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FRICTIONAL BEHAVIOR OF SYNTHETIC MOLYBDENUM DISULFIDE IN HIGH VACUUM

高真空中における合成二硫化モリブデンの摩擦特性

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1. Introduction

One of the authors (M. M.) studied on friction of molybdenum disulfide in high vacuum and got a result that the steady-state coefficient of friction** (μ_k) of molybdenum disulfide (MoS_2) in high vacuum is the lowest as compared with that in low vacuum and in air. He and his co-workers discussed the frictional behavior of MoS_2 according to the above assumption. They confirmed in their experiments that μ_k was high at the initial stage of sliding and that it decreased to a lower value when the friction test was continued in high vacuum[1]. After μ_k decreased to a lower value in high vacuum, μ_k did not rise under 10^{-2} Torr and there was a marked rise in μ_k at about 10^{-2} Torr when the air was introduced. The result is shown in Fig. 1.

However, it is natural to consider that μ_k in the absolutely clean MoS_2 surface will not be the lowest, that μ_k in MoS_2 slightly absorbed vapors will be the lowest, and that moist air rises the friction to a high value. Haltner[2] and Jamison[3] reported the phenomenon after their experiments and Tsuya also believes the theory[4]. By these considerations, the lowest friction at high vacuum as shown in Fig. 1 would be due to the contamination remained on the surface layer. In this report, it will be described that above-mentioned results are obtained in synthetic MoS_2 in authors' experiments.

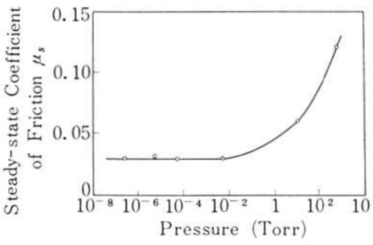

Fig. 1 Effect of pressure on the coefficient of friction of MoS_2.

2. Experimental methods

1) Specimens

The synthetic MoS_2 used was proprietary and was deposited on copper specimen by electrophoretic coating at the voltage of 500 V/cm in acetone containing MoS_2 2 g/l. The thickness of MoS_2 film was 1 μm after 10 minute's deposition. The coated MoS_2 is shown in Fig. 2 by electronmicroscopy.

2) Friction apparatus

Friction apparatus was described in the previous report[1], the load on specimen was 200 g, and the upper slider was a steel ball plated with copper. The other conditions were the same as the previous report[1].

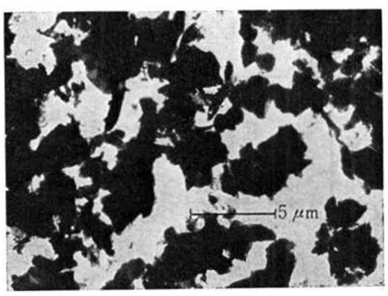

Fig. 2 Electronmicroscopy of synthetic MoS_2 used.

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** In this report, μ denotes coefficient of friction in general, μ_k that of steady-state and μ_i that of initial stage after stopping.

3. Experimental results

1) Effect of atmospheric pressure on μ_s

Fig. 3 indicates the effect of atmospheric pressure on μ_k and the electrical contact resistance when the room air was introduced in the vacuum system. It is shown that the minimum μ_k occurs at the range of 10^{-2} Torr, These results coincide with Haltner's[2]. It is interesting that the electrical contact resistance curves have nearly the same pattern as μ_k. The cause is not clear now.

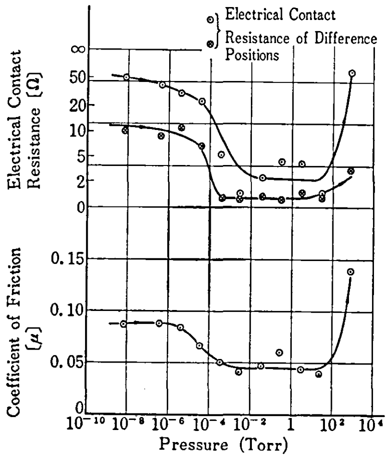

Fig. 3 Effect of atmospheric pressure on μ_k and the electrical contact resistance.

2) Stop time effect

The stop time effect on μ_k and the electrical contact resistance was measured. It was postulated from the previous report[1] that the stop time effect was originated from the vapor absorption on the surface during stopping. Examples of results in the synthetic MoS_2 are shown in Figs. 4 to 9. In the minimum μ_k range, μ_i rose during stopping indicating μ_k at higher atmospheric pressure. The higher the pressure, the higher μ_i was obtained as anticipated and these results are shown in Figs, 4, 5 and 6.

In the high vacuum and higher μ_k range, μ_i decreased during stopping, indicating also μ_k at higher atmospheric pressure where μ_k is lower. At extremely high vacuum, the decrease was not prominent as shown in Fig. 9. However, at 3.5 $\times 10^{-5}$ Torr, boundary of the high and low μ_k,

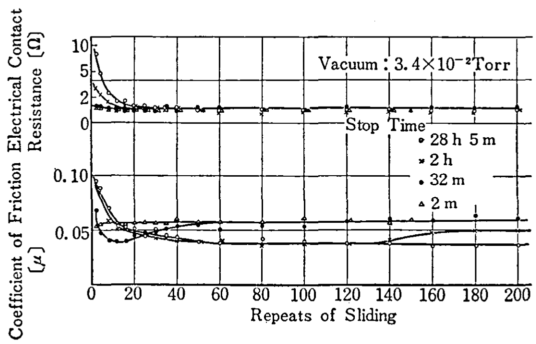

Fig. 5 Stop time effect at 3.4×10^{-2} Torr.

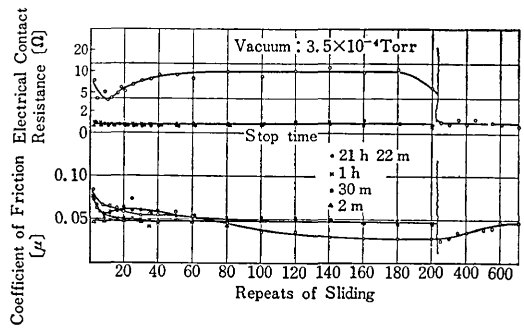

Fig. 6 Stop time effect at 3.5×10^{-4} Torr.

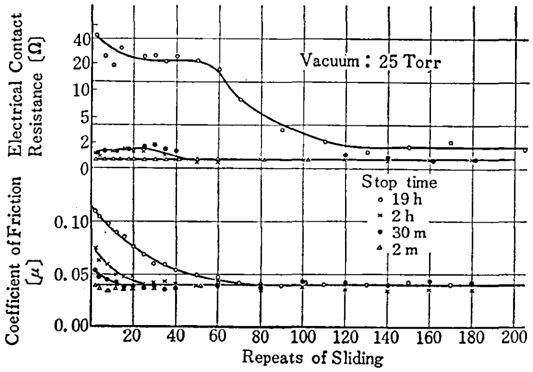

Fig. 4 Stop time effect at 25 Torr

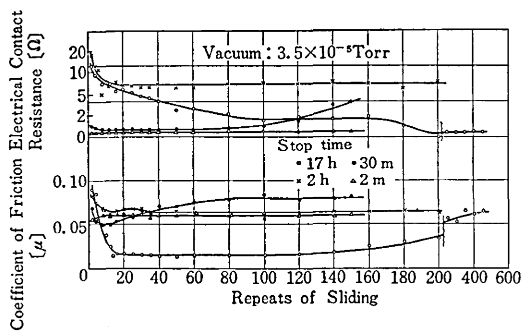

Fig. 7 Stop time effect at 3.5×10^{-5} Torr.

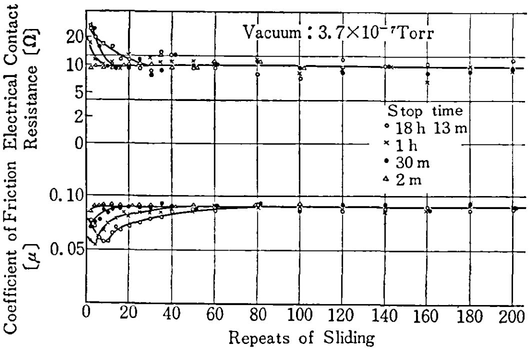

Fig. 8 Stop time effect at 3.7×10^{-7} Torr.

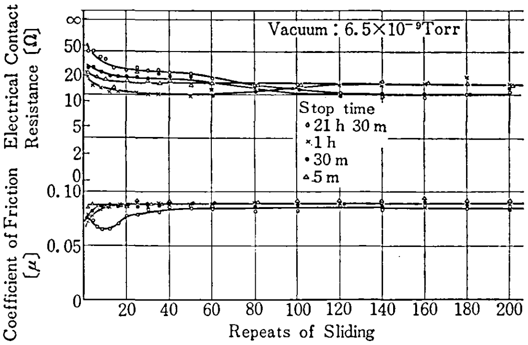

Fig. 9 Stop time effect at 6.5×10^{-9} Torr.

the decrease was prominent, especially after a long stop time, as shown in Fig. 7. This fact showed that the surface layer of MoS_2 with slightly absorbed vapors had the minimum μ_k.

4. Conclusions

From these experiments, following conclusions are derived,

1) μ_k on the extremely clean surface of synthetic MoS_2 is higher than that on the surface which absorbed vapor slightly.

2) It is not clear whether the only synthetic MoS_2 has the above-mentioned frictional characteristics or natural MoS_2 also has the same one.

3) As the minimum μ_k range, μ_i rises after stopping, and at the higher vacuum and higher μ_k range, μ_i decreases after stopping. This phenomena can be explained by vapor absorption theory.

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