Teflon FEP Analyzed After Retrieval From the Hubble Space Telescope

Hubble Space Telescope light shield sample retrieved during the second servicing mission; shown prior to removal.

During the Hubble Space Telescope (HST) Second Servicing Mission, 6.8 years after the telescope was deployed in low Earth orbit, degradation of unsupported Teflon FEP (DuPont; fluorinated ethylene propylene), used as the outer layer of the multilayer insulation (MLI) blankets, was evident as large cracks on the telescope light shield. A sample of the degraded outer layer (see the photograph) was retrieved during the second servicing mission and returned to Earth for ground testing and evaluation. Also retrieved was a Teflon FEP radiator surface from a cryogen vent cover that was exposed to the space environment on the aft bulkhead of the HST. NASA Goddard Space Flight Center directed the efforts of the Hubble Space Telescope MLI Failure Review Board, whose goals included determining the FEP degradation mechanisms. As part of the investigations into the degradation mechanisms, specimens retrieved from the first and second HST servicing missions, 3.6 and 6.8 years after launch, respectively, were characterized through exhaustive mechanical, optical, and chemical testing. Testing led by Goddard included scanning electron microscopy, optical microscopy, tensile testing, solar absorptance measurements, time-of-flight secondary ion mass spectroscopy (TOF-SIMS), Fourier transform infrared microscopy (μ-FTIR), attenuated total reflectance infrared microscopy (ATR/FTIR), and x-ray diffraction (XRD). The NASA Lewis Research Center contributed significantly to the analysis of the retrieved HST materials by leading efforts and providing results of bend testing, surface microhardness measurements, x-ray photoelectron spectroscopy, solid-state nuclear magnetic resonance spectroscopy, and density measurements. Other testing was conducted by Nano Instruments, Inc., and the University of Akron.

Results of mechanical properties testing of FEP specimens retrieved after 3.6 and 6.8 years of HST exposure indicated significant decrease in tensile test elongation at break and reduced tolerance to strain upon bending. Space-exposed samples also showed increased

surface hardness that decreased with depth. Solar absorptance of the space-exposed FEP was slightly increased. In general, analyses showed that all of the retrieved specimens underwent chain scission. Evidence of increased crystallinity was found only in the light shield specimen from the second servicing mission, which had curled on orbit and thus experienced a significantly higher temperature than is typical for the HST light shield. Heating specimens from the first servicing mission also generated increased crystallinity. The conclusions of the Hubble Space Telescope MLI Failure Review Board were based on the combined evidence of HST damage and data uncovered in ground-based experiments. The review board concluded the following:

> "The observations of HST MLI and ground testing of pristine samples indicate that thermal cycling with deep-layer damage from electron and proton radiation are necessary to cause the observed Teflon FEP embrittlement and the propagation of cracks along stress concentrations. Ground testing and analysis of retrieved MLI indicate that damage increases with the combined total dose of electrons, protons, UV, and x-rays along with thermal cycling."

Tests continue to determine the effects of the higher temperature limit that the second servicing mission MLI specimen experienced.

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