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Visualization of the ultrafast structural phase transitions in warm dense matter.[1]

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It is still a great challenge to obtain real-time atomistic-scale information on the structural phase transitions that lead to warm dense matter state. Recent advances in ultrafast electron diffraction (UED) techniques [1] have opened up exciting prospects to unravel the mechanisms of solid-liquid phase transitions under these extreme non-equilibrium conditions. Here we report on precise measurements of melt time dependency on laser excitation energy density that resolve for the first time the transition from heterogeneous to homogeneous melting. This transition appears in both polycrystalline and single-crystal gold nanofilms with distinct measurable differences. These results test predictions from molecular-dynamics simulations with different interatomic potential models [2-3]. These data further deliver accurate structure factor data to large wavenumbers that allow us to constrain electron-ion equilibration constants. Our results demonstrate electron-phonon coupling strength much weaker than DFT calculations [4], and contrary to previous results [5], provide evidence for bond softening. [1] M. Mo, et al. RSI 87,11D810 (2016). [2] S. Mazevet, et al. PRL 95, 085002 (2005). [3] Z. Lin, et al. PRB 73, 184113 (2006). [4] Z. Lin, et al. PRB 77, 075133 (2008). [5] R. Ernstofer, et al. Science 323, 1033 (2009).

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