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Critical concentration of Oxygen and Water molecules for Continuous Low Friction of Hydrogenated Carbon Nitride Coatings

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Extremely low friction (μ<0.05) obtained in friction system of Si_3N_4/CN_x:H in N_2 atmosphere with relatively low O_2 concentration and humidity has a limited life even if there is no difference in the presence of coating and/or transfer film. Such lifetime is drastically extended above a certain value of O_2 concentration and humidity in N_2 atmosphere, and in which extremely low friction continues up to 50,000 cycles set in this experiment. It suggests the possibility of a semi-permanent low friction system by continuous formation of low frictional interface due to tribochemical reaction.

Keywords: durability, carbon nitride coating, low friction, nitrogen atmosphere

1. Introduction

Hydrogenated carbon nitride (CN_x:H) is recognized as a coating capable of exhibiting extremely low friction (μ<0.05) in nitrogen gas (N_2) atmosphere by forming low friction interface due to tribochemical reaction [1]. For a wide range of applications of such extremely low friction, its durability is an important issue.

In this study, therefore, we focus on the effects of oxygen (O_2) concentration and relative humidity (RH) in the N_2 atmosphere, which are thought to affect the formation of low friction interface, and clarify the durability of such low friction of friction system with CN_x:H.

2. Methods

Ball-on-disk friction tests with Si_3N_4 ball and CN_x:H coated SiC disk were conducted under N_2 atmosphere. In N_2 atmosphere, O_2 concentration and RH were controlled in the range of 0.0001~0.05 vol.% and 0.01~5 %RH respectively. Applied load and sliding speed were 1 N and 0.05~0.25 mm/s respectively.

3. Results and discussion

Fig. 1 shows typical friction property of Si_3N_4/CN_x:H under N_2 atmosphere when both O_2 concentration and RH are relatively low. Although it shows stable and extremely low friction (μ<0.05) after running-in, it transits to an unstable value of about 0.1 after a certain friction cycle. Even after the increase in friction, however, no film delamination of coatings or presence of transfer film is observed on interface. This suggests that there is a lifetime as a system for extremely low friction (μ<0.05), which is different from the lifetime of the coating that shows low μ value of 0.1~0.2.

Fig. 2 shows the effects of O_2 concentration and RH in N_2 atmosphere on such lifetime. In case of relatively low O_2 concentration and RH, the lifetime is seen in several thousand cycles. However, when the O_2 concentration and RH are above a certain value, the extremely low friction (μ<0.05) continues up to 50,000 cycles set in this experiment.

These results suggest that the durability of low friction increases sharply in N_2 atmosphere where O_2 and H_2O molecules are present above a certain concentration, and the tribochemical reaction for forming low frictional interface continues to occur.

4. Conclusions

1. Even if there is no difference in the presence of coating and/or transfer film, a lifetime which keeps extremely low friction (μ<0.05) before transition to the normal low μ value of 0.1~0.2 is existed.
2. There are critical values of O_2 concentration and relative humidity in N_2 atmosphere, above that extremely low friction (μ<0.05) continues up to 50,000 cycles set in this experiment.

Reference

[1] N. Yamada, et al., "Effect of Oxygen on the Self-formation of Carbonaceous Tribolayer with Carbon Nitride Coatings under a Nitrogen Atmosphere", Tribology letters, 1, 65, 2017, 1-11.

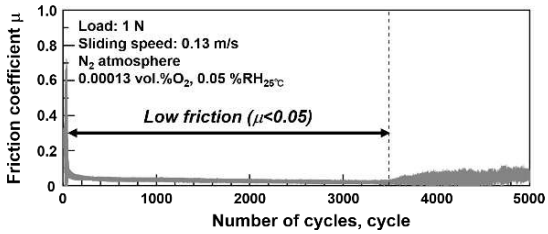
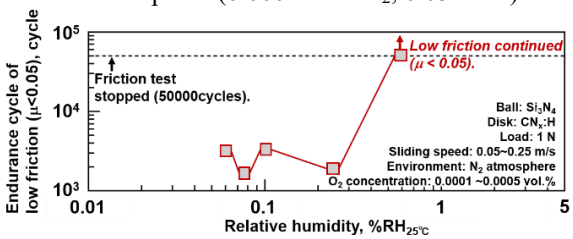
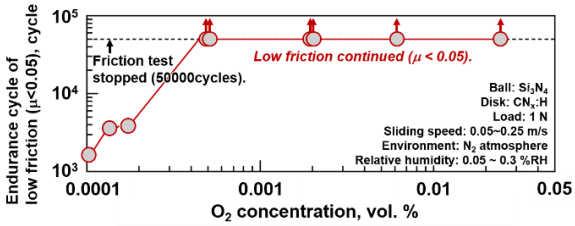


Fig. 1 Friction property of Si_3N_4/CN_x:H under N_2 atmosphere (0.0001vol.%O_2, 0.05%RH).



(a) relative humidity



(b) O_2 concentration

Fig. 2 Durability of low friction of Si_3N_4/CN_x:H as functions of (a) relative humidity and (b) O_2 concentration.