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Effects of radio-frequency power on the microstructure, morphology and wetting property of the silicon oxide films on glass and polyethylene terephthalate substrates by magnetron sputtering

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ABSTRACT

Silicon oxide films were deposited on glass and polyethylene terephthalate (PET) substrates by means of radio-frequency (RF) magnetron sputtering and the effects of the RF power on the microstructure, morphology, composition and wetting property of the films were investigated and compared. It was found that the films on PET have more voids and fissures than those on glass, especially those deposited with a RF power lower than 200 W, while the films on glass are all compact. All films possess the columnar structure and columns in the films on PET are coarser. These differences are supposed to result from the slower nucleation and faster diffusion on PET. Higher RF power provides particles with higher kinetic energy and produces films with denser structure and coarser columns. The silicon oxide films on both kinds of substrate have comparable thicknesses and compositions with an O/Si atomic ratio of 1.5. The surface roughness of the films is contributed from the roughness of substrate and the true roughness of films and the true roughness of films on both kinds of substrates reaches minimum at 200 W. The contact angle of water on the films shows a similar tendency, while the contact angle on PET is found lower than that on glass. The mechanism which explains the void formation of the film on PET can rationalize the difference.

1. Introduction

The demand on light weight of electronic portable products has been driving the development on the application of plastic substrates. The traditional glass substrate has a limitation of 0.4 mm in thickness. The plastic substrate is less dense and more ductile which can be produced in a lighter and thinner form and, especially, possesses well flexibility. The plastic substrate is becoming one of the most attractive objects nowadays in developing flexible electronic devices. However, the low resistivity of the plastic substrate against gas permeation and thermal damaging degrade its lifetime and quality. A barrier layer coated on the plastic substrate is essential [1]. In the field of biomaterials, the morphology of materials influences the behavior and shape of adhering cells [2]. It has been shown that cells preferentially adhere on the Island-like regions in micrometer scale which are coated with molecules of cell adhering protein. The form of the cells which influences the cell's functions can be confined by changing the shape and size of these regions [3].

One of the typical materials used for cell adhesion is silicon oxide. Silicon oxide thin films are also widely applied on microelectronic/optoelectronic products and food packages. In these applications, they can be used as insulating layers, anti-reflection layers and gas barrier layers [4, 5] respectively. There are many ways to produce silicon oxide thin films. The common methods include physical vapor deposition like thermal evaporation and sputtering [6–10], chemical vapor deposition (CVD) like plasma enhanced CVD [11–14], sol-gel method [15], etc. The substrates used included silicon wafer, glass, plastics including polycarbonate, polyethylene terephthalate (PET), polyether sulfone, etc.

In the previous studies, the most key subjects were laid on the measurement and analysis in application aspects. The analysis of the silicon oxide thin films on glass was stressed about their optical properties, while that on plastic was focused on their gas permeation resistivity. Few attentions have paid on the microstructural observation of the films. The comparison between the silicon oxide thin films on these two kinds of substrate is lacking.

In this work, glass and PET were chosen as substrates. Since the glass transition temperature of PET is 67–81 °C, the low temperature deposition process must be adopted. We chose the radio-frequency (RF) magnetron sputtering which is characterized as a low temperature

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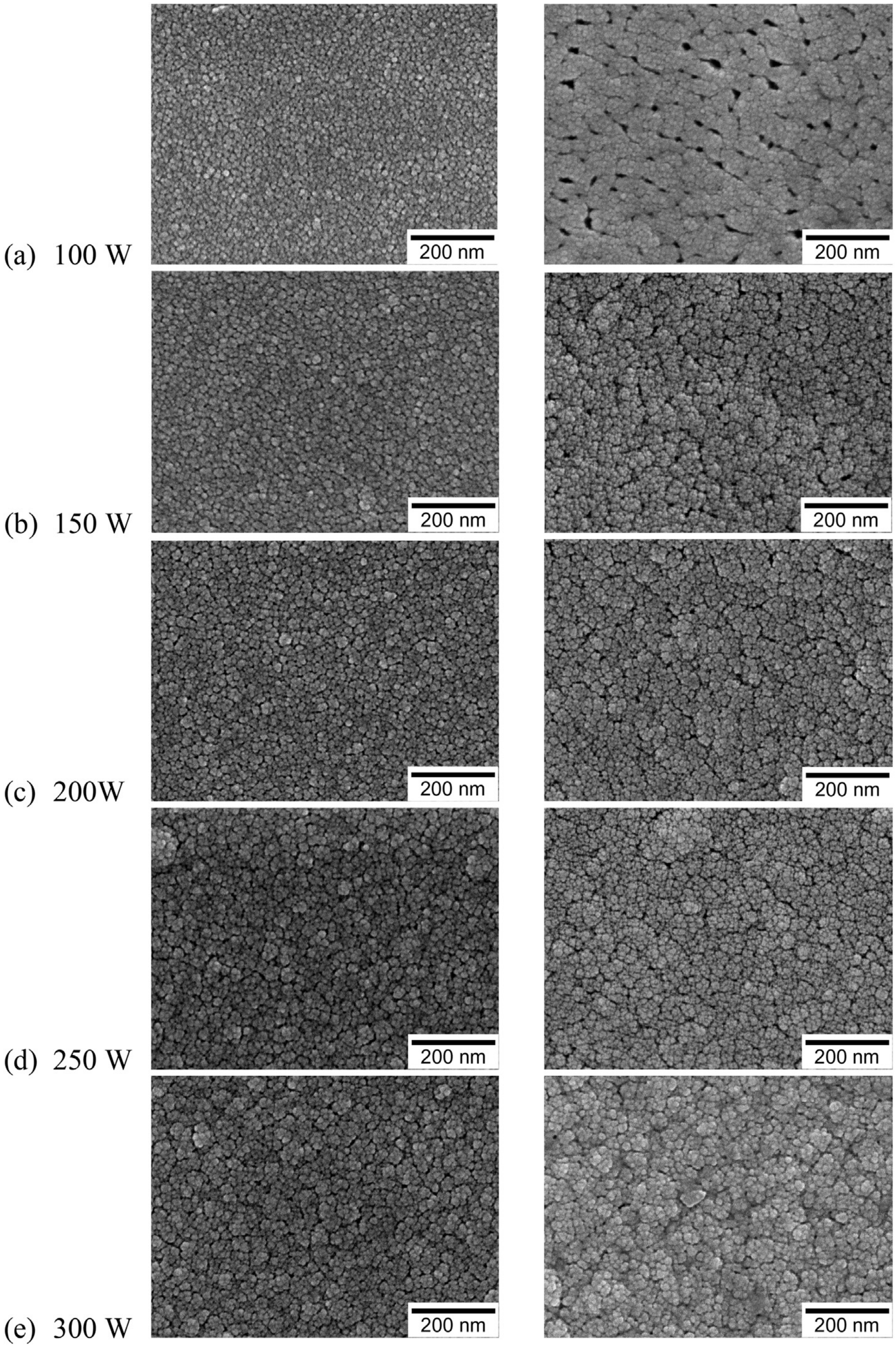

Fig. 1. Plane-viewed micrographs of silicon oxide films on glass (left) and PET (right) with various RF powers.

process with good composition control, low toxic inlet gas and low cost to deposit silicon oxide films and compared their microstructures, surface morphologies and wetting properties on different substrates.

2. Experimental

Silicon oxide thin films were deposited on glass (Deckgläser 100 No. 1) and PET (Nanya BD11–100 μm) substrates by means of the RF magnetron sputtering with a 5 N, 4 in. diameter, 3 mm thick silica target. A PET sheet was cut into $2 \times 2\,\mathrm{cm}^2$ pieces and cleaned with dehydrated alcohol. Round glass disks with a diameter of 1.5 cm were put in a 70% alcohol solution, vibrated ultrasonically for 5 min and dried. These substrates were adhered to a sample stage and cleaned with high pressure nitrogen gas flow. Finally the stage was set into the vacuum chamber of an in-house sputtering system. The RF generator and matching box used in the sputtering system were both made by Dressler Ltd., Germany, and their types are CESAR 36 and VMA/AW. The type of DC bias power source is 1 kW MDX low-power DC magnetron driver.

The chamber was evacuated by a vacuum system with a turbo pump till the base pressure reached 0.03 mTorr. An Ar flow was introduced as working gas and the substrate was pre-sputtered in plasma at a pressure of 36 mTorr and a bias of −300 V for 10 min. Silicon oxide films were deposited on stationary substrates for 30 min with varied RF powers from 100 to 300 W in a step of 50 W at a working pressure of 2 mTorr. The target-substrate distance was 9 cm and the Ar flow rate was 5 sccm.