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Structure and Morphology Study of Very Thin TiCrN Films Deposited by Unbalanced Magnetron Co-sputtering

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Abstract. Very thin titanium chromium nitride (TiCrN) films with various Ti content were deposited by unbalanced magnetron co-sputtering of Ti and Cr metals. Deposition time was set to 15 min to achieve film thickness ranging from 142 to 190 nm. Silicon wafers and copper grids were used as substrates. The Ti current (I_{Ti}) was varied from 0.4 to 1.0 A to achieve the differnt Ti content whereas Cr current (I_{Cr}) was fixed to 0.6 A. Effects of the Ti content on structure and morphology of these TiCrN thin films were studied by X-ray diffraction (XRD), transmission electron microscopy (TEM), atomic force microscopy (AFM), field emission scanning electron microscopy (FE-SEM), and energy-dispersive X-ray spectroscopy (EDS). The XRD revealed that the films showed crystalline structure with fcc phase and were formed as $Ti_xCr_{1-x}N$ solid solution with a crystallite size of about 13 nm. The TEM result confirmed that the films were polycrystalline. The AFM images of the films showed dome top characteristic with root-mean-square roughness slightly decreasing from 1.643 to 1.273 nm. FE-SEM cross-sectional images exhibited development of film morphology from columnar structure corresponding to zone 1 of Thornton's structure zone model to fine structure gradually with the increase of the Ti content.

Introduction

Ternary transition metal nitrides have been intensively studied to develop coatings with improved mechanical and tribological properties combining from binary nitrides such as TiN, CrN, or ZrN. Due to its high hardness, low friction coefficient, and high temperature oxidation resistance [1, 2], CrN-based ternary nitride films such as TiCrN [3], CrAlN [4], and CrZrN [5] have been applied for protective coatings on tools and machinery parts (e.g. cutting tools, molds, and dies). To be used as the protective layer, the nitride films usually were prepared to reach a thickness of 2 – 5 μm. Meanwhile, the deposition technique widely used is unbalanced magnetron co-sputtering that gives film uniformity and property control facility by way of variation of depositing condition. In addition to the hard coatings, relatively thin nitride films were developed to be used in other fields, such as CrN applied for energy storage application [6]. The film was reported on its good performances and was considered a promising material for use as an anode for lithium-ion battery. Consequently, the very thin nitride films were interesting for our group to study. Correspondingly, there are only a few reports on structure and morphology of this kind of coatings. In this work, the TiCrN film with the thickness of about 200 nm or lower was chosen to study. The co-sputtering technique was used to prepare the films to have various Ti content. Effects of Ti addition on the structure and morphology of these films would be characterized and discussed.