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ULTRA LOW FRICTION OF AMORPHOUS CARBON NITRIDE WITH CONTROLLING NANO SURFACE STRUCTURE

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ABSTRACT

Amorphous Carbon Nitride (CNx) coating is one of the promising materials among carbon system hard coatings used to obtain excellent mechanical properties. We reported that CNx coating showed a friction coefficient lower than 0.01 when was slid against a Si_3N_4 ball in N_2. The mechanism of the low friction coefficient was considered to be that the sliding surface changed to a graphite-like structure by sliding in N_2. In this presentation, we introduce the method how to measure the thickness and hardness of transformed layer during ultra low friction and show the effect of the transformed layer on friction. AFM scratch test showed nm-scale soft transformed layer on the topmost surface of CNx during ultra low friction. And spectroscopic reflectometry showed nm thickness of the transformed layer easily.

Keywords: ultra low friction, carbon nitride, transformed layer, AFM, reflectometry.

INTRODUCTION

Amorphous Carbon Nitride (CNx) coating is one of the promising materials among carbon system hard coatings used to obtain excellent mechanical properties. The mechanical properties and the friction coefficient of the coatings depend on their synthesis techniques. In particular Umehara *et al*. reported that CNx coating showed a friction coefficient lower than 0.01 when was slid against a Si_3N_4 ball in N_2 (Umehara, 1998, 2000). The mechanism of the low friction coefficient was considered to be that the sliding surface changed to a graphite-like structure by sliding in N_2. Since the friction coefficient of the graphite layer was not as low as that of CNx, the specific characteristic structure of graphite on the CNx could govern the low friction coefficient. It is important to understand the detailed mechanism of the low friction coefficient of CNx the optimum design of a solid lubricant. The effects of both nitrogen atoms in the coating and from ambient N_2 gas on the transformation of surface layers of CNx were investigated (Tokoroyama, 2006). AES and XPS results demonstrated that the topmost layers of the coating changed to a graphite-like structure without nitrogen atoms when the friction coefficient decreased to below 0.01, and the graphitization of the topmost layers was attributed to the low friction coefficient in N_2 gas. We first indicated N atom exodiffusion from the CNx surface during friction. This result provided the concept that nm scale surface structure could control friction properties especially for ultra low friction level. Therefore we tried to clarify the thickness and hardness of surface structure during ultra low friction. In this presentation, we explain the method how to measure the thickness and hardness of nm-scale transformed layer during ultra low friction and show the effect of the transformed layer on friction by AFM and spectroscopic reflectometry.

RESULTS AND CONCLUSIONS

The AFM scratch test is a good method to evaluate the mechanical properties of thin layers in case of that they are too thin to be measured (e.g. thickness t <10 nm)by conventional indentation methods. Furthermore, one can conduct in-depth measurements of mechanical properties by AFM scratch test. In the case of CNx coatings, we used two kinds of CNx specimens for comparison. First specimen was as-deposited CNx coating while the other one was after-running-in CNx coating that shows ultra low friction after the running-in process. Likewise, we conducted the same scratch tests on DLC after slid against steel disks in oil. The after-running-in CNx showed higher wear and the hardness was estimated to be lower than as-deposited CNx. based on the results of AFM scratch test as shown in Fig. 1.The deeper scratched area of the after-running-in CNx corresponds to its lower resistance against plastic deformation (hardness). The soft layers, as CNx coatings showed, are also confirmed only on the slid parts on the surface of DLC coating. The generation of transformed layer on the DLC after sliding in oil was also confirmed by the spectroscopic reflectometry.

From both experimental results, we believe that the concept of ultra low friction of CNx can be shown in Fig.2. After the running-in, the transformed layer that has adequate material properties provided ultra low friction. It can be considered that this CNx is quite smart that can change and adjust the proper material properties after sliding. I believe that we should develop such smart tribo surface as the future tribo material that has both properties of ultra low friction and wear.

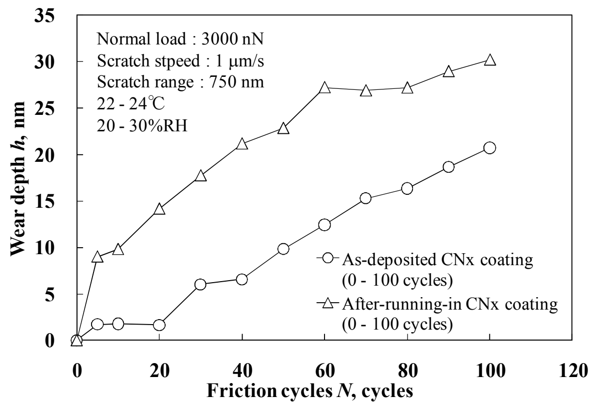

Fig. 1 - Variation of wear depth of sliding surfaces of CNx of as-deposited and after running-in for ultra low friction with repeated sliding cycles with AFM scratch test

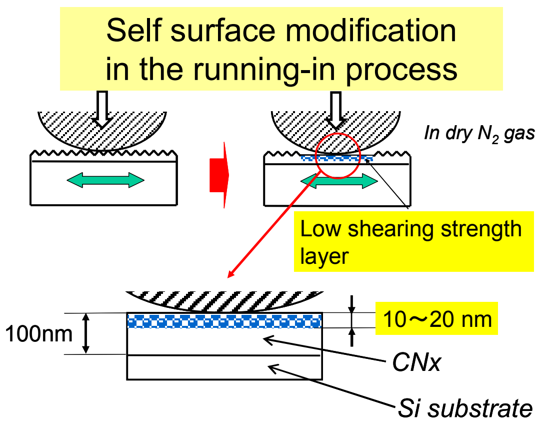

Fig. 2 - The concept for the ultra low friction surface

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