High-performance visible-light active Sr-doped porous LaFeO₃ semiconductor prepared via sol–gel method

Xi-Tao Yin, Hua Huang, Jie-Li Xie, Davoud Dastan, Jing Li, Ying Liu, Xiao-Ming Tan, Xiao-Chun Gao, Wahab Ali Shah and Xiao-Guang Ma

ABSTRACT
In this work, we have successfully fabricated Sr-doped porous LaFeO₃ samples via sol–gel method. The results reveal that Sr²⁺ cation is effectively doped into LaFeO₃ crystal lattice substituting La³⁺ cation. The visible light catalytic performance of the materials was evaluated by the degradation of 2,4-dichlorophenol (2,4-DCP) and Rhodamine B (RhB). The amount-optimized Sr-doped porous LaFeO₃ sample exhibited outstanding visible-light catalytic performance for the degradation of the model pollutants compared to the porous LaFeO₃ alone. The enhanced performance was accredited to the enlarged surface area, absorption extension via the surface states of the introduced Sr²⁺ below the conduction band bottom of LaFeO₃, and promoted charge carrier’s separation as confirmed by various experiments. Experiments of radical trapping reveal that -OH species are dominant intermediate oxidants involved in the oxidation of 2,4-DCP and RhB over the optimized sample. This research will provide new routes for environmental remediation based on the LaFeO₃ semiconductor.

1. Introduction
Water pollution has disturbed the equilibrium of melo- dious co-existence between living organisms and nature (1,2). In daily life, the toxic organic/inorganic by- products are released in industrial waste water and house sewage that could be efficiently degraded to protect the natural ecosystem (3,4). The most common and environmental hazardous pollutants include 2,4-DCP and RhB dye. These pollutants are highly toxic and carcinogenic, therefore enlisted by the United States Environmental Protection Agency (U.S. EPA) as a high-risk pollutant to be controlled (5,6). The commonly employed methods do not fulfil the requirement of efficient degradation of these pollutants (7). Thus it is necessary to replace the conventional techniques by advanced oxidation techniques.

Semiconductor photocatalytic technique has gained marvelous attention in the present decade due to its abundant virtues such as cost effective, non-toxicity, high chemical and thermal stability, and environmentally friendly nature (8,9). Different wide band gap semiconductors such as TiO₂ (10), ZnO (11), SnO₂ (12), and so on, have been widely used in photocatalysis for pollutants degradation due to their lower price, chemical/thermal stability, appropriate valence and conduction band potentials and low environmental impact. These semiconductors usually exhibit poor performance for pollutants degradation due to the limited solar energy consumption, i.e. ca. 4% (only UV range). To accomplish high performance for pollutants degradation, the use of narrow band gap semiconductors is highly recommended (13). The narrow band gap photocatalysts could absorb a wide range of solar spectrum that mainly comprises the visible light region.

Among the narrow band gap semiconductors, Lanthanum Ferrite (LaFeO₃) with general formula ABO₃ has received remarkable interest in photocatalysis due to its unique electronic structure (14). In LaFeO₃ oxide, La belongs to rare-earth elements while Fe belongs to the 3d transition metals. The presence of Fe element is very important because the catalytic processes depend upon redox behavior of Fe cation. Further, LaFeO₃ can probably
utilize visible light of solar spectrum because its band gap is only 2.0 eV (15). Nevertheless, the pollutant degradation performance of LaFeO₃ is still poor owing to the small specific surface area, short carrier diffusion lengths and the rapid recombination rate of charges (16).

To promote the photocatalytic performance of LaFeO₃, various modification strategies such as nanostructured fabrication (17), doping elements (18), semiconductors coupling (19) and creating pores (20) are widely employed. In various modification strategies, creating pores and doping elements are more beneficial because porous materials could provide more surface area for catalytic reactions and doping could extend the visible light response of nanomaterials. For example, Zhang et al. (21) fabricated mesoporous LaFeO₃ that exhibited enhanced catalytic activity for methyl chloride (CH₃Cl) combustion, which was accredited to the extremely large specific surface area due to porous morphology. In another work, Phan et al. (22) fabricated Cu-doped LaFeO₃ catalyst that showed high performance for decolorization of cation and anion dyes under visible light irradiation.

In present work, we have fabricated Sr-doped porous LaFeO₃ samples and explored their photocatalytic activities for organic pollutants degradation. So far, there have been no previous reports on the model pollutants, i.e. 2,4-DCP and RhB degradation over the Sr-doped porous LaFeO₃. Thus this work has a great scientific value in the field of photocatalytic environmental remediation. According to the experimental results, the optimized 1.5Sr-LaFeO₃ sample exhibited excellent catalytic performance for 2,4-DCP and RhB degradation under visible light. This research will provide new routes for the development of highly proficient visible light active LaFeO₃-based catalysts for environmental decontamination.

2. Experimental section

2.1. Chemicals

Analytical grade high purity chemical reagents were purchased and directly used in this research. The solvent deionized water was utilized throughout the experimentation.

2.2. Synthesis of porous LaFeO₃ and Sr-LaFeO₃ photocatalysts

To prepare porous LaFeO₃, an equimolar (0.02 mol) amount of Fe(NO₃)₃·9H₂O and La(NO₃)₃·6H₂O precursors was dissolved in a water/ethylene glycol (EG) solvent mixture (50/50 vol %) at room temperature. The solution was kept in ultrasonic bath for 30 min and then 100 nm size polystyrene (PS) spheres (size = 200 nm) were drenched in the solution under stirring for 6 h. The beaker-containing solution was put into the water bath and heated at 120 °C to get a gel, which was then dried at 85°C in an oven and annealed at 600°C (temp ramp 1°C min⁻¹) to get porous LaFeO₃. To prepare Sr-doped porous LaFeO₃, the same procedure was used except for Sr(NO₃)₂·H₂O precursor was used as a source of Sr. Porous LaFeO₃ samples containing different mass percentages of Sr (i.e. x = 0.5, 1, 1.5, 2%) were prepared.

2.3. Characterization of materials

The XRD pattern of the catalysts was determined via the Rigaku-D/Max-rA (XRD, made in Japan) powder diffractometer. Shimadzu UV-2550 Spectrophotometer was used for recording UV–visible diffuse reflectance spectra. The Fourier Transform Infrared (FTIR) spectra were measured with Thermo-Scientific Nicolet-1070 spectrometer equipped with ATR. JEOL-JEM-3010 electron microscope (made in Japan) was used for capturing TEM/HRTEM images. The BET isotherm curves were obtained with Micro-meritics ASAP-2020 M system. ST-2000 adsorption instrument was used BET surface area evaluation. The energy dispersive X-ray (EDX) spectra were obtained with the TEM-EDX. The XPS spectra were investigated using Al (mono) X-ray source with Kratos-Axis Ultra DLD. A PE-LS-55 spectro-fluoro-photometer with wavelength of 325 nm was used to obtain the photoluminescence (PL) spectra. Electrochemical impedance spectroscopy (EIS) spectra were measured via the Princeton Applied-Research, Versa, STAT-3 (f = 10⁻²–10⁻⁵ Hz) and 10 mV (RMS) amplitude was employed at 0.4 V potential vs. the Ag/AgCl electrode in Na₂SO₄ electrolyte (0.5 M L⁻¹). A high-power Xe lamp (300 W) with 420 nm cut-off wavelength was employed as a source of light. Electron paramagnetic resonance (EPR) spectra were measured with a Bruker D-200 instrument (IBM-Bruker) at room temperature.

2.4. Films preparation and photoelectrochemical analysis

For films preparation, following procedure was used. About, 20 mg of the sample powder was highly dispersed in 1 mL IPA (isopropyl alcohol) through ultrasonication for 20 min and then vigorously stirred for another 20 min. Then, 20 mg of polymer (Macrogol-(6000)) was highly grinded into fine powder and added to the dispersion. The dispersion was ultrasonically treated for 20 min and then stirred for another 20 min. Further, an appropriate volume of acetyl acetonate (i.e. 0.05 mL) was
added dropwise and kept under stirring for 72 h. After that, the paste was dropped onto the conductive side of a well-cleaned fluorine doped tin-oxide (FTO) glass already calcined at 400°C to prepare film. The film was dried and calcined at 500°C for 20 min. Finally, the FTO glass with film was cut into parts (i.e. 1.0 cm × 3.0 cm) having film surface area of 1.0 cm × 1.0 cm.

2.5. Pollutant degradation activity evaluation

A quartz cell was used for 2,4-DCP degradation activities. First, solution of 2,4-DCP (i.e. 10 mg L⁻¹ concentration) was prepared in a 1-L volume flask. For each experiment, a 60-mL solution of 2,4-DCP was taken in quartz cell and 100 mg catalyst powder was added to it. After stirring for 0.5 h in dark (i.e. adsorption/desorption equilibrium), the reactor was irradiated for 2 h under high power (300 W) Xe-lamp with 420 nm wavelength cut-off filter. Then, a desired amount was centrifuged and transferred to a quartz cell. The 2,4-DCP concentration was evaluated desired amount was centrifuged and transferred to a 60-mL solution of 2,4-DCP was taken in quartz cell and stirred for 30 min in dark (i.e. to accomplish adsorption equilibrium). Subsequently, a high power (300 W) Xe lamp with 420 nm cut-off filter was employed as an irradiation source and the reactor was kept under stirring and irradiated for 2 h. After a specific interval of time, the RhB concentration was analyzed at wavelength 553 nm, by taking appropriate amount of solution through a syringe, centrifuging and analyzing via the Shimadzu UV-2550 photometer.

2.6. Evaluation of hydroxyl radical (·OH)

50 mg catalyst powder was dispersed in 40 mL solution of coumarin (i.e. 10 mg L⁻¹) contained in a quartz cell to analyze hydroxyl radical amount. A high power (300 W) Xe-lamp with 420 nm cut-off lens was employed as irradiation source for 1 h under stirring. A proper volume was transferred to a Pyrex glass-cell and the hydroxyl radical amount was detected at 350 nm excitation wavelength via the coumarin fluorescence method.

3. Results and discussion

3.1 Structural morphology and composition

Figure 1(A) reveals the XRD pattern of porous LaFeO₃ and Sr-doped LaFeO₃ samples. The diffraction patterns of porous LaFeO₃ can be ascribed to the well-crystallized high purity orthorhombic phase (JCPDS No. 37-1493) (23). For Sr-doped LaFeO₃ samples, an obvious shift toward larger diffraction angle was observed as can be seen from Figure 1(B). It is demonstrated that the ionic radius of Sr²⁺ (1.44 Å) is slightly larger than that of La³⁺. Hence, the substitution of La³⁺ ion with Sr²⁺ results in the lattice distortion of LaFeO₃ (24). This proves that Sr cations are successfully doped into the porous LaFeO₃ crystal and substituted La cations. Figure 1(C) shows the UV–Visible absorption spectra of the catalysts. To estimate the energy bang gaps of porous LaFeO₃ and Sr-doped LaFeO₃ samples, Tauc plots were determined using Kubelka–Munk method (25). For porous LaFeO₃ sample, the estimated band gap was 2.09 eV (Figure 1D). The estimated band gaps for 0.5Sr-LaFeO₃, 1Sr-LaFeO₃, 1.5Sr-LaFeO₃, and 2Sr-LaFeO₃ samples were 2.06, 2.0, 1.91 and 1.79 eV, respectively. This clarifies that Sr doping has effectively reduced the band gap of porous LaFeO₃. Figure 2(A) shows the TEM image of porous LaFeO₃. As can be seen that porous LaFeO₃ exhibit crystallite size of around 100 nm and the pores can be observed. The selected area HRTEM image (Figure 2B) demonstrates that the fringes with d-spacing of 0.28 nm are attributed to LaFeO₃. The TEM image of 1.5Sr-LaFeO₃ sample (Figure 2C) reveals that the morphology of porous LaFeO₃ is slightly changed due to Sr-doping. This might be due to the lattice distortion of porous LaFeO₃. The lattice fringes can be seen in the selected area HRTEM image of 1.5Sr-LaFeO₃ sample (Figure 2D). The EDX spectrum of porous LaFeO₃ (Figure 2E) shows the presence of La, Fe and O element peaks, while that of the 1.5Sr-LaFeO₃ sample (Figure 2F) shows Sr, La, Fe and O element peaks. This shows the successful doping of Sr cation into the crystal lattice of porous LaFeO₃. The N₂ adsorption and desorption isotherm curves and the resultant pore size distribution curves of porous LaFeO₃ and 1.5Sr-LaFeO₃ samples are revealed in Figure 3. As clear, the sorption isotherm curves of LaFeO₃ and 1.5Sr-LaFeO₃ samples (Figure 3A) demonstrate hysteresis loops, which is the characteristic of porous materials (26). The Brunauer–Emmett–Teller (BET) surface area of porous LaFeO₃ was 28.56 m² g⁻¹. The average pore size of LaFeO₃ was about 14.56 nm (Figure 3B). The BET-specific surface area and average pore diameter of 1.5Sr-LaFeO₃ sample was 38.77 m² g⁻¹ and 12.64 nm, respectively. The decrease in pore diameter of 1.5Sr-LaFeO₃ may be due to the partial loss of structural order of porous LaFeO₃. To confirm the surface composition, Fourier Transform Infrared FTIR spectra of LaFeO₃ and the optimized 1.5Sr-LaFeO₃ samples were measured in the range 400–4000 cm⁻¹ as revealed in Figure S1. The broad peak at about 3450 cm⁻¹ is attributed to the O–H...
stretching vibration mode. The peak centered at 582 cm\(^{-1}\) is ascribed to the Fe-O stretching mode. Bands at 1370 and 1474 cm\(^{-1}\) can be assigned to the NO\(_3^-\) stretching mode. In 1.5Sr-LaFeO\(_3\) sample, the extra band at 859 cm\(^{-1}\) can be attributed to the Sr–O stretching mode. The chemical composition of porous LaFeO\(_3\) and 1.5Sr-LaFeO\(_3\) samples was determined with the help of X-ray photo-electron spectroscopy (XPS) technique. The XPS survey spectra determine that porous LaFeO\(_3\) contains peaks of La, Fe and O elements, while 1.5Sr-LaFeO\(_3\) sample contains peaks of Sr, La, Fe and O elements (Figure 4A). The La3d high-resolution XPS spectra of porous LaFeO\(_3\) and 1.5Sr-LaFeO\(_3\) samples are shown in Figure 4(B). The binding energies of La3d\(_{5/2}\) and La3d\(_{3/2}\) orbitals are respectively located at 833.83 and 850.74 eV, respectively, corresponding to the La cation 3\(^+\) oxidation state (27). As obvious, the binding energy peak of 1.5Sr-LaFeO\(_3\) sample is slightly shifted toward lower energy side. This confirms the partial substitution of La cations by Sr cations. The high-resolution Fe2p XPS spectra of porous LaFeO\(_3\) and 1.5Sr-LaFeO\(_3\) samples are revealed in Figure 4(C). The binding energy peaks of Fe2p\(_{3/2}\) and Fe2p\(_{1/2}\) orbitals are respectively located at 710.6 and 723.6 eV, corresponding to the Fe\(^{3+}\) oxidation state in porous LaFeO\(_3\) (28). The binding energy peaks of 1.5Sr-LaFeO\(_3\) sample are also slightly blue-shifted. The high-resolution O1s XPS spectra of porous LaFeO\(_3\) and 1.5Sr-LaFeO\(_3\) samples are shown in Figure 4(D). The O1s XPS spectra are broad and uneven, indicating two types of oxygen chemical states at binding energy values of 528.1 and 531.0 eV, assigned to the crystal lattice oxygen (OL) and the surface adsorbed oxygen (OA), respectively. The lattice oxygen (OL) corresponds to the La–O, and Fe–O bonds in the lattice of porous LaFeO\(_3\) (28). The binding energy peaks of Sr3d\(_{5/2}\) and Sr3d\(_{3/2}\) orbitals (Figure 4E) at 132.6 and 138.4 eV, respectively, are attributed to the +2-oxidation state of Sr cation (29).

### 3.2. Charge separation

Photoluminescence (PL) is a sensitive technique used to examine the structure and properties of active sites on
materials surfaces. Thus the PL technique is very helpful for understanding the surface phenomenon in semiconductor photocatalysis. In addition, the PL technique gives us evidence of the defects, oxygen vacancies, charge trapping, immigration and transfer. It is assumed that the PL response could mainly derive from the electronic transition, occurring from conduction bands to the valence bands of semiconductors. Higher the PL intensity of nanomaterials, charge recombination would be high, and vice versa (30). As obvious from Figure 5(A), the PL intensity of porous LaFeO₃ is very high. Principally, the PL intensity of Sr-doped LaFeO₃ samples is remarkably decreased and the lowest intensity was observed for the 1.5Sr-LaFeO₃ sample. This implies that charge recombination in the 1.5Sr-LaFeO₃ sample is drastically reduced. Generally, the photocurrent response of semiconductors could reveal an indication to the catalyst capability to produce and transfer the photo-induced charges indirectly, which greatly impacts the photocatalytic performance of catalysts. The photocurrent I–V curves of porous LaFeO₃ and Sr-doped porous LaFeO₃ electrodes under visible light are shown in Figure 5(B). Porous LaFeO₃ exhibited weak photocurrent density response, while for Sr-doped samples, it is quite obvious. The photocurrent density response of 1.5Sr-LaFeO₃ sample was remarkably improved suggesting the superior charge separation. The photocurrent I–t plots of the porous LaFeO₃ and Sr-doped porous LaFeO₃ electrodes under visible light are shown in Figure 5(C). As obvious, the porous LaFeO₃ showed a weak photocurrent response. However, enhancement in photocurrent was observed for Sr-doped porous LaFeO₃ samples. The highest photocurrent was observed for 1.5Sr-LaFeO₃ sample, which indicates fast charge transfer and highly efficient charge carriers separation through the 1.5Sr-LaFeO₃ electrode interface. This could drastically enhance the photo-activity for pollutants degradation. The effective charge separation in Sr-doped porous LaFeO₃ samples can be further verified by Nyquist plots. As revealed in Figure 5(D), the Nyquist arc radius of porous LaFeO₃ sample is quite large and it is strongly decreased in case of Sr-doped LaFeO₃ samples. The lowest arc radius was observed for 1.5Sr-LaFeO₃ sample, which further supports the suppression of charge carrier’s recombination. The PEC and EIS results well support the PL ones.

3.3. Visible light activities

The catalysts performance was appraised for photocatalytic degradation of 2,4-DCP for 2 h irradiation under visible light. The characteristic absorption spectra of 2,4-DCP and RhB after photocatalytic reaction in the presence of porous LaFeO₃ and Sr-doped porous LaFeO₃ samples were measured as provided in Figure S2 A and B, respectively. As clear from Figure 6(A), porous LaFeO₃ only degraded 34% of 2,4-DCP pollutant in 2 h. Worth noting, the degradation of 2,4-DCP over the Sr-doped samples was remarkably improved and
the optimized 1.5Sr-LaFeO₃ sample degraded 68% of 2,4-DCP pollutant. The catalysts performance was further appraised for Rhodamine B (RhB) degradation as shown in Figure 6(B). After stirring in dark for 30 min (i.e. adsorption equilibrium), the glass reactor was irradiated with visible light source and the desired volume of solution was collected at regular time interval (i.e. 30 min) for measuring the RhB concentration through UV–Visible spectrophotometer at 553 nm wavelength. The RhB degradation over Sr-doped LaFeO₃ samples is remarkably high compared to that of the porous LaFeO₃ sample. The highest activity was detected for 1.5Sr-LaFeO₃ sample (i.e. 71%) which fully supports the PEC, EIS and PL results. Thus, the improved photoactivities might be resulted from the enlarged specific-surface area due to porous morphology, enhanced light absorption and improved charge separation via doping Sr cations. The performance of our photocatalyst for pollutants degradation is better compared to those of the previous reports as mentioned in Table S1. Generally, it is believed that •OH is one of the most active intermediates involved various reactions with inorganic and organic molecules (31). To investigate the •OH formation, coumarin-fluorescence technique was employed to identify the •OH species amount produced by each sample during photocatalytic process. Figure 6(C) reveals that porous LaFeO₃ sample produced a small quantity of •OH as confirmed by the weak fluorescence intensity. However, the Sr-doped porous LaFeO₃ samples produced high quantity of •OH. Notably, the optimized 1.5Sr-LaFeO₃ sample produced significant quantity of •OH, which further suggests enhanced charge separation.

In photocatalysis, it is important to recognize the main oxidant species involved in the degradation of pollutants. In aqueous media, the photoinduced holes (h⁺), superoxide radical species (O₂⁻) and hydroxyl radical species (•OH) are important intermediates concerned with the degradation of organic pollutants. Commonly, ethylenediaminetetraacetic acid disodium salt (EDTA-2Na), para-Benzoquinone (BQ), and isopropyl alcohol (IPA) scavengers are used as trapping agents to capture the photo-generated h⁺, O₂⁻ and •OH during photocatalytic processes (32,33). These scavengers were used to prove which specie is governing in the oxidation of 2,4-DCP and RhB pollutants. The experiments were completed under the same conditions with the aid of scavengers. As can be seen in Figure 6(D), without adding scavengers, the 2,4-DCP and RhB degradation was decreased up to some extent in the existence of EDTA-2Na and BQ scavengers. Interestingly, it was strongly inhibited in the aid of IPA scavenger. These results demonstrate that •OH species are involved as dominant intermediates in the degradation process over the 1.5Sr-LaFeO₃ sample. To further confirm the scavenger’s trapping experiments, electron paramagnetic resonance (EPR) analysis was carried out to detect the reactive intermediates during photocatalysis. The trapping agent 5,5-Dimethyl-L-pyrroline N-oxide was employed to trap the active intermediates. As clear from Figure S3, the EPR peaks of •OH intermediate are detected after photocatalysis for 5 and 15 min in the presence of 1.5Sr-LaFeO₃ photocatalyst. This further confirms that •OH is the active intermediate involved in the degradation of pollutants over the Sr-doped LaFeO₃ photocatalyst.

The stability of the sample is an important parameter for evaluating its photocatalytic performance. Therefore,
the stability of 1.5Sr-LaFeO₃ sample was appraised for degradation of 2,4-DCP and RhB, by repeating the reaction 04-times (each of 3 h). As clear from Figure 6(E, F), the degradation of 2,4-DCP and RhB over the 1.5Sr-LaFeO₃ sample changes little, and even 66% and 70% of 2,4-DCP and RhB pollutants were degraded after recycling four times. This clarifies that the 1.5Sr-LaFeO₃ sample exhibit high stability during photocatalytic processes. To further confirm the stability of the optimized 1.5Sr-LaFeO₃ catalyst, the XRD and SEM analysis was carried out as provided in Figures S4 and S5. The structure and morphology of the catalyst before and after the

Figure 4. XPS survey spectra (A), La3d high resolution XPS (B), Fe2p high resolution XPS (C), and O1s high resolution XPS (D) of porous LaFeO₃ and 1.5Sr-LaFeO₃ samples. Sr3d high resolution XPS (E) of 1.5Sr-LaFeO₃ sample.
catalytic reaction is almost the same. This further confirms that the as-prepared 0.15Sr-LaFeO₃ photocatalyst is highly stable.

3.4. Mechanism

According to the Tauc’s plot of Kubelka–Munk method, the band gaps of porous LaFeO₃ and 1.5Sr-LaFeO₃ catalysts were respectively predicted to be 2.09 and 1.91 eV. Therefore, it is important to investigate the mechanism of pollutants degradation over 1.5Sr-LaFeO₃ sample under visible light irradiation. To confirm that Sr dopant has introduced surface states near conduction or valence band of porous LaFeO₃, XPS valence band spectra of porous LaFeO₃ and 1.5Sr-LaFeO₃ samples were measured. As obvious from Figure S6, the valence bands of the both samples were located at 2.4 V, which means that Sr dopant introduced surface states exists close to the bottom of the conduction band of porous LaFeO₃. Thus, the Sr introduced new energy levels near the bottom of the conduction band of porous LaFeO₃ has notably reduced its band gap to 1.91 eV. As the valence band potential and band gap energy values are known, thus the conduction band values can be calculated by using the equations as follows (34,35):

\[ E_{(VB)} = E_{CB} + E_g \]  

\[ X = [X(A)^aX(B)^bX(C)^cX(D)^d]^{1/a+b+c+d} \]

Herein, \( E_{VB} \) denotes valence band potential value, \( E_{CB} \) denotes conduction band potential value, \( \chi \) denotes the absolute electronegativity, \( a, b, c, d \) denote atomic number of the compounds, \( E_g \) represents band gap energy of the catalysts, and \( E_e \) is the free electron energy vs the H₂ electrode (4.5 V). Thus the conduction band values of porous LaFeO₃ and 1.5Sr-LaFeO₃ catalysts were predicted to be 0.4 and 0.49 V, respectively, as depicted in Figure 7. Thus the visible light irradiation upon interaction with the surface of 1.5Sr-LaFeO₃ catalyst will initiate the photo-catalytic reactions by
absorbing light energy (hv) equal to, or greater than its respective band gap energy. This will lead to the generation of charge carriers. The excited electron will transfer from the valence band of 1.5Sr-LaFeO₃ to its conduction band, meanwhile the holes will remain in its valence band. The photo-induced holes in its valence band would be trapped by the surface hydroxyl groups (OH-) of the photocatalyst and generate -OH, which are very efficient in pollutant degradation. The excited electrons in the CB would react with the adsorbed surface oxygen and produce superoxide anion radicals. The photoinduced valence band holes also directly contribute to the degradation. The scavengers-trapping experiments revealed that -OH species are the dominant reaction intermediate involved in pollutant degradation. From the experimental results, it is concluded that the

Figure 6. Photocatalytic activity for 2,4-DCP degradation (A), photocatalytic activity for RhB degradation (B), and -OH-related fluorescence spectra (C) of porous LaFeO₃ and xSr-LaFeO₃ samples. Scavenger trapping experiments for 2,4-DCP and RhB degradation (D), photocatalytic stability test for 2,4-DCP (E) and photocatalytic stability test for RhB (F) over 1.5Sr-LaFeO₃ sample.
activity enhancement of the catalysts is related to the enlarged surface area due to porous morphology and band gap narrowing due to the Sr introduced surface states in porous LaFeO3.

4. Conclusion

In this work, Sr-doped porous LaFeO3 samples are prepared via sol–gel method. The results reveal that Sr2+ cation is successfully doped into the lattice of LaFeO3 and substituted La3+ cation. The optimized 1.5Sr-LaFeO3 sample exhibited excellent visible light catalytic activities for RhB and 2,4-DCP degradation compared to the porous LaFeO3. Radical trapping experiments reveal that -OH species are the dominant reactive intermediates involved in the degradation of RhB and 2,4-DCP pollutant over the optimized 1.5Sr-LaFeO3 sample. The newly designed work will open new directions for the fabrication of LaFeO3-based high-performance catalysts for environmental remediation.

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Disclosure statement

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ORCID

Xi-Tao Yin http://orcid.org/0000-0003-0991-8128

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