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Properties of titanium oxide film prepared by reactive cathodic vacuum arc deposition

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Abstract

TiO_2 thin films were deposited on a soda-glass substrate as a function of gas pressure (0.1–2.0 Pa) using conventional unfiltered vacuum arc deposition (UFA), and also deposited using a macroparticle-filtered arc deposition source (FAD). Crystalline structure, microhardness, elastic modulus, and optical properties (transmittance, reflectance, refractive index, extinction coefficient, absorption coefficient, and optical bandgap) were measured or evaluated. All films deposited on unheated substrates were amorphous, and post-annealed films as well as films deposited with in-situ heating were of the crystalline anatase phase. Similar mechanical and optical properties were obtained for the films deposited by UFA over a wide pressure range (0.1–1.0 Pa). After the annealing process, the films became harder, and the extinction coefficient of the film increased. The transmittance and the extinction coefficients of films deposited by FAD were found to be slightly superior to those of films deposited by UFA. The optical bandgap was about 3.25 eV for as-deposited amorphous material prepared by both UFA and FAD as well as for in-situ heated anatase film prepared by FAD.

Keywords: Hardness; Ion plating; Optical properties; Titanium oxide

1. Introduction

In the last decade, titanium oxide (TiO_2) film has been extensively investigated due to remarkable optical, electronic, and chemical properties. For example, the high refractive index and high dielectric constant of TiO_2 film provides an excellent optical coating and protective layer on lenses and optical fibers. The recent interest in films with the anatase crystalline phase has led to applications in environmental cleaning such as a photocatalytic purifier [1–3], and in solar energy converters such as a photochemical solar cells [4]. Other applications include humidity and gas sensors, gate electrodes in semiconductors, and testing for good blood compatibility [5].

TiO_2 films have been prepared by a variety of deposition techniques such as the sol-gel process [2,3], colloid baking, chemical vapor deposition [6,7], evaporation [8], various reactive sputtering depositions [9–15], ion beam-assisted processes [5,16,17], atomic layer deposition [18], etc. The authors at the Toyohashi University of Technology have also synthesized TiO_2 films by the reactive cathodic arc deposition method [19]. They have obtained as-deposited anatase film without additional heating device by connecting the substrate holder with the anode and heating the holder by a partial arc current. A disadvantage of this method is the emission of macroparticles or droplets of the cathode metal from the arc spot. One of the authors from CSIRO has developed a macroparticle-filtered arc deposition method and obtained droplet-free TiO_2 film [20].

In the present study, TiO_2 films were prepared on a soda-glass substrate using both the unfiltered and filtered arc deposition methods. In the former, the depositions were carried out as a function of gas pressure without in-situ heating, and in the latter, the films were deposited at a certain gas pressure with and without in-situ heating. X-ray diffraction (XRD), ultramicroindentation measurements, spectrophotometry, and spectroscopic ellipsometry were used for characterization of the structural, mechanical and optical properties of the films. Comparisons of the characteristics of the film deposited by both the unfiltered and filtered arc methods were made.

2. Experimental procedure

Fig. 1a shows a schematic diagram of a conventional

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