Insights Developed Into the Damage Mechanism of Teflon FEP Thermal Control Material on the Hubble Space Telescope

Metalized Teflon FEP (DuPont; fluorinated ethylene propylene) thermal control material on the Hubble Space Telescope (HST) has been found to degrade in the space environment. Teflon FEP thermal control blankets retrieved during the first servicing mission were found to be embrittled on solar-facing surfaces and to contain microscopic cracks (the FEP surface is exposed to the space environment). During the second servicing mission, astronauts noticed that the FEP outer layer of the multilayer insulation blanketing covering the telescope was cracked in many locations. Large cracks were observed on the light shield, forward shell, and equipment bays. A tightly curled piece of cracked FEP from the light shield was retrieved during the second mission. This piece was severely embrittled, as witnessed by ground testing. A Failure Review Board was organized by NASA Goddard Space Flight Center to determine the mechanism causing the multilayer insulation degradation. This board included members of the Electro-Physics Branch of the NASA Glenn Research Center at Lewis Field.

Density measurements of the retrieved materials obtained under the review board's investigations indicated that FEP from the first servicing mission was essentially unchanged from pristine FEP but that the second servicing mission FEP had increased in density in comparison to pristine FEP (ref. 1). The results were consistent with crystallinity measurements taken using x-ray diffraction and with results from solid-state nuclear magnetic resonance tests (see the table and ref. 1). Because the second servicing mission FEP was embrittled and its density and crystallinity had increased in comparison to pristine FEP, board researchers expected that the first servicing mission FEP, which was also embrittled, would also have increased in crystallinity and density, but it did not. Because the retrieved second servicing mission material curled while in space, it experienced a higher temperature extreme during thermal cycling (estimated at 200 °C) than the first servicing mission material (estimated at 50 °C). Therefore, Glenn initiated and conducted an investigation of the effects of heating pristine FEP and FEP that had been exposed on the Hubble Space Telescope. Samples of pristine and first and second servicing mission FEP were heated to 200 °C and evaluated for changes in density and morphology. We hoped that the results would help explain why FEP degrades in the Hubble Space Telescope space environment.

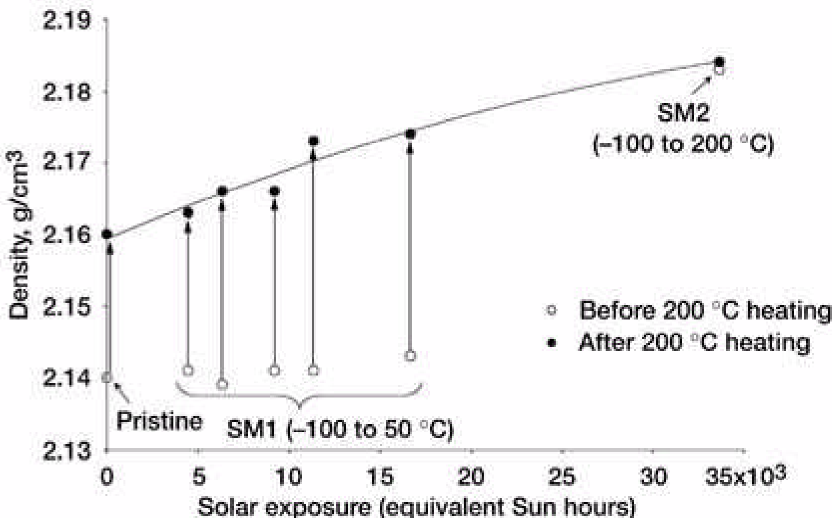
Elevated-temperature exposure was found to have a major impact on the density of the retrieved materials. The graph shows the density of pristine FEP and Hubble Space Telescope FEP (retrieved during both servicing missions) prior to and after ground laboratory heating to 200 °C for 7 to 9 days. The density of the pristine and first servicing mission FEP increased with heating at 200 °C, with an increase in density that corresponded to an increase in solar exposure. Nuclear magnetic resonance characterization of polymer morphology was consistent with the density results. Both techniques showed that the as-received first servicing mission FEP is structurally similar to pristine FEP and that the second servicing mission FEP is more tightly packed or crystalline. Heating at 200 °C changed the morphology of pristine FEP and first servicing mission FEP, with the first servicing mission FEP undergoing a greater change than pristine FEP. Heating at 200 °C produced no further change in second servicing mission FEP.

These results, along with analyses of x-ray exposed and thermal-cycled FEP, provided insight into the damage mechanism of Teflon FEP in space. The results indicate that irradiation of Teflon FEP in space causes chain scission, resulting in FEP embrittlement. Heating at the nominal temperatures experienced on the Hubble Space Telescope did not change the density or crystallinity of FEP. But heating at the levels experienced by the retrieved curled second servicing mission sample allowed increased mobility of the space-environment-induced scissioned short chains, with resulting increased crystallinity and density. The percent crystallinity of second servicing mission FEP was found to be 27-percent higher than that of pristine FEP. Heating of pristine FEP at 200 °C also increased the crystallinity and density, but the increases were not as great as for the heated space-exposed samples, which experienced chain scission due to irradiation in space.

SUMMARY OF FAILURE REVIEW BOARD FINDINGS
[See ref. 1.]

Property	**Pristine FEP**	**First servicing mission FEP, 11,339 ESH**[a]	**Second servicing mission FEP, 33,638 ESH**[a]
	Very ductile	Brittle microscopic cracks	Brittle macroscopic cracks
Tensile property, percent elongation to failure	363	156	≈0
Density, g/cm^3	2.140	2.138	2.184
X-ray diffraction crystallinity, percent	28.5	29.5	46.5
Nuclear magnetic resonance, $T1\rho(C)$[b]	35	33	41
Nuclear magnetic resonance, T_{CF} peak,[c] msec	2	2	≈ 1

[a] ESH, equivalent Sun hours.
[b] $T1\rho(C)$, ^{13}C relaxation in the rotating frame.
[c] T_{CF} peak, cross-polarization time for intensity maximum.



Density of pristine FEP and FEP retrieved from the Hubble Space Telescope during the first and second servicing missions, prior to and after heating at 200 °C for 7 to 9 days.

Find out more about this research on the World Wide Web:
http://www.grc.nasa.gov/WWW/epbranch/ephome.htm

References

1. Townsend, J.A., et al.: Hubble Space Telescope Metallized Teflon FEP Thermal Control Materials: On-Orbit Degradation and Post-Retrieval Analysis. High Perform. Polym., vol. 11, no. 1, 1999, pp. 81-99.

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