High Dimensional Diffractive Imaging with Soft X-rays at the Advanced Light Source

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The resolution limitation of scanning x-ray microscopes has recently been overcome through the development of x-ray ptychography. A ptychographic microscope operates much like a conventional scanning probe system in that the sample is scanned quickly and precisely through a focused illumination. During the scan, the sample is positioned such that neighboring positions are partially redundant and a full coherent diffraction pattern is measured at each point. Various phase retrieval algorithms have been developed which can reconstruct the complex valued transmission of the object and its illumination using knowledge of the diffraction intensities and the sample positioning [1,2]. Effective ptychographic imaging requires a high brightness x-ray beam, high speed detectors, precise and fast scanning, and high performance algorithms and computation for image reconstruction. The Advanced Light Source is leading an inter-divisional collaboration within Lawrence Berkeley National Laboratory which brings together the world's experts in each of these key areas for the development of a ptychographic imaging facility [2,3,4]. Our instrument, called the Nanosurveyor, can generate ptychographic data at 200 Hz and provide realtime imaging feedback to the user via streaming analysis algorithms run on remote, GPU based, computational resources connected by a high speed network. Using this instrument on a bending magnet x-ray source, we couple soft x-ray ptychographic imaging, x-ray absorption spectroscopy and computed tomography to map the oxidation states in a nano-particle based battery electrode at 11 nm resolution in three dimensions. Furthermore, we exploit the availability of both absorption and phase contrast in ptychographic imaging to measure the full refractive spectrum of various materials for the first time. We characterize the unique relationship between this spectrum and the achieved image resolution and show that the complex spectrum can be used to quantify chemical composition with few nanometer resolution. The Nanosurveyor instrument will be moved to a new high brightness beamline in 2016, called COSMIC, which will enable three dimensional imaging with chemical specificity, wavelength limited spatial resolution, and time resolution adequate for visualization of *in situ* electrochemical phase transformations.

References

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