Friction and material transfer of a textured wafer surface during sliding

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1. Introduction

In industrial applications, friction and wear are one of the major causes of failure in small devices such as micro-electromechanical systems (MEMS) [1]. In micro-meter length scale, macroscopic friction law is not always applicable. New understanding of friction is needed. In present research, an *in situ* approach to measure sliding friction of a patterned surface composing multi-materials and structures against a standard bearing ball was demonstrated. The effects of materials and material transfer on sliding friction were investigated. This study reveals insight into the possible failure mechanisms of sliding of small devices with textured surfaces.

2. Materials and Methods

The single crystal Si wafer (111), was pre-patterned with parallel nickel and silicon dioxide (SiO2) stripes. Before testing, it was chemical-mechanically polished. A standard bearing ball of AISI 52100 steel with 6 mm diameter was used to slide against the wafer surface.

Friction experiments were conducted using a homemade ball-on-flat tribometer with a linear reciprocal motion. The coefficient of friction (COF) and the electrical contact resistance (ECR) between the pin and the disk were recorded simultaneously and presented as "triboscopic" charts [2].

3. Results and discussion

The average ECR and average COF of each cycle were calculated and plotted in Fig. 1. In the first 20 cycles, both ECR and COF change little with increasing number of cycles. The friction measurements show that an increase in COF begins around cycle 20. It develops constantly till the end of the test. With more rubbing cycles, wear steadily progresses leading to the change of the wafer surface morphology. The surface becomes rougher in time so COF keeps increasing in the sliding process. On the other hand, ECR drops rapidly from cycle 20 and reaches the lowest value around the cycle 45. Then the ECR increases with more cycles of sliding. The change of ECR attributes to the material transfer between the Ni strip and the SiO2 strip. The Ni particles scratched away from the Ni strip adhere to the ball due to some adhesive process and then travel along the SiO2 strip. In the sliding on SiO2 surface, back-transfer of Ni from steel ball to SiO2 could be expected.

To confirm the material transfer during sliding, XPS imaging was conducted on the wear tracks. Fig. 2 shows a worn region with the wear track crossing two pre-patterned Ni stripes. The bright zone indicates the existence of Ni. The distribution of Ni along the wear track can be clearly determined.

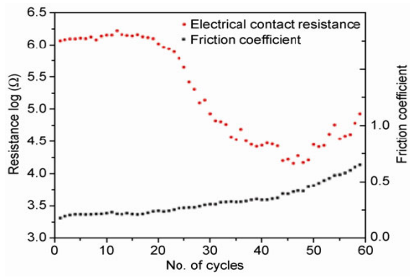

Fig. 1 Average COF and ECR vs. number of cycles.

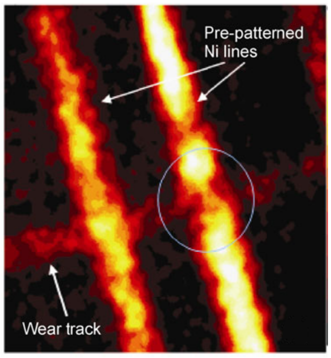

Fig. 2 XPS elemental images (Ni_{2p}) of tested wafer. Scale: 800 μm × 800 μm

4. Conclusion

COF and ECR of a patterned surface were measured *in situ* to study the kinetics of materials transfer during sliding. The average COF and ECR were monitored throughout. Local evolution are highlighted thanks to triboscopic charts technique. The XPS results showed the transfer of materials for a long distance along the wear track and that the mechanical mixing is an accumulative process. The current work provides important insights from the fundamentals of friction that benefits the design of new micro-devices.

5. References

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