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COMPARISIONS OF FRICTION CHARACTERISTICS OF A LIGHTLY LOADED PIN SLIDING OVER MAGNETIC DISKS COATED WITH POLAR AND NON-POLAR PFPE LUBRICANTS

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ABSTRACT

This paper deals with the measurement of friction force exerted on molecularly thin lubricant film surfaces using a specially arranged pin-on-disk type friction tester. The measurements were carried out by sliding a 1.5-mm-diameter glass ball slider on a rotating disk surface with small loading force. Polar and non-polar PFPE lubricants were dip-coated on magnetic disks covered with diamond-like-carbon (DLC) film. Lubricant film thickness was varied to constitute multiple layered film structures on the DLC surface. To clarify the stratified effect of thin lubricant film on friction, a lightly loading force and a slow rotational speed were selected. The tested results showed that the friction force on non-polar lubricant surfaces increase slightly for mono-layer and multi-layer cases, while the friction force on polar lubricants show steady and gradual increase with increasing loading force. We conclude that friction force at small loading force is dependent intimately on the thickness, molecular weight and end-group functionality.

1 INTRODUCTION

Perflouropolyethers (PFPEs) are extensively applied as the lubricants for magnetic media to improve tribological performance in current magnetic disk drives [1]. As the head-disk spacing has been minimized down to 10 nm, head-disk contacts intervening molecularly thin lubricant are likely to occur, and thus friction characteristics just on the lubricant surface becomes a significant concern. Thus far, PFPE friction characteristics are mainly measured under actual loading conditions or heavily loaded conditions to accelerate durability [2]. In this paper, PFPE friction characteristics have been measured in a lightly loaded and a slow velocity conditions to clarify the friction exerting just on the lubricant surface. Comparisons of friction characteristics between polar and non-polar lubricants hinted structural arrangement of lubricant molecules greatly affects friction characteristics.

2 EXPERIMENTAL DETAILS

The measurement was carried out by sliding a glass ball on a lubricated disk using a pin-on-disk type friction tester, which was specially arranged to permit lightly loaded low speed sliding motion. A schematic diagram of the experimental setup is given in Fig. 1. The glass ball is 1.5 mm in diameter with surface roughness of 0.6 nm Ra and 5 nm Rmax. The suspension has a spring constant of 18.4 N/m in the vertical direction. The sliding speed is fixed at 7.85 mm/s. Polar PFPE lubricants (Zdol4000 and Zdol2000) and non-polar lubricant (Z03) were dip-coated on magnetic disks covered with

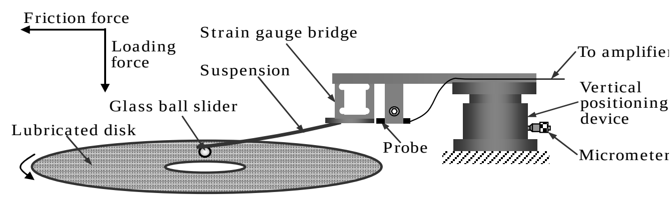

Fig.1. Schematic diagram of pin-on-disk friction tester

diamond-like-carbone (DLC: nitrogenerated amorphous carbon) film having a surface roughness of 0.45 nm Ra. All tests were conducted in the clean room at 20~24 ℃ and at a relative humidity (RH) 20%.

Considering the tiny loading force exerted on the lubricated disk and the vibration of the disk during the operation, contact point was accurately determined by the “jump into contact” effect as shown in Fig. 2. As the glass ball comes in close proximity of the disk, a sudden jump on account of the attractive force occurs, which leads to a sudden rise in the friction force at zero loading force caused by forming a meniscus around the contacting asperities. We define this point as the contact point.

The friction force was measured at 24 h after the lubricants were dip-coated on the disks. The loading force is incrementally increased after two sliding revolutions. The friction tester samples 12000 times at each sliding revolution, and the data are averaged over the two revolutions.

3 RESULTS AND DISCUSSION

Figure.3 shows the averaged friction forces of the lubricants within 1

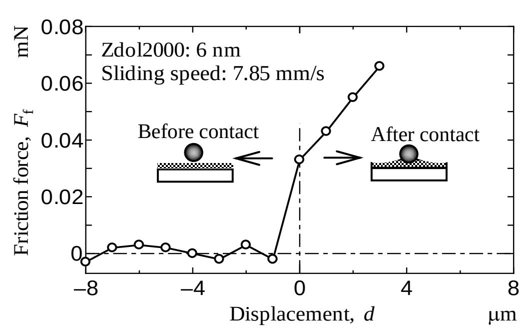

Fig.2. Changes of friction force before and after the glass ball contacts the lubricant on the disk

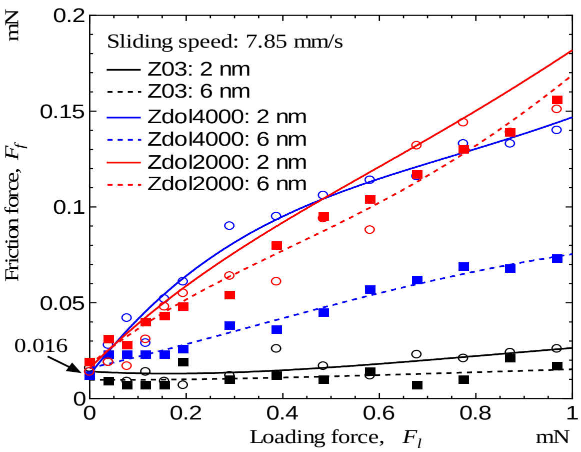

Fig.3. Friction of 6-nm-thick Zdol2000 and Z03

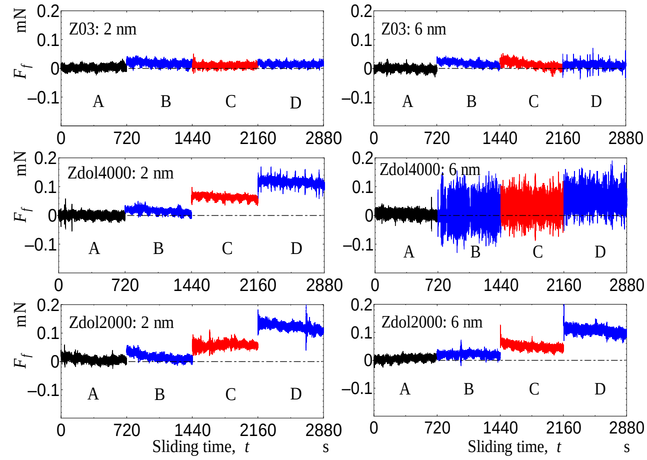

Fig.4. Friction force time histories during unloading (A) and loading at 0 mN (B), 0.19 mN (C), 0.58 mN (D)

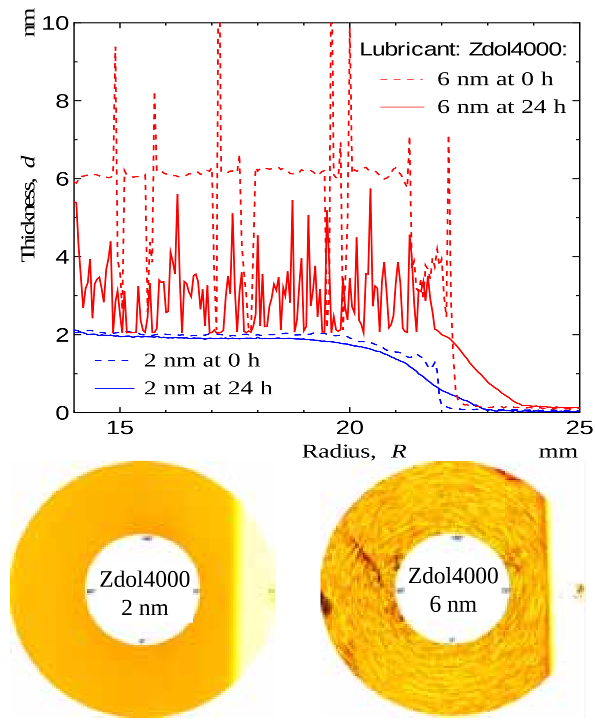

Fig.5. Profiles and surfaces of 2-nm-thick and 6-nm-thick Zdol4000 at 0h and 24 h

mN loading force, and the corresponding time histories during unloading and loading at 0 mN, 0.19 mN and 0.58 mN are shown in Fig.4. The thicknesses of each kind of lubricant are 2 nm and 6 nm. Based on the tested data, the friction force for the 2-nm-thick Z03 increases slightly with increasing loading force, and the case for the 6-nm-thick Z03 even shows a slighter change, almost constant during the testing range. The friction force for the thicker lubricant is a little smaller than that for the thinner one. The amplitudes of the time-dependent friction force of Z03 are small. For the polar lubricants, Zdol4000 and Zdol2000, the friction forces increase steadily and gradually with increasing loading force. Zdol2000 lubricants and 2-nm-thick Zdol4000 show a sharp increase compared with 6-nm-thick Zdol4000. It is interesting to found that the amplitude of the time-dependent friction force of 6-nm-thick Zdol4000 is significantly larger than that of other lubricants. This obvious change is attributed to the strong dewetting effect of 6-nm-thick Zdol4000. Figure.5 gives the profile and surface of Zdol4000 at 0 h and 24 h. The 6-nm-thick Zdol4000 has so strong dewetting effect that the rough surface can be observed even just after dip-coating process. No dewetting effect was found at the surface of 6-nm-thick Zdol2000 at 24 h in that it is a stable structure. All of the 2-nm-thick lubricants exhibit a mild spreading, and the surface become smoother with time. The sharp increases of friction forces are observed for Zdol2000 lubricants, and the friction force of thicker Zdol2000 lubricant is also a slightly smaller than that of thinner one.

The tested results show that the friction forces for polar lubricants show a steady and gradual increase with the increase of loading force. However, the friction force for non-polar lubricant exhibits a slight change behavior at small loading force. Polar end-groups help lubricant molecules to be tightly bonded on the DLC overcoat and reduce the removal rate of the lubricants during the contact sliding. Therefore, the friction force behaves like solid-solid friction property, which is characterized by the fact that the corresponding friction force increase steadily and gradually with increasing loading force. The gradient of friction force to loading force depends intimately on the thickness and molecular weight. This is, lubricants with smaller molecular weight and thinner thickness show a larger friction force. Contrastively, Non-polar lubricants have greater mobility, and take on liquid-like behavior. It should be noted that friction force was generated even at zero loading force. This is attributed to the fact that a meniscus was formed around the contact point, and generated internal loading force. Due to the small loading force exerted on the lubricant, the meniscus force is predominant relative to the external loading force, and the increase of the external loading force within 1 mN cannot conquer the effect of meniscus force. Consequently, the friction force of non-polar lubricant behaves nearly constant friction property.

5 CONCLUSION

Friction properties of molecularly thin lubricant film on magnetic disks were investigated at small loading force in this experiment. The tested results indicate that the friction force on the lubricant surface was intimately dependent not only on loading force but also on the lubricant properties. It concluded that polar end-groups, molecule weight and thickness play a vital role in determining the friction properties at small loading force.

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