Dynamic Compression Sector Opportunities to Understand Fundamental Material Deformation and Failure

S&T Campaign: Sciences for Lethality & Protection
Ballistics and Blast

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Research Objective

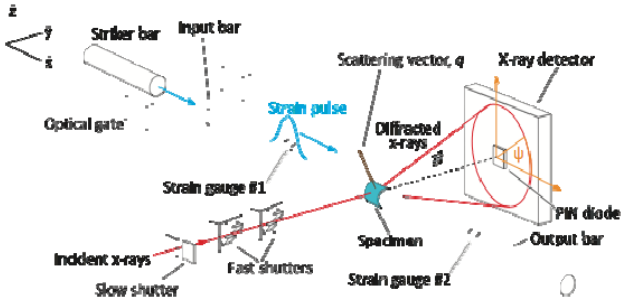
- To obtain *in situ* measurements of the structure of materials deformed under high strain-rate, high-pressure conditions. This includes studies of plastic flow, phase transitions, fracture, and chemical reactions.
- Using the Advanced Photon Source (APS) synchrotron, unprecedented x-ray diffraction (XRD) and phase contrast imaging (PCI) can be performed during high rate (e.g., impact) loading.

Dynamic Compression Sector (DCS) at the Advanced Photon Source

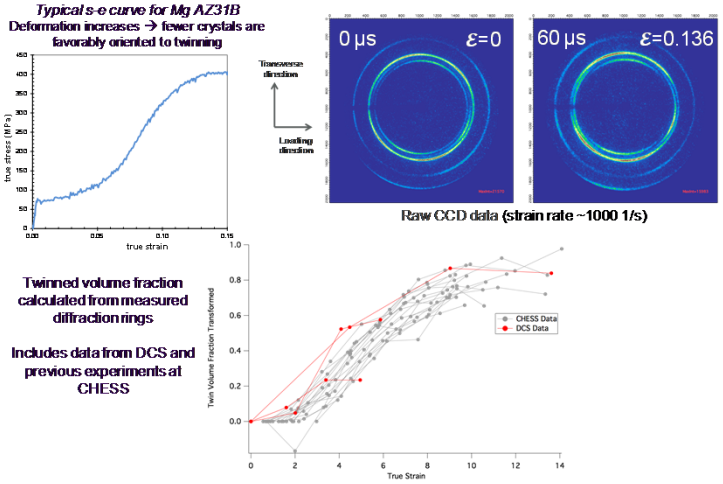
Challenges

Studies of the mechanisms behind observed mechanical responses are difficult under extreme conditions. While rapid continuum level measurements (e.g., shock profiles) exist, an absence of techniques to monitor changes at the grain/atomic level make interpretation of observed features speculative. High rate XRD and PCI have the potential to provide both quantitative and qualitative measurements to elucidate actual mechanisms at very small length scales.

The following shows in situ XRD performed in a Kolsky bar to study twinning in rapidly deformed magnesium alloys. This collaborative work was performed between the Hopkins Extreme Materials Institute (Hufnagel, Ramesh) and ARL.



A Kolsky bar configured for in situ XRD.



Mg AZ31 deformed in a Kolsky bar at approximately 7000/s. The XRD patterns show twinning, and can be used to calculate the volume fraction of twinned material during deformation (Johns Hopkins/ARL partnership).

ARL Facilities and Capabilities Available to Support Collaborative Research

- The DCS is a sector at the APS at Argonne National Laboratories. It is sponsored by the National Nuclear Security Agency and is run by Washington State University. ARL is a founding member of the DCS along with Los Alamos, Lawrence Livermore, Sandia, and the Naval Research Laboratory.
- Unique capabilities include
  - Light gas guns for shock loadings
  - Laser shock facility
  - Kolsky (Split Hopkinson) Bar
  - Interferometer instrumentation (VISAR and PDV)
  - X-ray diffraction, imaging, and scattering
  - Energies from 7-35 keV, up to 100 keV for imaging
  - X-ray beam spot sizes: 14 x 20 μm^2 to 19 x 68 μm^2
- Review of Scientific Instruments 85, 093901 (2014); doi: 10.1063/1.4893881
- More details about DCS at www.dcs-aps.wsu.edu

Complementary Expertise/ Facilities/ Capabilities Sought in Collaboration

- Expertise in mechanics, XRD, PCI
- Access to novel x-ray detectors, high speed cameras
- Coupling of electromechanical forces with normal stresses

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