PHOTOCATALYTIC ACTIVITIES OF TITANIUM DIOXIDE BLENDED WHITE CEMENT COATED ON SUBSTRATE

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Abstract: Coating of titanium dioxide (TiO_2 P-25) on various substrates always encounters a problem about the immobilization of catalyst particles. To overcome this problem and enhance the adhesion of P-25, a gold standard of TiO_2 photocatalyst, on substrate, white cement was selected to blend with P-25. In this research white cement provides a strong bonding between P-25 particles and substrate surface which is resulted from hydradation of the hardened cement, without extra treatments required. Samples were prepared via granulation process by coating of white cement on the substrate as the first layer, then curing in the air for 1 day. After that coating white cement mixed with 25 wt% TiO_2 P-25 was done as the second layer, then curing in air for 1 day and in water for another 3 days. The photocatalytic activities were measured spectrophotometrically through degradation of methylene blue (MB) and cumene hydroperoxide (CHP). The results of UV-Vis spectra indicated that the absorbance of the MB decreased 60%, while HPLC analysis confirmed that CHP concentration approximately decreased 70% after UV irradiation for 3h. This indicates that the prepared photocatalyst can potentially decompose the organic pollutants in wastewater, and is possible for better development.

1. Introduction

Of all the photocatalysts, TiO_2 is a viable photocatalyst in terms of activity, chemical inertness, photostability [1-3] and production cost. Its applications include self-cleaning [4], hydrogen production[5], degradation of organic compounds in wastewater, but in the powder form, it requires filtration to separate for reuse.

In recent years, there are many researchers tried to fixed TiO_2 on different types of supports, such as glass [6], polymers [7] and ceramics [8] by various methods including sol-gel [9], sputtering [10], chemical vapor decomposition [11] and spray pyrolysis [12]. However, the immobilization of TiO_2 on various support was still not strong enough and some methods required advance technology which was too expensive for commercial purpose.

Therefore, many reserchers had studied mechanical properties, microstructures, and surface of cement mixed TiO_2 for photocatalytic degradation [13-15], but there were still some disadvantages about calcium from cement encountering in the active site of TiO_2.

In this research, white cement with high Al_2O_3 content was introduced to mix with TiO_2 P-25, in order to act as an adhesive between P-25 powder and the substrate. Optimization for appropriate amounts of white cement and P-25 and photocatalytic activity of TiO_2 blended white cement was studied.

2. Materials and Methods

2.1 Materials

White cement (AC, 80% Alumina, KERNEOS), TiO_2-P25 (75% anatase and 25% rutile, Degussa, Germany), Cumene hydroperoxiden (CHP, 80% $C_6H_5C(CH_3)_2OOH$, AR-Grade, Merck Chemical Co.), Methylene blue (MB, Merck Chemical Co.) and porous glass beads (EC, ECOLITE®, diameter ~ 3 mm) were used in this study.

2.2 Preparation of samples

Samples were prepared via granulation process by coating of white cement on the glass substrates as a first layer, then curing in air for 1 day. After that coating white cement mixed with 25 wt% and 50 wt% TiO_2-P25 was done as the second layer, then curing in air for 1 day and in water for another 3 days.

2.3 Sample characterization

Crystalline phases of the sample were identified by X-ray Diffractometer (XRD, Bruker, D8 Advance). The absorbance of MB over the spectrum range of 300-600 nm was determined with a UV-VIS Spectrophotometer (Perkins Elmer, Lambda 35). CHP concentrations were measured by High Performance

Liquid Chromatography (HPLC, HP HEWLETT PACKARD SERIES 1100), and column (Thermoscientific® Hypersil Gold particle size 1.9 μm diameter 3 mm).

2.4 Photocatalytic activity studies

The photocatalytic activities of the samples were measured through the decomposition of MB (0.02 mM, 10 mL) and CHP (initial concentration 230 ppm, 10 mL) under UV irradiation (Lamp: Philips TL-D 18 w). The light intensity between light source and samples was 2 mW/cm^2 and for each test, an average absorbance of 2 samples was taken.

3. Results and Discussion

3.1 XRD pattern of the samples

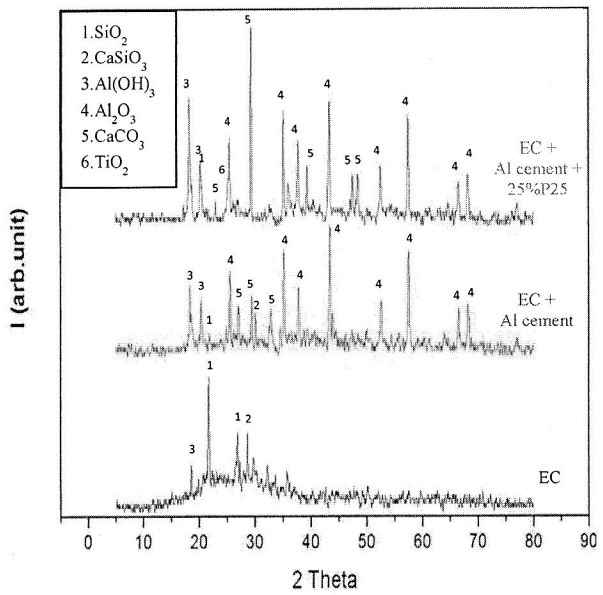

Figure1. XRD of EC glass substrate, coated with Al cement and with 25% TiO_2/Al cement.

XRD results of the samples before and after coating with TiO_2/Al cement shown in Figure 1 indicated that after coating, no reaction between TiO_2 and Al cement found, hence TiO_2 still can play a role as the photocatalyst. The peak match in XRD pattern of EC + cement + TiO_2 sample showed the phase of TiO_2 anatase as marked as number 6 in Figure 1. However, $Ca(OH)_2$ released from cement could react with CO_2 from the atmosphere to form $CaCO_3$ on the surface of EC substrate and might interfere with the active sites of the TiO_2, finally photocatalytic activity decreased.

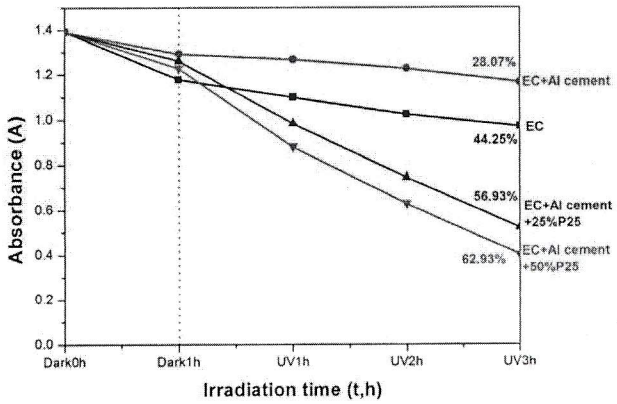

Figure2. The absorbance of MB after photocatalytic activity test of 4 samples EC, EC + Al cement, EC + Al cement + 25% P25, and EC + Al cement + 50% P25 measured by UV- VIS Spectrophotometer.

3.2 The photocatalytic results of MB

Figure 2, The results from UV-VIS spectra revealed that during one hour in the dark (Dark 0h – Dark 1h), the absorbance of MB in all condition slightly decreased by adsorption on the porous surface of the sample, and after UV irradiation for 3 h, the rate of MB still slightly decreased in case of EC substrate and EC coated with Al cement. On the other hand considering of EC substrate which contained P25 (25% and 50%), it revealed that after UV irradiation for 3h, the absorbance of MB suddenly decreased due to the photocatalytic activity of TiO_2-P25 on the sample surface. The adsorbing ability of EC substrate to MB was better than the EC substrate which was coated by Al cement. This is because of EC substrate surface contained more open pores than the coated one. Increasing of the amount TiO_2-P25 from 25% to 50%, did not promote much higher degradation of MB as clearly observed by the absorbance of MB which was decreased slightly lower than that of 25% TiO_2-P25. Mixing TiO_2-P25 in Al cement and coated on EC substrate be able to produce photocatalytic activity on the surface of sample and could decompose MB after UV irradiation for 3h up to 62.93%.

3.3 The photocatalytic results of CHP

The standard solution of CHP composed of 230 ppm CHP, 20 ppm dimethyl phenyl carbinol (DMPC) and 2 ppm acetophenone (ACP). The HPLC analyses of CHP concentrations in Figure 3(a) indicated that after subjecting EC substrate 10 samples in 10 ml of standard solution and left in the dark for 1h, the concentration of all compounds did not change even after UV irradiation for 2h and 4h. It is implied that only EC substrate could not decompose CHP. Fig 3(b) indicated that after subjecting EC coated with Al cement 10 samples in 10 ml of standard solution the results showed the similar effect as EC substrate. It can conclude that EC substrate and EC coated with Al cement could not decompose CHP after UV irradiation for 4h but in Fig 3(c) and 3(d) after subjecting of EC

coated with 25% and 50% P25/Al cement 10 samples in 10 ml of standard solution and left in the dark for 1h, the concentration of all compounds did not change but after UV irradiation for 2h and 4h the concentration of CHP decreased because P25 on the sample surface and UV light can promote photocatalysis reaction in order to decompose CHP to DMPC, ACP, Phenol and Acetone. Sample prepared by TiO_2-P25 blended Al cement coating on EC substrate could decompose CHP up to 78.87%, after UV irradiation and CHP changed to lower molecular weight chemical structure such as DMPC, ACP and phenol (as intermediate products). The higher increasing level of acetone (also as an intermediate product) was also detected.

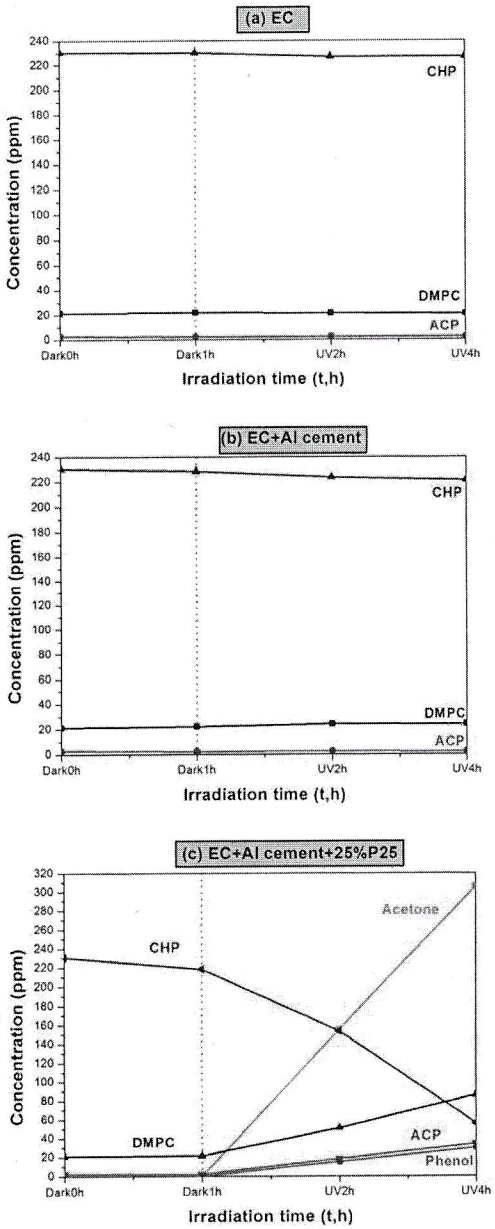

Figure3. Changing in concentrations (measured by HPLC) of CHP, DMPC and ACP in standard solution after subjecting of (a) EC, (b) EC coated with Al cement, (c) EC coated with 25%TiO_2 P25/Al cement, and (d) EC coated with 50% TiO_2 P25/Al cement

4. Conclusions

EC substrate coated with 25-50% TiO_2-P25 blended Al cement by granulation process are able to degrade methylene blue (MB) 56.93-62.93% under UV irradiation for 3 h and decompose cumene hydroperoxide (CHP) 75.94-78.87% under UV irradiation for 4 h. Accordingly, they might potentially decompose organic pollutants which mainly contained CHP in wastewater and it is promising to reuse this materials in wastewater treatment purpose.

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