SPECIALTY CARBONS FOR BIPOLAR PLATES OF FUEL CELLS

TIMREX®
Graphite

ENSACO®
Carbon Black

www.imerys-graphite-and-carbon.com
Imerys Graphite & Carbon, member of the Imerys Group, is the reference for innovative capability in the field of carbon-powder-based solutions: natural graphite and synthetic graphite powders, conductive carbon blacks, as well as silicon-carbon composites and water dispersions.

High standards in terms of employee health and safety, social behaviour and environmental responsibility are core values of the company, which is capturing opportunities by developing new products and applications, investing in assets & people, and growing its commercial presence worldwide.

**FINANCIAL STRENGTH**

- Profitable company, part of Imerys, the world leader in mineral-based specialty solutions for industry, listed on the Paris stock exchange

**IMERYS GROUP 2017**

- **Workforce**: 18,300
- **Revenue**: 4.6 Bn
- **Operating Margin**: 14.1%

**A STRONG COMPANY**

Imerys Graphite & Carbon is the reference for innovative capability in the field of carbon-powder-based solutions: natural graphite and synthetic graphite powders, conductive carbon blacks, as well as silicon-carbon composites and water dispersions. High standards in terms of employee health and safety, social behaviour and environmental responsibility are core values of the company, which is capturing opportunities by developing new products and applications, investing in assets & people, and growing its commercial presence worldwide.
Carbon materials are an essential element of most key components of fuel cells. This document is dedicated to carbon-polymer composite bipolar plates currently used in various fuel cell technologies. It is intended to help our customers to make the best possible selection from the wide range of Imerys Graphite & Carbon’s materials available for the use in their bipolar plate. Imerys Graphite & Carbon offers technical expertise to its customers through its Marketing and R&D Groups. Our team of specialists possesses extensive knowledge of carbon materials, polymers, compounding and corresponding application processes, as well as an excellent problem solving record.

Carbon material powders as well as dispersions, are used in gas diffusion layers, catalyst supports and as coatings for metal bipolar plates in fuel cell systems. Finally, graphite powder is also used as pore former in SOFC components.

The bipolar plate (BPP) is one of the key components in PEM and other fuel cell systems. It performs four basic functions in the fuel cell stack operation:

These functions correspond to key functional requirements for BPPs such as in-plane and through-plane (z direction perpendicular to the plane) electrical conductivity, and thermal conductivity to achieve stack cooling. Other functional requirements for BPPs include mechanical stability for stack integrity, hydrogen impermeability, resistance to corrosion for long life, low cost materials, and ease of manufacturing.

Graphite-based bipolar plates meet or exceed most of these key requirements.

<table>
<thead>
<tr>
<th>BIPOLAR PLATES TARGET PROPERTIES</th>
<th>CARBON POWDER REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>High electrical conductivity (through-plane)</td>
<td>High crystallinity and high pressed density, low anisotropy and rounder particle shape</td>
</tr>
<tr>
<td>High thermal conductivity (in-plane)</td>
<td>High crystallinity and high pressed density</td>
</tr>
<tr>
<td>Long life operation (low corrosion)</td>
<td>High purity carbons (&gt; 99.8 %C)</td>
</tr>
<tr>
<td>Good mechanical properties</td>
<td>High pressed density</td>
</tr>
<tr>
<td>Easy processing of compound (low viscosity at high carbon loading)</td>
<td>Optimized particle size distribution, rounder particle shape</td>
</tr>
</tbody>
</table>
Our carbon-related solutions for carbon-polymer composites have been optimized by selecting unique graphite grades as conductive and reinforcing fillers or by combining several carbon materials. Our carbon-related solutions are compatible with both thermoplastics and thermosets and can be processed under a wide range of composition and conditions. The corresponding carbon-polymer composite bipolar plates can be produced by either compression or injection molding.

Our solutions are based on high-purity primary synthetic graphite, expanded graphite, and highly conductive carbon black.

<table>
<thead>
<tr>
<th>CARBON TYPE</th>
<th>ROLE</th>
<th>HIGH ELECTRICAL CONDUCTIVITY (THROUGH-PLANE)</th>
<th>HIGH THERMAL CONDUCTIVITY (IN-PLANE)</th>
<th>LONG LIFE OPERATION (LOW CORROSION)</th>
<th>GOOD MECHANICAL PROPERTIES</th>
<th>EASY PROCESSING (LOW VISCOSITY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMREX® primary synthetic graphite</td>
<td>Main filler</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>TIMREX® expanded graphite</td>
<td>Additive</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>*</td>
</tr>
<tr>
<td>ENSACO® carbon black</td>
<td>Additive</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>+</td>
<td>*</td>
</tr>
</tbody>
</table>

TIMREX® highly crystalline primary synthetic graphite grades feature optimal particle shape, large crystallite size to ensure the mechanical stability, and high electrical conductivity. Primary synthetic graphite, with particle sizes (d90) ranging from 50 to 150 microns, performs very well in graphite polymer systems, while allowing the compound to be easily processed. Finer graphite is more difficult to handle (i.e. low density, dusting, and high compound viscosity) and typically results in lower conductivity, which is due to higher interparticulate contact resistance.

Coarser graphite powders display higher conductivity and allow better processing, yet reduce the mechanical stability of bipolar plates. Because the purity of primary synthetic graphite exceeds 99.9% in carbon content, this allows the carbon to exhibit superior performance and long life.

TIMREX® KS grades with medium to coarse particle size are commonly used in graphite-polymer composites. The highly isometric particle shape of KS grades results in good flowability, even at very high carbon loading that makes the compound easier to process. This allows the production of composite bipolar plate with high through-plane conductivity. Thus the low anisotropy of primary synthetic graphite is essential for optimum stack performance. The high crystallinity and the unique particle texture results in low oil (binder) absorption and more isotropic electrical conductivity.
Imerys Graphite & Carbon’s TIMREX® and ENSACO® Specialty Carbons for Bipolar Plates

**PRIMARY SYNTHETIC GRAPHITE AS MAIN FILLER**

<table>
<thead>
<tr>
<th></th>
<th>Carbon content</th>
<th>Surface area</th>
<th>Oil absorption</th>
<th>Particle size</th>
<th>Scott density</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMREX®</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KS150</td>
<td>&gt; 99.9 %</td>
<td>3.9 m²/g</td>
<td>47%</td>
<td>96% &lt; 150 μm</td>
<td>0.34 g/cm³</td>
</tr>
<tr>
<td>KS75</td>
<td>&gt; 99.9 %</td>
<td>7.2 m²/g</td>
<td>84%</td>
<td>d90 = 66 μm</td>
<td>0.24 g/cm³</td>
</tr>
<tr>
<td>KS5-75TT</td>
<td>&gt; 99.9 %</td>
<td>4.4 m²/g</td>
<td>39%</td>
<td>d90 = 70 μm</td>
<td>0.44 g/cm³</td>
</tr>
</tbody>
</table>

Typical values

**Electrical resistivity (mΩcm)**

- KS150 in-plane
- KS75 in-plane
- KS150 through-plane
- KS75 through-plane

1) Dry mix of graphite powder and phenolic resin
2) Pressed at 2 t/cm²
3) Thermal treatment

**Bending strength (N/mm²)**

1) Dry mix (80/20) of graphite powder and phenolic resin
2) Pressed at 2, 3, 5 t/cm²
3) Thermal treatment

**Pressed density (g/cm³)**

- KS5-75TT
- KS75

**SEM picture of primary synthetic graphite TIMREX® KS75**

**SEM picture of expanded graphite TIMREX® BNB90**

**TEM picture of carbon black ENSACO® 250G**
With TIMREX® KS grades as the main carbon filler, the performance of bipolar plates can be enhanced by the addition of expanded graphite and/or conductive carbon black. ENSACO® 250G is a conductive carbon black that can boost both in-plane and through-plane electrical conductivity of polymer-carbon composites. TIMREX® BNB90 is an expanded graphite designed for applications requiring high electrical and thermal conductivity at low carbon contents. TIMREX® BNB90 can not only boost both in-plane and through-plane electrical conductivity, but also increase the thermal conductivity. These materials are added in small quantities, since they may drastically increase compound viscosity.

The best solutions and the optimum concentration of minor fillers depend upon the target performance of bipolar plate, selection of polymer, compounding conditions, and molding process.
Imerys Graphite & Carbon produces a variety of specialty synthetic and natural graphite powders, conductive carbon blacks, silicon-carbon composites, calcined petroleum cokes, aqueous dispersions and silicon carbide, with highly consistent quality.

Our products are manufactured under stringent process control conditions, from the raw material stage through to the end product. As we own our raw material sources, we are today the only integrated player that can offer a complete range of products with security of supply, integrated with our innovative technologies, and sustainable processes.

Our teams of Marketing and Research & Development specialists cooperate in a synergetic manner with our customers, in order to fully understand their needs and provide them with customized solutions.

For further information, feel free to contact us, or visit our website: www.imerys-graphite-and-carbon.com

**Customized Solutions**

**Primary synthetic graphite powders**
- Isotropic & anisotropic
- Coarse, medium, fine, ultra fine
- High & very high purity

**Natural flake graphite powders**
- Flake
- Purified
- Expanded
- High crystallinity
- Coarse, medium, fine, ultra fine
- High purity

**Conductive carbon blacks**
- Granulated
- Powder

**Silicon-Carbon composites**

**Water-based dispersions**

**Coke powders**
- Coarse, medium, fine

**Silicon carbide**

---

**Carbon Materials**
- Natural Flake Graphite
- Synthetic Graphite
- Carbon Black
- Silicon-carbon Composites

**Research & Development**
- Product Development
- Application Development
- Scientific Support to Customers

**Applications**
- Polymers
- Mobile Energy
- Engineering Materials
- Refractories & Metallurgy

**Size Reduction**
- Exfoliation
- Mixing
- Sieving
- Milling
- CVD Coating
- CVD Silicon Nanowires

**Added Value Processes**
- Surface Modification
- Shape Modification
- Purification
EUROPE, AFRICA, MIDDLE EAST, INDIA

Imerys Graphite & Carbon Switzerland Ltd.
“Il Centro” Via Cantonale 65, CH-6804 Bironico, Switzerland
Tel: +41 91 873 20 10, Fax: +41 91 873 20 19
graphiteandcarbon.ch@imerys.com

AMERICAS

Imerys Graphite & Carbon Canada Inc.
990 Rue Fernand-Poitras, Terrebonne, QC, J6Y 1V1, Canada
Tel: +1 450 622 91 91, Fax: +1 450 622 86 92
graphiteandcarbon.ca@imerys.com

CHINA

Imerys Graphite & Carbon
1438 Hong Qiao Road, Chang Ning District 6F,
Gubei International Fortune Centre II, CN-201103 Shanghai, China
Tel: + 86 21 2223 0136, Fax: + 86 21 2223 0199
graphiteandcarbon.cn@imerys.com

SOUTH KOREA

Imerys Graphite & Carbon South Korea
7F, Gyodae Venture Tower, 64, Saimdang-ro, Seocho-gu, KR-06640 Seoul, Korea
Tel: +82 234 88 30 30, Fax: +82 234 88 30 79
graphiteandcarbon.kr@imerys.com

JAPAN & SOUTH EAST ASIA

Imerys Graphite & Carbon Japan K.K.
13F Setagaya Business Square tower 4-10-1 Yoga, Setagaya-ku, JP-158-0097 Tokyo, Japan
Tel: +81 3 4570 5410
graphiteandcarbon.jp@imerys.com

Imerys Graphite & Carbon is a trademark of the Imerys Group
imerys-graphite-and-carbon.com