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Study on the Nanoscale Tribological Characteristics of Thin Film Coatings

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Wear that occurs between two or more bodies in contact leads to functional problems of a system such as leakage, corrosion, and reduced efficiency. To overcome these problems, wear resistant coatings are applied on the surface through different methods, depending on the materials, scales, and applications. Thin film coatings are in demand due to advancing nano/micro technologies, and the wear characteristics in nanoscale should be examined since the thickness of the coatings can be as low as a few nanometers. In this study, nanoscale wear of thin film coating was investigated. The coatings were fabricated by magnetron sputtering system, and while maintaining the top layer the same, different sub-layers were applied to deviate the mechanical properties of each coating. The hardness and elastic modulus of the coatings were examined by nanoindentation method in order to assess the effects of different sub-layers on the mechanical properties. The surface roughness and topology were examined using an atomic force microscope (AFM) before and after the wear tests. AFM was also utilized in the wear experiments by controlling the normal loads and sliding a hard AFM tip on the surface to induce nanoscale wear. The wear results were examined and compared to analyze the wear characteristics of coatings according to their different mechanical properties. The results of this study will aid in optimizing the structure of thin film coatings in nano/micro applications.

1. Introduction

Friction and wear induced by bodies in contact play a major role in efficiency and working life expectancy of a mechanical system. Numerous efforts were made to protect the contact surfaces to minimize friction and wear by applying various types of coatings on the surface. To improve the wear performance of the coating, multilayer structured coating systems were developed [1-3]. It has been suggested that additional sublayers can improve the adhesion of overall coating on the surface [4-5]. The multilayer structures have benefits in blocking dislocation and dispersing stresses, and the structure also allows the control of mechanical property of overall coating which is important factor in wear performance.

As the NEMS and MEMS devices are advancing, contact region are becoming smaller and the wear behavior, mechanism, and factors can be different compared to that of macroscale wear. Also, since the thickness of the thin film coatings that are applied on the small-scale mechanical systems can be as low as a few nanometers, it is necessary to examine tribology in nanoscale. In the present work, multilayer coatings with various sublayers were investigated. The effects of sublayers on the mechanical and tribological behaviors of overall coating are experimentally analyzed.

2. Experimental methods

Multilayer coatings with DLC top layer of a consistent thickness were fabricated by magnetron sputtering on silicon wafer substrate. Titanium and chromium were selected as the sublayers since they were known to improve the adhesion of DLC coating [6-7]. A schematic of multilayer coating is shown in Fig. 1. The thickness of each coating was chosen to evaluate the effectiveness of the sublayer.

The mechanical properties such as hardness and elasticity were evaluated by nanoindentation. The indentation depth was controlled to be within the range of the thickness of DLC top layer, which was similar to the wear depth. An AFM was utilized in conducting the wear tests by controlling the normal loads, and the AFM was also used to examine the wear tracks. Fig. 2 shows a schematic diagram of AFM wear test.

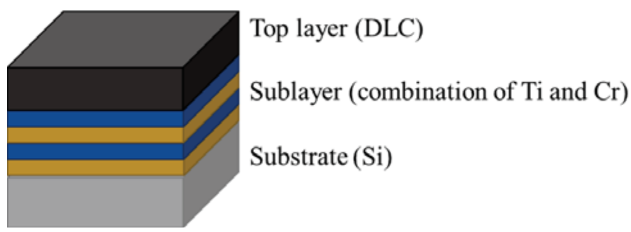

Fig. 1 Schematic of multilayer coating

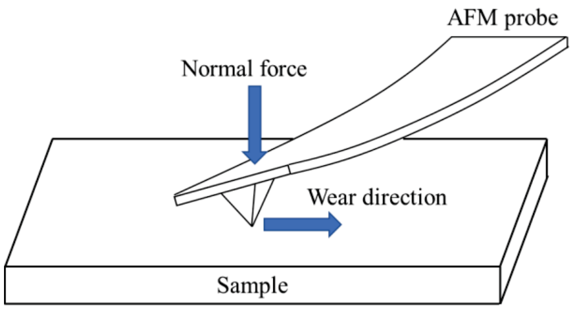

Fig. 2 Schematic of AFM wear test

3. Conclusions

The wear behaviors and mechanical properties of coatings varied depending on the number and thickness of the sublayer. Coating with thinner and more individual sublayers showed improved wear results as the applied normal loads increased, suggesting multilayers of coating affected and improved the overall wear performance. The experimental results obtained in this study provided insight into the wear of coating in nanoscale, and the results are expected to aid in designing of highly wear resistant multilayer thin film coating.

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