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Deformation twinning in hexagonal close packed metals

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Deformation twinning plays an important a role in determining the overall deformation response of hexagonal close-packed (hcp) polycrystalline materials, such as Zr, Mg, Be, Hf, and Ti. The formation of twins during deformation is a primary mechanism for accommodating plasticity along the c-axis of the individual crystals, and it has a dramatic effect on hardening behavior and texture evolution. While ongoing research is shedding light on the physics of twin nucleation at the atomic scales, twinning appears to be a largely stochastic or random process at the meso-scale. In this presentation, we describe an approach to include twin nucleation in constitutive laws for integration into crystal plasticity formulations or simulations. In this approach, the criteria for nucleation are not deterministically defined but instead the critical stress for nucleation events will vary with a probability that is influenced by grain boundary structure and local stress concentrations. Validation of the model is performed by incorporating the twin model into a mean-field polycrystal code and simulating the deformation response of Zr and Mg. The calculations are compared with mechanical test data, texture measurements, and results from detailed statistical analyses of microstructural data. In a more general sense, this work demonstrates a concept of including multi-scale effects into computationally efficient mean-field constitutive models via stochastic modeling. The net effect is prediction of microstructural evolution under mechanical deformation with minimal computational requirements.