Photocatalytic Degradation of 2-Propanol Diluted in Water with TiO$_2$ Photocatalyst Deposited on SiC$^*$

Yoshikatsu Nishida, Tetsutaro Omichi, Iwao Katayama, and Hiromi Yamashita$^\dagger$

Division of Materials and Manufacturing Science, Graduate School of Engineering, Osaka University, 2-1 Yamada-oka, Suita, Osaka 565-0871, Japan

Masaaki Narisawa
Department of Materials Science, Graduate School of Engineering, Osaka Prefecture University, 1-1 Gakuen-chou, Sakai, Osaka 599-8531, Japan

Yasuyuki Matsumura
National Institute of Advanced Industrial Science and Technology (AIST), Midorigaoka, Ikeda, Osaka 563-8577, Japan

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TiO$_2$-SiC was prepared by oxidation of TiC-SiC precursor which was obtained by carbothermic reduction process of TiO$_2$-SiO$_2$. XRD analysis indicated the formation of the mixture of anatase and rutile phases of TiO$_2$ crystalline after the oxidation of TiC-SiC sample. TiO$_2$-SiC photocatalyst exhibited the higher photocatalytic reactivity than TiO$_2$ loaded on SiO$_2$ (TiO$_2$-SiO$_2$) prepared by the conventional sol-gel method and commercial TiO$_2$ powder (P-25). These results indicated the advantages of SiC powders as catalyst support of the TiO$_2$ photocatalyst. [DOI: 10.1380/ejssnt.2005.311]

Keywords: Titanium oxide; Silicon carbide; Catalysis

I. INTRODUCTION

Several kinds of application of photocatalyst system have been of vital interest recently. The design of highly efficient photocatalytic systems which work for the reduction of global atmospheric pollution and the purification of polluted water is attractive and one of the most desirable yet challenging goals in the research of environmentally-friendly catalysts [1–10]. TiO$_2$ semiconductor photocatalysts are known as one of the most stable and highly reactive catalysts. During the process of purification of polluted water, photocatalyst has to be separated from treated water. To separate the photocatalyst from water, photocatalyst has to be supported on bulk materials. Silicon carbide (SiC) has physical bulk properties such as high thermostability, high mechanical strength, and high heat conductivity and has been claimed to be used as catalyst support. In addition, SiC is easy to be molded into a filter. Although it may be a useful support for photocatalysts used in liquid phase, there have been no reports on the properties of TiO$_2$ photocatalyst deposited on SiC.

In the present study, we deal with the preparation and characterization of TiO$_2$ photocatalyst deposited on SiC using the precursor of TiC-SiC powders [11] and carry out its successful utilization for the photocatalytic degradation of 2-propanol diluted in water. Moreover, the advantages of SiC powders as catalyst support of TiO$_2$ photocatalyst have been clarified

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$^\dagger$Corresponding author: yamashita@mat.eng.osaka-u.ac.jp

II. EXPERIMENTAL

On the basis of the process reported in the previous study [11], the liquid mixtures of tetraethyl orthosilicate, titanium tetraisopropoxide and phenolic resin were prepared. After the continuous stirring of the mixtures, the acid (30 wt% of toluenesulfonic acid solution in water) was
added to stir up to the gelation of the mixture. The obtained gels were dried in vacuum, crushed and pyrolyzed at 1273 K (heating rate: 5 K/min, holding time: 1 h) in a nitrogen atmosphere (heating rate: 1 L/min). The precursor pyrolyzed at 1273 K was put into the graphite furnace preheated at 1873 K under Ar flow rate of 1 L/min to yield the TiC-SiC (Ti/Si=0.4) powders by the carbothermic reduction. The obtained TiC-SiC powders were then calcined in air at 773 K and 873 K for 7 h to synthesize TiO$_2$ deposited on SiC powder (TiO$_2$-SiC). TiO$_2$-SiO$_2$ samples were prepared by the sol-gel method using TEOS, TTIP and ethanol. X-ray diffraction patterns of the samples were measured by Rigaku RINT2500 diffractometer with CuK$_\alpha$ radiation ($\lambda$ = 0.15406 nm). The XANES spectra were obtained in the fluorescence mode at the BL-7A facility of the Photon Factory at the National Laboratory for High Energy Physics, Tsukuba. X-ray photoelectron spectroscopy (XPS) was recorded with JEOL microprobe system using the Mg K$_\alpha$ line. The photocatalyst (50 mg) was transferred to a quartz cell with an aqueous solution of 2-propanol ($2.6 \times 10^{-3}$ mol dm$^{-3}$, 25 ml). Prior to UV light irradiation, the suspension was stirred in a flow of O$_2$ for 1 h under dark conditions. The sample was then irradiated at 295 K using UV light ($\lambda > 250$ nm) from a 100 W high-pressure Hg lamp with continuous stirring under O$_2$ atmosphere in the system. The products were analyzed by gas chromatography.

### III. RESULTS AND DISCUSSION

Figure 1 shows the XRD patterns of untreated TiC-SiC and TiO$_2$-SiC photocatalyst prepared by the oxidation of TiC-SiC at 773 K and 873 K, respectively. In the TiC-SiC sample, the formation of TiC and SiC crystalline phases were observed. After the oxidation of TiC-SiC sample at 773 K and 823 K, the formation of the mixture of anatase and rutile phase of TiO$_2$ crystalline was observed clearly. On the other hand, TiO$_2$-SiO$_2$ photocatalysts prepared by the sol-gel method and calcined at 873 K exhibited no XRD peak due to the crystallized phases, indicating that the TiO$_2$ species exist in an amorphous phase or as ultrafine particles.

The XANES spectra at the Ti K-edge showed several well-defined preedge peaks which are related to the local structure surrounding the Ti atom. The relative intensities of these preedge peaks provide useful information on the coordination number of the Ti atom [5–10]. TiO$_2$-SiC prepared by the oxidation at 773 K and 873 K exhibited three small well-defined preedge peaks which can be assigned to the presence of the mixture of anatase and rutile TiO$_2$ species with high crystallinity. These results indicate that the titanium oxide species can be crystallized easily to form the mixture of anatase and rutile TiO$_2$ ultrafine particles on the support of SiC.

Figure 2 shows The Ti 2p and Si 2p XPS spectra measured with TiO$_2$-SiC photocatalyst prepared by the oxidation at 873 K.
ation at 873 K. The spectra indicated that not only TiC was oxidized into TiO$_2$ but also partial of surface SiC was also oxidized into SiO$_2$ by the oxidation treatment.

Figure 3 shows the reaction time profiles of the liquid-phase photocatalytic reaction on the TiC-SiC sample and TiO$_2$-SiC photocatalyst. When UV light was turned on, TiO$_2$-SiC decomposed 2-propanol into acetone, CO$_2$ and H$_2$O, and finally, acetone was also decomposed into CO$_2$ and H$_2$O. On the other hand, TiC-SiC could not decompose 2-propanol under irradiation of UV light. Figure 4 shows the comparison of photocatalytic activity of TiO$_2$-SiC, P-25, and TiO$_2$-SiO$_2$. Among these three catalysts TiO$_2$-SiC photocatalyst calcined at 873 K exhibited the highest photocatalytic reactivity. This indicates that SiC is efficient support for TiO$_2$ photocatalysts.

**IV. CONCLUSIONS**

It has been found that TiO$_2$ photocatalyst deposited on SiC (TiO$_2$-SiC) prepared by the oxidation of the precursor TiC-SiC shows higher photocatalytic reactivity for the degradation of 2-propanol diluted in water than TiO$_2$ deposited on SiO$_2$ (TiO$_2$-SiO$_2$) and commercial TiO$_2$ powder (P-25). The formation of well-crystallized TiO$_2$ on SiC is found to be related to the efficient photocatalytic reactivity of TiO$_2$-SiC. Since SiC is mechanically strong enough to be used as a filter for water purification, SiC is a good support for the TiO$_2$ photocatalysts used in liquid phase reactions.

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