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Thin Solid Films 386 (2001) 276–280

thin solid films

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# Effect of substrate bias on AlN thin film preparation in shielded reactive vacuum arc deposition

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Received 17 June 1999; received in revised form 6 March 2000; accepted 6 March 2000

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## Abstract

Aluminum nitride (AlN) thin films were prepared using reactive cathodic vacuum arc deposition in conjunction with a macrodroplet shield plate. Various bias conditions, such as no bias (floating), 0-V bias (same potential as anode), DC bias of $-10$ to $-30$ V, and RF power of 25–200 W, were applied to the substrate table. For floating bias, *a*-axis-oriented film was obtained. For 0-V bias, the films prepared on molybdenum substrate showed no preferential orientation, although the film prepared on silicon and borosilicate glass showed *a*-axis-orientation. For RF bias, the orientation changed from the *a*- to the *c*-axis as the RF power increased. The hardest (27 GPa) film was obtained for 0-V bias, and the hardness of the other films ranged from 19 to 24 GPa. The refractive index of the film prepared on quartz substrate was approximately 2.0 over the visual and infrared regions for all films. The extinction coefficient was less than 0.01 over the visual and infrared regions, with the exception of the film prepared under the 0-V bias condition, which showed a higher value.

*Keywords:* Shielded reactive vacuum arc deposition; AlN film; Bias; Orientation; Film properties

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## 1. Introduction

Aluminum nitride (AlN) possesses various excellent properties, such as: high electrical resistance ($10^9$–$10^{11}$ $\Omega$ m) [1]; high thermal conductivity (up to 320 W/m K) [2,3]; low thermal expansion coefficient (*c*-axis parallel: $5.3\times10^{-6}$ /K, *a*-axis parallel: $4.2\times10^{-6}$ /K) [4]; high acoustic velocity (approx. 5.5 km/s for transverse waves and 11 km/s for longitudinal waves) [5,6]; high hardness (20 GPa) [7]; chemical stability; a high decomposition temperature (approx. 2700 K) [2,3]; a wide bandgap (6.2 eV at 300 K) [8]; and transparency in the visual and infrared regions. These properties enable AlN thin films to be used in numerous applications, including electrical insulators for heat sinks [9], surface acoustic wave (SAW) devices [6,10], protective coatings on fusion reactor blankets [11], and tribological coatings [12].

To date, AlN films have been prepared by a variety of chemical vapor deposition (CVD) and physical vapor deposition (PVD) methods. The authors first prepared AlN film by a conventional steered vacuum-arc deposition method [13]. However, numerous metal macrodroplets, which were emitted from the Al cathode, were present on the film, resulting in inferior film quality. We then employed the shielded vacuum-arc method [14] in order to eliminate the macrodroplets from the film, and a transparent AlN film was obtained [15]. In this case, no bias (= floating potential) was applied to the substrate without additional heating, and

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0040-6090/01/$ - see front matter
PII: S0040-6090(00)01673-4