CrAlN Film Hardness Uniformity Affected by Nitrogen Content

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Abstract. For transition metal nitrides, nitrogen content is an important factor that determines properties of achieved coatings. In this work, chromium aluminum nitride (CrAlN) films were prepared by reactive dc co-sputtering and were investigated against variation of the nitrogen content. N_2 gas flow rate was varied from 2.0 to 3.0 sccm for the nitrogen variation, whereas sputtering currents at both Cr and Al targets were fixed at 0.4 A. The CrAlN films were characterized by X-ray diffraction, field-emission scanning electron spectroscopy, energy-dispersive X-ray spectrometry, and nanoindentation. The results revealed that the increase of the N content led to target poisoning causing a reduction of Al fraction in the lattice of $Cr_{1-x}Al_xN$ solid solution. Meanwhile, morphology of the CrAlN films became denser at the higher N content. Similarly, crystallinity of the film was improved by the increase of the nitrogen. With the enhancement of the crystalline structure and morphology, the CrAlN film with the higher N content showed improved hardness and elastic modulus with good uniformity.

INTRODUCTION

Chromium nitride (CrN) based coatings were invented to combine the high oxidation resistance of CrN with the dominant properties of TiN, ZrN, or AlN coatings. The objective was to enhance structure and properties such as hardness, corrosion and wear resistance, and especially oxidation resistance that CrN fails at temperature above 700 °C [1]. Among these ternary nitride films, CrAlN was reported on excellent mechanical properties accompanying with better oxidation resistance [2-5]. However, achieving desired properties depends on techniques and parameters of film deposition. Sputtering is the deposition technique that gives coatings the uniformity and very good adhesion. The parameters during film preparation such as sputtering power at the targets, substrate bias, substrate temperature, and pressures of gases also play the importance role on film structure and properties [6]. For nitrogen partial pressure, the investigation of its influences on structure and properties of some coatings such as CrN [7], TiN [8], and TiAlN [9] have been reported. However, there are a few works devoted to the CrAlN coatings. Consequently, the aim of this work is to study effects of the nitrogen reactive gas on structure and mechanical properties of the CrAlN films. The films were prepared by reactive dc unbalanced magnetron co-sputter deposition with variation of the nitrogen gas flow rate. The structure and mechanical properties of the films were characterized and discussed against the nitrogen flow rates.

EXPERIMENTAL DETAILS

The CrAlN films were grown on silicon (100) wafers, microscope glass slides, and SUS304 stainless steels by unbalanced dc magnetron co-sputtering system, in a mixture of argon and nitrogen atmosphere. The high purity chromium (99.95%) and aluminum (99.999%) metals with a diameter of 3 inches and a thickness of 0.125 inches were used as sputtering targets. The substrates were ultrasonically cleaned in acetone and then in methyl alcohol for 15 min in each step and dried with nitrogen gas. After the cleaning process, the substrates were placed on a holder at

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