ELSEVIER

Surface and Coatings Technology 120–121 (1999) 383–387

SURFACE & COATINGS TECHNOLOGY

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Synthesis of *a*-axis-oriented AlN film by a shielded reactive vacuum arc deposition method

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Abstract

Aluminum nitride (AlN) thin films were fabricated by a non-shielded conventional reactive vacuum arc deposition method and by a shielded vacuum arc deposition method in which a droplet-shielding plate was located between the cathode and substrate. The properties of the films, such as surface morphology, number of droplets, deposition rate, crystalline structure, optical properties, hardness, and elastic modulus were investigated. The films deposited by the non-shielded method were metallic silver, very rough due to many macrodroplets, and easily peeled off from the substrate, whereas the films deposited by the shielded method were transparent in the visual and near-infra-red regions, smooth and almost droplet-free, and adhered well. The former exhibited a *c*-axis orientation, whilst the latter showed *a*-axis orientation. The refractive indices of the films deposited by the shielded method were 1.9–2.1, and the extinction coefficients were less than 10^{-2}. The films were much harder and stiffer than boro-silicated glass. © 1999 Published by Elsevier Science S.A. All rights reserved.

Keywords: *a*-axis orientation; Aluminum nitride; Film properties; Shielded reactive vacuum arc deposition

1. Introduction

A thin film of aluminum nitride (AlN), with a hexagonal wurtzite crystalline structure, is used for many applications in various fields because of its attractive thermal conductivity, electrical resistance, hardness, optical properties, acoustic velocity, etc. These applications include electrical insulators with a high thermal conductivity, surface acoustic wave (SAW) devices [1], surface protection of photoconductors [2], optical hard coatings [3], and protection coatings on fusion reactor blankets [4]. Recently, many studies have reported on AlN films deposited by a number of methods such as various chemical vapor depositions (CVD) [3,5,6], reactive sputtering [1,2,4,7–10], electron shower method [11], filtered arc deposition [12], laser ablation deposition [13], molecular beam epitaxy growth [14], and ion-beam-assisted deposition [15]. Most of them produce a *c*-axis oriented film. However, an *a*-axis oriented film is also necessary and used for transverse wave SAW devices. The influence of gas pressure [7–9,13], substrate temperature [13], ion energy and input power [10], and bias voltage [11,16] on the *a*-axis oriented film formation has been reported.

The authors have fabricated AlN film [16,17] as well as diamond-like carbon [18], titanium nitride [19], and titanium oxide [20], by a conventional steered cathodic vacuum arc deposition method. It has been found that the crystalline orientation of the AlN film varies with the application of the r.f. bias to the substrate [16]. However, the films prepared by this method were not transparent since many macrodroplets emitted from the cathode spot adhered to the film. Moreover, the *a*-axis oriented film had a poor adhesion and a rough surface. In this study, the shielded reactive vacuum arc deposition method [19,21,22] was employed to produce a droplet-free, transparent, and smooth AlN film. We prepared the film by shielded and non-shielded vacuum arc methods as a function of process pressure and then investigated film properties such as surface morphology, number of droplets, deposition rate, crystalline structure, optical properties, and mechanical properties.

2. Experimental

The reactive cathodic vacuum arc apparatus is shown in Fig. 1. The Al cathode (64 mm in diameter, 25 mm

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0257-8972/99/$ – see front matter
PII: S0257-8972(99)00389-8