Comley *et al.* Reply: In the preceding Comment [1], Hunter and Preston suggest inconsistencies with how the flow stress was calculated from the measured strain and with the strain rate used to compare strain-rate-dependent constitutive models to x-ray diffraction results of flow stress in shocked single-crystal Ta [2]. However, the Hooke's Law relation [2] is applied in a way consistent with how the single crystal elastic constants were computed, and it is not appropriate to use zero plastic strain rate in comparing the diffraction data to a time-dependent plasticity model like the multiscale strength (MS) model [3]. The shock front strain rate plays an important role in setting the dislocation density on the short time scale of the experiment.

We first address the model comparison point [1]. We have tuned simulations using the radiation-hydrodynamics code LASNEX [4] to match the simultaneous VISAR (velocity interferometer system for any reflector) measurements for a 100-GPa shock, optimizing the Ta sample and glue thicknesses within their measurement uncertainties, and scaling the measured laser power versus time. Shock impedance mismatches lead to some reverberations, so the shock is not a perfect textbook shock; the leading shock front maintains a steady velocity but the postshock reverberations are not steady. The original analysis [2] and LASNEX simulations estimate $\bar{P} \sim 100 \pm 21$ GPa and $T \sim 1650 \pm 550$ K for ~0.5 ns following the shock.

The simulated plastic strain rate is $d\varepsilon_p/dt = 0.5\text{–}4 \times 10^8$ s^{-1} over a region extending ~1.3 μm behind the leading shock (a slight ramp compression wave follows the shock front). The strain rate in most of the Ta behind the shock is not zero as stated in the Comment [1], but is more than 10× smaller than the strain rate in the shock front. Heating due to plastic work behind the shock is less than 200 K, smaller than the error bars on the Hugoniot conditions.

The MS model is a time-dependent plasticity model [3]; strain rate plays two roles. Through Orowan's equation, the plastic strain rate sets the dislocation velocity, and hence the mobility contribution to the flow stress. It also sets the saturation dislocation density, giving a high value in the shock front. At shock pressures greater than 65 GPa, molecular dynamics (MD) simulations predict homogeneous nucleation of dislocations [5], giving a very high dislocation density. For the 100-GPa shock ($\sigma_S = 113$ GPa) discussed in Ref. [2] with a Swegle-Grady strain rate of 4.5×10^9 s^{-1} [6], we used an initial dislocation density of $\rho_{\text{disloc}} = 5.6 \times 10^{16}$ m^{-2} in the MS model, based on the saturation density at the shock front strain rate, consistent with MD [5,7]. The MD and MS simulations show that the high dislocation density created at the shock front, even though subsequently supersaturated, does not change much for the short (< 1 ns) time scales of this experiment [3,5].

Also, it would be inappropriate to use a plastic strain rate of zero in calculating the work hardening contribution to the MS model flow stress, due to the dislocation density memory effect. For simplicity, we used [2] the shock-front $d\varepsilon_p/dt$ in both the Taylor hardening and dislocation mobility terms in the MS model, as well as in the Preston-Tonks-Wallace (PTW) model [8]. If, however, we estimate the post-shock strain rate as 2×10^8 s^{-1} for the MS mobility term and the PTW model, the MS and PTW predictions of von Mises stress drop to 11 ± 3 and 3.2 ± 0.2 GPa, respectively, compared to the experimental value of 18 ± 4 GPa. Both models predict a somewhat lower flow stress now, although the MS is nearly within the error bars of the experimental data.

Contrary to the Comment [1], the procedure we have used to calculate the shear stress from the shear strain appropriately accounts for P, T, and anisotropy in the single crystal. The shear stress for the shear strain $\Delta\varepsilon$ was calculated using the single crystal shear modulus $C'(P,T)$ for uniaxial [001] strain derived from the stress-strain coefficients B_{11} and B_{12} of Orlikowski *et al.* [9] evaluated at the shock pressure and temperature. The Hooke's Law formula we have used is suitable for the [001] single crystal and takes into account the Zener anisotropy. The original analysis did not include uncertainty in the elastic constants in the flow stress error bars; doing so increases the von Mises stress error bars from 10% [2] to 18% at 100 GPa.

A conclusive resolution of this debate will likely require additional research and new experiments that can better isolate mechanisms and test assumptions.

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