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Development of Buoyant Photocatalyst Ball Using Expanded Polypropylene(EPP) and Titanium Dioxide(TiO_2)

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***Abstract*—In this study, immobilization of TiO_2 powder to EPP ball with controlled-temperature melting method was developed. The photo activity of buoyant photocatalysts was evaluated using methylene blue solution under visible light irradiation(>420 nm). Based on the associated EDS analysis, the components of uncoated EPP balls are carbon and oxygen whereas those of TiO_2-coated EPP balls are carbon, oxygen, and titanium, indicating that patches of TiO_2 coating cover some part of EPP balls. Based on comparison of degradation efficiency between uncoated and TiO_2-coated EPP balls under UV illumination, the degradation efficiency can be significantly improved using TiO_2-coated EPP balls, and surface reactions in heterogeneous photocatalysis were more dominant than photo-induced radical reactions in aqueous solutions. Thus, TiO_2-coated EPP balls were found to be an effective photocatalyst for photodegradation of MB in aqueous solutions. Therefore, buoyant TiO_2-coated EPP balls can be used to treat contaminated surface water on site.**

***Keywords*—Expanded polypropylene(EPP), TiO_2, Buoyant photocatalyst ball**

I. Introduction

Over traditional water treatment processes, heterogeneous photocatalytic oxidation processes using semiconductor particles such as titanium dioxide (TiO_2)-based materials and other oxides (e.g., ZnO, Cu_2O, WO_3, V_2O_5, α-Fe_2O_3, Bi_2O_3 etc.) have been found to be a promising solution to remediate the water resources[1,2].

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However, heterogeneous photocatalytic oxidation processes cannot be applied to purify the river water since significant amount of expensive TiO_2 powder with filtration and recovery processes should be applied. Therefore, a potentially more practical approach to coat TiO_2 powder with expanded polypropylene (EPP) ball was developed in this study. EPP has been used extensively in shock-absorbing packing materials and specialized components industries, and EPP has also several other advantages such as good flexibility, greater resistance to mechanical fatigue and chemicals, light density, low melting point (i.e., 120 ℃) and non-toxicity[3]. Although various coating techniques (i.e., sol-gel, chemical vapor deposition, reactive magnetron sputtering, spray pyrolysis etc.) have been developed[4], these coating techniques are expensive and impractical. Therefore, in this study, immobilization of TiO_2 powder to EPP ball with controlled-temperature melting method was developed, and the photo activity of buoyant photocatalysts was evaluated using methylene blue solution under visible light irradiation (>420 nm).

II. Materials and Methods

Commercial low-density uniform EPP balls used for the filling materials of pillow were purchased in the market (HUG, Republic of Korea). The diameter of EPP balls is around 1 cm. P25 TiO_2 as a representative of photocatalyst was purchased from Skybright group (Hong Kong). Glycerine was used as the dispersing medium, and was purchased from DAEJUNG CHEMICLAS & METALS(Republic of Korea). A suspension of TiO_2 was prepared by dispersing 520g of TiO_2 in 3L of glycerine solution over 70 ℃ using heating pan with a digital thermoregulator and a magnetic stirrer. After complete dispersion of TiO2 in 3L of glycerine solution, the suspension was heated to the melting point of the EPP ball at 140 ℃. Then, EPP balls were completely soaked in suspension of TiO_2 about 5 seconds to melt the surface of EPP balls, and were completely soaked in cold water (1-4 ℃) to enhance the coating of TiO_2 to the surface of EPP balls. Finally, TiO_2-coated EPP balls were washed with tap water and dried at room temperature. The surface of both uncoated and TiO_2-coated EPP balls were characterized by scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM/EDS) (company, nation). As shown in Figure 1, the photocatalystic activity was analyzed from degradation efficiency of methylene blue using the TiO_2-coated EPP balls in a batch photocatalytic reactor(BPR) consisted of a rectangular mirror-coated PVC plastic and 4 UV-C lamps (8 W, 254 nm in wavelength). The 0.01g of methylene blue is dissolved in 500 mL of distilled water to make 20 mg/L of methylene blue (MB) solution. Experiment conditions of four quartz cell are as follows: 1. only UV, 2. TiO_2-coated EPP balls with UV, 3. uncoated EPP balls with UV, 4. only TiO_2-coated EPP balls without UV. 1.0 mL of aqueous sample was collected every 10 minutes during 1 hour and every 30 minutes after 1 hour. After the experiments, used TiO_2-coated EPP balls were washed and dried to repeat the same experiment for several times to evaluate the life span of TiO_2-coated EPP balls.

Figure 1. Pictorial view of the batch photocatalytic reactor (from right to left: 1. only UV, 2. uncoated EPP balls with UV, 3. TiO_2-coated EPP balls with UV, 4. only TiO_2-coated EPP balls without UV)

III. Results and discussions

A. *Characterization of TiO_2-coated EPP balls*

The scanning electron microscope (SEM) images of the developed TiO2-coated EPP balls at two different magnifications (i.e., x 50 and x 150) and SEM/EDS analysis are shown in Figure 2.

As shown in Figure 2, the surface of both uncoated and TiO_2-coated EPP balls has a relatively smooth surface. While the surface of uncoated EPP balls is very smooth without porosity, the surface of uncoated EPP balls is covered with patches of TiO_2 coating. Based on the associated EDS analysis, the components of uncoated EPP balls are carbon and oxygen whereas those of TiO_2-coated EPP balls are carbon, oxygen, and titanium, indicating that patches of TiO_2 coating cover some part of EPP balls.

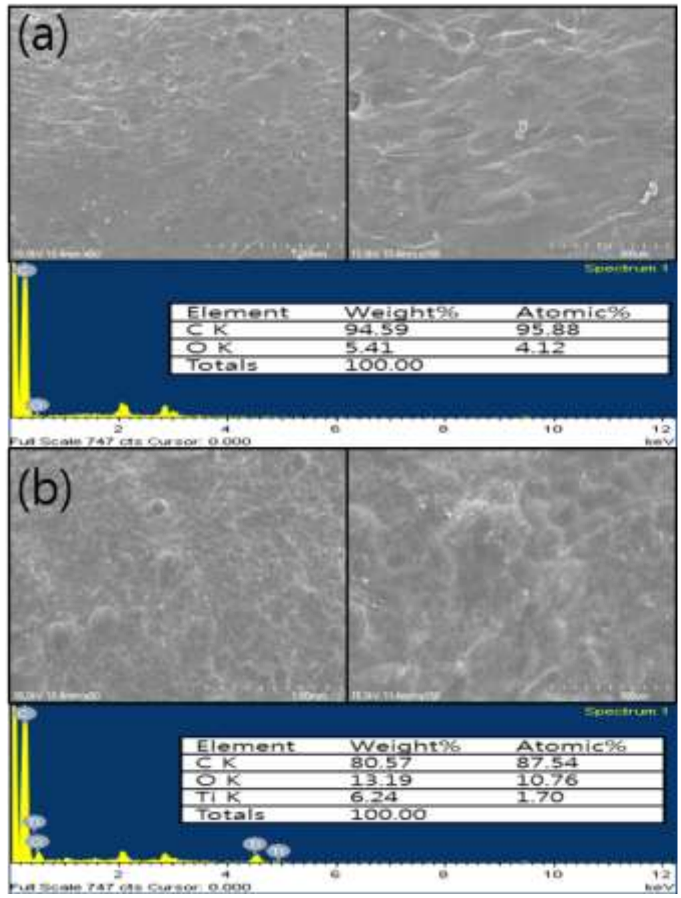

Figure 2. Scanning electron microscopic images of uncoated and TiO_2-coated EPP balls at different resolutions (i.e., x50 and x 150) and associated EDS analysis ((a) Uncoated EPP balls, (b) TiO_2-coated EPP balls)

B. *Degradation of methylene blue using TiO_2-coated EPP balls*

After batch experiments of MB were performed using only UV (photolysis), uncoated EPP balls with UV (photolysis+sorption), TiO_2-coated EPP balls with UV (photocatalysis+sorption), and TiO_2-coated EPP balls without UV in BPR, the removal efficiency of MB in aqueous phase was evaluated. As shown in Figure 3a, the degradation of MB were insignificant, indicating that photolysis of MB was found to be negligible. As also shown in Figure 3d, the sorption of MB to TiO_2-coated EPP balls was found be negligible. Sorption of MB to TiO_2-coated EPP balls is thermodynamically unfavorable due to the absence of chemical reactions.

Based on comparison of degradation efficiency between uncoated and TiO_2-coated EPP balls under UV illumination, the degradation efficiency can be significantly improved using TiO_2-coated EPP balls, indicating that TiO_2-mediated heterogeneous photocatalytic degradation occurred, and surface reactions in heterogeneous photocatalysis were more dominant than photo-induced radical reactions in aqueous solutions. Thus, TiO_2-coated EPP balls were found to be an effective photocatalyst for photodegradation of MB in aqueous solutions. Therefore, buoyant TiO_2-coated EPP balls can be used to treat contaminated surface water on site. Further studies are warranted to evaluate the durability of TiO_2 on the surface of EPP balls.

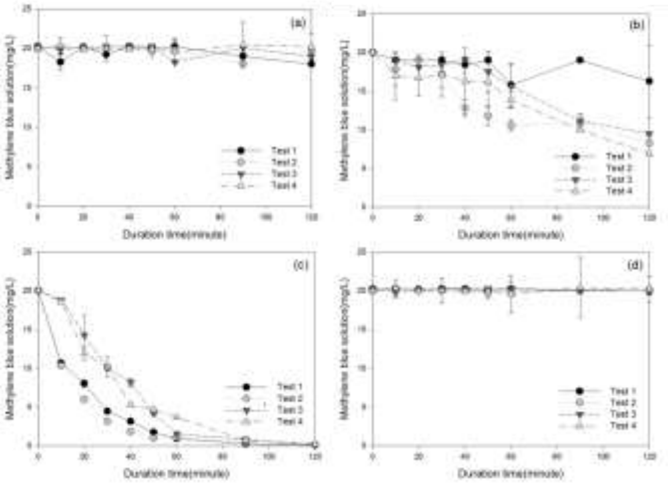

Figure 3. Degradation of methylene blue in the aqueous solutions under the various conditions ((a) UV only, (b) uncoated EPP balls with UV, (c) TiO_2-coated EPP balls with UV, (d) TiO_2-coated EPP balls without UV).

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