SHOCK05-2005-000194
Abstract for an Invited Paper
for the SHOCK05 Meeting of
the American Physical Society

Picosecond X-ray Diffraction from Laser-Shocked Copper and Iron

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In situ X-ray diffraction allows the determination of the structure of transient states of matter. We have used laser-plasma generated X-rays to study how single crystals of metals (copper and iron) react to uniaxial shock compression. We find that copper, as a face-centred-cubic material, allows rapid generation and motion of dislocations, allowing close to hydrostatic conditions to be achieved on sub-nanosecond timescales. Detailed molecular dynamics calculations provide novel information about the process, and point towards methods whereby the dislocation density might be measured during the passage of the shock wave itself. We also report on recent experiments where we have obtained diffraction images from shock-compressed single-crystal iron. The single crystal sample transforms to the hcp phase above a critical pressure, below which it appears to be uniaxially compressed bcc, with no evidence of plasticity. Above the transition threshold, clear evidence for the hcp phase can be seen in the diffraction images, and via a mechanism that is also consistent with recent multi- million atom molecular dynamics simulations that use the Voter- Chen potential.[1] We believe these data to be of import, in that it is the first conclusive in situ evidence of the transformed structure of iron during the passage of a shock wave.

[1]1 Kai Kadau, Timothy C. Germann, Peter S. Lomdahl, Brad Lee Holian, Science 296, 1681 (2002).