Experimental Techniques for Composite Interphases

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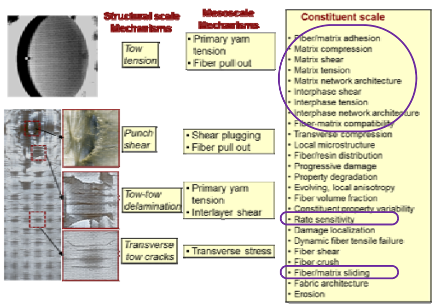
Enterprise for Multi-scale Research of Materials

How We Fit

Materials-by-Design Process

Mechanism-based Approach

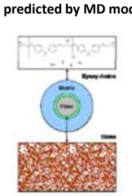


Goals and Motivation

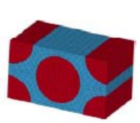
- Establish high strain rate mixed mode traction separation laws for glass fiber/epoxy interphases
- Design interphase for maximum energy absorption from both resin plasticity and interphase debonding mechanisms

Develop high strain rate mixed-mode traction-separation laws for glass fiber/epoxy interface

Validate traction laws predicted by MD models



Input to unit cell composite models

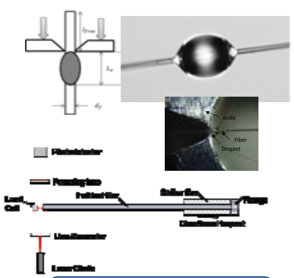


Input to fiber-level impregnated tow models

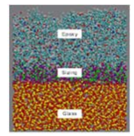
Technical Approach

Novel Kolsky Bar Techniques at the Nanometer to Micron Scale With Real Time Sensing and Visualization

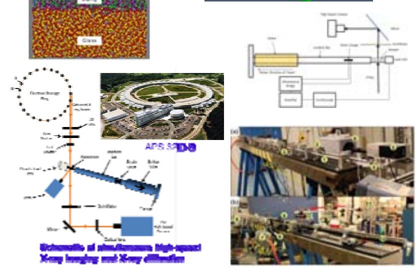
S-glass/epoxy microdroplet



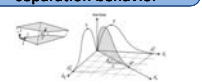
S Glass/Epoxy Interphase



S-glass/epoxy cruciform



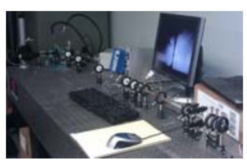
Validate MD prediction interphase traction separation behavior

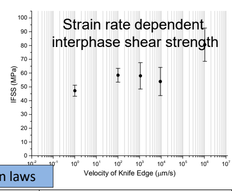


Visualization of damage in interphase

Major Results

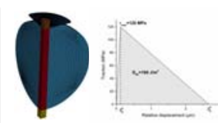
HSR S-glass/epoxy interphase characterization covering six decades of loading (up to 1.5x10^7 s^{-1})





FE modeling the QS and HSR microdroplet test method
Cohesive zone modeling of the interphase between fiber/matrix

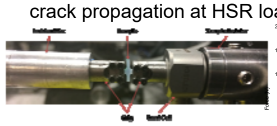
Mechanisms
Mixed mode damage initiation followed by mode II dominated crack propagation
Progressive interfacial debonding, frictional sliding

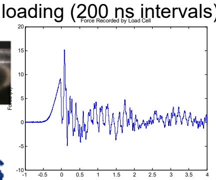


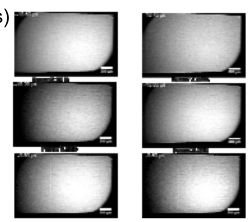
Traction separation laws

Sizing		Experimental IFSS (MPa)	Traction separation law	
Silane	Film former		Peak traction (MPa)	Critical energy release rate (J/m²)
γ-GPS + γ-PTMO	DGEBA epoxy	62	120	160
γ-APS	Silylated polyazamide	110	180	450
Commercial sizing γ-GPS, epoxy		47	120	110

Real time visualization of S-glass/epoxy interphase crack propagation at HSR loading (200 ns intervals)

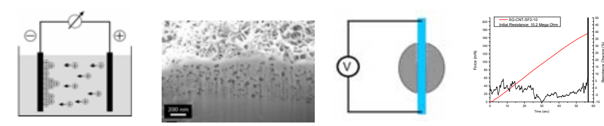






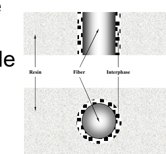
Key Accomplishments

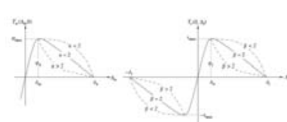
- Developed HSR Kolsky bar experimental technique for composite interphase characterization at the micromechanical length scale
- Real time visualization of interphase crack propagation at HSR loading with synchrotron X-rays at Argonne National Lab
- Modeling methodology to determine interfacial traction separation laws
- Carbon nanotubes (CNTS) as non-invasive sensor for crack monitoring

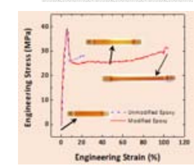


Future Directions

- Validate interphase mechanisms to maximize energy absorption during impact
- Interphase characterization under mixed mode HSR loading conditions using Drexel resins
- Validate MD traction laws and bridge length scales for composite RVE models
- Visualize damage in model composite







Impact

- New high strain rate interphase tests methods at the nanometer to micron length scale (insitu sensing visualization)
- Improved understanding of energy absorbing mechanisms within the interphase and the synergistic role of resin behavior
- Characterization and quantification of interphase properties at different loading rates for multi-scale models
- Critical element of materials-by-design framework for composite materials under high rate loading
- Will lead to improved protection materials while decreasing the cost and time for development of new lightweight energy absorbing composite materials

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