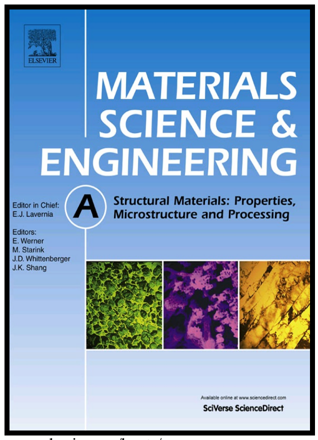

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Deformation and Failure in Extreme Regimes by High-Energy Pulsed Lasers: A Review☆

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Abstract

The use of high-power pulsed lasers to probe the response of materials at pressures of hundreds of GPa up to several TPa, time durations of nanoseconds, and strain rates of 10^6 – 10^{10} s^{-1} is revealing novel mechanisms of plastic deformation, phase transformations, and even amorphization. This unique experimental tool, aided by advanced diagnostics, analysis, and characterization, allows us to explore these new regimes that simulate those encountered in the interiors of planets. Fundamental Materials Science questions such as dislocation velocity regimes, the transition between thermally-activated and phonon drag regimes, the slip-twinning transition, the ultimate tensile strength of metals, the dislocation mechanisms of void growth are being answered through this powerful tool. In parallel with experiments, molecular dynamics simulations provide modeling and visualization at comparable strain rates (10^8-10^{10} s^{-1}) and time durations (hundreds of picoseconds). This powerful synergy is illustrated in our past and current work, using representative face-centered cubic (fcc) copper, body-centered cubic (bcc) tantalum and diamond cubic silicon as model structures.

☆ *This paper is dedicated to Professor J.C.M. Li on his 90th birthday. The seminal contributions of Professor Li have covered over sixty years of uninterrupted work and have advanced our understanding of the mechanical response of metals, polymers and metallic glasses in a significant manner. One of us (M.A. Meyers) had the fortune to follow Professor Li's work since his graduate student days (1970-1974), and the stellar example of his teaching role has been a guiding light in his career.*