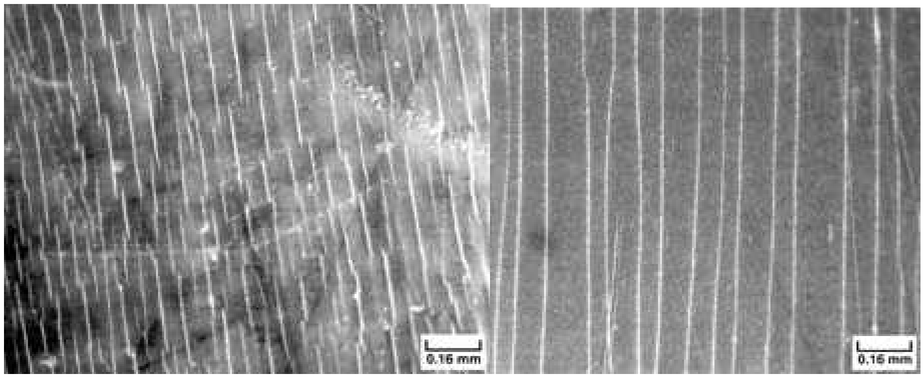
Soft X-Ray Exposure Testing of FEP Teflon for the Hubble Space Telescope

The FEP Teflon (DuPont) multilayer insulation (MLI) thermal-control blanket material on the Hubble Space Telescope is degrading in the space environment. During the first Hubble servicing mission in 1993, after 3.6 years in low Earth orbit, aluminized and silvered FEP Teflon MLI thermal-control blanket materials were retrieved. These materials have been jointly analyzed by the NASA Lewis Research Center and the NASA Goddard Space Flight Center for degradation induced in the space environment (ref. 1). Solar-facing blanket materials were found to be embrittled with through-the-thickness cracking in the 5-mil FEP. During the second Hubble servicing mission in 1997, astronauts noticed that several blankets had large areas with tears. The torn FEP was curled up in some areas, exposing the underlying materials to the space environment. This tearing problem, and the associated curling up of torn areas, could lead to over-heating of the telescope and to particulate contamination.

A Hubble Space Telescope MLI Failure Review Board was assembled by Goddard to investigate and identify the degradation mechanism of the FEP, to identify and characterize replacement materials, and to estimate the extent of damage at the time of the third servicing mission in 1999. A small piece of FEP retrieved during the second servicing mission is being evaluated by this failure review board along with materials from the first servicing mission. Since the first servicing mission, and as part of the failure review board, Lewis has been exposing FEP to soft x-rays to help determine the damage mechanisms of FEP in the space environment. Soft x-rays, which can penetrate into the bulk of FEP, are generated during solar flares and appear to be contributing to the degradation of the Hubble MLI.

Lewis researchers exposed FEP Teflon to soft x-ray radiation in an electron beam facility. In this facility, different target materials can be irradiated with an 8- to 10-kiloelectronvolts (keV) electron beam producing soft x-rays with different characteristic lines and continuous spectrums. Samples of FEP exposed to 5 hr of aluminum soft x-rays (characteristic and continuous spectrum radiation) were found to be embrittled to a similar extent as the materials retrieved from the first Hubble servicing mission. The photos show cracking of first servicing mission FEP and FEP exposed to aluminum soft x-rays after bending in tension. Tensile testing of first servicing mission samples produced significant decreases in the percent elongation as compared to unexposed FEP because of space-induced embrittlement. The elongation of the first servicing mission samples was 45-percent of the elongation for unexposed material, whereas the materials exposed to soft x-rays elongated 20 to 40 percent of the elongation for unexposed material (ref. 2). Subsequent testing with molybdenum radiation (the source was operated at 9 keV, which is below the threshold for the K_α characteristic radiation of molybdenum) provided evidence that continuous radiation can embrittle FEP.



Tension-induced surface cracking of embrittled FEP Teflon. Left: FEP from first Hubble servicing mission. Right: FEP exposed to aluminum soft x-rays.

Current work includes characterization of the x-ray intensity. Upon completion of facility characterization, proposed Hubble MLI replacement materials are to be exposed to soft x-rays to Hubble mission fluences as part of the failure review board test program. Plans also include a variety of soft x-ray exposure studies, such as variation in damage with energy, flux, and fluence. Also to be tested are the potential synergistic effects of soft x-ray exposure with thermal exposures, vacuum ultraviolet radiation, and atomic oxygen.

References

1. Zuby, T.M.; de Groh, K.K.; and Smith, D.C.: Degradation of FEP Thermal Control Materials Returned From the Hubble Space Telescope. NASA TM-104627, 1995.

2. de Groh, K.K.; and Smith, D.A.: Investigation of Teflon FEP Embrittlement on Spacecraft in Low Earth Orbit. NASA TM-113153, 1997.

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