DPP17-2017-000563

Abstract for an Invited Paper
for the DPP17 Meeting of
the American Physical Society

Observation of a New High-Pressure Solid Phase in Dynamically Compressed Aluminum

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Aluminum is ideal for testing theoretical first-principles calculations because of the relative simplicity of its atomic structure. Density functional theory (DFT) calculations predict that Al transforms from an ambient-pressure, face-centered-cubic (fcc) crystal to the hexagonal close-packed (hcp) and body-centered-cubic (bcc) structures as it is compressed. Laser-driven experiments performed at the University of Rochester's Laboratory for Laser Energetics and the National Ignition Facility (NIF) ramp compressed Al samples to pressures up to 540 GPa without melting. Nanosecond *in-situ* x-ray diffraction was used to directly measure the crystal structure at pressures where the solid–solid phase transformations of Al are predicted to occur. Laser velocimetry provided the pressure in the Al. Our results show clear evidence of the fcc–hcp and hpc–bcc transformations at 216 ± 9 GPa and 321 ± 12 GPa, respectively. This is the first experimental *in-situ* observation of the bcc phase in compressed Al and a confirmation of the fcc–hcp transition previously observed under static compression at 217 GPa. The observations indicate these solid–solid phase transitions occur on the order of tens of nanoseconds time scales. In the fcc–hcp transition we find the original texture of the sample is preserved; however, the hcp–bcc transition diminishes that texture producing a structure that is more polycrystalline. The importance of this dynamic is discussed. The NIF results are the first demonstration of x-ray diffraction measurements at two different pressures in a single laser shot. This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944.