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Laboratory study of dense planetary interiors and giant impacts using laser-driven shock waves

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The behavior of matter at Megabar pressures, a few times solid density, and eV temperatures presents a fundamental challenge, one that is critical to our understanding of dense planetary interiors, planetary evolution models, and giant impacts. Under these conditions bulk matter is strongly coupled, with temperatures approaching the Fermi energy and electron wavelengths comparable to the interatomic spacing - a quantum-classical "transition" regime not amenable to many of the traditional theoretical approaches used in condensed matter or plasma physics. The laser-driven shock wave has matured into a powerful tool for accessing and probing these conditions with several new techniques having been developed recently. Measurements of the equation-of-state and transport properties of important planetary materials including silica (SiO_2) and hydrogen have been performed. In particular, silica - the major constituent of terrestrial planets - has been shown to undergo an insulator-to-conductor transition above melting at conditions similar to those in giant impacts (such as the one believed to have created the Moon) and at the earth's core-mantle boundary. This continuous transformation, occurring at pressures between 1 to $\sim$4 Mbar, is accompanied by an anomalously high specific heat that returns to the Dulong-Petit value at completion of the transformation. This is suggestive of a "bond-breaking" process in the condensed system - analogous to dissociation in a gas - as the fluid transforms from liquid to dense plasma. Work performed in collaboration with T. R. Boehly, P. M. Celliers, J. H. Eggert, J. E. Miller, D. D. Meyerhofer, and G. W. Collins under the auspices of the US DOE by LLNL under Contract No. W-7405-ENG-48 and by the U. Rochester under Cooperative Agreement No. DE-FC03-92SF19460.