Structural Analysis of Interface between DLC films Having Various Wettabilities and Lubricants Using Neutron Reflectometry

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Structures of interfaces between materials and lubricants were analyzed using neutron reflectometry and discussed in the series of studies. In this paper, three kinds of DLC films having various wettabilities (normal DLC, hydrophilic DLC and hydrophobic DLC) were prepared as base materials, and water and 2-propanol were selected as lubricants. The instrument we used was a neutron reflectometer 'MINE' in Japan Atomic Energy Agency (JAEA). The DLC films were soaked into the lubricants in a specially-designed sample holder, and the neutron reflectivity profiles from the interface between DLC films and lubricants were directly obtained. Through an analytical fitting approach with Parratt's theory to the obtained profiles, authors presented the strict structure of the interface.

First, each DLC film was soaked into water in a sample holder, and the neutron reflectivity profiles from the interface between DLC films and water were obtained. Then, deuterated water (D2O) was used for clearer analysis because of its high sensitivity for neutron. Fitting operation to the obtained reflectivity profiles showed that density of water at the interface between normal DLC and water was same as density of bulk water and uniform along vertical direction. On the other hand, at the interface between hydrophilic DLC and water, water was infiltrating from the top surface of DLC to the 15 nm depth. In addition, we found that the 'dense water layer' existed from the top surface of DLC to the 2 nm depth. At the interface between hydrophobic DLC and water, 'low density water layer' existed on the film surface. The fitting approach confirmed that the thickness of the layer on the hydrophobic surface was 3nm, and its density was almost half of bulk water.

Structures of interfaces between each DLC film and deuterated 2-propanol (CD3CD(OD)CD3) were also analyzed using neutron reflectometry. We found that the 2-propanol was also infiltrating from the top surface of hydrophilic DLC to the 15 nm depth and was infiltrating from the top surface of normal DLC to the 9 nm depth.

The coefficients of friction of each DLC film under boundary lubricated condition were measured using a ball-on-disk friction tester. The ball material and size are SUJ2 and 3/16 inch in diameter. The applied load to the ball was 0.2 N. The obtained coefficient of friction of each DLC film under water lubricated or 2-propanol lubricated condition is shown in Fig. 1. This figure shows that the friction coefficient of hydrophilic DLC is lower and that of hydrophobic DLC is higher than that of normal DLC. It may be because that for the hydrophilic surface, lubricants are enough to reduce the friction, while that for the hydrophobic surface, friction surface runs short of lubricants under boundary lubricated condition. We conclude that the nano structure of interface between DLC and lubricants are very influential to the lubricated friction property.

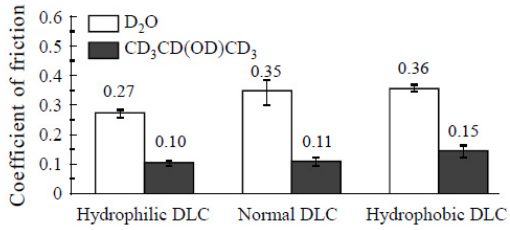

Fig. 1. Coefficients of friction under lubricated condition