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6D electron microscopy: combining real-space and reciprocal-space tomography

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STEM and TEM-based tomography has been used widely to study the 3D morphology of a wide range of materials. Similarly reciprocal space tomography in which a tilt-series of diffraction patterns are acquired offers a powerful method for the analysis of the atomic structure of crystalline materials. The natural progression is to combine these techniques into a complete three dimensional morphology and crystallography data set, allowing both features to be studied simultaneously. Using a tilt series of scanning precession electron diffraction measurements from a commercially available Ni-base superalloy as an example, the complete reciprocal lattice orientation for a number of components embedded within the matrix could be determined. It was straightforward to identify reciprocal lattice vectors that allowed dark-field images representing each phase to be produced post-acquisition. In turn these were combined using geometric tomography methods to yield a 3-D tomogram of the superalloy. Imaging these phases using conventional ADF STEM tomography would potentially be challenging given the compositional similarity between the different phases. From the combined dataset the spatial distribution of the component phases could be easily recovered but more importantly the orientational relationships between these different components could be unambiguously determined. In this way the thermo-mechanical history of the sample could be inferred from the arrangement of coherent and semi-coherent interfaces and a previously unreported crystallographic registry between metal carbide (MC) and the matrix f.c.c. phases could been identified. The possibilities for development and applications of this technique will be discussed further.

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