HIGH STRAIN RATE LABORATORY (HSRL)

Probing Materials at High Pressures and High Strain Rates

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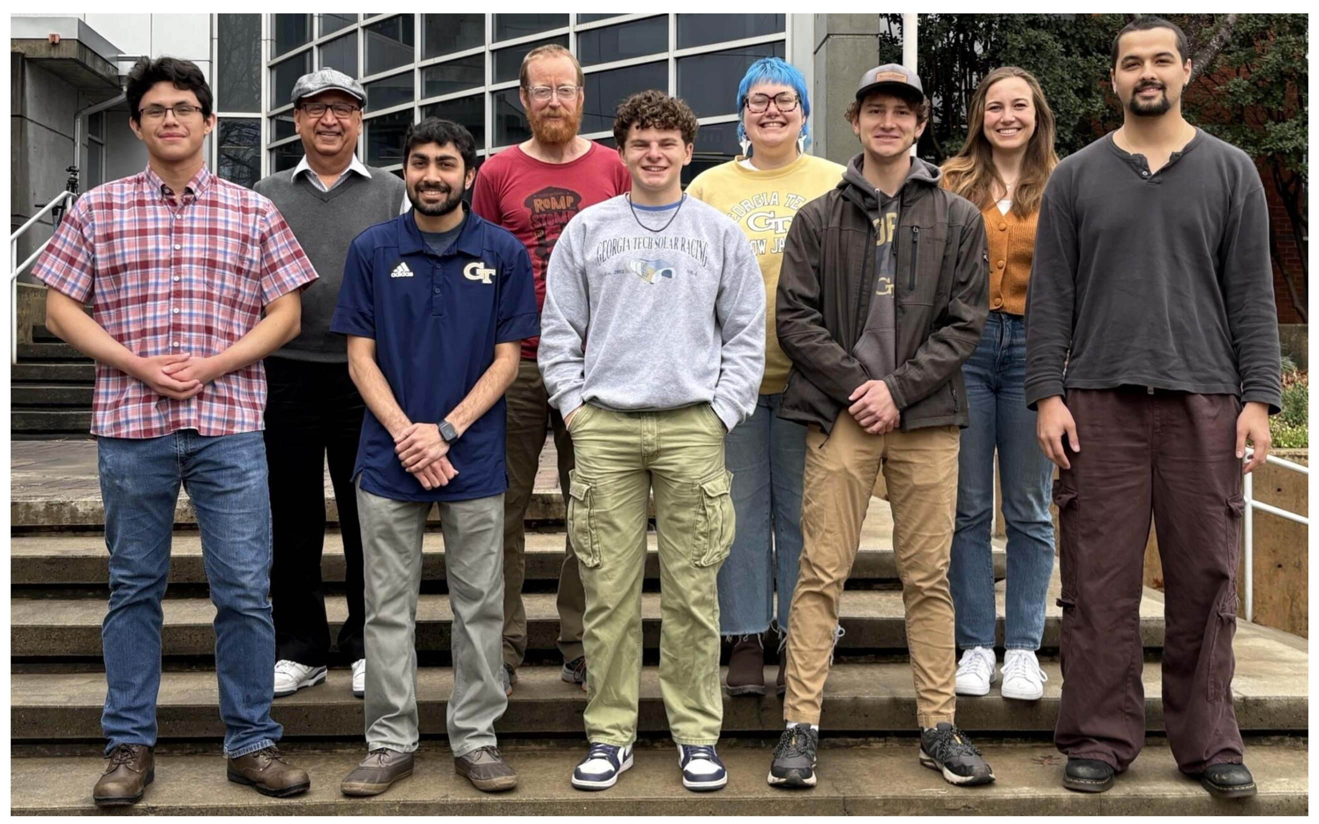
ABOUT HSRL

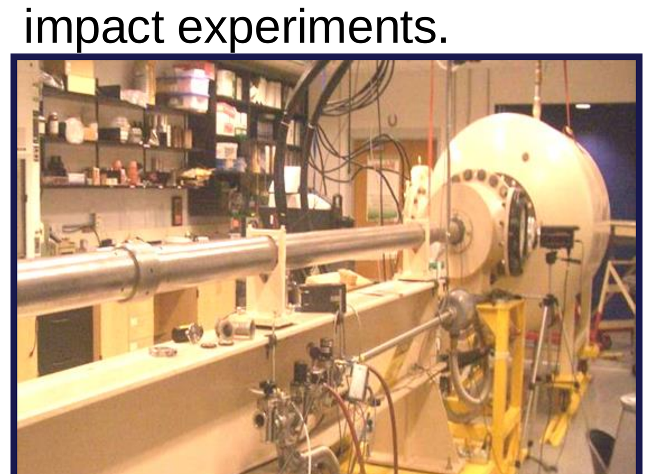
In the HSRL, we focus on probing materials under extreme dynamic conditions. Utilizing two light gas guns and a high energy pulse laser, we shock-compress materials to observe how high rates of strain and pressure affect material behavior and properties. GRAs develop as hands-on experimentalists while learning how to analyze data, simulate complex phenomena, and ultimately gain both expertise in this niche area of materials science and highly sought-after skillsets necessary to solve problems facing energy, space, or defense industries and beyond.



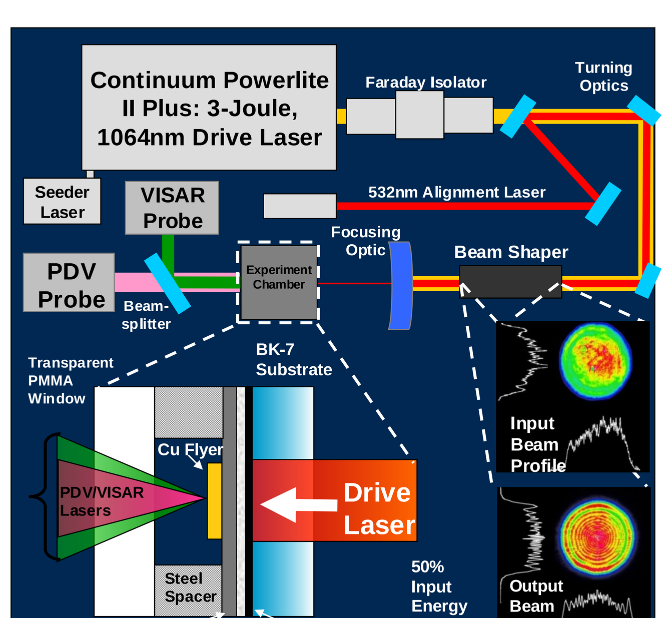
LABORATORY CAPABILITIES

Launch Systems and Diagnostics

Gun launched & laser launched systems are used to perform impact experiments.

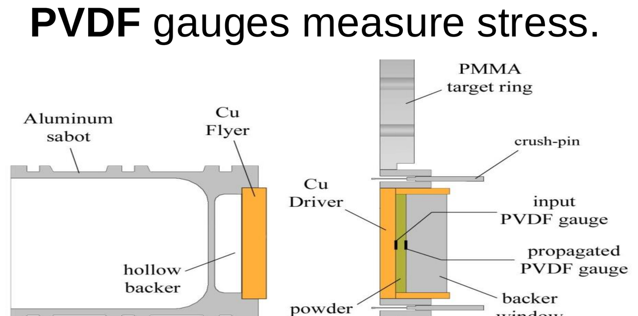


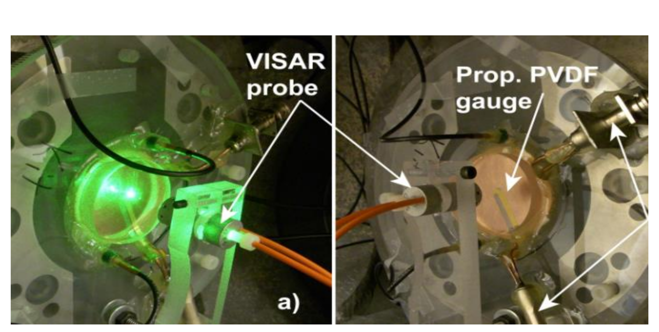
80-mm Gas Gun, 70 to 1200 m/s
7.62 mm Gas Gun, 50 to 1000 m/s

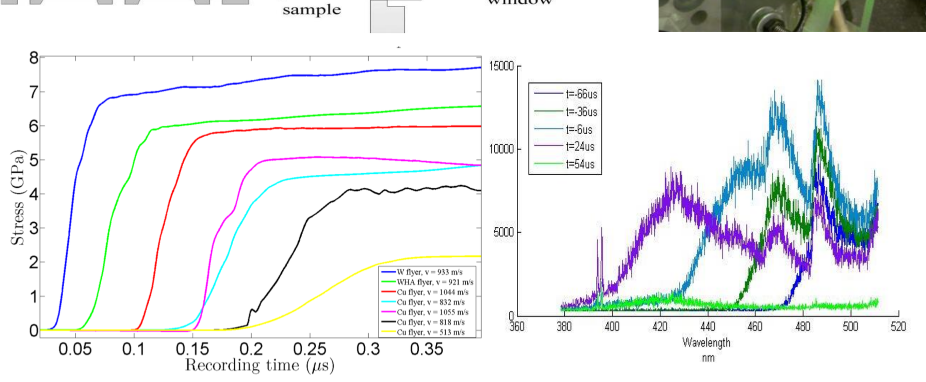


3-Joule 1064 nm Laser Setup

Laser interferometry is used to measure surface velocity while **PVDF** gauges measure stress.







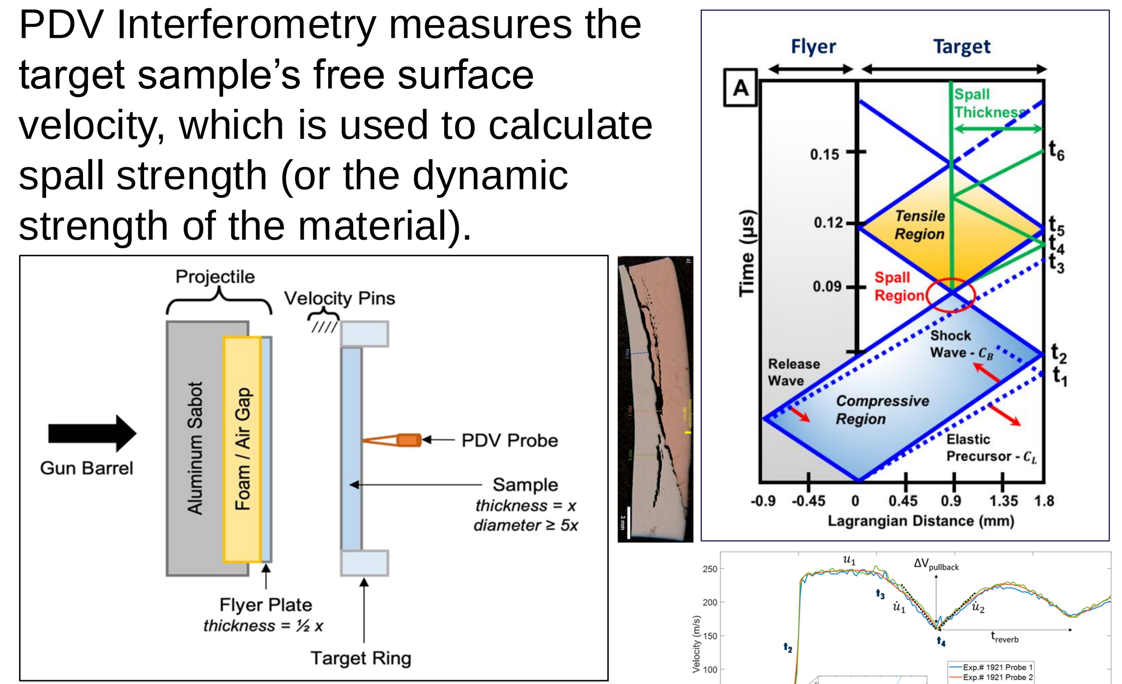
Resulting PVDF Stress Traces on back surface of sample for different impact velocities (left) while resulting wavelengths visualize reactions in Aluminum during shock compression (right).

Nanosecond-resolution diagnostics are used to probe shock induced physical, chemical, and mechanical changes in materials.

EXPERIMENTAL RESEARCH AREAS

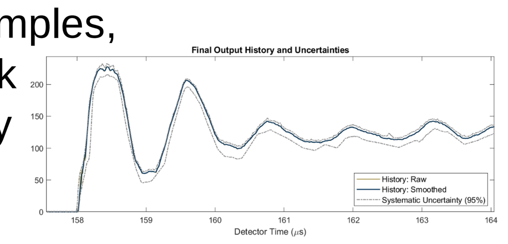
Spall Strength Measurements – Effects of Heterogeneities

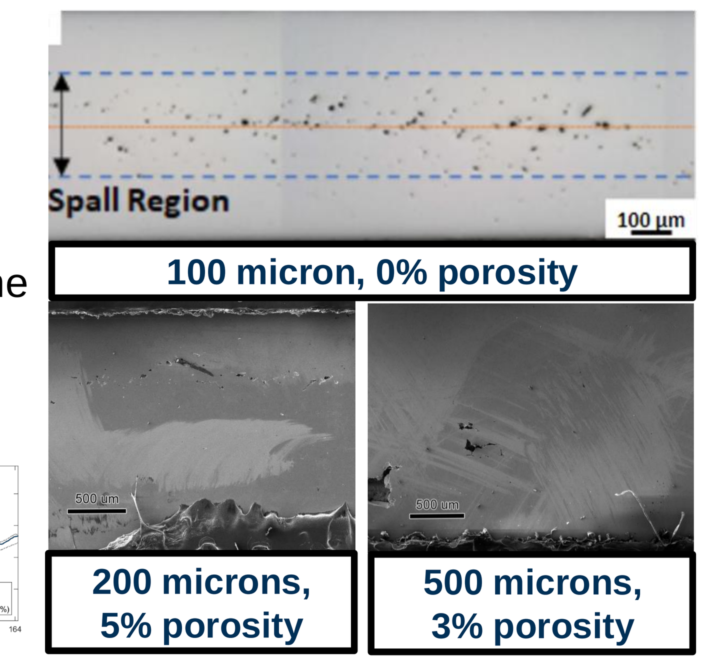
PDV Interferometry measures the target sample's free surface velocity, which is used to calculate spall strength (or the dynamic strength of the material).



$\sigma_{HEL} = \frac{1}{2}\rho_0 C_L u_{HEL}$ $\sigma_{spall} = \frac{1}{2}\rho_0 C_b(\Delta u_{fs} + \delta_{corr})$ $x_{spall} = \frac{1}{2}\Delta t_{spall} C_L$

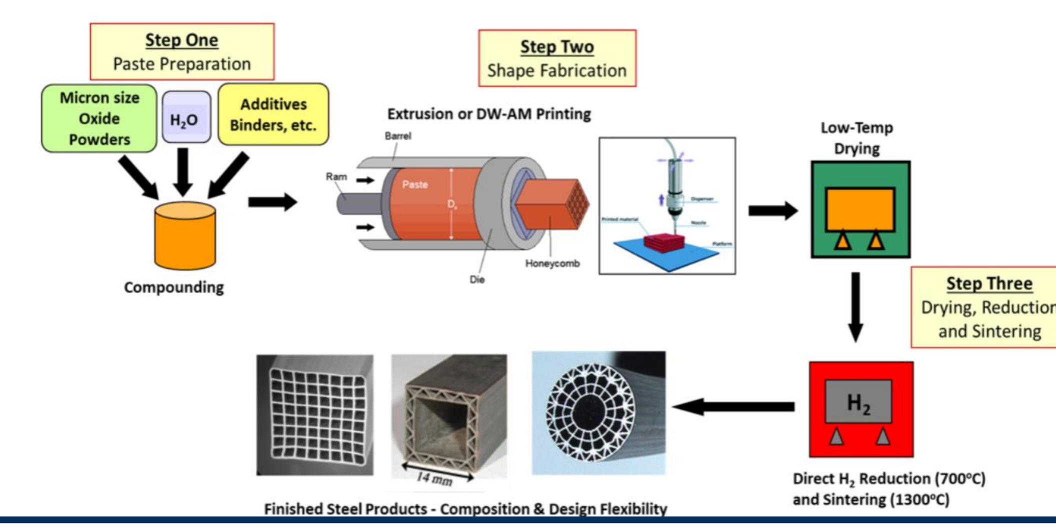
Shock compression of AM fabricated 316SS steel with intentional pores of controlled size and fraction shows complete absence or shifting of the spall plane due to shock energy dissipation. The pores slowed the shock wave movement through the matrix, evidenced by the shifting of the spall plane in low porosity samples, the lack of visible spallation in high porosity samples, and the lack of a velocity plateau in velocimetry data for all porosity levels.





Sustainable Steelmaking

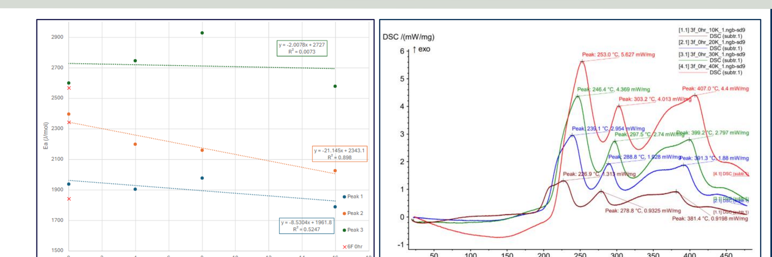
This project uses GT patented technology to produce net-shaped, high-value steel by direct hydrogen reduction.



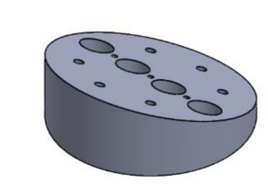
Process: Mix Fe_3O_4 + NiO + Co_3O_4 + Mo + TiH_2, extrude, reduce @ 900°C, inter-diffuse/sinter @ 1300°C
Product: Maraging 200 Steel (Fe-18Ni-12Co-4Mo-0.7Ti) at 20% density with 80% of solid axial strength

Thermal and Mechanical Ignition of Reactive Materials

This project **investigates the thermal & mechanical initiation of fast deflagration reactions** in Ni-Al nanolaminates under high rates of strain and pressure. Natural and artificial material aging can affect the onset and propagation of these reactions via the formation of intermixed constituent zones that act as a diffusion barriers.



Activation Energy vs Aging Time at different reaction peaks in DSC (left) and DSC curves generated from 0hr aged samples at different heating rates (right)

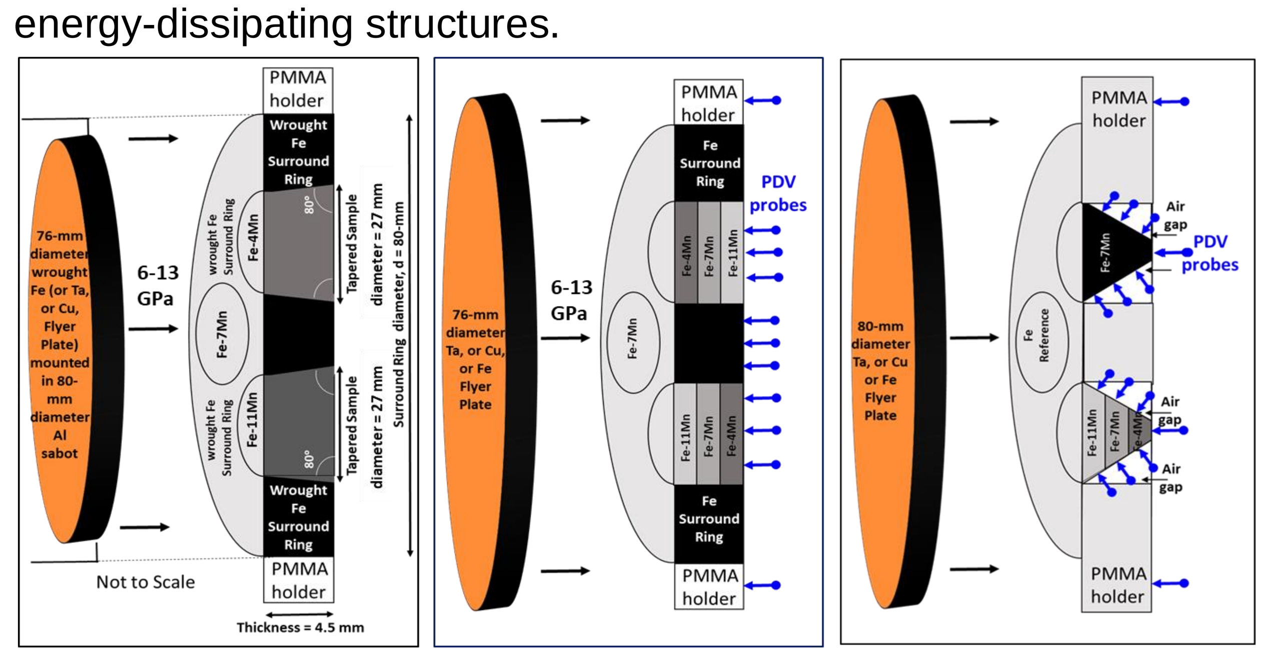


20 degree sample holder/ driver will allow angled flier to induce shear force on target samples

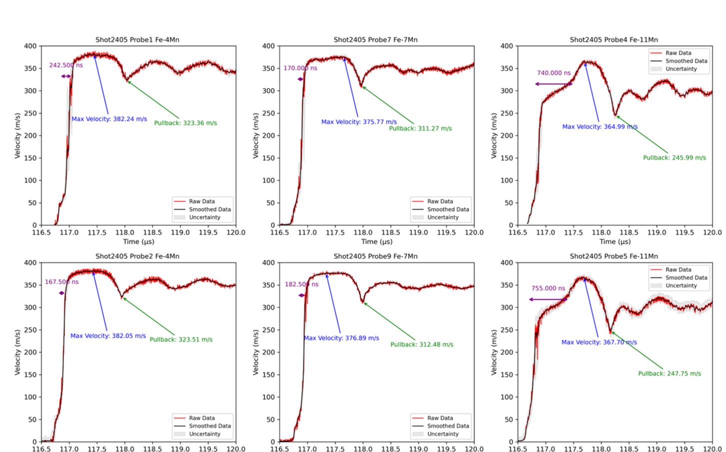
Pressure-shear oblique impact experiments will be performed for characterization of mechanical ignition of reactions.

Shock Disruptions in Fe-Mn Layered Alloys

This project seeks to investigate the shock disruptions caused by volume-changing phase transitions and wave interactions with impedance matched/mismatched interfaces, and their effects on spall failure for predicting materials response and designing energy-dissipating structures.



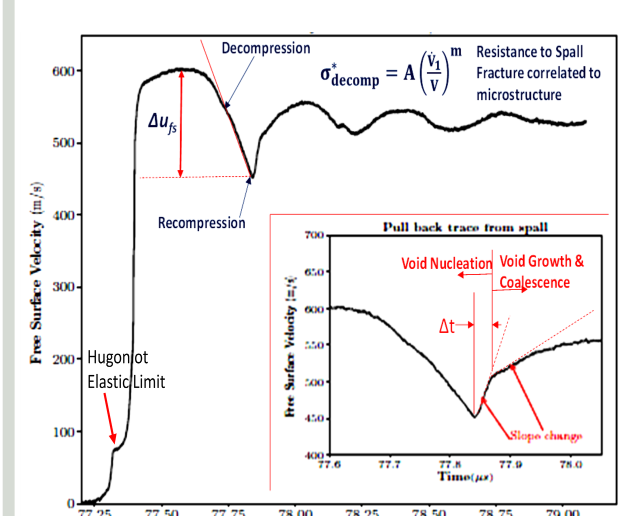
Experimental design of sample holder depicting tapered out (left), no taper (middle) and tapered in (right) sample holders and corresponding PDV probe locations. This setup allows for the data collection of wave interactions for subsequent analysis.



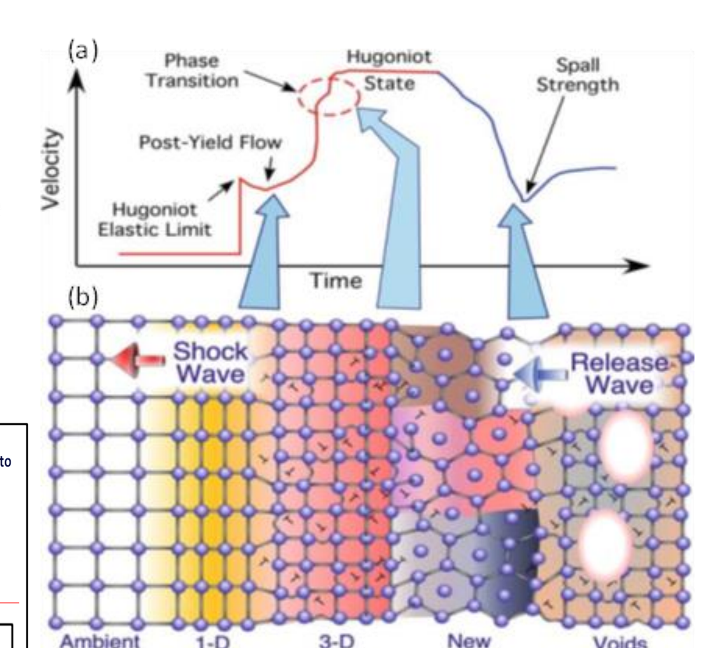
Resulting back-surface velocity profiles from initial testing captured using PDV can be used to identify phase changes and compared to analyze wave interactions.

Probing Effects of Dissipative Processes on Spall Failure of Materials

This project aims to understand how **mesoscale structure** influences shock **wave dissipation** and **spall failure** in AM fabricated single and mixed phase Ti5553 and compositionally graded Ti-Ta alloys.



Free surface velocity profile indicating elastic Limit, spall pullback velocity, and decompression and recompression events.

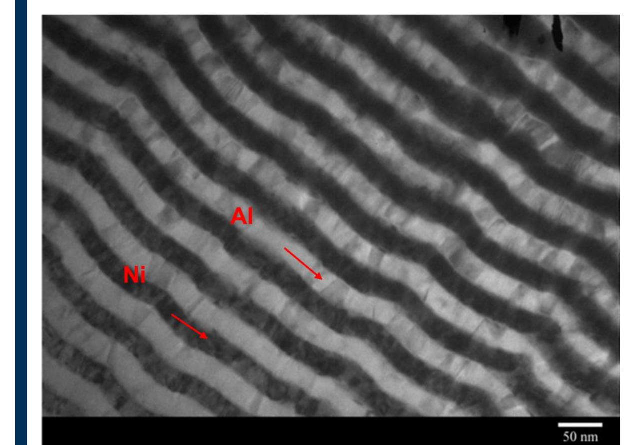


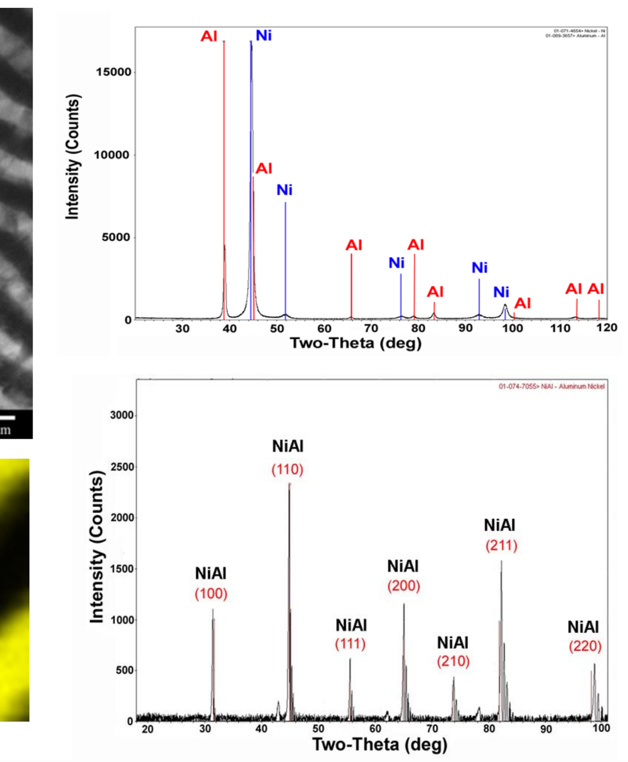
Shocked solid and corresponding velocity profile associated with material properties. Changes due to dissipative processes are indicated

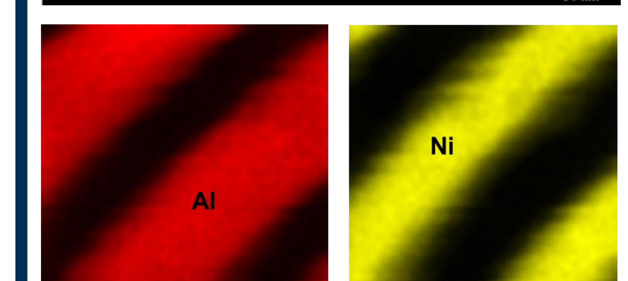
Gas-gun and planar impact experiments with soft-recovery will be used in conjunction with time-resolved optical, interferometry, and x-ray diagnostics to characterize dissipative processes associated with shock-induced deformation and their effects on spall failure.

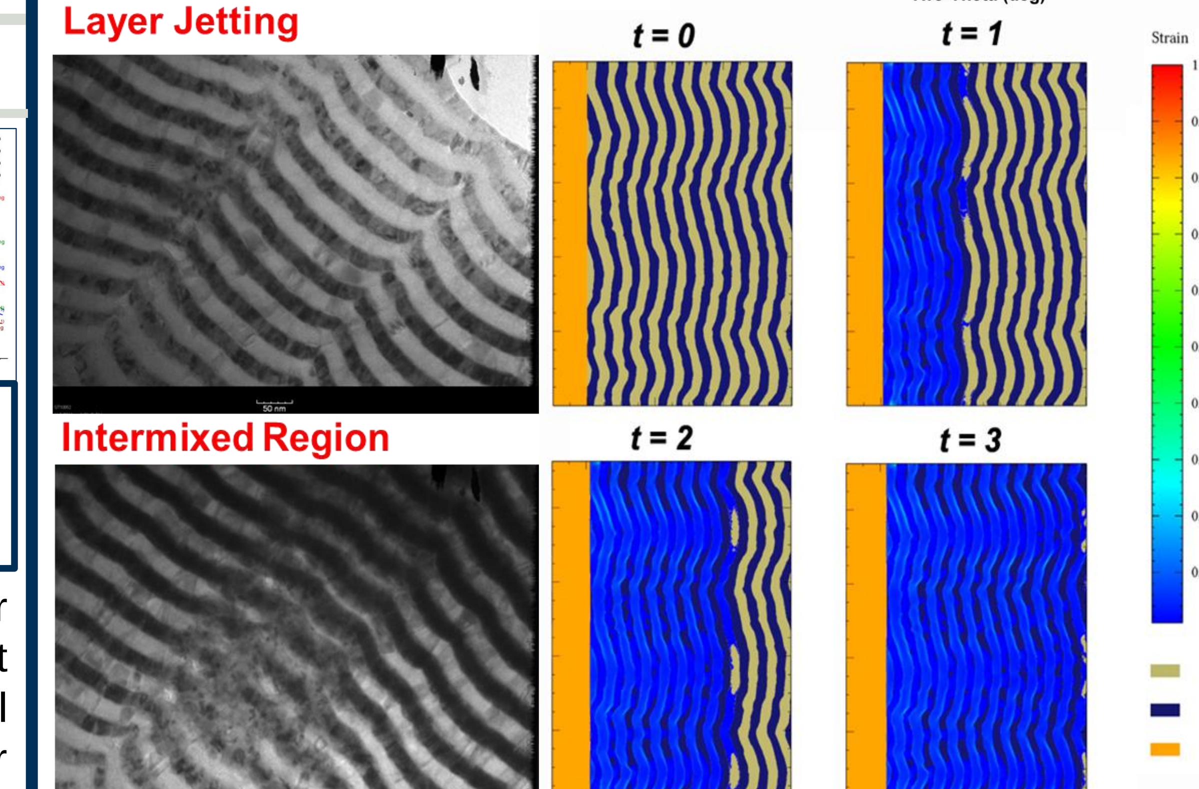
COMPUTATIONAL SIMULATIONS

Shock Chemistry in Nanolayered Ni+Al

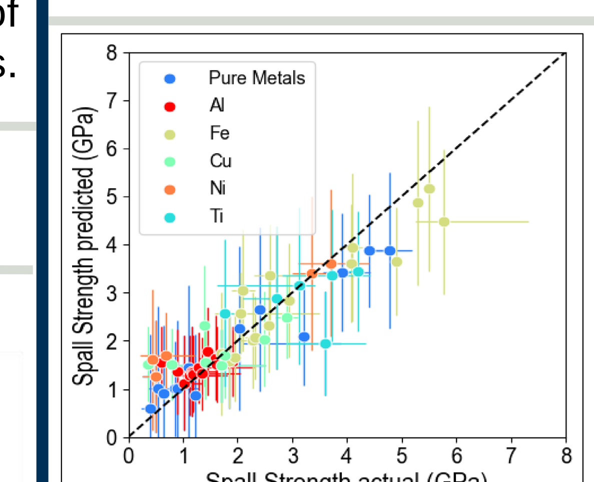


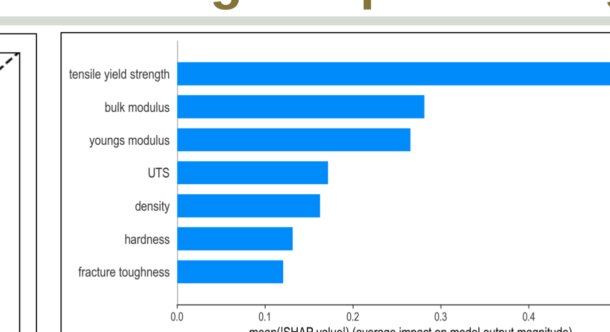






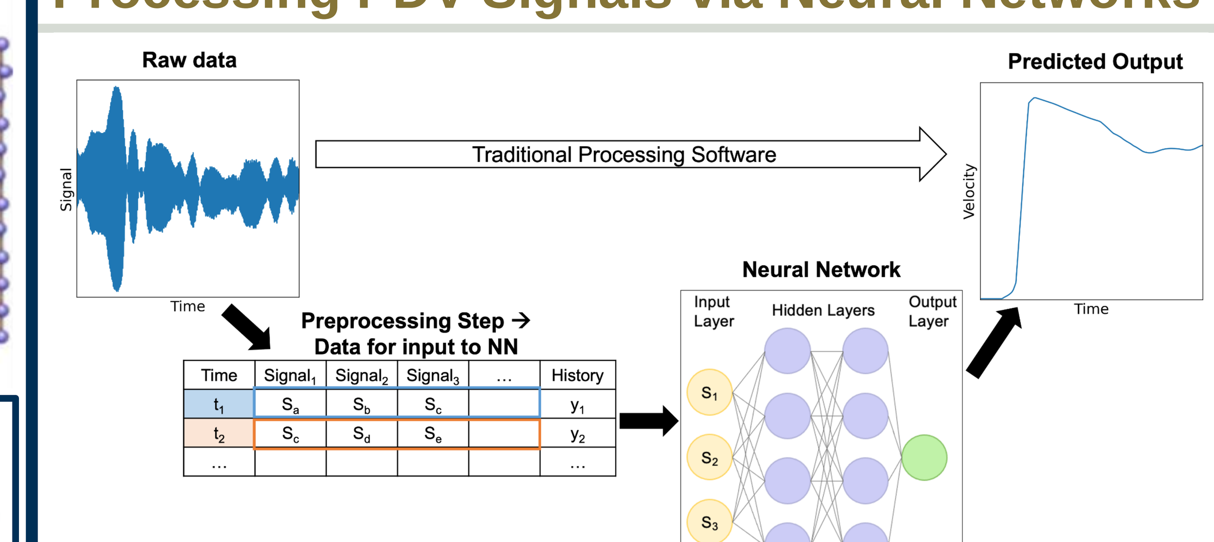
Predictive Machine Learning of Spall Strength





SHapley Additive exPlanations (SHAP) approach for importance of feature value

Processing PDV Signals via Neural Networks



Methods that can be used to process PDV signals

Advantages of using NN method compared to traditional processing methods:

- Automatic generation of history profile with no need for human intervention
- Faster than the traditional approach
- Expected to give optimum results because it will learn from past inferences

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