Full-Field X-Ray Imaging with Synchrotron Radiation for Materials Research and Life Sciences - Developments and Applications at KIT

Oral Presentation
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T. Baumbach et al.

Karlsruhe Institute of Technology, Institute for Photon Science and Synchrotron Radiation, Hermann-von-Helmholtzplatz 1, 76344 Eggenstein-Leopoldshafen and Laboratory for Applications of Synchrotron Radiation, Karlsruhe, Engesserstr. 15, 76131 Karlsruhe, Germany

*e-mail: tilo.baumbach@kit.edu

Digital 2D, 3D up to spatiotemporally resolved 4D x-ray imaging became a very dynamic methodical field at synchrotron facilities, thanks to high brilliance and spatial coherence in combination with progress in digital detector and computation technologies, and x-ray optics. The talk gives an overview about our full-field x-ray imaging portfolio for materials research and life science applications and reports about latest instrumental and methodical developments at our imaging stations at the KIT Light Source, the ESRF, and at PETRA III. It summarizes recent trends, including multiscale and multi-contrast up to hierarchical and correlated imaging, and increasing efforts devoted to high-throughput, *in situ*, *operando* and dose-efficient *in vivo* experiments for studying morphology and its evolution during technological or biological processes.

Understanding of life requires studying its building blocks and processes from molecules up to whole organisms. We address the higher hierarchical levels, studying morphology and morphodynamics of cells, tissues, organs up to complete specimens. The related scientific goals are to understand interrelation between morphology and biochemical pathways, genotype-phenotype correlation, reactions to internal and external stressors and stimuli including drugs, toxins, implants, scaffolds, and biotic environmental factors such as predators and parasites, abiotic natural factors and human impacts. These studies require quantitative morphological analyses, and their correlation with molecular, genetic, environmental and other information. The morphology of fossil, fixed and even living specimens contributes to our understanding of extinct and recent species with high relevance for e.g. evolutionary biology, developmental biology and biodiversity. Vertebrate model organisms such as fish, frog etc. provide indispensable paradigms to study development and disease, while arthropods such as insects fulfill key functions in our ecosystems. All cases share the need for qualitative and even quantitative morphological studies of whole organisms, their organs and tissues, all for a huge number of individuals. We will discuss strategies towards serial tomography of large sample collections at KIT's IMAGE beamline and will describe new opportunities of hierarchical and *in vivo* imaging at the upcoming HIKA (**H**ierarchical **I**maging **KA**rlsruhe) station at P23@PETRA III, and perspectives for morphological imaging at PETRA IV.

In the context of materials research, the talk will focus on dedicated instrumentation for X-ray computed laminography (CL). CL has unique capabilities for the 3D characterization of flat and laterally extended objects considerably exceeding the view field of the detector, such as plate-like material geometries. CL allows screening large sample areas and hierarchical imaging up to high 3D resolution by zooming into on-the-fly selected regions of interest (ROI), without sample dissection. Thus, CL enables hierarchical imaging with a particular suitability for *in situ* and *operando* studies under real-world conditions. Here we highlight latest developments for 4D *in situ* studies by various imaging contrasts. Particular examples describe hierarchically guided phase-contrast nano-laminography for damage analysis during mechanical load-pass changes and diffraction-contrast laminography detangling dynamics of dislocation networks during thermal wafer processing.

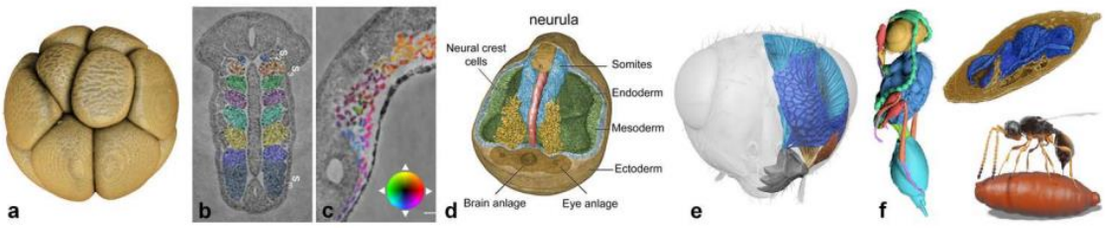

Fig. 1 Examples for morphological imaging of small organisms: *Xenopus laevis* during embryogenesis (a-d); extant and fossil insects (e-g)

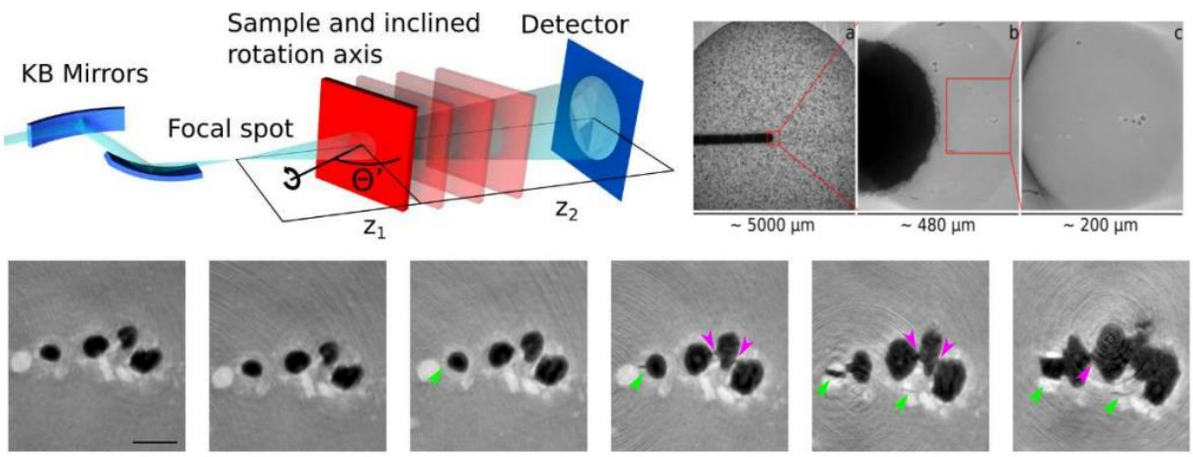

Fig. 2 Hierarchically guided *in situ* nano-laminography of damage processes in sheet-like materials

References

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