Environmental Exposure Conditions for Teflon FEP on the Hubble Space Telescope Investigated

The Hubble Space Telescope (HST) was launched into low Earth orbit on April 24,1990. During the first servicing mission in December 1993 (3.6 years after launch), multilayer insulation (MLI) blankets were retrieved from the two magnetic sensing systems located on the light shield. Retrieval of one of the solar arrays during this mission also provided MLI blanket material from the solar array drive arm. These MLI materials were analyzed in ground-based facilities, and results indicate that the space-facing outer layer of the MLI, aluminized Teflon FEP (DuPont; fluorinated ethylene propylene), was beginning to degrade. Close inspection of the FEP revealed through-the-thickness cracks in areas with the highest solar exposure and stress concentration. During the second servicing mission in February 1997 (6.8 years after launch), astronauts observed and documented severe cracking in the outer layer of the MLI blankets on both the solar-facing and anti-solar-facing surfaces. During this second mission, some material from the outer layer of the light shield MLI was retrieved and subsequently analyzed in ground-based facilities.

After the second servicing mission, a Failure Review Board was convened by NASA Goddard Space Flight Center to address the MLI degradation problem on HST. Members of the Electro-Physics Branch of the NASA Glenn Research Center at Lewis Field participated on this board. To determine possible degradation mechanisms, board researchers needed to consider all environmental constituents to which the FEP MLI surfaces were exposed. On the basis of measurements, models, and predictions, environmental exposure conditions for FEP surfaces on HST were estimated for various time periods from launch in 1990 through 2010, the planned end-of-life for HST. The table summarizes these data—including the number and temperature ranges of thermal cycles; equivalent Sun hours; fluence and absorbed radiation dose from solar event x rays; fluence and absorbed dose from solar wind protons and electrons trapped in Earth’s magnetic field; fluence of plasma electrons and protons; and atomic oxygen fluence.

The conclusions of the HST MLI Failure Review Board were based on the combined evidence of HST damage, data obtained from ground-based experiments, and understanding of the environmental exposure conditions for FEP exposed to the HST environment (ref. 1):

> "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."

An understanding of how the degradation of FEP on HST correlates with the environmental exposure conditions is important to spacecraft designers for predicting the lifetime of FEP components being used on spacecraft and for designing improved materials and MLI systems that will be durable in the space environment.

EXPOSURE CONDITIONS FOR TEFLON FEP ON THE HUBBLE SPACE TELESCOPE					
FEP surface on HST	**Light shield (HST body)**				**Solar array drive arm**
Exposure duration on HST, yr	3.6 (SM1[a])	6.8 (SM2[a])	10	20	3.6
Thermal cycles	19,700	37,100	55,000	110,000	19,700
Thermal cycling temperature range, °C Solar-facing Anti-solar-facing	–100 to 50 –200 to –10	–100 to 50 –200 to –10	–100 to 50 –200 to –10	–100 to 50 –200 to –10	–100 to >100 –100 to >100
Total solar exposure hours on solar-facing surfaces	16,670	33,638	50,000	100,000	20,056
Total solar exposure hours on anti-solar-facing surfaces	4477	3364	5000	10,000	6260
X-ray (0.1 to 0.8 nm) fluence, J/m^2	175	252	302	700	223
X-ray (0.1 to 0.8 nm) dose at 64 µm, krads	47	68	81	189	60
X-ray (0.05 to 0.4 nm) fluence, J/m^2	12	16	19	47	15
X-ray (0.05 to 0.4 nm) dose at 64 µm, krads	1.0	1.4	1.7	4.2	1.3
Trapped proton fluence >40 keV, #/cm^2	8.0×10^{9}	2.0×10^{10}	2.8×10^{10}	5.9×10^{10}	8.0×10^{9}
Trapped proton dose at 64 µm, krads	0.81	2.0	2.9	6.1	0.81
Trapped electron fluence >40 keV, #/cm^2	1.4×10^{13}	2.0×10^{13}	2.7×13	6.0×10^{13}	1.4×10^{13}
Trapped electron dose at 64 µm, krads	147	201	283	624	147
Plasma proton fluence, #/cm^2	1.1×10^{19}	1.6×10^{19}	2.3×10^{19}	5.0×10^{19}	1.1×10^{19}
Plasma electron fluence, #/cm^2	3.2×10^{19}	4.7×10^{19}	6.6×10^{19}	1.4×10^{20}	3.2×10^{19}

Atomic oxygen fluence, atoms/cm^2	$<3.1\times10^{20}$	$<3.2\times10^{20}$	$<6.0\times10^{20}$	$<1.1\times10^{21}$	1.2×10^{20}
[a]First (SM1) and second (SM2) servicing missions.					

Find out more about this research
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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