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OPTICAL CHARACTERIZATION OF LDEF CONTAMINANT FILM

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EXTENDED ABSTRACT

Dark brown molecular film deposits were found at numerous locations on the LDEF and have been documented in great detail by several investigators.[1,2,3,4] The exact deposition mechanism for these deposits is as yet unknown, although direct and scattered atomic oxygen, and solar radiation interacting with materials outgassing products have all been implicated in the formation process. Specimens of the brown molecular film were taken from below the flange of the experimental tray located at position D10 on the LDEF. The tray was one of two, comprising the same experiment, the other being located on the wake facing side of the LDEF satellite at position B4 (see Figure 1†). Having access to both trays, we were able to directly compare the effect that orientation with respect to the atomic oxygen flux vector had on the formation of the brown molecular film deposits.

The film is thickest on surfaces facing toward the exterior, i.e. the tray corner, as can be seen by comparing the lee and wake aspects of the rivets. The patterns appear to be aligned not with the velocity vector but with the corner of the tray suggesting that flux to the surface is due to scattered atomic oxygen rather than direct ram impingement. The role of scattered flux is further supported by more faint plume patterns (unfortunately not readily visible from the photograph in Figure 1) on the sides of the tray. The angle of these plumes is strongly aligned with the ram direction but the outline of the deposit implies that incident atoms are scattered by collisions with the edges of the opening resulting in a directed, but diffuse, flux of atomic oxygen to the surface.

Spectral reflectance measurements in the 2 to 10 micron (4000 to 1000 wavenumbers) spectral range are presented for the film in the "as deposited" condition and for the free standing film in Figures 2a and 2b. The material was analyzed by FTIR (Fourier Transform Infrared) microspectroscopy using gold as the reference standard. The "as deposited" specimen was on an aluminum rivet taken from beneath the tray flange while the free film was obtained by chipping some of the material from the rivet. The transmission spectrum over the 2 to 10 micron range for the free film is presented in Figure 3. This spectrum appears to be essentially the same as that presented by Crutcher et.al. (ref.2) for films formed at vent sites which faced into the ram direction and suggested to originate from urethanes and silicones used on the LDEF. Banks et.al. (ref.4) state that silicones, when exposed to atomic oxygen, release polymeric scission fragments which deposit on surfaces and form a glassy, dark contaminant layer upon further atomic oxygen exposure and solar irradiation.

† Atomic oxygen fluence distribution diagram from: Kinard, W.H., Martin, G.D, "LDEF Space Environments Overview," pg 54, Proceedings of the First LDEF Post-Retrieval Symposium, NASA CP-3134, 1992.

Examination of the film specimens via scanning electron microscopy (SEM) showed the films to be between 22 to 24 μm thick and reveled a layered structure composed of light and dark bands which are visible in Figure 4. These layers suggest a cyclic deposition mechanism related to the periodic variation of solar illumination and temperature seen around each orbit. The micrographs also show that the layers decrease in thickness going from the inner to the outer surface which is consistent with a decrease in the flux of materials outgassing species over the length of the mission. It is unclear, however, what gives rise to the light and dark bands, although density or compositional variations between the layers could manifest in this way when viewed via SEM. Electron Spectroscopy for Chemical Analysis (ESCA) probe examination of the film found it to be substantially the same composition down to the probed depth of 50 Å (Table 1).

Table 1. ESCA Probe Survey of Molecular Film

Element	Depth 0 Å	15 Å	50 Å
Carbon	72%	73%	74%
Oxygen	23%	15%	15%
Silicon	2%	4%	5%
Other	3%	8%	7%

1 Crutcher, E. R., Nishimura, L.S., Warner, W.J, Wascher, W.W., "Qualification of Contaminants Associated With LDEF," First LDEF Post-Retrieval Symposium, pp. 141-154, NASA CP-3134, 1992.

2 Crutcher, E.R., Warner, W.J, "Molecular Films Associated with LDEF," First LDEF Post-Retrieval Symposium, pp. 155-177, NASA CP-3134, 1992.

3 Harvey, G.A., "Organic Contamination of LDEF," First LDEF Post-Retrieval Symposium, pp. 179-196, NASA CP-3134, 1992.

4 Banks, B.A., Gebauer, L., Hill, C. M., "Atomic Oxygen Interactions With FEP Teflon and Silicones on LDEF," First LDEF Post-Retrieval Symposium, pp. 801-815, NASA CP-3134, 1992.

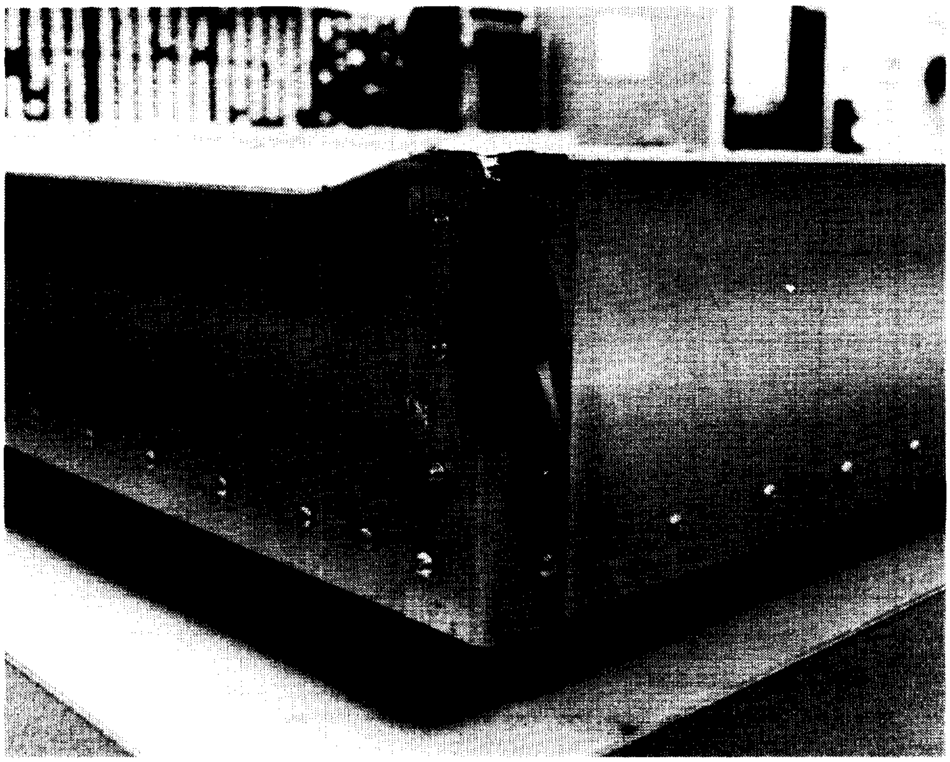


Figure 1a. Molecular film deposit below the mounting flange of experimental tray located at D10. Edge between Rows 9 and 10 pictured. RAM flow, left to right.

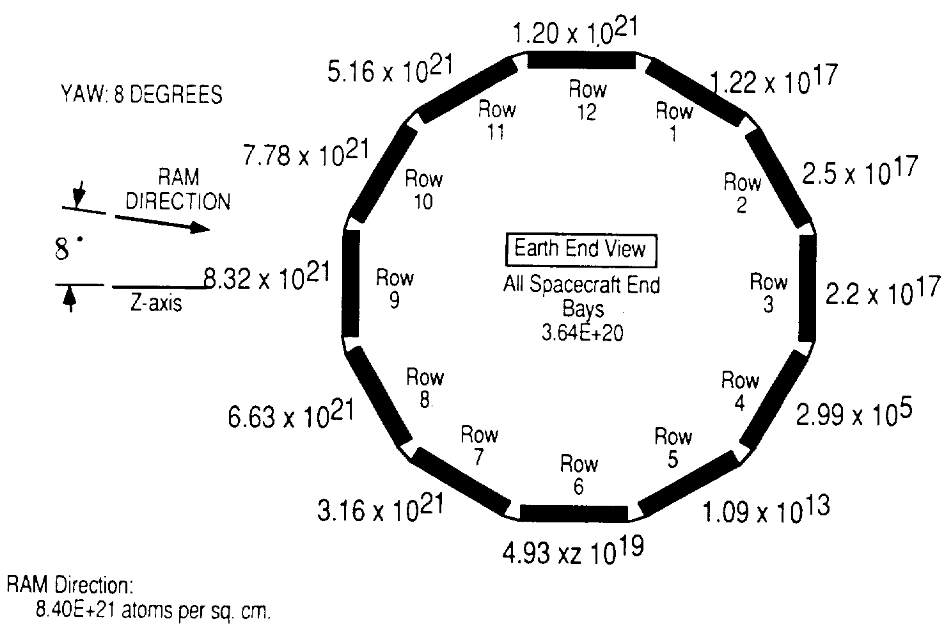


Figure 1b. Calculated distribution of atomic oxygen fluence on each of the LDEF surfaces. Note Rows 10 and 4.

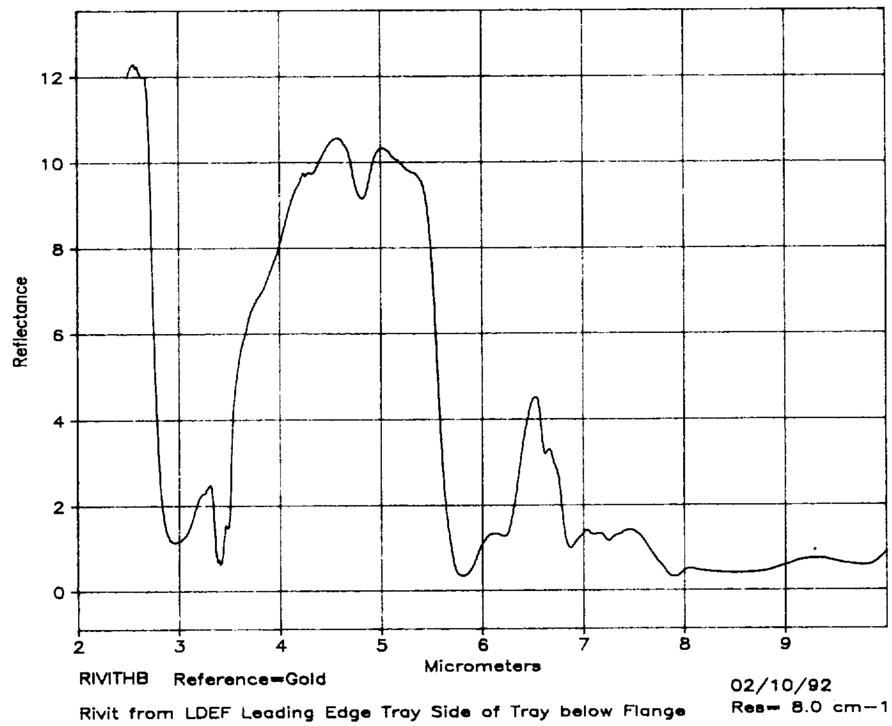


Figure 2a

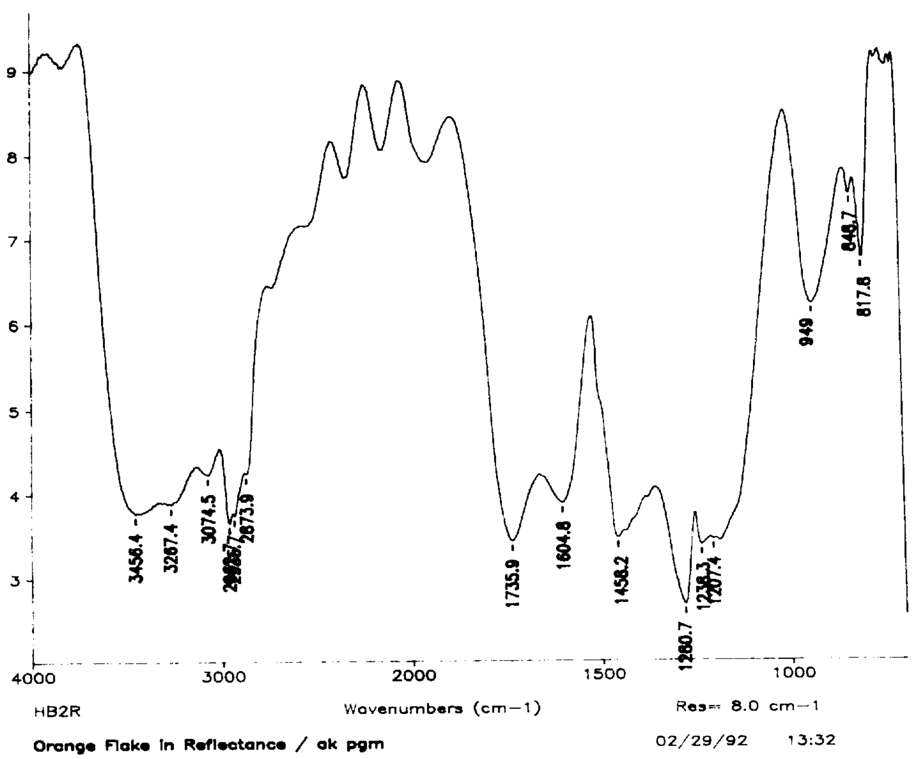


Figure 2b

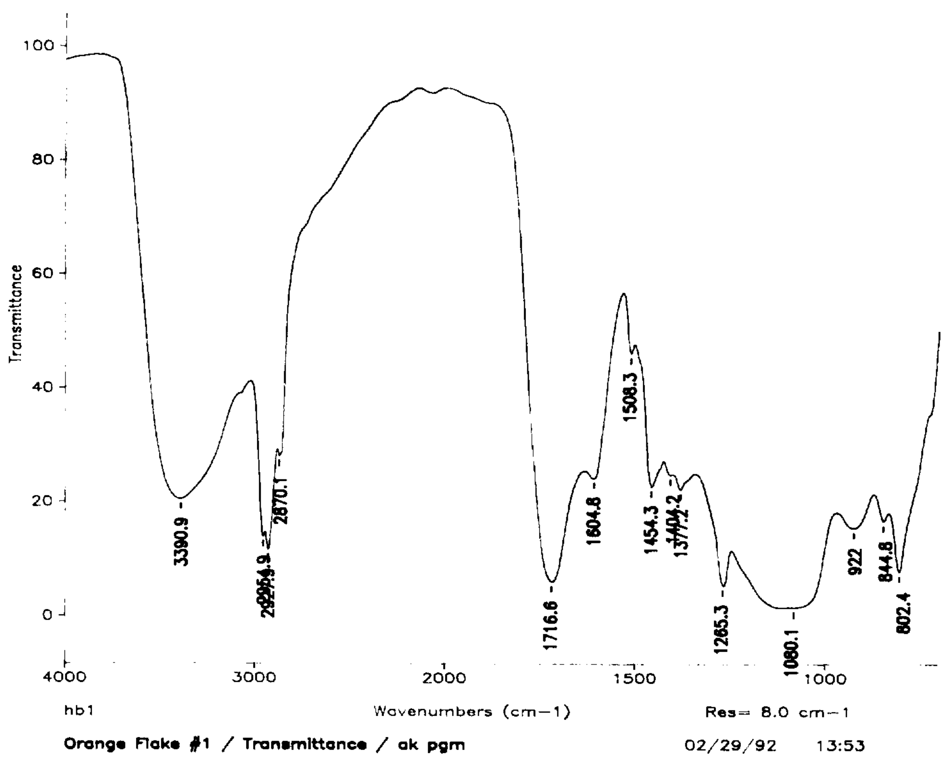
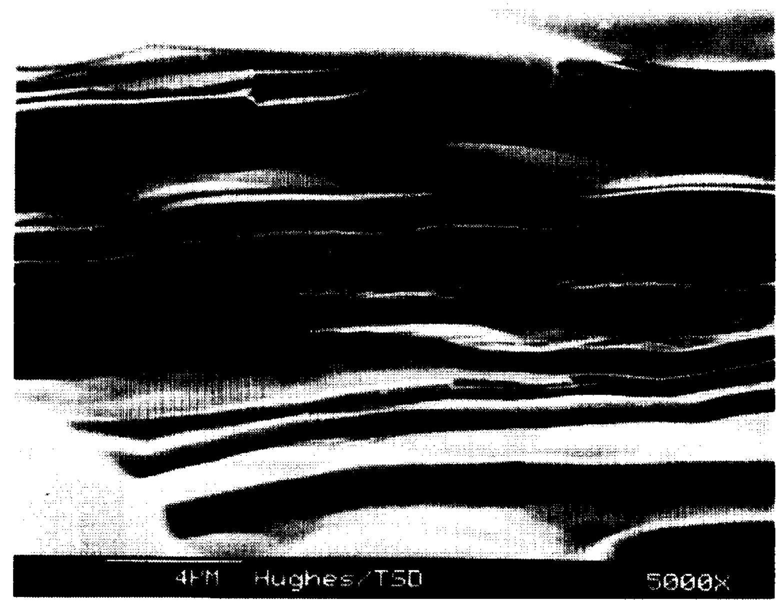
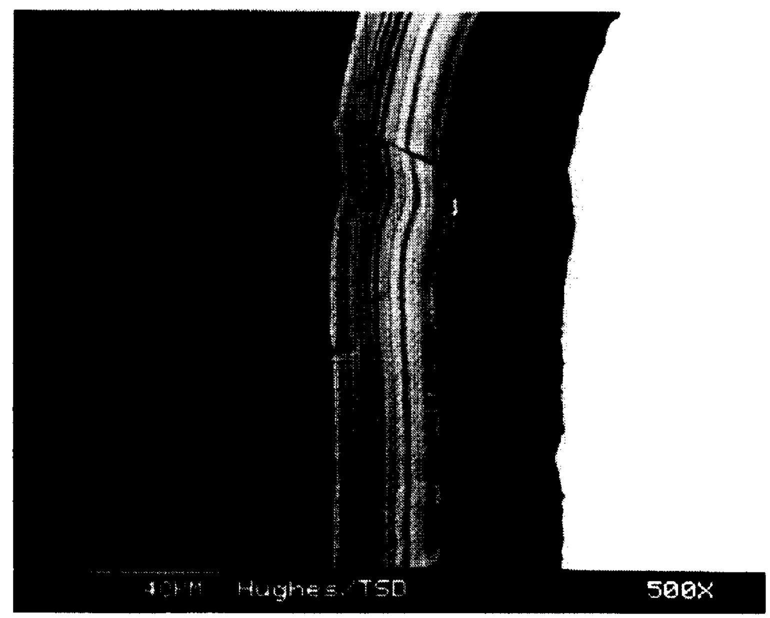

100
80
60
40
20
0
Transmittance
3390.9
2870.1
1716.6
1604.8
1508.3
1454.3
1265.3
1080.1
922
844.8
802.4
4000
3000
2000
1500
1000
hb1
Wavenumbers (cm−1)
Res= 8.0 cm−1
Orange Flake #1 / Transmittance / ak pgm
02/29/92 13:53

Figure 3

(a)



(b)



(c)

Figure 4. Molecular film deposit on D10 tray

4a. Molecular film on tray rivet.

4b. Layering of film indicating cyclic deposition.

4c. Light and dark bands through film cross section.