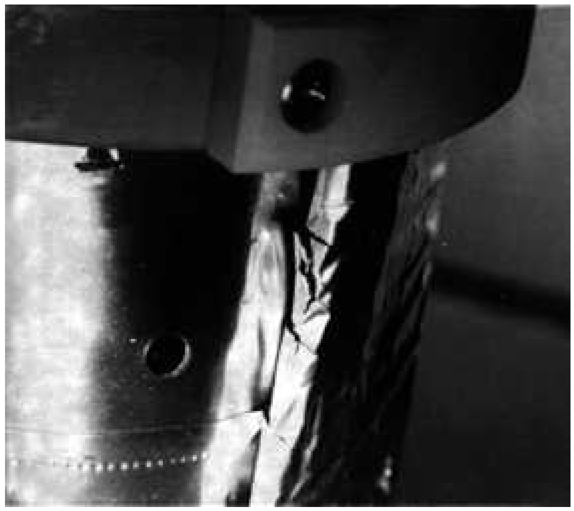
Investigation of Teflon FEP Embrittlement on Spacecraft in Low-Earth Orbit



Photograph of embrittled and cracked Teflon FEP retrieved from the Hubble Space Telescope.

Teflon fluorinated ethylene propylene (FEP) (DuPont) is commonly used on exterior spacecraft surfaces for thermal control in the low-Earth orbit environment. Silverized or aluminized Teflon FEP is used for the outer layers of the thermal control blanket because of its high reflectance, low solar absorptance, and high thermal emittance. Teflon FEP is also desirable because, compared with other spacecraft polymers (such as Kapton), it has relatively high resistance to atomic oxygen erosion. Because of its comparably low atomic oxygen erosion yield, Teflon FEP has been used unprotected in the space environment.

Recent, long-term space exposures, such as on the Long Duration Exposure Facility (LDEF, 5.8 years in space) and the Hubble Space Telescope (after 3.6 years in space), have provided evidence of low-Earth orbit environmental degradation of Teflon FEP. These exposures provide unique opportunities for studying environmental degradation because of their long durations and different conditions (such as differences in altitude). Samples of Teflon FEP from LDEF and the Hubble Space Telescope (retrieved during its first servicing mission) were evaluated for solar-induced embrittlement and for synergistic effects of solar degradation and atomic oxygen. Surface hardness measurements were obtained with unique Nano Indenter (Nano Instruments, Inc., Oak Ridge, Tennessee) techniques for polymers, which can measure hardness versus depth. Samples were bend tested to induce surface cracking, and then the bend-tested samples were cross-sectioned to determine crack depth. Tensile testing was conducted on Hubble samples and compared with LDEF data. Surface morphologies of Hubble and LDEF Teflon FEP samples were compared by using scanning electron microscopy and atomic force microscopy.

Nano Indenter results indicate that the surface hardness increased as the ratio of atomic oxygen fluence to solar exposure fluence (in equivalent Sun hours) decreased for the LDEF samples. This occurred because the atomic oxygen eroded away part, or all, of the solar-embrittled layer. Teflon FEP multilayer insulation retrieved from Hubble provided evidence of severe embrittlement on solar-facing surfaces. Some areas were cracked through the thickness of the 5-mil film. Nano Indenter measurements indicated higher surface hardness values for these samples. Cracks induced during bend testing were significantly deeper for the Hubble samples with highest solar exposure than for LDEF samples with similar atomic oxygen/solar exposure.

These results underscore the need to conduct further studies and the necessity to consider causes for Teflon FEP embrittlement in addition to direct atomic oxygen/solar exposure, such as the possible role of soft x-ray radiation, which is dependent on solar flares. Teflon FEP that was exposed to soft x-rays in a ground test facility showed similar embrittlement, which indicates that the observed differences between LDEF and Hubble Teflon might be due to varying soft x-ray fluences during these two missions.

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