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Exotic Behavior of Extremely Dense Plasmas: Phase Transitions, Kilovolt Chemistry, and Fusion[1]

GILBERT COLLINS, Lawrence Livermore National Laboratory

A new generation of materials experiments at high pressures and densities is now underway thanks to a variety of high energy density (HED) facilities and new compression techniques. Dynamic compression experiments can now probe materials from kilobar to gigabar pressures with timescales ranging from picoseconds to microseconds. Recent shock experiments have measured the insulator-conductor (IC) transition and the high-pressure equation of state of several low Z materials (C, H_2O, SiO_2,H_2,He) from kilobar to 10's of Mbar. The IC transition is sometimes coincident with melting (diamond), a change in chemistry (H_2, SiO_2) or thermal activation of carriers across a reduced band gap (He, H_2O). Melt curves at ultra-high pressures are often complex. For example, diamond is found melt to a liquid metal above 6 Mbar and have a negative Clausius slope between 6 and 10 Mbar. In the high pressure and partially ionized fluid, complex chemistry plays a key role in the thermodynamics. In addition to shock compression, ramp compression experiments are exploring "low" temperature and high-pressure multi-phase diagrams and phase transition kinetics. Over the next few years these new capabilities will allow us to understand fundamental questions in high pressure science including, what is nature of solids at 10's of Mbar, what chemistry occurs in the Gbar regime, and what is the nature of He and H_2 in the deep interior of Giant planets and low mass stars.

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