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Microwave assisted green synthesis $Ce_{0.2}Ni_{0.8}Fe_2O_4$ nanoflakes using calotropis gigantean plant extract and its photocatalytic activity

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Abstract

The cerium incorporated $NiFe_2O_4$ was prepared by microwave assisted combustion method using calotropis gigantean (C.G) plant extract which is an inexpensive, eco-friendly and greener way to synthesis of magnetic nanomaterials. The materials were analyzed by x-ray diffraction (XRD), scanning electron microscope (SEM) images, diffuse reflectance spectra (DRS), N_2 sorption studies and photoluminescence spectroscopy. The photodegradation efficiency of prepared catalysts was examined by removal of methylene blue (MB) dye under visible light irradiation. When cerium ions is introduced into nickel ferrite its change the band gap energy value from 1.13 to 1.04 which leads to the superior photocatalytic activity of $Ce_{0.2}Ni_{0.8}Fe_2O_4$catalyst compare than pure $NiFe_2O_4$ and also enhances surface area of the nickel ferrite which provides more active sites to degradation of the pollutant. Here cerium act as charge carrier it's reduce electron – hole recombination and accelerated the degradation and mineralization of dyes and further it was evident from the photoluminescence. The possible degradation mechanism for MB is also discussed. In

industrial point of view, the recovery and reusability of the catalyst which clearly indicate that $Ce_{0.2}Ni_{0.8}Fe_2O_4$ catalyst is a potential photocatalyst for the removal of organic pollutant.

Introduction

Human being and aquatic living being are in endangering because of toxic chemical discharge from various industries. Most of the chemical cannot be removed by conventional treatment technology [1,2]. Recently, advanced oxidation processes (AOPs) are the potential treatment method to remove the pollutant from wastewater. Typically, AOPs produces very reactive and non selective hydroxyl radical (HO•) which remove the various pollutant from water [[3], [4], [5], [6]]. Photo –fenton process generate more hydroxyl radicals from the different oxidizing reagent [7,8]. Spinel ferrite shows outstanding performance to degradation the organic pollutant from the industrial effluents [9]. Nickel ferrite are most proficient material due to its ferromagnetic properties, low conductivity and stable thermal ability and its used in many fields like gas sensors [10,11], microwave devices [12], data storage devices [13]. Moreover $NiFe_2O_4$ has poor quantum efficiency in photon irradiation its affect the photocatalytic performance [14,15]. To enhance the catalytic efficiency of catalyst by doping of rare-earth oxides and rare-earth containing polymetallic oxides are used by many researchers [[16], [17], [18]].

The properties of the catalyst is mainly depends on their structure and morphology. Synthesis methods play a vital role to control the structure and surface morphology of the catalyst. Several methods are used to synthesize the ferrite like hydrothermal [19], co-precipitation [20], and sol-gel method [21]. Due to the high energy consumption, long time period and calcinations processes are hinder the practical applicability of the above mentioned conventional synthesis methods. Microwave assisted combustion method is an eco-friendly and more efficient for nanomaterial synthesis because of it consume very less energy and cost effective method.

Another study reported the use of plant extract as an ecofriendly method for the synthesis of nanoparticles. The main advantage of using plant material reduces the release of toxic chemical during synthesis process [22]. *Calotropis gigantea* (crown flower) is a widely available species in Cambodia, Indonesia and India, which has medicinal benefits and it generally used for floral arrangements. The plant extract contains the following phytochemicals namely sugars, flavonoids, glycosides [23], terpenes and terpenoids which act as a reducing and capping agent. SnO_2 and ZnO is prepared using calotropis gigantea plant extract in biological method and photocatalytic activity of the materials was examined under UV light [[24], [25], [26], [27], [28], [29]]. Biological method has some disadvantage it

need more time remove the excess plant extract and calcination at higher temperature. But microwave combustion method is very efficient method to synthesis of nanomaterials within short span of time. In present work, we are reported that facile method to synthesis of Ce-doped $NiFe_2O_4$ nano-photocatalysts using calotropis gigantea plant extract. The prepared catalyst was characterized by XRD, SEM, EDS, DRS-UV and photoluminescence spectroscopy and its photocatalytic activity was studied under visible light illumination.

Section snippets

Preparation of Calotropis gigantean plant extracts

The Calotropis gigantean plant leaves collected around our institute. The collected leaves were washed with water and dried to remove the moisture. Calotropis gigantean leaves were grinded in mortar and its forms gel. Distilled water was poured into the prepared gel and stirred for 45mins to attain homogeneous solution. The final solution was labeled as calotropis gigantean plant extract. The C.G plant extract contains majorly flavonoids and polyphenols which form complex with metal ions. The

X-ray diffraction studies

XRD analysis was utlized to examine the crystal structure of the synthesized samples. The diffraction patterns of the synthesized $NiFe_2O_4$ and $Ce_{0.2}Ni_{0.8}Fe_2O_4$ nanoparticles were shown in Fig. 1. The synthesized materials have been indexed to cubic phase with space group *Fd3m* it could be confirmed by the diffraction peaks at $2\theta = 18.39°$, 30.38°, 35.54°, 37.42°, 43.51°, 54.08°, 57.12°, 62.77°, and 75.44°, which match the reflections of (111), (220), (311), (222), (400), (422), (511), (440), and

Possible mechanism of the degradation

The possible mechanistic pathway of degradation of MB using $Ce_{0.2}Ni_{0.8}Fe_2O_4$ catalyst is presented in Scheme 2. Incident light generate the positive holes and excited electron on

the surface of the catalyst. The excited electron transfer to cerium ions and react with molecular oxygen its generate superoxide radicals. The photogenerated holes react with water molecule to form hydroxyl radicals. Hence, the formed active radicals are leads to removal of MB dye under visible light illumination [56].

Conclusion

Visible light driven photocatalyst $Ce_{0.2}Ni_{0.8}Fe_2O_4$ were synthesized via microwave assisted combustion method using calotropis gigantean plant extract and catalytic efficiency of the prepared catalyst was examined by the removal of MB dye. XRD result reveals that the synthesized $Ce_{0.2}Ni_{0.8}Fe_2O_4$ catalyst well crystallizes in the cubic phase. Cerium ions introduced into the nickel ferrite which will enhance surface area of the nickel ferrite and provides more active sites for the degradation of

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Research data for this article

Data not available / Data will be made available on request

Further information on research data ↗

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> …FMNPs with smaller particle-size distribution is synthesized in a short duration on an industrial scale, and right quality product with better reproducibility is obtained at a low price [146]. The microwave assisted approach is employed in the synthesis of magnetite (Fe3O4) [147], manganese zinc ferrite (Mn0.5Zn0.5Fe2O4) [148], zinc-doped copper ferrite (Cu1−xZnxFe2O4) [149], cobalt ferrite (CoFe2O4) [150], zinc doped nickel ferrite (Ni1−xZnxFe2O4) [151], manganese-zinc ferrite (Mn0.745Zn0.173Fe2.082O4) [152], nickel ferrite (NiFe2O4) [153], cobalt doped copper ferrite (Cu1−xCoxFe2O4) [154], chromium doped cobalt zinc ferrite (CoxZn1−xCr0.5Fe0.5O4) [155], praseodymium-dysprosium doped strontium ferrite (Sr1−xRExFe12O19 (RE = Pr, Dy)) [156], cerium doped nickel ferrite (Ce0.2Ni0.8Fe2O4) [157]. Microemulsions are transparent, isotropic and thermodynamically stable dispersions made from two immiscible liquids using suitable surfactants.…

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Mg<inf>0.5</inf>Ni<inf>x</inf>Zn<inf>0.5-x</inf>Fe<inf>2</inf>O<inf>4</inf> spinel as a sustainable magnetic nano-photocatalyst with dopant driven band shifting and reduced recombination for visible and solar degradation of Reactive Blue-19

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