Molecular behaviors in thin film lubrication

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INTRODUCTION

The behavior of liquid lubricant molecules, especially the molecules near the solid surface is very important to the property of the whole tribo-system. Thin film lubrication (TFL)[1,2] has been proposed to characterize the molecular pattern in lubrication film less than hundred nanometers, which effectively bridged the gap between elastohydrodynamic lubrication (EHL) and boundary lubrication. Unfortunately, to date, the molecular model of TFL which was proposed 20 years ago has not been well proven. Recently a new method based on surface-enhanced Raman spectroscopy developed in our group allows us to access the molecular behavior in a nano-confined film, along with both the packing and orientation of the liquid molecules in TFL regime[3,4]. The presentation attempts to systematically review the major developments of TFL, including the state-of-art studies on experimental technologies, researches and applications. Future prospects of relevant researches and applications will be also discussed.

EXPERMENT

As shown in Figure 1, a Raman-measurement equipment with an Argon-ion laser with an emission wavelength of 514 nm was used as a Raman excitation source. The laser beam was focused on the lubricant film in the contact region through a long work distance objective with 50x magnification, as shown in Figure 1(b). A quarter-wave plate was used to transform the linear polarized light emitted by polarized laser into circularly polarized light. The scattered Raman radiation was collected by the objective and Raman spectroscopy was finally acquired at 24 ºC with a spectral resolution of 2 cm^{-1}. Integral time for each spectrum was 30 s and the laser power was 30 mW.

The distribution profiles were mapped by collecting spectra at the points of a 200×200 µm grid to evaluate the molecular distribution over the whole contact region, as shown in Figure 1(c). The diameter of the laser spot is 2 µm. The contact region is marked by a big yellow circle. The *Inlet*, *Outlet* and *Center* of the contact region and the *Bulk* region of unconfined fluid are marked with small yellow circles. To rapidly compare the distribution difference between different lubricants, an average spectrum of four measuring points within the small circle is used as a reference value. In order to analyse the distribution profile, the background of each spectrum was deducted and all the intensities of Raman spectra were divided by the peak intensity of the characteristic vibration model of base oil.

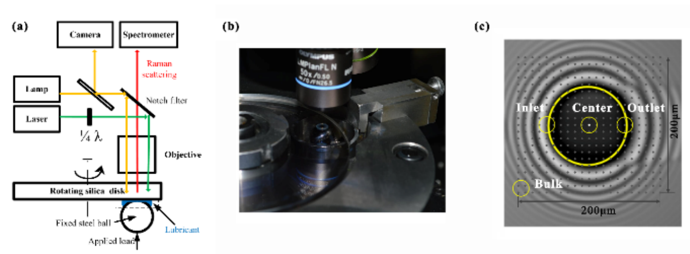

Figure 1. Experimental system: (a) the schematic diagram, (b) the photograph of the experimental apparatus and (c) the schematic of the measuring points.

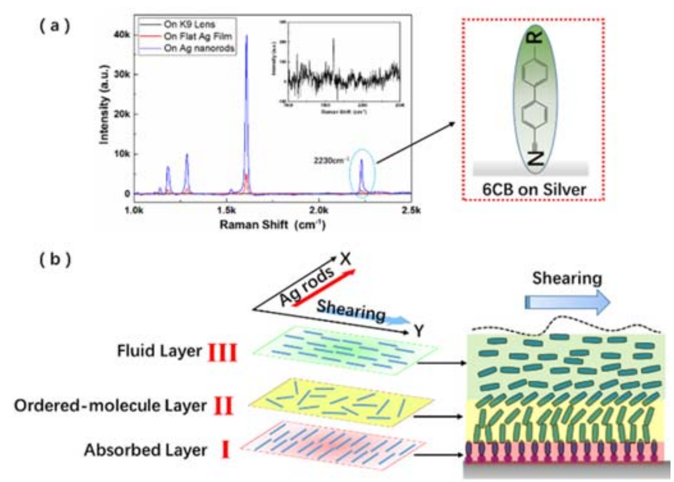

Figure 2. One-column illustration.

RESULTS

Based on experiments and discussion, a layered-molecules model exhibiting the molecular orientation in a nano-film in TFL regime was developed, as shown in Figure 2. Near the surface, a thin adsorption film formed, which is marked as the first layer I. In this case, the lubricant molecules were oriented perpendicularly to the solid surface due to the influence of surface adsorption, rather than the shearing force. The layer marked by III represents the fluid layer in the middle of the nano-film.

We supposed that between layer I and layer III, an ordered-molecule layer (marked as layer II) would exist, and the molecules in this layer were oriented via an induction force. Thus, it could be summarized that the molecules under a flow field confined in a nano-cell could orient in different ways; for molecules near or on surfaces, the ordering behaviour is affected significantly by the solid surface adsorption, while the alignment of molecules in the middle fluidic layer is directed by the shearing force. This conclusion is in agreement with the thin-film-lubrication model proposed by Luo et al.[1,2].

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