X-Ray diffraction studies of mineral phase transitions using gas-gun shock compression at the Dynamic Compression Sector

Sally June Tracy [1] and Thomas S. Duffy [2]

1. Geophysical Laboratory, Carnegie Institution of Washington, Washington, DC 20015, USA
2. Department of Geosciences, Princeton University, Princeton, New Jersey 08544, USA

Laboratory shock-wave experiments have long played an important role in Earth and planetary science. Shock experiments provide a powerful means of measuring equations of state, phase transitions, melting, and sound velocities at temperature-pressure conditions of the deep Earth. Furthermore, characterization of shock-compressed minerals is critical for the interpretation of shock metamorphism in samples from meteorites and natural impact sites.

In gas-gun based shock-loading experiments, an explosively-driven piston compresses a light gas (Helium or Hydrogen). The compressed gas, in turn, launches a high-velocity projectile which impacts a target sending a shock wave through the sample. This type of two-stage (gun powder + gas) driver can launch projectiles at velocities up to 7-8 km/s generating pressures up to 300 GPa and temperatures of several thousand degrees Kelvin. Optical diagnostics provide a continuous record of the pressure-density state during loading and release by tracking the Doppler shift of laser light reflected off the rear surface of the sample. While this type of velocimetry measurement can provide details about phase transformations and equation of state, *in situ* crystal structure of high-pressure phases formed under shock loading is generally not known. As a result, despite decades of study, the nature of the transformations and the identity of the high-pressure phases that form under shock loading remain poorly understood for major minerals including important silicates (quartz, enstatite, zircon) and other key minerals (rutile, calcite, iron-oxides).

Breakthrough capabilities coupling pulsed X-ray diffraction with gun-based shock loading techniques enable the direct determination of the lattice-level crystal structure of materials under shock loading. New user facilities including the Dynamic Compression Sector at the Advanced Photon Source provide novel capabilities to collect *in situ* X-ray diffraction using gun-based loading platforms. Simultaneous collection of *in situ* X-ray diffraction and velocimetry data allows for the development of a comprehensive picture of the material response from an atomic length scale up to the continuum level. Such experiments can resolve long-standing ambiguities concerning the crystal structure of the phases that form under shock loading. Furthermore, these measurements allow for the determination of time-dependent atomic arrangements providing a means to investigate the role of kinetics, texture development, and potential defect structures in shock compressed minerals.

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