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Materials response under extreme conditions: a path to materials science above 1000 GPa

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Solid state experiments at extreme pressures (10-100 GPa) and strain rates (1.e6 – 1.e8 1/s) are being developed on high-energy laser facilities. [1] A quasi-isentropic, ramped-pressure (shockless) drive is being developed on the Omega laser. [2] Constitutive models for solid-state strength under these conditions are tested with experiments measuring perturbation growth due to the Rayleigh-Taylor instability in solid-state samples. [3] Lattice compression, phase, and temperature are deduced from extended x-ray absorption fine structure (EXAFS) measurements, from which the shock-induced alpha-omega phase transition in Ti is inferred to occur on sub-nanosec time scales. [4] Time resolved lattice response and phase can be inferred from dynamic x-ray diffraction measurements, where the elastic-plastic (1D-3D) lattice relaxation in shocked Cu is shown to occur promptly (sub-nsec). [5] Large-scale MD simulations have elucidated the microscopic dynamics that underlie the 3D lattice relaxation. [6] Deformation mechanisms, such as the slip-twinning transition in shocked single-crystal Cu, are identified by examining the residual microstructure in recovered samples. [7] Designs will be shown for reaching much higher pressures, (greater than 1000 GPa), in the solid state on the NIF laser. [8] *This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48. [1] B.A. Remington et al., Met. Mat. Trans. 35A, 2587 (2004). [2] J. Edwards et al., PRL 92, 075002 (2004). [3] K.T. Lorenz et al., PoP, in press (May, 2005). [4] B. Yaakobi et al., PRL 92, 095504 (2004). [5] A. Loveridge-Smith et al., PRL 86, 2349 (2001). [6] E.M. Bringa et al., Nature, submitted (March, 2005). [7] M.S. Schneider et al., Met. Mat. Trans. 35A, 2633 (2004). [8] B.A. Remington et al., in press, ApSS 298 (July, 2005).