New regimes of high energy density experimental science on Omega and NIF

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With the availability today of high energy, high power lasers throughout the world, the scientific community can now experimentally study the high pressure, high density properties of matter along a shock Hugoniot up to pressures of 300 Mbar (30 TPa), [1] and along a staged shock or ramp compression, quasi-isentropic pathway to peak pressures of up to 50 Mbar (5 TPa). [2] This allows improved understanding of the properties of matter in planetary cores, brown dwarf interiors, white dwarf envelopes, and stellar interiors, based on measurements of density, pressure, ionization state, phase, temperature, conductivities, and high pressure material strength. The experimental techniques that have been developed for these studies include x-ray radiography, VISAR, SOP, x-ray Thomson scattering, x-ray diffraction, and EXAFS. A selection of recent research highlights in high pressure science primarily from Omega and NIF include: VISAR EOS studies of diamond in ramped compression to 50 Mbar, whereby the sample stays in its ambient phase, despite predictions of two phase transitions [2]; ramp compression of iron to 14 Mbar [3]; ramp compression of deuterium to 6 Mbar observing the transition from insulator to metallic hydrogen at ~2 Mbar [4]; water ice compressed to ~3 Mbar showing a superionic regime of conductivity whereby the oxygen stays locked in a lattice while the hydrogen becomes itinerant and flows through this lattice structure, adding significantly to the conductivity [5, 6]; the shock compression of stishovite and the melting of silica at planetary interior conditions [7]; x-ray radiography EOS studies of CH in spherical geometry along the Hugoniot from 1 – 300 Mbar [1, 8]; XRTS studies showing higher than predicted ionization levels [9]; dynamic EXAFS studies that give sample temperature at HED conditions [10]; dynamic diffraction in a variety of materials at extraordinarily high pressures to show the phase [11]; and a unique state of high pressure fluid flow relevant to planetary formation dynamics whereby the sample stays solid but flows fluid-like in the solid-state plastic deformation regime, and under which conditions lead can become a factor of ~250 stronger than in its ambient state, making it stronger than steel. [12] An overview will be presented, with selections from the results above to illustrate this new frontier field of very high pressure, time resolved materials studies on HED facilities such as lasers and high power magnetic pinch facilities.

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