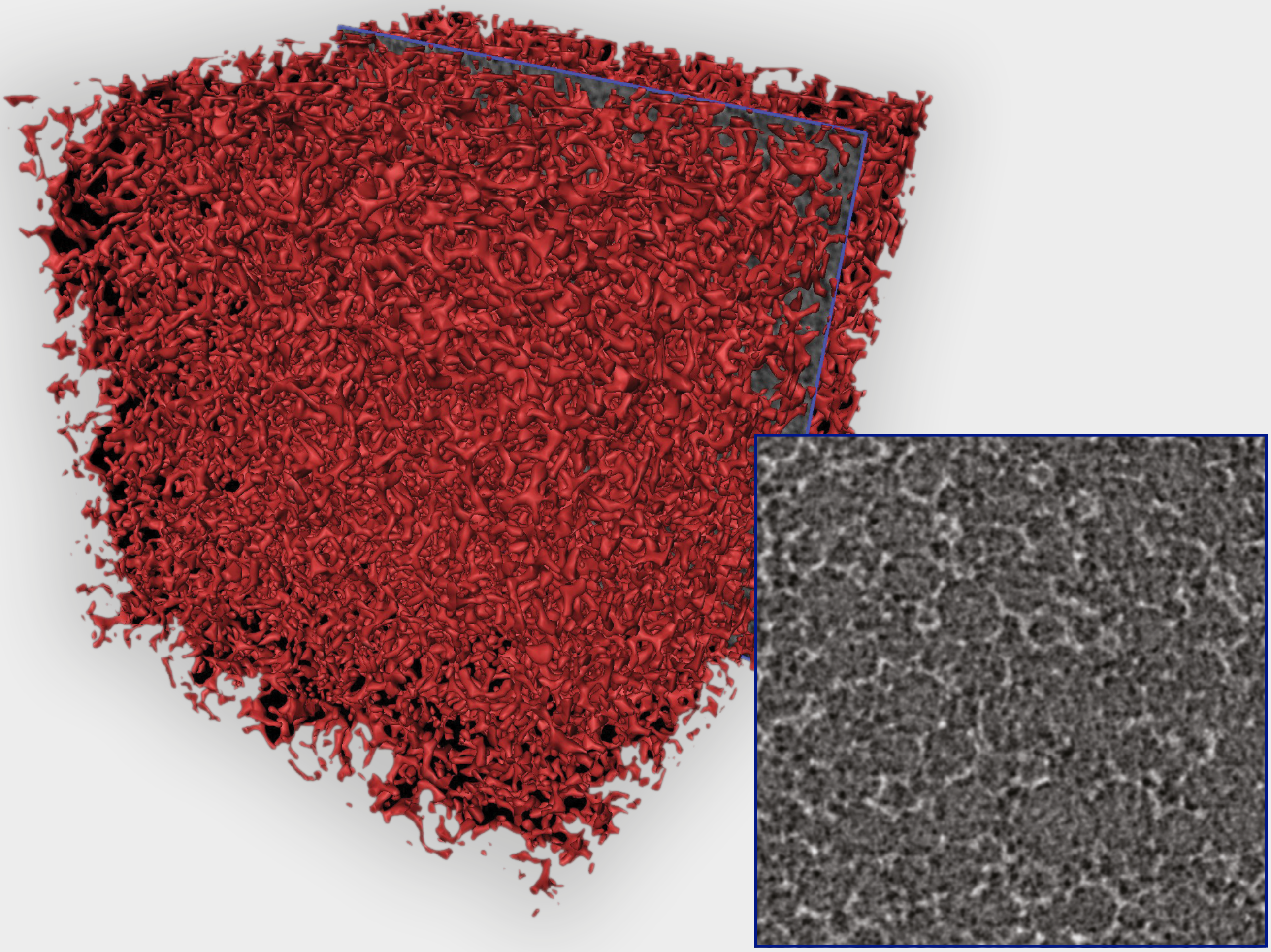
Application Note



High-resolution Characterization of Solid Foams

ZEISS 3D X-ray Microscopes

High-resolution Characterization of Solid Foams

ZEISS 3D X-ray Microscopes

Author: Carl Zeiss X-ray Microscopy, Inc.

Date: January 2019

Characterization of the 3D morphology of solid foams is extremely important but has been limited due to the shortcomings of conventional techniques. Some examples of these limitations are physical artifacts from destructive, high-resolution cross-sectioning methods or the low-resolution of non-destructive conventional micro-computed tomography. The ZEISS Xradia Versa and ZEISS Xradia Ultra seies of 3D X-ray microscopes provide a unique solution for non-destructive submicron resolution and the highest contrast in foam imaging that can be achieved.

Introduction

Solid foams are used in a vast variety of applications, such as shock and impact absorbers in vehicles, thermal and acoustic insulators, packaging material, load bearing components, and biomedical implants. These structures contain gaseous voids surrounded by a denser solid matrix (e.g. polymers, metals, or alloys) and provide unique benefits, such as high strength-to-weight ratios and the ability to remain intact under high levels of deformation.

The three-dimensional properties of the foam are the deciding factor of their application and performance, which in turn are intricately dependent on the foam's morphology, material properties, and composition. Due to their complex, irregular structures, proper characterization of these materials in 3D can be difficult, especially at sub-micron resolution.

High resolution techniques such as physical sectioning coupled with optical or electron microscopy are not only destructive and time-intensive, but can also introduce physical artifacts. Furthermore, because they are destructive, time-dependent microstructural evolution studies are impossible.

X-ray Techniques

The use of conventional X-ray micro-computed tomography (micro-CT) has grown during the past decade for non-invasive and non-destructive characterization of foams. These systems have enabled medium resolution, on the scale of microns, of pore structure and quantitative characterization of morphology, which provide a better understanding of physical and mechanical properties. However, some low-Z materials, such as polymer foams, have been difficult for micro-CTs to image with good contrast. Also, micro-CTs have generally been unable to resolve submicron foam pores.

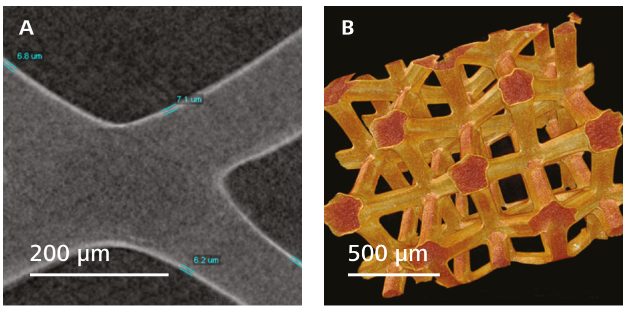


Figure 1 Ni – plated foam imaged using ZEISS Xradia Versa with 1.6 µm voxel size (A) The 2D virtual slice shows the thin Ni plating of about 7µm thickness. (B) The 3D rendering of the two phases of the foam.

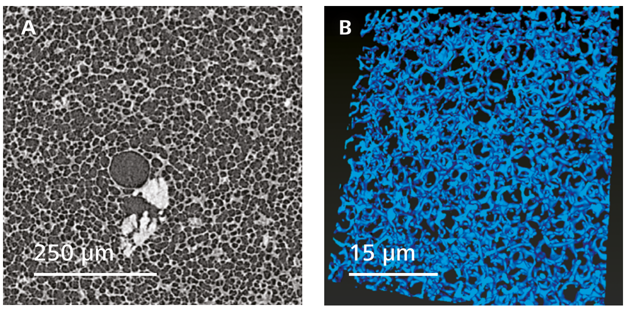


Figure 2 Solid Foams – (A) Microcellular foam imaged using ZEISS Xradia Versa and 1 µm voxel size resolutions. (B) Polystyrene foam imaged using ZEISS Xradia 800 Ultra using 65nm isotropic voxels. Images courtesy Los Alamos National Laboratory

With X-ray microscopes from ZEISS, foam structures can be imaged to submicron spatial resolutions: down to 500 nm on ZEISS Xradia Versa and 50 nanometers on ZEISS Xradia Ultra (Figures 1 and 2). Due to unique ZEISS Xradia X-ray optics architecture, such high resolution is maintained over large working distances and, unlike conventional micro-CTs, do not degrade as a linear function of sample size. This enables new capabilities such as high-resolution imaging for *in situ* studies, i.e. for compression of foam in an *in situ* rig. Larger sample sizes are required to accommodate the *in situ* rig, which makes it impossible to get high-resolution images with conventional micro-CTs. Moreover, the ZEISS Xradia-optimized scintillator detectors on the microscopes provide key advantages for high contrast imaging of low-Z foams.

4D *In situ* Compression of Foam Study

Cellular materials are used in several load bearing and structural applications where they routinely experience varying levels of stress or loading. For these types of foams, mechanical testing is an integral part of full characterization. The non-destructive nature of 3D X-ray microscopes adds unique characterization capability in that it makes possible 4D (time-dependent) studies in various environments using *in situ* chambers and devices. It not only offers a unique method to observe the foam's microstructural evolution, but also provides a method to verify computational modeling.

In this example, an *in situ* chamber is used to study collapse mechanisms of foams under compressive loads and to reveal how compression permanently affects the structure when restored to an uncompressed state. The foam was loaded to 50% compression and then allowed to decompress.

Each image in Figure 3 shows the results of the experiment. Captured by ZEISS Xradia Versa, each image is a full 3D representation of the material at different compressive states. The colored "balls" are the individual segmented cells in the foam.

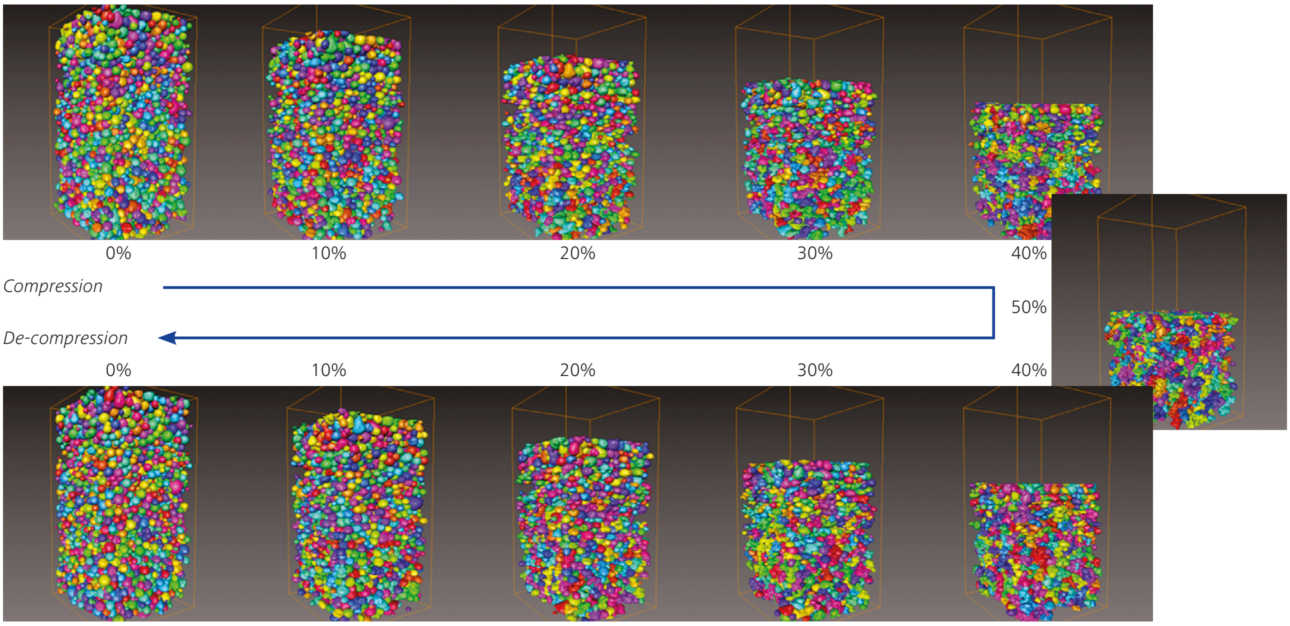


Figure 3 *ZEISS Xradia Versa Family captured 3D images of an* in situ *loading-unloading experiment. The results showed that the compression curve was not retraced during the decompression, showing that the foam cells did not exhibit 100% elastic properties.*
Images courtesy Los Alamos National Laboratory.

Carl Zeiss Microscopy GmbH
07745 Jena, Germany
microscopy@zeiss.com
www.zeiss.com/microscopy