GATE Center of Excellence at UAB for Lightweight Materials and Manufacturing for Automotive, Truck and Mass Transit

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Birmingham, Alabama

June 2015

Project ID# LM081

Project No: DE-EE-0005580
Program Manager: Adrienne Riggi

GATEWAY TO THE FUTURE
GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

UAB

This presentation does not contain any proprietary or confidential information

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Project Summary

Timeline
Project Start - Oct 2011
Project End – Sep 2016
77% complete

Budget
Total project: $750,000
DOE portion: $600,000
University Cost Share: $150,000
$600,000 DOE
$462,000 Expended
77% complete

Barriers
- Limited information on advanced materials database
- Lack of high temperature properties
- Personnel with comprehensive experience in advanced composites design, modeling & manufacturing

Partners
- ORNL
- MIT-RCF
- Owens Corning
- Polystrand, PPG
- Toyota R&D Center

Relevance

Overall VTP Relevance

- “Development and validation of advanced materials and manufacturing technologies to significantly reduce automotive vehicle body and chassis weight without compromising other attributes such as safety, performance, recyclability, and cost.”

DOE GATE Relevance

- “To provide a new generation of engineers and scientists with knowledge and skills in advanced automotive technologies.”
- Train and produce graduates in lightweight automotive materials technologies
- Structure the curricula to produce specialists in the automotive area
- Expose minority students to advanced technologies
- Develop innovative virtual classroom to expose students to manufacturing
- Integrate synergistic activities for design, product development and manufacturing technologies for next generation cars, trucks and mass transit vehicles.

Materials Processing & Applications Development (MPAD) Center at UAB – The research focus is on applications development with rapid transition for commercial and defense applications.

- 27,000 sq.ft. of industry scale equipment for advanced manufacturing
- 10 years history of rapid technology transition to industry – defense, transportation, infrastructure, aerospace and marine
- Strong industry partnerships with materials suppliers, integrators and end users; more than 40 active NDA's with industry collaborators.
- Partnerships with federal & state agencies, and national labs (NSF,DOD, DOE, etc)
- UAB provides incubation opportunities for start-up / spin-off companies

Advanced Composites Manufacturing 9000 square feet

New space 12,750 square feet for advanced Manufacturing acquired April 2015

Advanced Metals Manufacturing 9000 square feet

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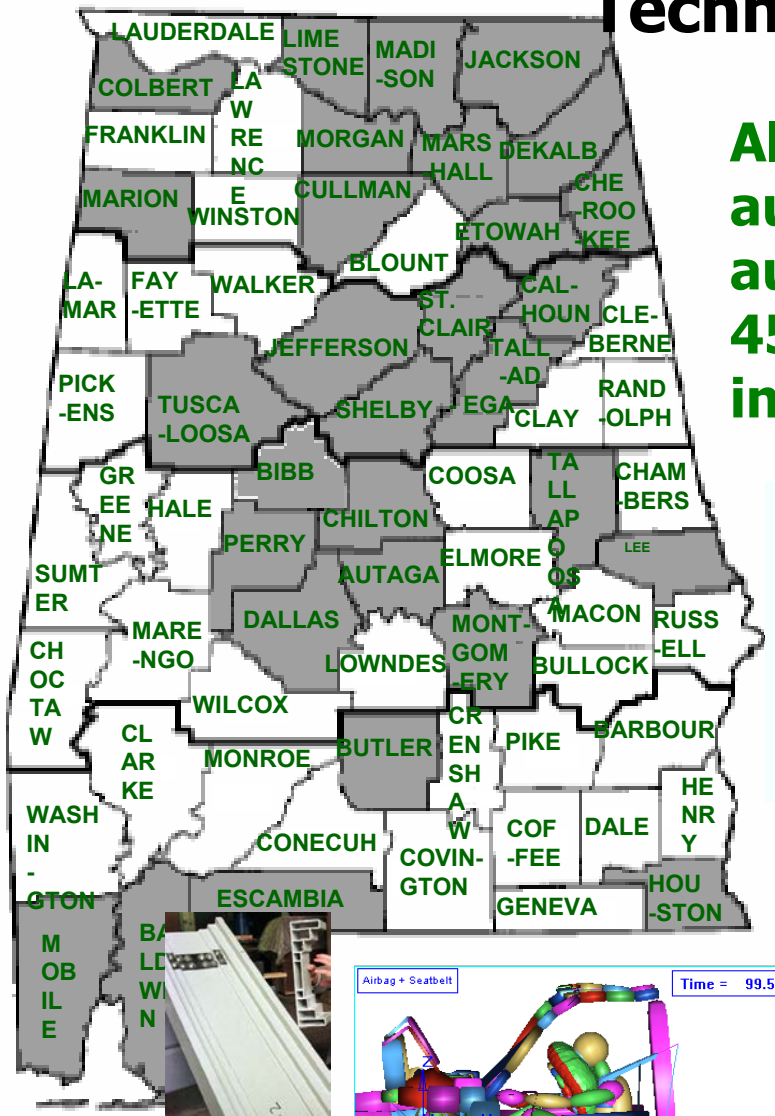
Automotive Industry Impact in the State of Alabama – UAB DOE Graduate Automotive Technology Education (GATE)



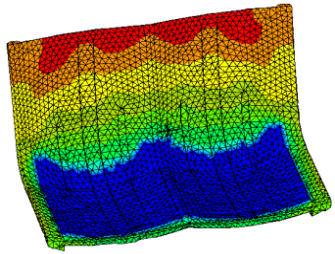
Alabama has a rapidly growing automotive industry. Since 1993 the automotive sector has created more than 45,000 new jobs and $8 billion in capital investment in Alabama.

- Training students in advanced lightweight materials and manufacturing technologies.
- Design and manufacturing of future generation transportation, including automobiles, mass transit and light, medium and heavy trucks.

Modeling of crash & protective padding

High speed computational facility

Automotive castings



Process modeling

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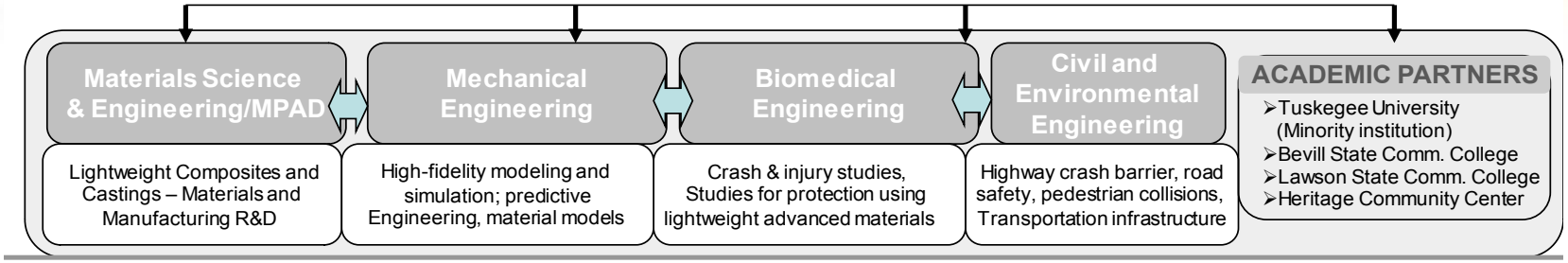
UAB GATE Center for Lightweight Materials and Manufacturing for Automotive and Transportation



TECHNICAL AREAS FOR GATE SCHOLARS THESIS / DISSERTATIONS

Lightweight Materials & Manufacturing – Engineered Composites / Castings / Enhanced Crashworthiness
(*Basic science studies leading to Prototype/Application Development & Commercialization*)

Next Generation Carbon Fiber for Automotive &Transportation	Textile grade carbon fiber; reclaimed carbon fiber; wet laid carbon fiber; intermediate forms, effects of sizing; compounded carbon/foams; LFT injection & compression
Next Generation Renewable Materials for Automotive &Transportation	Interface treatment of biocomposites, Bioresins, Moisture uptake and prevention; Processing and blending of natural fibers with synthetic fibers
Advanced Metal Castings	Magnesium and aluminum casting; Austempered steels, Lost foam casting, In-situ X-ray analysis, predictive engineering , pressure assisted casting
Biomechanical studies / Crashworthiness modeling	Injury biomechanics, side impacts-material/body interaction on pelvis; crashworthin--ess modeling; body collision, pedestrian and child car safety studies

INDUSTRY & Other Partnership

- ➢Automotive & Mass Transit Companies
- ➢ Economic Development Partnerhship Agency (EDPA)
- ➢Material Suppliers & End-Users
- ➢Alabama Manufacturers
- ➢ National Composite Center
- ➢ American Chemical Council

NATIONAL / DOE LAB Partnership

- ➢Oak Ridge National Lab (ORNL)
- ➢Pacific Northwest National Lab, (PNNL)
- ➢National Transportation Research Center (NTRC)
- ➢US Department of Agriculture (USDA)

ADVISORY BOARD

- ➢ Automotive & Heavy truck reps (Mercedes, Honda, others)
- ➢ DOE program managers_
- ➢ Material focused industry reps
- ➢ Economic Development reps

2014-2015 Milestones

Milestones	Status
Support 3 graduate students/year (two supported by DOE and one cost shared by UAB) with research projects focused on automotive applications	GATE scholars - Danila Kaliberov, Kristin Hardin, Hicham Ghossein, Qiushi Wang (Graduated, PhD), Melike Onat (Graduated, PhD) Siddhartha Brahma; Dominique Everett and Mark King Jr (new students)
Support 4 undergraduates each year in automotive related research	Hayden Martin, Sarah Elliott, David Gilmore, Danish Guelemans, Lonnie Butler
Develop and offer automotive related courses with the potential to impact 20 – 30 students per year	Frontiers of Automotive Materials – 30 students enrolled (Summer 2015) / Online offering
• Influence at least 30 students per year through hands-on workshops • Undergraduate students (promote graduate studies) • High school students (exposure to automotive area) • Include a focus on minority students (tap into workforce)	DOE GATE workshops on lightweight metal casting, composites manufacturing, materials selection and recycling offered Summer & Fall 2014 and Spring 2015.
Interact with industry and DOE Labs	• Interaction with ORNL CFTF and materials team • ~15 industry relationships leveraged

Approach/Strategy

What is Project Intended to Accomplish?

- To provide a new generation of engineers and scientists with knowledge and skills in advanced automotive technologies.

Project objectives, including tasks from Statement of Project Objectives

- Train and produce graduates in lightweight automotive materials technologies
- Structure the engineering curricula to produce specialists in the automotive area
- Leverage automotive industry in the State of Alabama
- Expose minority students to advanced technologies early in their career
- Develop innovative virtual classroom capabilities tied to real manufacturing operations
- Integrate synergistic, multi-departmental activities to produce new product and manufacturing technologies for more damage tolerant, cost-effective, and lighter automotive structures.

How project is integrated with other research or deployment projects within the VT Program – Close interactions with DOE Oak Ridge National Laboratory Carbon Fiber Technology Facility (CFTF).

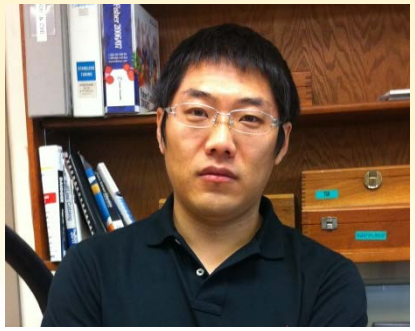
Milestones: GATE scholars, industry and DOE interaction and course offerings are on target

Current GATE Scholars

Mark King
PhD topic: Chemistry of interfaces

Kristin Hardin
PhD topic: Thermoplastic Recycling compounding

Alejandra Constante
PhD topic: Thermoplastic Biocomposites



Qiushi Wang
PhD topic: New Test Standards in Carbon Thermoplastic

Dominique Everett
PhD topic: Sound and vibration optimization in advanced materials

Danila Kaliberov
PhD topic: LFT & CFTF joining

William Warriner:
PhD: Process modeling of lightweight metals

Ahmed Hassen
PhD topic: NDE of long fiber thermoplastics and lightweight metals

Siddhartha Brahma
PhD topic: Carbon thermoplastics

Melike Dizbay-Onat
PhD : Nonowvens for emission reduction

Hicham Ghossein
PhD topic: Wet-laid Carbon fibers

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DOE GATE Undergraduate Pipeline

Austin Shorter, Junior, MSE

Dominique Everett,
Bridge to Doctorate

Sarah Elliott, Senior, MSE
ORNL intern, Summer 2015

Danila Kaliberov, U/G to PhD, MSE

Kelly McCool, Junior, MSE

GATE students working on Industrial scale facilities - Training

Theresa Bayush (MS candidate) and Melike Onat (PhD candidate) working on natural fiber extrusion

Alejandra Constante (PhD candidate) and Samuel Jasper (PhD candidate) working on composite beams

- **35 graduate students**
- **~20-30 undergraduate work study/semester**
- **Experiential Learning Academy / Short courses**
- **100's of class tours – UAB & partner schools**

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GATE fellows to date (2006-present)

32 graduate students (9 MS + 23 PhD)

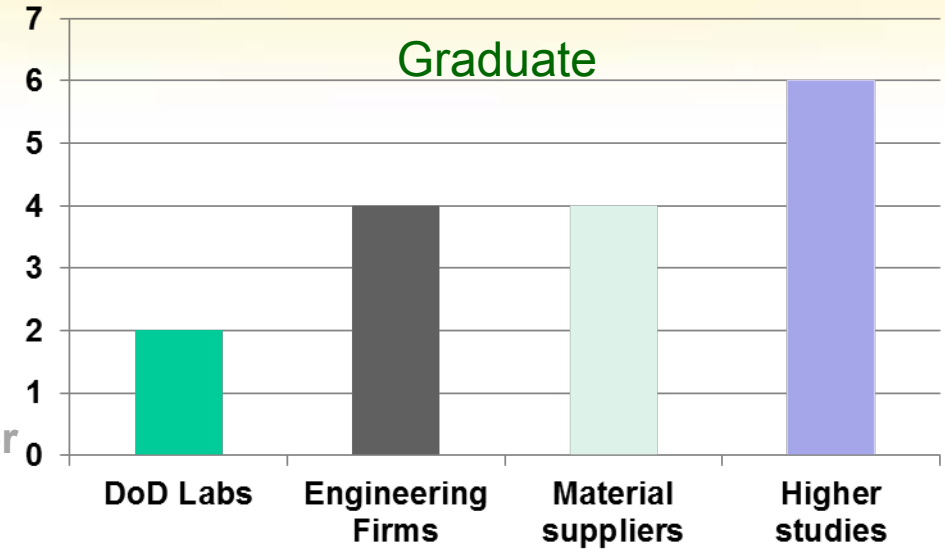
- **Partially or fully funded by DOE GATE**
- **Research dissertation/thesis focus on GATE topics**
- **Peer-reviewed research publications & papers**

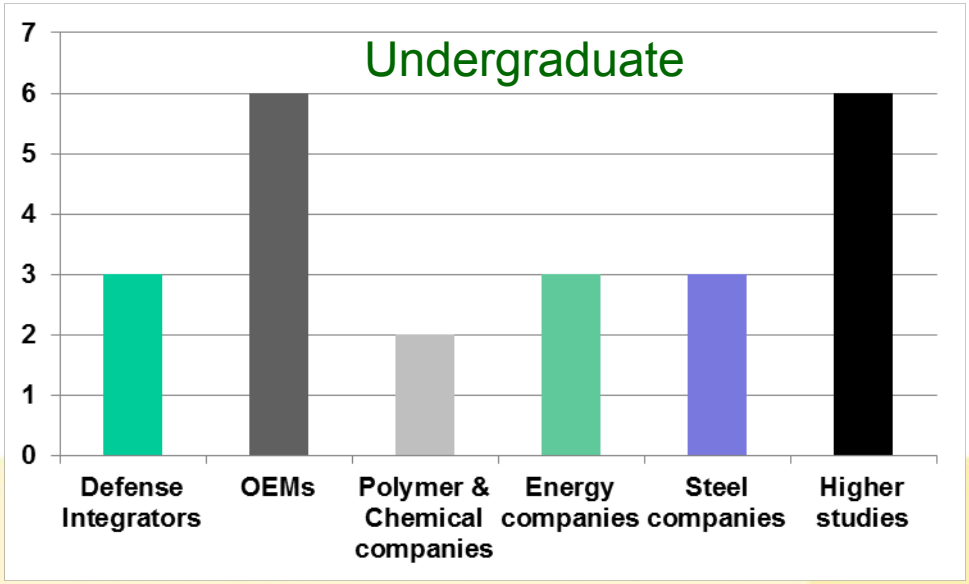
40+ undergraduate students (GATE funded)

- **Work study students serve as pipeline for graduate program & GATE fellows**
- **Experiential learning**
- **8 transitioned from undergraduate to become GATE scholars**
- **Participate in poster competitions and undergraduate research forums**

<u>Approximate Demographics</u>

- **30% minority (African-Americans & Hispanic Americans)**
- **40% female engineers**
- **50% Interdisciplinary fields**





Experiential Learning Academy (ELA) – June-July 2014; 22 high-school, community college and freshmen from outside UAB

Students gain experience in advanced materials and sustainable manufacturing, modeling and characterization

Experiential Learning Academy 2014

GATE courses

(some newly developed, some based on tailoring content in existing courses)

- Frontier of Automotive Materials
- Composite Design and Manufacturing Technologies for Automotive Applications
- Process Modeling and Simulation for Lightweight Materials
- Optimized Lightweight Material Designs for Prevention of Crash-Related Injuries
-
- Composites Manufacturing
- Advanced Composite Mechanics
- Nano materials for Automotive Applications.
- Process Quality Engineering
- Nondestructive Testing & Evaluation

- Carbon Fiber Technologies for Automotive and Truck
- Sustainable/Renewable Materials and Processing Technologies for Automotive
- Predictive Engineering – Integrated Process Modeling and Design in Composites & Castings
- Materials by Design for Heavy Trucks and Mass Transit
- Materials and Design for Fuel Cell and Hybrid Vehicles
- Modeling and Simulation for Crashworthiness

A GATE scholar takes at least 6 courses of the above 14. The GATE certificate option will be make available to the industry participants as well.

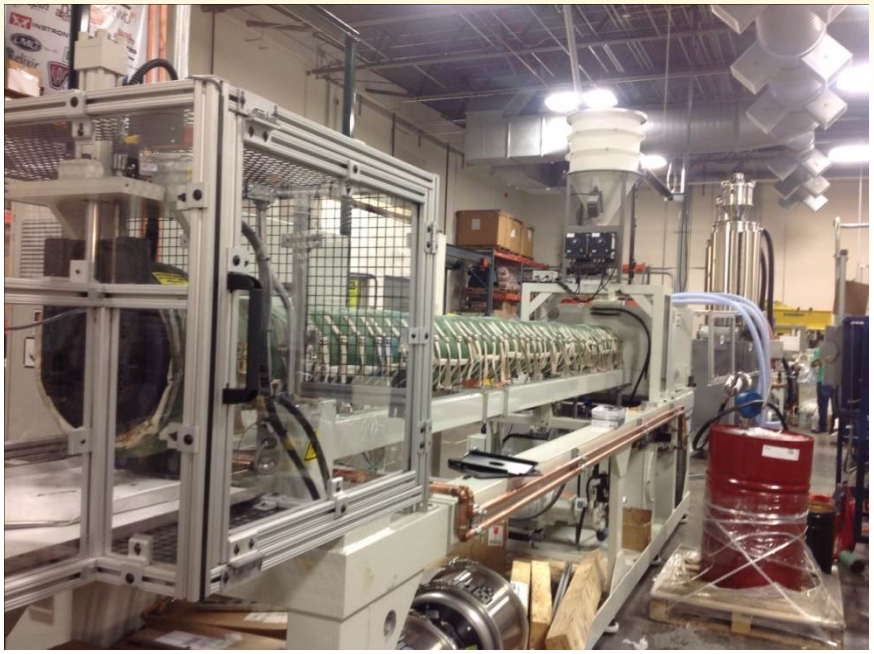
GATE Collaboration with Community Colleges and Partners

- **Roane Community College, Oak Ridge – with Dave Warren, ORNL – Composites Accelerator Program**

- **Peninsula Community College, Seattle – Recycling of Composites**

- **On-line workshops for industry**
  - **Thermal Analysis & Rheology of Polymers**
  - **Design & Modeling of Composites**
  - **Sustainable & Green Composites**
  - **Frontiers of Automotive Materials**

State of the Art Thermoplastic Composite Manufacturing Cell

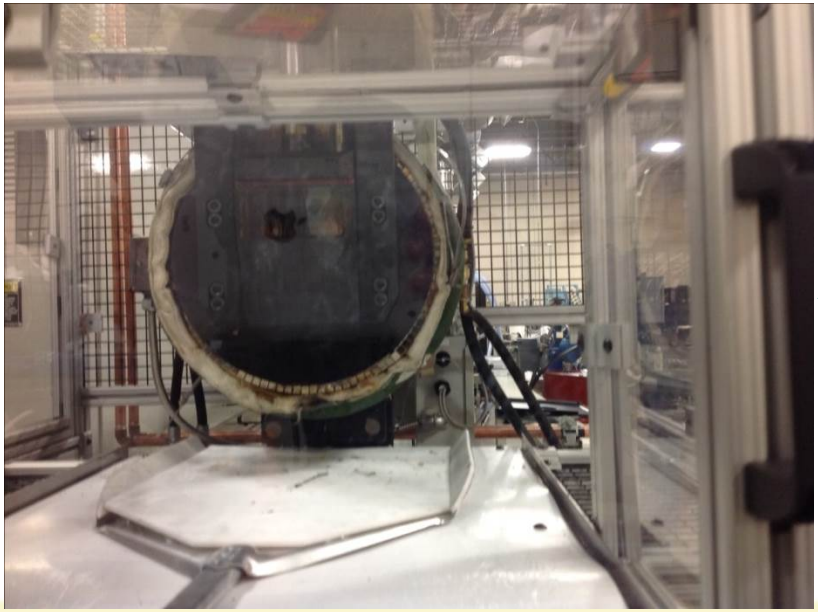


Extrusion-compression molding
Industrial scale plasticator (150 mm, 15 lb single charge) -fast acting press – 36” x30” platen size, 36” DLO

Examples of consistent charge resulting from glass/polypropylene pellets

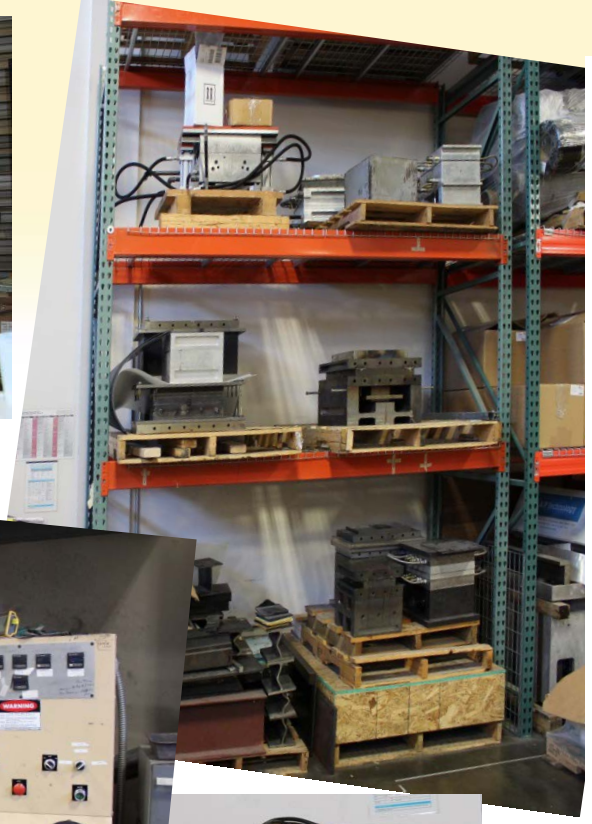
Starting material
Glass/Polypropylene pellets

Representative charges for compression molding



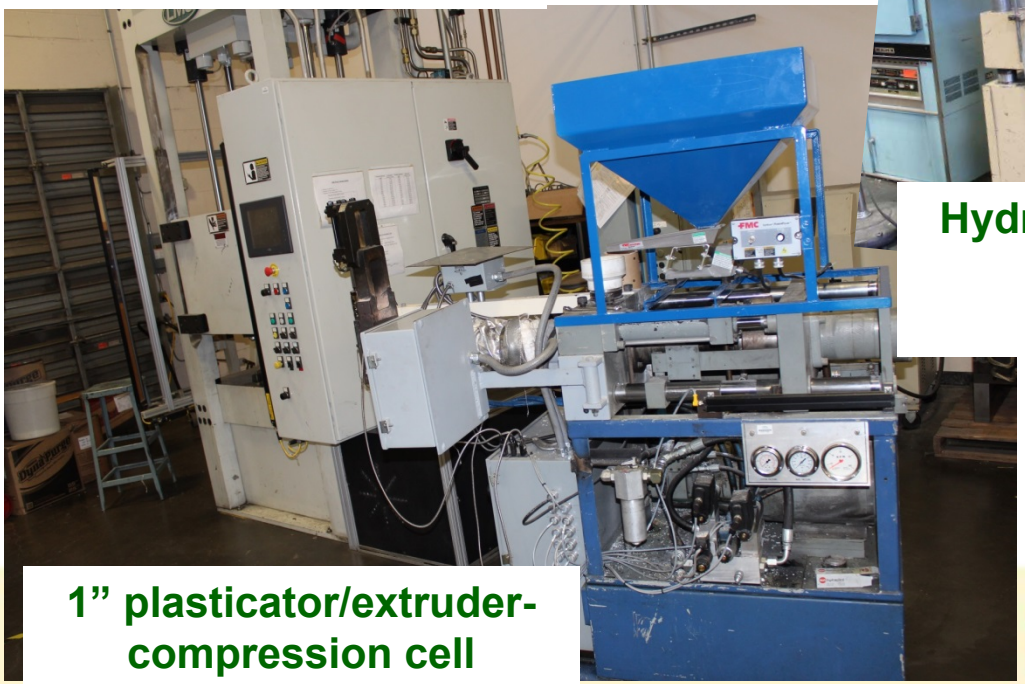
Knife end on the plasticator

3.5” plasticator/extruder



350 metric ton fast acting compression press

Hydraulic compression Press 150 ton 750F capable

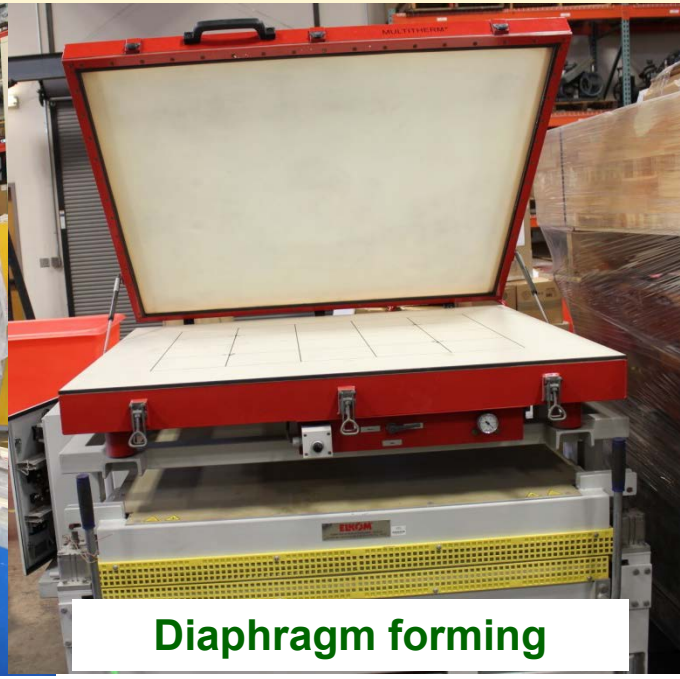


1” plasticator/extruder-compression cell

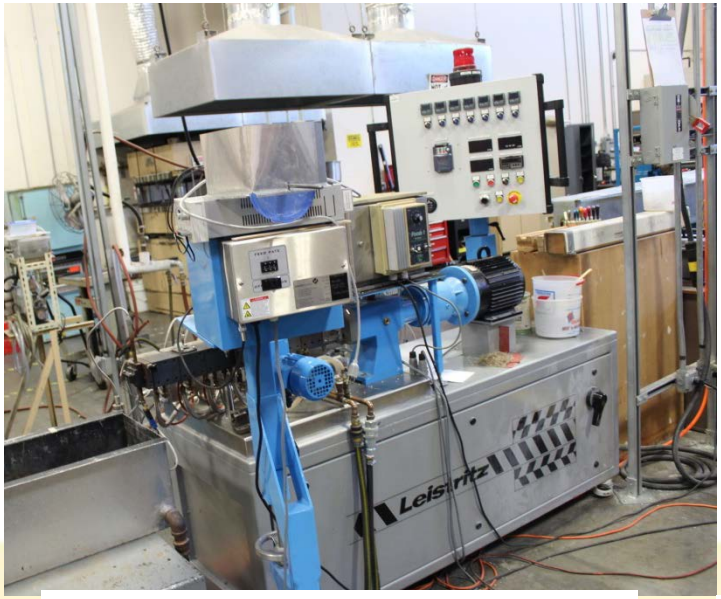
Variety of tooling- flat and shaped parts/features 6”x6”, 12”x12”, 24x24”

Sheet thermoforming

Thermoplastic pultrusion

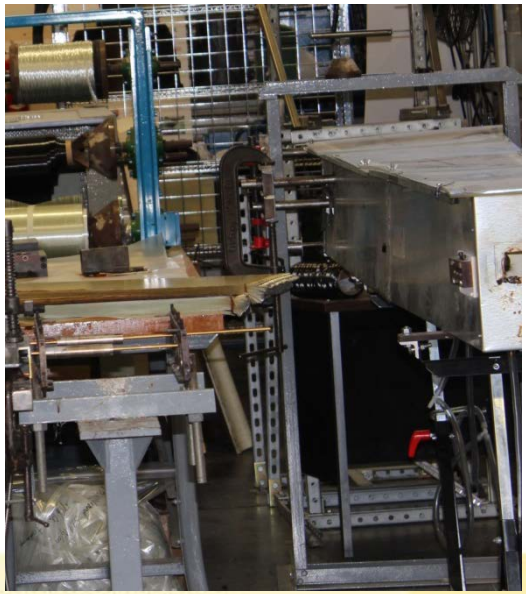


Diaphragm forming



Twin screw compounding

Single screw extruder



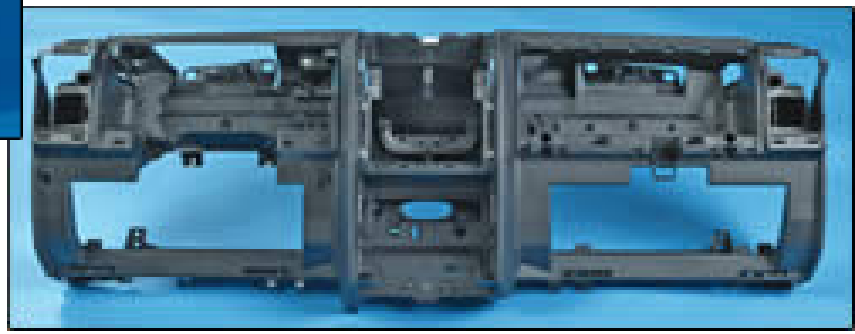
Hot melt line impregnation

Technical Accomplishments and Progress

Thermoplastic Composites in Automotive & Mass transit

Injection-molded concentric slave cylinder used in the automotive industry

Headliner of the 2007 Honda Acura MDX



Long glass/PP structural duct : 2007 Dodge Nitro SUV

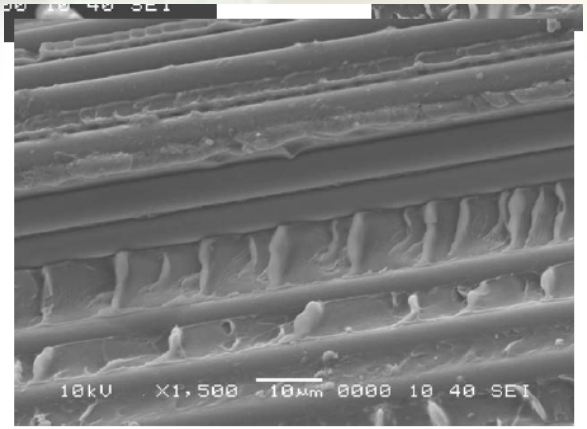
All-terrain vehicle (ATV) footwell

Brake sensor housing for the automotive industry

Wiper pivot housing used in automotive industry

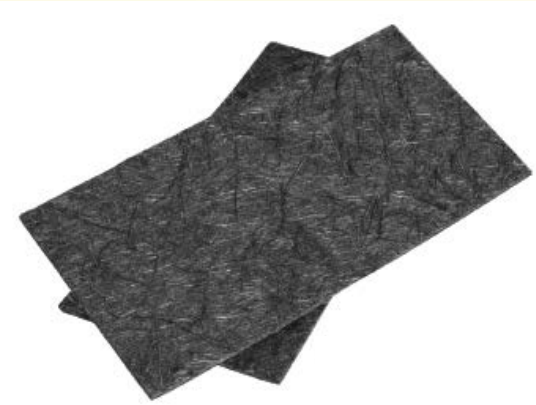
Source: Ticona

Emerging Intermediate Thermoplastic Material Forms

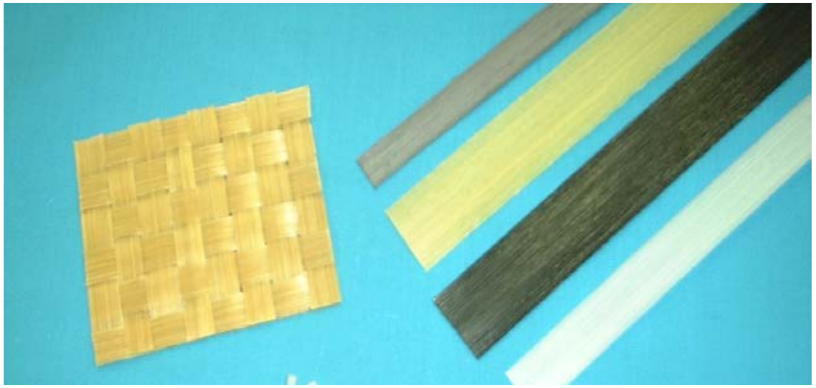


Multi-scale functional tailored interfaces

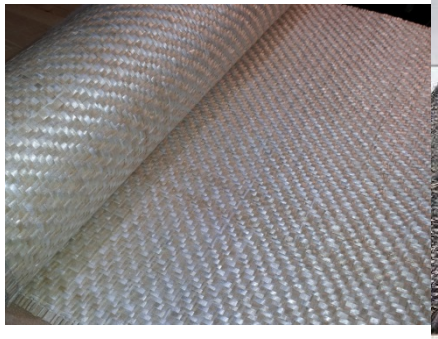
Long fiber pellets



Wet-laid or roll bonded



Tapes, Woven Fabrics



TP prepregs

Hybrids

Processing approaches with ORNL CFTF Carbon Fibers - Bluestar (B12, 24 and 48) and Kaltex (K)

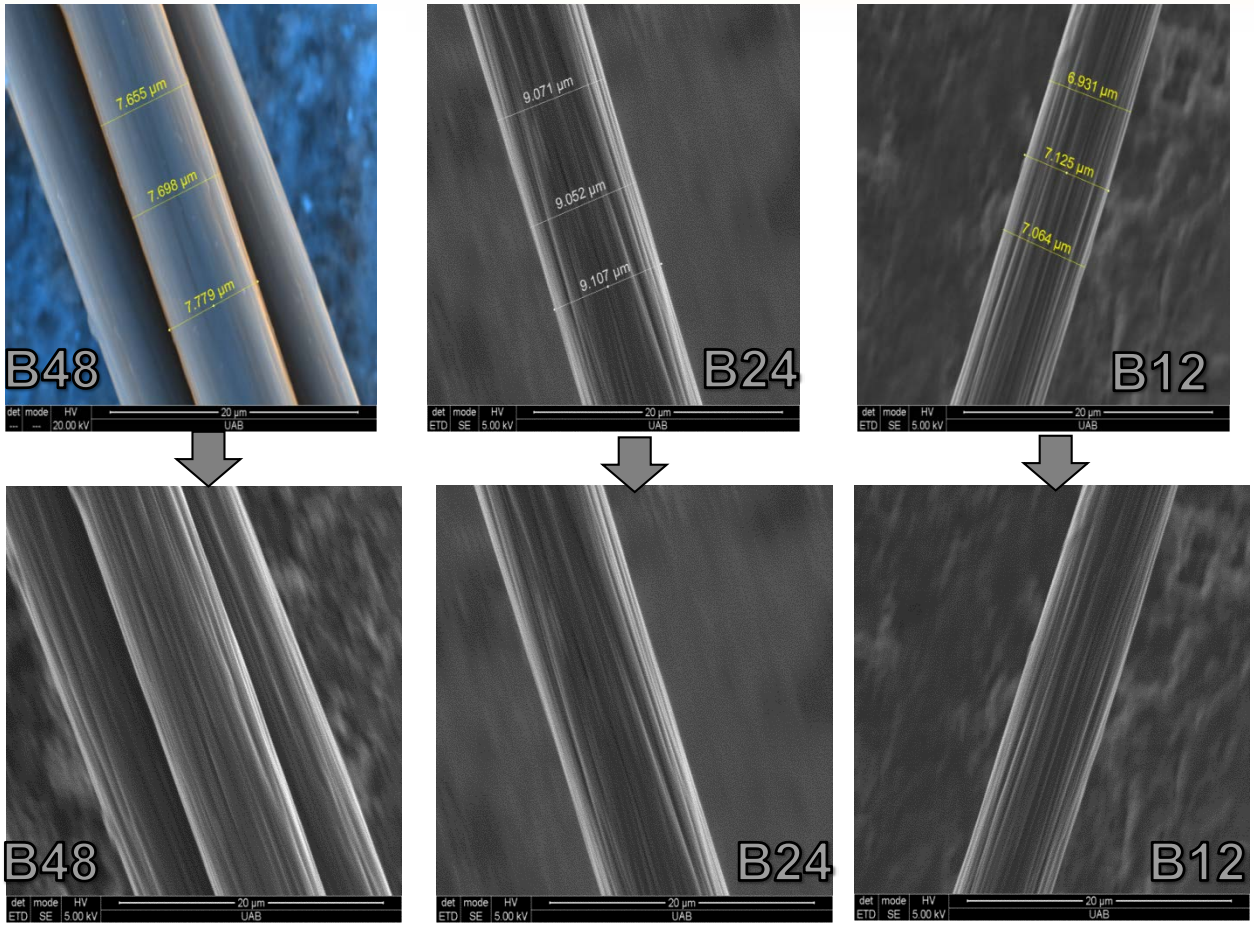
Processing of ORNL fibers

- Hot melt impregnated carbon fiber thermoplastic tapes
- Twin screw direct compounding of carbon fiber – thermoplastic tapes
- Wet-laid creation of ‘carbon only’ mats and ‘carbon-thermoplastic’ mats
- Film stack impregnation of carbon fiber mats
- Dry filament winding of carbon fiber spools

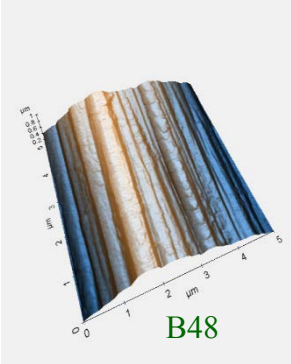
Downstream manufacturing options

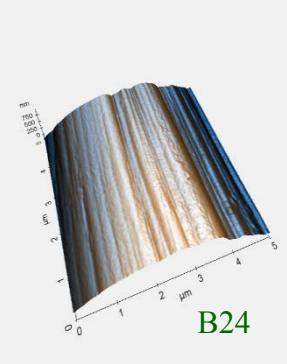
- Extrusion-compression molding (LFT or flakes)
- Thermoplastic pultrusion
- Compression molding
- VARTM (thermosets)

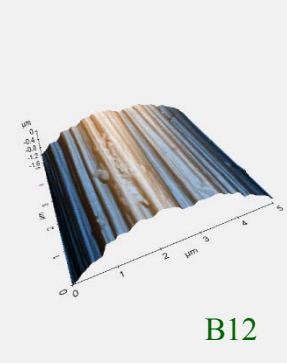
ORNL CFTF Fibers (Bluestar)

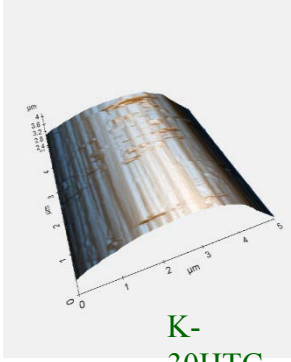


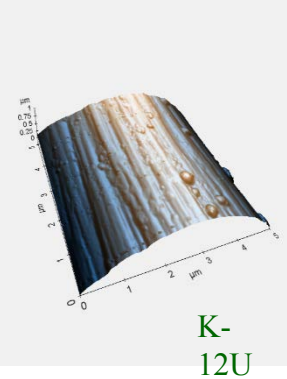
Surface characterization for Carbon Fibers

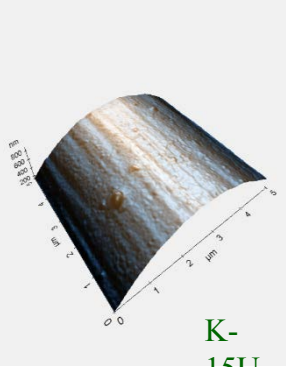






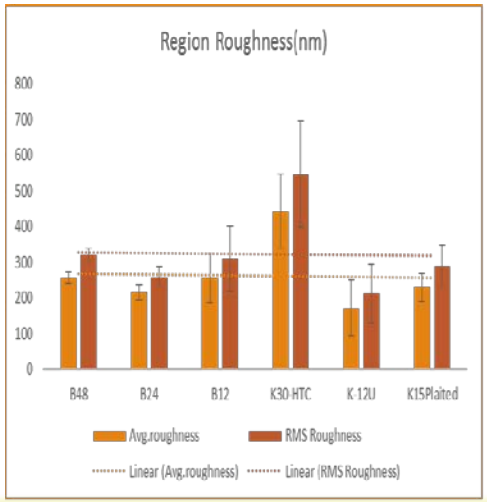


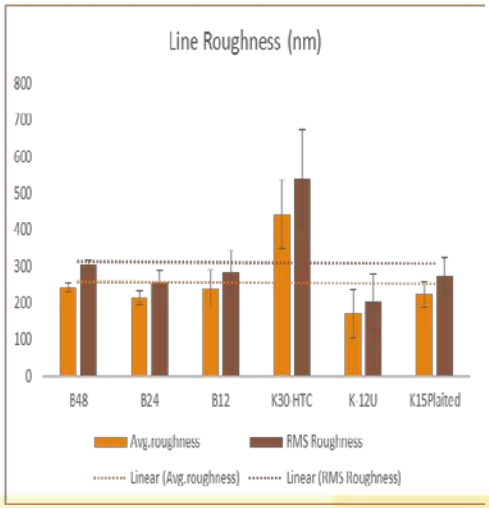




Topography images for a scan size of 5 µm width

Carbon Fiber	Type	Tow Size	Form
Sample 1-S1	B48	48K	Chopped
Sample 2-S2	B24	24K	Chopped
Sample 3-S3	B12	12K	Continuous
Sample 4-S4	K30-HTC	30K	Continuous
Sample 5-S5	K-12U	12K	Chopped
Sample 6-S6	K-15U Plaited	15K	Continuous





ORNL Fiber Conversion to Intermediate Thermoplastic Forms

Carbon Fiber

Continuous spools

Chopped fibers

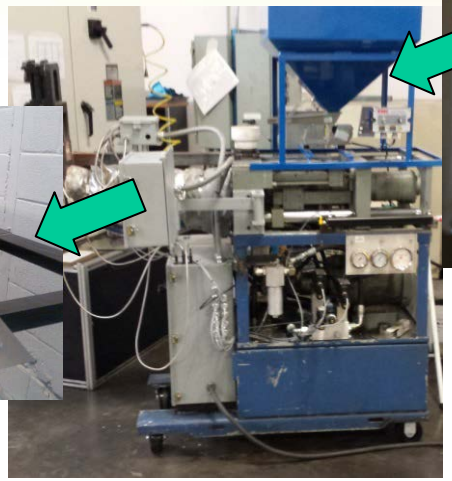
Twin Screw Compounding

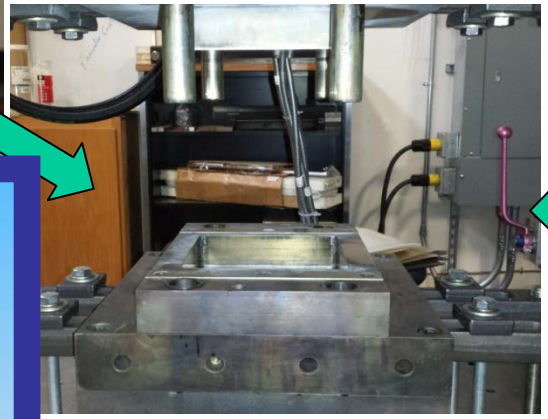
Hot Melt Processing

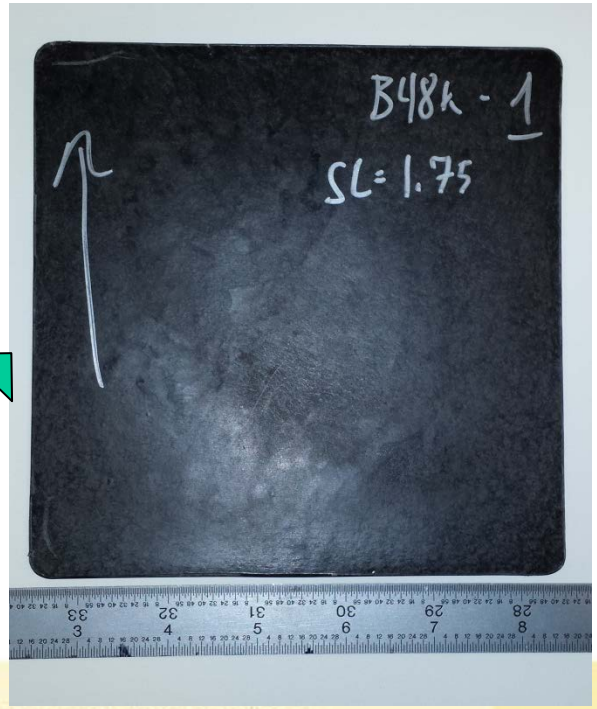
Compression Molding of tapes and mats

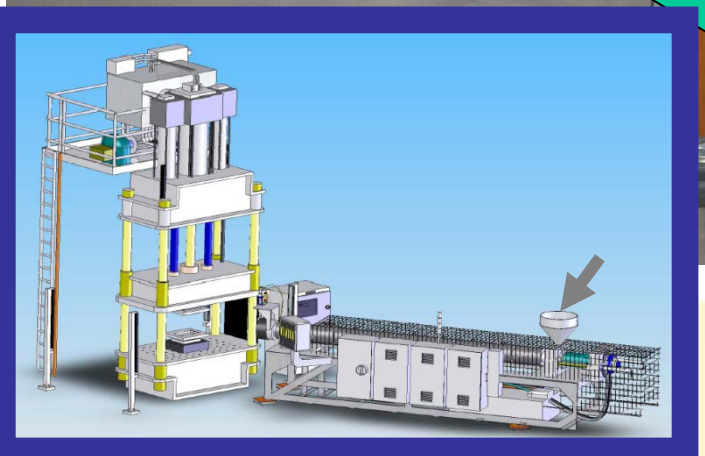
Wet Laid

Extrusion-compression molding of hot-melt impregnated and twin screw compounded tape-flakes. All test plates molded this way.









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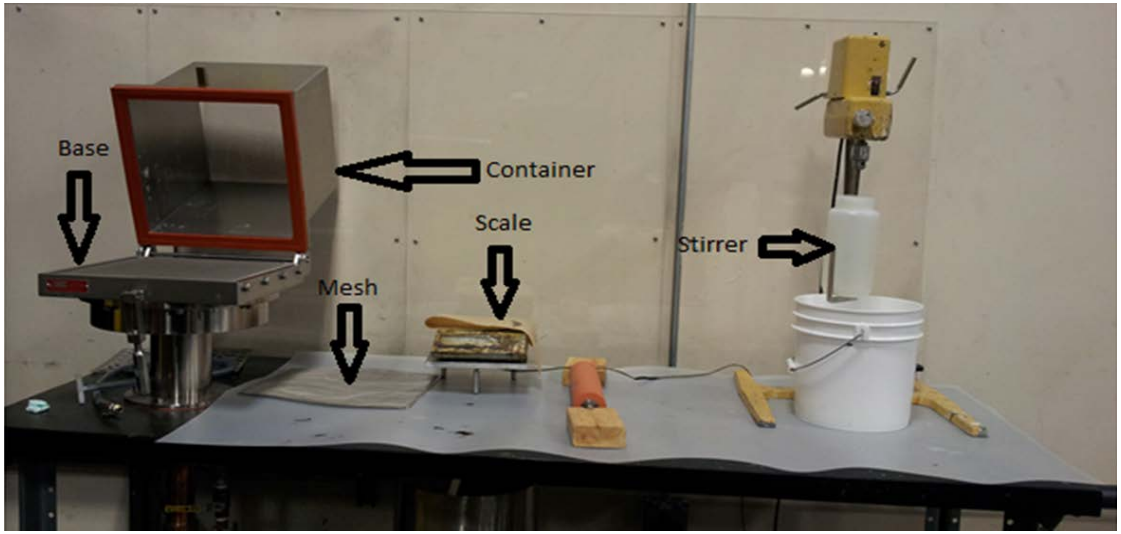
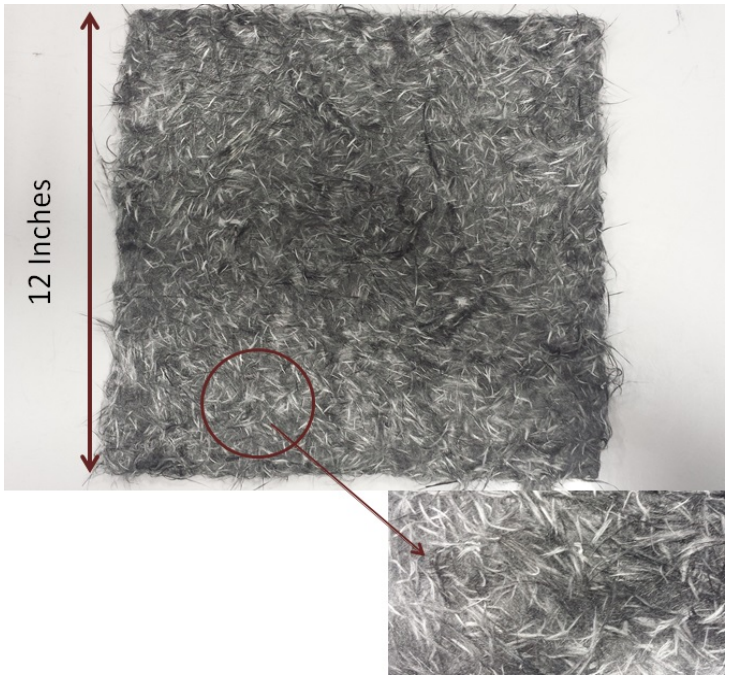
Wet Laid Bluestar Carbon Fiber Thermoplastic Fiber mats (PP, PA6, PPS)

PPS fiber

B48k tow carbon fiber



Wet laid set up



40 wt% carbon/PPS
1” length carbon fiber

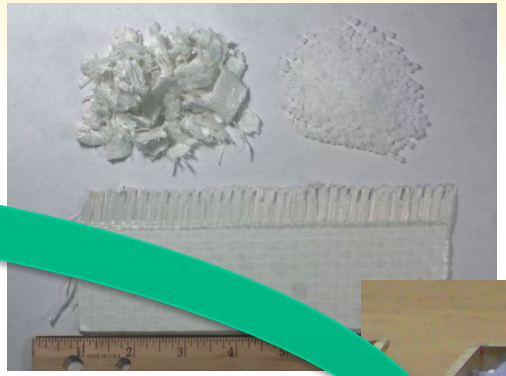
MPAD Center Representative Industry and Federal Partners

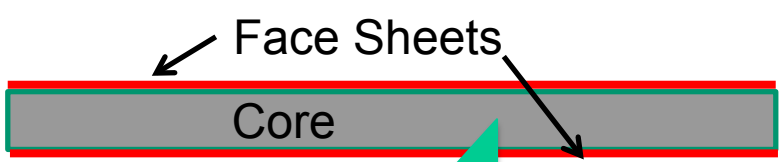
Collaboration and Coordination with Other Institutions

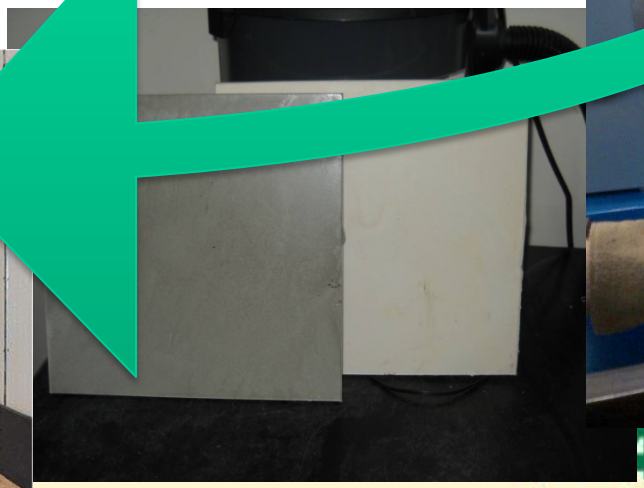
Industry / National Lab Partner	Technology Focus
Past work with mass transit bus	Floor, Battery Access Door, AC roof, Seat, Frames
Oak Ridge National Lab, CFTF	Thermoplastic composites from ORNL carbon fiber
Bus Company	Side door – thermoplastic sheet product
Automotive OEM1	Carbon fiber thermoplastic connecting rod
Automotive OEM 1	Valve cover (Carbon fiber thermoplastic drawing)
Daimler Truck North America	Truck side door
Polystrand/Rassini	Glass fiber thermoplastic suspension
Material supplier 1	Nanofiber filtration
Automotive OEM 3	Headliners and door inner
Carbon fiber manufacturer 1	Processing, testing, Thermoplastic compounding
Automotive OEM 4	VARTM carbon fiber hood, tailgate
Milliken	Self reinforced polypropylene, Nexcore sandwich fatigue
Glass fiber supplier	Lightweighting and design innovation
Automotive Tier 2	Transmission, Differential

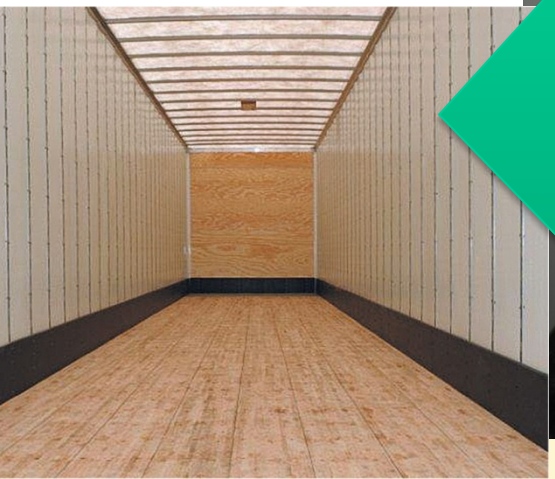
Recycled Carbon Fiber Product Development

Recycled High Strength Materials and Processes for Ground Transportation









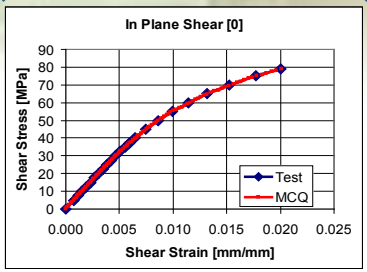
THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Discontinuous Fiber Parts made from wet-laid and impregnated carbon fiber thermoplastics

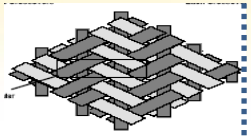
MCQ Composites: Modeling of Discontinuous Fibers

Input

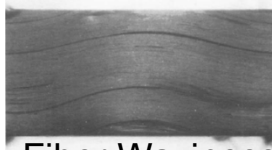
Material Non Linearity

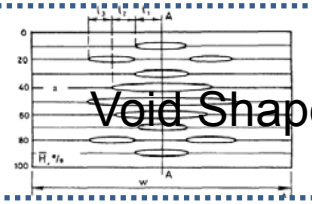


Fiber Architecture



Manufacturing Defects, As-Built

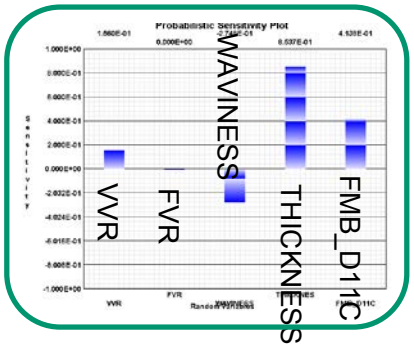




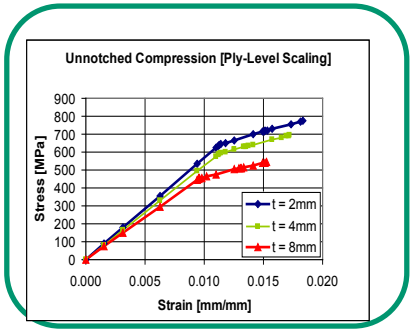
MCQ Composites

Predicts Laminate Properties, Reduce Coupon Testing & Accounts for Scatter

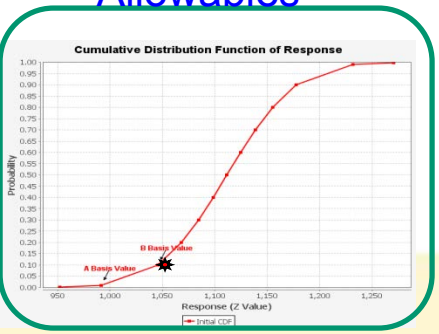
Probabilistic Sensitivity



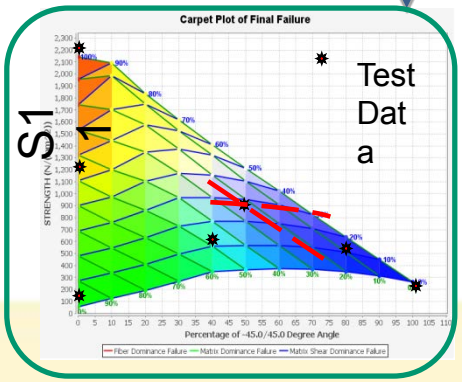
Thickness Effect



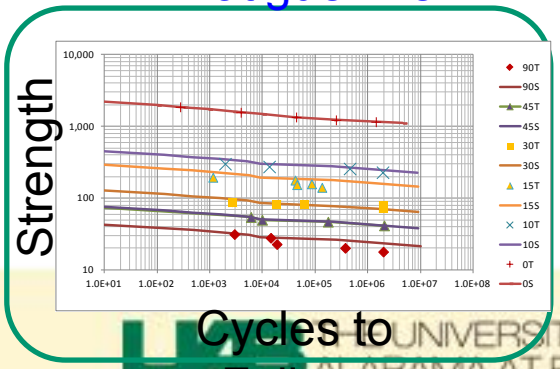
A- & B-Basis Allowables



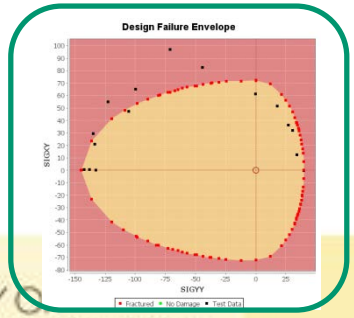
Parametric Carpet Plots



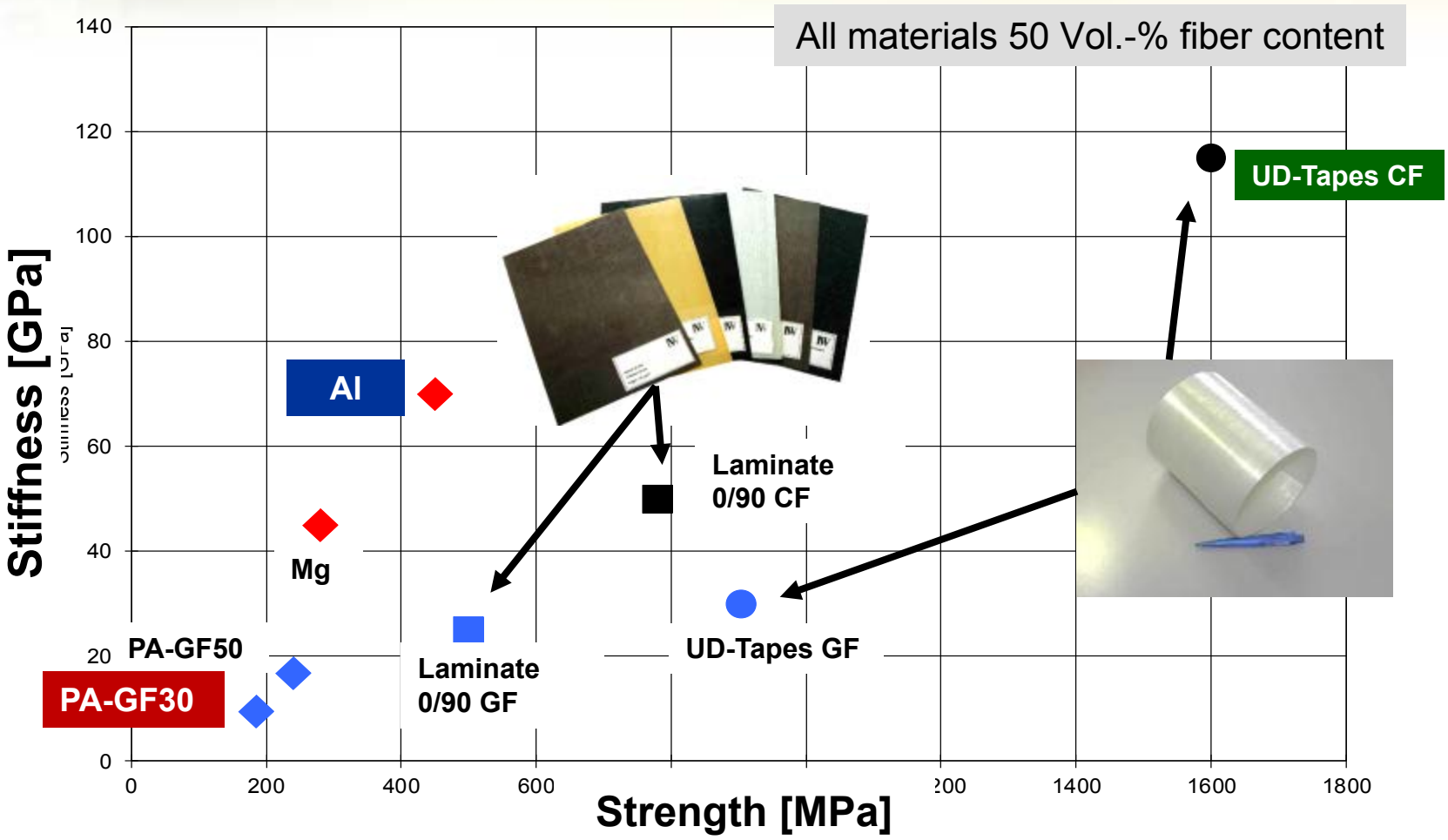
Fatigue Life



Design Failure Envelope

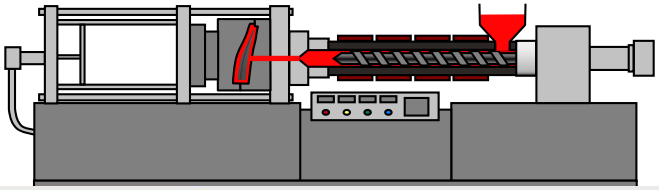


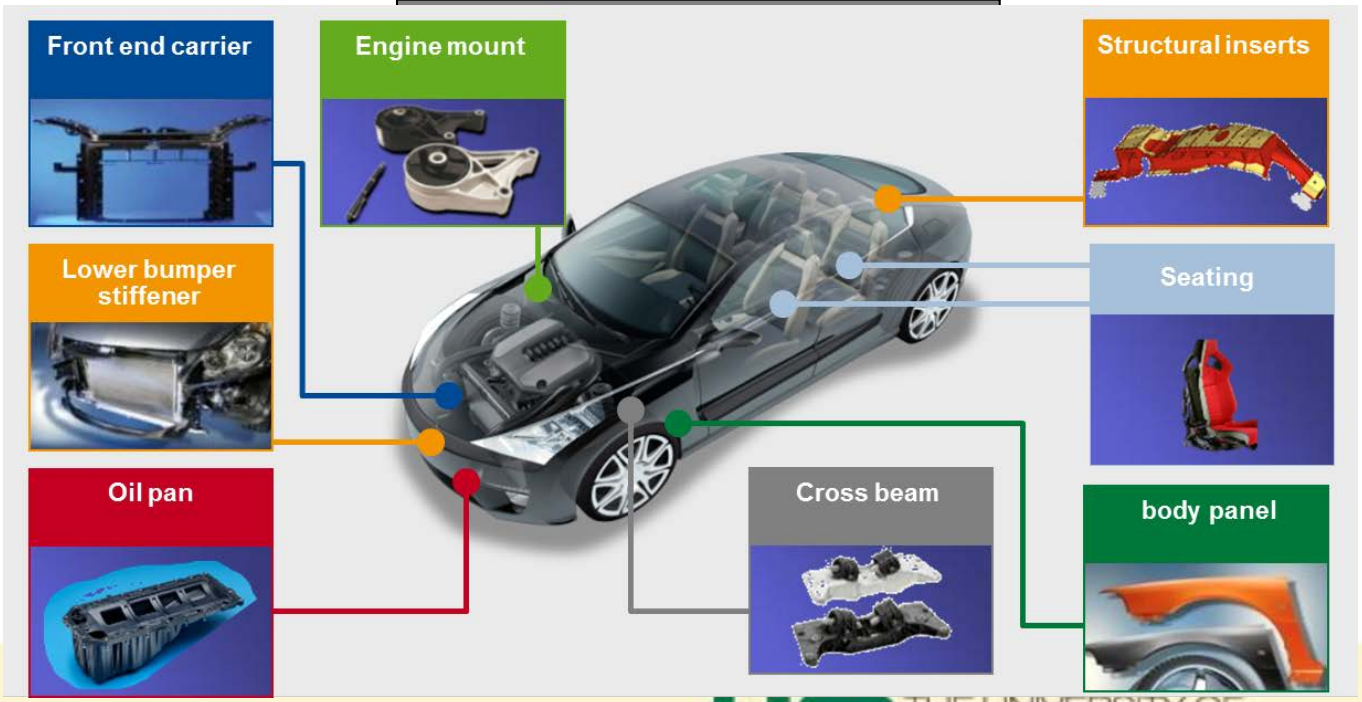
Continous Fibers
Injection Molded Component with CFRT



Thermoplastics Today...

- Injection molding – proven, cost effective high volume and well established manufacturing process
- Semi-structural components – short glass engineering plastics

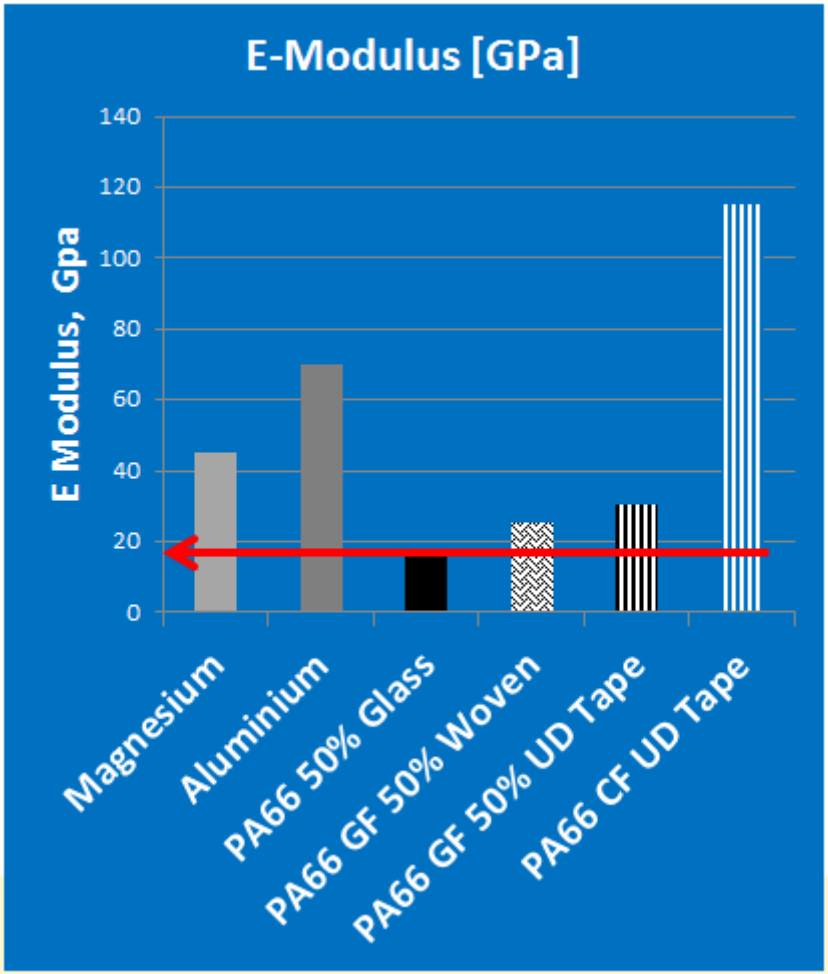


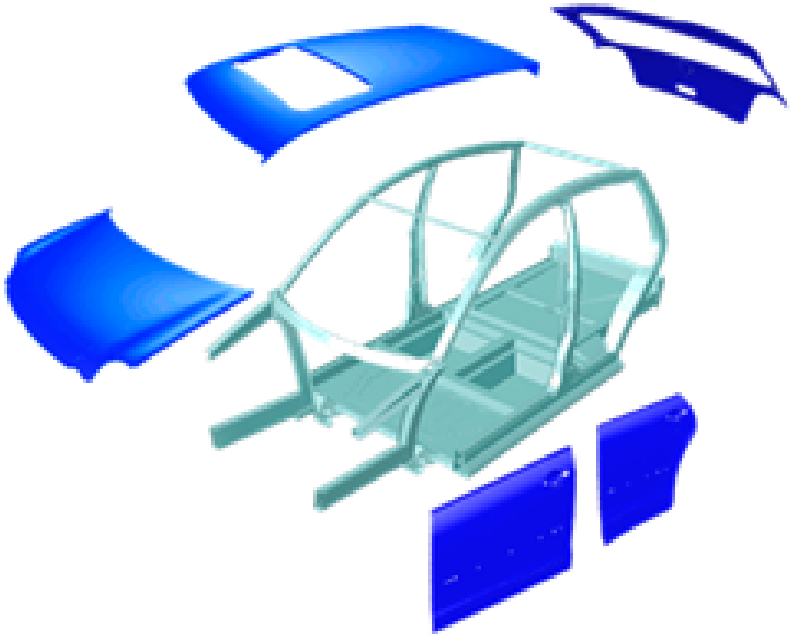


Courtesy: BASF (Morgan)

Challenges for Injection Molded thermoplastics - *structural* components

Increased stiffness especially >100 °C!



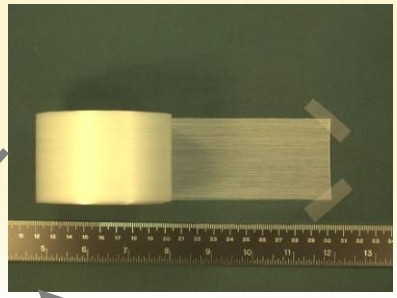


“2.5D” planar parts
ifficult for Injection molding process

Courtesy: BASF (Morgan)

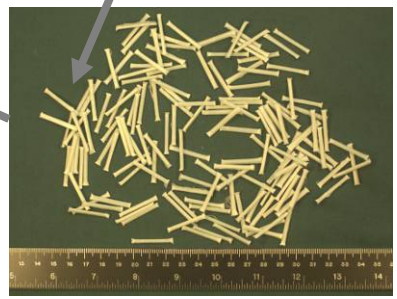
LFT Co-molded with Continuous Thermoplastic Tapes

- **Co-molding LFT with pre-consolidated / continuous reinforced tape**
- **Local reinforcements**
  - **Replace traditional rib structures**
  - **Local tailored strength & stiffness**
  - **Functional integration**
- **Parameters influencing final properties**
  - **Processing**
  - **Bonding interface**
  - **Stiffness of the materials**
  - **Thickness ratio**

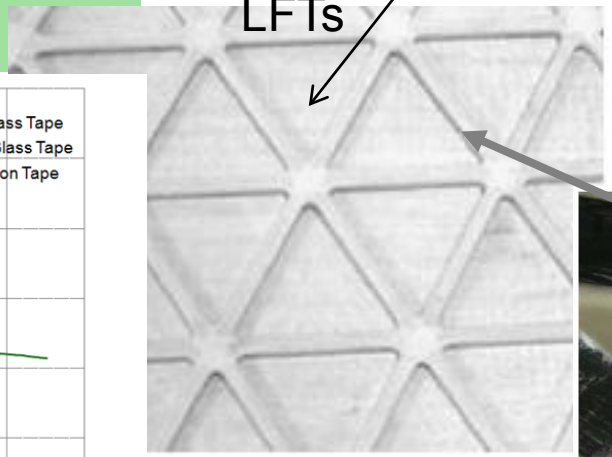


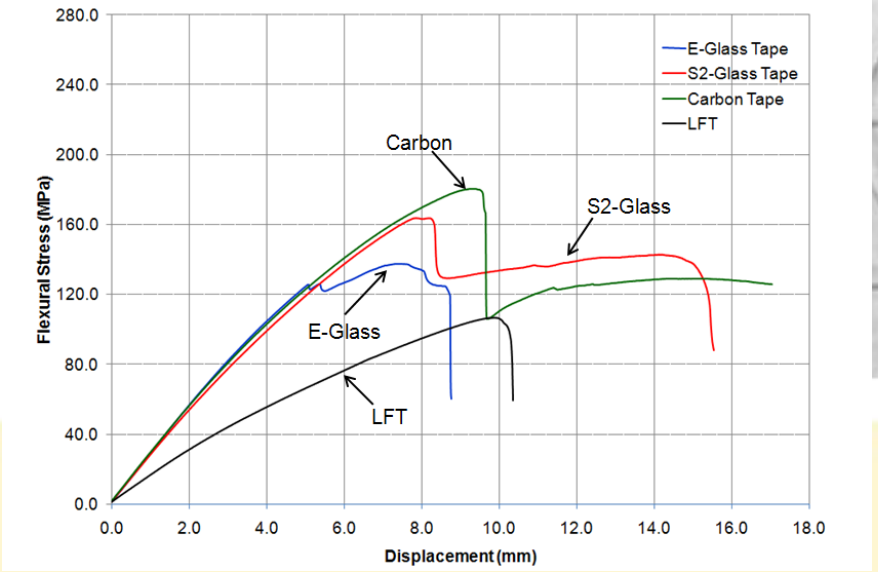
Continuous Tapes

LFT



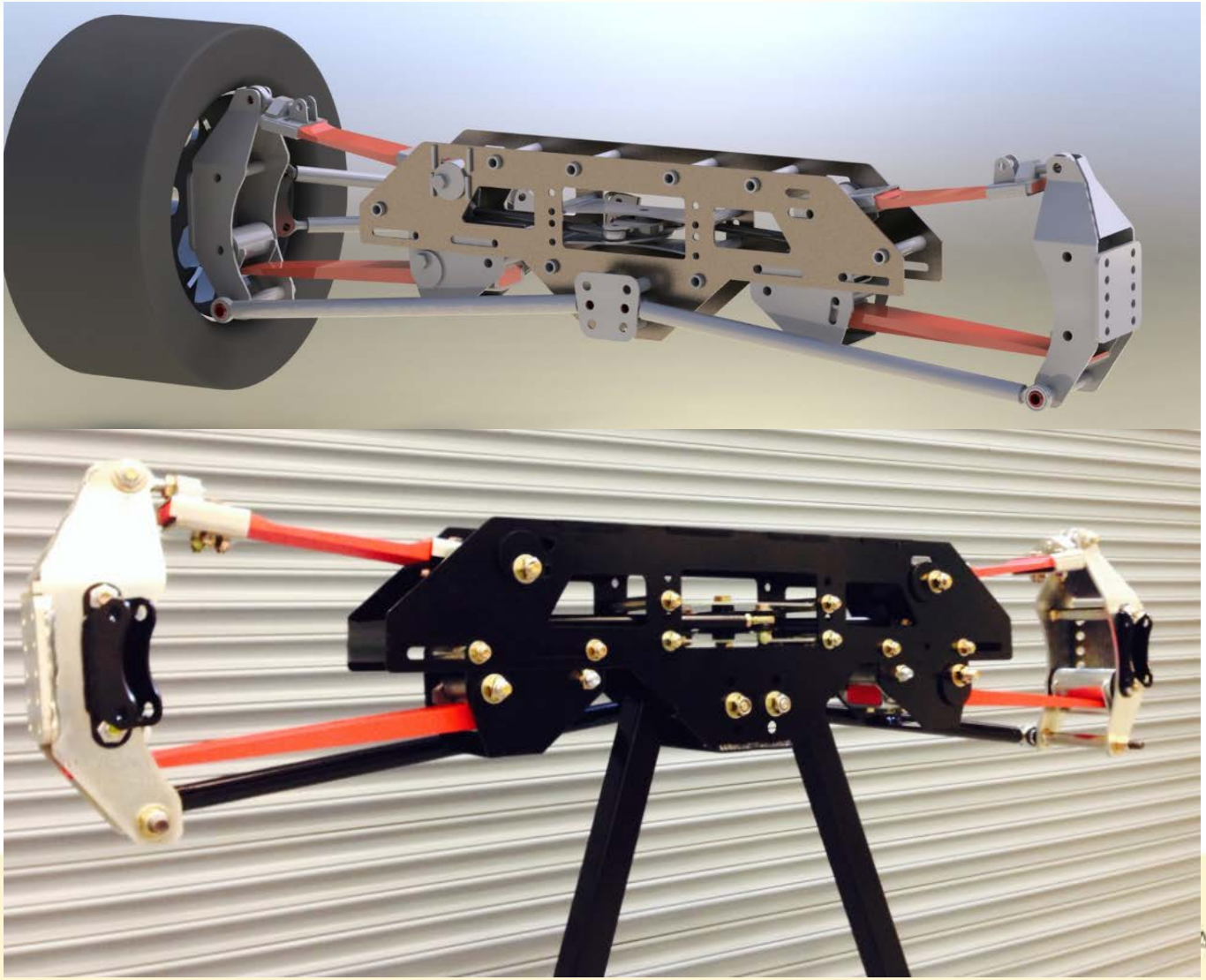
Co-molded LFTs



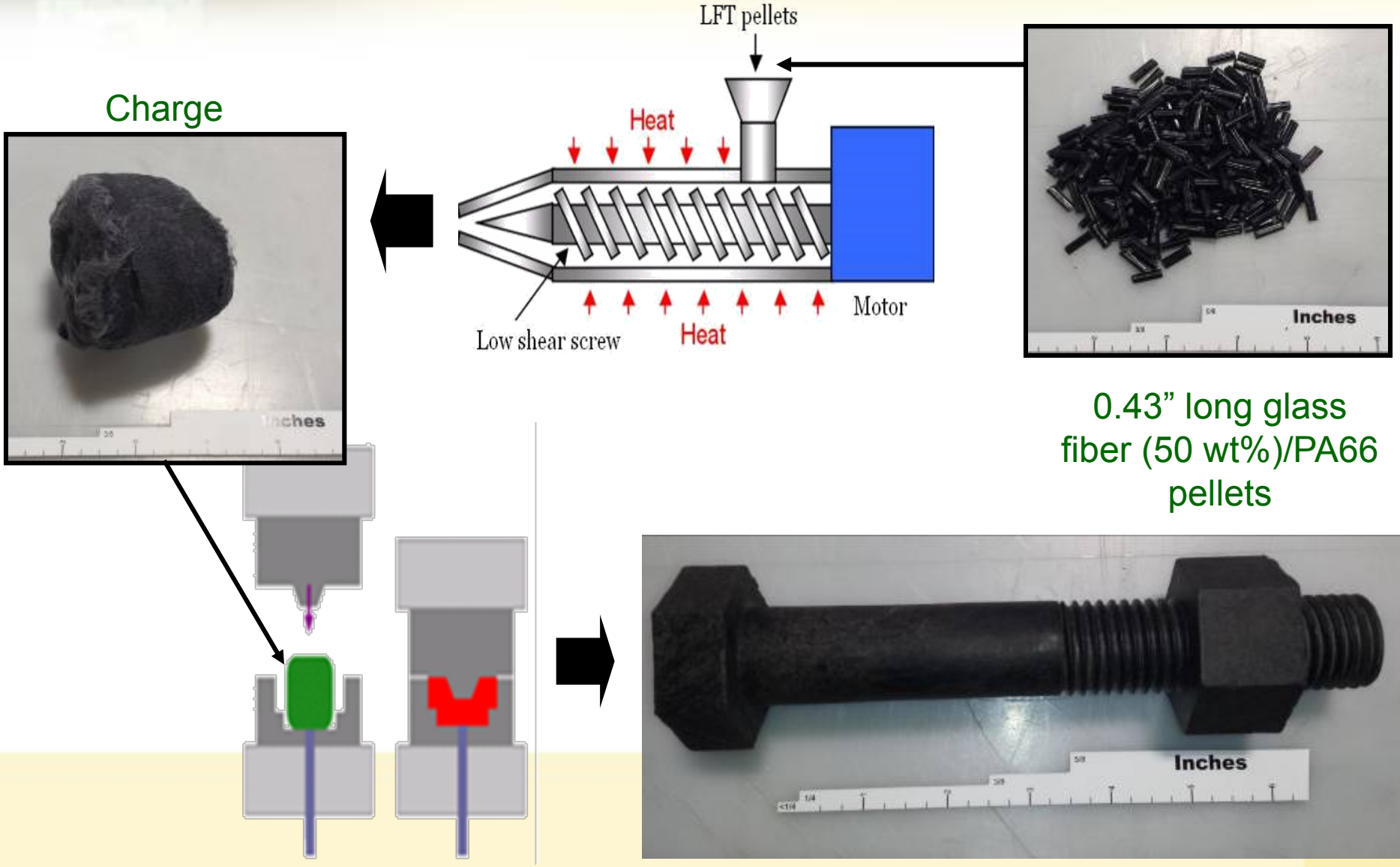


Polymer Composites, In-print, Jan 2013

Truck Leaf Springs
PolyStrand/SanLuis Rassini/PPG



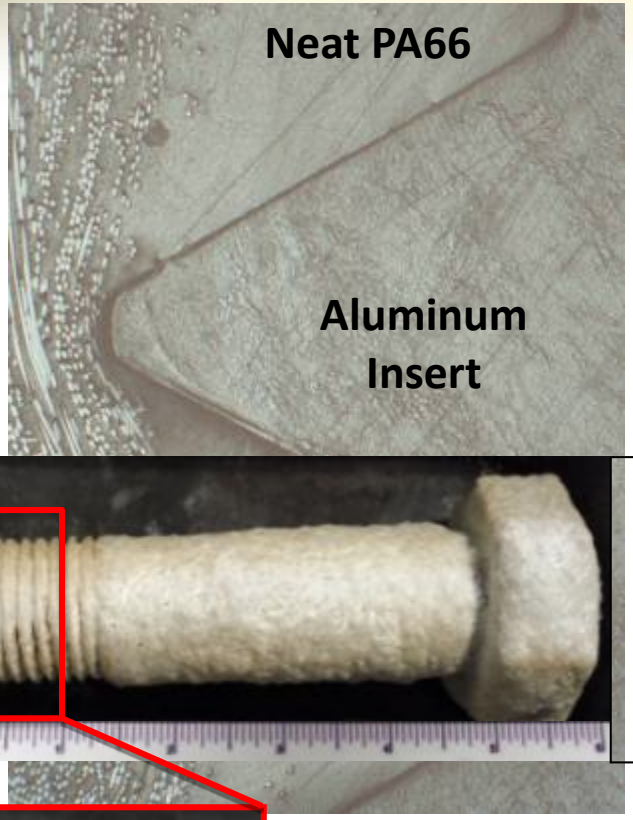
Threaded Fasteners - Manufacturing

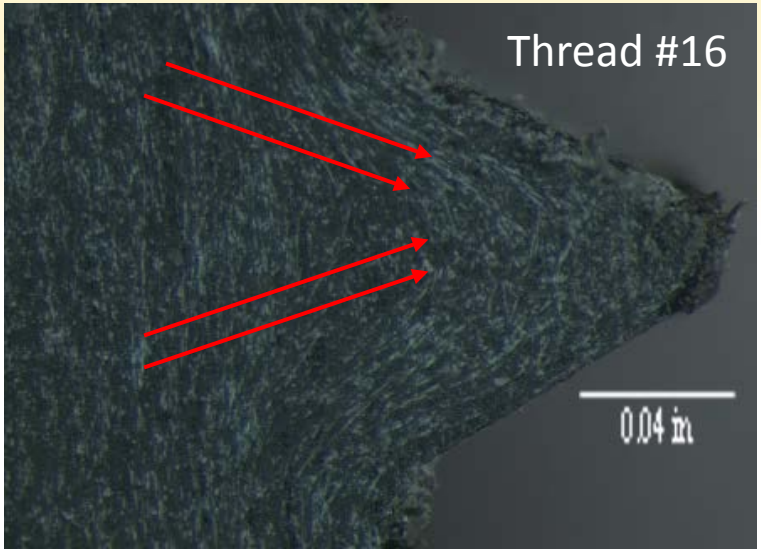


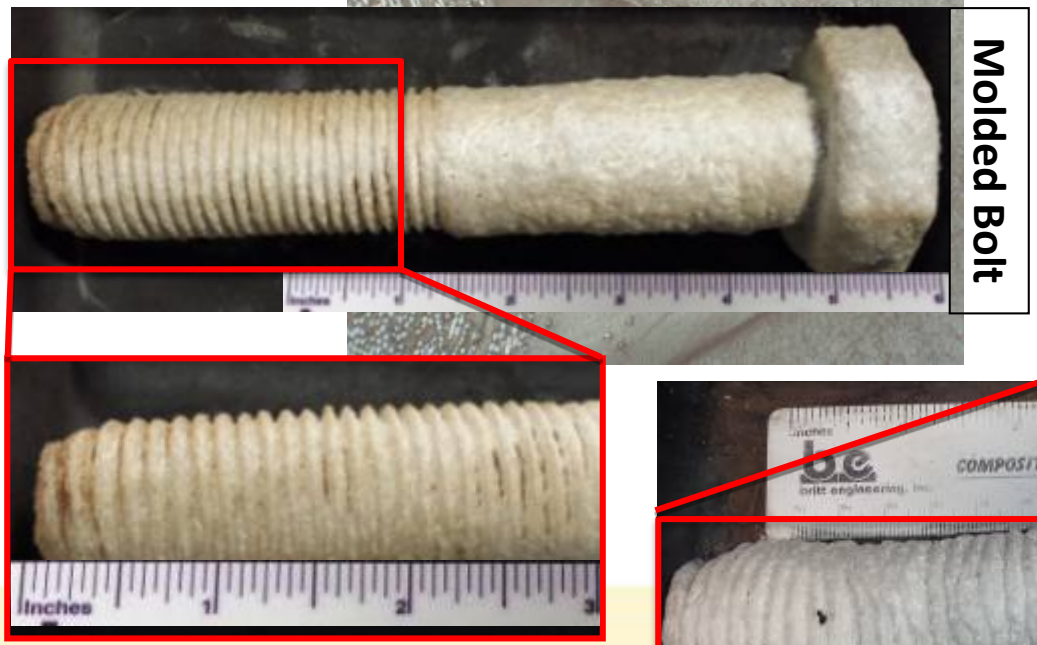
0.43” long glass fiber (50 wt%)/PA66 pellets

LFT Threaded Fasteners

- Burn off of resin using ASTM D2584 standard
- Fiber content of the both molded and machined bolt was ~49%







Remaining Challenges and Barriers

- Manufacturing options for thermoplastic forms
- Cycle time optimization
- Thermal management: Rapid heating/cooling - tools
- Fiber orientation (wash) for thermoplastic tapes in compression molding
- Limited database for emerging thermoplastics
- Long term durability, fatigue, high temperature properties
- Effect of fiber sizing
- Modeling & progressive failure of complex preforms

Proposed Future Work

- Leverage GATE and expand industry partnerships
- ORNL carbon fiber evaluation at fundamental level
- Conversion of carbon fiber into broad range of thermoplastic composites
- Further processing, test data and design parameters for recycled carbon fibers
- Compounded recycled carbon fibers for injection and compression molding

Summary

- Next generation work-force development and trained engineers for DOE, OEMs and related industries
- The work with ORNL carbon fiber is leading to new knowledge about the down stream processing into thermoplastic and thermoset carbon fiber composites
- Designers and end-users will benefit from the data base and material-manufacturing knowledge
- Tooling is available at the UAB Center for mass transit components – prototypes and product intent parts can be readily scaled up with ORNL and related fibers
- Selective insertion of cost-effective, lighter, high performing, mass produced composite parts for automotive and transportation