THE UTILITY OF SILICA AEROGEL AS A COSMIC DUST CAPTURE MEDIUM ON THE SPACE STATION

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INTRODUCTION To fulfill the dream of collecting interplanetary dust particles (Cosmic dust, IDPs), and perhaps interstellar dust particles, with their velocity and trajectory information intact, it is necessary to operate above the atmosphere (as much as is possible). This goal will be achievable using the Space Station Freedom as a permanent base. An integral part of the Space Station Cosmic Dust Collection Facility will be the particle deceleration/ collection media. These materials must decelerate incoming particles with the minimum loss of the chemical, isotopic, and (although not generally) structural character. One of the brightest candidates for a collection medium is silica aerogel. We have initiated a study of the behavior of this material during simulated particle impacts and the ease of particle extraction. The results of our studies are thus comparable to those of a parallel research effort led by P. Tsou of JPL [1]. In addition, we report on efforts to evaluate the behavior of silica aerogel in low earth orbit, specifically the possibility of its erosion by oxygen.

SILICA AEROGEL The attraction of this material is attributable to its general transparency (so that captured materials can be readily observed within it), the low bulk densities in which it may be fabricated, and its compositional simplicity (~97 to 99 wt% SiO_2). However, these desirable properties have demonstrated limits. Using current technologies, silica aerogels with bulk densities less than about 0.005 g/cc are opaque [2]. As a future goal, it is desirable to determine whether procedures can be developed for the production of ultra-low (<0.005 g/cc) density transparent silica aerogels. Currently, silica aerogels with densities down to ~0.1 g/cc are commercially available [3], but materials with far lower densities are available from specialty laboratories. Another limit imposed by the current state of aerogel production technology is the level of organic contaminants (typically methanol or formic acid), which approaches 3 wt% [2].

ATOMIC OXYGEN EROSION The environment of low-Earth orbit itself presents several potential hazards to the Cosmic Dust Collection Facility, including the possibility of capture media degredation by oxygen erosion. To investigate this possibility we subjected two different samples of silica aerogel to an oxygen flow in a Low Temperature Asher (LFE Corp.) (operated at 2 torr and 100 watts). This instrument has been found to well-reproduce the effects of oxygen erosion in low-Earth orbit. We subjected each sample to the equivalent of at least several years of orbital exposure. A commercial aerogel with a density of 0.1 g/cc and an organic content of <1 wt% [4] was unaffected by the plasma exposure. However, a less dense (0.058 g/cc) and more organic-rich (~3 wt%) [2] silica aerogel reacted to the extent that a thin (<1 mm) surficial densified (melted?) layer formed. We are currently examining this extremely undesirable result. Although the 0.1 g/cc density silica aerogel is resistant to oxygen erosion in low earth orbit, cosmic dust grains trapped within it may be selectively etched away.

COSMIC DUST SIMULANTS To properly evaluate the performance of cosmic dust particle capture media we have had to manufacture artificial cosmic dust. Similar materials have been prepared by D. Brownlee [1, 5]. We obtained a suite of well-characterized, well-crystalline minerals characteristic of cosmic dust in the wild; these minerals include olivine, spinel, pyroxene, graphite, pyrrhotite, calcite, smectites and serpentine. For the purposes of determining the degree of chemical and structural change in these materials during collection simulation experiments, we use only unshocked starting materials. Thus, for one example, we used only forsterite crystals from Zabarget Island, because most other (lower crustal- or mantle-derived) natural olivine is highly stressed and deformed. We developed a procedure for fabricating aggregate projectiles from these minerals which can be launched from a light-gas gun. We bond mineral powders together with epoxy, and the result simulates cosmic dust in mineralogy and grain size. We then carefully grind these appregates are into 1 mm diameter spheres.

PARTICLE CAPTURE SIMULATIONS We launched individual cosmic dust simulant spheres into targets of the 0.1 g/cc silica aerogel, using a horizontal, two-stage light gas gun at JSC. In four shots the measured projectile velocities ranged from 6.2 to 7.2 km/sec (6.8 km/sec ave.). In each case the projectiles penetrated approximately 2.5 cm into the aerogel, ejecting substantial volumes of aerogel during the formation of a conical crater. We do not observe the long "carrot" shaped impact craters produced by collection into organic foams [6], and we observe more destruction of the aerogel than is seen during capture experiments using a powder rather than a single solid projectile [1]. As observed before [1], individual grains (<200 um) from the projectiles are observed within the aerogel, from which they may be excavated for examination. We embedded small aerogel chips containing projectile grains using a low viscosity epoxy (EMBED 812), and prepared ultramicrotomed slices [7] for TEM characterization. All projectile grains examined are at least partially coated with a layer of white, opaque, amorphous, probably melted, aerogel. Many recovered projectile mineral grains are similarly amorphous, with rounded morphologies. However, a significant fraction of the projectile mineral grains are still crystalline, or contain crystalline domains. These latter minerals include the olivine, pyrrhotite and calcite. The survival of calcite indicates that relatively delicate minerals survive collection relatively intact. Our work characterizing these projectile residues continues.

CONCLUSIONS Silica aerogel is a promising candidate for cosmic dust collection media in low-Earth orbit. Although the lowest possible densities for this material are nominally to be desired, it appears that available materials below ~0.05 g/cc may be unacceptable due to optical and stability problems. However, further developments in aerogel production technology may eliminate these problems. A portion of the inorganic mineral grains from cosmic dust particles traveling at velocities of at least 7 km/sec (relative to the Space Station) can be collected intact using 0.1 g/cc density silica aerogel, although large impactors can be expected to eject possibly significant amounts of pulverized aerogel from the facility. Although the 0.1 g/cc density silica aerogel is resistant to oxygen erosion in low-Earth orbit, cosmic dust grains trapped within it may be selectively etched away. This possible problem may, however, be ameliorated by the presence of a "melted" coating of aerogel on the projectile residue.

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