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Structure and Mechanical Properties of Unheated Chromium Aluminum Nitride Coatings Sputter-Deposited with Various Aluminum Content

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Abstract. Chromium aluminum nitride (CrAlN) has been extensively studied because of high hardness, high oxidation and corrosion resistance, and good wear resistance. However, utilizing substrate treatments such as heating and voltage biasing during film deposition usually leads to relatively high surface roughness that affects wear rates. It has been found that sputter deposition at low substrate temperatures can produce nano-grain coatings with enhanced structure and mechanical properties. For this reason, the CrAlN in this study was prepared by a reactive co-sputtering technique without the substrate treatments. Effects of Al content on structure and mechanical properties were investigated by X-ray diffraction, field-emission scanning electron microscopy, energy-dispersive X-ray spectrometry, atomic force microscopy, X-ray photoelectron spectroscopy, and nanoindentation. The results suggest that these CrAlN films formed as solid solutions by substitution of Al for Cr in the CrN crystalline structure. The deposition with increasing Al but fixed N leads to N deficiency, therefore at high Al content these films form under 1:1 stoichiometric nitride. This lowers film crystallinity and hence refined film morphology. Surface roughness and hardness of the films decreased from 5.737 to 1.135 nm and from 31.69 to 26.56 GPa, respectively. However, the solid solution strengthening arising from the further increase of the Al content causes these values to rebound to 2.466 nm and to 30.16 GPa.

Introduction

The minimization of friction and wear in metal parts has both economical and environmental benefits for industry. Thesse include lowering energy losses leading to less fuel consumption, decreasing heat generation during machine operations, reducing costs for maintenance or machinery part replacement, lowering production stops, and increasing lifetime. Smoothening the working surfaces of tools and machinery leads to the reduction of friction coefficient and hence improves wear resistance [1]. Among CrN-based coatings, chromium aluminum nitride (CrAlN) can be used in many applications such as machining tools, automotive industry, and semiconductor electronics [2, 3]. That is due to high hardness [4-7], good corrosion and oxidation resistance [8-10], and high sliding and abrasive wear resistance [6, 11]. However, to achieve good mechanical properties, the CrAlN films are prepared by a sputtering technique with some substrate treatments, i.e. heating and voltage biasing. Most of the films have been reported to have high hardness ranging from 30 to 38 GPa. However, these came with relatively high surface roughness in the range of 6 – 15 nm [5, 6, 12]. Only Barshilia et al. [13] obtained a hardness of 33 GPa with very low roughness of 1.13 nm. The objective of this study was to obtain CrAlN thin films possessing good mechanical properties