Lab-based nanoCT as a tool for the 3D structural and mechanical characterization of additive manufactured metamaterials

R. Debastiani[1,2,3*], C. M. Kurpiers[2,4], R. Schwaiger[2,5], P. Gumbsch[1,2,6,7]

[1] Institute of Nanotechnology, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany

[2] 3DMM2O-Cluster of Excellence (EXC-2082/1-390761711), Karlsruhe Institute of Technology, 76128, Karlsruhe, Germany

[3] Karlsruhe Nano Micro Facility (KNMFi), 76344, Eggenstein-Leopoldshafen, Germany

[4] Institute of Applied Materials - Mechanics of Materials and Interfaces, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany

[5] Institute of Energy and Climate Research, Forschungszentrum Jülich, 52425, Jülich, Germany

[6] Institute of Applied Materials - Reliability and Microstructure, Karlsruhe Institute of Technology, 76128, Karlsruhe, Germany

[7] Fraunhofer Institute for Mechanics of Materials IWM, 79108, Freiburg, Germany

The lab-based X-ray microscope Xradia Ultra 810 with mechanical in situ testing, here referred to as nanoCT, is a versatile new tool for structural characterization of complex 3D samples down to 50 nm resolution with and without loading. It allows for the observation of microstructural changes as a function of time and mechanical load. With its low energy X-ray source (Cr source, 5.4 keV), absorption and Zernike phase contrast, the setup is ideal for the characterization of polymeric additive manufactured metamaterials.

Polymeric tetrahedral microlattices manufactured using 3D direct laser writing method and different laser parameters were characterized using the in situ nanoCT with and without loading. Differences in the structures were obtained scanning the samples in absorption and phase contrast modes, using a field of view of 65 µm and a voxel size of $(128\ nm)^3$. While the absorption contrast scan provides suitable images for the segmentation and the digital volume correlation, the phase contrast enhances the pores and defects within the microstructures. The same 2D slice acquired with absorption and phase contrast is shown in Figure 1, demonstrating better identification of the pores in the phase contrast image.

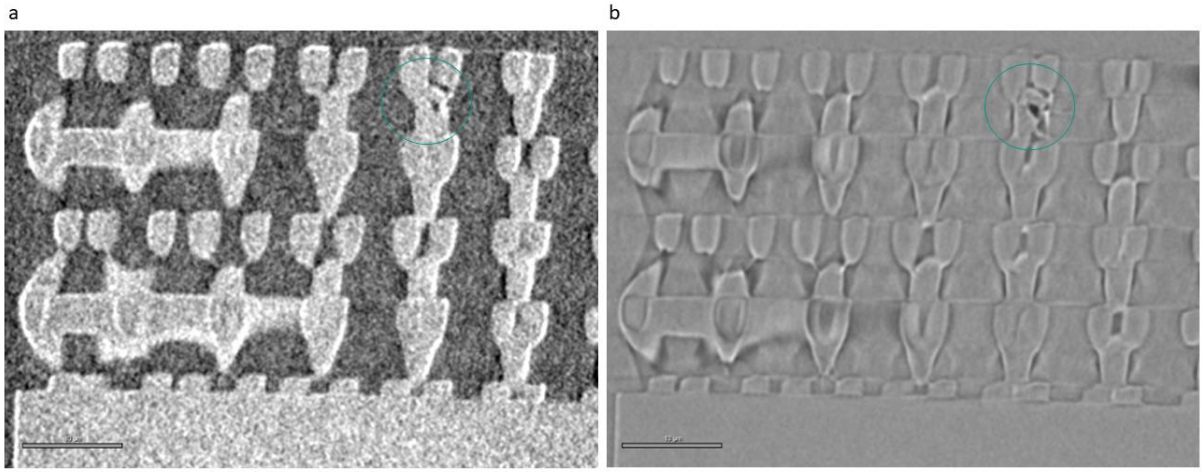

Figure 1: 2D slice of tetrahedral metamaterial in a) absorption and b) phase contrast modes, highlighting the pores within the microlattices. The pores are better resolved in phase contrast, while the absorption contrast is suitable for the sample segmentation and digital volume correlation. Scale bars: 10 µm.