ABSTRACT:

Stress-Free? A Myth at the Grain Scale

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Mechanical stresses exist at all length scales and are generally detrimental to the performance and reliability of materials. While significant residual stresses are expected in industrial, multi-phase materials, they are commonly assumed to be negligible in single-phase, coarse-grained systems after stress-relief heat treatment.

In this talk, we present an experimental study on coarse-grained Armco iron using state-of-the-art 3D X-ray diffraction microscopy at beamline ID11 at the ESRF (Grenoble, France). By combining Diffraction Contrast Tomography (DCT), far-field 3D X-ray diffraction microscopy (FF-3DXRD) and micro Laue diffraction, we obtain a full three-dimensional grain map, crystallographic orientations, and the average elastic strain tensor for each individual grain during *in situ* tensile testing. This approach allows us to track the mechanical response of up to 3000 individual grains during loading – particularly during the elastic regime.

Unexpectedly high elastic strains are already present in the undeformed state. The corresponding stress distributions reveal a substantial fraction of grains with local stresses exceeding the macroscopic yield strength of Armco iron (~130 MPa). A careful analysis of the experimental data, supported by a critical review of the literature, demonstrates that these stresses are intrinsic and not experimental artifacts. We discuss the underlying mechanisms responsible for their origin, the evolution during uniaxial tensile loading and address the implications for the concept of stress-free microstructures for instance on micro plasticity as well as fatigue crack initiation and growth.