



## Ag surfactant effects of TiO<sub>2</sub> films prepared by sputter deposition

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### ABSTRACT

The surfactant effect of Ag on the thin film structure of TiO<sub>2</sub> by radio frequency magnetron sputtering has been investigated. Comparisons between the atomic force microscopy images revealed that the surface roughness of TiO<sub>2</sub> film mediated by Ag was smaller than that of the TiO<sub>2</sub> film without Ag. The surface segregation effect of Ag was confirmed using X-ray photoelectron spectroscopy. The results of X-ray diffraction revealed that the initial deposition of a 0.4 nm thick Ag surfactant layer onto a Fe buffer layer prior to the deposition of the TiO<sub>2</sub> film reduced the rutile (110) growth and enhanced the anatase (100) growth. It was concluded that Ag was an effective surfactant for changing the thin film structure of TiO<sub>2</sub> on the Fe buffer layer. The photocatalytic effect of the fabricated TiO<sub>2</sub> film was also investigated using the remote oxidation process. TiO<sub>2</sub> films with the Ag surfactant exhibited higher photocatalytic activity than conventionally deposited TiO<sub>2</sub> films.

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### 1. Introduction

TiO<sub>2</sub> has received considerable attention in the field of material science and has been extensively researched for its unique physical and chemical properties. It is well known that TiO<sub>2</sub> films have found various applications, for example, photocatalysis [1] and photochemical solar cells [2]. TiO<sub>2</sub> photocatalysts have been applied to glass, tile, filters, and many other materials that possess self-cleaning, deodorizing, self-sterilizing, antifogging, and air-cleaning functions [3–6]. The photocatalytic activity of the TiO<sub>2</sub> thin films has been attributed to their crystallinity, surface morphology, chemical composition, electronic structure, and preferred crystal orientation [7–13]. Therefore, the control of thin film growth of TiO<sub>2</sub> has attracted much interest from the viewpoints of material science and applications.

The structure of thin film surfaces is determined by thermodynamics and growth kinetics. Therefore, it can be controlled by the growth conditions (including growth temperature, deposition rate, and pressure in the vacuum chamber). However, during the thin film growth, it is often the case that the desired film structure is not thermodynamically and/or kinetically favorable. Several recent reports have shown that the surface energy and growth kinetics can

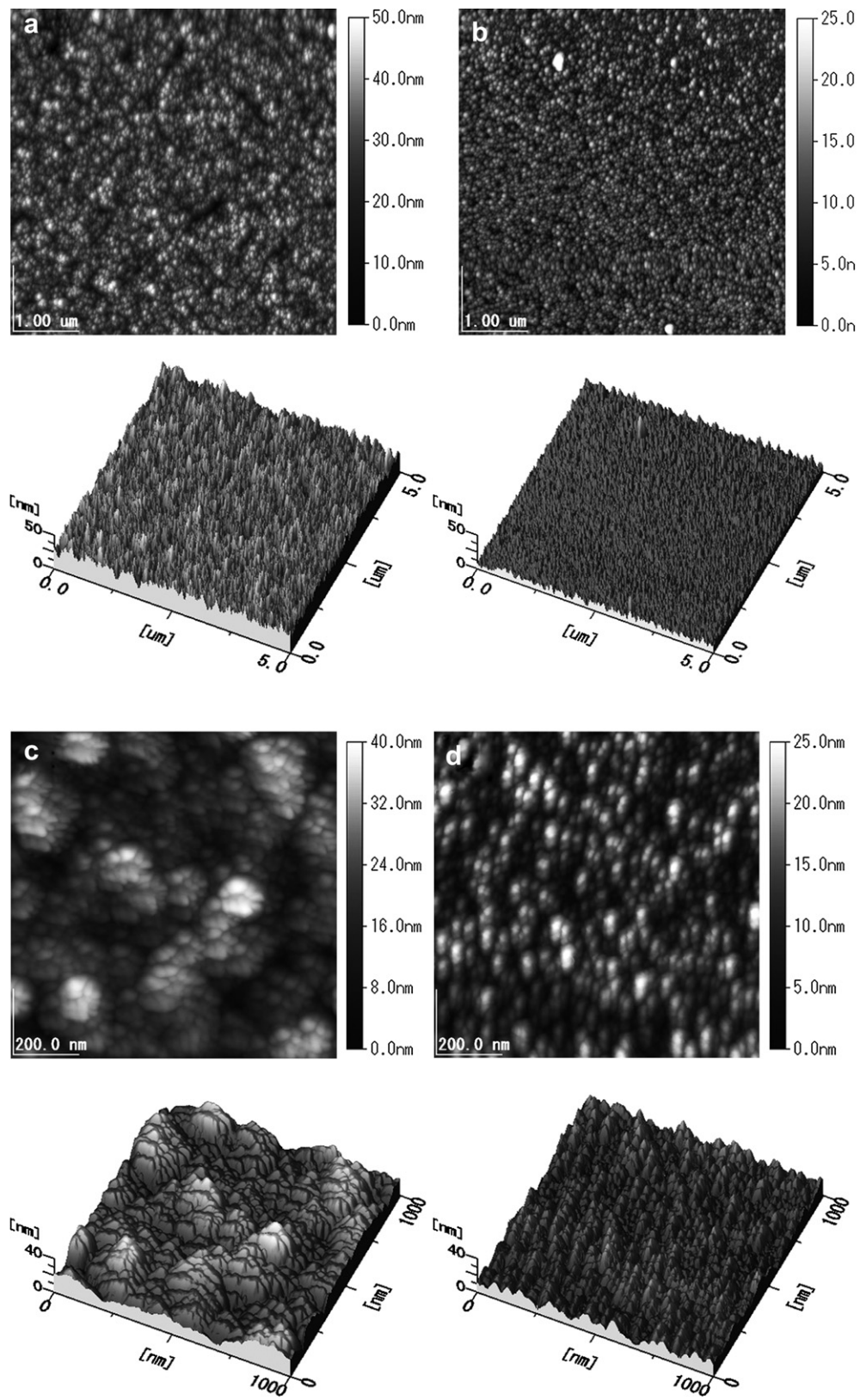
be changed by covering the substrate surface with a small amount of a third substance. Such additional surface species that enhance the two-dimensional (2D) growth [14,15] or three dimensional (3D) island growth [16] are known as surfactants. Besides the enhancements of these growth modes, the surfactant method has also various functions in the thin film growth, for example, controlling the preferential growth direction [17], enhancement of epitaxial growth [18], suppression of twin formation and interdiffusion [19,20].

In our previous studies, we used Ag as a surfactant and experimentally found that it induced the layered growth of metal thin film [21]. Significant previous work in the growth of Ag-doped YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub> is one excellent example of the effects of Ag on oxide film growth [22–24]. Therefore, Ag is a good surfactant candidate for changing the thin film growth of TiO<sub>2</sub>. In this study, we investigated the influences of Ag surfactant layer on the growth of TiO<sub>2</sub> thin films prepared by radio frequency (RF) magnetron sputtering.

### 2. Experimental procedure

RF magnetron sputtering experiments were performed in this study. In comparison to the conventional wet processes, sputter deposition should have a high potential for epitaxial film growth, where the crystallographic structure or orientation can be controlled precisely. The base pressure did not exceed  $2.67 \times 10^{-5}$  Pa, and the pressures during deposition were about

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**Fig. 1.** AFM images of surface after deposition of TiO<sub>2</sub> films (36 nm) (a, c) without and (b, d) with a 0.4 nm thick Ag layer. The images are measured over areas of (a, b) 5.0 × 5.0 and (c, d) 1.0 × 1.0 μm<sup>2</sup>. RMS roughness of these surfaces are (a) 5.30 ± 0.10 nm, (b) 3.32 ± 0.16 nm, (c) 5.25 ± 0.49 nm, and (d) 3.33 ± 0.49 nm, respectively.

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