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ZnO film formation using a steered and shielded reactive vacuum arc deposition

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Abstract

Zinc oxide (ZnO) thin films were prepared on a borosilicate glass substrate by a steered and shielded reactive vacuum arc deposition method. The cathode spot was driven on a cathode surface using weak and strong permanent magnets, placed behind the cathode. The radial magnetic flux densities at the bottom of cathode shoulder were 1.0 mT and 5.5 mT, respectively. The arc was operated at DC 30 A and the in-process pressure was varied from 0.1 to 5.0 Pa. No bias was applied to the substrate. The substrate temperature was below 75°C after 20-min deposition. The deposition rate increased with the in-process pressure until 1.0 Pa with both weak and strong magnets. X-Ray diffraction analysis revealed that all films had a strong ZnO (200) peak, indicating *c*-axis orientation. In particular, the films strongly oriented to (200) were obtained at 0.5–3.0 Pa for the strong magnet. Highly transparent films in visual region were obtained at 0.5 and 3.0 Pa with both weak and strong magnets. A refractive index at 600 nm varied from 1.75 to 1.95. With the strong magnet, electric resistivity varied from 10^{-3} to 15 Ω cm as the pressure increased. However, with the weak magnet, resistivity of the order of 10^{-3} Ω cm was obtained over a wide pressure range of 0.1–1.0 Pa.

Keywords: Steered and shielded vacuum arc; Reactive deposition; Zinc oxide film; Cathode erosion; Film properties

1. Introduction

Transparent conductive films have attracted great interest because of their potential use in industrial applications as transparent electrodes in optoelectronic devices such as liquid-crystal displays and solar cells [1]. Zinc oxide (ZnO) is one of the candidates for such applications, since it has optical transparency in visual regions, low electrical resistivity, piezoelectric, photoelectric, and electrooptic properties, and a wide optical band gap (typically, 3.3 eV). ZnO thin film has also been considered for other applications, such as surface acoustic wave (SAW) devices, ultrasonic transducer arrays, chemisorption gas sensors, mass-loading sensors, optical wave-guides, and others [2,3]. To date, ZnO thin film has been produced by a variety of techniques, such as spray pyrolysis [4–6], chemical bath deposition [7], chemical vapor deposition (CVD) [8,9], various sputtering techniques [3,10,11], laser deposition [2], and cathodic arc deposition [12].

The cathodic vacuum arc deposition process is an ion-plating method that exhibits a high deposition rate, excellent adhesion, ease of system scale-up, and does not require a crucible. However, the major disadvantage of the process is the emission of macrodroplets from the cathode spot and their adhesion to the films under preparation. Several techniques have been developed to overcome this problem, such as the steered method [13], a variety of magnetically filtered methods [14,15] and the shielded method [16]. The authors have employed the shielded method and have successfully prepared various metal-nitride and oxide thin films [12,17–19]. In the present study, ZnO films were prepared by the hybrid method of steered and shielded arc

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