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Multiscale strength (MS) models: their foundation, their successes, and their challenges[1]

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Multiscale strength (MS) models are constructed to capture a natural hierarchy in the deformation of metals such as V and Ta starting with atomic bonding and extending up through the mobility of individual dislocations, the evolution of dislocation networks and so on until the ultimate material response at the scale of an experiment. In practice, the hierarchy is described by quantum mechanics, molecular dynamics, dislocation dynamics, and so on, ultimately informing a continuum constitutive model. We review the basic models and describe their extension to plastic flow in shocked metals and the response of polycrystalline materials. In experimental systems that match the assumptions of the multiscale strength models, they work surprisingly well, both for fundamental experiments like in-situ single crystal diffraction, and for more integral experiments like Rayleigh-Taylor plastic flow experiments. There are also clear challenges, however. The current MS models do not include failure, and they are expensive to create, due to the large amounts of computer time needed. Still, MS models provide compelling insight into metals under extreme pressures and strain rates.

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