In-Situ Observation of Solid-Liquid Interface and Its Nanotribological Property

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For further friction reduction in the trend toward the use of ultralow viscosity oil for automotive engine, the optimum usage of 'organic friction modifiers' is definitely important and one of key technologies. On such background, the use of *in-situ* physical/chemical analyzers is quite effective for understanding the state of 'real' solid-liquid interface, and the relationship between 'interfacial structure at solid-liquid interface' and 'tribological property' has been gradually clarified in recent days. Some studies revealing the relationship by several *in-situ* analyzers are introduced in this presentation.

Keywords: *in-situ* observation, adsorbed additive layer, solid-liquid interface, nanotribological property

1. Introduction

With the trend toward the use of ultralow viscosity oil for automotive engine, the requests for novel development and/or optimization of additives that can achieve lower friction coefficient and higher wear durability are highly increasing. For further friction reduction, the optimum usage of 'organic friction modifiers (OFMs)' is definitely important and one of key technologies. However, the observation of soft additive layers formed on metal surfaces has been recognized as being difficult because *in-situ* observation/analysis of the layer in oil is necessary.

On the other hand, with the rapid progress of *in-situ* physical/chemical analyzers, the relationship between 'interfacial structure at solid-liquid interface' and 'tribological property' has been gradually clarified. Some studies revealing the relationship by the combined use of several *in-situ* analyzers, neutron reflectometry (NR), frequency-modulation atomic force microscopy (FM-AFM) etc., are introduced in this presentation.

2. Case 1 – Growth of Adsorbed Additive Layer

About 100 years has been already past from the time when Hardy published the concept of boundary lubrication with the impressive illustration of adsorbed additive layer on sliding surface. A lot of tribologists are still caught up in his conception, but the illustration is not real.

NR is the unique technique for evaluating the thickness and density of adsorbed additive layer formed on metal surface in oil[1]. FM-AFM is also powerful tool and enables direct observation of the additive layer in oil; one example observed by FM-AFM is shown in Fig. 1[2].

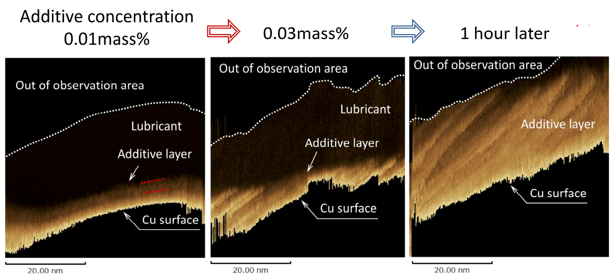
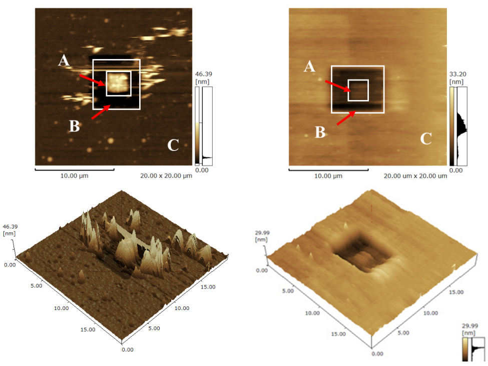


Figure 1: Cross-sectional images captured by FM-AFM, where the additive was palmitic acid as a typical acid.

3. Case 2 – Combined Use of a Couple of Additives

The effect of combined use of several kinds of additives is being focused much more deeply than before because the combined use of traditional additives, such as ZDDP and MoDTC etc., and OFM because it may be highly possible to derive further friction reduction at sliding surfaces. As an example, to investigate the interfacial structure formed by the combined use of MoDTC and OFM, NR and ATR-IR were applied. The results by them showed that the soft boundary layer with higher density was formed when the both of MoDTC and OFM were mixed into base oil. Moreover, to understand the relationship between morphological change before and after a scratch test and nanotribological properties of the sliding surface, a colloidal probe AFM was applied for the measurement in oil. As the test results, when the oil only with MoDTC was used, hard and thick layer (MoS_2 layer, maybe) over 10 nm-height was formed in the scratched area, as shown in Figure 2(a). On the other hand, when the oil with MoDTC and OFM, the soft boundary layer was formed and then the formation of hard layer was suppressed, as shown in Figure 2(b). The coefficient of friction was the smallest when the MoDTC and OFM were used together even though the production of MoS_2 was suppressed due to the existence of OFM molecules in oil.



(a) + MoDTC (b) +MoDTC+OFM

Figure 2: Morphological change before and after scratch test captured by a colloidal probe AFM.

References

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[2] T. Hirayama et al., *Langmuir*, 33 (2017) 10492.