

EFFECTS OF Ta BUFFER LAYERS ON STRUCTURE OF TiO₂ THIN FILMS PREPARED BY SPUTTER DEPOSITION

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Introduction

As has been reported in many thin film systems, the chemical or physical properties of thin films are strongly associated with the quality of those structures. The control of the crystallinity of thin films is therefore important to achieve a better understanding of the origin of these properties. The key advantage of the use of the underlayer (buffer, seed, and surfactant layers) is that one can stabilize multiple crystal structures and/or orientations of a given element [1]. In this study, we report the influences of the Ta buffer layers on the growth of TiO₂ thin films prepared by Radio frequency (RF) magnetron sputtering.

It is well known that TiO₂ films have found various applications. The photocatalytic activity of the TiO₂ thin films was attributed to their crystallinity, surface morphology, chemical composition, electronic structure, and preferred crystal orientation [2]. Therefore, the control of thin film growth of TiO₂ at low temperature has attracted much interest from the viewpoints of material science and applications.

Experimental

RF magnetron sputtering experiments were performed. The base pressure did not exceed 2.0×10^{-7} Torr, and the pressures during deposition were about 15.0 and 5.0 mTorr for the TiO₂ thin films and the metal underlayers (Ta buffer and Ti seed layers), respectively. Glass substrates were ultrasonically cleaned with acetone and ethanol. The TiO₂ films were grown by using metal Ti target in a mixture gas of Ar and O₂ at room temperature (RT). The O₂ flow ratio and power were kept at 30% and 300 W.

The crystallographic structures of the TiO₂ thin films were analyzed by XRD. The morphology of the surfaces after deposition of TiO₂ thin film was determined by AFM. To evaluate remote oxidation abilities of photocatalysts, we subjected an octadecyltriethoxysilane (ODS)-modified glass plate to the remote oxidation and water contact angle of the plate surface was monitored [3]. The UV light intensity was 30 mW cm^{-2} ($\lambda = 365 \text{ nm}$).

Results and Discussion

The results of XRD measurements of the TiO₂ films deposited at RT on the glass substrate are shown in Fig. 1. In the case of TiO₂ films without a Ta buffer layer (Fig. 1(a)), no clear TiO₂ peaks are observed. This implies that the fabricated TiO₂ film is an amorphous one in this experimental condition. In

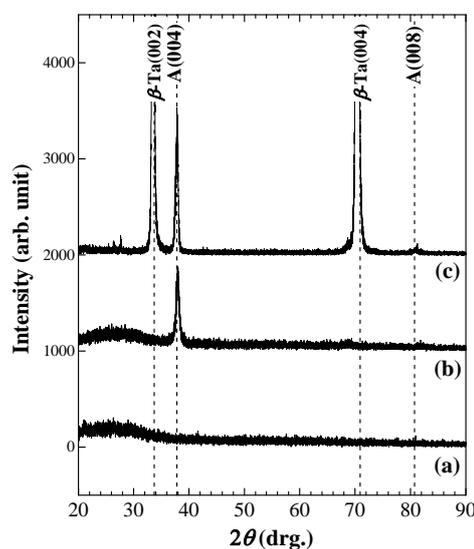


Fig.1 XRD patterns of (a) TiO₂/glass, (b) TiO₂/Ta(40 nm)/Ti(5 nm)/glass, and (c) TiO₂/Ta(500 nm)/glass deposited at RT. The thickness of the TiO₂ layer is 86 nm.

contrast, when the Ta buffer layer is deposited on the glass substrate prior to the deposition of Ti, the crystal structure of TiO₂ film is changed. As shown in Fig. 1(c), a strong anatase (A) (004) peak and a weak A(008) peak can be seen in the case of TiO₂ film deposited on a 500 nm-thick of Ta buffer layer at RT. This change caused by crystallization of the Ta buffer layer on the glass plate. As shown in Fig. 1(c), strong tetragonal Ta (β -Ta) (004) and (008) peaks are confirmed [4]. Therefore, these results indicate that the anatase TiO₂ film deposited at RT is formed by crystallization of Ta buffer layer on the glass substrate.

Figure 2 shows AFM surface topographies of the TiO₂ films. The RMS roughnesses of these surfaces measured over an area of $1.0 \times 1.0 \mu\text{m}^2$ are (a) 3.77, (b) 3.32, and (c) 3.28 nm, respectively. RMS analysis revealed that the surface roughnesses of the TiO₂ films on the Ta buffer layer decreased.

Remote oxidation was performed with the TiO₂ films (86 nm) prepared with the Ta buffer layer. The results are shown in Fig. 3. In the case of TiO₂/glass film (Fig. 3(a)), the water contact angle of the ODA-coated glass surface with 10 minute irradiation decreased by about 41% compared with no irradiation. On the other hand, the TiO₂ films on the Ta buffer layers exhibited relatively high activities among the photocatalysts examined; the water contact angle with 10 minute

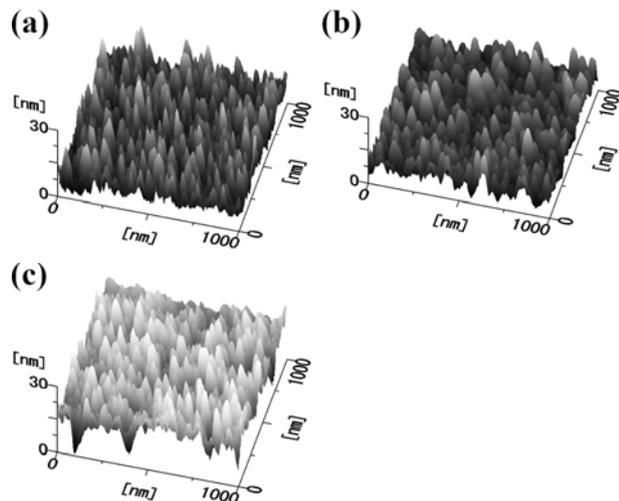


Fig.2 AFM images of the surface of TiO₂(86 nm) films (a) without a buffer layer, (b) with a Ta(40 nm)/Ti(5 nm) underlayer, and (c) with a Ta(500 nm) buffer layer.

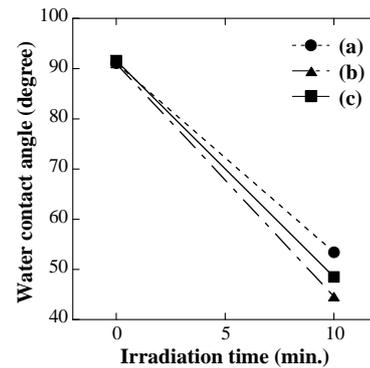


Fig.3 Time courses of the water contact angle of the ODS-coated glass plate during remote oxidation with (a) a TiO₂ film on glass, (b) a TiO₂/Ta(40nm)/Ti(5nm) film, and (c) a TiO₂/Ta(500 nm) film.

irradiation decreased by about 47 ~ 51% compared with no irradiation.

Conclusion

The XRD results exhibited that the fabricated TiO₂ films at RT on the Ta buffer layers showed an anatase polycrystalline structure, whereas the TiO₂ film on the glass showed an amorphous one. Comparisons between the AFM images revealed that the surface roughness of TiO₂ film on the Ta buffer layer is smaller than that of the film without the Ta buffer layer. The TiO₂ films on the Ta buffer layers were relatively high photocatalytic active than TiO₂ film directly deposited on glass substrate.

References

1. Kamiko, M., Ha, J.-G., Aotani, K., and Yamamoto, R. Influences of underlayers on structure of TiO₂ thin films prepared by radio frequency magnetron sputtering. *J. Ceramic Soc. Jpn.*, **118** (2010) 5-8.
2. Sirghi, L., Aoki, T., and Hatanaka, Y., Hydrophilicity of TiO₂ thin films obtained by radio frequency magnetron sputtering deposition. *Thin Solid Films*, **422** (2002) 55-61.
3. Tatsuma, T., Tachibana, S., and Fujishima, A. Remote oxidation of organic compounds by UV-Irradiated TiO₂ via the gas phase. *J. Phys. Chem.*, **B105** (2001) 6987-6992.
4. Lee, S. L., Doxbeck, M., Mueller, J., Cipollo, M., and Cote, P. Texture, structure and phase transformation in sputter beta tantalum coating. *Surf. & Coatings Tech.*, **177-178** (2004) 44-51.