Thakurata DG, J Environ Sci Curr Res 2023, 6: 041
DOI: 10.24966/ESCR-5020/100041

HSOA Journal of Environmental Science Current Research

Research Article

Green Synthesized Silver Nanoparticles Grafted Zinc Ferrite (Ag/Znfe2o4): An Effective Nanocatalyst Fabricated For the Efficient Degradation of Malachite Green (MG) and Methylene Blue (MB)

Debasish Guha Thakurata[1,3]*, Krishna Chandra Das[2,3] and Siddhartha Sankar Dhar[3]

[1]*Department of Chemistry, Srikishan Sarda College, Hailakandi, Assam, India*

[2]*Department of Chemistry, G. C. College, Silchar, Assam, India*

[3]*Department of Chemistry, National Institute of Technology Silchar, Assam, India*

Abstract

Green silver nanoparticles (AgNPs) grafted on zinc ferrite (ZnFe2O4) prepared by co-precipitation and calcination are used as a novel nanocatalyst designed for the degradation of malachite green (MG) and methylene blue (MB). FTIR, XRD, SEM, EDX-VSM, and TEM analysis were used to characterize the synthesized compound. In the case of malachite green (MG), 98 % degradation is reported just in one minute with the assistance of 1 ml of 10% H2O2. In the absence of H2O2, however, degradation takes a long time. This compound can also catalyze the degradation of methylene blue (MB), however it is not especially successful. Since hydrogen peroxide is so significant in catalysis, the catalytic reaction must follow the fenton type mechanism by generating reactive oxygen species (ROS). Furthermore, the grafted silver nanoparticles serve as a sink for electrons that pass from the valence to the conduction bands, reducing the possibility of electron-hole recombination. Based on various spectrophotometric findings it is possible to infer that the catalytic degradation follows 1st order kinetics.

***Corresponding author:** Debasish Guha Thakurata, Department of Chemistry, Srikishan Sarda College, Department of Chemistry, National Institute of Technology Silchar, Assam, India, Tel: 9435379780; Email: guhathakuratadebasish@gmail.com

Citation: Thakurata DG, Das KC, Dhar SS (2023) Green synthesized silver nanoparticles grafted zinc ferrite (Ag/ZnFe2O4): An effective nanocatalyst fabricated for the efficient degradation of Malachite green (MG) and Methylene blue (MB). J Environ Sci Curr Res 6: 041.

Received: February 8, 2023; **Accepted:** February 20, 2023; **Published:** February 26, 2023

Introduction

The phenomenon of catalysis has an extensive range of impending applications in different arena such as waste water purification, environmental remediation etc. Spinel structured metal ferrites and their diverse nanocomposite acts as a vibrant photocatalyst in the degradation of several toxic organic dyes present in the industrial effluents which makes aquatic environment unhygienic. Discharge of these colored materials in the water bodies may cause eutrophication, oxidation, hydrolysis and other detrimental chemical reactions [1-4]. Because of its toxic nature, high COD content, and biological deterioration, sewage from material factories is causing a serious environmental catastrophe. [5,6]. Different methods like chemical treatment, adsorption and biodegradation are presently accessible in the treatment of these waste materials [7,8].

The present research workforce are paying attention in the novelty of photocatalytic material which can utilize solar radiation which composed of 40% visible light in the degradation of organic dyes. Currently ferrite based nanocomposite gained more interest as heterogeneous photocatalyst in this area due to its remarkable microstructure, morphology, magnetic property and narrow band gap [9]. Spinel zinc ferrite has a very narrow band gap and it's composite with TiO_2 and Al_2O_3 can successfully degrade methyl red and thymol blue photocatalytically [10]. Spinel metal ferrites (MFe_2O_4, M is a bivalent cation such as Mn^{+2}, Zn^{+2}) coupled with g-C_3N_4 has widely used in the photodegradation of various organic dyes [11]. Green synthesized ZnO nanorod composite with $NiFe_2O_4$ has remarkable superparamagnetic property can effectively degrade methylene blue under UV and solar radiation and the catalyst can easily separate magnetically [12]. Hydrothermally prepared magnetically separable $ZnFe_2O_4$ – graphene composite has amazing degradation potential of methylene blue in prescence of H_2O_2 [13,14]. The surface of multi walled carbon nanotube (MWCNT) decorated with $ZnFe_2O_4$ has up to 99% methylene blue photodegradation ability [15]. Magnetically recoverable Mn-Fe_2O_4/g-C_3N_4/TiO_2 nanocomposite has been effectively utilized in the photodegradation of methyl orange under solar irradiation. Silver decorated Zinc/ calcium ferrite was found to exhibit exceptional photodegradation capacity of rohadimine B [16]. Silver doped $CuFe_2O_4$/TiO_2 nancomposite effectively degrade different azo dye photocatalytically [17]. Grafting of noble metal like Ag, Au, and Pt on the exterior of nanomaterial has the benefit of enhancement of electron hole partition by acting as electron trap and also extends the light absorption in the visible range by the mechanism of surface Plasmon resonance [18-20].

Taking into thoughtfulness of all these aspects, the present study aims at the synthesis of novel green synthesized silver nanoparticle grafted on the surface of spinel structured zinc ferrite to get the

collective effect of improvement of electron hole partition and absorption of visible light radiation due to surface plasmon resonance by silver nanoparticle. In this attempt, we detail the fabrication, characterization and catalytic activity of green synthesized silver nanoparticle grafted Zinc ferrite. In absence of direct visible light catalytic performance was evaluated based on the degradation of Malachite Green (MG) and Methylene Blue (MB). FTIR, XRD, VSM, TEM, HR-TEM, SEM, and EDX were used to characterize the nanocatalyst's structural and physicochemical properties.

Experimental

Materials

Iron (III) nitrate nanohydrate [$Fe(NO_3)_3.9H_2O$], zinc nitrate hexahydrate [$Zn(NO_3)_3.9H_2O$], silver nitrate ($AgNO_3$) and sodium hydroxide (NaOH) are procured from Merck. Methylene blue as well as malachite green is arranged from Sigma-Aldrich. Required chemicals were used without being purified in any way.

Preparation of Zinc ferrite

Co-precipitation was used to produce zinc ferrite ($ZnFe_2O_4$) nanoparticles, which were then calcined in a muffle furnace [21,22]. Analytical grade 4M sodium hydroxide (NaOH) solution was gradually added to salt solutions of 5 mM ferric nitrate [$Fe(NO_3)_3.9H_2O$] and 2.5 mM zinc nitrate [$Zn(NO_3)_2.6H_2O$] during the synthetic procedures. The pH of the mixture was revised up to 12 by introducing NaOH solution drop wise. After washing with distilled water and ethanol, the precipitate was dried in a low-temperature oven. The extracted precipitates were eventually calcined in a muffle furnace for 5 hours at 500°C.

Green synthesis of Silver Nanoparticles

For the biosynthesis of silver nanoparticles 4mM silver nitrate solutions was prepared. To 100 ml of this solution 20 ml of water extract of flowers of *Brassica oleracea italica* (Broccoli) was added and kept in dark for 24 hrs. Formation of dark brown colour (Figure 1) indicates the formation of silver nanoparticles, which is confirmed by UV visible study.

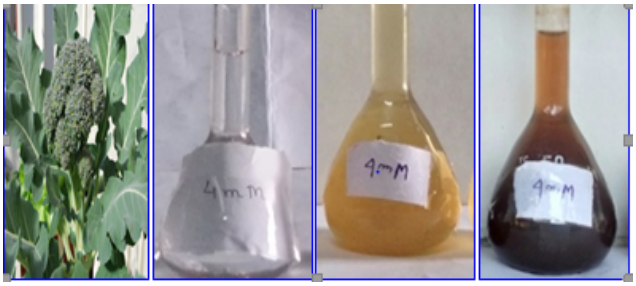


Figure 1: Silver nanoparticles formation from the flower extract of Brassica oleracea italica (Broccoli).

Grafting of Silver Nanoparticle on Zinc Ferrite

1 g of the as synthesized zinc ferrite is dispersed in the 100 ml of previously synthesized silver nanoparticle by green method. The binary mixture is stirred for 6 hours in a magnetic stirrer before being sonicated for 1 hour. Centrifugation is being used to separate the silver grafted zinc ferrite nanoparticles that have already been formed.

Study of the catalytic performance

The ability of silver nanoparticles grafted zinc ferrite catalyst to degrade Malachite Green (MG) and Methylene Blue (MB) in the absence of direct sunlight and in the presence and absence of hydrogen peroxide was investigated according to published literature. [23,24]. The extent of degradation is monitored spectrophotometrically (Analytical Technologies TS-2080) and degradation percentage is calculated with the help of the equation. 1.

$$\text{Degradation (\%)} = \left(\frac{A_0 - A}{A_0}\right) \times 100 \quad (1)$$

Where A_0 and A are the absorbance's of the dye before and after the degradation.

Results and Discussion

FTIR studies4

As revealed in Figure. 2(a), the Fourier transform infrared (FTIR) spectrum verified the formation of the as-fabricated zinc ferrite spinel structure. The intrinsic stretching vibration of iron-oxygen and zinc-oxygen bonds is assigned to the two major bands at 440.66 cm^{-1} and 556.18 cm^{-1} respectively in the tetrahedral and octahedral sites of the spinel ferrite [25,26]. The same stretching vibration of Metal - Oxygen is observed when zinc ferrite is grafted with nano silver particle (fig.1b). The band at 1, 123.02 cm^{-1} (figure.2a) and 1118.25 cm^{-1} (figure.2b) ascribed to a stretching vibration of phenolic group of flavonoide type of compounds present in the plant extract used as stabilizing agent. The band at 1,462.1 cm^{-1} corresponds to the vibration mode of O-H band. At 3, 427.80 cm^{-1} (figure.2a) and 3432.57 cm^{-1} (figure.2b), the wide band corresponds to the O-H stretch vibration of the water molecule of moisture rapt in the compound. An additional small band at 877.27 cm^{-1} in (figure 2) reflect the incorporation of silver nano particle in the zinc ferrite.

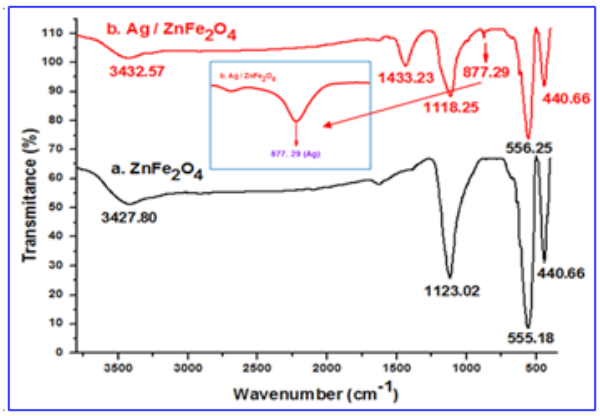


Figure 2: FTIR spectra of (a) $ZnFe_2O_4$ (b) $Ag/ZnFe_2O_4$.

VSM studies

The M-H hysteresis curve analyses the magnetic properties of zinc ferrite and it's composite with grafted silver nano particles (figure 3). The magnetic parameters are tabulated in the Table 1.

Sample		Magnetic Parameters	
	Ms (emu/g)	Hc (Oe)	Mr (emu/g)
ZnFe2O4	1.5555	99.528	24.167
Ag/Zn-Fe2O4	0.37020	610.87	48.745

Table 1: VSM parameters of $ZnFe_2O_4$ and the Ag/ $ZnFe_2O_4$ composite.

Compared with zinc ferrite (1.555 emu / g), the saturation magnetization value of the composite is significantly decreased by one fourth (0.3702 emu / g). This demonstrates the doping of zinc ferrite with the silver nano particle. However, the extraordinary rise in composite coercivity (610.87 Oe) compared with zinc ferrite (99.528 Oe) suggests an improvement in the composite's ferromagnetic character.

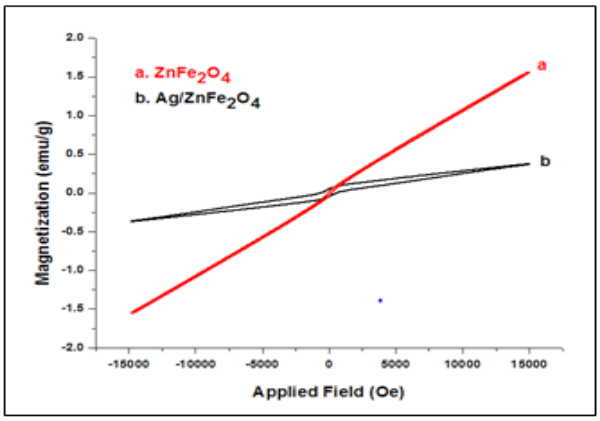


Figure 3: M-H curves of (a) $ZrFe_2O_4$ and (b) $Ag/ZnFe_2O_4$.

XRD studies

The powder XRD pattern of $ZnFe_2O_4$ and $Ag/ZnFe_2O_4$ are presented in the figure 4 (a, b). In figure. 4 (a), the uppermost peak at angle $2\theta = 35.3$ corresponds to the plane (311) for the $ZnFe_2O_4$ sample precisely corresponding with the JCPDS card No. 89-1012. Other prominent peaks of zinc ferrite and their corresponding planes are well established. High crystalline nature of the compound is suggested by sharp peaks in the XDR pattern of the sample. The grafting of silver nanoparticles on the surface of zinc ferrite can be ascertained by the appearance of two low intensity peak at 38.4 and 44.6 corresponds to the plane of (111) and (200) of silver [27]. The mean crystallite size (Dc) of the $ZnFe_2O_4$ and $Ag/ZnFe_2O_4$ was expected to be 36.76 nm and 40.77 nm respectively using the Debye–Scherrer equation [28]. The increase in the crystallite size indicates the grafting of silver nanoparticle on the surface of zinc ferrite.

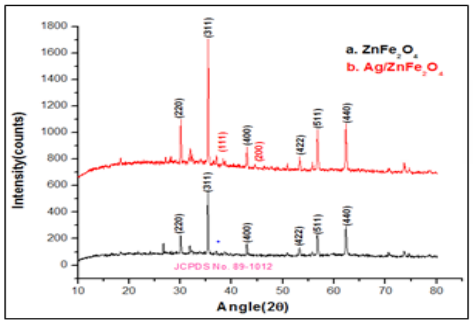


Figure 4: XRD pattern of (a) $ZrFe_2O_4$ and (b) $Ag/ZnFe_2O_4$.

SEM and EDX studies

The SEM image of $ZnFe_2O_4$ (Figure 5A, 5B) reveals that the Zn-Fe_2O_4 has a fine-grained structure with consolidated morphology. The presence of silver in composite in dispersed form is confirmed from the SEM picture of Ag/ $ZnFe_2O_4$ (Figure. 5C, 5D). The EDX spectrum of ZnFe2O4 (Figure 6A) revealed the existence of only the elements Zn, Fe, and O, with no particulates. However the EDS spectrum of $Ag/ZnFe_2O_4$ (Figure 6B) confirmed the grafting of Silver in the surface of zinc ferrite.

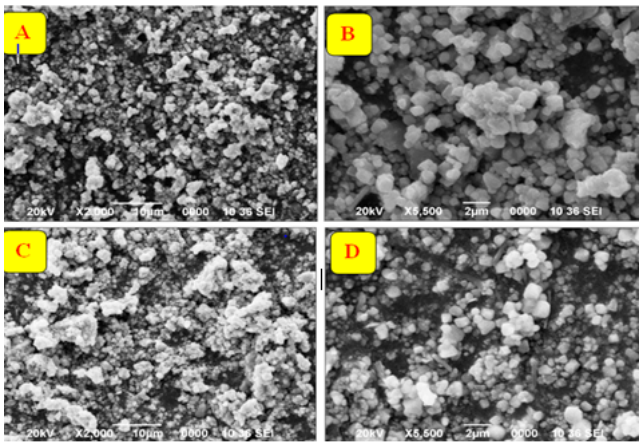
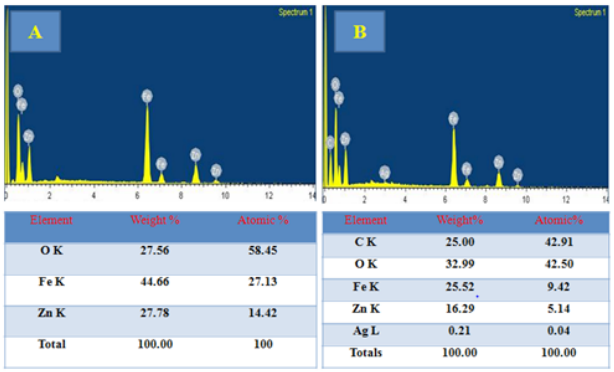


Figure 5: SEM image of $ZrFe_2O_4$ (A, B) and $Ag/ZnFe_2O_4$ (C, D).



Element	Weight %	Atomic %
O K	27.56	58.45
Fe K	44.66	27.13
Zn K	27.78	14.42
Total	100.00	100

Element	Weight%	Atomic%
C K	25.00	42.91
O K	32.99	42.50
Fe K	25.52	9.42
Zn K	16.29	5.14
Ag L	0.21	0.04
Totals	100.00	100.00

Figure 6: EDX pattern of (A) $ZrFe_2O_4$ and (B) $Ag/ZnFe_2O_4$.

TEM, HRTERM and SAED Studies

Transmission electron microscopy image of the as synthesized silver nano grafted zinc ferrite particles are shown in figures 7 (a, b). The cubic nature of the particles is clearly visible, with an average size of 67 nm, which varies from the average size estimated using the Debye Scherer equation from XRD observation. This disparity arises from the fact that XRD studies only take into consideration thickness in the lattice plane. With a mean size of 5.168 nm, the implanted silver nanoparticles on the surface of zinc ferrite are clearly identifiable (figure 7c). According to the HR-TEM analysis, the [220] plane corresponds to the lattice fringe length of 0.270 nm (Fig. 7d). Selected area electron diffraction (SAED) study indicates the crystalline nature of the prepared compound (figure 7e).

Catalytic performance of $Ag/ZnFe_2O_4$ nanocatalyst

The ability of newly synthesized silver nanoparticle grafted zinc ferrite to degrade malachite green (MG) and methylene blue (MB) at

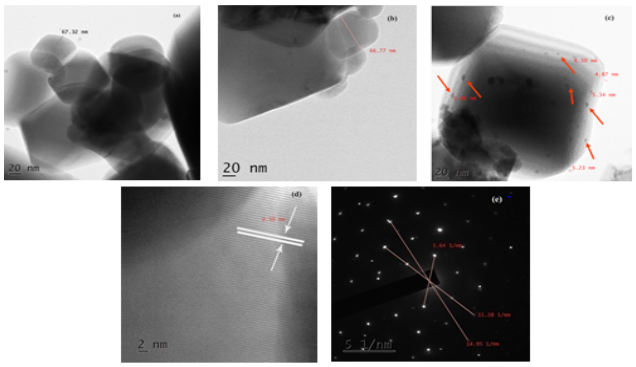


Figure 7: TEM (a, b and c), HRTEM (d) and SAED (e) pattern of nano silver grafted zinc ferrite.

room temperature in the presence and absence of hydrogen peroxide was investigated. The spectrophotometric analysis makes it possible to calculate the percentage of catalytic degradation of both dyes over a given time frame. It was reported that by using 10 mg, 30 mg and 50 mg of the catalyst in the presence of 1 ml of 10% H_2O_2 instantaneous degradation of the dye was observed in 10 ppm, 30 ppm, and 50 ppm concentrations of the dye. However, in the absence of H_2O_2, the degradation takes a considerable time interval, implying that H_2O_2 performs a significant role in the process. In the presence of 1 ml 10 % H_2O_2 this catalyst resulted in a maximum of 98 % degradation of malachite green. Fig.8 depicts the spectral changes of malachite green during instantaneous degradation under various conditions.

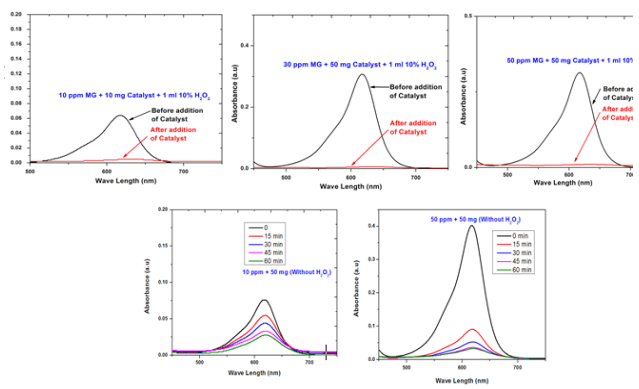


Figure 8: Spectral change of the degradation of malachite green (MG) in assistance of H_2O_2.

The degradation of methylene blue was also monitored using the same catalyst under the same conditions; however, 0nly 77 % degradation is achieved in 100 min time interval (figure 9). Thus, in comparison to the previous observation, the catalyst's efficiency in degrading methylene bule is inadequate.

Study of the degradation kinetics

Considering the effectiveness of the synthesized nanocatalyst in the degradation of MG over MB, the rate of the degradation of MG is only monitored and it was found to follow first order kinetics. The rate equation of degradation can be written as; ln (C_0/C) = kt, where 'C_0' and 'C' are the initial and concentration of MG after time 't' with rate constant 'k' of the reaction. Concentration can be used in place of absorbance because they are both directly proportional according

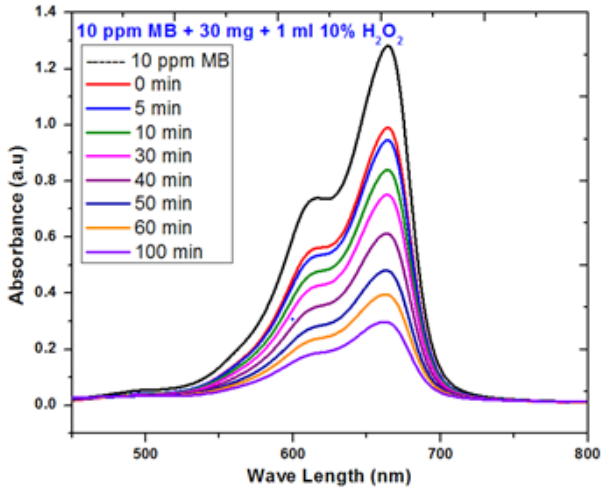


Figure 9: Spectral change of the degradation of methylene blue (MB) in assistance of H_2O_2.

to Beer-Lambert's law. Plots of ln C_0/C against time (t) at 617 nm for different catalytic amounts showed a linear nature, as shown in the figure 10a, 10b and 10c.

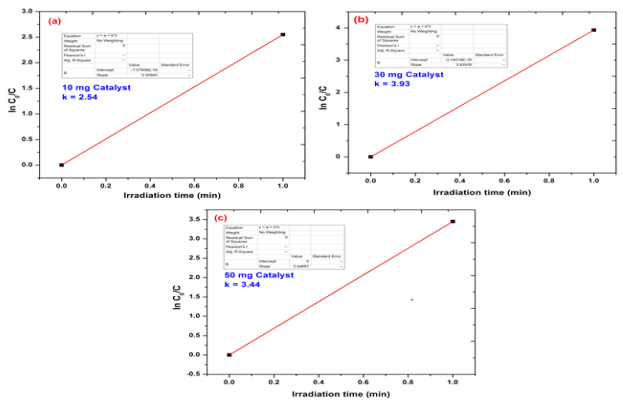


Figure 10: Plots of ln C0/C versus irradiation time due to Ag/$ZnFe_2O_4$ in different catalytic amount.

The rate constant (k) for malachite green degradation in the existence of hydrogen peroxide was found to be 2.54 min^{-1}, 3.93 min^{-1}, and 3.44 min^{-1} for 10 mg, 30 mg, and 50 mg catalyst, respectively, based on these linear plots. Since this highest rate constant (k) value for 30 mg catalyst signifies a maximum degradation rate, 30 mg may be regarded as the optimum catalytic dose in this degradation process.

Expected mechanism of the degradation of MG

In this study, hydrogen peroxide, in addition to Ag/$ZnFe_2O_4$ plays an important role in speeding up the rate of toxic malachite green degradation. As a consequence, the reaction kinetics of such a degradation process could be supported by fenton type mechanisms**.** The generation of reactive oxygen species (ROS) such as hydroxyl and perhydroxyl radicals is the primary cause of MG degradation. [29]. Furthermore, the grafted silver nanoparticles serve as a sink for electrons that pass from the valence to the conduction bands, reducing the possibility of electron-hole recombination. The superoxide anion is formed when these electrons combine with the oxygen molecule. The

holes in the valence band interact with the water molecule to produce hydroxyl radicals, which cause catalytic degradation [30]. The combined mechanism is shown in the figure 11.

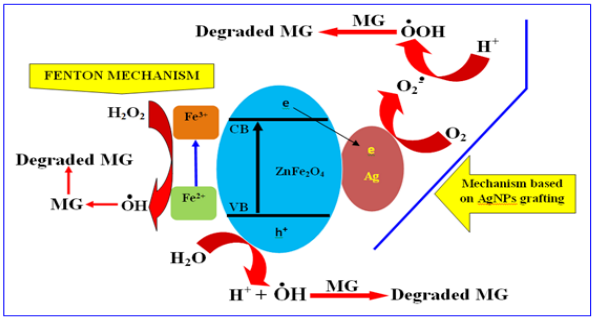


Figure 11: Expected combined mechanism of catalytic degradation of MG.

Study of the recyclability of the nanocatalyst

The recyclability of the nanocatalyst was reviewed by centrifuging the catalyst from the reaction mixture. The retrieved catalyst was reused five times to degrade malachite green solution. Figure 12 show that $Ag/ZnFe_2O_4$ nanocatalyst retains its catalytic competence after five consecutive runs for the purpose of malachite green degradation.

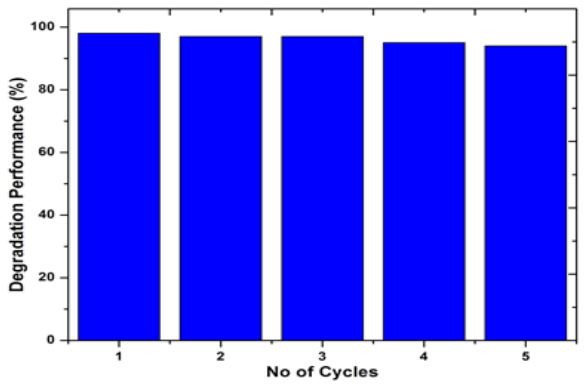


Figure 12: Recyclability Test of the catalyst $Ag/ZnFe_2O_4$.

Comparative study of MG degradation with other catalyst.

The effectiveness of the $Ag/ZnFe_2O_4$ catalyst in MG degradation was evaluated by comparing to that of other documented catalysts in the literature. With an elevated percentage of degradation, $Ag/ZnFe_2O_4$ is found to be advanced and novel in this degradation strategy. The comparison is tabulated as under in Table 2.

Conclusion

By grafting green silver nanoparticles onto the surface of zinc ferrite, a novel $Ag/ZnFe_2O_4$ catalyst was successfully fabricated. The TEM analysis shows a significant visual of grafted AgNPs on the surface zinc ferrite, with an average particle size of 5.168 nm. Its exemplary performance as a catalyst is confirmed by the 98 % degradation of malachite green in one minute in the presence of hydrogen peroxide. In the occurrence of hydrogen peroxide, the catalyst was also able to degrade methylene blue. It is logical to conclude that such catalytic nanomaterials can be used to remove toxic dyes from water resources, thereby mitigating environmental challenges.

Catalyst	MG Conc	Amount	Degradation Time	Percentage	Reference
CoFe2O4/mpg-C3N4	10 mg/L	80 mg	120 min	93.41 %	[31]
MnO2-MCM	100 mg/L	100 mg	60 min	100 %	[32]
Chitosan-Ascorbic Acid@NiFe2O4	70 mg/L	70 mg	90 min	99.92 %	[33]
Zno	20 mg/L	20 mg	100 min	85.29 %	[34]
Ni – dopped Bi2Se3	10-5 mol/L	25 mg	5 min	100 %	[35]
Ag/ZnFe2O4	10 mg/L	10 mg	1 min	98%	This Work

Table 2: Comparative study of MG degradation with other catalyst.

Acknowledgement

The contributors are indebted to the Department of Chemistry, NIT Silchar, the Department of Chemistry, S. S. College, Hailakandi and G. C. College, Silchar, Assam, India, for allocating appropriate research amenities. The researchers would like to express their gratitude to CIF, NIT, Silchar, Assam; STIC, Cochin, Kerala; and SAIC, Tezpur University, Assam for providing analytical equipment for this study.

Graphical Abstract

References

1. Senapati KK, Borgohain C, Sarma KC, Phukan P (2011) Photocatalytic degradation of methylene blue in water using $CoFe_2O_4$–Cr_2O_3–SiO_2 fluorescent magnetic nanocomposite. Journal of Molecular Catalysis Chemical 346: 111-116.

2. Bianco Prevot A, Baiocchi C, Brussino MC, Pramauro E, Savarino P, et al. (2001) Photocatalytic degradation of acid blue 80 in aqueous solutions containing TiO_2 suspensions. Environmental science & technology 35: 971-976.

3. Neppolian B, Choi HC, Sakthivel S, Arabindoo B, Murugesan V (2002) Solar light induced and TiO_2 assisted degradation of textile dye reactive blue 4. Chemosphere 46: 1173-1181.

4. Saquib M, Muneer M (2003) TiO2-mediated photocatalytic degradation of a triphenylmethane dye (gentian violet), in aqueous suspensions. Dyes and pigments 56: 37-49.

5. Patil MR, Shrivastava VS (2014) Photocatalytic degradation of carcinogenic methylene blue dye by using polyaniline-nickel ferrite nano-composite. Der Chemica Sinica 5: 8-17.

6. Yazdanbakhsh M, Khosravi I, Goharshadi EK, Youssefi A (2010) Fabrication of nanospinel ZnCr2O4 using sol–gel method and its application on removal of azo dye from aqueous solution. Journal of hazardous materials 184: 684-689.

7. DeJohn PB, Hutchins RA (1976) Treatment of Dye Wastes with Granular Activated Carbon. Textile Chemist & Colorist 8.

8. Patil SS, Shinde VM (1988) Biodegradation studies of aniline and nitrobenzene in aniline plant wastewater by gas chromatography. Environmental science & technology 22: 1160-1165.

9. Indrayana IPT, Julian T, Suharyadi E (2018) UV light-driven photodegradation of methylene blue by using Mn0. $5Zn0.5Fe_2O_4/SiO_2$ nanocomposites. In Journal of Physics: Conference Series 1011: 012062.

10. Hankare PP, Patil RP, Jadhav AV, Garadkar KM, Sasikala R (2011) Enhanced photocatalytic degradation of methyl red and thymol blue using titania–alumina–zinc ferrite nanocomposite. Applied Catalysis B: Environmental 107: 333-339.

11. Vadivel S, Maruthamani D, Habibi-Yangjeh A, Paul B, Dhar SS (2016) Facile synthesis of novel CaFe2O4/g-C3N4 nanocomposites for degradation of methylene blue under visible-light irradiation. Journal of colloid and interface science 480: 126-136.

12. Vignesh K, Suganthi A, Min BK, Kang M (2014) Photocatalytic activity of magnetically recoverable MnFe2O4/ $g\text{-}C_3N_4/TiO_2$ nanocomposite under simulated solar light irradiation. Journal of Molecular Catalysis A: Chemical 395: 373-383.

13. Fu Y, Chen H, Sun X, Wang X (2012) Combination of cobalt ferrite and graphene: high-performance and recyclable visible-light photocatalysis. Applied Catalysis B: Environmental 111: 280-287.

14. Fu Y, Chen Q, He M, WanY, Sun X, et al. (2012) Copper ferrite-graphene hybrid: A multifunctional heteroarchitecture for photocatalysis and energy storage. Industrial & engineering chemistry research 51: 11700-11709.

15. Singhal S, Sharma R, Singh C, Bansal S (2013) Enhanced photocatalytic degradation of methylene blue using/MWCNT composite synthesized by hydrothermal method. Indian Journal of Materials Science.

16. Fernandes RJ, Magalhães CA, Amorim CO, Amaral VS, Almeida, BG, et al. (2019) Magnetic Nanoparticles of Zinc/Calcium Ferrite Decorated with Silver for Photodegradation of Dyes. Materials 12: 3582.

17. Masoumi S, Nabiyouni G, Ghanbari D (2016) Photo-degradation of Congored, acid brown and acid violet: Photo catalyst and magnetic investigation of $CuFe_2O_4$–TiO_2–Ag nanocomposites. Journal of Materials Science Materials in Electronics 27: 11017-11033.

18. Harikishore M, Sandhyarani M, Venkateswarlu K, Nellaippan TA, Rameshbabu N (2014) Effect of Ag doping on antibacterial and photocatalytic activity of nanocrystalline TiO_2. Procedia materials science 6: 557-566.

19. Wang P, Huang B, Dai Y, Whangbo MH (2012) Plasmonic photocatalysts: harvesting visible light with noble metal nanoparticles. Physical Chemistry Chemical Physics 14: 9813-9825.

20. Khaghani S, Ghanbari D (2017) Magnetic and photo-catalyst Fe_3O_4–Ag nanocomposite: green preparation of silver and magnetite nanoparticles by garlic extract. Journal of Materials Science Materials in Electronics 28: 2877-2886.

21. Hankare PP, Jadhav SD, Sankpal UB, Patil RP, Sasikala R, et al (2009) Gas sensing properties of magnesium ferrite prepared by co-precipitation method. Journal of Alloys and Compounds 488: 270-272.

22. Elahi I, Zahira R, Mehmood K, Jamil A, Amin N (2012) Co-precipitation synthesis, physical and magnetic properties of manganese ferrite powder. African journal of pure and applied chemistry 6: 1-5.

23. Das KC, Dhar SS (2020) Rapid catalytic degradation of malachite green by $MgFe_2O_4$ nanoparticles in presence of H_2O_2. Journal of Alloys and Compounds 828: 154462.

24. Rabie AM, Abukhadra MR, Rady AM, Ahmed SA, Labena A, et al. (2020) Instantaneous photocatalytic degradation of malachite green dye under visible light using novel green Co–ZnO/algae composites. Research on Chemical Intermediates 46: 1955-1973.

25. Kaiser M (2009) Effect of preparation condition on nickel zinc ferrite nanoparticle: a comparison between sol-gel. Journal of Alloys and Compounds 468: 15-21.

26. Waldron RD (1955) Infrared spectra of ferrites. Physical review 99: 1727.

27. Awwad AM, Salem NM (2012) Green synthesis of silver nanoparticles byMulberry LeavesExtract. Nanoscience and Nanotechnology 2: 125-128.

28. Lassoued A, Lassoued MS, Dkhil B, Ammar S, Gadri A (2018) Synthesis, structural, morphological, optical and magnetic characterization of iron oxide (α-Fe2O3) nanoparticles by precipitation method: effect of varying the nature of precursor. Physica E Low-dimensional Systems and Nanostructures 97: 328-334.

29. Abbas M, Rao BP, Reddy V, Kim C (2014) Fe3O4/TiO2 core/shell nanocubes: Single-batch surfactantless synthesis, characterization and efficient catalysts for methylene blue degradation. Ceramics International 40: 11177-11186.

30. Rabie AM, Abukhadra MR, Rady AM, Ahmed SA, Labena A, et al. (2020) Instantaneous photocatalytic degradation of malachite green dye under visible light using novel green Co–ZnO/algae composites. Research on Chemical Intermediates 46: 1955-1973.

31. Hassani A, Eghbali P, Ekicibil A, Metin Ö (2018) Monodisperse cobalt ferrite nanoparticles assembled on mesoporous graphitic carbon nitride (CoFe2O4/mpg-C3N4): a magnetically recoverable nanocomposite for the photocatalytic degradation of organic dyes. Journal of Magnetism and Magnetic Materials 456: 400-412.

32. Nanda B, Pradhan AC, Parida KM (2016) A comparative study on adsorption and photocatalytic dye degradation under visible light irradiation by mesoporous MnO2 modified MCM-41 nanocomposite. Microporous and Mesoporous Materials 226: 229-242.

33. Hasan I, Bassi A, Alharbi KH, BinSharfan II, Khan RA, et al. (2020) Sonophotocatalytic Degradation of Malachite Green by Nanocrystalline Chitosan-Ascorbic Acid@ $NiFe_2O_4$ Spinel Ferrite. Coatings 10: 1200.

34. Saikia L, Bhuyan D, Saikia M, Malakar B, Dutta DK (2015) Photocatalytic performance of ZnO nanomaterials for selfsensitized degradation of malachite green dye under solar light. Applied Catalysis A General 490: 42-49.

35. Kulsi C, Ghosh A, Mondal A, Kargupta K, Ganguly S (2017) Remarkable photo-catalytic degradation of malachite green by nickel doped bismuth selenide under visible light irradiation. Applied Surface Science 392: 540-548.

HERALD

Advances In Industrial Biotechnology | ISSN: 2639-5665

Advances In Microbiology Research | ISSN: 2689-694X

Archives Of Surgery And Surgical Education | ISSN: 2689-3126

Archives Of Urology

Archives Of Zoological Studies | ISSN: 2640-7779

Current Trends Medical And Biological Engineering

International Journal Of Case Reports And Therapeutic Studies | ISSN: 2689-310X

Journal Of Addiction & Addictive Disorders | ISSN: 2578-7276

Journal Of Agronomy & Agricultural Science | ISSN: 2689-8292

Journal Of AIDS Clinical Research & STDs | ISSN: 2572-7370

Journal Of Alcoholism Drug Abuse & Substance Dependence | ISSN: 2572-9594

Journal Of Allergy Disorders & Therapy | ISSN: 2470-749X

Journal Of Alternative Complementary & Integrative Medicine | ISSN: 2470-7562

Journal Of Alzheimers & Neurodegenerative Diseases | ISSN: 2572-9608

Journal Of Anesthesia & Clinical Care | ISSN: 2378-8879

Journal Of Angiology & Vascular Surgery | ISSN: 2572-7397

Journal Of Animal Research & Veterinary Science | ISSN: 2639-3751

Journal Of Aquaculture & Fisheries | ISSN: 2576-5523

Journal Of Atmospheric & Earth Sciences | ISSN: 2689-8780

Journal Of Biotech Research & Biochemistry

Journal Of Brain & Neuroscience Research

Journal Of Cancer Biology & Treatment | ISSN: 2470-7546

Journal Of Cardiology Study & Research | ISSN: 2640-768X

Journal Of Cell Biology & Cell Metabolism | ISSN: 2381-1943

Journal Of Clinical Dermatology & Therapy | ISSN: 2378-8771

Journal Of Clinical Immunology & Immunotherapy | ISSN: 2378-8844

Journal Of Clinical Studies & Medical Case Reports | ISSN: 2378-8801

Journal Of Community Medicine & Public Health Care | ISSN: 2381-1978

Journal Of Cytology & Tissue Biology | ISSN: 2378-9107

Journal Of Dairy Research & Technology | ISSN: 2688-9315

Journal Of Dentistry Oral Health & Cosmesis | ISSN: 2473-6783

Journal Of Diabetes & Metabolic Disorders | ISSN: 2381-201X

Journal Of Emergency Medicine Trauma & Surgical Care | ISSN: 2378-8798

Journal Of Environmental Science Current Research | ISSN: 2643-5020

Journal Of Food Science & Nutrition | ISSN: 2470-1076

Journal Of Forensic Legal & Investigative Sciences | ISSN: 2473-733X

Journal Of Gastroenterology & Hepatology Research | ISSN: 2574-2566

Journal Of Genetics & Genomic Sciences | ISSN: 2574-2485

Journal Of Gerontology & Geriatric Medicine | ISSN: 2381-8662

Journal Of Hematology Blood Transfusion & Disorders | ISSN: 2572-2999

Journal Of Hospice & Palliative Medical Care

Journal Of Human Endocrinology | ISSN: 2572-9640

Journal Of Infectious & Non Infectious Diseases | ISSN: 2381-8654

Journal Of Internal Medicine & Primary Healthcare | ISSN: 2574-2493

Journal Of Light & Laser Current Trends

Journal Of Medicine Study & Research | ISSN: 2639-5657

Journal Of Modern Chemical Sciences

Journal Of Nanotechnology Nanomedicine & Nanobiotechnology | ISSN: 2381-2044

Journal Of Neonatology & Clinical Pediatrics | ISSN: 2378-878X

Journal Of Nephrology & Renal Therapy | ISSN: 2473-7313

Journal Of Non Invasive Vascular Investigation | ISSN: 2572-7400

Journal Of Nuclear Medicine Radiology & Radiation Therapy | ISSN: 2572-7419

Journal Of Obesity & Weight Loss | ISSN: 2473-7372

Journal Of Ophthalmology & Clinical Research | ISSN: 2378-8887

Journal Of Orthopedic Research & Physiotherapy | ISSN: 2381-2052

Journal Of Otolaryngology Head & Neck Surgery | ISSN: 2573-010X

Journal Of Pathology Clinical & Medical Research

Journal Of Pharmacology Pharmaceutics & Pharmacovigilance | ISSN: 2639-5649

Journal Of Physical Medicine Rehabilitation & Disabilities | ISSN: 2381-8670

Journal Of Plant Science Current Research | ISSN: 2639-3743

Journal Of Practical & Professional Nursing | ISSN: 2639-5681

Journal Of Protein Research & Bioinformatics

Journal Of Psychiatry Depression & Anxiety | ISSN: 2573-0150

Journal Of Pulmonary Medicine & Respiratory Research | ISSN: 2573-0177

Journal Of Reproductive Medicine Gynaecology & Obstetrics | ISSN: 2574-2574

Journal Of Stem Cells Research Development & Therapy | ISSN: 2381-2060

Journal Of Surgery Current Trends & Innovations | ISSN: 2578-7284

Journal Of Toxicology Current Research | ISSN: 2639-3735

Journal Of Translational Science And Research

Journal Of Vaccines Research & Vaccination | ISSN: 2573-0193

Journal Of Virology & Antivirals

Sports Medicine And Injury Care Journal | ISSN: 2689-8829

Trends In Anatomy & Physiology | ISSN: 2640-7752