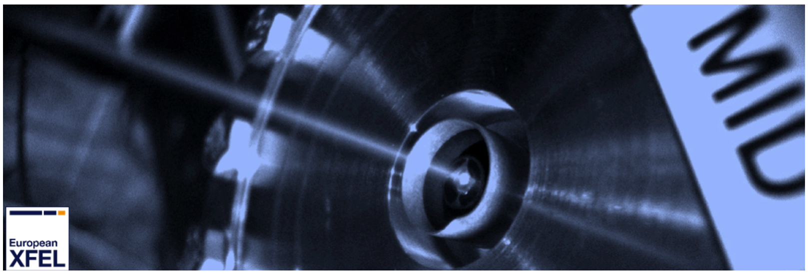

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Multiscale materials science: movies of irreversible processes within realistic environments

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Crystalline materials are ubiquitous. The performance of metals, ceramics and semiconductors is critical for addressing societal challenges; geoscience relates to rocks, ice and sediments while biomineralisation is an integral part of biology and Health technology. The physical and mechanical properties of such materials is often governed by their structure, which tend to be organized on many length scales in a hierarchal way. Associated with this are competing dynamics spanning many time scales. Probing these simultaneously is notoriously difficult as one needs to probe a volume that is representative of all length and time scales in a non-destructive way. Another complication is that structural processes such as phase transformations, nucleation-and-growth and damage are typically non-reversible. Today the science of crystalline materials is founded on a posteriori data. Better understanding of the dynamics is essential to fulfil visions of "materials design in the computer"as well as for optimisation of existing components and devices.

A hard x-ray microscope in the range 20-80 keV at the EuXFEL has the prospect of overcoming this limitation. Recently the propagation of acoustic waves in mm sized crystals were visualised at 10 keV by diffraction contrast with 1 µm and <1 ps resolution. We propose to make a dedicated set-up for both dark and bright field movies of irreversible phenomena at the repetition rate of the XFEL. The extended x-ray energy range is critical to provide penetration power in order to study medium and high Z elements and devices in general under realistic conditions.

The science case includes:

• Direct observation of martensitic transformation in steel and shape memory alloys as well as dislocation dynamics during plastic deformation –fundamental materials science with a high socioeconomic impact
• Domain switching in ferroelectrics and dielectric breakdown, for introduction of a new generation of power capacitors as part of the green transition
• Interaction of defects and grain boundaries with thermal or optical waves, e.g. for understanding metamaterials and seismic waves in the mantle of the Earth.
• Engineering: e.g. additive manufacturing and damage
• Extreme condensed matter.
• Movies of magnetic domains evolution, e.g. pinning and melting of the Abrikosov lattice in type II superconductors

Primary author: FRIIS POULSEN, Henning (DTU Physics)

Presenter: FRIIS POULSEN, Henning (DTU Physics)

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