Laboratory X-ray Computed Tomography for High-Resolution 3D Imaging of Materials and Structures

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X-ray imaging and X-ray computed tomography (XCT) provide non-destructive characterization capabilities on opaque objects across a range of length scales, observing features with sizes down to several 10 nanometers. Laboratory-based micro XCT in projection geometry with a resolution of about 1 μm and nano XCT with focusing X-ray lenses with a resolution down to about 50 nm are used for two- or three-dimensional inspection of medium and small sized objects, as well as object interiors and materials' microstructure components. Because of their ability to reveal structural characteristics, materials' microstructure and flaws, such as cracks and pores, or local composition and density differences, they are potential techniques for imaging of micro- und nano-structured objects (e.g. microelectronics products), advanced multi-component materials (e.g. composites and porous or skeleton materials) as well as biological objects (e.g. diatoms and shells) [1]. In this talk, the huge potential but also today's limits of laboratory X-ray microscopy and nano XCT for nondestructive 3D imaging of materials and biological objects will be described. Applications for nondestructive evaluation of geometrical features, materials' microstructure and flaws will be shown. Examples will be selected from several branches: energy storage and conversion, lightweight construction, microelectronics.

In this talk, perspectives of X-ray microscopy and nano XCT for nondestructive 3D imaging of materials and biological objects will be provided, including discussion of challenges of sample preparation. It will be shown that these laboratory X-ray imaging techniques have a huge perspective for materials science and engineering. Potential and limits for nondestructive evaluation of geometrical features, materials' microstructure and flaws will be discussed. Future developments in high-resolution X-ray microscopy and nano XCT will enable to investigate thicker samples using higher photon energies (> 10 keV), to reduce the measurement time and consequently the time-to-data, and to improve the spatial resolution. Novel laboratory X-ray sources, e. g. using micro-patterned anodes, and recently developed focusing optics, e. g. multilayer Laue lenses, will enable spatial resolutions down to 10 nm for X-ray microscopy. These developments will open the floodgates on fundamentally new knowledge in the physics and chemistry of materials, as well as for the application in industry, e.g. for materials and process development, process monitoring and quality assurance of high-tech products with internal components that have geometrical dimensions or microstructure features in the micro- and nanometer range.

[1] E. Zschech et al., „Laboratory Computed X-ray Tomography – A Nondestructive Technique for 3D Microstructure Analysis of Materials“, Pract. Metallogr. 55, 539–555 (2018)