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PHOTOCATALYTIC REACTION OF TiO_2 FOR PURIFICATION OF AIR

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Abstract

Photo-excited TiO_2 surface has a strong ability to induce various chemical reactions. Our study concentrates mainly on the utilisation of light energy to induce reactive radicals for environmental protection application. For instance, we have successfully used TiO_2 to break down foul smelling substances in air. In order to retain and separate the TiO_2 catalyst from the reactants and products, TiO_2 was immobilised by fixing onto various substrates. TiO_2 catalyst coated onto glass, wall paper and painted panel was found to show significant deodorising effect. The deodorising effect continues as long as TiO_2 is exposed to light irradiation.

Key words : *Photocatalytic reaction, TiO_2 film, reactive radicals, deodorising effect, light irradiation.*

1. INTRODUCTION

A solar energy conversion system (a photoelectrochemical cell) invented by A. Honda and K. Fujishima[1] can split water into oxygen on the semiconductor electrode surface and hydrogen on the other counter electrode. When the distance between the two electrodes gets closer, the two electrodes will finally touch each other. Furthermore, if the sizes of the two electrodes become as small as nano size, the system is thought of as particles being suspended in aqueous solution. It was reported that a photocatalytic reaction could be induced on these particles' surface under light irradiation[2-5].

This paper focuses on applications of photocatalytic reaction for purification of air by fixing a thin, transparent film of TiO_2 to various substrates.

2. EXPERIMENTAL DETAILS

2. 1 Pre-treatment

2. 1. 1 Glass

a. Sandblasting

The glass was sprayed by aluminium carbide, ultrasonically cleaned in D.I. water for 20 minutes and dried at 105℃ for 30 minutes.

b. Pre-treatment by NaOH or HF or HCl solutions

The glass was soaked in 0.1N NaOH solution and sonicated for 20 minutes. Then, it was rinsed twice by D.I. water and dried at 105℃ for 30 minutes. The same procedures using 3% HF or 10% HCl were also applied to the glass.

2. 1. 2 Wall paper

Normally, organic substrate has poor surface wettability. In this work, plasma treatment was used to improve surface wettability of wall paper. The effectiveness of plasma treatment was gauged using a contact angle meter, whereby the angle formed by the edge of water droplet and the surface of wall paper was determined. Wall paper was ultrasonically cleaned in acetone for 3 minutes and then ultrasonically rinsed in D.I. water for 3 minutes. Then it was placed into a plasma treatment system. Air was vacuumed out from the chamber and when the pressure fell to 5×10^{-2} mbar, O_2 gas was introduced into the chamber to pressure of 4.8×10^{-1} mbar and the power was on at 400W. The plasma treatment lasted for 3 minutes.

2. 1. 3 Painted panel (mixture of Abesto and cement)

The panels were soaked overnight in water. The wet panels were left in air for 1 week. A coat of emulsion paint was applied onto the panel. After 1 hour, a second coat was painted over and left to dry at room temperature for 48 hours. Then, the painted panels were brushed with 10% inorganic binder of HAS-SiO_2 sol-gel and dried at room temperature.

2. 2 Coating of TiO_2

Dip coating was used for glass and wall paper. They were dipped into 6wt% anatase TiO_2 (7A diameter in size) sol-gel solution and dried at room temperature. Then they were heated at 105℃ for 30 minutes and cured at different temperatures (glass:450℃, wall paper:200℃) for 30 minutes to achieve good adhesion. Steps were repeated for multiple-coatings (3, 5, 7 and 10 coats). Since HAS-SiO_2 sol-gel is hydrophobic without heating, several coats of TiO_2 sol-gel must be brushed onto the painted panels.

2. 3 Photocatalytic reaction of TiO_2 for purification of air

A piece of plasma treated wall paper (6cm×5 cm) coated with TiO_2 was placed inside a Quartz top glass container (1600ml in vol). 0.02ml of acetaldehyde gas was introduced through the bottom of the container and left overnight. 2ml of the gas was withdrawn from the top of the container and injected into a Shimadzu Gas Chromatograph. Three injections were carried out to test the uniformity of the gas inside the container before the whole Quartz top glass container was subjected to UV exposure at the wavelength of 365nm. After 10 minutes of UV exposure, 2ml of gas from the container was withdrawn from the top of the container for GC analysis. This was repeated after 20, 30 and 40 minutes of UV exposure.

2. 4 Abrasion test and adhesion test

The coated surface was subjected to a moderate abrasion test conforming to MIL-E-12397 by rubbing with a 6.4mm thick by 9.5mm wide pad of clean dry, laundered cheesecloth affixed to the tester. Adhesion test was carried out conforming to ASTM D3359-93 (Test Method B). A lattice pattern with eleven cuts in each direction was made in the film to the substrate, a 3-inch long cellulose tape was applied over the lattice and then removed, and adhesion was evaluated by comparison with descriptions and illustrations.

3. RESULTS AND DISCUSSION

3. 1 Coating of TiO_2

3. 1. 1 Glass

The results showed that the adhesion and abrasion properties remained excellent even with 10 TiO_2 coatings (Table 1). The thickness of TiO_2 on glass might be used as a reference for the thickness of TiO_2 on other substrates.

Good uniformity was achieved even with 10 TiO_2 coatings for pre-treatment by 10% HCl solution. However, good uniformity was only restricted to 1 TiO_2 coating for pre-treatment by 3% HF solution or by 0.1N NaOH solution.

3. 1. 2 Wall paper

Previous studies have shown that a good adhesion of TiO_2 film could only be obtained by heating the substrate at 400-600℃ after coating. If we can develop a simple method to coat TiO_2 thin film onto substrates such as plastic sheets, wooden plates and curtains at very low temperatures, then this application would be more widely adopted. Wall papers were used for the study. The lower the contact angles the better the surface wettability. The degree of wettability was dependent on the pressure of the plasma gas (O_2) and the power used. With the plasma treatment, the adhesion of TiO_2 thin film was relatively strong although the wall paper had very poor surface wettability. The wall paper could be coated easily with the TiO_2 film, while retaining its photocatalytic ability (Photograph 1).

Table. 1

No. of TiO_2 coatings	Average thickness (㎛)	Abrasion test	Adhesion test
1	0.383	Good	5B
3	0.572	Good	5B
5	0.702	Good	5B
7	1.040	Good	5B

3. 1. 3 Painted panels

UV light is essential for the photochemical reaction of TiO_2 to take place. However, direct exposure to UV light and the photocatalysis by TiO_2 may cause degradation in paint (oxidation of organic molecules). A protective layer, e.g. 10% HAS-SiO_2 sol-gel, was applied before TiO_2 onto the painted panels. The specimens were exposed to UV in Accelerated Weatherometer for 3 weeks to study its effectiveness for preven-

Table. 2

Power (W)	400	450	550
Contact Angle (°) Pressure with O_2 gas flow: 2.5×10^{-1} mbar	26.3	28.7	32.8
Contact Angle () Pressure with O_2 gas flow: 4.8×10^{-1} mbar	18.6	37	67.5

Photograph 1 Plasma treated wall paper coated with TiO_2

tion of paint degradation (Table 3). It was found that no paint discoloration with the undercoat layer of SiO_2.

3. 2 Photocatalytic reaction of TiO_2 for purification of air

As shown in Fig. 1, the concentration of acetaldehyde gas was tested at ten thousand times higher than that of normal human scent detection limit. The strong odour gas was decomposed effectively with the TiO_2 film under light irradiation.

Table 3

Colour	No any coating	TiO_2 coating	A protective layer followed by TiO_2 coating
White	No change	No change	No change
Light yellow	No change	Slightly discolours	No change
Greyish blue	No change	Discolours	No change

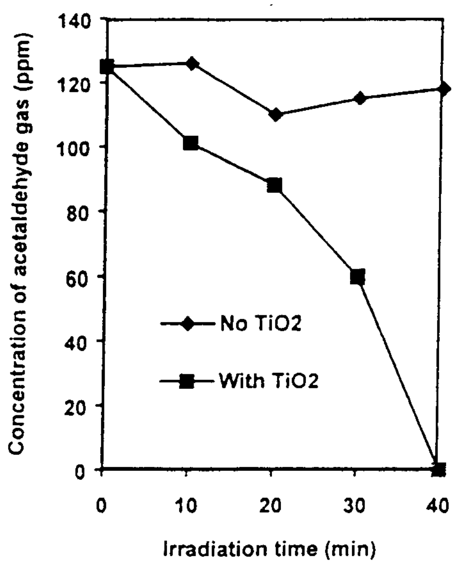

Fig. 1 Relationship between irradiation time and concentration of acetaldehyde gas.

4. CONCLUSION

Photocatalytic reaction of TiO_2 can be applied for purification of air by fixing the photocatalyst onto appropriate substrates. Plasma treatment is effective in improving surface wettability of organic substrates. Undercoat layer of SiO_2 sol-gel is useful in preventing paint discoloration for painted panels.

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