SURFACTANT-ASSISTED IMMOBILIZATION OF TiO_2 ONTO GLASS SUBSTRATES FOR PHOTOCATALYTIC DEGRADATION OF MATHYLENE BLUE

E.G. Mariquit[1], W. Kurniawan[1], H. Hinode[1] , C. Salim[2]

[1]Department of International Development Engineering, Tokyo Institute of Technology, Meguro, Tokyo, Japan
Email: mariquit.e.ab@m.titech.ac.jp
[2]Department of Environmental Engineering, Surya University, Banten, Indonesia

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Abstract

Titanium dioxide-based photocatalysis is a type of advanced oxidation process that can be used to completely degrade and mineralize organic pollutants. The semiconductor titanium dioxide (TiO_2) is used as a photocatalyst and is activated when it absorbs photon energy equal or greater than its band gap energy. The activation of TiO_2 as a photocatalyst leads to the formation of active sites on its surface that can trigger series of oxidative-reductive reactions to mineralize the pollutants. In most cases, TiO_2 is commonly used in slurry form and the recovery of the catalyst after water treatment often requires another separate process.

To address this concern, TiO_2 photocatalyst have been immobilized on the surface of soda borosilicate glass slides with the aid of a commercial non-ionic surfactant, under the trade name Triton X-100. The TiO_2 thin film was prepared using sol-gel process and immobilized on the glass surface at different number of coatings using the dip coating technique. The TiO_2 thin films were characterized using FE-SEM, XRD and TGA and its photocatalytic activities were tested in the degradation of a model organic pollutant, methylene blue (MB).

Characterization of the prepared samples by XRD showed that TiO_2 in the form of anatase was successfully deposited on the glass slides. The addition of surfactant created thicker TiO_2 thin films that showed better performance during photocatalytic activity test. The result of the activity tests showed that the TiO_2 on the glass slide was able to degrade MB and the number of times that TiO_2 was coated on the glass slide also affected the rate of MB degradation.

Keywords: Dip-Coating, Surfactant, TiO_2 Immobilization, TiO_2 Sol-Gel

Introduction

Titanium dioxide is a known photocatalyst and is often employed in advance oxidation processes for the complete degradation and mineralization of organic pollutants. The destruction of the organic pollutant on the surface of the TiO_2 photocatalyst is usually brought about by the series of oxidative-reductive reactions on the surface of the TiO_2 initiated by the generation of electron-hole pairs when the semiconductor TiO_2 absorbs energy equal or greater than its band gap energy. The energy is usually supplied by a UV light source. In the UV-TiO_2 system, TiO_2 is commonly used in slurry form. Even though the use of TiO_2 in slurry form is very effective in pollutant degradation in water, post treatment recovery of TiO_2 powder poses a problem because it entails a separate process for the sole purpose of recovering TiO_2 catalyst.

Researchers have studied different ways to immobilize TiO_2 photocatalyst so that post-treatment recovery of the catalyst will be easier. In our study, TiO_2 photocatalyst have been immobilized on the surface of soda borosilicate glass with the help of a non-ionic surfactant, Triton X-100. Surfactants or polymer templating technique has been applied in the sol-gel process to prepare mesoporous TiO_2 thin films. It was reported by some researches such as Chen et al. (2008) that surfactants are potential structure directing agents that can improve the transparency and photocatalytic activity of the TiO_2 films. The deposited TiO_2 films were tested in a photocatalytic degradation of a model organic pollutant, methylene blue (MB), a cationic dye.

Materials and Methods

Chemicals

Titanium tetraisopropoxide, min. 95.0% purity, acetic acid, min. 99.9%, ethanol (ethyl alcohol), 99.5%, and 1 N nitric acid solution, 99.8%, all from Wako Chemicals were used as received in the experiments. Laboratory-grade Triton X-100 from Sigma Aldrich was used as the surfactant. Methylene blue C.I. 52015 from Merck Chemicals was used in the test of the catalyst activity. The procedure to immobilize TiO_2 onto glass slides was outlined in the following section.

Preparation of TiO_2 Thin Films

The thin film was prepared using sol-gel process and immobilized on the glass surface using dip coating technique. Titanium tetraisopropoxide, acetic acid and ethanol were combined to make the TiO_2 sol that was used as the dipping solution. Borosilicate microscope slides were used as the glass substrate. The surfactant, Triton X-100, at 10 mol% with respect to TiO_2, was also added to aid in the dispersion and immobilization of TiO_2 onto the microscope slides. The dipped glass slides were calcined at 450 deg C. for 1 hour. The number of coatings was varied to one, three and six coatings of TiO_2 thin film deposited on glass slides and labeled TX101, TX103, and TX106, respectively. For comparison NS6 or a sample with six coatings of TiO_2 film without surfactant was also prepared. All of the films that were produced were transparent even after undergoing numerous dip-calcine cycles.

Photocatalytic Activity Test

In the photocatalytic activity testing of the thin films, TiO_2 glass slides were dipped in 10 ppm solution of methylene blue. An area of approximately 0.135 cm^2 of the TiO_2 thin film was in contact per ml of MB solution, and irradiated using 15 W UV lamps with peak wavelength at 360 nm. The activity of the TiO_2 immobilized without surfactant and the film that was immobilized using Triton X-100 are compared. A blank, consisting of methylene blue solution only exposed to UV light was included as a control. The methylene blue was allowed to be adsorbed on the glass slides for 30 minutes before turning on the UV lamp. Samples were taken every hour and the absorbance of MB solution at 665 nm were analyzed using UV-Vis spectrophotometer (UV 1800, Shimadzu Corp., Japan)

Results and Discussion

Characterization of TiO_2 Thin Film

FE-SEM Images

The morphology, surface structure, and thickness of the films were studied using FE-SEM. Fig.1 shows the difference between the morphology of the TiO_2 films that was deposited with surfactant Triton X-100 (TX106) compared to the other that did not use the surfactant (NS6). Both of the films underwent dip-calcine cycles until TiO_2 layer reaches six. When surfactant was added, the characteristic of the TiO_2 film surface changed, creating a patterned surface compared to the relatively smooth and fine surface of the TiO_2 film that was immobilized without the surfactant.