La$_2$Sn$_2$O$_7$/g-C$_3$N$_4$ nanocomposites: Rapid and green sonochemical fabrication and photo-degradation performance for removal of dye contaminations

Zeinab Talebzadeh a, Maryam Masjedi-Arani a, Omid Amiri b, c, Masoud Salavati-Niasari a, *

Suffixes

a Institute of Nano Science and Nano Technology, University of Kashan, Kashan, P. O. Box:87317-51167, Iran
b Faculty of Chemistry, Razi University, Kermanshah 6714414971, Iran
c Department of Chemistry, College of Science, University of Ruparin, Rania, Kurdistan Region, Iraq

ARTICLE INFO

Keywords:
Nanostructure
Ultrasonic irradiation
Graphitic carbon nitrides
La$_2$Sn$_2$O$_7$
Photocatalyst

ABSTRACT

The deficiency of drinking water sources has become a serious crisis for the future of the world due to the existence of numerous artificial dyes and poisonous organic impurities. In the present study, rapid ultrasonic treatment was performed to obtain La$_2$Sn$_2$O$_7$/Graphitic carbon nitrides (LSO/CN) nanocomposites with advanced photo-catalytic performance. Broccoli extract was utilized as a natural surfactant with active surface groups to control nucleation and growth of formed crystals with the creation of spatial barriers around the cations, and finally prevent nano-product agglomeration. Changing experimental parameters in synthesis reaction in turn offers a virtues control over the nano-products size and shape. The shape and size distribution of particles was considered via diverse characterization techniques of microscopic and spectroscopic. The photocatalytic behaviors along with a kinetic study of the nanoparticles were examined by elimination and degradation of different artificial dyes under the UV waves. Effect of particle size, weight ratio of LSO-CN, type of dye, scavenger kind, dye and catalyst loading was designated on altering proficiency of nano-catalyst function. Also, the probable mechanism of removal dye by photocatalytic function was studied.

1. Introduction

Nowadays, the deficiency of drinking water sources has become a serious crisis for the future of the world due to the existence of numerous artificial dyes and poisonous organic impurities in aqueous environments. There are many methods to remove artificial dyes from drinking water such as nanofiltration [1], adsorbent [2], biosorption [3] and the photocatalytic process [4,5]. Among them, the photocatalytic activity received more attention because of its privileges of low energy consumption, high stability, environmental and economical friendly [6–9]. The mechanism of photocatalytic process is described in the following path: (1) the absorption of photons with energy ≥ the bandgap of nano-catalyst, (2) photoexcited electrons create at conduction band and the same amount of positive holes at valence band, (3) The various oxidants of OH$^-$, O$_2$ and H$_2$O$_2$ could proficiently oxidize dye compounds into harmless combinations of CO$_2$ and water [10–12].

Numerous efforts have been prepared in the field of produce various forms of photocatalyst such as graphene-based nanocomposite [13,14], binary oxides [10,15] and ternary nano-photocatalyst [16]. La$_2$Sn$_2$O$_7$

Pyrochlore-type oxide as a semiconductor nano-oxide has an appropriate performance in diverse applications such as photocatalysis [17], energy storage [18,19] and catalysis [20,21]. Owning to the intense efficacy of fabrication approaches on the form and dimension of nano-products, the preparation path of pyrochlore La$_2$Sn$_2$O$_7$ nano samples is significant. La$_2$Sn$_2$O$_7$ nano-sized structures were created via several chemical techniques [17,22,23]. Despite the extensive researches carried out on nano-photocatalyst synthesis and performance, there is still an essential requirement to suggest a beneficial nano-scale sample...
nanosized La nanostructures due to their non-hazardous and safe features to the environment. Through a low-cost, fast and eco-friendly way. Recently, green chemistry-based methods have been noticed to the creation of diverse nanocomposites such as La(NO$_3$)$_3$·6H$_2$O (99.99%), SnCl$_2$·5H$_2$O (98%) and melamine were commercially available and employed without further purification. A multiwave ultrasonic generator (MPI Ultrasonics; welding, 1000 W, 20 KHz, Switzerland), immersed directly in the reaction solution. X-ray diffraction (XRD) patterns were recorded by a Philips-X’pertpro, X-ray diffractometer using Ni-filtered Cu Ka radiation. Fourier transform infrared (FT-IR) spectra were recorded on Nicolet Magna- 550 spectrometer in KBr pellets. The electronic spectrum of the sample was taken on Perkin-Elmer LS-55 luminescence spectrometer. Scanning electron microscopy (SEM) images were obtained on LEO-1455VP equipped with an energy dispersive X-ray spectroscopy. The EDX analysis with 20 kV accelerated voltage was done. Transmission electron microscopy (TEM) image was obtained on a Philips EM208 transmission electron microscope with an accelerating voltage of 200 kV.

2. Experimental

2.1. Materials and physical measurements

All the chemical reagents for the synthesis of La$_2$Sn$_2$O$_7$/g-C$_3$N$_4$ nanocomposites such as La(NO$_3$)$_3$·6H$_2$O (99.99%), SnCl$_2$·5H$_2$O (98%) and melamine were commercially available and employed without further purification. A multiwave ultrasonic generator (MPI Ultrasonics; welding, 1000 W, 20 KHz, Switzerland), immersed directly in the reaction solution. X-ray diffraction (XRD) patterns were recorded by a Philips-X’pertpro, X-ray diffractometer using Ni-filtered Cu Ka radiation. Fourier transform infrared (FT-IR) spectra were recorded on Nicolet Magna- 550 spectrometer in KBr pellets. The electronic spectrum of the sample was taken on Perkin-Elmer LS-55 luminescence spectrometer. Scanning electron microscopy (SEM) images were obtained on LEO-1455VP equipped with an energy dispersive X-ray spectroscopy. The EDX analysis with 20 kV accelerated voltage was done. Transmission electron microscopy (TEM) image was obtained on a Philips EM208 transmission electron microscope with an accelerating voltage of 200 kV.

### Table 1

| Sample | Calcination condition | Ultrasonic irradiation time (min) | Alkaline agent | Natural surfactant | Crystalline size (nm) |
|--------|-----------------------|----------------------------------|---------------|-------------------|----------------------|
| LSO1   | 800°C, 3 h            | 15                               | NH$_3$        | –                 | –                    |
| LSO2   | 900°C, 3 h            | 15                               | NH$_3$        | –                 | –                    |
| LSO3   | 900°C, 5 h            | 15                               | NH$_3$        | –                 | 22.4                 |
| LSO4   | 900°C, 3 h            | –                                | NH$_3$        | –                 | 25.7                 |
| LSO5   | 900°C, 5 h            | 15                               | en            | –                 | 23.9                 |
| LSO6   | 900°C, 5 h            | 15                               | Broccoli extract | – | 30.3               |
| LSO7   | 900°C, 5 h            | 30                               | Broccoli extract | – | 25.8               |

2.1. Materials and physical measurements

All the chemical reagents for the synthesis of La$_2$Sn$_2$O$_7$ nanostructures synthesized by ultrasonic irradiation in presence of green broccoli surfactant. Graphitic carbon nitride (g-C$_3$N$_4$) polymeric component was selected to the formation of La$_2$Sn$_2$O$_7$/CN nanocomposite because of suitable energy gap (2.7 eV), high surface area and cheap synthesis route as well as finally, advanced photocatalytic activity [34]. Numerous researches illustrate that using g-C$_3$N$_4$ has a favorable impact on photocatalytic efficiency [35,36]. In this work, La$_2$Sn$_2$O$_7$/g-C$_3$N$_4$ nanocomposites were fabricated via green and rapid ultrasonic technique in presence of broccoli extract natural surfactant. After characterization of obtained nano-products in various experimental circumstances, photo-degradation efficiency of them was evaluated in several experimental tests such as particle size, weight ratio of LSO:CN, type of dye, scavenger kind, dye and catalyst loading. Moreover, the photo-driven degradation mechanism of erythrosine dye by LSO/CN nanocomposite was studied.

### Scheme 1

Schematic model for sonochemistry preparation of LSO nanoparticles by natural surfactant.
2.2. Preparation of broccoli extract

An appropriate amounts of fresh broccoli leaves were carefully washed via distilled water and air-dried. Then, the clean leaves were crushed in the food processor and filtered via filter paper. The obtained broccoli extract was kept in a refrigerator for further use.

2.3. Sonochemical fabrication of La$_2$Sn$_2$O$_7$ nano products

La(NO$_3$)$_3$·6H$_2$O (99.99%) and SnCl$_4$·5H$_2$O (98%) salts were purchased from Sigma-Aldrich Company and weighed based on stoichiometric ratios (1:1) and dissolved in deionized water, separately. Then, two solutions were added to each other. Broccoli extract was utilized as a natural surfactant. Meanwhile, NH$_3$ was added to the cationic solution dropwise till set the pH to 11. Afterwards, A multiwave ultrasonic generator (MPI Ultrasonics; welding, 1000 W, 20 kHz, Switzerland), immersed directly in the reaction solution for 15 min. The attained products were centrifuged, dried and calcined at 900$^\circ$C for 5 h. In order to reach favorable dimension and morphology of nano-scaled structures for enhanced photocatalytic performance, the effect of calcination conditions, ultrasonic time and type of alkaline agent was evaluated that has been exemplified in Table 1. Also, a blank test without Broccoli surfactant was carried out. The obtained nanocomponents were considered through various physical analyses. The schematic plan of La$_2$Sn$_2$O$_7$ nanoparticle creation by sonochemical route has been displayed in Scheme 1.

2.4. Preparation of g-C$_3$N$_4$/La$_2$Sn$_2$O$_7$ nanocomposites

The optimized La$_2$Sn$_2$O$_7$ nano-samples in terms of size and shape along with melamine were dispersed in ethanol in an ultrasonic bath for 30 min. then, the centrifuged precipitates were dried and heated at 500 $^\circ$C for 4 h. The g-C$_3$N$_4$/LSO nanocomposites prepared in various weight ratios have been listed in Table 1.
2.5. Photocatalytic tests

The photodegradation process was accomplished in a home-produced glass reactor set containing 100 mL aqueous solutions of 10 ppm of erythrosine and methyl violet. For every reaction, 10 mg \( \text{La}_2\text{Sn}_2\text{O}_7 \) nano-structures were dispersed in a dye solution. The achieved suspensions were stirred at room temperature and kept in dark circumstances for 30 min. To end, the organization set was irradiated under a UV lamp (Osram ULTRA-VITALUX 300 W) consisting of UVA (\( \lambda = 320 \) to 400 nm) and UVB (\( \lambda = 290–320 \) nm).

![Fig. 3. SEM images of \( \text{La}_2\text{Sn}_2\text{O}_7 \) nano-samples prepared in different calcination circumstances (a, b) LSO1, (c, d) LSO2 and (e, f) LSO3.](image-url)
3.1. X-ray diffraction investigations

X-ray diffractograms of La-Sn-O sample prepared through sonochemical route in calcination condition of 800 °C for 3 h (LSO1) have been presented in Fig. 1a. This time and temperature of heat treatment are not sufficient for the preparation of La$_2$Sn$_2$O$_7$ nano-structures. By increasing temperature to 900 °C (LSO2), the peaks are still presented in non-crystallized form (Fig. 1b), but pure cubic La$_2$Sn$_2$O$_7$ structures (JCPDS No = 73–1686) were created at 900 °C for 5 h that have been illustrated in Fig. 1c (LSO3). It was concluded that a heat process of 900 °C for 5 h is essential for the fabrication of La$_2$Sn$_2$O$_7$ nanocrystals. Cubic La$_2$Sn$_2$O$_7$ structures are including four main peaks at 2θ that of 28.88, 33.47, 48.06 and 57.04 related to (2 2 2), (4 0 0), (4 4 0) and (6 2 2) plans. The XRD pattern of La$_2$Sn$_2$O$_7$ crystals prepared in blank condition without ultrasonic irradiation has been demonstrated in Fig. 2a (LSO4). By using the precipitation route, La$_2$Sn$_2$O$_7$ powder along with little amount impurity of SnO$_2$ (JCPDS No = 03–0439) were formed. To the investigation of alkaline agent, ethylene diamine (en) was utilized instead of ammonia (Fig. 2b). The en has a lower release rate of hydroxide anion than NH$_3$. In the presence of en, pure cubic lanthanum tin oxide nano-powder was fabricated (LSO5). In order to formation of structures with smaller dimensions, the presence of surfactant is vital. Fig. 2c represents XRD diffractogram of La$_2$Sn$_2$O$_7$ nano samples in existing of broccoli extract as a natural surfactant (LSO6) that indexed to pure La$_2$Sn$_2$O$_7$ nano-structures (JCPDS No = 73–1686). Moreover, one specimen was synthesized with an increasing ultrasonic irradiation time of 30 min (LSO7) that has been indicated in Fig. 2d. As seen in Fig. 2d, the peaks intensity of La$_2$Sn$_2$O$_7$ nanostructures has increased. The crystalline size of La-Sn-O nano-grains was calculated by the Scherer equation [37] and listed in Table 1.

3.2. Morphology investigation (SEM & TEM)

Fig. 3 indicates SEM images of La$_2$Sn$_2$O$_7$ nanostructures fabricated in various times and temperatures of heat treatment. Interconnected particles were formed in 800 °C for 3 h (Fig. 3a, b) that by increasing temperature to 900 °C for 3 h (Fig. 3c, d), nanorods with the size of 30 nm in diameter and 500 nm in length were created besides aggregated particles. With the intensification of time to 5 h, regular particles were synthesized (Fig. 3e, f).

La$_2$Sn$_2$O$_7$ structures prepared through precipitation technique without ultrasonic irradiation have large and irregular size that shown in Fig. 4a, b. Ultrasonic waves help to formation uniform fine particles with accelerating chemical reaction. To investigate of precipitating operator on the final properties of LSO products, the ethylene diamine was applied instead of ammonia. As observed in Fig. 4e, d, uniform particles were synthesized with the size range of 20–40 nm. The en has a lower release rate of hydroxide anions (OH$^-$) than NH$_3$ and finally, helps to control of nucleation and growth of nanoparticles. Fig. 4e, f present SEM images of La$_2$Sn$_2$O$_7$ nanostructures prepared in presence of Broccoli extract. Spherical nanoparticles formed have homogeneous size and shape. Broccoli was utilized as both green surfactant and alkaline agent including active glucosinolate and polyphenol groups that can conjugate to created nuclei, control their growth and finally create favorable nano-sized samples [31,32]. The influence of sonochemical time was evaluated on the appearance features of La$_2$Sn$_2$O$_7$ nano-products. By growing reaction time of ultrasonic to 30 min, larger particles were created with a range size of 20–100 nm (Fig. 4g, h) and reaction time of 15 min was designated as an ideal time.

Particle size distribution diagrams of La$_2$Sn$_2$O$_7$ nanostructures obtained in different circumstances (LSO4, LSO5, LSO6 and LSO7) have been demonstrated in Fig. 5 that calculated by Digimizer software. With evaluating of particle size distribution diagrams was concluded that the lowest size distribution is related to La$_2$Sn$_2$O$_7$ nanostructures prepared via broccoli extract and 15 min ultrasonic irradiation (LSO6).

Fig. 6 illustrates TEM pictures of optimized La$_2$Sn$_2$O$_7$ nanoparticles fabricated via sonochemical route and broccoli natural surfactant (LSO6). Spherical-shaped nanoparticles have a size about 15–50 nm.

Fig. 4. SEM images of La$_2$Sn$_2$O$_7$ nano-samples prepared in different experimental circumstances (a, b) LSO4, (c, d) LSO5, (e, f) LSO6 and (g, h) LSO7.

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3.3. Ultrasonic formation mechanism

La$_2$Sn$_2$O$_7$ nano-products with optimized features are created through the simultaneous outcomes of ultrasonic irradiation and broccoli as a natural surfactant. Appropriate structures in the nano-sized form are produced via the generated cavitation with ultrasound waves. Excessive temperatures and pressures are created with huge energies according to hot-spot theory and make active components of radicals [28]. The development of preparation mechanism of samples via the sonochemical method stated as below:

$$\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$$
$$\text{H}^+ + \text{H}^+ \rightarrow \text{H}_2$$
$$\text{OH}^- + \text{OH}^- \rightarrow \text{H}_2\text{O}_2$$
$$\text{NH}_3 \text{ (or en)} + \text{H}_2\text{O} + \text{H}^+ \rightarrow \text{NH}_2^+ \text{ (en-H$^+$)} + \text{OH}^-$$
$$\text{Sn}^{4+} + \text{OH}^- \rightarrow \text{Sn(OH)}_4$$
$$\text{La}^{3+} + \text{Sn(OH)}_4 + \text{OH}^- \rightarrow \text{La}_2\text{Sn}_2\text{O}_7 \text{ nanoparticles}$$

3.4. Optical features

UV–vis absorption mode was utilized to evident the optical features and energy structure in semiconductor materials. The UV–Vis outcomes for La$_2$Sn$_2$O$_7$ nano (LSO6) and bulk (LSO4) particles were exposed in Fig. 7a, b. The absorption peaks for both samples are around 200–400 nm. The band gap of La$_2$Sn$_2$O$_7$ nano and bulk specimens was gauged by Tauc’s equation [38] about 3.35 and 3.30 eV, respectively.

The luminescence characteristic of La$_2$Sn$_2$O$_7$ nano crystals prepared via sonochemical route in optimized circumstances has been illustrated in Fig. 8 under the excitation of 270 nm. As shown in Fig. 8, three peaks exist at 320, 450 and 650 nm. In the La$_2$Sn$_2$O$_7$ nanoparticle, the La and Sn cations with inversion symmetry are coordinated to eight and six oxygen, respectively in a geometry only slightly distorted from a regular octahedron [39].

3.5. Characterization of La$_2$Sn$_2$O$_7$/g-C$_3$N$_4$ (LSO/CN) nanocomposites

Fig. 9a–c display XRD patterns of LSO/CN nanocomposites prepared in various weight ratios of LSO/CN 30:70, 50:50 and 70:30, respectively. All diffractograms confirm the presence of La$_2$Sn$_2$O$_7$ nanocrystals. Owing to the small intensity of CN peak versus great intensity of La$_2$Sn$_2$O$_7$ peaks, existing of LSO is not significantly observed. In Fig. 9a, a small peak in 2θ about 28° is seen because of high weight ratios of LSO/CN 30:70. Fig. 9d present the XRD pattern of pristine g-C$_3$N$_4$ component (JCPDS No. 75-2078).

The SEM images of La$_2$Sn$_2$O$_7$/g-C$_3$N$_4$ (LSO/CN) nanocomposites obtained in different LSO/CN weight ratios of 30:70, 50:50 and 70:30 have been specified in Fig. 10a–c. The homogeneous distribution of LSO nanoparticles in ultra-thin sheets of g-C$_3$N$_4$ is confirmed. Moreover, more amount CN sheets are observed in Fig. 10a.

The results of EDX analyses of pure LSO nanoparticles and divers LSO/CN nanocomposites have been represented in Fig. 11a–d, respectively. In Fig. 11a, the existence of La, Sn and O lines confirm the
formation of pure La$_2$Sn$_2$O$_7$. Also, in Fig. 11b-d presence of C and N peaks along with La, Sn and O lines approve the combination of LSO and CN in nanocomposites. Moreover, the intensity of C and N peaks is higher in LSO:CN weight ratio of 30:70.

3.6. BET analysis

The nitrogen adsorption–desorption isotherms and pore size distribution curves of LSO/CN nanocomposite with a weight ratio of 30:70 have been revealed in Fig. 12a, b. The hysteresis type of nanocomposite is related to aggregate particles with slit-like pores with broad size.
The attained pore volume and average pore size for LSO/CN nanocomposite in ideal circumstances are 4.50 cm$^3$ g$^{-1}$ and 20.28 nm, respectively. Furthermore, the specific surface area evaluates 19.92 m$^2$ g$^{-1}$. By evaluating obtained BET results, LSO/CN nanocomposite with a weight ratio of 30:70 is a favorable applicant for photocatalysis systems.

3.7. Photocatalytic degradation efficiency and kinetic studying

Due to suitable electronic band gap and high surface area properties of LSO nanoparticles and LSO/CN nanocomposites, the photocatalytic activity of nanostructures was evaluated under UV irradiation for degradation of water pollutants. The impact of various parameters of photocatalytic degradation was investigated in order to achieve the highest degradation percentage. The factors of catalyst type, different weight ratios of LSO:CN, nano-catalyst amount, dye type, dye concentration and different additives as the scavengers were considered. Fig. 13a indicates the photocatalytic performance of LSO nanoparticles prepared via ultrasonic irradiation and LSO bulk structures synthesized without ultrasonic irradiation. The details and results of the degradation efficiency of erythrosine dye under UV light have been presented in Fig. 13. As illustrated in Fig. 13a, degradation efficiency of LSO nanostructures (LSO6) is more than LSO bulk structures (LSO4) that is related to the higher surface area of nano into the bulk. The degradation efficiency of products is calculated as follows (Eq. (1)):

\[ \text{degradation efficiency} (\%) = \left( \frac{A_0 - A_t}{A_0} \right) \times 100 \tag{1} \]

Which $A_0$ and $A_t$ are absorbance amounts in times of start and t min. According to Eq. (1), the degradation percentage of nanoparticles and bulk products was obtained 84 and 75 % after 120 min. Also, in order to consider kinetic properties of samples according to Langmuir–Hinshelwood mechanism, the promising reaction rate coefficients can be gained from Eq. (2):

\[ \ln \left( \frac{C_0}{C_t} \right) = kt \tag{2} \]

Which $C_0$ and $C_t$ are dye concentration in times of start and t min and $k$ is the pseudo-1st-order rate coefficient (min$^{-1}$) [41]. According to linear dependences of ln($C_0$/C$_t$) versus reaction time, the 1st-order rate constant $k$ has been attained. As observed in Fig. 13b, the rate constant of $k$ for nanoparticles is more than bulk structures that confirm catalytic degradation of erythrosine dye under UV light have been presented in Fig. 13. As illustrated in Fig. 13a, degradation efficiency of LSO nanostructures (LSO6) is more than LSO bulk structures (LSO4) that is related to the higher surface area of nano into the bulk. The degradation efficiency of products is calculated as follows (Eq. (1)):

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Which $C_0$ and $C_t$ are dye concentration in times of start and t min and $k$ is the pseudo-1st-order rate coefficient (min$^{-1}$) [41]. According
Fig. 13 e, f exhibit the results of photo-degradation of LSO6 nano-catalyst in different amounts of 0.02 and 0.01 g. It is obvious that photocatalytic activity is completely performed in presence of more amount of nanocatalyst (0.02 g) with speed about four times faster ($k = 0.0491 \text{ min}^{-1}$) than 0.01 g LSO6 nanocatalyst ($k = 0.0157 \text{ min}^{-1}$).

The photocatalytic activity of LSO6 nanocatalyst was evaluated for degradation of anionic erythrosine and cationic methyl violet dyes to acquire developed efficiency. As indicated in Fig. 14 a, b, the behavior of La$_2$Sn$_2$O$_7$ nanoparticles for degradation of erythrosine as an anionic dye is better than methyl violet as a cationic dye and photocatalytic efficiency was reported 100 and 82 %, respectively. Also, the degradation speed of erythrosine is higher than methyl violet dye.

Fig. 14 c, d compare the photocatalytic performance of LSO6 nanocatalyst in different erythrosine dye concentrations of 10 and 20 ppm. The outcomes exhibit optimized La$_2$Sn$_2$O$_7$ nanoparticles have better function in lower dye concentrations.

Fig. 15 displays the photo-degradation percentage of LSO6 nanocatalyst in presence of three different scavenger agents of Ethylenediaminetetraacetic acid (EDTA), Benzoic acid (BA) and benzoquinone (BQ) to trap h$^+$, 'OH and 'O$_2$ active specimens [44], respectively for more realization of photo-degradation mechanism of erythrosine dye by UV irradiation. As illustrated, the photo-degradation efficiency of erythrosine dye by La$_2$Sn$_2$O$_7$ nanocatalyst has noticeably reduced in presence of BQ as a 'O$_2$ scavenger. It is concluded that 'O$_2$ active component has the most contribution in removal dye pollutant of water. However, according to Fig. 15 and a slight decrease in photocatalytic efficiency, 'OH also plays little role in destruction of toxic dye. The mechanism of erythrosine contamination via optimized nanocatalyst by superoxide anion and hydroxyl radicals has been summarized in follows:

LSO nano-catalyst $\rightarrow$ LSO nano-catalyst$^*$ ($e^-_{CB} + h^+_{VB}$)

$O_2 + e^- \rightarrow 'O_2^-$

'$O_2^- + e^- + 2H^+ \rightarrow H_2O_2$

$H_2O_2 + e^- \rightarrow OH^- + 'OH$

Fig. 10. SEM images of g-C$_3$N$_4$/La$_2$Sn$_2$O$_7$ nanocomposites prepared in various weight ratios of LSO/CN (a) 30:70, (b) 50:50 and (c) 70:30.
h⁺ + H₂O → 'OH + H⁺

Erythrosine dye + ('O₂ + 'OH active agents) → product + H₂O + CO₂

The schematic design of photo-degradation mechanism of LSO/CN nanocomposite has been illustrated in Scheme 2.

4. Conclusions

In summary, we were productively designed binary La₂Sn₂O₇/g-C₃N₄ nanocomposites through ultrasonic waves with distinctive structural and optical features for photocatalytic activity under UV irradiations for elimination of drinking water pollutants. Effect of particles size, weight ratio of LSO:CN, type of dye, scavenger kind, dye and catalyst loading was designated on altering proficiency of nano-catalyst

Fig. 11. EDX spectra of (a) pure LSO, different LSO/CN weight ratios of (b) 30:70, (c) 50:50 and (d) 70:30.

Fig. 12. (a) N₂ adsorption/desorption isotherms and (b) pore size distribution of LSO/CN nanocomposite with weight ratio of 30:70.
function. As a result, La$_2$Sn$_2$O$_7$/$g$-C$_3$N$_4$ nanocomposites with 30% La$_2$Sn$_2$O$_7$ nanoparticle (η=99%) have better efficiency than pristine La$_2$Sn$_2$O$_7$ nanoparticle (η=72%) and $g$-C$_3$N$_4$ specimen (η=91%). Moreover, the photocatalytic activity is completely performed in presence of more amount of nanocatalyst. Also, the probable mechanism of removal dye by photocatalytic function was studied using three types of scavengers of EDTA, Benzoic acid and benzoquinone to trap h$^+$, 'OH and 'O$_2$ active specimens, respectively. Finally, it is found that 'OH and 'O$_2$ radicals promote photo-degradation of dye.

**CRediT authorship contribution statement**

Zeinab Talebzadeh: Methodology, Investigation, Software, Formal analysis. Maryam Masjedi-Arani: Investigation, Writing – original draft, Writing - review & editing, Formal analysis. Omid Amiri: Visualization, Investigation, Software, Data curation. Masoud Salavati-Niasari: Visualization, Writing – original draft, Writing - review & editing, Validation, Investigation, Data curation, Conceptualization, Methodology, Supervision, Project administration.
Fig. 14. Photocatalytic performance and plots of ln(C/C₀) vs time of LSO nano-products for different (a), (b) dye solutions, (c) and (d) dye concentrations.

Fig. 15. Degradation percentage vs time of LSO nano-products in presence of three types of scavenger of benzoic acid, EDTA and Benzoquinone.
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.

Acknowledgment

Financial support from the Iran National Science Foundation (97017837) and University of Kashan, Grant No (159271/ZT1) is gradually acknowledged.

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