Contamination by Fibers on Space Shuttle Flight OSS-1 Microabrasion Foil Experiment

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IN March 1982 the Microabrasion Foil Experiment (MFE) flew on the Space Shuttle Columbia as part of the OSS-1 "Pathfinder" mission. MFE was designed to measure the microparticle flux in low-Earth orbit and consisted of a 0.4 m^2 capture cell array of which the upper surface was 5-μm thick aluminum foil.[1]

After eight days' exposure to space, MFE was returned to the laboratory for analysis. In the course of searching for micrometeoroid impacts, several rod-like particles were found to have pierced the aluminum foil. These rods are 6 μm in diameter, optically transparent, and protrude some 20 μm through the foil (see Fig. 1). There is a zone of plastically deformed aluminum 1 μm in thickness at the rod-aluminum interface; in one case a plug of aluminum was seen to have been punched from the foil by the rod. Every rod exhibited ends with brittle fractures.

Elemental analysis using energy-dispersive x-ray analysis revealed the presence of silicon, calcium, and aluminum in the rods. It was not possible to obtain analyses for light elements such as oxygen due to the type of energy-dispersive detector used.

Examination of the panels used for thermal control of the OSS-1 pallet, the "thermal close-out panels," also revealed a rod of similar composition 1 mm long and 8 μm in diameter. The elemental analyses and observed physical properties of these rod-like contaminants suggest that they are fibers of E-glass, frequently used for the construction of fiberglas reinforced materials. This conclusion is supported by the results of post-flight wipe tests[2] done on the OSS-1 pallet, which picked up fibers identified as E-glass although that sample had diameters of 3 to 5 μm.

It is very unlikely that the glass fibers found on MFE were picked up in space as part of the microparticle flux in orbit. If this were the case, the fibers would have disintegrated in a hypervelocity impact and created a hole several times their diameter.[3] As MFE was constructed and transported under clean conditions, the origin of the fibers is therefore likely to be the Shuttle or pallet integration environment.

To test the hypothesis for the mechanism of implantation, samples of glass fibers were obtained and various methods selected to recreate the foil perforation in the laboratory. The glass fibers were unsized, with a diameter of 12 μm and an average length of $\sim$100 μm. The manufacturer's designation was EMF 1629.

Simply wiping the fibers across the foil surface only pressed them longitudinally into the metal. Shaking the foil and fibers together, however, produced penetrations in the foil very similar to those encountered on MFE, typical of low-velocity impacts well below the hypervelocity regime. A third test, whereby glass fibers were fired at the foil in an airstream at approximately 50 ms^{-1} via a compressed air gun also caused the fibers to penetrate the aluminum foil. Thus, low- and medium-velocity impacts by glass fibers onto 5 μm Al foil reproduce the type of penetration seen as contamination on the MFE, whereas pressing or rubbing the fibers does not align them suitably for this to occur. Allowing the glass fibers to fall through the air onto the foil failed to produce penetrations.

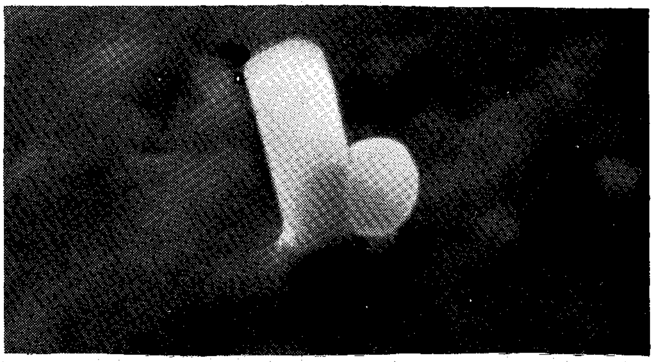

Fig. 1 Scanning electron micrograph of a 6-μm diam glass fiber contaminant protruding through the underside of the 5μm-thick aluminum foil used in the MFE on the "Pathfinder" mission of the Space Shuttle.

A search for the source of such contamination on the Shuttle revealed a type of fiberglas reinforced cloth known as "beta-cloth" which must become the prime suspect; this is extensively used in the Shuttle pallet and is very probably the origin of the fibers found in MFE. Since it has been shown that the fibers need to be thrown against the foil surface for penetration, the periods of launch and re-entry when vibration is greatest[4] would appear to be likely times for these events to occur. Venting could also lead to airborne implantation at velocities typical of those found necessary for reproduction of the effects in the laboratory.

Other workers[5] investigating the field of ballistic impact on plates with cylindrical projectiles have predicted penetration and plug formation as seen in this case. Only three glass fiber penetrations have been located on MFE thus far, but as these were located accidentally while examining microparticle hypervelocity impacts,[6] there may, in fact, be many more. If these events were caused by debris in the payload bay being accelerated during launch or re-entry, then there may be a problem for delicate exposed surfaces flown in the future aboard the Space Shuttle.

Acknowledgments

The authors would like to thank Mr. D.R. Beardsworth of Turner Glass Fibres Ltd. for providing glass fiber samples and helpful discussion. We thank Mr. Ken Kissin (project manager), Dr. W. Neupert (project scientist), and Dr. J. Weinberg (principal investigator) for their assistance in securing the experiment opportunity.

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Received Nov. 10, 1983.

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