X-ray Microtomography Study of Reticulated Vitreous Carbon Foams

E. A. Behne,[1] L. J. Atkins,[1] G. T. Seidler[1,2,*]

[1] *Physics Department, University of Washington, Seattle WA, U.S.A.*

[2] *PNC-CAT Sector 20, Advanced Photon Source, Argonne IL, U.S.A.*

* *Author to whom correspondence should be addressed, seidler@phys.washington.edu*

Introduction

Natural and man-made foams play important roles in a range of applications spanning medicine, building construction, food preparation, and aerospace vehicles.[1] Despite the considerable economic importance of foams, few studies have been performed to characterize the topological details of the microstructure of 3-dimensional (3-D) foams.[2] Here, we report that synchrotron x-ray microtomography (XMT) is a useful tool for rapidly characterizing the 3-D connectivity of commercial carbon foams.

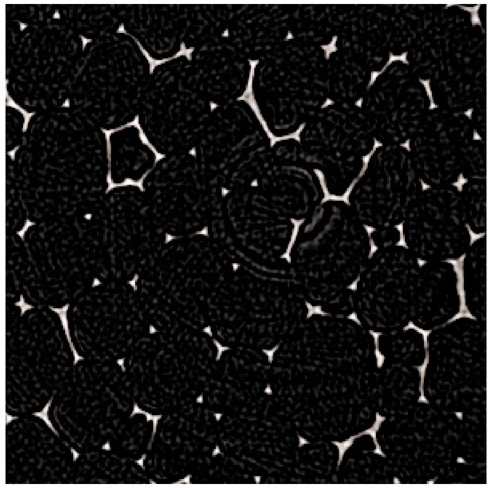

FIG. 1. A 3.6 x 3.6 mm^2 subsection of a tomogram of the 100 ppi RVC foam.

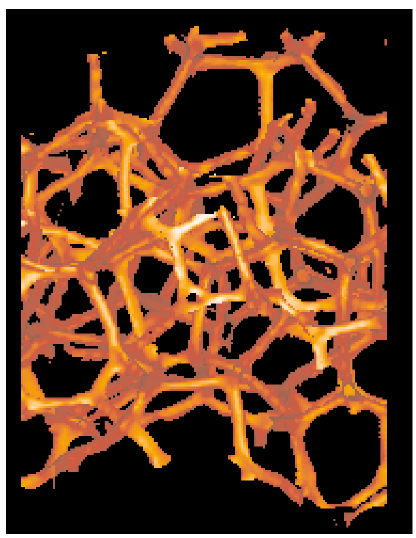

FIG. 2. A 3-D rendering of a 2 mm^3 subvolume of the 100 ppi RVC foam.

Methods and Materials

This experiment was performed at sector 20-BM of the Pacific Northwest Consortium Collaborative Access Team (PNC-CAT) beamlines at the Advanced Photon Source. This beamline is optimized for x-ray absorption spectroscopies with a double Si <111> monochromator with an energy bandwidth of less than 2 eV for the photon energies used here. The narrow bandwidth of this monochromator is not necessary for tomography, but we have found that the incident flux is still sufficient for rapid XMT of many samples. The vertical beam position is stabilized by active feedback to the second monochromator crystal based on the output of a split ion chamber, and the monochromator is detuned ~20% to effectively eliminate the contribution to the flux from Bragg harmonics. All data were collected during top-off mode operation of the synchrotron.

The area detector of our tomography apparatus follows the general considerations of Koch et al.[3] and uses a thermoelectrically cooled 12-bit camera (Roper Scientific). The scintillator is a 0.5-mm-thick YAG:Ce plate, and a NIKKOR 24 mm (1:2.8) camera lens was used to focus the radiogram onto the CCD so that the effective pixel edge length is approximately 13 µm.

The tomography sample stage consists of two small linear translators for centering mounted on an air-bearing rotary stage (Precision Instruments) actuated by a stepper motor driven worm gear. The motorized rotary stage is itself mounted on a tilt stage with a tilt axis approximately parallel to the x-ray beam direction. A second tilt axis in the horizontal plane but normal to the beam is provided by the independent vertical adjustment of the legs of the experiment table in 20-BM-B. These two tilts are adjusted to ensure that the rotation axis was simultaneously perpendicular to the beam direction and to the effective CCD line scan direction with a precision of 0.5 mrad. The GRIDREC FFT-based algorithm[4] was used to reconstruct the tomograms from the rotational sequence of radiograms.

The samples studied were reticulated vitreous carbon (RVC) foams from the Destech Corporation. Carbon foams are useful as filters, insulation, and lightweight building materials. We have performed XMT studies of samples having 100 and 500 pores per inch (ppi), i.e., mean pore sizes of 250 µm and 50 µm. The samples were manually cut into cylinders with diameters of ~7 mm, and the sinograms are formed from a rotational sequence of approximately 900 radiograms for each sample.

For the 100 ppi sample, the incident photon energy was 8 keV, the camera exposure time was 5.5 sec, and the total experimental time was 1 hr 35 min. For the 500 ppi sample, the incident photon energy was 12 keV, the camera exposure time was 1.2 sec, and the total experimental time was 35 min. The integration times were chosen so as to provide approximately 3500 counts (85% saturation) in a typical pixel in the white field. All radiograms were white-field and dark-field corrected.

Results

In Fig. 1, we show a section of a tomogram of the 100 ppi RVC foam. In Fig. 2, we show a 3-dimensional rendering of a subvolume of the same sample. Tomograms of the 500 ppi foam has similar signal to noise, and clearly demonstrated that the foam was only partially reticulated, with many intact cell walls. More complete surveys of the structure of these foams will be presented elsewhere.[5]

Discussion

The high quality and rapid acquisition of foam tomograms suggests that synchrotron XMT will be a useful tool for investigating the structural properties of a wide variety of foams. The cell sizes of many foams, both natural and artificial, are easily resolved by XMT. This will enable future *in situ* studies of cell compression or cell fracture under stress. Additionally, 3-D image processing may be used to determine the pore size distribution, cell genus, spar genus, and spar geometry, thus characterizing the bulk topological properties of the material.

Acknowledgments

This research was supported by the Research Corporation. The operation of the PNC-CAT beamlines is supported by the U.S. Department of Energy, Basic Energy Sciences, and by the NSERC in Canada. The operation of the Advanced Photon Source was supported by the U.S. Department of Energy, Basic Energy Sciences, Office of Science, under contract No. W-31-109-ENG-38.

References

[1] L.J. Gibson and M.F. Ashby, *Cellular Solids: Structure and Properties*, 2nd edition (Cambridge University Press, 1997).

[2] see, for example, C.P. Gonatas et al., Phys. Rev. Lett. **75**, 573 (1995).

[3] A. Koch, C. Raven, P. Spanne, and A. Snigirev, J. Opt. Soc. Amer. A **15**, 1940-1951 (1998).

[4] B.A. Dowd et al., Proc. SPIE **3772**, 224 (1999).

[5] E.A. Behne, L.J. Atkins, and G.T. Seidler, in preparation.