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2018CerSuperTask2 - Characterization of dynamic mechanical properties and *in situ* visualization of fracture in boron carbide

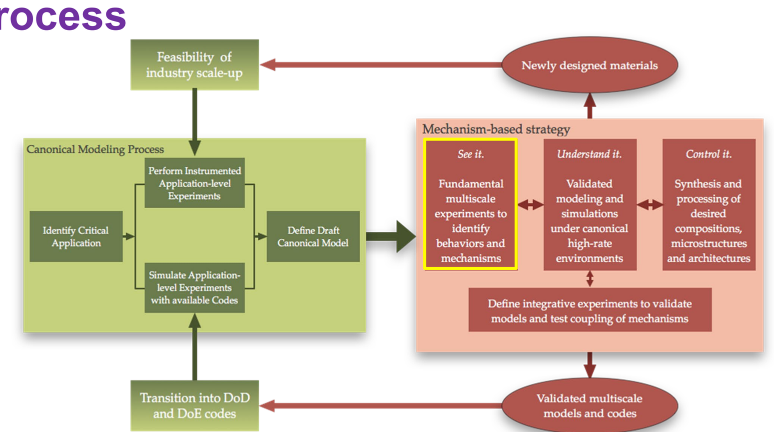
ARL

Enterprise for Multi-scale Research of Materials

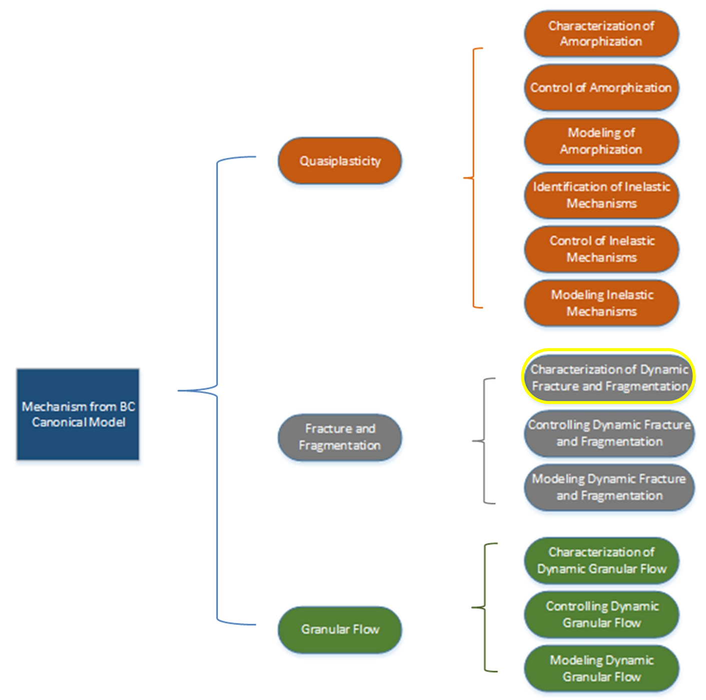
Jiajie Huang, Andrew F. T. Leong, Jason Parker, Hao Sheng, Ming Guan, Qinglei Zeng, K.T. Ramesh, Todd C. Hufnagel (JHU)
Nick Sinclair, Xianghui Xiao (APS) Brian E. Schuster, Daniel T. Casem (ARL)

How We Fit

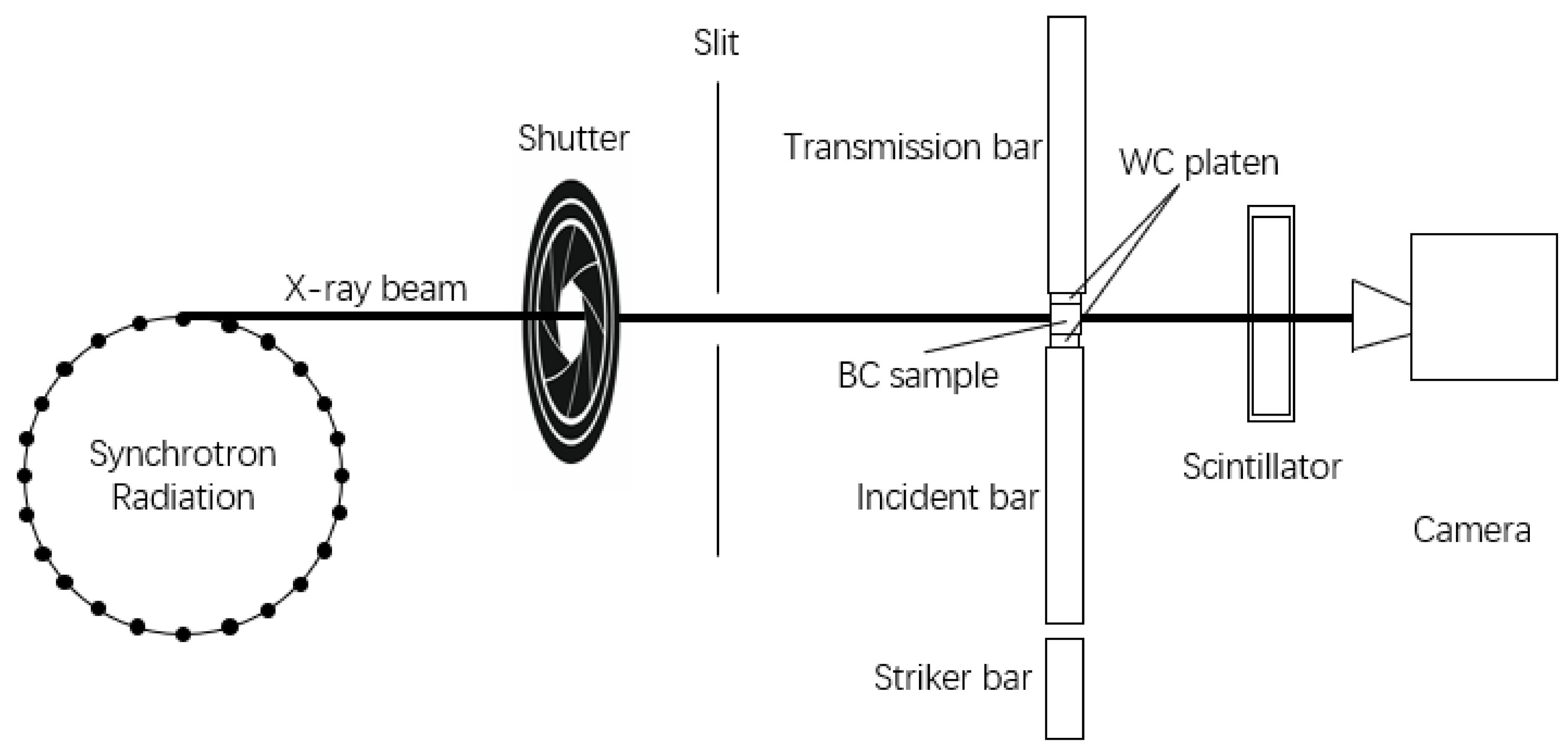
Materials-by-Design Process



Mechanism-based Approach



Technical Approach



- Commercial grade boron carbide cut into 1.5 mm cuboids with a 1 μm surface finish.
- X-ray phase contrast imaging performed at beamline 35-ID-C (APS-ANL).
- Kolsky bar uniaxial compression test was conducted at the same time.

Key Accomplishments

- Tested the viability of XPCI to visualize crack initiation and growth at high strain rates.
- Key fracture-related events in XPCI images correspond to changes in stress-strain curve.
- Measured damage semi-quantitatively using XPCI.
- Damage qualitatively consistent with density of cracks seen in the XPCI images.

Transitions to ARL, within CMRG and to other CMRGs

- Assistance of Casem, Meredith and Schuster from ARL with imaging experiments and image interpretation.
- Sharing of equipment for synchrotron experiments.
- Our experiments provide direct inputs on defect distributions to the models of Tonge *et al*.
- Our experiments provide key parameters for fracture modeling and examination of coalescence, with Sikhanda Satapathy (ARL), Robbins and Graham-Brady (JHU).
- Our experiments identify key subscale mechanisms for the integrative models of Qinglei Zeng (JHU).

Key Goals

- The superior hardness and low density of boron carbide (BC) makes it an ideal armor material.
- However, failure mode and damage extent of boron carbide under high strain rates are still unknown.
- X-rays possess the penetrative power and resolution to non-destructively study the defects in boron carbide and the intensity to study crack behavior *in situ*.

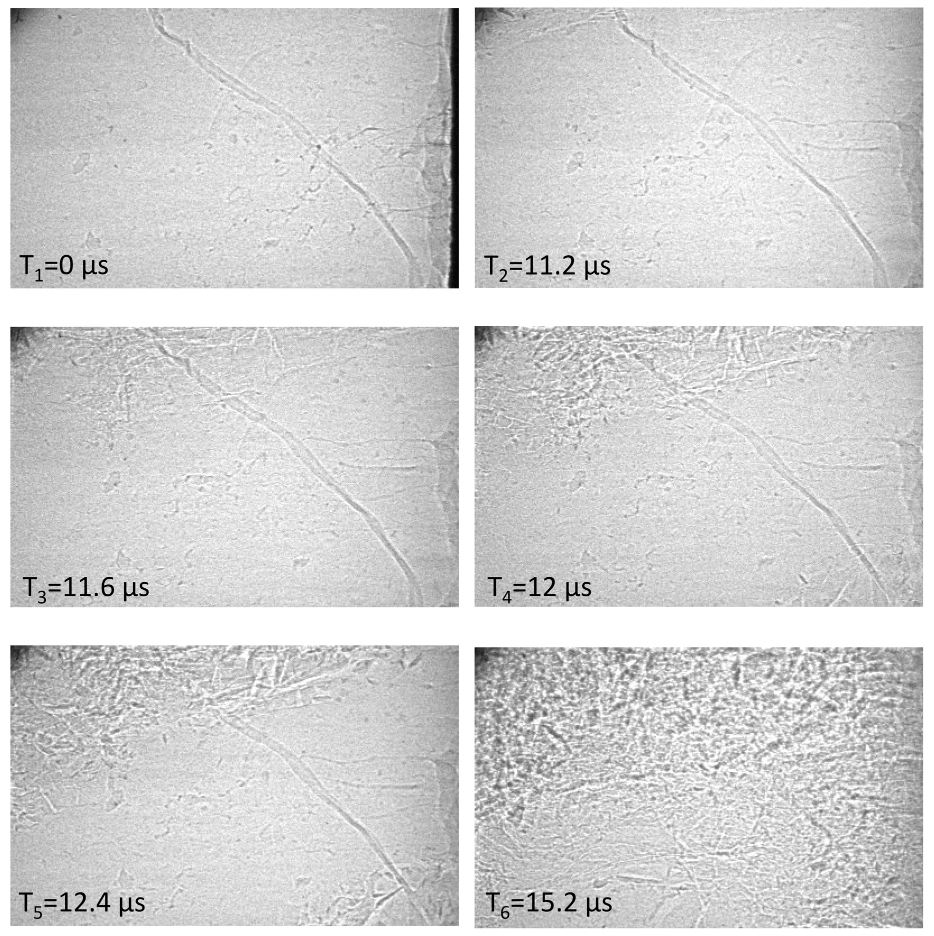
Effort is currently focused on using:

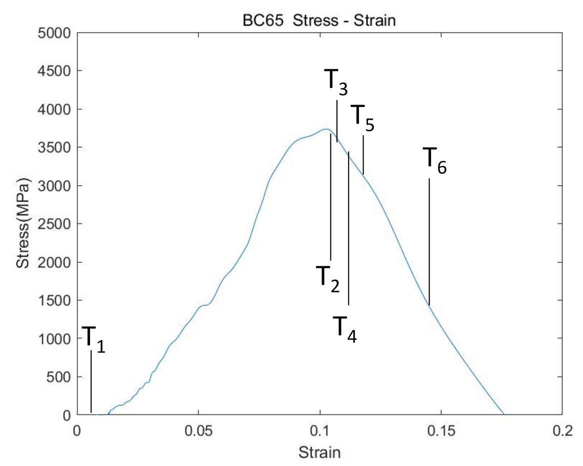
- Kolsky bar uniaxial compression test to characterize the dynamic mechanical properties of BC.
- X-ray phase contrast imaging to visualize crack behavior in real-time.

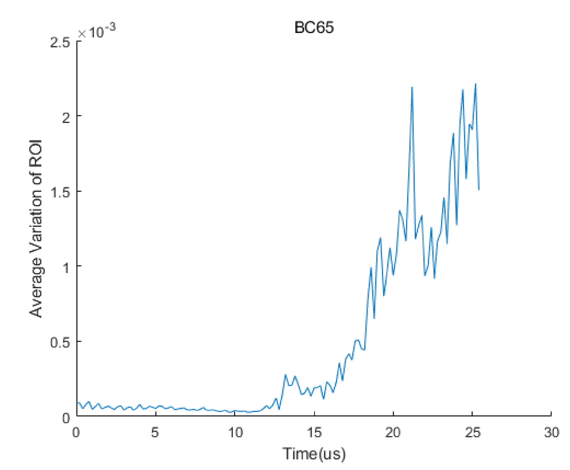
Objective

- Combine the dynamic mechanical properties and images derived by X-ray phase contrast imaging (XPCI) technique to understand the failure mode and damage extent of BC during high rate loading.

In situ visualization of fracture







Damage in BC is semi-quantified from XPCI image recordings by measuring the intensity signal variance in each image. The increase in the degree of damage correlates with the density of cracks seen in the XPCI images and the stress state of the BC sample.

Impact

Insight into dynamic properties and visualization of fracture can:

- understand the failure mode and damage extent of BC during high rate loading.
- Guide the development and validation of physics-based constitutive models for dynamic failure of brittle materials.
- Standardize fabrication of boron carbide-based materials to optimize its performance under extreme conditions.

References

- Tonge and Ramesh (2016) JMPS **86** 117-49
- Lamberson and Ramesh (2015) **87** 61-79

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