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Title	Fabrication of TiO_2 Photocatalytic Coatings on PET by Plasma Spraying(Materials, Metallurgy & Weldability, INTERNATIONAL SYMPOSIUM OF JWRI 30TH ANNIVERSARY)
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Citation	Transactions of JWRI. 2003, 32(1), p. 179-181
Version Type	VoR
URL	https://doi.org/10.18910/9013
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Fabrication of TiO_2 Photocatalytic Coatings on PET by Plasma Spraying†

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Abstract

To endow polyethylene terephthalate (PET) plastic material with photocatalytic properties, anatase TiO_2 powders were plasma sprayed under various plasma spraying conditions. The effects of spraying parameters on the microstructure and photocatalytic activity of TiO_2 coating were systematically studied. The photocatalytic activity of the TiO_2 coating was evaluated by the decomposition test of acetaldehyde gas.

From the experimental result, it was found that fabrication of TiO_2 coating was possible on PET substrate at arc currents of 200, 300 and 400A. The TiO_2 coatings became thicker with increasing arc current. However, the coating was not formed when the plasma spraying was carried out on steel substrates even at a high arc current of 400 A. It was found from the acetaldehyde decomposition test that all fabricated TiO_2 coatings exhibited photocatalytic activity regardless of spraying parameters. Even coatings with thin layers also showed the same photocatalytic performance as thick coatings. From the XRD analysis, the reason for the efficient photocatalytic activity in the coatings was due to the high anatase phase content.

KEY WORDS: (TiO_2) (Photocatalysis) (PET)(Plasma Spraying)

1. Introduction

Titanium dioxide (TiO_2) is well-known as a photocatalytic material since the discovery of the Fujishima and Honda phenomenon [1]. In recent years, applications of TiO_2 photocatalyst for environmental purification, such as decomposition of organic compound in polluted air and waste waters, have increased [2, 3].

Generally, in the case of photocatalytic efficiency, micro-powders are superior to coatings due to their larger specific surface area. But in practical application, several problems with using micro-powders in photochemical processing are apparent. The problems include difficulty with respect to separation of the catalyst from suspension after reaction and aggregation of suspended particles, especially when they are present in high concentrations. In order to improve these technical problems, we tried fabrication of TiO_2 photocatalytic coatings by plasma spraying. The plasma spraying technique can fabricate coatings on large size objects and various materials in short times.

On the other hand, plastic material, for its superior property, is used for many applications, such as personal belongings, car and motorcycle components, and construction materials. Therefore, in this study, PET plastic material was used as the substrate to allow for the deposition of a TiO_2 photocatalytic coatings. The characteristics of the coatings were analyzed with SEM and XRD. The photocatalytic property of the coatings was also evaluated.

2. Materials and Experimental Procedures

2.1 Materials

Anatase TiO_2 powders were used for the experiments. The mean particle size was 33.7μm and the original grain size of TiO_2 was 0.2μm. Meanwhile, polyethylene terephthalate plastic material was used as substrate.

2.2 Thermal Spraying

Plasma spraying (PlasmaDyne) was used to deposit

† Received on January 31, 2003
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Transactions of JWRI is published by Joining and Welding Research Institute of Osaka University, Ibaraki, Osaka 567-0047, Japan

TiO_2 coatings. Spraying was performed in ambient air. The spraying conditions of TiO_2 powders are shown in Table 1. In the case of plasma spraying of TiO_2 powders, argon was used as primary plasma gas without helium secondary gas to prevent temperature of plasma jet from increasing. The arc current was varied to investigate the effect of heat input on the structure and photocatalytic efficiency of the coatings.

2.3 Characterization of the TiO_2 Coating

The structure of the coating was characterized by X-ray diffraction (XRD) analysis. Anatase ratio which means the relative content of anatase TiO_2 in the coating, f, was estimated from the following equation [4],

$$f = \frac{1}{1 + 1.265 \frac{I_R}{I_A}}$$

where I_R and I_A are the diffraction intensities of the strongest rutile and antase reflections, respectively. On the other hand, the microstructure of the TiO_2 coating was examined by scanning electron microscopy (SEM).

Table 1 TiO_2 plasma spraying conditions.

Spraying atmosphere	Air
Ar gas pressure (MPa)	0.41
He gas pressure (MPa)	0
Arc current (A)	200、300、400
Spraying distance (mm)	50
Step width (mm)	4
Traverse speed of gun (mm/s)	67
Spraying pass	3

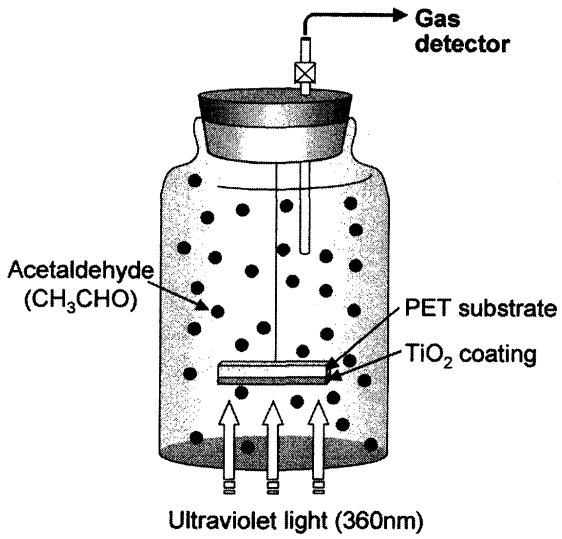

Fig. 1 Schematic illustration of experimental set-up for decomposition test of acetaldehyde gas.

2.4 Evaluation of Photocatalytic Property of the TiO_2 Coating

In order to characterize the photocatalytic property of the coating, decomposition tests on acetaldehyde gas were carried out. The experimental set-up is illustrated in Fig. 1. The volume of the container shown in Fig.1 was 2.3×10^{-6} m^3. Initially, the container was filled with acetaldehyde gas at 100 ppm. Next, the ultraviolet lamp with 360nm wave length was switched on. Finally, the concentration of the acetaldehyde gas was measured with a gas detector after certain time intervals.

3. Results and Discussion

3.1 Structures of the Coatings Fabricated by Plasma Spraying on PET substrate

Cross-sectional microstructures of the coatings sprayed with the anatase TiO_2 powder at arc currents of 200, 300 and 400 A are shown in Fig. 2. At the arc currents of 200, 300 and 400 A, TiO_2 coatings with average thicknesses of 16, 47 and 81 μm were obtained. Therefore, we have found that the TiO_2 coatings were thicker with increasing arc current.

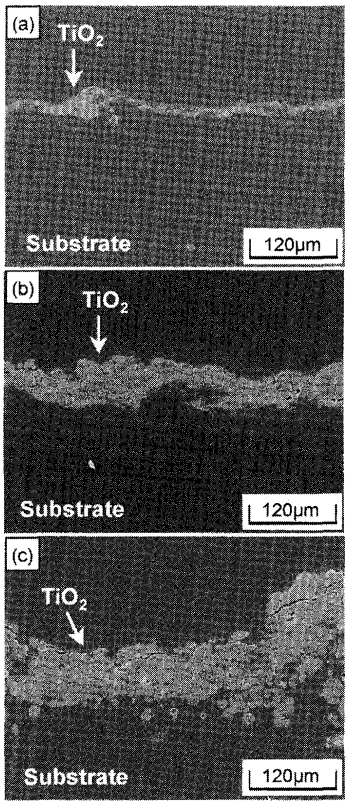

Fig. 2 Cross-sectional microstructures of coatings sprayed under the condition of (a) 200 A, (b) 300 A, (c) 400 A on PET substrate.

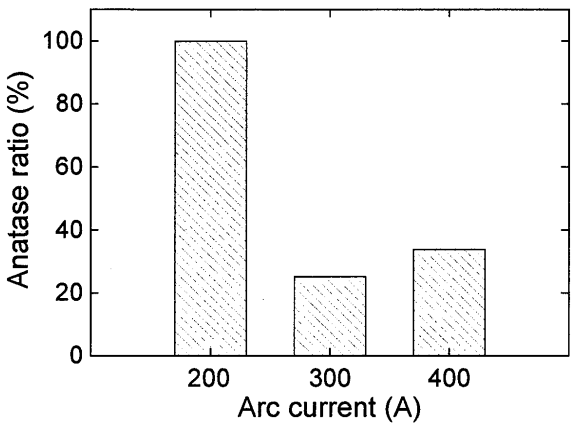

Fig. 3 Effect of arc current on anatase ratio of coating sprayed on PET substrate.

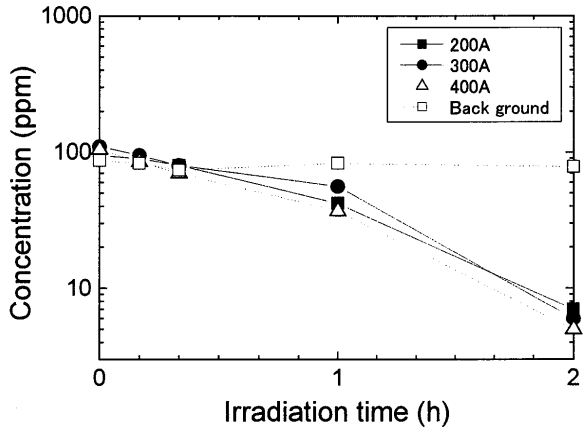

Fig. 4 Decay characteristics of acetaldehyde gas by coatings sprayed at various arc currents on PET substrate.

The anatase ratio of these coatings on PET substrates is shown in Fig. 3. At the arc current of 200 A, the anatase ratio was 100%. Meanwhile, at arc currents of 300 and 400 A, the anatase ratio was about 30%.

3.2 Decomposition Characteristics of Acetaldehyde Gas by the TiO_2 coating on PET substrate

Results of decay characteristics of acetaldehyde gas by the TiO_2 coatings sprayed under the condition of arc current of 200, 300 and 400 A are shown in Fig. 4. In all the coatings, acetaldehyde gas was almost completely decomposed after 2 hours.

The TiO_2 coating with thin layer as shown in Fig. 2(a) exhibited the same photocatalytic performance as compared to the other thicker coatings. As shown in Fig. 3, the reason for the efficient photocatalytic activity of the coating was considered to be due to the high anatase phase content.

4. Summary

Anatase TiO_2 powders were sprayed on PET substrates under various spray conditions to provide photocatalytic properties. The effects of spraying conditions on structures, anatase ratio and decomposition characteristics of acetaldehyde gas of prepared coatings were investigated. The results are summarized as follows:

(1) TiO_2 coatings were fabricated on PET substrate by plasma spraying at arc currents of 200, 300 and 400 A.

(2) The anatase ratio of the coating sprayed on PET substrate at the condition of 200 A was 100%, and those of 300 and 400 A were about 30%.

(3) All fabricated TiO_2 coatings exhibited photocatalytic activity regardless of spraying parameters from the acetaldehyde decomposition test.

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