Evaluation of Friction Durability for Composite Materials of Porous Anodic Alumina and Concentrated Polymer Brushes

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Abstract

In this research, porous anodic alumina (PAA), which has many pores, and concentrated polymer brushes (CPB), which exhibits low friction properties, were combined to prepare a highly endurable low-friction material. The results showed extremely low coefficients of friction on the 10^{-4} to 10^{-3} scale at loads from 300 g to 1200 g. After long-time sliding of 100 round trips, the coefficients of friction remained extremely low on the 10^{-4} scale. These results suggest that the composites form a lubricating film with extremely high stability.

1. Introduction

Friction causes energy loss and material degradation, and the economic impact of improving friction is estimated to be as much as 3% of Japan's GDP.[1)] Surface texturing is expected to be one of the most promising processing methods for low-friction materials, as it imparts fine surface irregularities. We focused on PAA and CPB as surface texturing processes that reduce friction. PAA is a porous oxide film obtained by anodizing aluminum, and is expected to retain lubricant in its pores. CPB is polymer chains modified on the surface at very high density by living radical polymerization and has ultra-low friction properties.[2)] In this research, a PAA-CPB composite material was prepared by combining these two materials. This material is expected to further improve friction properties and increase endurance by adding the lubricant retention capacity of PAA to the low-friction properties of CPB. In order to put this material to practical use, the friction properties of the material were evaluated when various loads were applied, long-time sliding, and at high temperatures.

2. Experiment

2.1 Prepared composite materials

The glass plates were ultrasonically cleaned in acetone, methanol, and ultrapure water for 5 minutes each, followed by boiling in concentrated nitric acid at 140 °C for 75 minutes, rinsing in ultrapure water, and drying with a jet of nitrogen gas. After plasma etching at a current of 15 mA and etching time of 30 seconds, aluminum was immediately deposited in a vacuum to a thickness of 200 nm. The PAA was prepared by anodizing it in 0.5 M-oxalic acid solution at a voltage value of 60 V. Figure 1 shows the results of SEM observations of the PAA surface. Uniform size-aligned pores were observed. After plasma etching of the PAA at a current value of 15 mA and etching time of 30 seconds, the initiator BTEE was added to the surface by silane coupling reaction. Using this as an initiator, polymer brushes with a degree of polymerization of 5000 were polymerized by atom transfer radical polymerization (ATRP) of the ionic liquid monomer DEMM-TFSI.

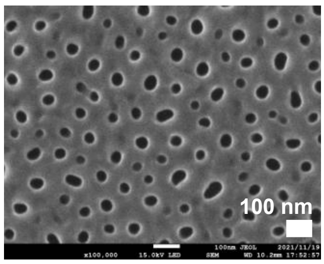

Figure 1. SEM image of PAA surface

2.2 Friction test method

The friction properties of the prepared samples were evaluated by a reciprocating sliding test using TRIBOGEAR TYPE: 38 (TRIBOGEAR TYPE: 38, manufactured by Shinto Kagaku Co., Ltd.). Smooth glass thin film was used as the mating material. The lubricant was 320 µl of DEME-TFSI, which is an ionic liquid. For the load bearing evaluation, the load was varied from 300 g to 1200 g and the velocity from 0.5 mms^{-1} to 50 mms^{-1} for 10 round trips.

3. Result and discussion

Figure 2 shows the results of friction measurement tests on composite materials at loads from 300 g to 1000 g. The composites exhibit extremely low coefficients of friction on the scale of 10^{-4} to 10^{-3}. The decrease in the coefficient of friction with decreasing velocity indicates that the composite is in the fluid lubrication regime. The same trend was observed for all loads, indicating that the composite exhibits low friction regardless of the load. The test results comparing Glass-CPB and PAA-CPB at 1200 g are shown in Figure 3. The friction coefficient of Glass-CPB increased with decreasing velocity, indicating that Glass-CPB belongs to the mixed lubrication region. The friction coefficient of PAA-CPB is found to be more than two orders of magnitude lower than that of Glass-CPB. It was found that the low friction properties were maintained under high load conditions by the PAA textured substrate. This result may be attributed to the presence of PAA, which resulted in sufficient retention of lubricant. On the other hand, Figure 4 shows the results of repeated durability tests on PAA-CPB, in which 100 round trips were measured at a sliding velocity of 0.5 mms^{-1} under an applied load of 700 g. The coefficient of friction remained extremely low at 0.0009 during 100 round trips. The results show that this composite material maintains stable low-friction properties even after repeated use. This sliding system is considered to be sufficiently practical.

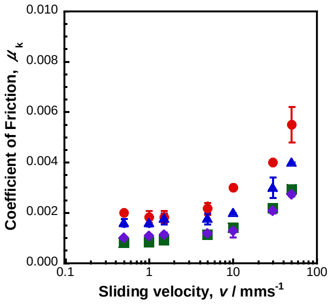

Figure 2. Friction test result 300 g(●), 500 g(▲), 700 g(■), 1000 g(◆)

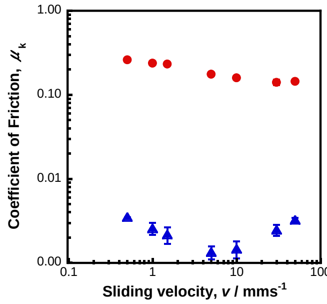

Figure 3. Friction test result Glass-CPB(●), PAA-CPB(▲)

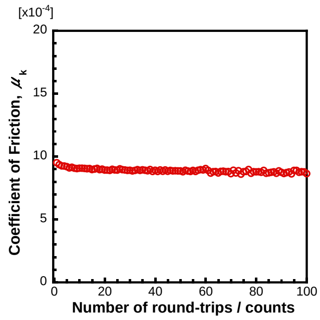

Figure 4. Repeated durability test result.

4. Conclusions

Glass-CPB and PAA-CPB were prepared by polymerizing CPB with a degree of polymerization of 5000 on the surfaces of Glass and PAA. Friction test results show that under a load of 1200 g, PAA-CPB exhibits a coefficient of friction more than two orders of magnitude lower than that of Glass-CPB. Repeated durability test showed that PAA-CPB maintained an extremely low coefficient of friction of 0.0009 for 100 round trips.

References

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