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# Quantitative Density Analysis of Ultra-Low Density Polymer Foams Using Various X-ray Imaging Techniques

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Laboratory-based nano-scale X-ray computed tomography is a valuable tool for the visualization and quantification of microstructures within various materials. With approximately 150 nm 2D resolution, internal structures of a system can be probed *non-destructively,* which is not available with other imaging systems. Of significant interest is the microstructure of high internal phase emulsion (HIPE) chlorinated polystyrene foams for use in inertial confinement fusion targets.[1,2] In addition to local microstructure, another important property of polystyrene foams is the density of the foam; this property is traditionally measured using gravimetric methods. However, this is a bulk method which can be plagued with large uncertainties if the sample is of ultra-low density. Furthermore, this method yields no information of larger scale density gradients within the foam. A solution to this analytical problem is monochromatic X-ray radiographic imaging.[3] With this characterization technique, a quantitative density measurement is possible based on the X-ray transmission of the sample. In addition, density gradients within the polystyrene foams can be observed. Herein, we report the microstructural characterization of a series of HIPE polystyrene foams using laboratory-based nano-scale X-ray computed tomography. As can be seen in the nano-scale CT reconstructed slice, presented in Figure 1, these low-density foams contain an internal void microstructure. The densities of these foams were also measured from radiographs (Fig. 2) obtained non-destructively using a monochromatic X-ray imaging system utilizing a chromium source operating at 5.4 keV. The densities of these foams range from ~70 to 160 mg $cm^{-3}$, as determined by X-ray imaging. The majority of the X-ray based density measurements agree well with measured gravimetric densities; however, a subset of the polystyrene foams exhibit relatively large diameters (~400 μm), resulting in low X-ray transmission (~0.9%) and large relative percent differences between the image-based measurements and gravimetric measurements (Fig. 3). This result highlights the need for a monochromatic X-ray imaging system which operates at higher energy which would allow for a relatively larger transmission through thick foam samples.

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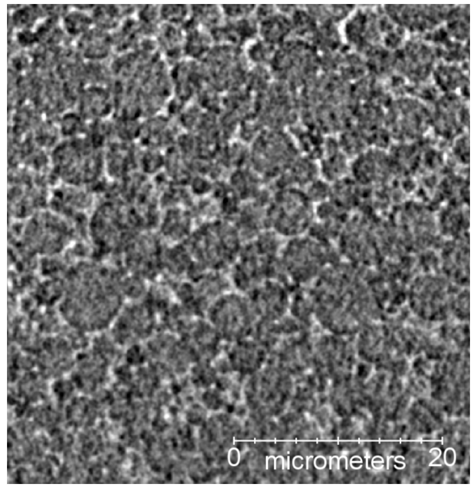


**Figure 1.** A reconstructed slice of polystyrene foam imaged using nano-CT in phase contrast mode. Bright areas correspond to foam ligaments, dark areas correspond to voids within the foam structure. Isotropic voxel size is 65 nm.

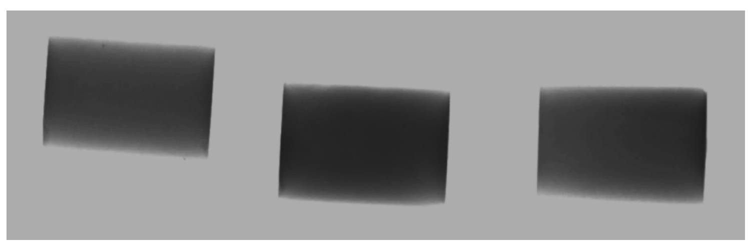

**Figure 2.** Radiographs of three polystyrene foams imaged using the monochromatic X-ray imaging system.

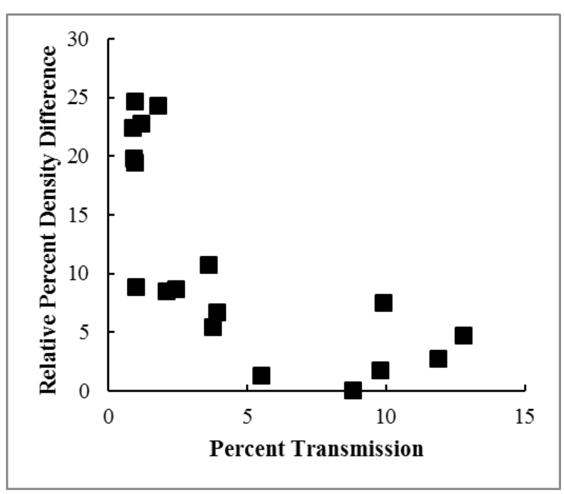


**Figure 3.** The relative percent density difference of the gravimetric density and the density determined from X-ray imaging as a function of percent X-ray transmission, highlighting the need for higher energy X-ray source to adequately determine the density of thick polystyrene foams.

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