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Visible light photocatalytic activity of magnetically diluted Ni–Zn spinel ferrite for active degradation of rhodamine B

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Abstract

The nanoparticles of $Zn_xNi_{1-x}Fe_2O_4$ ($0.0 \leq x \leq 1$ in steps 0.5) were prepared with the application of urea (CH_4N_2O) as a fuel in the sol-gel auto combustion technique and also used to remove the Rhodamine B (RhB) from the industrial waste-water. Before the process of water treatment began, the Ni–Zn ferrite nanoparticles were characterized by XRD, FT-IR, FE-SEM, VSM, and UV–Vis spectrophotometer. The measurement of XRD confirms that the cubic structure with the Fd-3m space group and the crystalline size was also calculated with the help of the Williamson-Hall (W–H) plot. The FT-IR spectra of Ni–Zn ferrite nanoparticles show two prominent absorption bands in the range of 390–560 cm^{-1}. Optical properties of the prepared nanoparticles were evaluated using UV–Vis spectrophotometer and PL studies. The photocatalytic activity of the prepared NPs was studied under the sunlight and the percentage of maximum degradation was found to be 90%, 94%, and 98%, respectively, under 180 min.

Introduction

The expressive development in the human population and precise decimation of the natural resources in order to make room for industrialization has serious drawbacks on the atmosphere of Earth [[1], [2], [3]]. In general, it has been found that a number of different effluents are disposed of in the various water sources. These hazardous waste materials, particularly the manufactured dyes, are found to be responded with disinfectants (e.g., chlorine) used for the water sources and caused cancer-causing diseases. Some of the non-biodegradable organic dyes can infiltrate through human skin and affect the functioning of typically the lungs and heart.

Spinel ferrites are called promising candidates because of their remarkable physicochemical properties and high adaptability in nanoscale technologies [[4], [5], [6]]. Currently, spinel ferrites are broadly used in the production of modern ceramics in which nanoscale materials having the quality of superior exhibitions are needed. Spinel ferrites have been applied in the various applications such as catalyst [7], magnetic hyperthermia [[8], [9], [10], [11]], drug delivery [12], nanofluids [[13], [14], [15]] and electronic industries. Nickel spinel ferrite having chemical formula $NiFe_2O_4$ is applied in various techno-societal applications, for example, gas sensors [16], ferrofluids [17], nanocatalyst [[18], [19], [20]], photomagnetic materials [21], and microwave gadgets [22]. To the compliment, zinc spinel ferrite with chemical formula $ZnFe_2O_4$ has wide application including semiconducting photocatalysis [23] and photon-instigated electron transport [24]. Nickel–zinc ferrites having the capabilities of acting as super porous material in the mixed form make them broadly utilized in the techno-societal fields, for example, inducting and microwave wave safeguards [25,26]. At present, apart from this specialized utilization, there is a developing need of these materials for their photocatalytic applications in the decontamination of industrial polluted water [27,28].

The magneto-optical properties of spinel nanoferrites are firmly bonded with the crystalline structure [29]. Spinel nanoferrites are solidified in the form of cubical spinel structure with Fd-3m space grouping, in which cations with two and three valence states are orchestrated toward the tetra-A and octa-B interstitial locales [30]. Magnetically active cation with two valences (Ni^{2+}) shows a solid inclination for the octa-B destinations, and, consequently, $NiFe_2O_4$ can be considered as an inverse spinel. Conversely, magnetically non-active cation with two valences, for example, Zn^{2+}, occupies tetra-A destinations [31], so in this manner, $ZnFe_2O_4$ is considered as a normal spinel [32,33]. The arrangement of spinel ferrite may be altered, whereas the essential nanocrystalline nature remains same, which implies that the different physicochemical properties of nanoferrites may be effortlessly tailored just by changing the proportion cationic distribution [[34], [35], [36]]. Recently, many methods have emerged for the nanoscale synthesis of spinel ferrite nanoparticles [37,38], among which the sol-gel auto combustion technique was proved to be a one of the best methods [[39], [40], [41], [42], [43]].

As the conventional catalyst are very costly, the recuperation and recycling of the catalyst is of great interest. Moreover, the NPs having superior surface to volume ratio are of great interest for catalytic

and industrial scale applications. Therefore, the currently available photocatalysts such as TiO_2, ZnO, MnO_2, ZnS etc. are non-magnetic in nature and due to this, their recovery is not easy and also they are very expensive and time consumables. As a result, the inappropriate recovery of the non-magnetic photocatalyst results in the loss of photocatalytic properties and it creates the residual which can pollute the environment. These issues constraints the practicability of the non-magnetic photocatalyst. In order to tackle this issue, the magnetic NPs of spinel structured ferrites holds a better place for the efficient and cost-effective photocatalyst applications. Moreover, the spinel structured ferrite nanoplatforms have shown improvement in the degradation rate of the toxic dyes and they can easily recovered from the reaction mixtures after being used.

In this report, we will discuss the refined structure, morphological, and photocatalytic activity of pristine nickel ferrite ($NiFe_2O_4$) and zinc ferrite ($ZnFe_2O_4$) along with mixed nickel–zinc ferrite ($Ni_{0.5}Zn_{0.5}Fe_2O_4$) for the active deprivation of RhB dye in the influence of the sunlight.

Section snippets

Preparation of ferrite nanoparticles

$Zn_xNi_{1-x}Fe_2O_4$ ($0.0 \leq x \leq 1$ in steps 0.5) nanoparticle was prepared by the solution combustion route. Reagents in the form of nitrate for Ni^{2+}, Zn^{2+} and Fe^{3+}, urea (CH_4N_2O), and ammonia (NH_3) with the purity of 99.9% were used as raw materials in this process. First, all the reagents were dissolved in the DD-H_2O in order to obtain a mixed solution. The ratio of stoichiometric proportion of metal nitrates to urea was 1:4. Constant pH 7 was maintained using ammonia. The mixed solution that was…

XRD studies

The single-phase formation with the cubic spinel structure of all the synthesized $Zn_xNi_{1-x}Fe_2O_4$ ($0.0 \leq x \leq 1$ in steps 0.5) was confirmed through the X-ray diffraction (XRD) analysis. The Rietveld refinement analysis for XRD data of $NiFe_2O_4$, $ZnFe_2O_4$, and $Ni_{0.5}Zn_{0.5}Fe_2O_4$ nanoparticles was carried out by using Fullprof software as shown in Fig. 2. The black-colored point in the figure represents the experimental data, while red-colored points show the calculated intensity. Pink-colored vertical…

Conclusion

In summary, Ni–Zn ferrites NPs have been successfully prepared by the combustion route. The Rietveld-refined XRD studies clearly showed the single-phase spinel structure formation without having any residual phase formation. The study of FT-IR spectra confirms the characteristic peaks of

spinel ferrites in the scope of 380–600 cm^{-1} related to metal-oxygen bonds. The analysis of optical properties revealed that the compound has an optical bandgap in the range of 2.75, 1.91, and 2.20 eV. The…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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References (65)

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