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Mechanical and tribological properties of nano-layered coatings

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Relationship between structure, mechanical and tribological properties of metal-carbon nanolayer periodical coatings were reported. It was found that even structures with thicknesses of individual layers of several nanometers were able to provide high macroscale wear resistance. FEM analysis showed that high wear resistance of the multilayer coatings could be attributed to the unique combination of their mechanical properties.

Keywords: tribology, wear, multilayer, coating, nanostructure

1. Introduction

In order to reduce the friction and wear of mechanical components various strategies have been developed, including the use of hard and soft metallic coatings[1)], super hard diamond-like coatings[2)], chemical coatings[3)], micro- and nanocomposites[4)]. All these coatings have shown to be successful for reduction of friction and wear in certain applications. Compared to the benefits of using a coating that consists of a single layer, a coating that consists of several layers may provide additional benefits due to synergistic effects. In the case of multi-layer coatings, advantages of different materials may be utilized together to further improve the properties of the solid surface. For example, an interlayer can be used to improve the adhesion between a substrate and a hard protective layer. In a typical tribological application, the mechanism in which the multilayer coatings improves the frictional properties depends on the type of coating, thickness of individual layers, number of layers and their stacking order. It has been demonstrated that just using two well designed coating layers resulted in a significant reduction of friction and wear[5)].

Furthermore, the ability of nanomaterials to reduce wear at the macro-scale has been well documented[6)]. It has been shown that several monolayers of graphene could reduce the friction and wear during dry sliding of a steel ball on a copper plate[7)]. In the present work, coatings that consisted of various layers with a total thickness of a couple of hundred nanometers were investigated. The effects of structure of coatings on their mechanical and tribological properties were assessed. The results of this work are expected to aid in better design of nano-layered coatings for tribological applications.

2. Experimental methods

The carbon-metal multilayer coatings were deposited by magnetron sputtering on silicon substrates. Structure of coatings was investigated by transmission electron microscopy (TEM), low-angle x-ray diffractometry (LAXRD), Raman analyses. The surface morphology was examined by atomic force microscopy (AFM). Wear was characterized by using of high resolution 3D Laser microscopy.

Tribological behavior of the coatings were assessed by using of custom-build reciprocating tribotester. Finite element method (FEM) analysis was used for evaluation of the experimental data and developing of the new model of wear resistant nanostructures.

3. Results

Wear resistance of carbon-metal coatings significantly depended on the structure of the metal layer. The structure may be amorphous or polycrystalline and its transformation was determined by the thickness of the metal layer and deposition conditions. For example, in the case of chromium-carbon multilayer coatings, wear resistance of the coatings increased as the thickness of the cobalt layer increased from 0.1 to 0.25 nm with the fixed thickness of 1 nm carbon layer (Fig. 1). However, further increase in the thickness of the chromium layer led to decrease in the wear resistance.

The initial increase in the wear resistance could be attributed to increasing amount of the hard layer (chromium) and improvement of the mechanical properties of the coatings. However, the decrease in the wear resistance for the coatings with the thickness of the chromium layer more than 0.3 nm was a result of structural changes in the metal layer. The results of this work showed that even multilayer coating with thickness of the individual layers below one nanometer could provide high wear resistance.

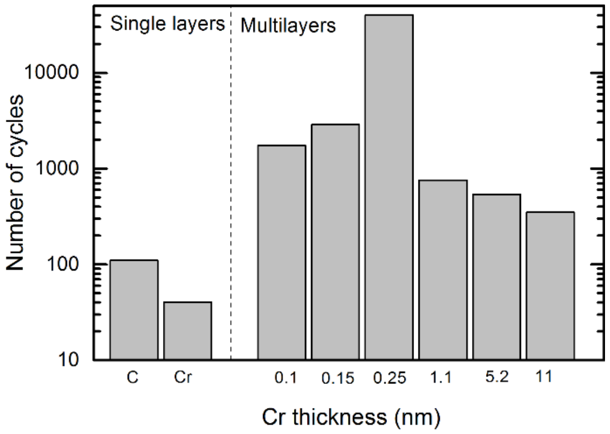

Fig.1 Lifetime of chromium-cobalt multilayers as a function of the thickness of the chromium layer.

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5. References

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