Multimodal 3D X-Ray Imaging of Grain Boundary Migration at Triple Junctions

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Classic grain growth (GG) models are unable to reproduce the complexity observed experimentally, as they rely on oversimplified assumptions such as purely curvature-driven mechanisms or evolution governed solely by topology. As a result, standard GG models offer limited predictive capability, with numerical simulations being strongly constrained by the experimental data available.

Aiming to overcome these limitations, we have implemented a non-destructivein situdiffraction techniques capable of capturing the involved phenomena with high sensitivity and nanometer-scale spatial resolution in a three-dimensional microstructural context. The process has been characterized by combining general mapping methods for the bulk matrix and neighbors (Diffraction Contrast Tomography (DCT), Phase-Contrast Tomography (PCT) or 3D X-ray Diffraction (3DXRD)), with Dark-Field X-ray Microscopy (DFXM). The latter technique allows magnifying the identified regions of interest and provides strain sensitivity on the order of 5×10 with ~100 nm spatial resolution, thereby enabling a multiscale characterization framework.

In this study, we investigate a polycrystalline AA1050 alloy subjected to multiple annealing steps at temperatures close to its melting point (0.96 T). Following volumetric mapping of the sample using DCT and 3DXRD, the analysis focuses on three neighboring grains forming a triple junction (TJ). For each grain within the selected region of interest, the evolution of local intragranular strain, grain boundary energies and boundary migration at the TJ are tracked. In addition, the presence of second-phase particles is identified and the constraints they impose on the observed boundary motion are assessed. Finally, a direct link between intragranular dislocation structures and grain boundary migration is established, enabling an evaluation of the persistence of these mechanisms at high homologous temperatures (Figure 1). In this way, this work brings us closer to establishing the experimental foundation needed to validate and improve physically based GG models.