The Enablers

Our continuous carbon fiber tows

SIGRAFIL®
We focus on what keeps our customers one step ahead. Continuous carbon fiber tows are heavy tows with 50,000 filaments (50k). Each of our 50k heavy tows have outstanding mechanical properties that can be transferred to the finished products and components. The fibers can be chosen to match specific requirements, for example by prioritizing stiffness or strength. In addition, these wide 50k fiber tows offer time and cost advantages, especially in high-volume processes. Smart solutions from SGL Carbon – the real enablers.
SIGRAFIL® continuous carbon fiber tows
The basis for high-performance composites
Our continuous carbon fiber tows

Continuous carbon fiber tows from SGL form the basis of many composite applications and are used in numerous industries. To guarantee the very highest quality, we manufacture our SIGRAFIL continuous carbon fiber tows exclusively in our plants in Europe and North America. In addition, our customers benefit from our unique expertise in 50k fibers across all processing stages.

Market segments of our Business Unit Composites – Fibers & Materials

<table>
<thead>
<tr>
<th>Typical applications</th>
<th>Automotive</th>
<th>Industrial Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Structural components</td>
<td>• Medical technology</td>
</tr>
<tr>
<td></td>
<td>• Design components</td>
<td>• Robotics and automation technology</td>
</tr>
<tr>
<td></td>
<td>• Chassis components</td>
<td>• Measuring technology and optics</td>
</tr>
<tr>
<td></td>
<td>• Drive train</td>
<td>• Machinery manufacture</td>
</tr>
</tbody>
</table>

Typical products

|                      | Pultruded profiles | Woven, unidirectional, and multiaxial fabric/prepreg production |
|                      | Braided components | Pultruded profiles |
|                      | Filament-wound components | Filament-wound components |
|                      | Thermoplastic composite materials | Thermoplastic composite materials |

Materials used from SGL Carbon

|                      | SIGRAFIL® continuous carbon fiber tows 50k | SIGRAFIL® continuous carbon fiber tows 50k |
|                      | SIGRAFIL® continuous carbon fiber tows 24k |.SIGRAFIL® continuous carbon fiber tows 24k |
Endless possibilities
For high-tech applications requiring high strength and stiffness combined with lightweight, SIGRAFIL continuous carbon fiber tows are indispensable. They form the basis for carbon fiber-reinforced plastics (CFRP), are suitable for a wide variety of processing technologies, and open up new possibilities in the serial production of CFRP components.

It is no wonder, then, that our continuous carbon fiber tows have consistently proven their value over many years: for example in the automotive industry, the aerospace industry, the energy sector, and many other industrial applications. More and more customers are making use of our comprehensive 50k expertise for trouble-free processing of 50k heavy tows.
Fibers that transform ideas into reality

You have the idea, we have the transformers: continuous carbon fiber tows with 50,000 filaments. Our 50k tows are the ideal basis for high-performance textiles, pre-impregnated products, and composite components. Together with you, we find the best carbon fiber for your application, develop new solutions, and ensure efficient production – from small to high-volume manufacturing.
SIGRAFIL® continuous carbon fiber tows based on PAN

We manufacture SIGRAFIL on the basis of a polyacrylonitrile fiber (PAN fiber). With its high strength, high elastic modulus, and low density, SIGRAFIL is a high-performance material that makes it possible to produce very stiff yet lightweight composites.

We use heavy tows with 50,000 filaments that offer time and cost advantages in many different processes. By making application-tailored adjustments, we can provide individual solutions for different requirements and processes.

Typical applications
- Unidirectional and multiaxial fabric/prepreg production
- Pultrusion
- Braiding and filament winding processes
- TowPreg production
- Use for C-SMC
- Production of thermoplastic composite materials

SIGRAFIL material advantages
- Best mechanical properties
- Low density (light weight)
- Low thermal expansion
- Good electrical conductivity
- High corrosion resistance
- Excellent impregnation behavior
- Good spreadability

Production process for SIGRAFIL® continuous carbon fiber tows

PAN precursor → Oxidation 200 – 300 °C (392 – 572 °F) → Carbonization 1200 – 1600 °C (2190 – 2912 °F) → Surface treatment → Sizing → Winding
SIGRAFIL continuous carbon fiber tows are far superior to glass and aramid fibers. Particularly when it comes to the key properties of strength and stiffness, carbon performs significantly better as a fiber material than glass and aramids. What’s more, carbon fibers do not undergo temperature-dependent expansion or shrinkage. With these exceptional properties, carbon fibers are the ideal material basis for high-quality composites.

Stronger, stiffer, more heat-resistant: carbon outperforms glass and aramids in key areas

Comparison of our SIGRAFIL® continuous carbon fiber tows with other fiber materials

Overview of SGL basic fiber types
The Enablers | Material properties

Enhanced performance by sizing

By applying different types of sizing, the carbon fibers can be optimally matched to different matrix systems. In this way, it is possible to produce application-tailored versions as well as the standard materials. So, together with our customers, we find optimized solutions for their challenges.

### Material data of our SIGRAFIL® continuous carbon fiber tows

<table>
<thead>
<tr>
<th>Typical properties</th>
<th>Units</th>
<th>C T50-4.0/240-E100</th>
<th>C T50-4.4/255-E100</th>
<th>C T50-4.8/280-E100</th>
<th>C T24-5.0/270-E100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of filaments</td>
<td>50k</td>
<td>50k</td>
<td>50k</td>
<td>3070</td>
<td>1600</td>
</tr>
<tr>
<td>Finess of yarn dry</td>
<td>tex (g/1000m)</td>
<td>3420</td>
<td>3420</td>
<td>6.6</td>
<td>6.9</td>
</tr>
<tr>
<td>Density</td>
<td>g/cm²</td>
<td>1.80</td>
<td>1.80</td>
<td>1.78</td>
<td>1.79</td>
</tr>
<tr>
<td>Single filament diameter</td>
<td>µm</td>
<td>7.0</td>
<td>7.0</td>
<td>6.6</td>
<td>6.9</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>GPa</td>
<td>4.0</td>
<td>4.4</td>
<td>4.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>GPa</td>
<td>240</td>
<td>255</td>
<td>280</td>
<td>270</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>%</td>
<td>1.70</td>
<td>1.65</td>
<td>1.65</td>
<td>1.90</td>
</tr>
<tr>
<td>Single filament resistivity</td>
<td>µΩm</td>
<td>15</td>
<td>17</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Sizing type</td>
<td></td>
<td>epoxy</td>
<td>epoxy</td>
<td>epoxy</td>
<td>epoxy</td>
</tr>
<tr>
<td>Sizing content</td>
<td>%</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Sizing types for our SIGRAFIL® continuous carbon fiber tows

<table>
<thead>
<tr>
<th>Sizing type</th>
<th>Thermoset matrix</th>
<th>Thermoplastic matrix</th>
<th>Matrix compatibility</th>
<th>Sizing content [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>E100</td>
<td>●</td>
<td></td>
<td>Epoxy, polyurethane, phenol, vinyl ester</td>
<td>1.0</td>
</tr>
<tr>
<td>V100</td>
<td>●</td>
<td></td>
<td>Vinyl ester (and all radical-based curing systems), unsaturated polyester, epoxy</td>
<td>1.3</td>
</tr>
<tr>
<td>UN</td>
<td>●</td>
<td>●</td>
<td>Epoxy, phenolic, vinyl ester, polyurethane, polycarbonate, polyester, polysulfone, cyanate ester, polyamide, BMI, PESU, PEEK, PEKK, PVC, polyimide</td>
<td>0.0</td>
</tr>
<tr>
<td>T115</td>
<td>●</td>
<td></td>
<td>Polypropylene</td>
<td>0.9</td>
</tr>
<tr>
<td>T140</td>
<td>●</td>
<td></td>
<td>Polyamide (up to 300°C), polyurethane, polyester</td>
<td>0.6</td>
</tr>
<tr>
<td>T150</td>
<td>●</td>
<td></td>
<td>PA-RIM process (in-situ polymerization of caprolactam, e.g. reactive PA processing)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

### Nomenclature

**SIGRAFIL C T50-4.4/255-E100**

1. Brand name: SIGRAFIL
2. Material: C = carbon
3. Type: T = Continuous tow
4. Number of filaments: 50 = 50,000
5. Mechanical properties: Tensile strength/elastic modulus in GPa
6. Sizing type: E100 = epoxy
Maximum performance in the component: with our sizings for thermoset and thermoplastic systems

Continuous carbon fiber tows for epoxy resin matrix systems
Numerous CFRP components are based on an epoxy resin matrix. For this sector, our continuous carbon fiber tows coated with E100 sizing have been used successfully for many years in a wide variety of applications. A good example is our extensive experience in the large-scale serial production of 50k carbon fibers for high-quality automotive applications. Continuous carbon fiber tows from SGL with various resin systems ensure excellent composite properties such as tensile strength, elongation at break, and stiffness. They are a perfect basis for the production of high-performance components.

Typical epoxy composite properties*

<table>
<thead>
<tr>
<th>Typical properties</th>
<th>Units</th>
<th>Test method</th>
<th>C T50-4.0/240-E100</th>
<th>C T50-4.4/255-E100</th>
<th>C T50-4.8/280-E100</th>
<th>C T24-5.0/270-E100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength 0°</td>
<td>MPa</td>
<td>ISO 527</td>
<td>2000</td>
<td>2150</td>
<td>2350</td>
<td>2450</td>
</tr>
<tr>
<td>Tensile modulus 0°</td>
<td>GPa</td>
<td>ISO 527</td>
<td>140</td>
<td>150</td>
<td>165</td>
<td>160</td>
</tr>
<tr>
<td>Elongation at break 0°</td>
<td>%</td>
<td>ISO 527</td>
<td>1.45</td>
<td>1.45</td>
<td>1.45</td>
<td>1.55</td>
</tr>
<tr>
<td>Compressive strength 0°</td>
<td>MPa</td>
<td>ISO 14126</td>
<td>1100</td>
<td>1150</td>
<td>1200</td>
<td>1250</td>
</tr>
<tr>
<td>Compressive modulus 0°</td>
<td>GPa</td>
<td>ISO 14126</td>
<td>125</td>
<td>130</td>
<td>137</td>
<td>135</td>
</tr>
<tr>
<td>Interlaminar shear strength</td>
<td>MPa</td>
<td>ISO 14130</td>
<td>82</td>
<td>82</td>
<td>82</td>
<td>82</td>
</tr>
</tbody>
</table>

* Standardized to a fiber volume content of 60%. Compressive strength and interlaminar shear strength greatly depend on the resin system used and composite structure.
Continuous carbon fiber tows for fiber-reinforced thermoplastics
Besides thermoset matrix systems, increasing use is being made of thermoplastic systems. To provide solutions for our customers that ensure the best possible performance of these systems in the component, we have developed two sizings specially optimized for fiber-reinforced thermoplastics: T140 for polyamide-based matrix systems and T115 for polypropylene matrix systems.

T140 – sizings for polyamide matrix systems
The tailored chemistry of the T140 carbon fiber surface permits an optimum fiber/matrix bond, hence enabling full utilization of fiber stiffness and strength in the final component. Compared to standard epoxy sizings, a performance enhancement of over 100% is possible in the polyamide composite.

Under the microscope, the difference can be clearly seen: in a PA6 composite with T140-coated carbon fibers, the matrix bonds significantly better to the fibers than is the case when an E100 sizing is used. With their thermal stability of up to 300 °C, our T140 fibers cover the entire spectrum of polyamide materials from PA6 and PA66 to PPA. Their good fiber protection and spreading behavior ensure easy textile processing in a wide range of processes.

T115 – sizing for polypropylene matrix systems
Continuous carbon fiber tows coated with T115 sizing are our answer to the special requirements for carbon fibers when used in polypropylene. They provide an optimum matrix bond and ensure that fiber strength and stiffness are fully transferred to the components being produced. Compared with the use of other currently available carbon fiber sizings (epoxy, thermoplastic), SIGRAFIL sized with T115 provides 200% better fiber/matrix interaction and correspondingly increased 90° flexural strength in polypropylene.

<table>
<thead>
<tr>
<th>Mechanical properties of SIGRAFIL carbon fibers sized with T115 in a polypropylene matrix</th>
<th>Flexural strength 90° [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy</td>
<td>8.3</td>
</tr>
<tr>
<td>Thermoplastic</td>
<td>8.2</td>
</tr>
<tr>
<td>T115</td>
<td>25.7</td>
</tr>
</tbody>
</table>

↑ Fiber/matrix bond in PA6 with E100 size
↑ Fiber/matrix bond in PA6 with T140 size
Successful together

We don’t just think about products but also about smart solutions for our customers. With continuous carbon fiber tows, for example, this means we also advise you on the special features of processing 50k fibers.

Drawing on our extensive experience with 50k heavy tows, we help our customers plan new plants or optimize existing plants for processing 50k carbon fiber tows.

In partnership with you, we find solutions ensuring a highly reliable process that is gentle on the material and provides the best possible performance of our products in the component.
50k – unwinding is simply no problem

50k heavy tows used in optimized processes offer time and cost advantages without compromising quality. To ensure trouble-free, gentle processing of 50k fibers, only a couple of differences in fiber guidance from processing 12k or 24k fibers need to be considered.

Good guidance is crucial
Fiber guidance is crucial for optimally realizing the properties of the carbon fibers in the laminate. Generally speaking, the deflection angle, material surfaces, radii, fiber tension values, and type of fiber guide element are important for carbon fibers. In the case of heavy tows with 50,000 filaments, the unwinding angle and spacing between deflection points are also factors that need to be taken into account to avoid tow faults during processing. Problems such as folds, filament breakages, abrasion or varying tow widths can be avoided from the outset by optimized fiber guidance.

Finding the optimum process together
We want our customers to obtain the best possible quality results with our products and at the same time benefit from reliable and efficient processes. We contribute many years of experience and our comprehensive know-how – especially in handling 50k fibers – to the planning or optimization of your plants.
Smart Solutions

Be it materials, components or production processes, we focus our thinking and actions on the customer and keep an eye on the big picture. Our solutions already anticipate the future today.

The following examples show a selection of our unique product range.

**Mobility**
- Lightweight components and structural parts based on fiber-reinforced composites for automotive and aerospace manufacture
- Graphite anode material for lithium-ion batteries in electric vehicles
- Carbon-ceramic brake disks for sports cars and luxury sedans

**Energy**
- High-temperature solutions based on specialty graphites and fiber materials for the photovoltaic industry
- Carbon fiber materials for rotor blades
- Gas diffusion layers for fuel cells
- Systems for more efficient heat exchange and heat recovery
- Carbon fibers for pressurized gas containers

**Digitization**
- Carbon, graphite, and CFC components for polysilicon and monocrystal pulling in the semiconductor industry
- High precision, coated graphite carriers for the production of LEDs

→ Wet pressing process for CFRP component production in the Lightweight and Application Center
SGL Carbon

We are leaders in the development and manufacture of products based on carbon, graphite, carbon fibers, and fiber-reinforced composites. In partnership with our customers, we develop intelligent, trendsetting, and sustainable solutions that deliver a clear benefit.

With our in-depth material, engineering, and application know-how, we make a substantial contribution to the major future topics mobility, energy, and digitization.
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