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Laser-Based Dynamic Compression of Solids to Ultrahigh Pressures

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Laser-based dynamic compression provides new opportunities to study the structures and properties of materials to ultrahigh pressure conditions. In this technique, high-powered laser beams are used to ablate a sample surface and by reaction a compression wave is generated and propagate through the sample. By controlling the shape and duration of the laser pulse, either shock or ramp (shockless) compression can be produced. Diagnostics include velocity interferometry (from which the stress-density response of the material can be determined) and x-ray diffraction from which structural information is obtained. Magnesium oxide is a fundamental ionic solid which has been extensively examined at high pressures. Theoretical studies predict a change in MgO from a rocksalt (B1) crystal structure to a cesium chloride (B2) structure at pressures of about 400–600 GPa but diamond anvil cell experiments have not been able to reach these pressures. Here we present dynamic X-ray diffraction measurements of ramp-compressed magnesium oxide. We show that a solid–solid phase transition, consistent with a transformation to the B2 structure occurs near 600 GPa. On further compression, this structure remains stable to 900 GPa. Our results provide an experimental benchmark to the equations of state and transition pressure of magnesium oxide, and may help constrain interior properties of super-Earth extrasolar planets. We have also examined the high-pressure behavior of molybdenum under both shock and ramp loading. The melting curves and high-pressure phase diagrams of transition metals have been controversial, and Mo is an excellent test case for resolving these discrepancies. We have conducted shock compression experiments on Mo with an X-ray diffraction diagnostic to address previous claims of high-pressure phase transitions and to determine the location of the Hugoniot melting point. We have also carried out ramp compression experiments to test predictions of phase transitions in Mo at ultrahigh pressures and low temperatures.

Keywords: Shock compression, X-ray diffraction, High Pressure