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主 論 文 の 要 旨

論文題目　Tribological properties and the mechanism of ta-C coatings with filtered cathodic vacuum arc deposition at elevated temperature
（フィルタードカソーディックアーク真空成膜法による ta-C の高温中摩擦摩耗特性及び摩擦摩耗メカニズム）

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論 文 内 容 の 要 旨

In modern industry, sliding machines are subjected to high temperature environments. Solid lubricating coatings are primarily used to control friction and wear in high temperature environments, where conventional liquid lubricants cannot provide lubrication function due to deterioration and oxidation at high temperature. Solid lubricating coatings include nitrides coatings, carbides coatings, oxides coatings, carbon coatings, soft metals, polymers coatings and lamellar solids. Among these solid lubricating coatings, carbon coatings attract much attention because their excellent mechanical properties and tribological properties, such as low friction, high hardness and high wear resistance. However, the high temperature tribological behaviors and mechanism of carbon coatings are still not clarified yet. Consequently, in this study, tetrahedral amorphous carbon (ta-C) coatings were investigated with respect to their thermal stability and high temperature tribological properties.

The aim of this study is to clarify effects of substrate bias and elevated temperature during sliding on tribological properties. In addition to investigations the effects of substrate bias on mechanical and micro-structural properties of ta-C coating, ball-on-disk friction tests were conducted in high temperature conditions using Si_3N_4 ball. Besides, friction and wear behavior as a function of different sliding cycles were analyzed to further understand the running-in cycle, wear and formation of carbonaceous transfer layer in high temperature. Additionally, in order to get a comprehensive understanding of the effect of defects in ta-C coating related to running-in cycle, the defects in a designated area on the surface of the ta-C coating were observed and their morphology, structural and tribological behavior were compared with those obtained under high temperature condition.

First, we prepared ta-C coatings by using filtered cathodic vacuum arc (FCVA) deposition. The effect of bias and temperature on properties and tribolgical behavior of the ta-C coating is not clarified. The tribological behaviors of 1 μm of ta-C coatings deposited with different substrate biases of 0 V, -100 V and -300 V were examined under elevated temperature up to 600 °C. Wear behaviors were found in two distinct ranges in temperature. The variation of the specific wear rate of ta-C coatings in region I at 23, 100 and 200 °C are affected by abrasive particles of high sp^3 content of ta-C coatings. In region II at 300, 400 and 500 °C, the transfer layer play a major role in reduction of wear rate as a function of substrate bias.

In the high temperature condition, the high sp^3 content ta-C coating deposited at substrate bias of -100V were found high wear resistance compared to ta-C fabricated at substrate bias of 0 V over testing temperature of 300 °C. This is caused by the remained hardness and high sp^3 content. We focused on ta-C coating deposited at substrate bias -100 V. Then we clarified wear-in and running-in cycle and role of carbon transferred layer. Ta-C coatings were also subjected to friction tests under 200 ℃ in air with different sliding cycles. The friction coefficient reached 0.02 at steady state after finishing a running-in cycles approximately 2,000 cycles. After reaching the steady state, wear rates of ta-C decreased with increasing number of cycles. The decrease of wear rates was caused to polish defects presented on surface and to form a carbon transferred layer on the counter-part material. The mechanism of those tribological properties was analyzed by measurements of Raman spectroscopy, observation of scanning electron microscope and non-contact type microscopy.

This study examined the tribological behavior of ta-C coating fabricated at a substrate bias of -100 V with FCVA deposition. Defect in ta-C coating was categorized with droplet, pore and spikes regarding with morphological, structural and mechanical properties of ta-C surface. Friction tests were conducted at a temperature of 170 °C in ambient air using a ball on disk tribo-meter. Friction coefficient was 0.08 during a steady state and wear rate was 4.3×10^{-6} mm^3/Nm. To explain the friction and wear behavior, a shape and structural properties of defects in designated area was compared with a different sliding cycles. Droplets were remained during the friction test at 170 °C at designated area. During the sliding, formation of tribo-layer on Si_3N_4 ball prevented to form spike. These spikes became abrasive particles, resulting in severe wear at pore which had sp^2 rich structure and low mechanical properties.