O_2 plasma treating of space-technology polymers

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Synopsis This study examines the degradation of Kapton films in Low Earth Orbit (LEO) due to chemical erosion by atomic and ionized oxygen. Samples were exposed to O_2 plasmas, revealing erosion changes analyzed via SEM and XPS. The research aims to improve the understanding of degradation mechanisms by combining mass spectrometry and photoelectron spectroscopy, with future applications extending to polystyrene and graphite.

Polymeric films are extensively used in aerospace applications due to their lightweight nature, remarkable flexibility, and insulating properties for both electricity and heat [1]. However, in Low Earth Orbit (LEO), which extends up to 2000 km above Earth's surface [2] and encompasses key space assets such as the International Space Station (400 - 420 km) and the Hubble Space Telescope (515 km), these materials undergo severe degradation. An important factor responsible for this deterioration is chemical erosion caused by atomic oxygen (O) and ionized oxygen (O^+), which dominate the atmospheric composition at these altitudes.

This study focuses on analyzing the effects of non-thermal oxygen plasmas on spacecraft coating materials. Kapton films have been exposed to an RF O_2 plasma under varying conditions of exposure time, O_2 flow rate, and plasma power. Figure 1 presents scanning electron microscopy (SEM) images comparing an untreated Kapton film to one subjected to an O_2 plasma treatment at 100 W power and 100 sccm O_2 flow for 8 hours. While the untreated film exhibits a smooth surface due to its manufacturing process, the plasma-exposed sample shows clear signs of erosion. Additionally, two distinct surface modification phenomena are observed: (i) exfoliation, where large fragments detach, with some areas displaying curled features, and (ii) the emergence of rounded conglomerates of different sizes. Preliminary X-ray photoelectron spectroscopy (XPS) analyses have also been performed.

A major ongoing challenge in this research is the integration of a residual gas analyzer (RGA) for in situ quadrupole mass spectrometry (QMS) measurements. The combination of QMS and XPS techniques could enable a detailed assessment of desorbed species and surface modifications induced by plasma treatment. These complementary methods can contribute to identifying the weakest molecular bonds in polyimide films, offering a deeper understanding of polymer degradation mechanisms. Future investigations will extend this approach to polystyrene and graphite processing.

Figure 1. Backscattered electron data (BED) from scanning electron microscopy of (Left) a non-processed Kapton film and (Right) one ex-posed to a 100 W O_2 plasma, with an O_2 flow rate of 100 sccm for 8 hours.



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