RESEARCH HIGHLIGHT

PURDUE MATERIALS ENGINEERING

Dynamic Mechanical Behavior of Materials

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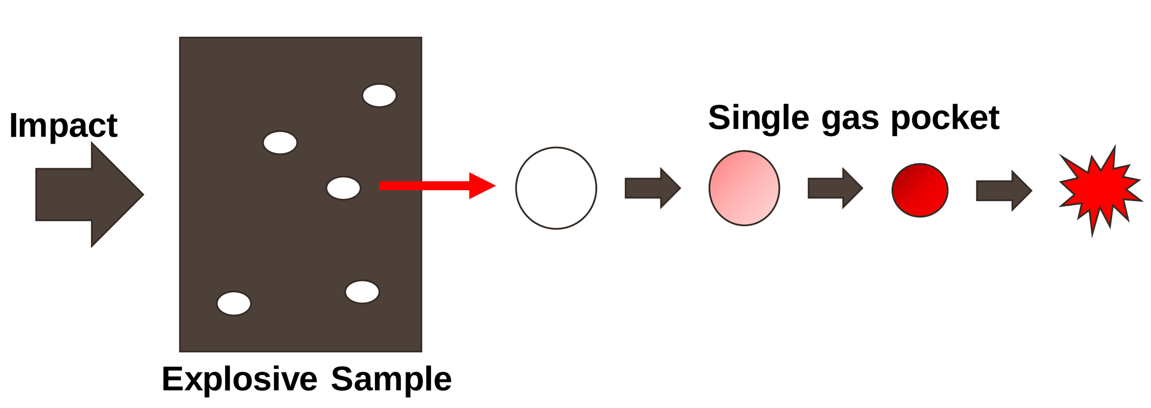
The Impact Science's Laboratory specializes in the development of novel dynamic experimental methods to characterize the mechanical behavior of materials at intermediate to high-strain rates. Our main capabilities include a high-speed mechanical test frame, as well as specialty Kolsky bars and light gas-guns. A standard drop tower system and powder gun are also available. We explore transient damage mechanisms *in-situ,* via high-speed imaging (≤ 10M fps), flash x-ray tomography, and dynamic Synchrotron X-ray phase contrast imaging (PCI) techniques. A wide range of material systems are currently being investigated and they encompass energetic composites, biological tissues, polymer fibers, advanced ceramics, and 3D printed metals and polymers. These studies observe material responses to loading conditions in tension/compression, torsion, transverse bending, multiaxial compression, dynamic fracture, and penetration.

Hot Spot Formation in Energetic Composites Under Dynamic Loading

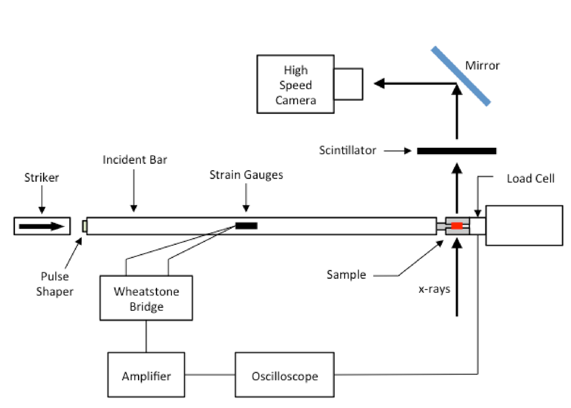
Energetic composites are materials which are typically composed of an inert binder and reactive compound. They are primarily used as catalysts in explosive ordnance. During use, ignition of the explosive is driven by an external stimulus which triggers a propagating chemical reaction within the reactive compounds. A common way to initiate this reaction is by inducing shock, and it can be intentional (in combat zones) or unintentional (during ground transport). Hence, a need arises to determine the mechanism by which the two distinct impact events lead to reaction.

Hotspot formation is the proposed mechanism for which a reaction in an energetic materials occurs.

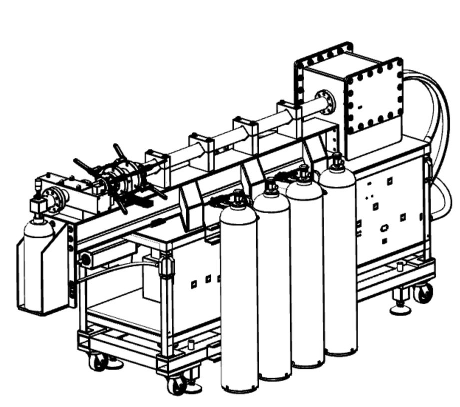


Rapid Compression → Localized Temperature Peak

Dynamic Synchrotron X-ray phase contrast imaging (PCI) technique is being used to characterize this phenomenon in HMX crystals imbedded in HTPB and subject to dynamic loading conditions via compression/tension Kolsky bar and light gas-gun apparatus.

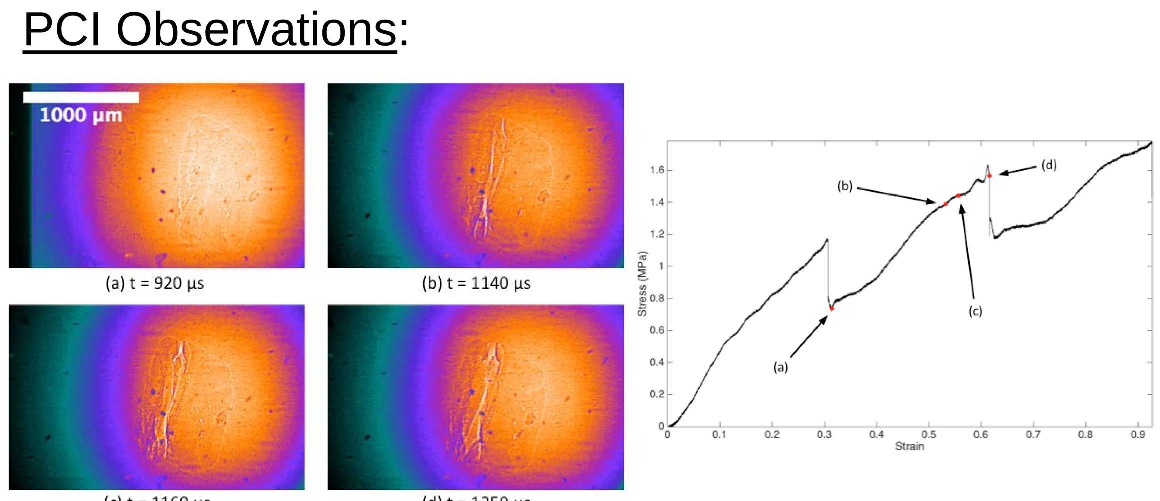


Kolsky Bar (Compression)

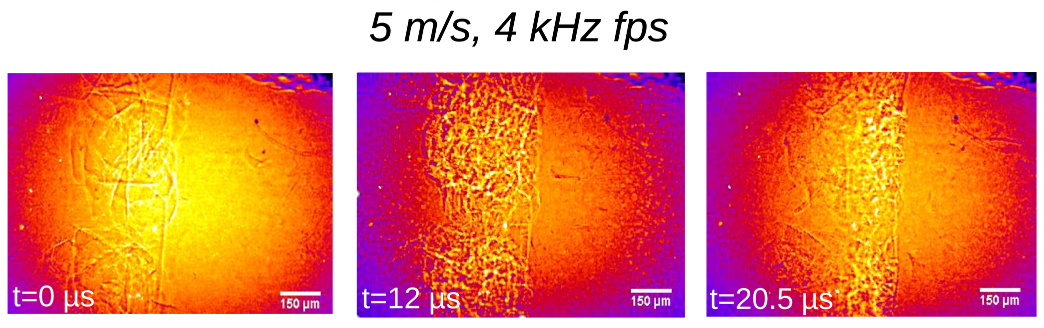


Light Gas-Gun System

PCI Observations:



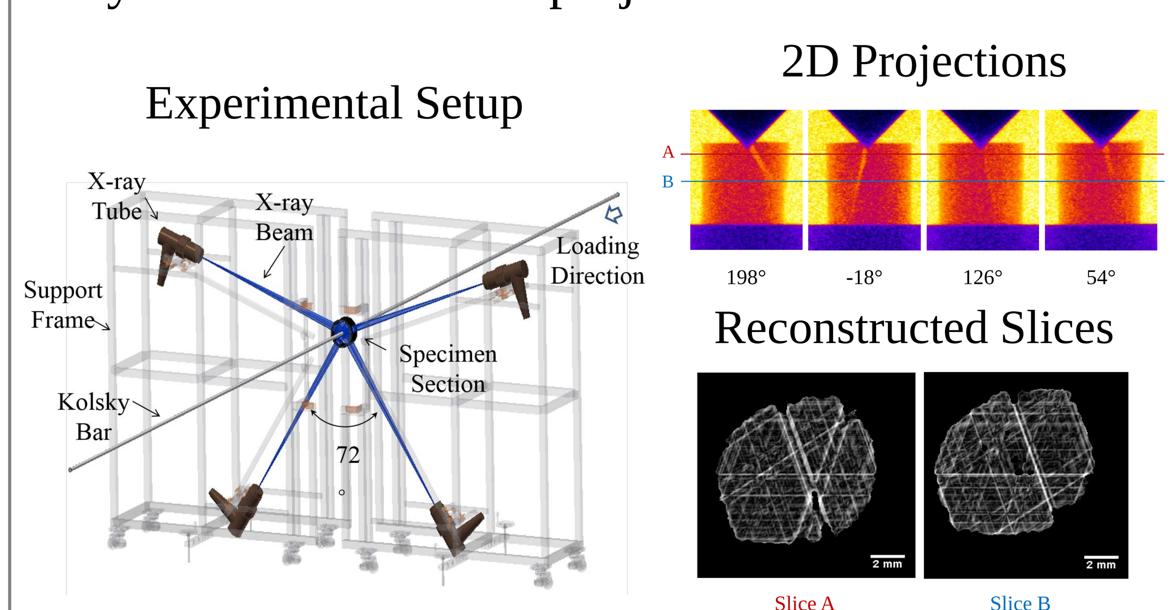
Dynamic tensile loading of HMX crystal in HTPB binder 5 m/s, 4 kHz fps



High velocity impact of HMX crystal in Sylgard binder 429 m/s, 2 MHz fps

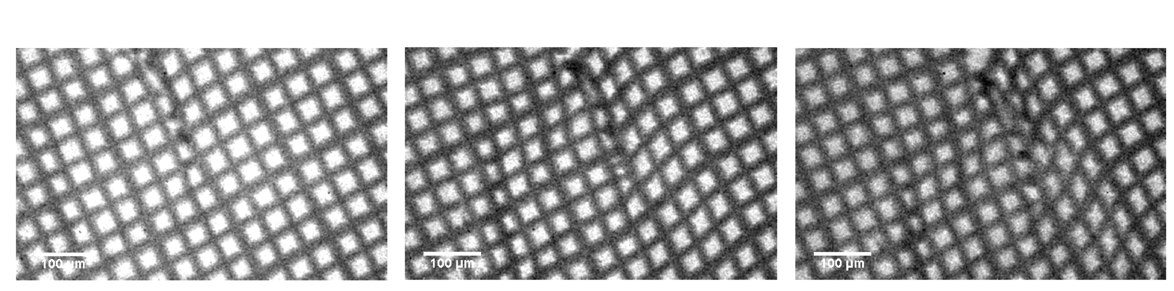
In-situ Flash X-ray Tomography of 3D Fracture under Dynamic Indentation

In-situ visualization of specimen 3D cracking process is vital to understand its dynamic fracture behavior and calibrate failure models. A high speed flash X-ray based method is developed to provide out-of-plane information of the specimen cracks during Kolsky bar indentation. This method is capable of producing sub-millimeter-resolution reconstructions of dynamic fracture process from very limited number of projections.



Visualization of Damage around a Propagating Dynamic Crack

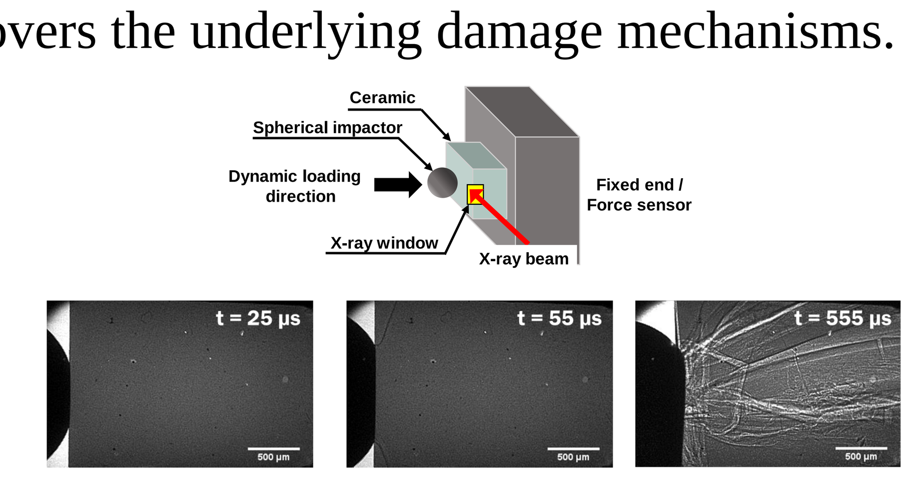
A propagating crack results in damage around its tip. The visualization of this damage filed is essential to understand the conditions that lead to dynamic crack propagation and the associated energy dissipation. A Kolsky bar integrated with the high-speed Synchrotron X-ray imaging technique is used to observe the damage field under dynamic loading in real time.



Dynamic compression of a notched polyoxymethylene (POM) 5 m/s, 1 MHz fps

Dynamic Hertzian Fracture of Ceramic

Dynamic hertzian fracture characterizes the high-rate toughness of ceramic materials. Advanced ceramics with improved toughness are relevant in serval applications including turbine engines. Real-time observation of the transient fracture process uncovers the underlying damage mechanisms.

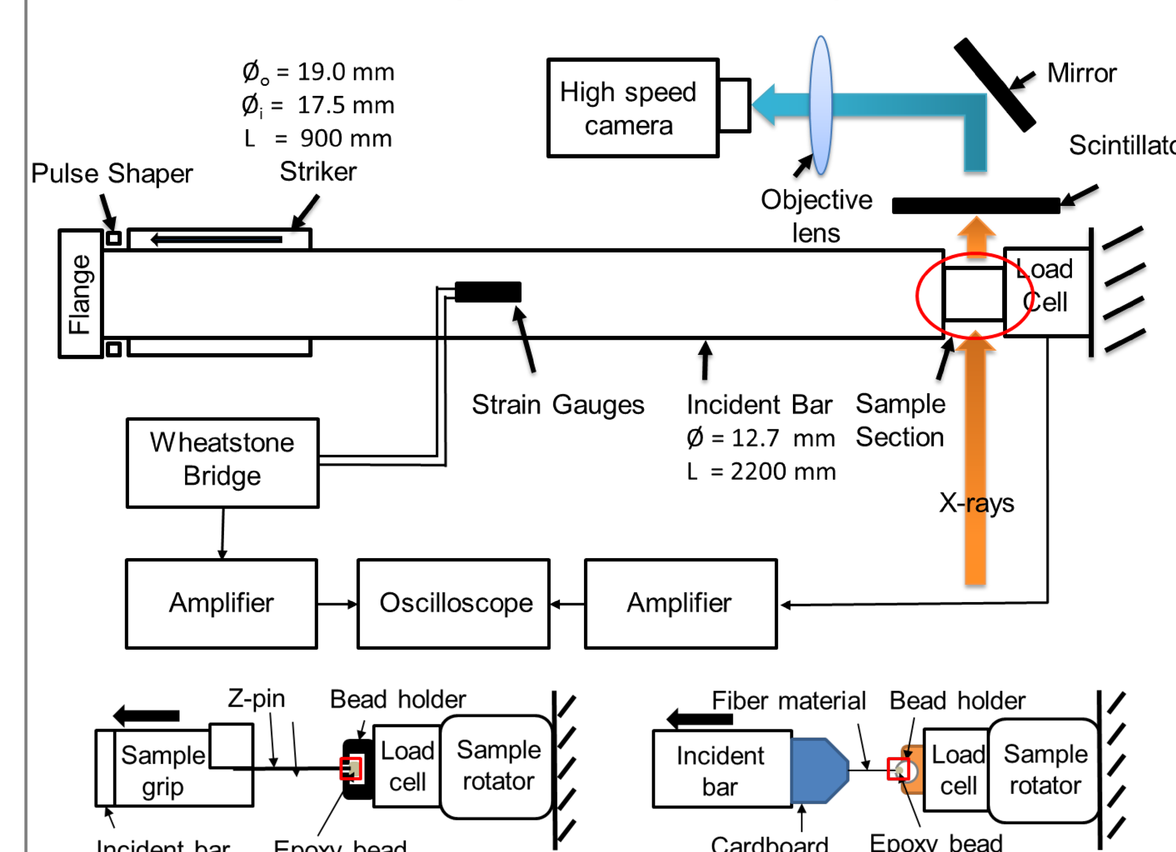


Dynamic indentation of Nitride ceramic 5 m/s, 2 MHz fps

Visualization of Dynamic Fiber/Matrix Interfacial Debonding Mechanism

The post-damage and post-failure behaviors of materials are crucial in the impact energy dissipation under impact loading conditions. To develop a physics-based models, it is necessary to identify the dynamic damage initiation and propagation mechanisms in composites that lead to the failure of the material. The Synchrotron X-ray visualization methods developed by Purdue and Argonne have made it possible to visualize such meso-scale mechanisms under high rate impact.

Experimental Setup



Results