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DEGRADATION OF FLUORINATED POLYMERS/LUBRICANTS DUE TO HYPERTHERMAL NITROGEN COLLISION IN VERY LOW EARTH ORBIT

K. Yokota*, K. Nakayama, S. Nishioka, K. Ueta, M. Tagawa*
*yokota@mech.kobe-u.ac.jp; tagawa@mech.kobe-u.ac.jp
Graduate School of Engineering, Kobe University
Rokko-dai 1-1, Nada, Kobe 657-8501, Japan

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ABSTRACT
Altitude lower than 300 km is being focused for the next generation communication constellation system and earth observation satellites for small delay transmission and high resolution images. Such an altitude range is called "very low earth orbit (VLEO)". VLEO satellite needs to orbit in dense atmosphere which generates large atmospheric drag. High density atmosphere produces aerodynamic forces which is applicable also to attitude control of satellite. Such attempt has already been successfully carried out by the European cube sat [1]. For such applications, environmentally durable solid lubricants are necessary.

Atomic oxygen (AO) is the most dominant species in LEO and degradation of solid lubricants such as MoS_2 has been studied many years ago [2]. It was demonstrated that loss of sulfur from the surface due to oxidation and high wear rate of MoS_2 film shorten the wear life of MoS_2 film. Therefore, an intrinsically oxidation resistant lubricant in AO environment is required. Fluorinated materials, such as PTFE or FEP, are known as AO resistant materials in LEO, and considered as a candidate for VLEO applicable materials. Even though these materials are durable in LEO, it has not been evaluated in VLEO environment where AO density is more than two orders higher than LEO. Moreover, VLEO atmosphere includes N_2 almost comparable to AO. The effect of N_2 collision of fluorinated polymers has not been investigated. In this study, effect of N_2 collision on fluorinated polymer was experimentally examined using laser detonation beam source.

The experiment was carried out using laser-detonation beam source which is able to produce 8 km/s electrically neutral atom beams. In order to simulate physical effect of N_2 collision in VLEO, hyperthermal Ar beam was formed by this system. 1.0 MPa O_2 and Ar gases are mixed by the mixing system and beam composition was adjusted by the quadrupole mass spectrometer equipped in the beam line. Mass loss of FEP Teflon was measured by an analytical micro balance. Since synergistic effect was not observed on the fluorinated erosion by AO and Ar , we calculated the erosion yield of FEP by AO (Ey(AO)) and by Ar (Ey(Ar)) independently by using two beam conditions (70%AO+30%Ar and 30%AO+70%Ar).

It was clearly indicated that Ey(Ar) is 20 times greater than Ey(AO), which means that hyperthermal Ar collision (N_2 collision in space) is the major origin of erosion of FEP. This experimental finding explains the unsolved problems in space environmental effect community, i.e., Ey data of fluorinated polymers on ground experiment is an order of magnitude greater than those measured in ISS. It is suggested that the origin of this phenomenon is caused by the undecomposed hyperthermal O_2 component included in the AO beam generated in the laser detonation source.

The experimental result also suggests that the erosion of FEP in VLEO at 200 km is should be estimated by considering not AO density but N_2 density. Otherwise, erosion of fluoropolymers in VLEO is much underestimated. The same situation will occur also in Martian and Venusian atmosphere beside VLEO where AO and CO_2 exist in atmosphere. This analytical conclusion obtained by the ground-based experiment is supported by the world first FEP erosion data in VLEO flown on SLATS/MDM mission.

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