Aerogel

Aerogel is an effective capture medium for hypervelocity particles. An ultra-low-density solid, the molecular structure and transparency of aerogel allow it to capture particles impacting at hypervelocity and in contact with the aerogel to capture the particles [1, 2]. Aerogel has been used successfully in past particle capture missions, including the NASA Stardust mission which returned material from comet Wild2 in 2006 [3]. It will potentially be used again in future sample return missions. Particles captured in aerogel through hypervelocity impacts create three-dimensional (3D) tracks representing unique impact events. The nature of each track-forming event, including the original state of the impactor, is recorded in 3D track morphology and material distribution. Locating single grain particle fragments and identifying true track and particle size and shape are necessary to understanding original impactor properties.

Confocal Microscopy and 3D Images

Confocal microscopy is an imaging technique which is capable of imaging sequential optical sections. A pinhole placed in a conjugate focal plane allows only focused light to hit the microscope’s detector and blocks stray light from all other focal planes. The diameter of the pinhole determines how thick each optical section will be. By using a small pinhole diameter and varying the focal plane, samples can be imaged layer by layer. Because each optical section is imaged separately, the three-dimensional distribution of particles is preserved in the resulting image stack without disrupting or destroying the sample.

Comparing PSFs

To quantitatively compare the functionality of both the measured and theoretical PSFs, we imaged an aerogel keystone containing 500nm beads. Deconvolutions using both measured and theoretical PSFs were then performed on this image set. Deconvolution is expected to increase an image’s contrast and to bring out small spatial features by removing larger, out of focus features. This can be seen in Figure 2, which shows the 3D center of the initial raw data (a) alongside the results of both deconvolution tests (b and c). Comparing the raw data (a) with the results of a deconvolution using a theoretically determined PSF (c), one can observe how the deconvolution enhances some features from the original image; however, these features are not necessarily real. The extra structure could be due to a deviation from ideality in our optical setup, the aerogel that the beads are embedded in causing a mismatch of refractive indices, or a combination of the two. A reconstructed 500nm bead is represented best by the results of the deconvolution performed using a measured PSF (b).

Why Deconvolve?

Due to the configuration of the optical path in any LSCM, axial distortion occurs along the z-axis of three-dimensional images (Figure 3, b and c)[11]. Removing this aberration is a necessary step in order to accurately quantify track dimensions and particle locations [7]. For 3D deconvolution of raw image data, we use SVI’s Huygens Professional V4.1 software. The Huygens’s Software [8] is designed to restore convoluted images using an instrumental point spread function (PSF). The PSF can be obtained from either a theoretical calculation, or by experimental means through a series of measurements. A theoretical PSF provides a good approximation, however only takes into account the best alignment and imaging conditions on a given microscope and does not account for any deviations from an ideal setup. An experimental PSF uses images obtained under the same conditions as the sample in question accurately accounts for more variables of the experimental setup than the theoretical PSF. Using aerogel keystones with 100nm fluorescent latex beads embedded in the aerogel during its manufacture, we have created an experimental PSF from images obtained under the same conditions as images of Stardust cometary tracks.

References


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