EFFECT OF ULTRAVIOLET IRRADIATION ON ADHESIVE FORCE AND ELONGATION OF MONOLAYER LUBRICANT FILMS COATED ON MAGNETIC DISK SURFACE

Yasuji OHSHIMA*, Takashi SUMI**, Hedong ZHANG***,
Yasunaga MITSUYA**** and Kenji FUKUZAWA*****

* Liberal Arts Department, Aichi Konan College, 172 Ohmatsubara, Takaya-cho, Konan, 483-8086, JAPAN
E-mail: ohshima@konan.ac.jp

** Department of Mechanical Science and Engineering, Graduate School of Engineering, Nagoya University
Furo-cho, Chikusa-ku, Nagoya, 464-8603, JAPAN

*** Department of Complex Systems Science, Graduate School of Information Science, Nagoya University
E-mail: zhang@nuem.nagoya-u.ac.jp

**** Division of Research, Nagoya Industrial Science Research Institute
Noa-Yotsuya Build. 2F, Yotsuya-douri 1-13, Chikusa-ku, Nagoya 464-0819, JAPAN
E-mail: mitsuya@ktb.biglobe.ne.jp

***** Department of Micro/Nano System Engineering, Graduate School of Engineering, Nagoya University
E-mail: fukuzawa@nuem.nagoya-u.ac.jp

ABSTRACT

We measured the effect of ultraviolet (UV) irradiation to perfluoropolyether (PFPE) monolayer lubricant films on the adhesive force and the vertical elongation of the lubricant bridge formed between the lubricant films on magnetic disk surfaces and a diamond tip. It was found that PFPE Fomblin Z03 was more susceptible to UV irradiation than Fomblin AM3001 in terms of the adhesive force and the elongation of the lubricant bridge.

1. INTRODUCTION

In recent hard disk drives, the flying height has been decreased to less than 10 nm to allow a higher recording density. In such a small spacing, the undesirable head-disk contacts would be likely to happen, in consequence, viscoelastic properties of the lubricant films coated on the disk surface become a significant concern to achieve stable and durable operation of the device. To fulfill those demands, the UV irradiation-induced bonding of PFPE lubricant on the disk surface is employed to enhance the self-retention function. In this study, to elucidate the effect of the UV irradiation on the viscoelastic properties of the monolayer lubricant films, we measured the adhesive force and the elongation of the lubricant bridges formed by polar and non-polar lubricant films.

2. EXPERIMENTAL METHOD

The schematic diagram of the self developed experimental apparatus is shown in Fig. 1. A diamond tip and a micro-mirror were attached on the under and upper surfaces of the cantilever, respectively. The micro-mirror reflected the incident laser beam to form the Michelson interference fringes for detecting displacement of the tip, which enabled us to measure a long displacement of sub-micrometers with a high accuracy of sub-nanometers [1]. An ultra high-speed video camera with higher

resolution (512 x 128 pixel) and deeper bit depth (10 bits) was newly employed. The camera is capable to capture the interference fringe patterns on the micro-mirror and the disk surface simultaneously at a satisfactory fast rate (24,000 fps). Unwanted vibration caused by the disturbance was reduced through the background subtraction between the micro-mirror and the disk surface images. As a result, the measurement accuracy of the tip displacement was improved from 2.3 nm in the previous method [1] to 0.65 nm.

Two different types of PFPE lubricants, AM3001 having polar functional end groups and Z03 having non-polar functional end groups, were selected. The lubricant films were coated on the disk surface using the dip-coating method. The disk surfaces with the lubricant film were irradiated inside the nitrogen-filled chamber. An excimer lamp (172 nm, 10mW/cm) was used as a UV ray source. The UV irradiation time was varied from 0 to 90 seconds to make bonding ratio of the lubricant films set in the range from 0 to 0.9. The initial film thickness just after dip coating was adjusted to compensate UV-irradiation-induced thinning effects so that all

Fig. 1 Experimental apparatus

experiments were performed at a constant film thickness of around 2 nm.

After the tip was pushed to the disk surfaces at a prescribed load, the tip was pulled off at 12 $\mu\text{m/s}$ (a hundred times faster than the SPM probe in common use). During the separation, the high-speed video camera recorded transient vibrations of the tip in the form of shifting of the interference fringe pattern. Elongation and adhesive force of lubricant films were identified from these captured images [2].

3. EXPERIMENTAL RESULTS

Figure 2 shows the relationships between the bonding ratio (i.e., ratio of bonded thickness to total film thickness) and the duration of the UV irradiation. It was found that both Z03 and AM3001 were rapidly bonded up to the bonding ratio of around 0.6 within 30 s and then it gradually increased to 0.9 within 90 s. It should be noted that for the Z03 case, a few seconds irradiation sharply increase the bonding ratio from 0 to over 0.25, indicating that Z03 was highly susceptible to the UV irradiation.

The result of the adhesive force measurement is shown in Fig. 3. The symbol, “-”, indicates each experimental value and the closed and open squares denote the average value of each experiment. From the wide scattering of each experimental value, the experimental accuracy seems insufficient. However, the scattering is not originated from insufficient accuracy, but can be attributed to locality in the contact conditions. To yield enough meaningful results, we performed the same experiment ten times using different points and averaged the results. From the averaged values, it is found that the adhesive force of AM3001 maintained nearly a constant value of 30 nN for the whole range of the bonding ratio. On the contrast, the adhesive force of Z03 monotonically decreased from 70 nN to 30 nN.

Figure 4 illustrates the elongation of the lubricant bridge at each bonding ratio. The elongation of AM3001 slightly decreased with increasing the bonding ratio until 0.5 and changed to increase slightly with further increasing bonding ratio. In contrast, the elongation of Z03 drastically increased with increasing bonding ratio until 0.2 and changed to decrease with further increasing bonding ratio larger than 0.4. These results indicate that the minimum value appears around 0.5 for AM3001, while the maximum value appears around 0.3 for Z03. It is interesting to note that UV irradiation affected larger

Fig. 2 Increase of bonding ratio by UV irradiation

for Z03 than AM3001 in the terms of the adhesive force and the elongation variations, even though the latter has a higher UV absorbance.

4. CONCLUSION

The effect of the UV irradiation to the lubricant film on the adhesive force and the elongation of the lubricant bridge were measured. It was found that the UV irradiation increased the bonding ratio of less UV-susceptible Z03 as well as UV-susceptible AM3001, and differently affected Z03 and AM3001 in terms of the adhesive force and the elongation of the lubricant bridge.

REFERENCES

- [1] Mitsuya, Y., Ohshima, Y., Zhang, H., Aoyama, K., Kawai, T., Fukuzawa, K., Stiffness and Damping of Thin PFPE Lubricant Bridging Between Magnetic Disk and Diamond Probe Tip, *Trans. ASME, J. Tribol.*, Vol. 129, 2007, pp.720-728.
- [2] Ohshima, Y., Mitsuya, Y., Iwase, T., Measurement of Adhesion Force and Elongation of Molecularly Thin Lubricant by Using Transient Response of SPM Cantilever, *Trans. ASME, J. Tribol.*, Vol. 126, 2004, pp.738-744.

Fig. 3 Adhesive force of UV irradiated lubricant film

Fig. 4 Elongation of UV irradiated lubricant film