Available online at www.sciencedirect.com
SCIENCE DIRECT
Thin Solid Films 502 (2006) 223 – 227
thin solid films
www.elsevier.com/locate/tsf

The underlayer effects on the electrical resistivity of Ag thin film

Yasutaka Tsuda [a,*], Hideo Omoto [a], Katsuto Tanaka [a], Hisashi Ohsaki [b]

[a] *Glass Research Center, Central Glass Co., Ltd, Mie, Japan*
[b] *Research Center for Advanced Science and Technology, The University of Tokyo, Tokyo, Japan*

Available online 15 September 2005

Abstract

The effects of AZO (Aluminium-doped Zinc Oxide) undercoats on electrical resistivity of Ag thin films have been investigated. The characteristics of Ag films in 20 nm Ag / 15 nm AZO / glass stacks have been analyzed. In the layer stacks, the AZO films were deposited with various sputtering conditions, such as applied power (0.1 – 1.2 kW), gas pressure (0.3 – 5.0 Pa) and O_2 concentration of sputter gas (0 – 50%), and the Ag films were deposited on those AZO undercoats in a fixed condition. The combination of asymmetric 2θ and symmetric $\theta - 2\theta$ X-ray diffraction (XRD) measurements makes the structural characteristics concerning the preferred orientation clear, distinguishing from the degree of crystallinity. From these XRD analyses, it was found that the crystalline orientation of AZO film is affected with the deposition parameters. Especially, the preferential growth of ZnO with its (002) planes parallel to the substrate is more enhanced with increasing the applied power. Also, the AZO undercoat affects the crystalline orientation of overcoated Ag film as the highly oriented Ag films with their (111) planes parallel to the substrate are deposited on the more preferentially grown AZO undercoats. It was found that highly oriented Ag films have lower electric resistivity. The obtained results indicate that the orientation of AZO crystallites affects the initial growth of Ag crystallites and the electrical resistivity of Ag films can be controlled by the sputter condition of AZO undercoat.

Keywords: Silver; Zinc oxide; X-ray diffraction; Electrical properties and measurements

1. Introduction

Silver metal has the lowest resistivity and low refractive index around 0.1 in the visible wavelength region. This kind of optical characteristics enables to design the bandpass filter with a layer construction of a sandwich of a silver layer with two dielectric-material layers or its reiteration [1]. Such silver/dielectric-material multilayers have been applied to the low emissivity coatings (Low-E) and recently this multilayer system has been extendedly applied to the electromagnetic interference (EMI) shielding filter for plasma display panels, featuring the silver's lowest electrical resistance [2].

When the optical filter devices include a basic layer construction of silver/dielectric-material, low sheet resistance is required for sufficient EMI shielding. The sheet resistance of an Ag layer proportionally decreases with the Ag thickness when the resistivity of Ag is independent of its thickness. Adding to that, the resistivity itself also decreases with the Ag thickness and asymptotically reaches to the bulk one. However, thicker Ag films deteriorate optical properties in the visible wavelength region such as transmittance, reflectance and reflective color. Therefore, EMI shielding efficiency and optical properties run counter each other. For finding a way out of the difficulties, key physical parameter is the electrical resistivity of Ag thin film, which is possibly required for such a practical use. Recently, it is known that electrical resistivity of Ag thin film changes with its underlayer materials; the resistivity of Ag becomes low when Ag is deposited on ZnO undercoats [3]. However, the mechanisms are not clear on how the ZnO undercoats affect the electrical resitivity of the Ag thin film.

We investigated the effect of AZO (Aluminium-doped Zinc Oxide) undercoats on the electrical resistivity of Ag thin films. The preferred orientation of Ag layers deposited on AZO undercoats was studied with asymmetric 2θ and symmetric $\theta - 2\theta$ XRD analyses and the relationship

* Corresponding author.
E-mail address: yasutaka.tsuda@cgco.co.jp (Y. Tsuda).

0040-6090/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.tsf.2005.07.279

between the crystal orientation and resistivity of the Ag layer are discussed in this paper.

2. Experimental

We used an in-line type planar DC magnetron sputter coater (Shinku Seiko Ltd., SP-D-3) for depositing 20 nm Ag/15 nm AZO layer stacks on soda–lime–silicate glass at room temperature. In all deposition, target–substrate distance was 25 mm, and 200 × 70 mm size of rectangular targets were used. The AZO ceramics target including 2.3 at.% Al was used for depositing AZO films. The AZO films were deposited with various sputtering conditions, such as applied power (0.1–1.2 kW), gas pressure (0.3–5.0 Pa) and O_2 concentration of sputter gas (0–50%). Ag films were deposited on those AZO undercoats in a fixed condition; applied power: 0.1 kW, Ar sputter gas pressure: 0.3 Pa. The thickness of the films was measured using a stylus type surface tracer (Rank Taylor Hobson, Talystep). The electrical resistivity of the Ag film was measured with a collinear four-point probe. XRD measurements were performed in asymmetric 2θ (incident angle being 0.8°) and symmetric $\theta-2\theta$ configurations. We used Rigaku RINT2000 and RINT1500 diffractometer in asymmetric 2θ and symmetric $\theta-2\theta$ measurements, respectively. In both instrument, CuKá radiation was used as an X-Ray source. The surface roughness of the films were measured by an atomic force microscope (Seiko Instruments Inc., SPI 3700).

3. Results and discussion

3.1. Dependence of applied power to AZO

Fig. 1 shows the change of the XRD patterns of 20 nm Ag/15 nm AZO/glass samples deposited with changing the applied power of AZO sputter deposition, where the sputter gas pressure and O_2 concentration in the gas were fixed as 0.3 Pa and 10%, respectively. Fig. 1(a) and (b) represent the XRD patterns obtained at the symmetric $\theta-2\theta$ and asymmetric 2θ arrangement, respectively.

The diffraction peak at $2\theta = 34°$ is the only peak observed coming from the ZnO and is assigned to (002). The peaks at 38°, 44°, 64°, and 77° are assigned to (111), (200), (220) and (311) of Ag, respectively. When increasing the applied power for sputter deposition of AZO, ZnO (002) and Ag (111) peaks grow in Fig. 1(a). From these results, two possible stories are introduced: one is that the films develop their crystallinity with corresponding preferred orientations; the other is that the films are constructed from the crystallites originally but the orientation of the crystallites becomes more ordered with increase of the applied power.

Fig. 1(b) shows that only the Ag (220) peak grows but the other peaks shrink with increase of the applied power. In this asymmetric configuration, any diffraction peaks from the planes parallel to the substrate can't be observed. However, the Ag (220) plane and Ag (111) plane enclose an angle of 35.26°. This is similar to the sum of the Ag (220) diffraction angle, theta being 32.21°, and the angle of incidence of 0.8° between the X-ray beam and the samples plane. Hence the X-rays are diffracted preferably by (220) planes of the crystallites with their (111) planes being parallel to the substrate.

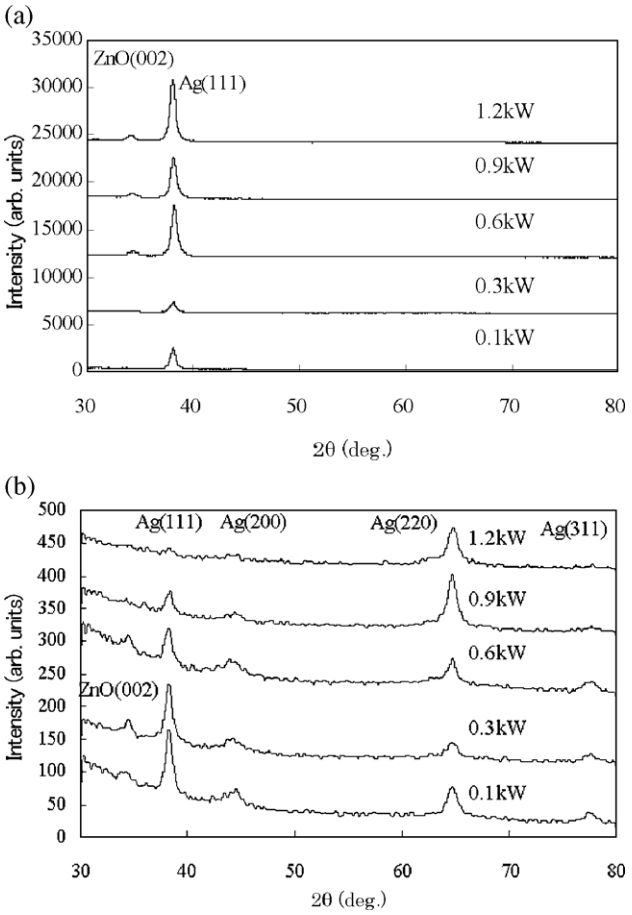

Fig. 1. XRD patterns for 20 nm Ag/15 nm AZO/glass samples with changing AZO sputter power: the applied power is represented just above each XRD profile. (a) Shows the results on the symmetric $\theta-2\theta$ measurements and (b) shows that on the asymmetric 2θ measurements.

Therefore, Fig. 1(a) and (b) consistently induce the clear picture concerning with the crystalline orientation as follows; AZO and Ag films are constructed from crystallites having a preferred orientation in some extent when the AZO was deposited in low applied power condition; the preferential growth of ZnO with its (002) planes parallel to the substrate is more enhanced with increasing the applied power and in consequence, the highly oriented Ag films with their (111) planes parallel to the substrate were deposited on the more preferentially grown AZO undercoats.

Fig. 2 shows the change of the resistivity and surface roughness of Ag/AZO/glass samples when increasing the applied power to AZO.