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UV-vis light endeavoring decomposition of organic pollutant using $Si_{0.9}Re_{0.1}O_2$ novel developed photo-catalyst

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ABSTRACT

Efficiency of the newly developed photo-catalyst ($Si_{0.9}Re_{0.1}O_2$) was studied by observing the decomposition of organic pollutant (Methylene Blue, MB) under UV-vis light. The photo-catalyst was prepared by hydrothermal process. The newly developed catalyst was characterized by using various techniques, for example, X-ray diffraction, scanning electron microscopy, Brunauer–Emmett–Teller and energy dispersive X-ray. The results showed an enhancement in the output for the deprivation of aqueous solution of MB. From the results obtained, it is claimed that the developed photo-catalyst may have numerous uses in several progressive fields.

Keywords: Photo-catalyst; Hydrothermal process; Aqueous solution; Methylene blue

1. Introduction

Wastewater and toxic pollutants produced from various industries especially textile industries that use dyes to color their products have become a serious issue for the environment. A strenuous study is obligatory to cultivate innovative and the most active photo-catalytic ingredients that can help the society to improve the standard of living. The intensifying reliance on skill of our living style/standard needs further approaching submissions in innovative technologies, for example, clean energy production, water and air purification. Innovative and the most effective photo-catalytic materials with various qualities such as harmlessness, comparatively cost-effective, chemically stable, anti-corrosive features and promising optoelectronic properties are only the solution of various environmental related issues [1–9].

Mesoporous SiO_2 (2–50 nm) with high surface area has various qualities such as a very clear pore shape that was observed as hexagonal, fine dissemination of pore size, insignificant pore blocking, a significant pore ordering, exceptional sorption capacity, and comfort of alteration of surface characteristics, good chemical and mechanical stability [10]. SiO_2 was selected for the support, where Re has been doped.

Photo-catalysis plays a key part in the advanced oxidation process and it can be expected to solve both energy and environmental concerns through degrading the organic pollutants and splitting water [11]. Advanced oxidation processes have been developed and implicated for organic pollutant degradation, especially, semiconductor photo-catalytic technology can remove and degrade organic pollutants by photo-catalytic reaction driven by solar energy, which has been considered as a promising technology for environmental purification because of the advantages such as high efficiency and environmental friendliness [12].

In this study, metal Re was doped on developed support SiO_2 using thermal process. Re doped on high surface mesoporous SiO_2 has momentous effects on the photo-catalytic activity. In this paper, we reported Re-doped SiO_2

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($Si_{0.9}Re_{0.1}O_2$) photo-catalyst for testing the efficiency of the developed photo-catalyst for the decomposition of organic pollutant (MB) under UV-vis light.

2. Experimental setup

To develop $Si_{0.9}Re_{0.1}O_2$ photo-catalyst, tetraethyl orthosilicate reagent grade, tetraethyl orthosilicate reagent grade, 98%, *n*-butanol, pluronic-P-123, rhenium oxide, HCl (35%) were purchased from Sigma-Aldrich and used as in the proper stoichiometric ratios for hydrothermal method. Since the structure of SiO_2 is hexagonal, the role of P-123 is important because it controls the structure of SiO_2.

$Si_{0.9}Re_{0.1}O_2$ (1 wt. %) photo-catalyst was developed using hydrothermal process. To prepare the novel photo-catalyst, 6 g of P-123 was melted in 218 mL of deionized water and 7.92 mL HCl solution (35%) at 35°C. After complete dissolution, 7.41 mL of *n*-butanol was added followed by the stirring of 1 h at 35°C. After that 14.85 mL TEOS and 1.54 g of rhenium oxide was inserted into the prepared mixture following stirring for more 24 h at 35°C. Afterward the mixture was thermally treated for 24 h at 100°C. The slurry was filtered and dried at 100°C the whole night. The calcination was continued at 550°C for 5 h. A detailed procedure is displayed in Fig. 1.

The developed catalyst was characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive X-ray (EDX) and Brunauer–Emmett–Teller. These characterization tools were used to confirm the crystal structure, morphology and surface area.

To confirm the efficiency of the developed photo-catalyst, MB was selected as the organic pollutant. For this purpose, photo-reactor (as shown in Fig. 2) equipped with UV-vis light (generates energy at 185 nm, which is particularly effective in producing ozone) was used. The detailed process can be noted somewhere else [4,9].

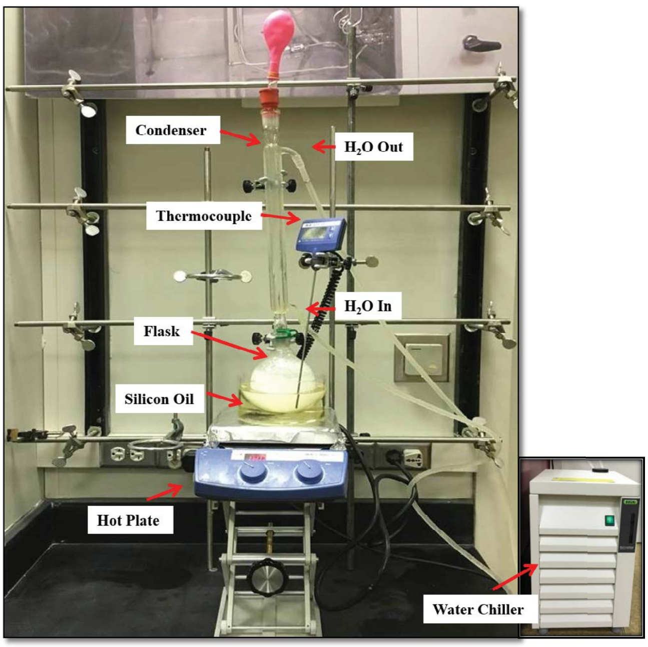

Fig. 1. Flow sheet diagram of the photo-catalyst developing process.

3. Results and discussion

Fig. 3 displays XRD analysis of the developed photo-catalyst and the position of peaks are with the reflection of SiO_2 crystal arrangement. The distinctive peaks at $2\theta = 2.50°$ and 22.50° are observed in SiO_2 samples.

Surface area (m^2/g), pore volume (cm^3/g) and average pore size (nm) of $Si_{0.9}Re_{0.1}O_2$ photo-catalyst are summarized in Table 1.

Pore volume and size were deliberate from adsorption–desorption isotherms as shown in Fig. 4. This is obvious from Table 1 that Re particle size detention has a prominent.

Particle morphology of as-developed $Si_{0.9}Re_{0.1}O_2$ photo-catalyst is obvious from the SEM images (Fig. 5). Based on these SEM images, the reduction in the size of particle was observed.

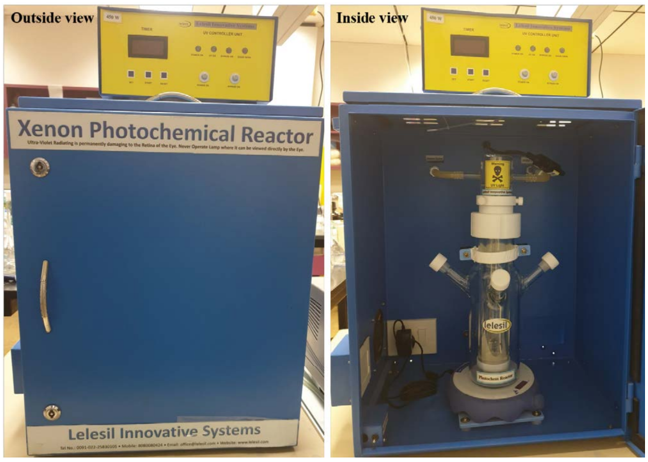

Fig. 2. Setup of photo-reactor for dye degradation.

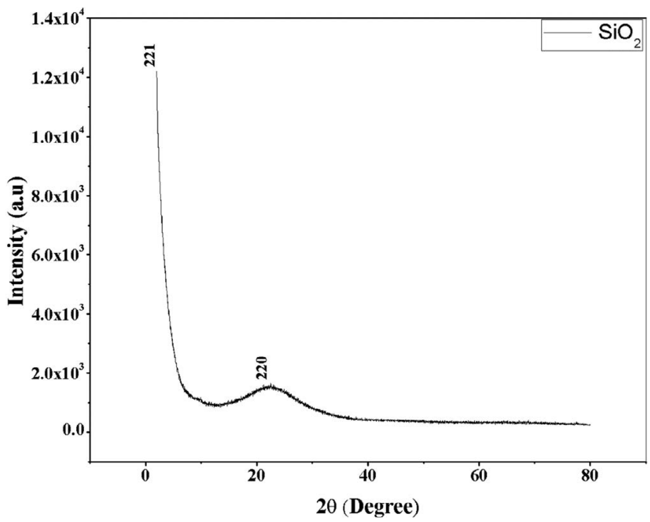

Fig. 3. XRD patterns of SiO_2 support.

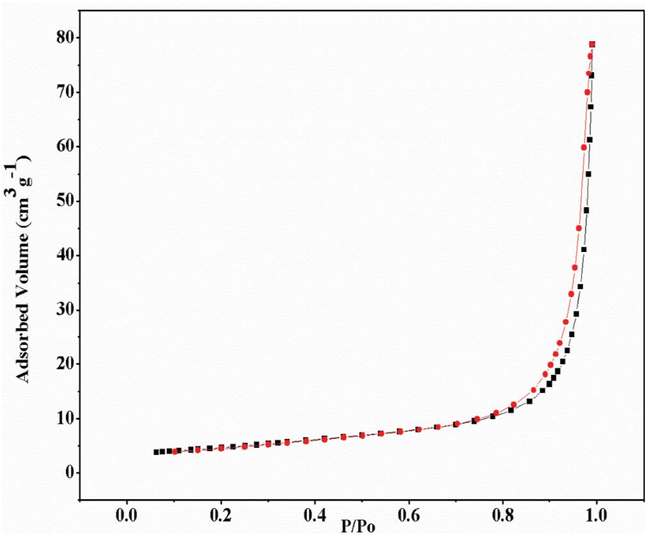

Fig. 4. BET-N_2 adsorption–desorption isotherms for SiO_2.

Table 1
BET analysis of newly developed $Si_{0.9}Re_{0.1}O_2$ photo-catalyst

Samples	Surface area (m^2/g)	Pore volume (cm^3/g)	Average pore size (nm)
SiO_2	814	0.37	31.51
$Si_{0.9}Re_{0.1}O_2$	813	0.35	31.42

BET: Brunauer–Emmett–Teller.

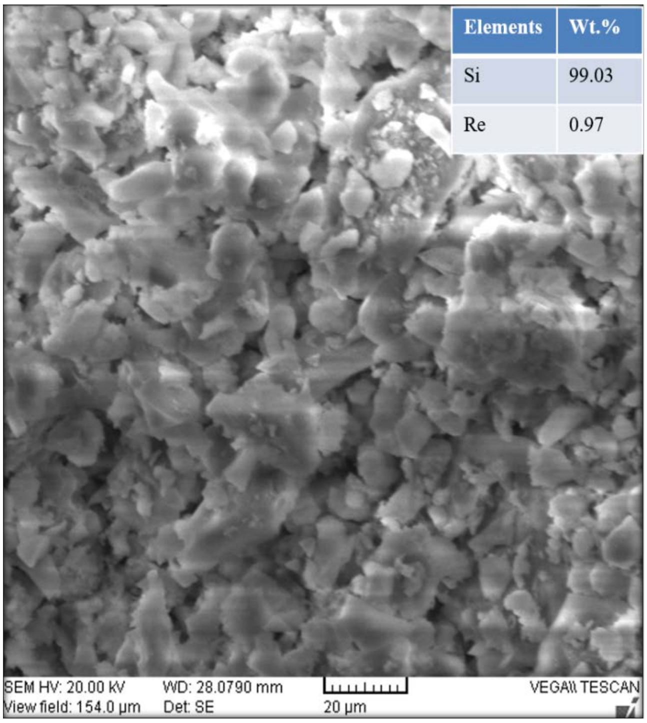

Fig. 5. SEM micrographs of $Si_{0.9}Re_{0.1}O_2$ photo-catalyst.

Moreover, the EDX observation clarify the existence of Re and further elemental ingredients of the samples, for example, Si and O as displayed in the inset of Fig. 5.

3.1. Photo-catalytic performance

Fig. 6 displays the peaks of the degraded solution of dye under UV-vis light with time range from 0 to 240 min. The photo-catalytic activity of $Si_{0.9}Re_{0.1}O_2$ photo-catalyst was conducted by the degradation of MB as the model of pollutants in aqueous solution at ambient temperature.

It is obvious that the MB absorption and irradiation time was directly proportional. The minimum degradation was noted after enlightening the solution for 240 min under UV-vis light. For $Si_{0.9}Re_{0.1}O_2$ photo-catalyst, the MB displayed an encouraging degradation under UV-vis light, as displayed in Fig. 6. Since the $Si_{0.9}Re_{0.1}O_2$ accelerate the transport of photo-generated electrons and which in result showed very good effect on the MB degradation.

The optimal 240 min was the highest photo-catalytic activity as compared with that of pure 0 min. Moreover, the decreasing absorption spectrum degraded MB was shown in Fig. 6 (from 0 to 240 min), which revealed that the molecular structure of pure MB was gradually destroyed under visible light irradiation. The effect of UV on concentration comparison with time (0, 120 and 240 min) was shown in the inset of Fig. 6. The figure exhibits the corresponding apparent degradation rate constants of pristine sample.

4. Conclusions

A novel developed photo-catalyst ($Si_{0.9}Re_{0.1}O_2$) was used for the decomposition of organic pollutant (Methylene Blue, MB) under UV-vis light. The obtained results revealed that the quality of $Si_{0.9}Re_{0.1}O_2$ photo-catalyst was significantly high. The specific surface area of the $Si_{0.9}Re_{0.1}O_2$ photo-catalyst was high. The results showed an enhancement in the output for the deprivation of aqueous solution of MB. From the results obtained, it may be claimed that the developed photo-catalyst may have numerous uses in several progressive fields.

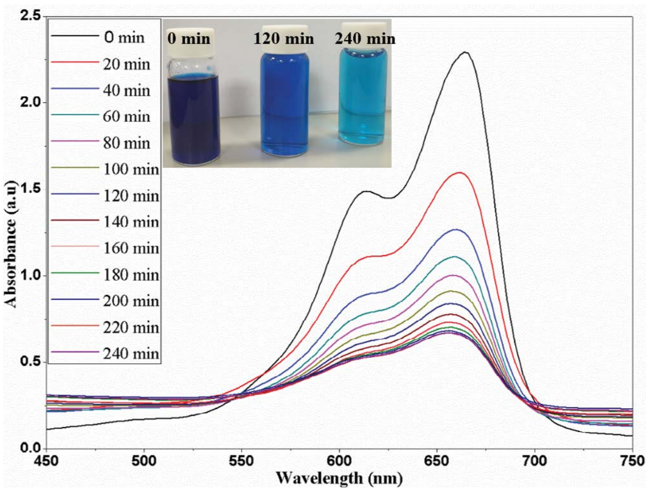

Fig. 6. UV–vis absorption spectra of $Si_{0.9}Re_{0.1}O_2$ photo-catalyst.

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