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Measurements and simulations of grain-scale deformation in tantalum multicrystals

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ABSTRACT

Most engineering materials have complex microstructures that can affect their properties in various ways. Metals are usually polycrystalline, and their inherently heterogeneous crystallographic nature can produce strong variations in deformation behavior at the grain (i.e., micron) scale. In small components, or when deformations are localized by defects or intentional geometry (e.g., holes or fillets), the details of grain-scale deformation can dictate the material's performance. In this study, we used micron-scale digital image correlation (μDIC), electron backscatter diffraction (EBSD), and finite element analysis to measure and predict, respectively, the evolution of surface strains and crystallographic orientations during the tensile deformation of tantalum multicrystals containing only a few columnar grains in the gauge section. These measurements are compared to crystal plasticity finite element simulations of the subgrain surface strain fields, and the predictions provide an accurate estimate of the location of failure initiation. We will outline the μDIC, EBSD, and crystal plasticity finite element methods; describe the procedure by which large-grained tantalum multicrystals were fabricated; discuss the validation of the simulations' predictions against the experimental data; and provide examples of the application of the simulations to real engineering components.