The effect of surface wettability on the frictional condition for PVA roll brush

Y. Hara[a], T. Sanada[a] , A. Fukunaga[b], H. Hiyama[c]

[a]Shizuoka University, 3-5-1 Johoku, Naka-ku, Hamamatsu, 432-8561, Japan
[b]Ebara Corporation, 4-2-1 Honfujisawa, Fujisawa, Kanagawa 251-8502, Japan
[c]Ebara Corporation, 11-1 Haneda Asahi-cho, Ohta-ku, Tokyo 144-8510, Japan

INTRODUCTION

As the future size of semiconductor device rapidly shrinking, the surface contamination becomes the critical issues. Especially CMP process essentially contains nano-scale particles that must be removed before the next process. Typically PVA (PolyVinyl Acetal) brush is used for cleaning such contaminations. However the mechanisms of brush cleaning are still under discussion. Hydrodynamic drag force, direct contact of brush, and so on, have been proposed as a cleaning mechanisms [1-5]. Recently, we measured the shear and normal forces due to PVA brush rotation and evaluated the coefficient of friction [6]. The results indicate that the coefficient of friction shows relatively large value and the value is decreased as the rotation speed increased. This suggests that the tribological contact condition between the brush and surface are outside of the fluid lubrication regime. In this study, we change the wettability of the surfaces and measure the coefficient of friction between surface and PVA brush. We discuss the effect of water existing inside and around the brush on the contact condition.

METHOD

In this study, the coefficient of friction η between PVA brush and plates that have different contact angle are determined by measuring the shear force and the normal force. The materials of each plate are Teflon, aluminium, acryl, polypropilen and its water contact angle are about 100˚, 22˚, 63˚, respectively. The detail of the experimental setup is in Fujiwara et al. [6]. The condition of the experiments are brush rotation speed n = 50 – 1000 rpm and compression distance d_b =1 – 4 mm.

RESULTS AND DISCUSSION

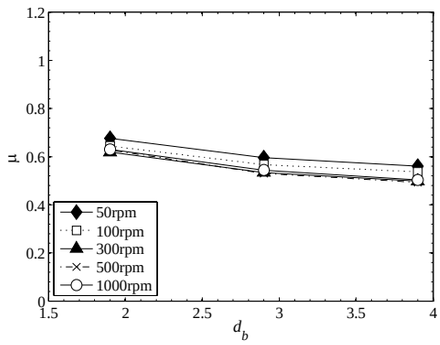
Figure 1 shows the result of the COF values. Figure 1 (a), (b), and (c) are the case of surface materials of aluminium, Teflon, polypropylene, respectively. All results show the COF values decrease with increasing the brush rotation speed and the lowest value are almost identical. In all cases, the COF values indicate larger than 0.5. This imply following two points. First, this system has a characteristic that the real contact area of the brush increases over the contact time. Second, The brush and surface are under the condition of contact because typical fluid lubrication regime has low COF value under 0.01.

Next, we discuss the effect of the surface material. When the rotation speeds are 50 rpm, the COF of Teflon is the highest of all results, and the one of aluminium is the lowest. In addition, the ranges in COF value with rotation speed are different. The case of Teflon surface, which has hydrophobic property, the COF vary significantly owing to the brush rotating speed, on the contrary, the case of aluminum surface show a minimal change.

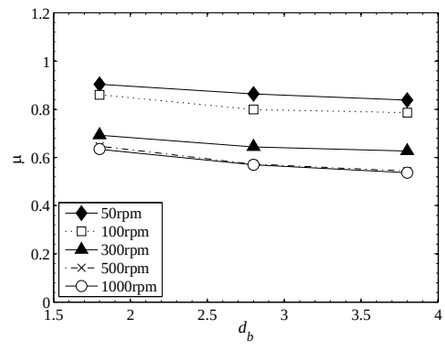
These results indicate that the difference of surface wettability changes the COF. We believe that this is due to the change of the real contact area. The PVA brush has super-hydrophilic nature and water can be easily soak up by capillary action. Therefore, real contact area of Teflon is easy to increase than that of alminium. As a result, the COF of Teflon is the highest of the all cases under the low rotation speed case. From these experimental observations, surface wettability has an impact on the friction condition between PVA brush and surfaces.

REFERENCE

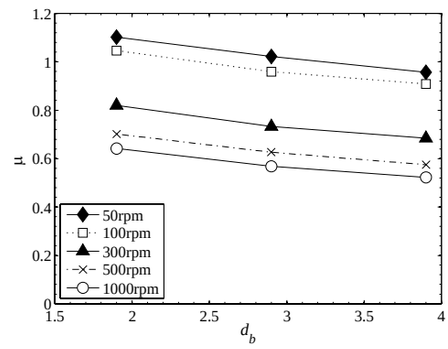
[1] K. Xu et al., J. Vac. Sci. Technol., B 23 (5), 2160-2175 (2005).
[2] D. Ng et al., Electrochem. Solid-State Lett., 10 (8), H227-H231 (2007).
[3] A. Philipossian et al., Electrochem. Solid-State Lett., 12 (3), H84-H87 (2009).
[4] J. An et al., Jpn. J, Appl. Physics, 51, 026501 (2012).
[5] D. Ng et al., J. Tribology, 130, 021603-(1-5) (2008).
[6] T. Fujiwara et al., Solid State Phenomena, 195, 213-216 (2013).



(a) Alminum (θ = 22˚)



(b) Polypropylene (θ = 63˚)



(c) Teflon (θ = 100˚)

Fig.1 The coefficient of friction between PVA brush and different materials.