Friction properties of Si-DLC films under water vapor lubricating conditions

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1. Introduction

The increasingly stringent environmental regulations are encouraging to reduce friction and wear. In terms of saving dissipated energy by friction without compromising durability, application of surface coatings, including chromium nitride (CrN), titanium nitride (TiN), aluminum titanium nitride (AlTiN), etc., has been regarded as the potential solutions, and among them, diamond-like carbon (DLC) films have shown excellent functions [1, 2]; wear resistance, low friction, corrosion resistance, optical transparency, and gas barrier properties [3]. Meanwhile, there is a growing demand for dry sliding to meet the environmental regulations that minimize the use of lubricants by industries. However, dry sliding often leads to excessive heat generation due to high friction, resulting in material degradation and wear. To achieve smooth and low-frictional dry sliding, this research highlights water vapor lubrication. Carbonaceous materials like graphite are known to demonstrate low friction behavior under highly humid environments since water molecules saturate the carbon dangling bonds on the surface. In particular, Si-doped DLC (Si-DLC) films exhibit superior tribological properties under water-lubricated conditions [4, 5], which can develop into a promising candidate as a protective coating for dry sliding. However, there remains a research gap in the tribological investigation of Si-DLC films under water vapor lubricating conditions. With the purpose of expanding environmentally friendly friction reduction across various industries, this research studied the tribological characteristics of Si-DLC films under water vapor lubricating conditions. Systematic efforts were given to understanding the tribochemical mechanism that causes friction reduction.

2. Experiments

DLC and Si-DLC films were deposited onto SKH51 steel using a bipolar plasma-based ion implantation and deposition (PBII&D). To fabricate the DLC film, 10 sccm of toluene was flowed into the vacuum chamber, whereas a mixture gas of toluene and tetramethylsilane (TMS) was introduced. The tribological properties of both films were evaluated using a reciprocating-type tribometer. An aluminum ball was used as the counter material, and a normal load of 25 N was applied. The experiments were conducted at a sliding frequency of 1 Hz and a stroke length of 6 mm. The environmental conditions were controlled at a temperature of 20-22°C and a humidity of 90-92%, with a test duration of 330 seconds.

3. Results and discussion

The tribological properties of DLC and Si-DLC films were significantly influenced by the presence of silicon. Fig. 1 illustrates the change in the coefficients of friction (COFs) over time for DLC and Si-DLC films under water vapor lubricating conditions. Both DLC and Si-DLC films required approximately 60 s to stabilize their COFs. The steady-state COF of DLC fell in the range of 0.06 to 0.07, whereas Si-DLC demonstrated lower values of 0.04 to 0.05. The low-frictional characteristic of Si-DLC film is attributed to the formation of hydroxyl and carboxyl groups formed at the surface interface. According to ref. [6], the water lubrication of Si-DLC films generates hydroxyl and carboxyl groups on the sliding surfaces and these promote the hydrophilicity, facilitating the adsorption of water molecules. This process is likely to occur under water vapor lubricating conditions.

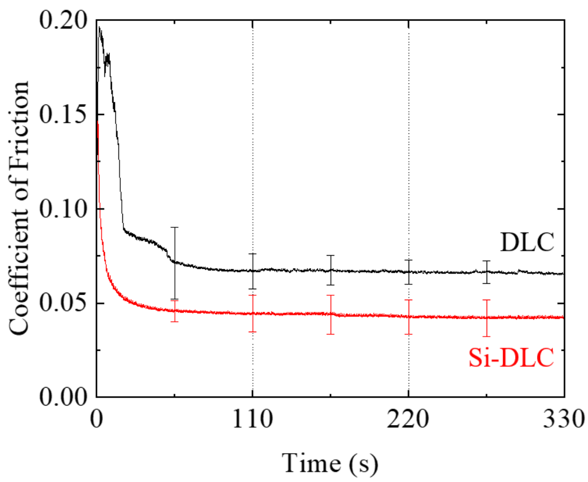

Fig.1 The coefficients of friction with respect to times under water vapor lubricating conditions for DLC and Si-DLC films

4. Conclusion

This research highlights the tribological properties of DLC and Si-DLC films under water vapor lubricating conditions. The results showed that the COF of Si-DLC film was more stable and lower than that of DLC film under water vapor lubricating conditions. The low-frictional nature of Si-DLC film is likely due to the formation of hydroxyl and carboxyl groups. These groups enhance hydrophilicity and promote water molecule adsorption, resulting in low shear stress at the sliding interface.

References

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