Non-Silicate Aerogel as a Hypervelocity Particle Capture Material S. M. Jones[1] and G. J. Flynn[2]
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The Stardust Mission used silica aerogel as the hypervelocity particle capture and return material since silica aerogel was the most reproducible to manufacture and the most thoroughly evaluated type of aerogel at the time [1]. However, the Stardust Science Team recognized that the use of silica aerogel, while expedient, introduced limits to mission's eventual science return. This is due to the fact that planetary geochemists generally measure and report element/silicon ratios in the analyses of terrestrial and extraterrestrial samples. During the particle capture process, material from the Stardust aerogel, i.e., silica, will accrete onto the particles, thus obscuring portions of the chemical analyses that can be performed on the samples. By using non-silicate aerogels to complement the silica aerogel being employed in a sample capture instrument, the full spectrum of chemical analyses available can be performed without interference by any specific element from the aerogel.

Aerogel is used as a hypervelocity capture and return medium because it can decelerate hypervelocity particles while incurring minimal damage to the particle [2]. This is due in large part to the fact that the network that makes up the aerogel is composed of filaments that are nanometer in size, while the particles are micron sized, and are comparatively widely spaced. Thus, aerogels can be extremely low in density, < 0.100 grams/cc, and are frequently more than 99% air by volume.

Methods for producing non-silicate aerogels have been reported in the scientific literature for many years, with carbon aerogel being the most extensively produced and thoroughly tested [3-6]. Although the production of non-silicate oxide based aerogels has been reported, there has been little in the way of results that verify the production of reasonably large monoliths of non-silicate aerogel and the structural robustness of these materials. To be used as the capture medium in a sample capture and return instrument, non-silicate aerogel must be produced as reasonably large monoliths (25 to 250 cc's), they must be mechanically robust to survive launch loads, and they must have a network that is suitable for efficient hypervelocity particle capture.

Based on methods outlined in previously published articles monoliths of carbon, alumina, titania, germania, zirconia, niobia, tin oxide, and hafnia have been produced for this study. Table 1 lists the types of non-silicate aerogel produced for this study, the atomic number of the metal (or carbon) in each, and the lowest density of each type produced thus far. The atomic number is listed since the chemical analysis conducted on these aerogels after impact testing will be x-ray fluorescence, and for the higher atomic number elements the various x-ray wavelengths begin to interfere. The density of the cometary Stardust aerogel gradates from 10 mg/cc to 50 mg/cc in each piece, which was determined to be the optimal density range for efficient hypervelocity particle capture. Thus, sample densities in approximately this range are desirable.

Table 1- Non-Silicate Aerogel

Type of Aerogel	Atomic Number	Density (mg/cc)
Carbon	6	60
Alumina	13	35
Titania	22	30
Germania	32	40
Zirconia	40	25
Niobia	41	80
Tin Oxide	50	125
Hafnia	72	65

Various methodologies for producing non-silicate aerogels were tested and it was determined that using metal alkoxides in a short-chain alcohol as the solvent was the best method. By using this type of chemistry the capability of making gradient density non-silicate aerogels, similar to that used on the Stardust Mission, is retained. Each of the samples produced were approximately 4 by 2 by 3 cm in size. They were heated to 450 degrees to strengthen the network, and only the zirconia samples displayed in significant shrinkage.

Each of the different types of non-silicate aerogel produced, as well as silicate samples as the reference material, was observed with a scanning electron microscope to examine the micro-structure of the aerogel network. The micro-structure of each of the non-silicate aerogel networks was observed to be composed of nanometer sized filaments, while the pores are typically tens to hundreds of nanometers in size, similar to that of the silica aerogel. This implies that these non-silicate samples could act as efficient capture and return materials for hypervelocity particles.

Samples of carbon, alumina, germania, zirconia and titania aerogel were hypervelocity impact tested using a mixture of 20, 50, and 100 micron glass microspheres at impact velocities of approximately 2 and 5 km/sec. Portions of the aerogel were removed to extract embedded particles from the aerogel interior. A 100 micron glass sphere was extracted from a zirconia aerogel after a 2 km/sec impact test. It was observed that the particle was still quite spherical, indicating that little or no ablation occurred during the capture process. A 50 micron glass microsphere was also extracted from an alumina aerogel after a 5 km/sec impact test, which, due to the higher velocity, did exhibit minimal ablation.

Recently, impact testing was conducted employing meteoritic particles (Northwest Africa, Murchison and Tagish Lake) with carbon, alumina, germania, zirconia and titania aerogels as the capture materials. Particles from the Northwest Africa and Murchison meteorites were generated by impacting them with millimeter sized aluminum spheres. The secondary particles produced from the initial impact with the meteorites were captured in the aerogels. Particles from the Tagish Lake meteorite were shot directly into samples of the non-silicate aerogels. Studies are currently being conducted on these samples.

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