Nanosecond timescale plasticity in shock-compressed polycrystalline MgO up to pressures above 100 GPa

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Abstract

MgO is an important industrial ceramic and serves as a model for experimental and computational studies of mechanical behaviour. At very low strain rates (10^{-16} /s) and high pressures, the slow diffusion of oxygen impedes dislocation recovery and strengthens MgO dramatically [1]. At high pressures above 50 GPa, a change in deformation mechanism is also predicted where the slip system changes from [110](110) to [110](100) [2]. Here, we focus on the mechanical behaviour of dynamically compressed MgO at conditions up to 150 (20) GPa and 2000 (300)K. We use laser shock compression along with ultra-fast diagnostics at the HED sector of the European XFEL to probe how the rapidly changing pressure-temperature conditions affect microstructures in shock-compressed polycrystalline MgO. These observations, coupled with elasto-viscoplastic self-consistent (EVPSC) simulations, unequivocally prove that MgO attains plastic regime in the nano-seconds scale which we successfully study and model in terms of strength and deformation mechanisms. The experiments point to a rich intricate mechanical behaviour in shocked polycrystalline ceramics for the first time based on in-situ XRD measurements at the nanosecond timescale. The method may have profound impact on studies of plastic behavior of ceramics under high P/T conditions, including the viscosity and rheological behaviour of Earth and Earth-like exo-planets.

References

[1] Cordier et al., Nature vol 613 (2023) page 303-307.
[2] Amodeo et al., Crystals, vol 8 (2018), ppage 240.