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Strain at the nanoscale revealed by 3D lens-less x-ray microscopy

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Hard X-ray lens-less microscopy holds the promise of a resolution power meeting the need of nanoscience, owing to the possibility of circumventing the limits of state-of-the-art X-ray lenses [1]. Beyond the resolution issue, the complex-valued wavefield is imaged, hence ensuring truly quantitative information on the sample scattering contrast. Furthermore, combining this approach to the Bragg geometry allows providing images of defects and strains in nanocrystals, in a non-destructive manner [2].

Lens-less microscopy makes use of far-field coherent intensity patterns produced by third generation synchrotron sources. Instead of lenses, numerical approaches are employed to retrieve the exit-field at the sample position [1]. An overview of the capabilities and the actual limits will be given in this presentation, in the specific case of crystalline imaging. In particular Bragg coherent diffraction imaging, Fourier transform holography [3] and ptychography [4] will be discussed and compared.

The accurate and detailed knowledge of the crystalline structures at the nanoscale is highly desirable for its potential to bring new insight and understanding in a large variety of nanoscience material problems: this challenge is expected to be met by Bragg lens-less X-ray microscopy.

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X-ray ptychography

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The increased availability of coherent X-ray sources have opened the door to innovative investigation techniques for structure determination of non-periodic samples. These techniques, often called "coherent diffractive imaging", have piqued the interest of many X-ray microscopists as a mean to overcome limitations imposed by current X-ray optics fabrication. Other benefits of these lensless imaging techniques (expected or verified) are high resolution and high contrast, quantitativeness, flexibility and multi-modality. These potential benefits have a price: relaxing experimental conditions means that the imaging effort is transferred from hardware to software, serious reconstruction problems may occur.

X-ray ptychography, a scanning diffraction imaging technique [1], [2], has evolved rapidly in the recent years [3], [4]. Its recent success can be explained, on one hand, by the availability of better sources and detectors and, on the other hand, by an important progress in reconstruction algorithms.

This talk will give a broad overview of the current state-of-the-art in reconstruction algorithms. A general reconstruction framework for ptychographic datasets will be presented, as well as ways of extending the technique's range of applications, either as a way to gain additional information on a sample, or to overcome experimental requirements. Extensions to three-dimensional imaging, reconstruction from heterogeneous datasets, and imaging with non-monochromatic sources will be discussed.

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Coherent x-ray diffraction of copper islands under in situ loading

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We have studied sub-micron epitaxial islands of copper grown on a tantalum 001 substrate. The islands are under tensile strain due to the epitaxial relation with the substrate. We measured the 002 Bragg peak of individual islands with a microfocused coherent x-ray beam. The detailed structure of the diffraction patterns reveal the strong strain inhomogeneity within the islands. With the help of finite-element modeling, we could reproduce the diffraction patterns and deconvolute several key factors in the diffraction patterns: shape, size, anisotropy of the tensor of elasticity and plastic deformation. Using an Atomic Force Microscope tip precisely aligned with the x-ray beam, we applied *in situ* stress on individual islands and studied their deformation by monitoring their diffraction pattern. We could identify characteristic features of plastic deformation that conventional x-ray diffraction would not reveal. Reciprocal strain of the islands on the substrate is also evidenced.

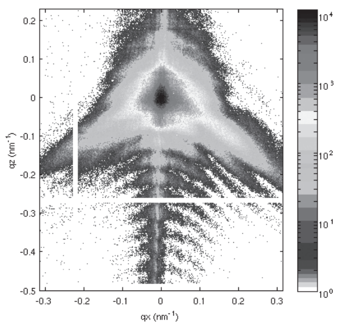

Figure 1: Slice through the 002 Bragg peak of a copper island.

Keywords: X-ray, coherence, strain