Observation of Solid–Solid Phase Transitions in Ramp-Compressed Aluminum: The crystalline structure of solid aluminum compressed up to 5 Mbar was measured using x-ray diffraction (XRD). These compression experiments traverse the region of phase space along the aluminum isentrope between 1 to 5 Mbar where the fcc–hcp (face-centered cubic–hexagonal close-packed) and hcp–bcc (hexagonal close-packed–body-centered-cubic) solid–solid phase transitions are predicted by density functional theory calculations.

OMEGA EP beams ramp compressed aluminum samples over 10 to 20 ns to various constant-pressure states. When the sample reached the desired pressure, it was probed with 8.4-keV x rays from a Cu backlighter of 1-ns duration. The velocity interferometer system for any reflector (VISAR)[1] measured the free-surface or interface velocities to deduce the pressure state of the sample, and x-ray diffraction patterns were recorded on image plates in the powder-x-ray-diffraction-image-plate (PXRDIP)[2] diagnostic shown in Fig. 1(a). Figure 1(b) shows the pulse shape (black line) and VISAR data from a typical shot. At the time the x rays probed the sample (~10 ns), the velocity is constant in the VISAR data, indicating the aluminum sample is at a relatively constant pressure over the 1-ns x-ray probe duration.

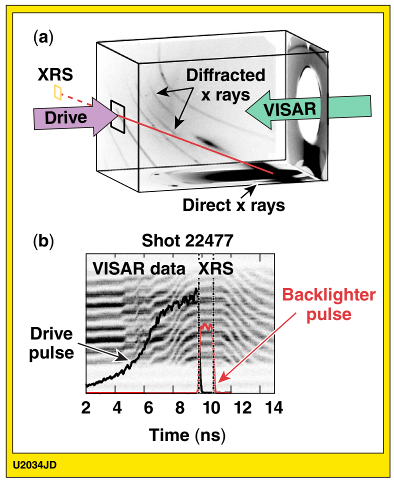

Figure 1. OMEGA EP shot 22477 (a) PXR-DIP geometry. UV drive beams are incident on the target package mounted on the front of the (PXRDIP) box. Diffracted x rays from compressed aluminum are collected on image plates lining the inside of the box. The x-ray source (XRS) is directly imaged on the bottom image plate. A large aperture on the back face of the box allows the (VISAR) laser to probe the target. (b) The 10-ns drive laser pulse (black line) is designed to compress the aluminum sample along an isentropic compression path and create a pressure steady-state in the aluminum sample. The 1-ns backlighter pulse (red) timing is offset from the drive pulse to probe the constant pressure state. The corresponding VISAR data measures the Al/LiF interface velocity.

At ambient pressure and temperature, aluminum is an fcc close-packed crystal and has been observed to transform to hcp when compressed to ~2.2 Mbar in a diamond anvil cell.[3] Figure 2 shows the XRD data, projected onto $2\theta-\phi$ space, from a sample compressed to ~2.6 Mbar, well above the fcc–hcp transition pressure. The calculated XRD lines for hcp aluminum at compression of 2.1 (2.6 MBar) are plotted (vertical blue dashed lines) on top of the data integrated in ϕ (black line). The intense lines in the data (at 2θ = 39°, 56°, and 70°) are calibration lines (vertical red dashed lines) from the tungsten pinhole.

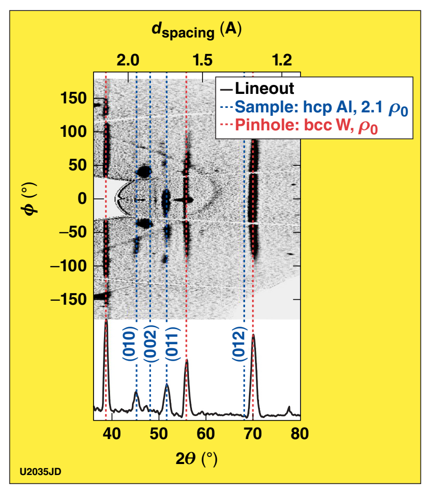

Figure 2. X-ray diffraction (XRD) image-plate data projected into 2θ–ϕ space for a shot at ~2.6 Mbar. The hcp aluminum diffraction lines at 2.1 ρ_0 are plotted in blue on top of the data. The lineout of the data at the bottom shows peaks in the pattern consistent with the hcp phase. Diffraction off of the bcc tungsten pinhole (shown in red) provides an *in-situ* calibration.

The presence of diffraction lines at 45° and 52° are consistent with the (010) and (110) lines of hcp aluminum at 2.1 compression. These diffraction signals are distinctly different from those obtained for pressures below ~1.7 Mbar where the signals indicated the aluminum was still in the fcc phase. These results confirm the predicted and observed high-pressure fcc–hcp transition in aluminum and are the first observations in dynamically compressed aluminum showing the transition occurs nominally on the subnanosecond time scale.

Omega Facility Operations Summary: The Omega Laser Facility conducted 197 target shots in April (132 on OMEGA and 65 on OMEGA EP) with average experimental effectiveness of 94.7% and 99.2%, respectively. The ICF program accounted for 78 of these shots for experiments led by LANL, LLNL, and LLE. Eleven HED experiments led by LANL, LLNL, and LLE had 101 target shots and two NLUF campaigns led by the University of California, Berkeley and MIT, respectively, carried out 18 shots on the OMEGA laser.

1. L. M. Barker and R. F. Hollenbach, J. Appl. Phys. **43**, 4669 (1972); 2. J. R. Rygg *et al.*, Rev. Sci. Instrum. **83**, 113904 (2012); 3. Y. Akahama *et al.*, Phys. Rev. Lett. **96**, 045505 (2006).