Formation process of metal-rich tribo-film on the counter face during sliding against metal/diamondlike-carbon nanocomposite coatings

M. Goto[1*], K. Ito[2], J. Fontaine[3], T. Takeno[4], and H. Miki[5]

[1)] Department of Mechanical Engineering, Ube National College of Technology, 755-8555 Ube, Japan.
[2)] College of Engineering, Nihon University, 963-8642 Koriyama, Japan.
[3)] Laboratoire de Tribologie et Dynamique des Systèmes, Ecole Centrale de Lyon, 69134 Ecully, France.
[4)] Graduate School of Engineering, Tohoku University, 980-8579 Sendai, Japan.
[5)] Center for Interdisciplinary Research, Tohoku University, 980-8577 Sendai, Japan.

[*]Corresponding author for mi-goto@ube-k.ac.jp

1. Introduction

Although Diamond-like carbon (DLC) coatings have been attracting a lot of researchers because of their excellent tribological characteristics, the DLC has some disadvantages such as lacking of electrical conductivity and sensitive tribological behaviors to the sliding condition and so on [1]. Adding metals to DLC coatings is thus considered as a powerful method to improve electrical conductivity as well as tribological properties. Copper and silver are powerful candidates as additives because of their low electrical resistivity. In recent years, we have reported that the tribological properties of Cu and Ag doped DLC (Cu-DLC and Ag-DLC) [2]. Copper-rich tribofilm formed on the counterface when the Cu-DLC showed the low and stable friction behavior under various loading condition in air. The tribofilm consist of almost pure copper determined by energy dispersive X-ray spectroscopy (EDS), though the Cu concentration in the film is 50 at. %. The morphology of the tribofilm becomes continuous metal plate as the initial Hertz contact pressure increase. The similar phenomenon was observed for the tribotest of Ag-DLC. In this study, the formation process of metal-rich tribofilm on the counterface during sliding is discussed.

2. Experimental

The Cu-DLC and the Ag-DLC were deposited on a Si (100) wafer using a hybrid deposition process combining plasma enhanced chemical vapor deposition and DC magnetron sputtering. By transmission electron microscopy, we observed that Cu or Ag metal clusters with the diameter less than 20 nm are dispersed in an amorphous DLC matrix. The diameter decreases as the metal concentration decrease.

The tribological experiments were performed under a sliding speed of 2.0 mm/s for a wide range of contact pressure: 0.5 to 1.4 GPa, using pin-on-flat type tribometer in atmospheric condition. Mirror polished bearing steel ball with a diameter of 6 mm was used as slider.

3. Result and discussion

Figure 1 shows Cu-rich tribofilms formed on counter face of Cu=DLC after sliding cycles of 2000 under the different loading conditions. Carbon-rich wear debris is surrounding tribo-films. The morphology of tribo-film shows “continuous plate” under the high contact pressure. Whereas the morphology become “mosaic” when the contact pressure is low. The origin of the tribo-film is the Cu clusters in Cu-DLC. The clusters in wear debris agglomerate selectively on the counter face, and then the agglomerated clusters were formed to “continuous plate”, even in the oxidizable environment. The solidification of oxidizable metal powder was reported by Miki et al, under combined high compression with high shear rate [3]. The copper clusters were considered to be solidified between the frictional interface which generate high pressure and high shear rate.

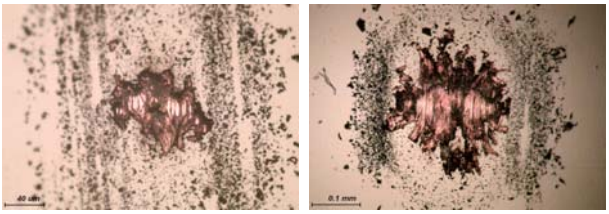

Fig. 1 Morphology of Cu-rich tribofilm
Slider material: 5700 bearing steel. Theoretical Hertz contact pressure: a) 0.5 GPa and b) 1.4 GPa.

4. Summary

The morphology of metal-rich tribo-film becomes continuous plate under high contact pressure. The solidification under high compression and high shear rate in frictional interface is considered to be the important factor to form the continuous plate morphology originated from oxidizable metal clusters.

5. References

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