Leichtbau mit Carbonfasern

Material Solutions for Advanced Lightweight Design

Dr. Steffen Janetzko | Hannover Messe | April 16th, 2015
Company Profile
SGL Group

- One of the world’s largest manufacturers of carbon-based products
- Comprehensive portfolio ranging from carbon and graphite products to carbon fibers and composites
- 42 production sites worldwide
- Service network covering more than 100 countries

- Sales of ~€ 1.3 bn in 2014
- Head office in Wiesbaden/Germany
- ~ 6,300 employees worldwide
- Listed on German Stock Exchange
Our core markets and industries

- Coarse grain graphite
  - Iron and steel
  - Aluminum

- Fine grain graphite and natural graphite
  - Semiconductor
  - High temperature technology
  - Mechanical engineering
  - Automotive
  - Chemicals
  - Solar

- Carbon fibers and composites materials
  - Automotive
  - Aviation
  - Energy
  - Environmental technology
  - Sports
Technology & Innovation
Focus on three areas of research and support platforms

<table>
<thead>
<tr>
<th>Synthetic graphite</th>
<th>Energy systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite electrodes</td>
<td>Materials for:</td>
</tr>
<tr>
<td>Furnace linings</td>
<td>Lithium-Ion Batteries</td>
</tr>
<tr>
<td>Cathodes</td>
<td>Redox-Flow Batteries</td>
</tr>
<tr>
<td>Graphite specialties</td>
<td>Fuel cells</td>
</tr>
<tr>
<td></td>
<td>Thermal Management</td>
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<table>
<thead>
<tr>
<th>Carbon fibers &amp; composite materials</th>
<th>Support Platforms</th>
</tr>
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<tbody>
<tr>
<td>Precursor</td>
<td>Raw materials platform</td>
</tr>
<tr>
<td>Carbon fibers</td>
<td>Process platform</td>
</tr>
<tr>
<td>Duroplasts and thermoplasts</td>
<td>New Business Development</td>
</tr>
<tr>
<td></td>
<td>Group IP</td>
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</tbody>
</table>
### Growth opportunities

**Global megatrends**

<table>
<thead>
<tr>
<th>Traditional carbon markets</th>
<th>New carbon markets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GDP growth</strong></td>
<td><strong>Energy</strong></td>
</tr>
<tr>
<td>Urbanization</td>
<td>Renewables</td>
</tr>
<tr>
<td>GDP growth - CAGR -</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>(2012 - 2035)</td>
<td>Energy storage</td>
</tr>
<tr>
<td>+3.5%</td>
<td></td>
</tr>
<tr>
<td>World Population</td>
<td></td>
</tr>
<tr>
<td>+38%</td>
<td></td>
</tr>
<tr>
<td>Energy Consumption</td>
<td></td>
</tr>
<tr>
<td>+41%</td>
<td></td>
</tr>
<tr>
<td>CO₂ Emissions</td>
<td></td>
</tr>
<tr>
<td>+29%</td>
<td></td>
</tr>
<tr>
<td>Semiconductor Ind. - CAGR -</td>
<td></td>
</tr>
<tr>
<td>+4.7%</td>
<td></td>
</tr>
</tbody>
</table>

**Sources:** BP 2014 – Energy Outlook; United Nations, International Energy Agency (IEA), Semiconductor Industry Association (SIA)
Lightweight Solutions
Key for achieving global CO₂ emissions targets

National and global regulations for selected segments

**Automotive - EU fleet targets**
- Actual: ~ 130g CO₂/km
- Target: ~ 95g CO₂/km
- ~ 27%

**Aerospace - CleanSky**
- Actual: ~ 622Mt CO₂
- Target: ~ 310Mt CO₂
- ~ 50%

**Railway - Deutsche Bahn**
- Actual: ~ 7Mt CO₂
- Target: ~ 6Mt CO₂
- ~ 14%

**Maritime - Int. Maritime Organization**
- Actual: ~ 865Mt CO₂
- Target: ~ 714Mt CO₂
- ~ 17%

Sources: AllianzProSchiene, DB AG, Reinf. Plastics Mag. 07/08-12; CleanSky, GBI Research; EU CAFE; IMO
Solid future growth
Carbon Fiber Demand by Application

Annual Carbon Fiber Demand – all tow sizes [000t]

- CAGR -

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<tr>
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<tbody>
<tr>
<td>Aerospace</td>
<td>24%</td>
<td>8%</td>
</tr>
<tr>
<td>Sports</td>
<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td>Industrial</td>
<td>12%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Sources: SGL Group, Oct 2014
## Carbon Fibers / Composite Materials

SGL Group only integrated European carbon fiber producer

### Carbon Fibers & Composite Materials

- **PAN Precursor**
  - **Fisipe** (100%)
  - **MSP**: JV with Mitsubishi Rayon (33%)

- **Carbon Fiber**
  - **Prod. Capacity**
    - ~4kt in UK
    - ~2kt in USA
  - **SGL-ACF**: JV with BMW (51%)
    - ~3kt in USA

- **Composite Materials**

### Composite Components*

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Carbon Fiber</th>
<th>Prepreg Preform</th>
<th>Automotive &amp; other industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benteler SGL (50%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brembo SGL Carbon Ceramic Brakes (50%)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* Former Business Unit Rotor Blades sold as of December 31, 2013
** Business Unit Aerostructures reclassified to discontinued operations as of June 30, 2014
*** Tripling of capacity to 9kt announced on May 9, 2014
Lightweight Carbon Composite Materials as Enabler for E-Mobility

Weight Reduction Potential for Car Body

CFRP* Car Body compensates battery weight

<table>
<thead>
<tr>
<th>Materials</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>1.0</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.6</td>
</tr>
<tr>
<td>CFRP*</td>
<td>0.4</td>
</tr>
</tbody>
</table>

- **CFRP* Car Body**: 40% lighter than steel
- **Steel**: 60% lighter than Aluminum

**Examples**
- **BMW 1er**: 1.280kg
- **BMW i3**: 1.250kg

* Carbon Fiber Reinforced Polymers
**Carbon Fiber Reinforced Polymers (CFRP)**

Material Systems with superior properties

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**Main characteristics of CFRP**

- Low weight
- High strength and break resistance
- Good rigidity
- Corrosion resistance
- Vibration resistance
- Low thermal expansion
- Freedom of design

**Applications for various Industries**

- Automotive
- Aviation
- Energy
- Civil & Mechanical Engineering
- Sports
- Medical Technology
- Robotics & Automation
Aerospace
History of Lightweight Design & CFRP Materials

Share of CFRP in Primary Structure [in %]

- Boeing 767
- Boeing 777
- Boeing 787
- Airbus A320
- Airbus A330/340
- Airbus A380
- Airbus A350

Composite intensive A350
- >50% of the primary structure weight in CFRP
- Process characteristics
  - Long cycle times
  - Small serial
  - Higher quality standard

Sources: BofA Merrill Lynch, Airbus
Automotive History of Lightweight Design

Empty weight development of vehicles 1970-2020 [in kg]

Sources: VW, Opel, Ford

Models / Vehicles
- Golf (I-VII)
- Kadett / Astra
- Escort / Focus

Page 12 | Dr. Steffen Janetzko, Hannover Messe 2015
Automotive
History of CFRP Materials

Sources:
Source: RedBull F1, Daimler AG, Audi AG, BMW AG
Lightweight Design for E-Mobility
BMW i3/i8 – A benchmark for CFRP in Automotive

- Overall concepts **dedicated to** electro mobility
- Structural design **aligned with** composite requirements
- **Large scale production** of Carbon fibers and Composites
SGL Automotive Carbon Fibers
Global supply chain

1. Precursor
   - Japan -

2. Carbon Fiber Production
   - USA -

3. Textiles and Recycling
   - Germany -

4. Composite Components
   - Germany -

5. BMW i3/ i8 Production
   - Germany -

1 | Otake
2 | Moses Lake
3 | Wackersdorf
4 | Landshut
5 | Leipzig

- Mitsubishi Rayon-SGL Precursor
- SGL Automotive Carbon Fibers
- BMW Group
SGL Automotive Carbon Fibers
Production Sites

**Moses Lake / USA**

Selection Criteria

- **100 % Green Energy:**
  - Hydro-electric power station nearby

- **Low Energy Costs:**
  - Approx. 0,03USD/kwh at Moses Lake

**Wackersdorf / Germany**

Key facts

- **Production:** 6000 t/p.a. of carbon fiber fabrics

- **Recycling:** Recycling of cutting trims

- **Sustainability:** Site runs on renewable energy

- **Employment:** 500 employees
Current status of Lightweight Design by CFRP
Aerospace & Automotive

- Material and automation concepts in aerospace address **small lot-sizes** with **high performance**
- Textile & infusion based manufacturing technologies have **an upper lot-size limit**

**Aerospace**
Serial Production ≈ **100 units / p.a**

**Automotive**
Serial Production ≈ **10,000 units / p.a**

- Low **material utilization** of carbon fabrics
- High **process costs** due to thermoset materials
  - Infusion and polymerization time
  - Autoclave curing of epoxy prepregs
- Manufacturing equipment **efficiency too low**
**Current challenges for CFRP materials**  
**Automated manufacturing technologies**

### Requirements

<table>
<thead>
<tr>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ High <strong>technical availability</strong></td>
</tr>
<tr>
<td>▪ High overall <strong>equipment efficiency</strong> (OEE)</td>
</tr>
<tr>
<td>▪ <strong>Integrated quality management</strong> systems</td>
</tr>
</tbody>
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### Challenges

**Manufacturing Concepts**

- **Aerospace**
  - Barrel Production
  - Boeing

- **Automotive**
  - i3 Production Leipzig
  - BMW Group

**Transfer of Automation Concepts is NOT feasible**
Current challenges for CFRP materials
Disposal & Recycling

Requirements

<table>
<thead>
<tr>
<th>CFRP Recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Consistent <strong>scrap availability</strong></td>
</tr>
<tr>
<td>• Appropriate <strong>size reduction technologies</strong> for the CFRP waste</td>
</tr>
<tr>
<td>• Established <strong>process parameters</strong></td>
</tr>
<tr>
<td>• <strong>Infrastructure</strong> for secondary operations</td>
</tr>
</tbody>
</table>

Challenges

<table>
<thead>
<tr>
<th>Reclaim CFRP Scrap / Wastage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopped</td>
</tr>
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</table>

Recycled CFRP are perceived to be “secondary” with lower quality
### Current challenges for CFRP materials
#### Multi-material Design Concepts

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CFRP Potential Analysis</strong></td>
<td><strong>Multi-material Design Concepts</strong></td>
</tr>
<tr>
<td>- Load path</td>
<td>- Joining concepts</td>
</tr>
<tr>
<td>- Design room</td>
<td>- Thermal expansion</td>
</tr>
<tr>
<td>- Location of the component</td>
<td>- Assembly line integration</td>
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</table>

**Analysis of the body in order to identify components with high CFRP potential**

- B-pillar: CFRP Insert for increased impact stability

**Source:** Audi AG

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Thermoplastic Materials
Enabler for High Volume Production?

- Short Cycle Times
- Recycling
- Repair Concepts
- Hybrid Materials
- Welding
- Transport and Storage at Room Temp.

Source: BMBF Project SpriForm, SGL Group
**SGL’s innovation approach for a growth in CFRP**

**Three pillars for a sustainable development**

<table>
<thead>
<tr>
<th>Facilitate Education</th>
<th>Joint Developments</th>
<th>Industrial Associations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institute for Carbon Composites (LCC)</strong></td>
<td><strong>Leading Edge Cluster M-A-I Carbon</strong></td>
<td><strong>Carbon Composites e.V.</strong></td>
</tr>
</tbody>
</table>
| ▪ Endowed chair at TU Munich  
  - R&D support and services  
  - Joint projects  
  - Education | ▪ Joint technology development targets  
  - ↓ 90% process cost  
  - ↓ 50% material cost  
  - 60 - 80% value add in GER | ▪ The Carbon Composite Association  
  - Joint projects  
  - Networking platform  
  - Marketing |
Carbon Fiber Reinforced Polymers
Industry Snapshot

**CFRP** materials still **represent a small niche**

**i3/i8** production is **industrial pioneering** for the future of urban mobility

Transfer from **manual** production **to serial production**

**Multi-material mix** addresses major issues

Still major **challenges ahead**

**Networks** are requisite for future success
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