SPECIALTY CARBONS FOR **BIPOLAR PLATES OF FUEL CELLS**

TIMREX® Graphite

ENSACO® Carbon Black

IMERYS

ADVANCED KNOWLEDGE AND EXPERTISE FOR HIGH QUALITY, HIGH PERFORMING SOLUTIONS

EXPERTS IN CONDUCTIVE ADDITIVES

Inspired by future technologies and with the strength of over a century of experience in the development of specialty carbon additives for the most advanced applications, Imerys Graphite & Carbon markets high quality solutions for a wide range of needs.

All of our solutions are developed in close partnership with our customers representing diverse markets. Our particular expertise in the mobile energy market covers lithium-ion batteries, fuel cells, alkaline batteries and lead acid batteries.

A global presence and extensive networks, state-of-the-art laboratories, scientists and technical experts support the continuous development of innovative, high quality products suitable for the most sophisticated applications.

CARBON POWDERS FOR FUEL CELLS

SOLUTIONS FOR KEY COMPONENTS

Carbon based materials are an essential element of the key components of fuel cells. Imerys Graphite & Carbon has a broad portfolio of high purity graphite powders, carbon based dispersions and conductive carbon blacks well suited for a variety of fuel cell technologies.

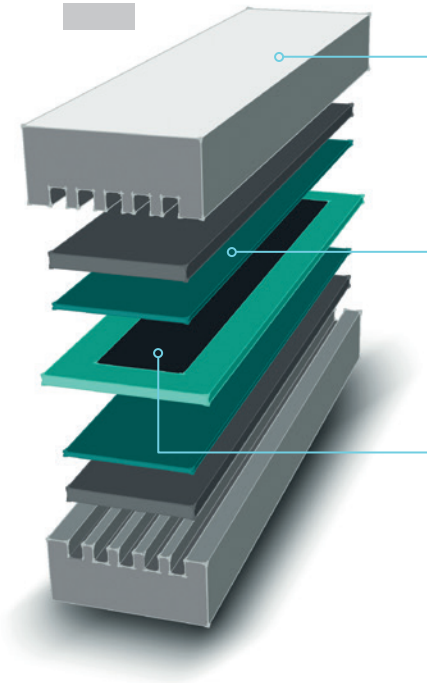
Imerys' carbon based powders and dispersions, are used in gas diffusion layers, catalyst supports and as coatings for fuel cell systems using metal bipolar plates. Graphite powders are also used as pore formers in solid oxide fuel cell components.

Finally, Imerys graphite powders and conductive carbon blacks are ideal for the **bipolar plates** of proton-exchange membrane fuel cells (PEMFC), also known as polymer electrolyte membrane fuel cells.

Our team of experts works closely with our customers to identify the ideal solution for their specific technological needs.

POLYMER ELECTROLYTE MEMBRANE (PEM) FUEL CELL

Negative Electrode
(Anode)



BIPOLAR PLATES
- Primary synthetic graphite
- High aspect ratio graphite
- Conductive carbon black

GAS DIFFUSION LAYER
- Carbon based dispersions
- Primary synthetic graphite
- Conductive carbon black

CATALYST SUPPORT
- Conductive carbon black

Positive Electrode
(Cathode)

IMERYS SPECIALTY CARBONS FOR BIPOLAR PLATES

INDUSTRY REQUIREMENTS

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

- Distributes fuel gas and air
- Conducts electrical current from cell to cell
- Removes heat from the active area
- Prevents leakage of gases and coolant
- Removes water

These functions correspond to key operational requirements for BPPs including:

- Electrical conductivity (in-plane and through-plane – z direction perpendicular to the plane),
- Thermal conductivity to achieve stack cooling
- Mechanical stability for stack integrity
- Hydrogen impermeability
- Resistance to corrosion to ensure durability
- Cost effective materials
- Ease of manufacturing

	CARBON MATERIAL CHARACTERISTICS REQUIRED	**TIMREX®** PRIMARY SYNTHETIC GRAPHITE	**TIMREX® C-THERM™** HIGH ASPECT RATIO GRAPHITE	**ENSACO®** CONDUCTIVE CARBON BLACK
USE		Main Functional Additive	Specialty Additive	Specialty Additive
HIGH ELECTRICAL CONDUCTIVITY	High crystallinity	+++	+++	+++
HIGH THERMAL CONDUCTIVITY	High crystallinity	++	+++	+
LOW CORROSION	High purity carbons (> 99.8%C)	+++	++	+++
GOOD MECHANICAL PROPERTIES	Optimized particle size distribution	++	++	++
EASY PROCESSING (LOW VISCOSITY)	Optimized particle size distribution High bulk density Low specific surface area (BET)	+++	+	+
LOW GAS PERMEABILITY	High aspect ratio	++	+++	+

IMERYS SPECIALTY CARBONS FOR BIPOLAR PLATES

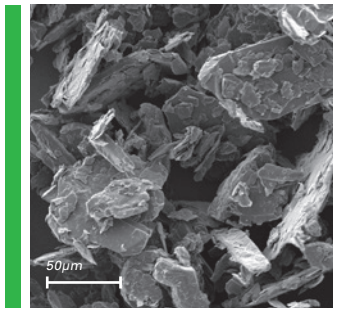
OUR PORTFOLIO

Our portfolio of carbon based solutions for carbon-polymer composites has been optimized through the development of unique graphite grades and combinations of carbon materials which provide excellent conductivity and reinforcing properties.

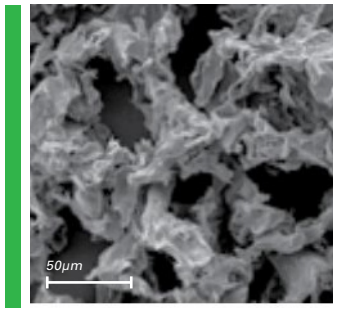
Our carbon-related solutions are compatible with both thermoplastics and thermosets and can be processed under a wide range of compositions and conditions.

The corresponding carbon-polymer composite bipolar plates can be produced by either compression or injection molding, extrusion or a roll-to-roll process.

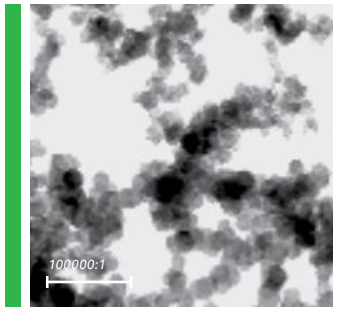
Our solutions consist of high-purity primary synthetic graphite, high aspect ratio graphite, and highly conductive carbon black.



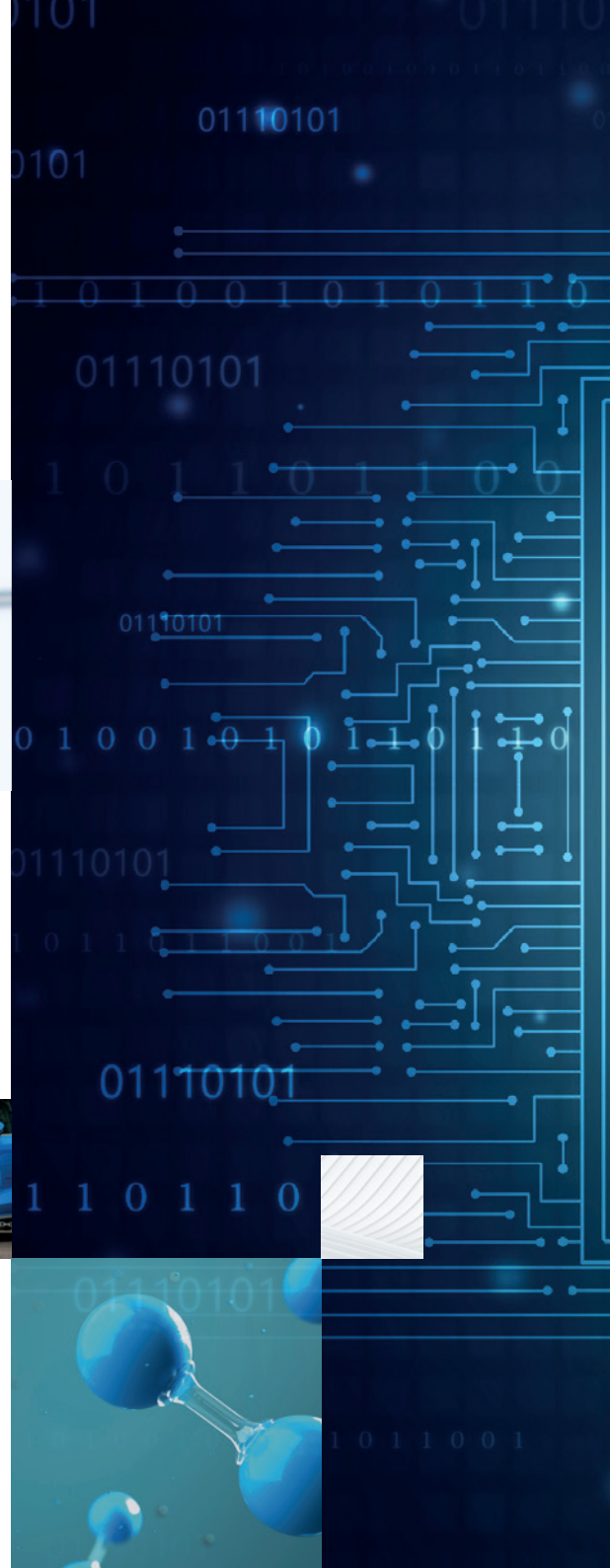
TIMREX® KS75 Primary Synthetic Graphite



TIMREX® C-THERM™ High Aspect Ratio Graphite



ENSACO® 250G Carbon Black



TIMREX® PRIMARY SYNTHETIC GRAPHITES

MAIN FUNCTIONAL ADDITIVES

TIMREX® highly crystalline primary synthetic graphites feature optimal particle shape, and large crystallite size which enables electrical conductivity without compromising mechanical stability. Primary synthetic graphite, with particle sizes (d90) ranging from 50 to 150 microns, performs very well in graphite polymer systems, as it allows for easy processing and results in higher electrical conductivity. The high purity of Imerys primary synthetic graphite (> 99.9%) ensures optimal performance and durability. TIMREX® SFG graphites are flaky, have high crystallinity and low BET which allows for high levels of in-plane electrical and thermal conductivity. TIMREX® KS graphites are more isotropic and allow for the production of graphite-composite bipolar plates with high through-plane conductivity essential to optimize stack performance.

TIMREX®	CARBON CONTENT (%)	SURFACE AREA, BET (m^2/g)	OIL ABSORPTION (%)	PARTICLE SIZE (µm)	SCOTT DENSITY (g/cm^3)
KS150	> 99.9	3.9	47	90% < 150	0.34
KS75	> 99.9	7.2	84	d90 = 69	0.24
KS5-75TT	> 99.9	4.4	39	d90 = 88	0.44
SFG 75	> 99.9	3.5	72	d90 = 76	0.22
SFG 150	> 99.9	2.3	39	92% < 150	0.26

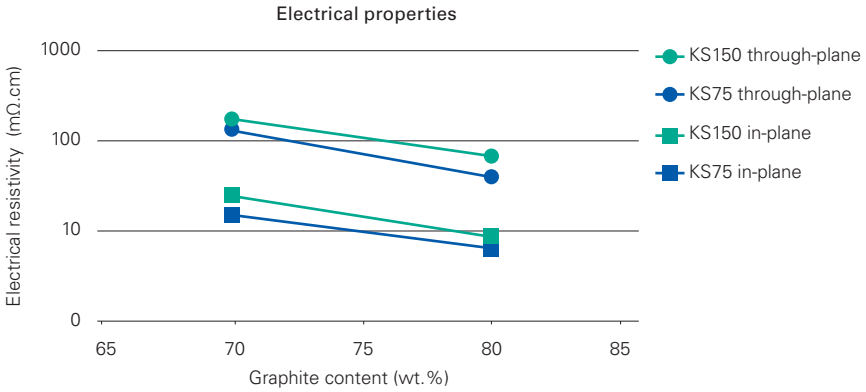
TIMREX® HIGH ASPECT RATIO GRAPHITES & ENSACO® CONDUCTIVE CARBON BLACKS

SPECIALITY ADDITIVES

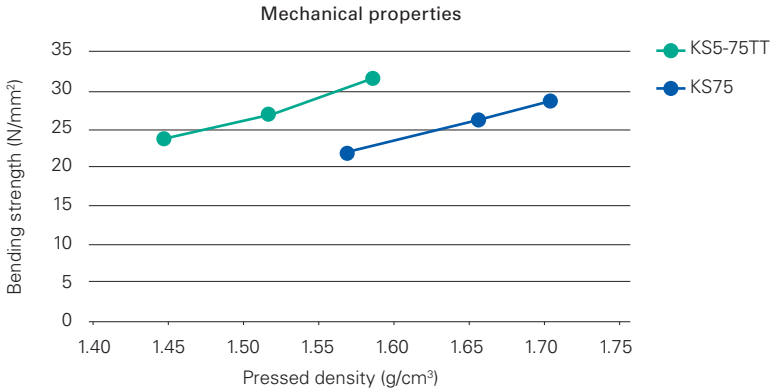
The performance of bipolar plates made with TIMREX® KS or SFG grades can be further enhanced by the addition of high aspect ratio graphite and/or conductive carbon black.

TIMREX® C-THERM™ is a high aspect ratio graphite that provides high electrical and thermal conductivity at low carbon content. These materials are added in small quantities depending on the performance targets of the bipolar plates, compounding conditions and the chosen molding process. ENSACO® 250G is a conductive carbon black that can boost both in-plane and through-plane electrical conductivity of polymer-carbon composites.

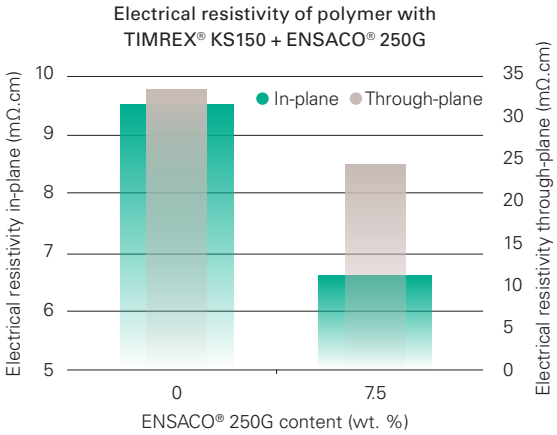
CARBON FILLERS FOR THERMOSET BIPOLAR PLATES



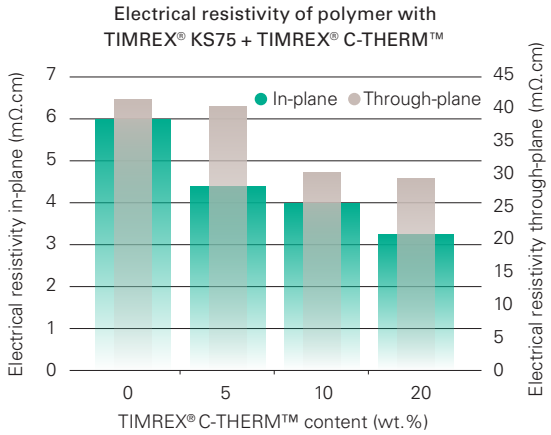
Dry mix (80/20) of graphite powder and phenolic resin. Pressed at 2t/cm². Thermal treatment.



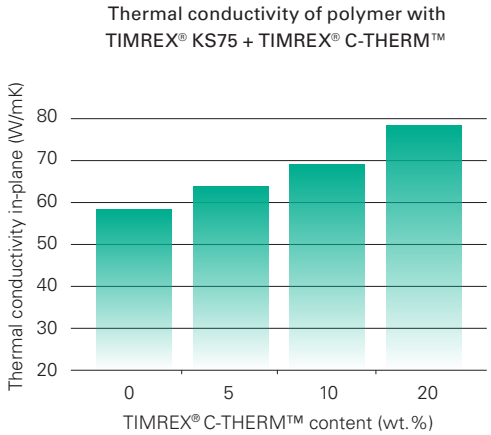
Dry mix (80/20) of graphite powder and phenolic resin. Pressed at 2,3,5t/cm². Thermal treatment.



Dry mix (80/20) of carbon (TIMREX® KS150 + ENSCAO® 250G) and phenolic resin. Pressed at 2t/cm². Thermal treatment.



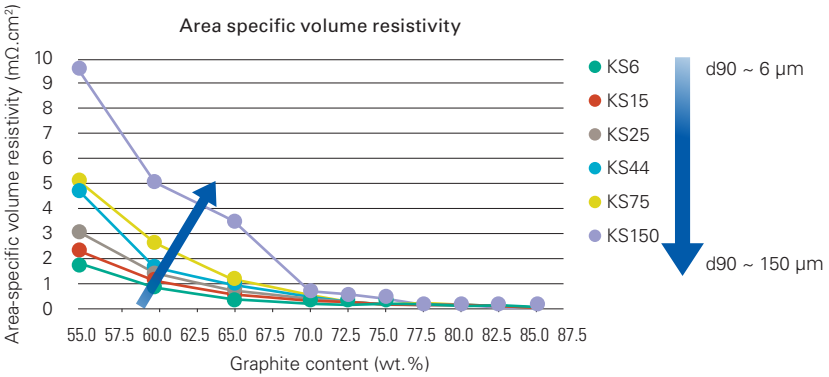
Dry mix (80/20) of carbon (TIMREX® KS150 + C-THERM™) and phenolic resin. Pressed at 2t/cm². Thermal treatment.



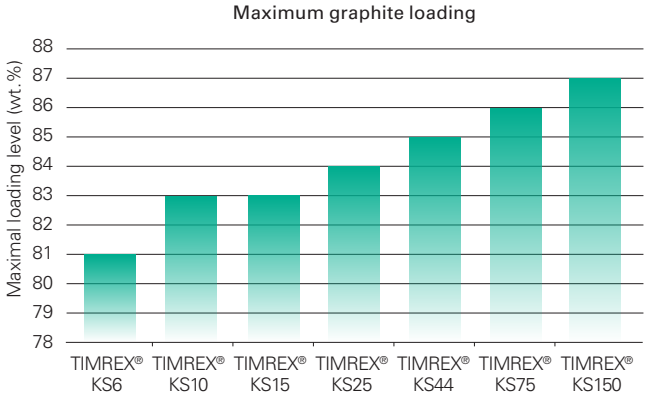
Dry mix (80/20) of carbon (TIMREX® KS150 + C-THERM™) and phenolic resin. Pressed at 2t/cm². Thermal treatment.

GRAPHITE FILLERS FOR THERMOPLASTIC BIPOLAR PLATES

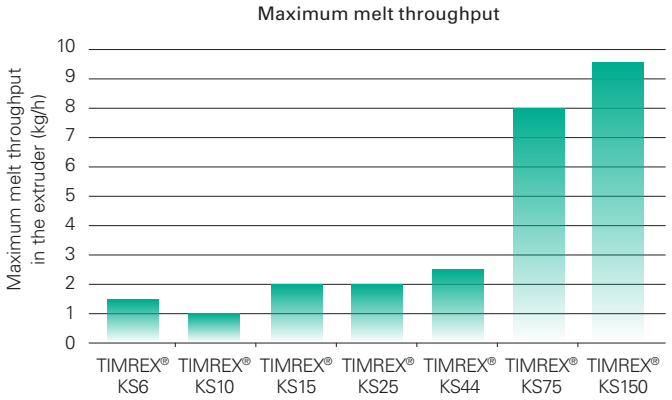
The following data shows the impact of graphite particle sizes on compounds with polypropylene (PP), injection molded specimens:



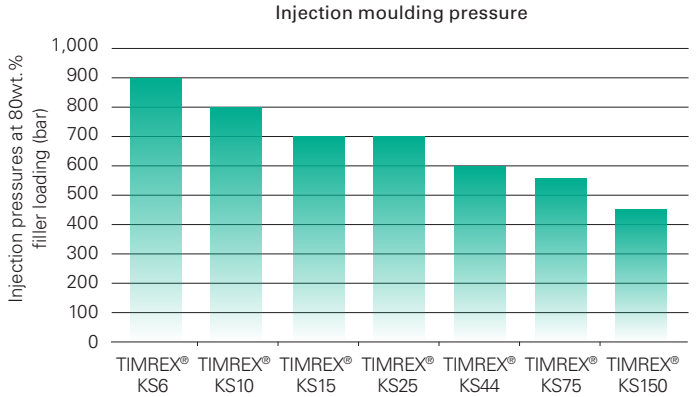
The percolation threshold is lower for fine graphite, but at higher graphite content the electrical conductivity is similar for all graphite particle sizes.



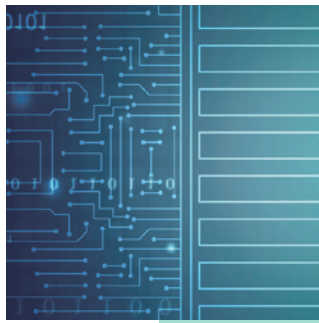
The maximal graphite loading level is higher for coarse graphite.



The production throughput of twin screw extruder and the energy costs can be improved by using coarse graphite d90 >75 microns.



The injection moulding pressure decreases with increasing graphite particle size.

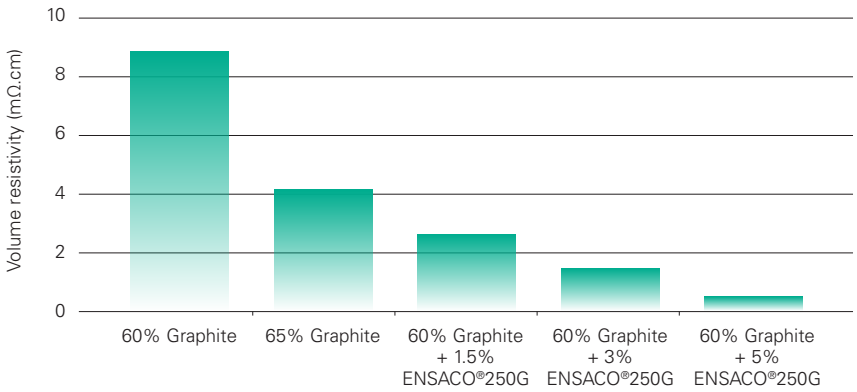


Source: R.Gilardi, T. Derieth, Kunststoffe International 8/2015

SYNERGISTIC EFFECTS BETWEEN SYNTHETIC GRAPHITE AND CONDUCTIVE CARBON BLACK

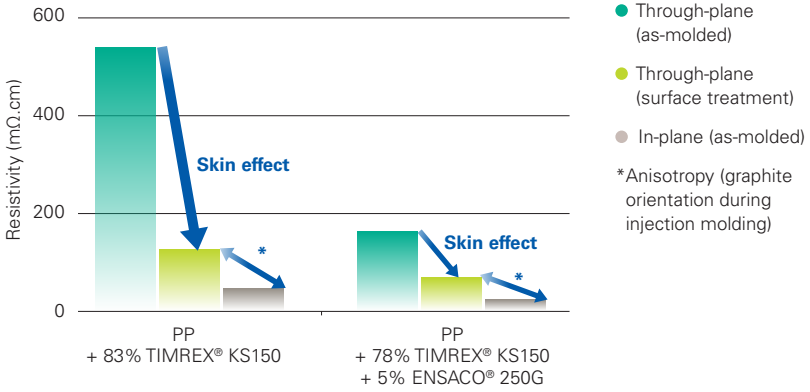
The addition of a small quantity of conductive carbon black to a highly loaded graphite compound can significantly improve electrical conductivity. Replacement of 5% graphite (**TIMREX® KS150**) with carbon black (**ENSACO® 250G**) improves electrical conductivity and mechanical properties, while reducing anisotropy and skin effects.

Compression molded bipolar plates



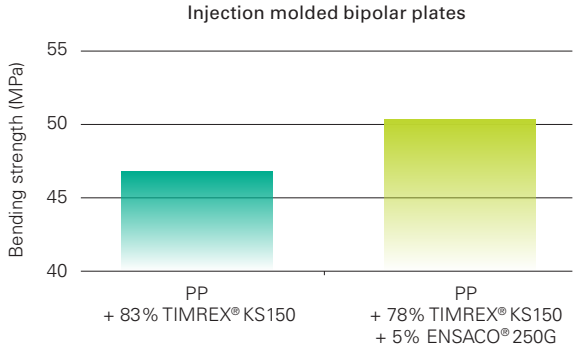
Polymer: Polypropylene **Compound:** Internal mixer **Processing:** Compression molding

Injection molded bipolar plates



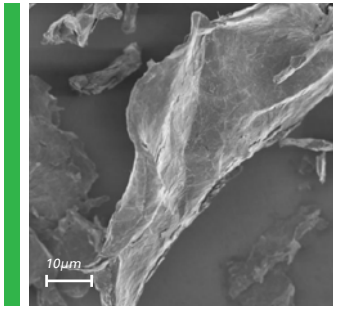
Polymer: Polypropylene (PP) **Compound:** Twin-screw extruder **Processing:** Injection molding

Injection molded bipolar plates

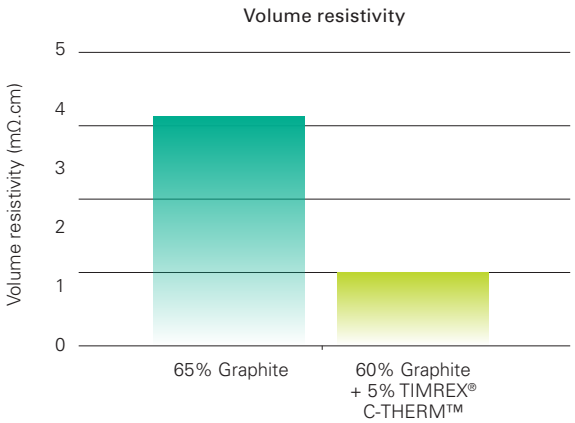


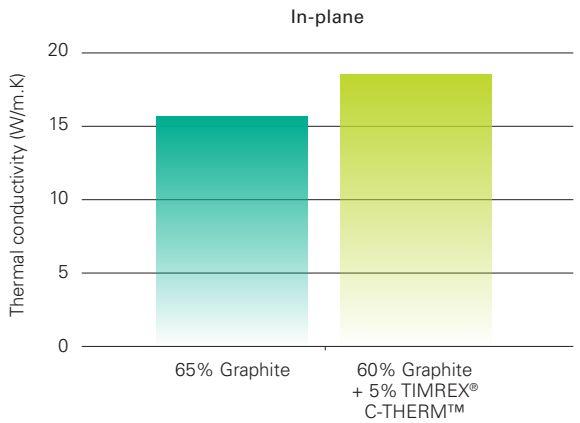
SYNERGISTIC EFFECTS BETWEEN SYNTHETIC GRAPHITE AND HIGH ASPECT RATIO GRAPHITE

Replacement of 5% graphite with high aspect ratio graphite (TIMREX® C-THERM™) in highly loaded graphite compounds leads to a significant increase in both electrical and thermal conductivity.

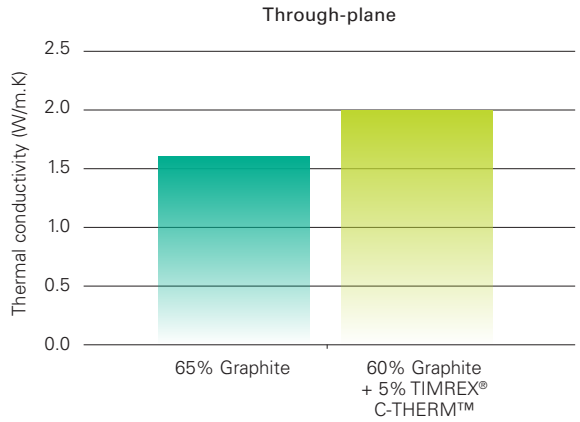


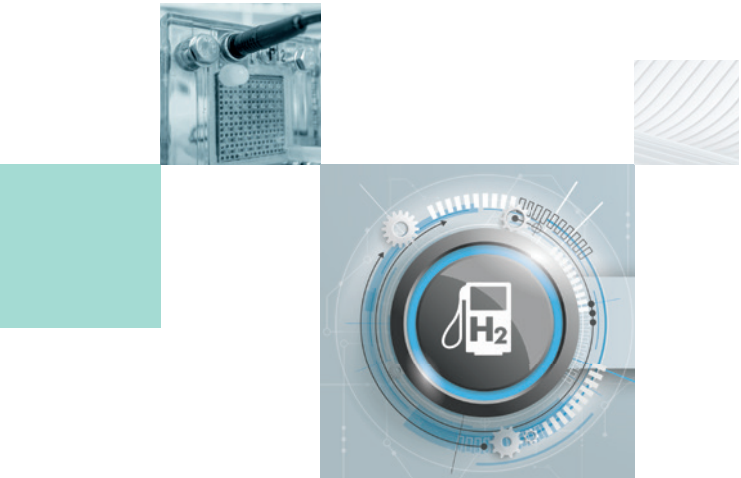
TIMREX® C-THERM™





Polymer: Polypropylene
Compound: Internal mixer
Processing: Compression molding





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
sales_gc.emeia@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
sales_gc.americas@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
sales_gc.cn@imerys.com

KOREA & SOUTH EAST ASIA

Imerys Graphite & Carbon South Korea
3F, Keumseong Building, 314, Teheran-Ro
Gangnam-Gu, KR-06211, Seoul KOREA

Tel: +82 234 88 30 30 Fax: +82 234 74 45 82
sales_gc.kr@imerys.com

JAPAN & TAIWAN

Imerys Graphite & Carbon Japan K.K.
Shinagawa Seaside South Tower
11F, 4-12-1, Higashi Shinagawa
Shinagawa-ku, Tokyo 140-0002 JAPAN

Tel: +81 3 4570 5410
sales_gc.apac@imerys.com