Disruptive X-ray methods for a new generation of materials science

With recent and ongoing developments in ever brighter X-ray sources and new computational analysis methods, materials science is on the brink of another transformative breakthrough, comparable to the advent of electron microscopy.

We probe large statistical populations with classical X-ray scattering techniques, but evidence suggests that important and defining characteristics are determined by the modulations to the average, the defects and details at the interfaces. After more than a 100 years of refining the classical scattering, diffraction and spectroscopic X-ray methods, we are now starting to explore, this realm of ultra-high resolution in space and time where we will be able to monitor the formation of structures as we make them, and follow the functionality as we induce it.

With the advent of the fourth-generation synchrotron X-ray facilities, spearheaded by the MAX IV in Lund, we will be able to image structures in 3D with resolutions down to 1 nm, of micron-scale volumes. No less important than spatial resolution, ultra-high resolution in time, is crucial for monitoring and manipulation of functional materials. Another recent and disrupting technology is the realization of free electron X-ray lasers, in the United States, in Japan, and soon also in Sweden, Switzerland and Germany. At these amazing facilities, we will be able to make exactly these kinds of observations, with femto-second X-ray pulses. And this probe will not only be able to resolve physical structure and morphology, but also the electronic, chemical and magnetic properties as they evolve.

In my lecture, I will show examples from the our journey through soft and hard X-ray scanning transmission microscopy to the use of ultra-high resolution inverse phase contrast microscopy and its application to 3D tomography analysis applied to demanding low contrast sample systems consisting of soft materials. I will also show our most recent, first ever results from the new 4^{th} generation synchrotron in Lund, MAX IV. Finally, I will present some of the visions for ultrafast imaging, envisaged for experiments at the European XFEL in Hamburg.