these electron traps, preventing them from recombining with holes. As a result, the concentration of photo-generated electrons increases, which can subsequently combine with organic contaminants to destroy them. During the doping process, the bandgap values steadily drop [11].

Co-precipitation method

Sabrina Roguai, Dr. et.al discovered that when the Fe is doped with zinc oxide (ZnO) nano particles the degradation efficiency is 20%. Zinc oxide acts as a transparent semiconductor and a wide band gap of 3.37eV. the size of the crystals of the doped samples decreased as the dopant concentration increases. The synthesized ZnO powders was crystallized in a hexagonal wurtzite structure [20].

L. Anju Chanu et.al discovered that when zinc oxide is doped with gadolinium and exposed to UV light, the degradation efficiency increases to 96%. Electrons are trapped by Gd ions. This means that they can capture electrons produced by light absorption. This keeps electrons from recombining with holes, which is a primary cause of photocatalytic activity loss. The band gap has been reduced to 3.32 eV. When gadolinium is doped into zinc oxide, a hexagonal wurtzite structure is generated [1].

When copper (Cu) was doped into zinc oxide (ZnO), the degradation efficiency increased to 89.2% in the presence of sunlight, according to S. Sivakumar et al. The band gap was increased from 3.27 to 3.44 eV by doping copper in zinc oxide. Zinc oxide morphology was discovered to be spherical nano crystals [19].

M.A Kareem et al. discovered that when silver (Ag) was doped into zinc oxide in the presence of UV radiation, the degradation efficiency of the ZnO increased to 98%. The band gap of pure ZnO is 3.37, and the band gap is decreased to some amount once silver is doped into Zinc Oxide. Silver doped ZnO exhibited hexagonal wurtzite structure.[13]

K. Janani Archana et al. noted that the degradation efficiency increased from 21% to 35% when Copper was doped into Zinc oxide the presence of UV visible light. The bandgap was narrowed due to the doping. Spherical structure has been observed [3].

Solvothermal method

Irshad Ahmad et.al discovered that when ZnO is doped with aluminium and exposed to simulated sunlight, the degradation efficiency jumps to 98%. When aluminium is doped into ZnO, the band gap narrows from 3.67 eV to 2.96 eV., allowing it to absorb visible light. This enables for greater use of the solar spectrum for photocatalysis, increasing degradation efficiency. Because aluminium is a donor impurity contribute electrons to the conduction band, thereby closing the band gap. The morphology of aluminium doped zinc oxide is hexagonal wurtzite as well [6].

Hydrothermal method

Mohd shkir et.al reports an attractive enhancement in photocatalytic activity for Ni doped ZnO nanoparticles. Specifically, they found that with 3.0 wt.% Ni doping in ZnO, the degradation of methylene blue (MB) and tetracycline (TCN) pollutants were remarkably improved to 96%. The energy gap was found to reduce from 3.287 eV for pure ZnO to3.258 eV for ZnO doped with 3.0 wt.% Ni. The morphology is nanocluster like structure[5].

Shadi Kohzad et.al reported that doping zinc oxide (ZnO) nanoparticles with molybdenum increased degrading efficiency by 95% when measured under sunlight because Molybdenum introduces free electrons into the ZnO lattice. These liberated electrons can act as catalysts for pollutant breakdown. Because molybdenum atoms introduce defects into the ZnO lattice, the bandgap of ZnO nanoparticles dropped from

3.67 eV to 2.8 eV. These defects operate as electron energy traps, lowering the energy required to jump from the valence band to the conduction band. As a result, the band gap is reduced [12].

M. Suresh et.al reported that degradation efficiency of Zinc oxide is increased to 92% when nitrogen was doped into Zinc oxide under the presence of visible light. The bandgap of Zinc oxide is decreased from 3.16 to 3.03 eV when nitrogen was doped into it. The prepared Zinc oxide nano composite possesses a hexagonal wurtzite structure [17].

Manmohan et.al discovered that the degradation efficiency of Zinc oxide is increased to 98.5% when Neodymium (Nd) was doped into Zinc oxide in the presence of UV light. The study indicates that energy band gap of Nd doped ZnO sample was 3.19 eV while in case of ZnO sample 3.26 eV. Hexagonal rod shape morphology was observed in the analysis [20].

Raijin Liu et.al reported that when Silver (Ag) doped into Zinc oxide (ZnO) the degradation efficiency of Zinc oxide increased to 97% in the presence of simulated sunlight. The band gap observed in ZnO nanocomposite is 3.1 eV when Silver was doped. The sample show the ZnO structure as hexagonal wurtzite [19].

Dhilleswara Rao Vaddi et al. discovered that when yttrium was doped into ZnO nano rods, the degradation efficiency improved to 96.8%, although the pure efficiency is 22% in the presence of visible light. With ZnO nanorods have a band gap of 2.779 eV with a hexagonal wurtzite shape [15].

Manmohan Lal et al. reported that the degrading efficiency of ZnO improves with increasing temperature, reaching 95% at 550^0 C under X-ray diffraction. Along with this, the band gap steadily lowers from 3.36 to 3.23 eV. When the temperature rises, the size of its hexagonal crystalline structure shrinks [16].

Auto-combustion method:

Mahesha et.al observed that when Chromium is doped in Zinc oxide in the presence of visible light, the degradation efficiency increases to 95.4%. Chromium is a highly stable element, which means that it does not easily decay under the effect of light or heat. Chromium-doped [5].

ZnO is thus a more stable photocatalyst than undoped ZnO. The band gap has been reduced from 3.27 to 2.74 eV. The hexagonal wurtzite shape of chromium doped Zinc oxide is seen.[10]

Simple combustion method:

K.S. Mamatha et.al found out that when calcium is doped in zinc oxide in the presence of UV radiation, the degradation efficiency jumps to 90%. Calcium doping boosts ZnO's photoactivity, or its capacity to create electrons and holes in the presence of light. ZnO can absorb more photons and transform them into electrons and holes, which can subsequently be used to oxidize and destroy organic pollutants. When the fuel concentration is increased, the band gap of ZnO changes from 3.41 to 3.33 eV. The morphology of calcium doped Zinc oxide is hexagonal wurtzite, as discovered [13].

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