International Journal of Chemical and Physical Sciences, ISSN:2319-6602
IJCPS Vol. 4 Special Issue ETP – 2015
www.ijcps.org

Solar Photocatalytic Activity of Hydrothermal treated P25 TiO_2 Powder

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Abstract

The TiO_2 has a large scale application in paint, pigment, solar cell, photocatalyst, environment purification application etc. The commercial available P25- TiO_2 degussa powder was used in our work. The P25 TiO_2 powder was treated in hydrothermal reaction with DI water. The reaction temperature was set at 180 ^0C for 15 hour. The synthesized P25 powder was characterized by FESEM for the morphological study. The optical properties of commercial (P25) and synthesized P25 powder were evaluated by UV-Visible absorbance spectrophotometer. The photocatalytic activity of synthesized powder was studied under sun light containing 5 % UV light in region 300 – 400 nm and its photocatalytic activity was compared with commercial available P25-TiO_2 powder. The photocatalytic activity for hydrothermal treated P25 powder found to be enhancing in sun light.

Keywords: Hydrothermal; TiO_2-P25; Solar photocatalysis; Dye degradation.

Introduction

The industrial wastewater is major problem in all over the world. The municipal waste water is low toxic as compared to industrial waste water. It has a large concentration of toxic and non-biodegradable pollutants such as fats, oil, organic dye etc. The organic dyes are mostly used in textile, dying and pharmaceutical industries. The organic dyes are toxic in nature and they cannot be easily degraded by available waste water treatment plants [1]. The available techniques such as filtration, biodegradation, activated carbon etc. have high cost and disposal problem [2]. The advance oxidation process is suitable for the degradation of large range of organic compound using semiconductor photocatalyst and UV light. The semiconductor photocatalyst TiO_2 mostly is used due to its, cost effective, non-toxicity, long-term stability and high stability against photocorrosion [3]. The TiO_2 (P25) degussa contain anatase and rutile phases and it has a good photocatalytic activity. Kontos et al. [4] reported that photocatalytic activity of TiO_2 thin film can be enhanced by hydrothermal treatment of TiO_2 (P25). The photocatalytic activity of TiO_2 (P25) was enhanced by different calcinations treatment and its photocatalytic activity enhanced by two times in comparison with P25 powder [5]. The use of solar light for the degradation of organic compound is economical approach as compared to UV based system. In this paper, P25 powder was hydrothermally treated in deionised (DI) water at specific reaction temperature and time. The photocatalytic activity of hydrothermal treated P25 and non-treated powder were studied under the sun light.

Experimental Work

Powder preparation

In a typical experiment TiO_2 (P25) powder 0.4 gm was taken in a 170 ml DI water. This solution was stirred for few minute to form a homogenous solution. This solution then transfer into a 250 ml Teflon liner stainless steel autoclave. The reaction temperature was set at 180 ^{0}C for 15 h duration. After completion of reaction the hydrothermal system cooled to a room temperature. The powder were collected by centrifugation and dried in an oven for 60 ^{0}C for 10 h duration.

Photocatalytic studies

In this experiment, methylene blue stock solution was prepared with DI water. The small amount ~ 5 mg of photocatalyst was added in this 70 ml solution. The solution was kept in dark condition to achieved adsorption desorption equilibrium for one hour. The photocatalytic activity was performed in sun light at open atmosphere on the roof of college building. The sunlight focused by using lens on the borosilicate glass beaker containing solution. The sample was collected for a specific period of time. The photocatalytic degradation of methylene blue was examined by using UV-visible spectrophotometer.

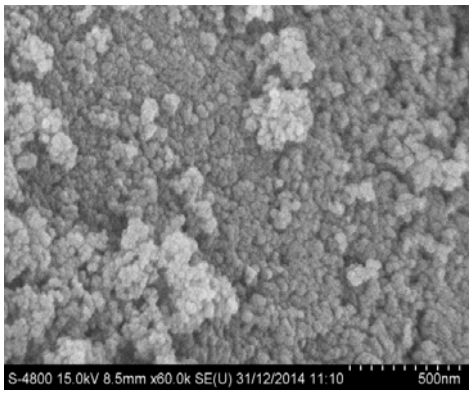
Results and Discussions

Morphological studies

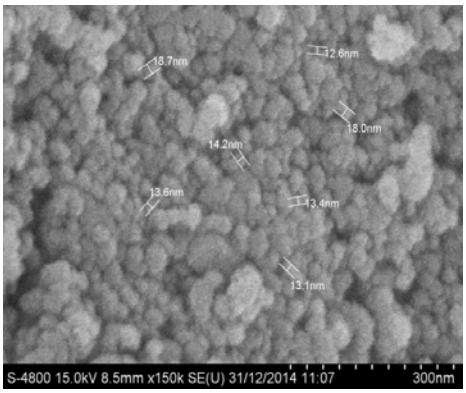
The hydrothermal treated P25-TiO_2 powder morphology was studied by using FESEM. The FESEM characterization was done by using Hitachi S - 4800 Type-II field emission scanning electron microscope. The Figure 1 (a) shows SEM image of synthesized TiO_2 (P25) powder and Figure 1 (b) shows magnified image with size notation. It indicates that crystallite size has not change in overall hydrothermal treatment and the particles are agglomerated. The particle sizes are in the range of 10 - 20 nm. The particle agglomeration may be due to the change in surface properties of the TiO_2 crystals.

Optical properties

The UV-Visible spectroscopy study reveals absorption spectra of TiO_2 (P25) powder.



(a)



(b)

Figure 1. SEM images of hydrothermally treated P25 powder (a) and (b) magnified image

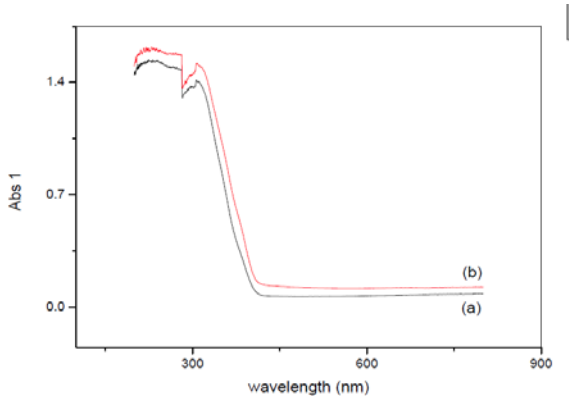


Figure 2. UV - visible absorption spectra of both TiO_2 powders
(a) non-treated and (b) hydrothermally treated

The Figure 2 shows that UV-Visible absorption spectra of both TiO_2 powder. The absorbance of hydrothermally treated TiO_2 is slightly increased in the visible region. The energy band gap of these TiO_2 powders are in the range of 3.1 eV to 3.4 eV. It means the powder can absorb more photons and it responsible for enhancing photocatalytic activity.

Photocatalytic degradation studies

The photocatalytic degradation of methylene blue (MB) was compared with P25 TiO_2 and hydrothermally treated P25 TiO_2 powders. The absorbance peak of methylene blue was 664 nm. The decrease of the absorbance peak of a solution indicates degradation of methylene blue. The Figure 3 shows absorption spectra of methylene blue (MB) solution with different time interval over the P25 powder. The Figure 4 shows absorption spectra of methylene blue (MB) solution with different time interval over hydrothermally treated P25 powder.

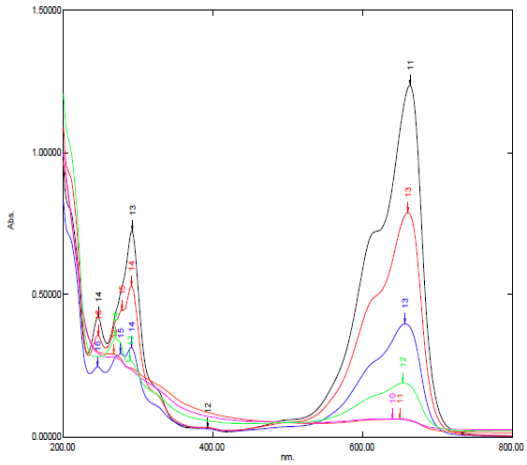


Figure 3. Absorption spectra for degradation of MB using P25 powder

The degradation efficiency of hydrothermally treated P25 was higher than non-hydrothermally treated P25. For methylene blue solution after the reaction of 1 hour, there is no characteristic peak observed in Figure 4. The irradiation time is less as compared to the absorbance spectra of Figure 3 non-hydrothermally treated P25. The photocatalytic activity enhanced after hydrothermal treatment of TiO_2 powder is due to increasing hydroxyl group of rutile TiO_2 surface. The hydroxyl group on the surface of rutile reduces a recombination rate of electron and hole and presence of anatase phase causes an increase in photocatalytic activity [6].

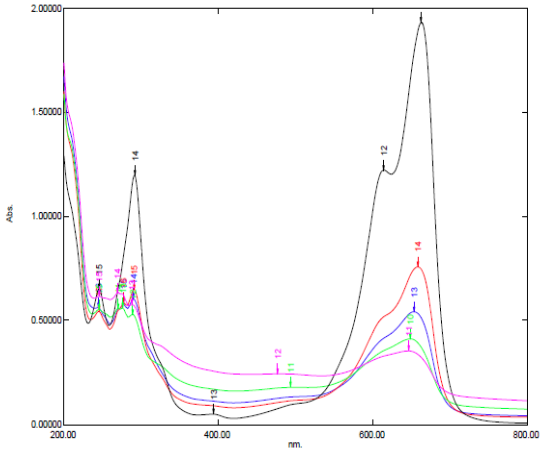
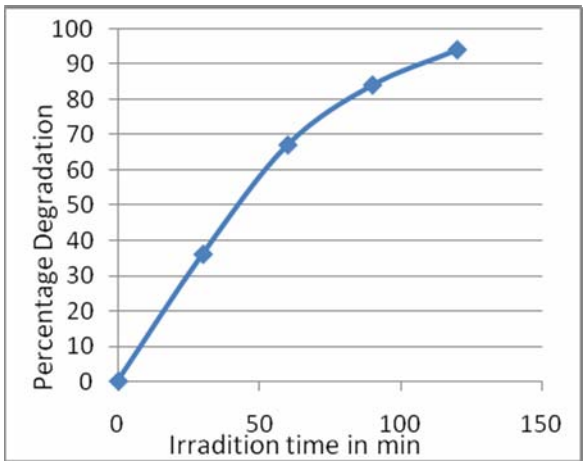
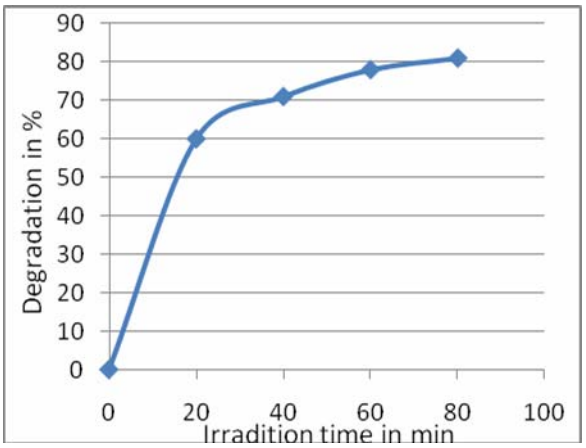


Figure 4. Absorption spectra for degradation of degradation of MB using hydrothermally treated P25 powder

The percentage degradation efficiencies of both powders are given below in Figures 4 and 5.



(a) MB using P25 powder



(b) MB using hydrothermally treated P25 powder

Figure 5. Percentage degradation

It shows percentage degradation of hydrothermally treated P25 is higher. It takes a less time for irradiation and MB solution degraded 81 % in 80 min. as shown in figure 5. The percentage degradation was calculated by using formula,

$$\%(= \ (A_i0 - A_it)/A_i0 \quad \text{--- (1)}$$

where, A_0 = Initial absorbance and A_t = absorbance after time t

Conclusions

Hydrothermally treated P25 shows higher photocatalytic activity as compared to original P25 powder in the sunlight. The sunlight contains 5 % UV light in the range of 300 -400 nm. The hydrothermally treated P25 powder rutile phase shows higher photocatalytic activity due to the increases in hydroxyl group.

Acknowledgement

The authors are thankful to management of R. C. Patel Education Society, Shirpur for providing research facilities.

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