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Synthesis of Anatase TiO_2 Film by Reactive Vacuum Arc Deposition Method

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SUMMARY

TiO_2 in anatase crystalline structure has strong photocatalysis. In this paper, TiO_2 films are deposited on soda-glass substrate using a Ti cathode vacuum arc with O_2 flow. Experimental conditions are as follows: arc current, 50 A; pressure, 0.3 and 1.0 Pa; O_2 flow rate, 20 ml/min; cathode–substrate distance, 250 mm; bias dc voltage to the substrate, none and −300 V. As-deposited films are annealed for 60 min under atmosphere and vacuum. The following results were obtained. (1) Deposition rate is 0.07 μm/min. (2) As-deposited films are amorphous. (3) Films annealed at 250 to 500 °C have an anatase crystalline structure. These results are independent of pressure, bias, and annealing environment.

In another process, the films are deposited for 30 min when the substrate holding table is connected to the anode chamber. Experimental conditions are as follows: arc current, 50 A; pressure, 1.0 Pa; O_2 flow rate, 20 ml/min; cathode–substrate distance, 250 mm. Almost 30% of the arc current was observed to flow through the substrate table, and the surface temperature of the table increased up to 450 °C. The reason for this is considered to be that Joule heating occurs when the current flows through the film deposited on the table. The film deposited in this process is dominantly anatase.

The above experiments show that anatase TiO_2 film can be deposited on soda-glass by the reactive vacuum arc method. © 1999 Scripta Technica, Electr Eng Jpn, 126(4): 12–20, 1999

Key words: TiO_2 film; anatase structure; reactive vacuum arc deposition; soda glass substrate; photocatalysis.

1. Introduction

Titanium dioxide (TiO_2) appears in three types of crystalline structures: anatase, rutile, and brookite [1]. TiO_2 in an anatase crystalline phase is known as an extremely active photocatalytic material [2]. If anatase TiO_2 is irradiated with light having an energy greater than the optical bandgap (~3.2 eV), the TiO_2 will be photoexcited and will generate electron–hole pairs on its surface. Possessing an extremely strong oxidation power, the holes will oxidize and decompose the materials that contact the surface. For this reason, TiO_2 is being considered for applications in the fields of environmental decontamination such as sterilization, antibacterial substances, and pollution prevention [3]. Especially in recent years, the use of a TiO_2 photocatalyst in glass building materials and structural walls has been promising as a technology to degrade and settle automobile exhaust gas in tunnels or along chronically congested roads [4]. In addition, since TiO_2 thin films are transparent, research and development are progressing for its use as a basic material in optical semiconductors and transparent wet solar cells [5]. TiO_2 thin films have been formed by a sol-gel coating method [6, 7] and a reactive sputtering method [8]. For TiO_2 to function as a photocatalyst, a thickness (~1 μm) that can absorb light is necessary [9]. However, in the sol-gel coating method, the thickness of the film applied in a one-time process is 0.2 μm or much less. This film deposition process must be repeated several times to obtain a film thickness of 1 μm. In the reactive sputtering method, the rate of film growth is extremely slow, ~ 0.003 μm/min [8]. To effectively utilize TiO_2 as a photocatalyst, instead of these methods, development of a higher-rate film deposition technology is desired.

The authors have been using a reactive vacuum arc deposition method to prepare AlN [10], TiN [11], and diamondlike carbon [12] films. In this method, high-energy ions emitted from the cathode of an arc discharge in a medium vacuum (0.01 Pa to 10 Pa) are reacted with atmospheric gas to form a composite film on a substrate. Compared to other deposition methods, this method has the advantages that the film grows quickly, a large surface area can be applied, and the film possesses excellent adhesive characteristics.

Based on the above background, this paper will first describe a reactive vacuum arc deposition method that uses

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