# Synchrotron Vacuum Ultraviolet Light and Soft X-Ray Radiation Effects on Aluminized Teflon FEP Investigated

Since the Hubble Space Telescope (HST) was deployed in low Earth orbit in April 1990, two servicing missions have been conducted to upgrade its scientific capabilities. Minor cracking of second-surface metalized Teflon FEP (DuPont; fluorinated ethylene propylene) surfaces from multilayer insulation (MLI) was first observed upon close examination of samples with high solar exposure retrieved during the first servicing mission, which was conducted 3.6 years after deployment. During the second HST servicing mission, 6.8 years after deployment, astronaut observations and photographic documentation revealed significant cracks in the Teflon FEP layer of the MLI on both the solar- and anti-solar-facing surfaces of the telescope. NASA Goddard Space Flight Center directed the efforts of the Hubble Space Telescope MLI Failure Review Board, whose goals included identifying the low-Earth-orbit environmental constituent(s) responsible for the cracking and embrittling of Teflon FEP which was observed during the second servicing mission. The NASA Lewis Research Center provided significant support to this effort.

Because soft x-ray radiation from solar flares had been considered as a possible cause for the degradation of the mechanical properties of Teflon FEP (ref. 1), the effects of soft x-ray radiation and vacuum ultraviolet light on Teflon FEP were investigated. In this Lewis-led effort, samples of Teflon FEP with a 100-nm layer of vapor-deposited aluminum (VDA) on the backside were exposed to synchrotron radiation of various vacuum ultraviolet and soft x-ray wavelengths between 18 nm (69 eV) and 0.65 nm (1900 eV). Synchrotron radiation exposures were conducted using the National Synchrotron Light Source at Brookhaven National Laboratory. Samples of FEP/VDA were exposed with the FEP surface facing the synchrotron beam. Doses and fluences were compared with those estimated for the 20-yr Hubble Space Telescope mission.

The table summarizes the results of tensile testing of synchrotron radiation-exposed FEP/VDA and gives comparisons to samples retrieved from the HST. As indicated in the table, specimens with the worst damage--those with a loss of elongation greater than 50 percent--received synchrotron exposure doses significantly in excess of HST's 20-yr lifetime estimated dose. However, these samples did not experience the complete loss of elongation shown by the samples retrieved from the telescope, which were exposed to the space environment for 6.8 years. This indicates that, at HST 6.8-yr equivalent exposure doses, using synchrotron radiation between 69 and 1900 eV, it is not possible to produce the extent of degradation observed for HST space-exposed materials. Some of the least-damaged specimens, those with less than 10-percent loss of elongation, were also exposed to radiation doses significantly in excess of the HST 20-yr estimated dose. Although exposure to synchrotron radiation in the vacuum ultraviolet and soft x-ray range of energies can degrade the mechanical properties of Teflon FEP, this radiation alone could not be the cause for the severe degradation of FEP surfaces that was observed after the 6.8-yr exposure on the Hubble Space Telescope. Other environmental factors, such as continuum x-ray radiation of energies up to 10 keV, electron and proton radiation, thermal cycling, and synergistic effects of radiation and thermal cycling, have also been investigated by NASA Lewis and NASA Goddard. Exposure to electron and proton radiation followed by thermal cycling similar to HST mission exposures caused greater degradation than exposure to radiation alone. However, further testing is required to positively identify the environmental exposure conditions responsible for the severe degradation of the FEP/VDA material retrieved after 6.8-yr exposure on the HST.

TABLE I.--SUMMARY OF TENSILE TESTING OF SYNCHROTRON-EXPOSED FEP/VDA SAMPLES AND COMPARISON TO SAMPLES RETRIEVED FROM THE HST

| Energy, eV | Attenuation length,[b] µm | Fluence, $J/m^2$ | Sample dose/ HST 20-yr x-ray dose | Loss of ultimate tensile strength, UTS, percent | Loss of elongation, percent |
|---|---|---|---|---|---|
| Most damaged: >50 percent loss of elongation | | | | | |
| 1489 | 2.74 | 95 900 | 1482[c] | 28 | 83 |
| 1489 | 2.74 | 16 100 | 249[c] | 30 | 67 |
| 290<br>700[a] | .262<br>.403 | 1 600<br>1 500 | 207[c]<br>136[c] | 26 | 66 |
| 290<br>700[a] | .262<br>.403 | 1 600<br>1 500 | 216[c]<br>137[c] | 27 | 59 |
| Least damaged: <10 percent loss of elongation | | | | | |
| 69 | 0.033 | 5 300 | 5638[c] | -0.2 | 1.5 |
| 1489 | 2.74 | 200 | 2.5[c] | -5.5 | -7.2 |
| 1489 | 2.74 | 8 200 | 127[c] | -6.7 | -7.7 |
| 1900 | 5.36 | 3 000 | 27.5[c] | -.2 | -2.0 |
| Samples retrieved from HST | | | | | |
| 1500 to 25 000 | ------ | 225 | 0.32[d] | 42<br>37 | 46<br>68 |
| 1500 to 25 000 | ------ | 255 | .36[d] | 50<br>92 | 100<br>100 |

[a]Samples were exposed sequentially to 290- and 700-eV radiation.

[b]Attenuation length for a specific energy of radiation is defined as the depth into material where radiation intensity has been reduced to 1/e times the intensity at the surface.

[c]Sample dose is that absorbed at an attenuation length of synchrotron exposure energy. The HST 20-yr x-ray dose is for x-rays in the energy range 1.5 to 12 keV absorbed within the attenuation length for the synchrotron exposure energy.

[d]Dose absorbed within the full 127-µm specimen thickness for the range of x-ray radiation energies between 1.5 and 25 keV.

# Reference

1. Milintchouk, A., et al.: Influence of X-Ray Solar Flare Radiation on Degradation of Teflon in Space. J. Spacecr. Rockets, vol. 34, no. 4, Jul.-Aug. 1997, pp. 542-548.

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