Carbon Fiber Technology Facility

Contract Number

Oak Ridge National Laboratory

FY16

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U.S. DOE Advanced Manufacturing Office Program Review Meeting

Washington, D.C. June 14-15, 2016

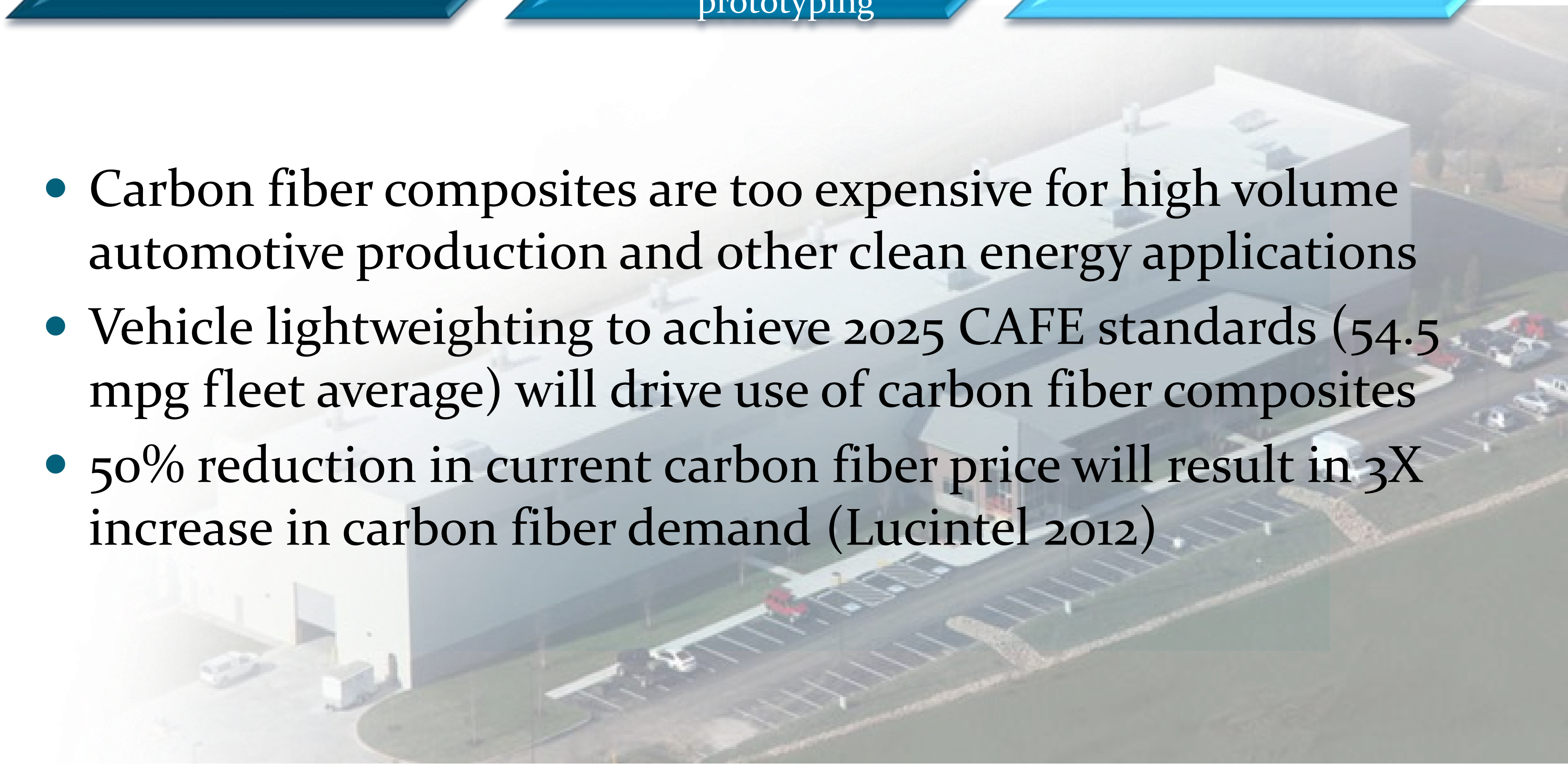
Project Objective

Reduce carbon fiber cost by using low cost alternative precursors

Produce quantities of low cost carbon fiber for material and process evaluations and prototyping

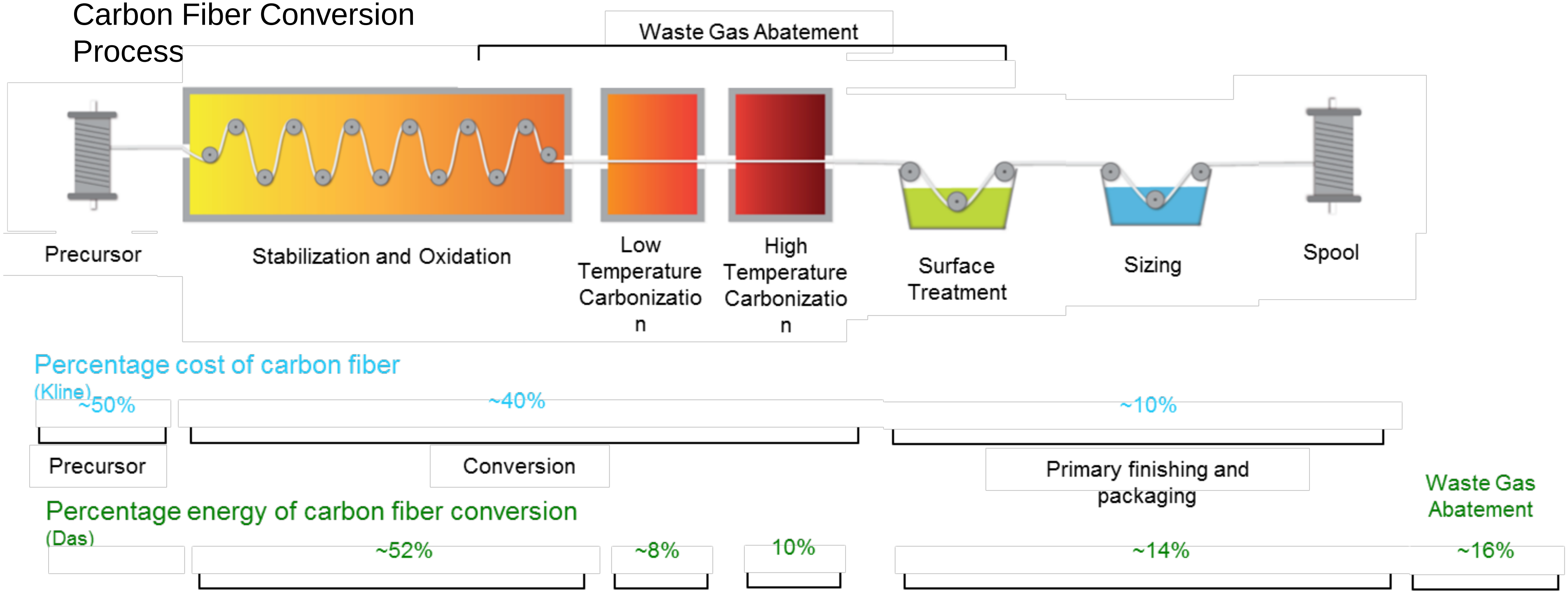
Support training of the the future advanced composites workforce

- Carbon fiber composites are too expensive for high volume automotive production and other clean energy applications
- Vehicle lightweighting to achieve 2025 CAFE standards (54.5 mpg fleet average) will drive use of carbon fiber composites
- 50% reduction in current carbon fiber price will result in 3X increase in carbon fiber demand (Lucintel 2012)



Technical Innovation

Carbon Fiber Conversion Process



- Intellectual property developed around scalable process for producing low cost carbon fiber

From low-cost, commercially available commodity fiber

Exhibits properties comparable to industrial grade carbon fibers

Increase in capacity greater than 3x over traditional conversion process equipment

Power reduction up to 60% per unit vs. traditional conversion techniques

>50% cost reduction over traditional production methods

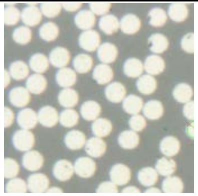
Technical Approach

- Integrated approach to low cost carbon fiber
  - Identify high potential, low cost alternative precursors
  - Develop optimal mechanical properties of resultant carbon fiber from alternative precursors
  - Provide sample quantities to industrial partners for testing
  - Address feedback from industrial partners
  - Improve carbon fiber manufacturing cost metrics
  - Commercialization

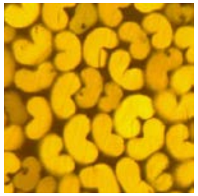
Textile Polyacrylonitrile Fiber

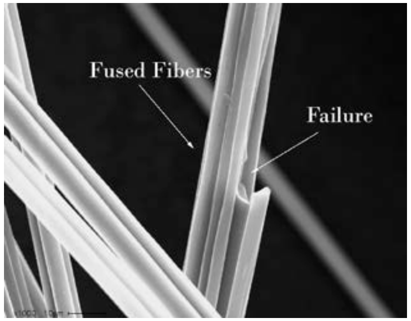
- < 5% PAN fiber used for carbon fiber, balance used by textile industry
- Advantages of textile PAN
  - Low cost due to high volume for commodity product
  - Readily available supply for Multiple global suppliers
- Challenges
  - Challenging conversion process to achieve useable properties
  - Ultra large tow format (300k – 610k vs. 12k – 24K) fragile and difficult to handle
  - Current composite processes require modification

Commercial Carbon Fiber Precursor 12K – 24K tow

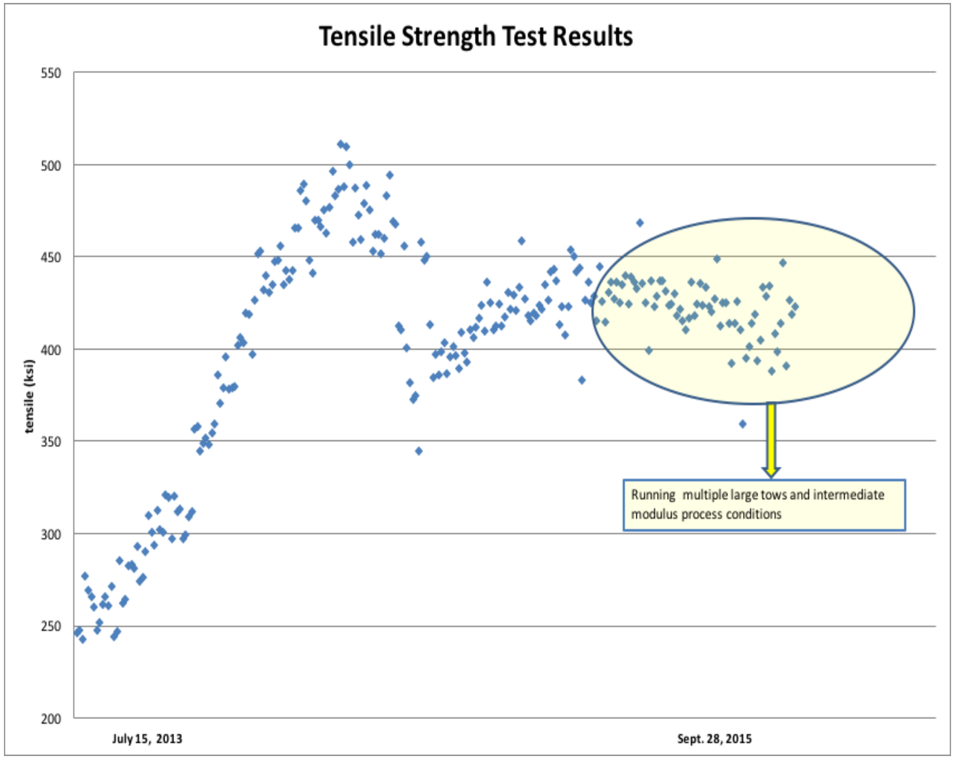


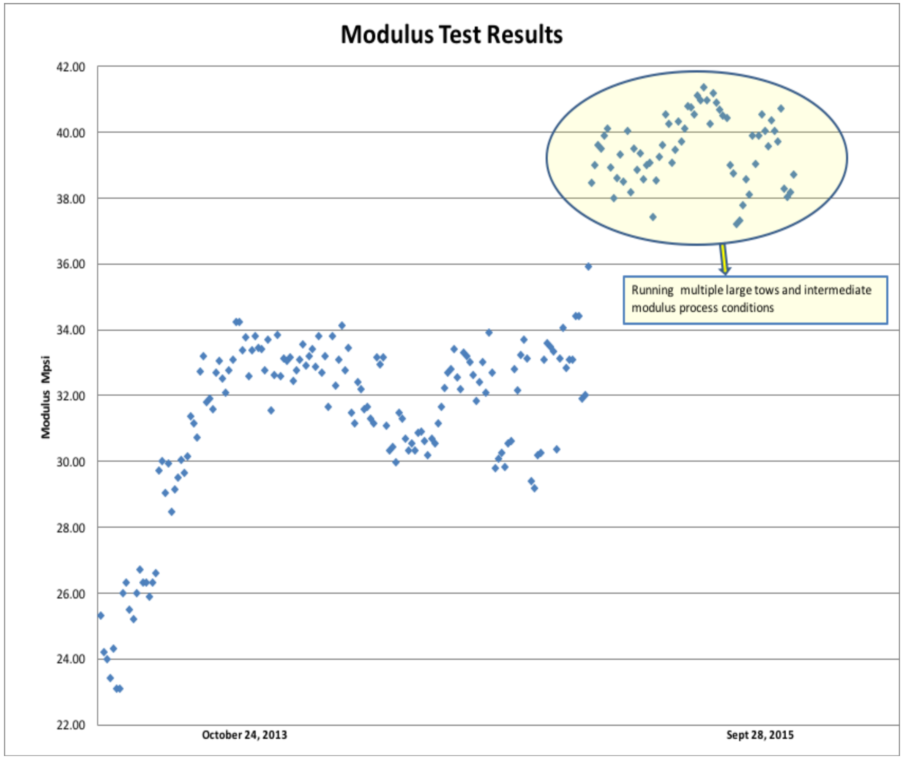
Textile PAN Precursor (Kaltex) Up to 610K tow





Tensile Strength and Modulus

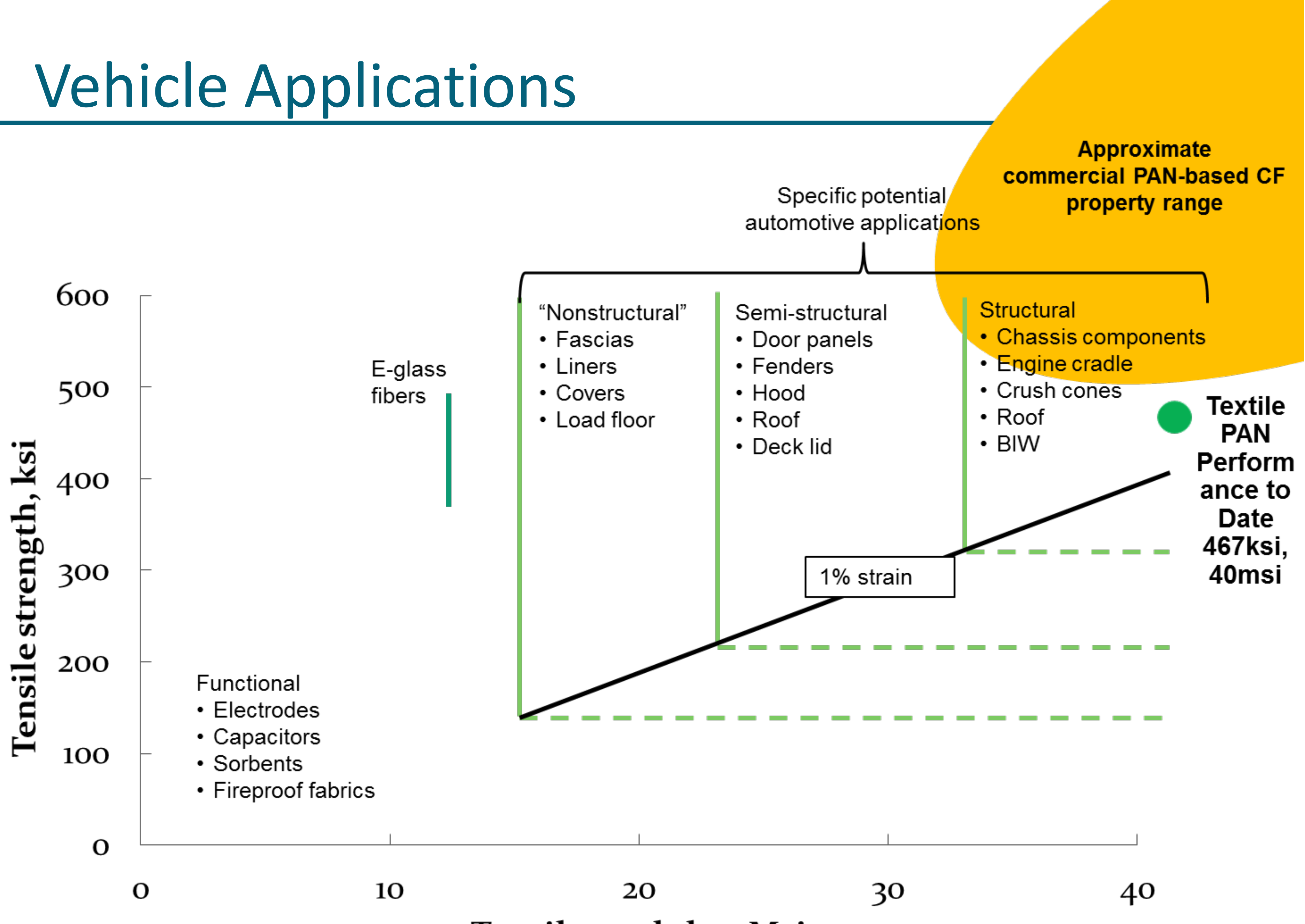




Precursor	Tensile Strength (ksi)	Tensile Modulus (msi)
Kaltex (to date)	467.8	40.3
Taekwang* (preliminary)	268.7	25.1
Thai Acrylic* (preliminary)	252.5	26.0

*Preliminary results based on a few weeks of processing, but expect to be able to achieve similar performance levels as shown by the Kaltex material.

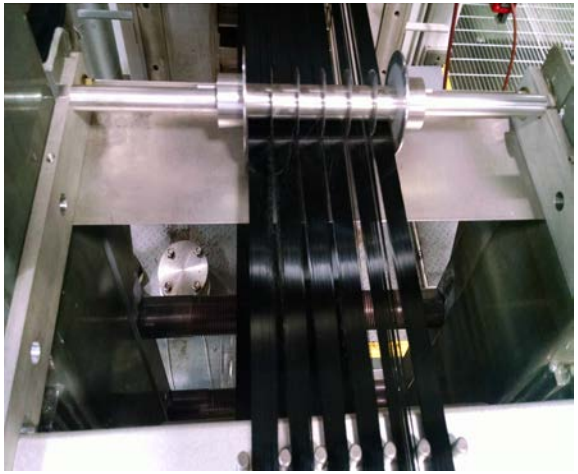
Vehicle Applications

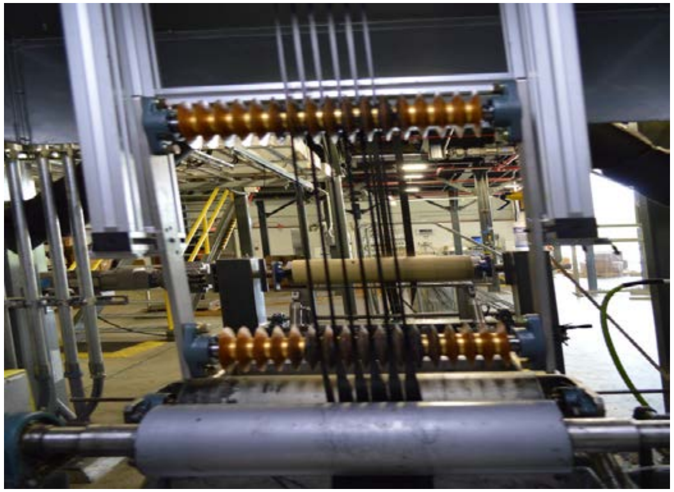


Data courtesy Plasan Carbon Composites

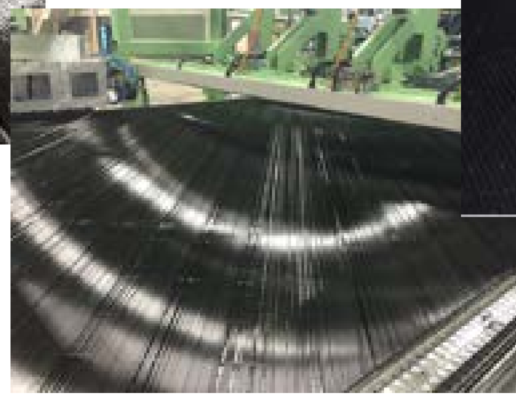
Improve Downstream Handling - Tow Splitting

- Traditional carbon fiber tows
  - 12K – 24K
  - Traditional compositing techniques require small tows
- Textile based carbon fiber tows
  - 300K – 610K
  - Compositing opportunities available with large tow, such as chopped, tape, sheet, prepreg fabrication among others
- CFTF has attempted several techniques to split large tows
- Also possible to work with precursor suppliers to split tow
  - No impact on high volume throughput with smaller tows

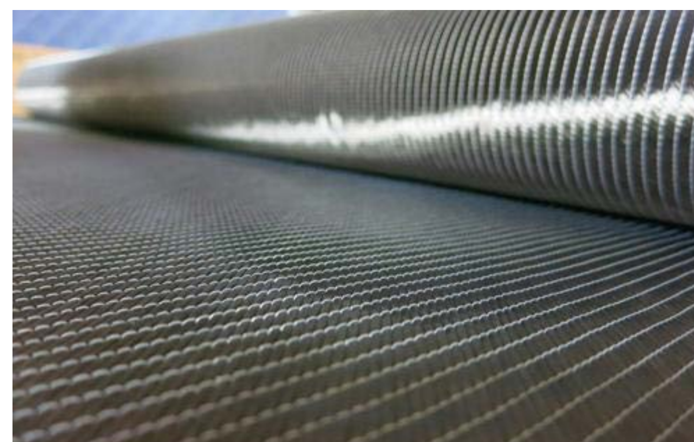




Fabric/Sheet Fabrication

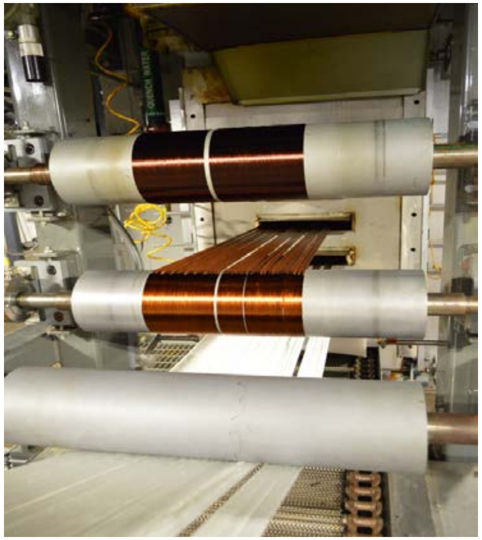


Chomarat C-PLY non-crimped carbon fiber sheet



Vectorply VectorUltra carbon fiber sheet

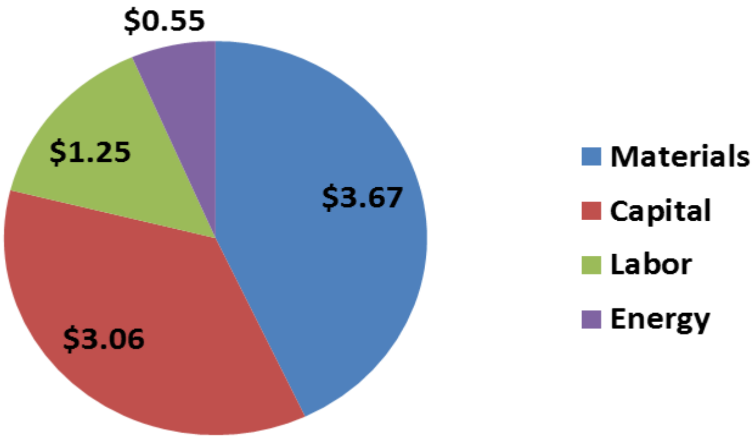
High Volume Throughput Trials



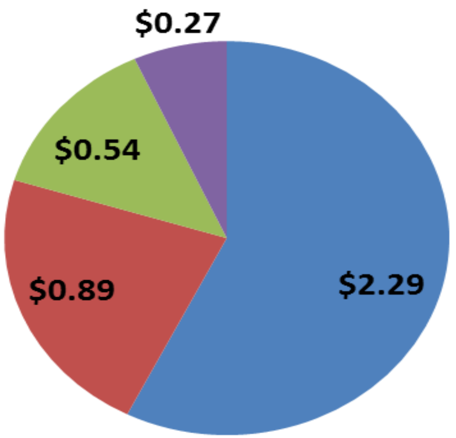
- Increase throughput with textile PAN
  - Demonstrated 3X (2x shown in pictures) nameplate (25 tons) capacity (75 tons)
- Benefits
  - Reduce CAPEX per unit CF
  - Reduce OPEX per unit CF
  - Changes 1500 ton line to 4500 ton line in commercial space

Example Cost Analysis

Baseline: $8.53/lb



Heavy Textile Tow: $3.99/lb



Major differences in underlying assumptions for a 3m wide conversion facility

PARAMETER	BASELINE	HEAVY TEXTILE TOW
Precursor Cost	$1.65/lb	$1.02/lb
Tow Size	50K	>457K
Tow Yield (g/m)	3.4	20
Tow Spacing	24 mm	50 mm
Tows/Line	120	58
Mass Rate	211 kg/hr	461 kg/hr
Annual Prodn. Volume	1500 t/y	3290 t/y
Est. Capital Investment	$58M	$31M

Transition and Deployment

- Licensing opportunity timeline
  - 88 participants in the webinar
  - 42 companies expressed interest
  - 9 qualified license applications received
    - Includes small businesses and current carbon fiber manufacturers
  - Anticipate 3-5 licenses

March 15 - Opportunity Announcement

April 7 - Webinar

April 8 – May 14 - Company Due Diligence

May 15 – License Applications Due

Early June – Invitations to Negotiate Licenses

Measure of Success

- Potential to enable the large scale introduction of low cost carbon fiber into the automotive and clean energy industries
- Support the auto industry in achieving 2025 CAFE standards
- Support IACMI in achieving institute goals
  - 25% lower carbon fiber composites cost
  - 50% reduction in carbon fiber composite embodied energy
  - 80% composite recyclability into useful products

Project Management & Budget

- Key milestones
  - Process and development of alternative precursors
    - Taekwang
    - Thai Acrylic
    - Dralon
  - Demonstrated control of key variables to increase throughput and reduce energy consumption
  - Initiated commercialization efforts

	FY 2013	FY 2014	FY 2015	FY 2016
AMO and VTO	$6.2 M	$6.2 M	$5.0 M	$5.2
Project and Other				0.5
Total	$6.2 M	$6.2 M	$5.0 M	$5.7

Results and Accomplishments

- Demonstrated large volume carbon fiber production using 3 different textile polyacrylonitrile (PAN) precursors at semi-production scale
  - Kaltex, Taekwang, Thai Acrylic
- Demonstrated 3x nameplate capacity of the CFTF
  - 25 tons/year to 75 tons/year
- Demonstrated reproducibility of processing conditions with multiple precursor lots
- Demonstrated commercially viable properties at ~50% reduction in energy consumption and production cost
  - 510ksi and 33msi – trials to maximize strength (Kaltex)
  - 467ksi and 40msi – trials to maximize modulus (Kaltex)
- Publically announced breakthrough and initiated licensing negotiations for commerciallization