The Use of Multiple X-ray Imaging Techniques to Better Understand Density and Structure Variations within Aerogels and Polystyrene Foams

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Of significant interest is the microstructure of high internal phase emulsion (HIPE) chlorinated polystyrene foams for use in inertial confinement fusion targets. 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. Two laboratory techniques are currently being tested for their suitability for obtaining these characteristics; nano-scale X-ray computed tomography and a purpose built, mono-chromatic meso scale radiography instrument. 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. The second technique, monochromatic radiography, provides the opportunity to couple the known X-ray opacity for the foams with their transmission characteristics to measure their 2D density and density gradients.

In this presentation, we will provide an overview of the microstructural characterization of the internal void microstructure of a series of HIPE polystyrene foams using laboratory-based nano-scale X-ray computed tomography. The densities of these foams were also measured from radiographs 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. 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 thicker foam samples.