Investigating the Tribochemistry of Silicon Oxide-Doped Diamond-Like Carbon: *from Ultra-High Vacuum Systems to the International Space Station*

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1. Introduction

Silicon oxide-doped diamond-like carbon (SiO_x-DLC) coatings are amorphous thin-film materials consisting of two interpenetrating, interbonded networks, one being hydrogenated amorphous carbon (a-C:H), and the other silica glass (SiO_x)[1]. The combination of good mechanical properties, low residual stresses, high thermal stability compared to a-C:H[2], and excellent tribological properties across many environments (including humid/oxidizing ones, an improvement over a-C:H[3]), makes these coatings attractive solid lubricants for technologically important applications, including aerospace components[4], high-performance tools, overcoat materials to protect the magnetic layer in hard disks, microelectromechanical systems (MEMS), and atomic force microscopy (AFM) probes[5].

The improved thermal and environmental performance of these films compared to conventional a-C:H motivates considering them for extreme environment applications, including outer space. The Materials International Space Station Experiments (MISSE) provides the scientific community with a platform for experiments in the harsh low Earth orbit (LEO) environment. During the seventh MISSE mission (MISSE-7b), eight pin-on-disk tribometers were delivered to the International Space Station (ISS) where they ran non-continuously for 18 months[6]. A SiO_x-DLC coating was tested on one of the four tribometers on the wake face (*i.e.*, trailing surface). This work presents the analysis of the film after LEO exposure, as well as control experiment on SiO_x-DLC samples.

2. Results

X-ray photoelectron spectroscopy (XPS) and cross-section transmission electron microscopy (X-TEM) results indicate that after LEO exposure the outermost layer of SiO_x-DLC is primarily composed of silicon dioxide (SiO_2). Significant amounts of Si and O found on other wake-face MISSE-7b samples suggest the presence of a common contamination source, potentially being silicone oil. However, the degradation of SiO_x-DLC through the breakage and subsequent oxidation of C-C bonds induced by the harsh LEO environmental conditions cannot be ruled out as a contributing factor to the formation of a thick SiO_2 layer.

Control experiments were performed on Earth using an ultra-high vacuum tribometer at different partial pressures of H_2 and O_2. Both species were found to drastically decrease friction and wear, indicating that passivation of dangling bonds produced during sliding is essential to the film's performance.

To assess the thermal and oxidative stability of SiO_x-DLC, environmental XPS was used to acquire spectra at elevated pressures and in angle-resolved mode while heating the sample *in situ*. SiO_x-DLC films were annealed from 150°C to 500°C both under high vacuum conditions and at different O_2 partial pressures. Subsequent *ex situ* AFM and Raman measurements were conducted to correlate the evolution of morphology, nanoscale tribological properties, and structure with the surface chemical changes occurring on SiO_x-DLC surface.

3. References

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