Lightweighting Composites and Lower Cost Carbon Fiber

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ORNL’s mission

Deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security, and in doing so create economic opportunity for the nation.
ORNL’s Composites and Carbon Fiber Timeline

- **Technology transfer Federal Work-for-Other**
- **Begin DOE Lightweight Material Program & ACC collaboration**
- **Carbon Fiber Technology Facility**
- **Composite Joining**
- **Centrifuge Program**
- **Begin CF advanced conversion R&D**
- **Begin alternative precursor R&D**
- **DOE Low-cost carbon fiber initiative**
- **Industry calls for scale-up facility at ORNL workshop**

Timeline:
- 1960s
- 1980s
- 1990s
- 2000s
- 2010s
- 2020s
We use more in Transportation Alone than We Produce

The Oil Situation – Economic Vulnerability

Source of Oil
Gross Imports 45%
Domestic 55% (11.34 mbd)

Consumption
Transportation 69.8%

Cost of Imports (@ $50/bbl)
$567,000,000/day
$1,134,000,000/day @ $100/bbl

Transportation
69.8%

Industry
24.0%

*According to the Transportation Energy Data Book 2009 – Consumption of Petroleum by End-Use Sector, Table 1.13.

25.2 Million barrels per day
Source: EIA Website

Source: EIA Website

Transportation 69.8% Industry 24.0%
Vehicle Mass Reduction Opportunities

FC = 0.0052 (Wt) + 1.6736

- 10% Weight Reduction → 6-8% FE Improvement
- 1 kg Weight Reduction → 20 kg CO₂ Reduction

Carbon Fiber and Magnesium offer the greatest mass reduction & CO₂ reduction opportunity. Cost & how to use them are the greatest obstacles for implementation.

Source: 2011 Model Car U.S. Specifications and Prices, Ward's Automotive Group, a division of Penton Media Inc.
### Materials with 50+% Mass Reduction Potential

#### From March 2011 DOE Lightweighting Materials Workshop

<table>
<thead>
<tr>
<th>Structural Materials</th>
<th>Wt. Reduction Potential</th>
<th>Three Most Significant Technical Technology Barriers to Widespread Implementation</th>
<th>Major Market Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>30-60%</td>
<td>Joining dissimilar materials and 7000 series.</td>
<td>Better casting and manufacturing methods.</td>
</tr>
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</table>

**CF Barrier: Price is too High**

**Vehicle Materials Goal: Reduce the Cost of Carbon Fiber**

**Cost (DOE) and Price (OEM) Goal: $5 - $7 Per Pound**

**Property Goals:** Minimum 250KSI Strength, 25 MSI Modulus, >1% Strain

(Some debate on what properties are required)
Composite Materials Program History

Focal Project I: Escort Front End Crash Protection

Focal Project II: Pick-Up Bed Manufacturability/Cost

Focal Project III: Carbon Fiber BIW 67% Mass Savings

Focal Project IV: Composite Seat Floor Pan

Low Cost Carbon Fiber Precursor

Mg/Composite Crash Structure

DOE/ACC Focal Projects

1990s

Silverado Truck Composite Bed

Delphi Heavy Vehicle Tie Rods

CF Composite Rear Deck Lid and Seat

CF Fenders, Wheel House, and Floor Pan

2000s

Aston Martin Cargo Deck and Body Sides

Volvo Class 8 Truck Hood

Ford Carbon Fiber Hood

BMW Carbon Fiber Roof

Industry Major Composites Introductions
If the Demand is so Great, Why Don’t we see more applications in Automotive and other Industries?

“Chicken or Egg: Which came first?”

CF Industry: Can’t Develop lower cost fiber until there is demand.
Other Industries: Can’t Develop new applications until price is lower.

#1 Reason - $$$$$$$

But there are other Reasons

A Carbon Fiber Producer will want Multiple Markets
10 Obstacles to Market Growth in Transportation

#2 Designers are not comfortable with carbon fiber composites, especially in crash critical applications. Test Standards not uniform.

#3 Many composite processing methods are optimized for performance, not production rate efficiency.

#4 Larger structures are more cost sensitive to the raw material cost. Less material is needed for smaller structures = manufacturing costs dominate.

#5 Aerospace production processes pass through too many hands driving costs too high.

New Integrated Partnerships
BMW – SGL
Daimler – Toray
Toyota – Toho Tenax
Audi – GmbH
Evonik - CAMIMSA
10 Obstacles to Market Growth in Transportation

#6 Capital investment already sunk into metal forming equipment.

#7 Size of the carbon fiber industry cannot support large scale vehicle or other industry utilization.

#8 Boom or bust nature of the market. Aerospace preference.

#9 The secret art of surface treatment and sizing. CF secure market position by guarding ST & Sizing.

#10 The lack of resin targeted sizing systems. Sizings for aerospace systems are well developed. Not so for higher volume systems.
Carbon Fibers can be divided into 4 Broad Cost/Performance Categories:

**High Performance (Aerospace)**
- >750 KSI
- > 35 MSI
- Cost is not Limiting
- Performance Driven

**Moderate Grade (Industrial)**
- 500 – 750 KSI
- 25 – 35 MSI
- Cost and Performance
- Balance

**High Volume Grade (Not currently made)**
- 250 – 500 KSI
- < 25 MSI
- Cost Sensitive
- Performance Enabling

**Non Structural**
- Usually Low Cost - Chemical & Electrical Properties
## Cost Reducing Technologies

### Precursors
- **High PE Polyolefins** (Savings: $5.65)
- **Polyolefin Blends** (Savings: $2.00-$5.00)
- **PAN-VA Textile** (Savings: $2.61)
- **PAN-MA Textile** (Savings $5.00 from a different baseline)
- **High Content Lignin** (Savings: $2.68-$5.98)
- **Lignin Blends** (Savings: 11-25%)

### Stabilization & Oxidation
- **Advanced Oxidative Stabilization** (Savings: $2.69 – Mass Throughput Increase)

### Carbonization/Graphitization
- **Microwave Assisted Plasma** (Savings: $1.31)

### ST/Sizing
- **$1.78** (17%)
- **$1.41** (14%)
- **$0.80** (8%)
- **$0.65** (6%)

### Spooling & Packaging

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The ultimate goal is to combine technologies where possible: Example: Savings from a new precursor produced by the advanced oxidation and MAP processes coupled with the fiber volume reduction achieved through interfacial optimization. The combining of technologies will occur in the CFTF along with scale-up with and transfer to industry.
Precursor Evaluation System

- Designed for development of conventional processing recipes with limited quantities of precursor
  - Residence time, temperature, atmospheric composition, and tension are independently controlled in each furnace
  - Can process single filament up to thousands of filaments
  - Precise tension control and stretching capability allows stretched/tensioned processing of ~20-filament tows
  - Temperature capability from room temperature to 2,500ºC
**Conventional Pilot Line**

- 1:20 speed of a commercial grade production line
- Capacity for 1-5 tows
- Preferred tow size ≥ 3k
Carbon Fiber Technology Facility

- 25 tonnes/yr carbon fiber production capacity
- Multiple precursors and material forms
- Demonstrate technology scalability
- Produce fibers for material and process evaluation
- Develop partnerships and US workforce
- Forecast start-up in Feb 2013

Photos courtesy of R&R Partners – Developer
Blaine Construction – Construction manager
Barge, Waggoner, Sumner, and Cannon – Designer

Facility and equipment perspective.
ORNL has Fostered the Development of the Only Industry Consortium Focused on Low-Cost Carbon Fiber
There are Several Potential High-Volume Applications for Carbon Fiber

Civil Infrastructure
Rapid Repair and Installation, Time and Cost Savings

Bio-Mass Materials
Alternative Revenue Waste Minimization

Non-Traditional Energy
Geothermal, Solar & Ocean Energy

Non-Aerospace Defense
Light Weight, Higher Mobility

Aircraft Secondary Structures

Power Transmission
Less Bulky Structures Zero CLTE

Electronics
Light Weight, EMI Shielding

Oil and Gas
Offshore Structural Components

Vehicle Technologies
Necessary for 50+% Mass Reduction

Wind Energy
Needed for Longer Blade Designs

Energy Storage
Flywheels, Li-Ion Batteries, Supercapacitors

Pressurized Gas Storage
High Specific Strength

Carbon Fiber Producers will want to sell into Multiple Markets

www.bangordailynews.com
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Thank you for your attention.

Questions?