Emerging Innovation Trends in Composites

Presented To

11:30am Forum 3, Composites Engineering Show 2015

Presented By / Date

Nigel O’Dea, Lucintel / November 4, 2015
Table of Content

- About Lucintel
- Executive Summary
- Innovation: A Necessity for Survival
- Composites Industry Overview
- Emerging Innovations in Materials
- Emerging Innovations in Composite Applications
- Innovation Mega Trends
About Lucintel

Lucintel is a leading global management consulting & market research firm that helps companies in growth financing, M & A, market research and strategic consulting.

- An Associate Member of the UK National Composites Centre since March 2014

Vision:
- To provide accurate data, insights, strategy and innovation which empowers companies to make better informed decisions.

History
- Founded in 1998.
- Team of over 120 analysts / consultants - USA / Europe / India

Industry Leadership
- Over 1000 clients from 70 countries – Fortune 500 companies
- 15 years of proven global strategic management consulting and market research experience
- Panelists and key note speakers at leading conferences

Published Market Reports:
- Over 500 published market reports - > 50 covering the ‘Composites & Advanced Materials’ sector

Consulting Services:
- Market entry strategy, Opportunity screening, Competitive assessment, Strategic consulting,
- M & A services, Due diligence, Growth finance
1000+ Clients in 70 Countries Value Our Service
Key Contacts

**Sanjay Mazumdar, Ph.D.**
CEO, Author, & Strategist
Email: sanjay.mazumdar@Lucintel.com
Tel.: 972-636-5056

**Melissa Wilkinson**
Director of Client Engagements
Email: melissa.wilkinson@Lucintel.com
Tel.: 978-457-6323

**Nigel O’Dea**
Business Development Manager, Europe, Chemicals and Composites
Email: nigel.odea@Lucintel.com
Tel.: +44 741.357.1716

**Eleanor Eaton**
VP Strategy (3 Years at McKinsey)
Email: eleanor.eaton@Lucintel.com
Tel.: 972-636-5056

**Roy Almaguer**
Director of Sales
Email: roy.almaguer@Lucintel.com
Tel.: 210-878-7693
Table of Content

- About Lucintel
- Executive Summary
  - Innovation: A Necessity for Survival
  - Composites Industry Overview
  - Emerging Innovations in Materials
  - Emerging Innovations in Composite Applications
  - Innovation Mega Trends
Executive Summary

• Global composite materials market is estimated at $24.4 billion in 2014, and is forecast to grow at 5.8% CAGR in next five years to reach $34.4 billion in 2020

• Lucintel expects significant innovations in the composites industry in the next 50 years. Key mega trends in composite materials innovation are as follows:
  ➢ Continued light weighting of automotive, aerospace, and industrial parts
  ➢ Enhanced mechanical, chemical, and conductive properties of fiber and resin systems
  ➢ Cost reduction in various composite parts
  ➢ Faster and more predictable infusion
  ➢ Reduction in number of part counts in many applications
  ➢ Environmentally friendly resin and fiber systems

• Most of the innovations in composite materials are focusing on performance improvement and cost benefits:
  ➢ In carbon fiber, improvement in stiffness and strength along with development of low-cost carbon fiber for automotive, wind, and industrial applications are the major innovation trends
  ➢ Continuous innovation is expected in development of higher performance glass fibers and core materials to meet higher mechanical and chemical requirements
  ➢ Focus on green materials would give momentum to development of high strength natural fibers to increase penetration in Automotive, Construction, and other industries
Table of Content

• About Lucintel
• Executive Summary
• Innovation: A Necessity for Survival
• Composites Industry Overview
• Emerging Innovations in Materials
• Emerging Innovations in Composite Applications
• Innovation Mega Trends
Companies Continuously Innovate to Meet Unmet Needs & Stay Competitive in Complex Business Environments

Innovation creates “business value”, where value can be derived from a combination of:

- Meeting ‘unmet’ functional needs in target markets, and/or
- Meeting existing needs better or more economically

Range of performance that customers can utilize

Pace of technological progress

Unmet needs

Scope for Innovation

Performance

High

Low


Time
Table of Content

• About Lucintel
• Executive Summary
• Innovation: A Necessity for Survival
  • Composites Industry Overview
  • Emerging Innovations in Materials
  • Emerging Innovations in Composite Applications
  • Innovation Mega Trends
Existing Composite Applications and Competing Materials in Major End Use Market

Aerospace
- Fuselage
- Wings
- Control surfaces
- Fan blades
- Tail cones
- Interiors

- Aluminum
- Steel
- Plastics

Transportation
- Monocoque/Chassis
- Body closures
- Under the body
- Interiors
- Front cabin (train)

- Aluminum
- Steel
- Iron
- Plastics

Wind Energy
- Wind blades
- Nacelles
- Spinners

- Steel
- Iron

Construction
- Bathtub
- Doors & Windows
- Roofing & Cladding
- Putruded profiles
- Swimming pools

- Concrete
- Steel
- Plastics

Marine
- Hull
- Decks
- Flybridges
- Radomes
- Mast
- Rudders & Centreboards

- Aluminum
- Wood
- Steel
- Plastics

Source: Lucintel
Aerospace, transportation, and construction segments are expected to grow at a higher rate in the next five years than the composites industry average of 5.8% CAGR (2015-20).

Recovery of the housing market is likely to drive the construction market in coming years.

Wind energy segment rebounded significantly with about 40% growth in 2014 from 2013.
# Table of Content

- **About Lucintel**
- **Executive Summary**
- **Innovation: A Necessity for Survival**
- **Composites Industry Overview**
- **Emerging Innovations in Materials**
  - **Emerging Innovations in Composite Applications**
  - **Innovation Mega Trends**
Composites Compete in a US$953 Bn Global Structural Materials Market with Low Market Penetration, Offering Significant Growth Opportunities

<table>
<thead>
<tr>
<th>Segments</th>
<th>Global Composite Materials Market in 2014</th>
<th>Global Materials Market in 2014 (Steel, Aluminum, Composites)</th>
<th>Market Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>$6.0 Billion</td>
<td>$166.0 Billion</td>
<td>4% 96% $166.0 B</td>
</tr>
<tr>
<td>Marine</td>
<td>$0.7 Billion</td>
<td>$32.0 Billion</td>
<td>2% 98% $32.0 B</td>
</tr>
<tr>
<td>Aerospace</td>
<td>$1.4 Billion</td>
<td>$6.0 Billion</td>
<td>23% 77% $6.0 B</td>
</tr>
<tr>
<td>Pipe &amp; Tank</td>
<td>$3.5 Billion</td>
<td>$120.0 Billion</td>
<td>3% 97% $120.0 B</td>
</tr>
<tr>
<td>Construction</td>
<td>$3.9 Billion</td>
<td>$510 Billion</td>
<td>1% 99% $510.0 B</td>
</tr>
<tr>
<td>Wind Energy</td>
<td>$2.2 Billion</td>
<td>$11.0 Billion</td>
<td>20% 80% $11.0 B</td>
</tr>
<tr>
<td>Consumer Goods</td>
<td>$1.9 Billion</td>
<td>$66.0 Billion</td>
<td>3% 97% $66.0 B</td>
</tr>
<tr>
<td>E &amp; E</td>
<td>$3.7 Billion</td>
<td>$24.0 Billion</td>
<td>15% 85% $24.0 B</td>
</tr>
</tbody>
</table>

Source: Lucintel
Key Performance Gaps of Composites vs. Steel & Aluminum

**Affordability in materials and composites products**
- $0.5/lb
- $1.0/lb
- $0.7/lb
- $10-15/lb (Carbon Fiber)

**Recycling**
- Steel: >80%
- Aluminum: >85%
- Glass Fiber: Negligible
- Carbon Fiber: Negligible

**Ease of Repair**
- Steel: High
- Aluminum: High
- Glass Fiber: Low
- Carbon Fiber: Low

**Part Manufacturing Cycle Time**
- 1-2 minutes
- 2-3 minutes for GFRP
- Sub 5 minutes for CFRP now possible

**Education to engineers and end users**
- Steel: High
- Aluminum: High
- Glass Fiber: Low
- Carbon Fiber: Low

Source: Lucintel
Key Emerging Innovations in Composite Materials: A Bird’s Eye View

- **Carbon Fibers**
  - Improvement in strength and stiffness for aerospace applications
  - Cost reduction, with a target of US$ 5-7/lbs raw material cost for high volume automotive applications

- **Glass Fibers**
  - Improvement in strength and stiffness for automotive applications
  - Reduction in impurities for property enhancements
  - Reduction in diameter for PCBs

- **Natural Fibers**
  - Improvement in strength and stiffness to compete with glass fiber
  - Finding new application areas to expand the footprints in different industries

- **Resin**
  - Shorter cure time for high volume automotive applications
  - Optimum gel time for long wind blade size
  - Increasing resin strength by using nano tubes

- **Core Materials**
  - Lower density core materials to meet end use industries demand
  - Improvement in strength and stiffness for automotive and other applications

- **Compounds**
  - Improvement in strength and stiffness for automotive applications
  - Improvement in impact resistance and aesthetic properties
Lucintel Studied >300 Innovations Across the Value Chain of Composites Industry to Identify Direction of Innovation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Description</th>
<th>Innovation Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Integration</td>
<td>How easily material / product can be integrated in manufacturing system or existing system. Does it require any additional investment or changes in the system?</td>
<td>Low to High</td>
</tr>
<tr>
<td>Application Enhancement</td>
<td>Will this new innovation in material or product improve performance of the system or reduce the overall system cost</td>
<td>Low to High</td>
</tr>
<tr>
<td>Market Acceptance Probability</td>
<td>What is the probability that this material / product can be accepted if enough marketing and technical resources are deployed. Does this innovation solve key industry challenges?</td>
<td>Low to High</td>
</tr>
<tr>
<td>Overall Innovation Attractiveness</td>
<td></td>
<td>Low to High</td>
</tr>
</tbody>
</table>

Composites becoming the material of choice for various industries due to its cost-performance benefits. Lots of innovations are taking place in the market across the value chain. Lucintel has analysed the innovation attractiveness from different angles.
Most Innovations are Focusing on Performance Improvement & Cost Benefits in Composites Industry

Innovations in Composites Industry Towards Cost and Performance - Total Sample Size: 260 *

Cost Benefit 30%
Performance Benefit 70%

* Note: Sample size is based on Lucintel’s innovations studies over the last three years

Source: Lucintel

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Glass Fibers</th>
<th>Carbon Fibers</th>
<th>Natural Fibers</th>
<th>Resins</th>
<th>Compounds</th>
<th>Core Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curing Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Performance Improvements

Cost Reduction

Source: Lucintel
To Meet Market Expectations of Low Cost Carbon Fiber - A New Cellulose-based Carbon Fiber made from Recycled Plant Matter

Key Features

- It has the ability to replace glass fibers in high-performance composites used in cars and airplanes.
- It is more sustainable and environmentally friendly unlike the traditional carbon fiber made from polyacrylonitrile (PAN) that generates toxic gases such as hydrogen cyanide as by-products.
- It has very good mechanical properties with a Young’s modulus of over 70 GPa, strength of 1.5 GPa, and breaking strain of 2.2%.
- It also helps in lowering greenhouse gas emission.

Recycled plant matter converted into cellulose fibers Cordenka™ to form high strength carbon fibers

Developed by The Universities of Exeter and Manchester
About Lucintel

Executive Summary

Innovation: A Necessity for Survival

Composites Industry Overview

Emerging Innovations in Materials

Emerging Innovations in Composite Applications

Innovation Mega Trends
Innovations in Composite Applications

• Lightweighting and cost reduction are the two ‘mega trends’ in various application segments, such as automotive, aerospace, and wind energy:
  
  ➢ In automotive industry, low-cost carbon fiber composite parts for different applications are emerging. Government regulations on fuel efficiency are putting pressure on OEMs to make their vehicles lighter
  
  ➢ In aerospace, increasing usage of carbon composite and nano composite applications are emerging. Aerospace industry is moving towards automated tape laying (ATL) and automated fiber placement (AFP) process to increase throughput
  
  ➢ In wind energy, there is growing trend towards developing one-piece and modular wind blade technology. Carbon fiber usage is also growing in line with increase in blade lengths > 50 Mtrs

New one piece CFRP wheel  
BMW i3- CF recycled roof  
New carbon fiber chair  
New modular wind blade  
Boeing 737 Max – winglet  
New glass roving for LFT
Material Trends in the in North American Light Vehicles

Automotive Material Mix from 1975 to 2010
(Average Vehicle Weight in lbs)

<table>
<thead>
<tr>
<th>Year</th>
<th>Steel</th>
<th>High Strength Steel</th>
<th>Iron</th>
<th>Aluminum</th>
<th>Other Metals</th>
<th>Plastics &amp; Composites</th>
<th>Other Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>3.6%</td>
<td>15.0%</td>
<td>2.2%</td>
<td>6.3%</td>
<td>3.8%</td>
<td>6.5%</td>
<td>4.6%</td>
</tr>
<tr>
<td>1995</td>
<td>12.6%</td>
<td>8.8%</td>
<td>3.8%</td>
<td>7.5%</td>
<td>3.9%</td>
<td>7.8%</td>
<td>3.0%</td>
</tr>
<tr>
<td>2002</td>
<td>9.0%</td>
<td>11.3%</td>
<td>7.5%</td>
<td>9.0%</td>
<td>5.9%</td>
<td>9.4%</td>
<td>2.2%</td>
</tr>
<tr>
<td>2010</td>
<td>40.8%</td>
<td>44.4%</td>
<td>13.8%</td>
<td>40.8%</td>
<td>17.3%</td>
<td>17.3%</td>
<td>6.1%</td>
</tr>
</tbody>
</table>

Change in Materials Usage Per Vehicle from 1975 to 2010 (in lbs)

- Steel: -598 lbs
- High Strength Steel: 419 lbs
- Iron: -348 lbs
- Aluminum: 258 lbs
- Other Metals: 57 lbs
- Plastics & Composites: 199 lbs
- Other Materials: 154 lbs

Average Vehicle Weight in lbs:
- 1975: 3,900 lbs
- 1995: 3,694 lbs
- 2002: 3,924 lbs
- 2010: 4,040 lbs
Emerging Use of 3D Printing with Composites for Making Automotive Parts in Less Time

Key Features

- Local Motors and Thermwood has developed first 3D printed car named as Strati.
- This car takes 44 hours to print, 1 day to mill and 2 days to assemble, making a 5 day build process in total.
- The Strati is printed by stacking down layer upon layer of a combination of about 80% ABS plastic and 20% carbon fiber reinforcement.
- It takes about 212 layers of this material to complete the Strati’s chassis.
- It is the first time that the main portion of a car has been printed in one piece using direct digital manufacturing.

Made from a mix of carbon fibre and plastic (ABS)

It opens the door for mass production of automotive parts and car with 3D printing
Part Consolidation – One Piece Monocoque

Aventador

CFRP by Weight

80%

50%

One Piece CFRP Monocoque

Sesto Elemento

Faster

Lighter

Technology

RTM-Lambo

ARALDITE epoxy & dry stitched fabric

One-shot Forged Composites Technology

Vinyl ester resin & 1- to 2-inch long cut 12k carbon fibers

Material

Car Weight

3472 lbs

2202 lbs
One Piece Design Few Examples

- **Mclaren: MP4-12C MonoCell**
- **Lamborghini Aventadore Monocoque**
- **Lamborghini Sesto Elemento Monocoque**
- **Alfa Romeo: 4C Monocoque**
- **BMW: I3 Passenger Cell**
Composites Continue To Replacing Traditional Materials in the Aerospace Industry

Stronger and more lightweight materials help make more fuel efficient aircraft

- Fuel price increased from ~US$30/barrel in 1970 to a peak of ~$127/barrel in 2013 (Oct 2015 ~US$60/barrel)
- Composites have excellent strength-to-weight ratio

Source: Lucintel
# One-Piece Fuselage Section

<table>
<thead>
<tr>
<th>One-Piece Fuselage</th>
<th>Key Features &amp; Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="787" /></td>
<td>• Made of carbon composites</td>
</tr>
<tr>
<td><img src="image2.png" alt="HondaJet" /></td>
<td>• 22 feet long and 19 feet in diameter</td>
</tr>
<tr>
<td></td>
<td>• Parts consolidation thus low joints and low need for fasteners</td>
</tr>
<tr>
<td></td>
<td>• Lower maintenance cost than that of aluminum planes</td>
</tr>
<tr>
<td></td>
<td>• The fuselage is created from a cutting-edge combination of co-cured integral structure and honeycomb sandwich structures</td>
</tr>
<tr>
<td></td>
<td>• Increased cabin space</td>
</tr>
<tr>
<td></td>
<td>• Better performance</td>
</tr>
<tr>
<td></td>
<td>• Greater fuel efficiency</td>
</tr>
</tbody>
</table>
Monolithic Design: Siemens B75 - World's Largest Fiberglass Component Cast in One Piece

Covers a Surface Area of 18,600 m² Equivalent to Two and a Half Soccer Fields

<table>
<thead>
<tr>
<th>Highest Blade Length</th>
<th>75 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>6MW</td>
</tr>
<tr>
<td>Rotor Diameter</td>
<td>154 m</td>
</tr>
<tr>
<td>Highest Length to Weight Ratio</td>
<td>3 m/ton</td>
</tr>
<tr>
<td>High Tip Speed</td>
<td>80 m/s</td>
</tr>
</tbody>
</table>

Process
Siemens uses the patented IntegralBlade process, in which the entire blade is poured as a single piece made of glass fiber-reinforced epoxy resin and balsa wood.
Table of Content

- About Lucintel
- Executive Summary
- Innovation: A Necessity for Survival
- Composites Industry Overview
- Emerging Innovations in Materials
- Emerging Innovations in Composite Applications
- Innovation Mega Trends
Lucintel Expects Significant Innovations in the Composites Industry Over the Next 50 Years

Mega Trends in Composites Industry Innovations

- Lightweighting of automotive, aerospace and industrial parts
- Enhanced mechanical, chemical and conductive properties of fiber and resin systems - incorporation of nano technology in next generation composites
- Cost reduction of composite parts - role of additive manufacturing & robotics
- Faster and more predictable infusion
- Reduction in number of part counts in many applications (reduced BOMs)
- Environmental-friendly resin and fiber systems

Composites are under represented in many markets and potential applications.

The above innovations trend will enable composite materials to increase penetration across different industries such as automotive, aerospace, wind, etc.
Top Five Areas for Composites Innovations to Address Market Needs

1. Application Development
   - Aerospace: Fuselage, Wing, Fan Blades, etc.
   - Automotive: Suspension Control Arm, Wheels, roof panels, etc.
   - Wind Energy: Tower, Drive Shafts

2. Low Materials Cost
   - ORNL and Weyerhaeuser working to lower carbon fiber raw material cost to the level of US$5 – US $7/lbs

3. Low Cycle Time and High Layup Rate *
   - High Pressure RTM (~3-10 minutes)
   - CFRTP parts made by RTM/ LCM using technology by Toho Tenax and Hexion (~1-1.5 minutes)
   - Pressure Press by Plasan Composites (~17 minutes)
   - Combination of AFP and ATL Machines (150 kg/hr)

4. Property Enhancement
   - Increase in mechanical performance (strength, stiffness, etc.) of Glass and Carbon Fibers
   - Develop better resin system (low cure, low gel, higher strength)

5. Composites Recycling
   - Closed-loop CFRP Recycling Technology by BMW for its i3
   - Collaboration between BMW and Boeing for composite recycling

* 52% of patents granted for Composites in Europe during 2011-12 were related to Robotics and Automated Manufacturing Systems
Automotive, Civil Engineering, Oil & Gas, and Medical Markets Expected to be Key Future Growth Engines for Composites & Innovation
Thank You for your kind attention.

If you wish to receive a PDF copy of this presentation, please leave your business card with me.