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The electrical and morphological properties of magnesium oxide/alumina bilayered thin films prepared by electron beam evaporation at oblique incidence

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ABSTRACT

The electrical and morphological properties of magnesium oxide (MgO)/alumina (Al_2O_3) bilayered thin films prepared by electron beam evaporation at oblique incidence are reported. The MgO thin films are deposited when the incline angle is 55° on various Al_2O_3 thin films incline angles. A columnar grain with a roofing-tile-shaped surface is observed in these MgO/Al_2O_3 thin films. X-ray pole figures and θ-2θ scan, ω-scan are used to characterize in-plane and out-of-plane textures. The relationships between ω-FWHM, capacitor, leakage current, and the inclined angles are studied. The morphology is investigated by using scanning electron microscope (SEM). So the oblique angle deposition method is an effective way to control the microstructure of thin films.

1. Introduction

The oblique angle deposition (OAD) method is a physical evaporation technique that is capable of controlling film nanostructure and porosity [1–3]. The OAD thin films have extremely high surface areas, and can be made of any material compatible with physical vapor deposition processes. With different conditions, a variety of morphologies, such as inclined columns [4], zigzag [5], etc., can be grown. These features make OAD thin films potential applications in relative humidity (RH) sensor [6–10], magnetic-storage media [11], and so on.

Magnesium oxide (MgO) thin films deposited on inclined substrates are first observed to have preferred orientation by Aboelfotoh in 1973 [12]. The use of the OAD technique to fabricate MgO buffer layers for coated conductor applications is reported [13–16]. Recently, the optical properties of the OAD alumina (Al_2O_3) thin films are reported [17]. However, systematic studies have been seldom done on the electrical and morphological properties of MgO/Al_2O_3 bilayered thin films fabricated by using OAD method. Thus, in this paper, the effect of Al_2O_3 inclined angle on the electrical and morphological properties of MgO/Al_2O_3 bilayered thin films deposited by using electron beam evaporation with OAD method is presented and discussed. Various Al_2O_3 thin films inclined angles are used to control the surface morphology of the MgO thin films. The capacitor, leakage current, morphology, and texture are respectively investigated by using an impedance analyzer, semiconductor parameter analyzer, scanning electron microscope (SEM), and X-ray diffraction (XRD).

2. Experimental procedure

MgO/Al_2O_3 bilayered thin films are deposited on 10mm × 5 mm Pt/n-Si (1 0 0) substrates by using electron-beam evaporation with OAD method. A simplified schematic diagram of the OAD method is shown in Fig. 1. α is the vapor flux incident angle. The Pt/n-Si (1 0 0) substrates are ultrasonically cleaned for 15 min using acetone and methanol successively. Then the Pt/n-Si (1 0 0) substrates are cleaned with DI water and dried with nitrogen. High-purity 99.999% MgO and Al_2O_3 provided by Acetron are used as an evaporation source. MgO and Al_2O_3 layers are

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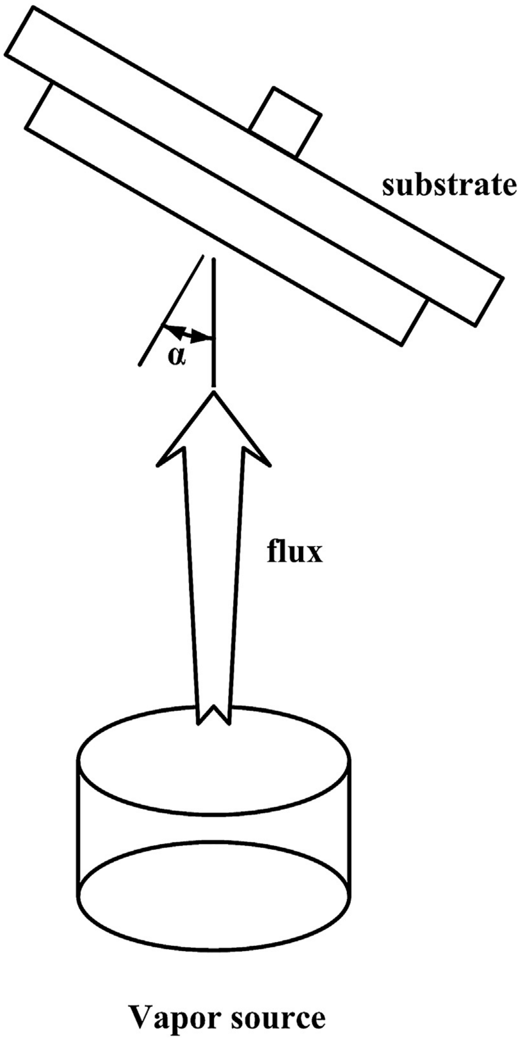

Fig. 1. Schematic diagram of the oblique angle deposition (OAD) method for electron beam evaporation.

deposited by electron beam evaporation at high voltage of 9 kV. During deposition, the chamber pressure is ~5×10^{-6} Torr. The substrate temperature is actively controlled by a thermocouple attached to the substrate holder. The substrate temperature is maintained at 423 K during deposition. The inclined angles of Al_2O_3 thin films vary between 0 and 80°. The Al_2O_3 layer is controlled to 0.7 μm at a deposition rate of 0.39 nm s^{-1}. The inclined angle of MgO thin films is 55°. The MgO layer is controlled to 1.9 μm at a deposition rate of 2.1 nm s^{-1}. The Au top electrodes with a diameter of 200 μm are by using electron-beam evaporation.

X-ray diffraction (XRD) θ-2θ scan, ω-scan, and pole figure are used for the phase examination and texture analysis with Cu-Kα radiation (as for the OAD MgO (0 0 2) tilt away from the substrate normal, the out-of-plane and in-plane texture are defined as the texture along the MgO (0 0 2) plane hereafter). The surface and cross-section morphology of the MgO/Al_2O_3 thin films is characterized by using a scanning electron microscope (SEM). The dielectric measurements of the capacitors employing MgO/Al_2O_3 in the range 100–10 MHz are performed by using an Agilent 4294A impedance analyzer. The leakage current measurements are carried out by using an HP 4155B semiconductor parameter analyzer.

3. Results and discussion

The biaxial texture of the OAD MgO films is characterized by X-ray diffraction pole figure analysis. The typical pole figure of an OAD MgO film deposited at an inclined angle $\alpha = 55°$ (thickness 1.9 μm), as shown in Fig. 2(a). The MgO (0 0 2) planes are parallel to the substrate surface, the MgO (0 0 2) axis of the OAD MgO layer is tilted away from the substrate normal. The asymmetric distribution of the pole peaks reveals that the MgO (0 0 2) planes have a tilted angle toward the deposition direction. Additionally, a distinct in-plane texture leads to well defined poles of the (0 2 0) and (2 0 0) axis, respectively. The in-plane texture of MgO (2 2 0) poles is characterized in Fig. 2(b).

XRD θ-2θ scans are performed on these samples. As shown in Fig. 3(a). The small peaks of Pt (1 1 1) and (2 0 0) and the large peak of MgO (2 0 0) observed on the XRD θ-2θ scan. The intensity of MgO (2 0 0) decreases with the increasing Al_2O_3 inclined angles.

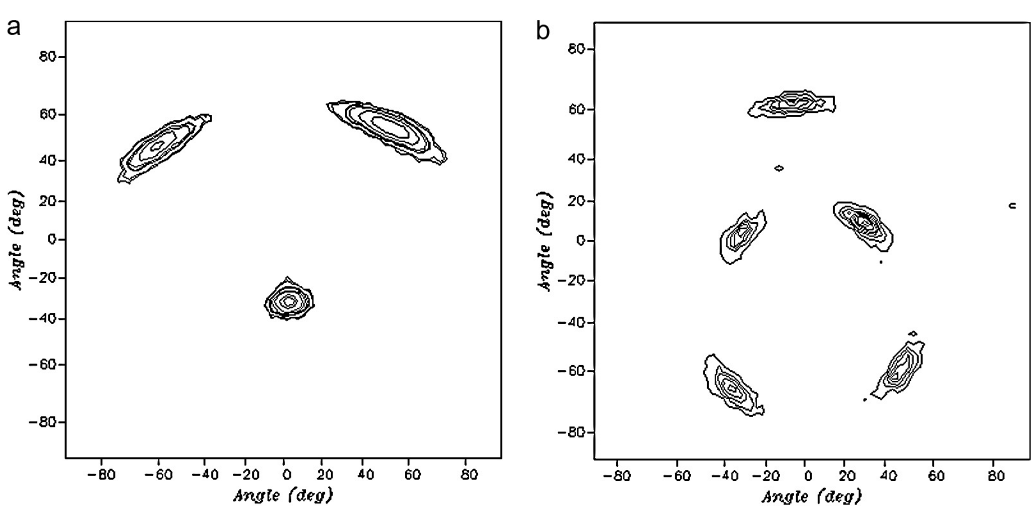

Fig. 2. Pole figures of OAD MgO thin films fabricated with $\alpha = 55°$ of the various Al_2O_3 thin films inclined angles: (a) MgO (0 0 2), (b) MgO (2 2 0).