PHOTOVOLTAICS

Carbon and graphite solutions for a competitive PV industry
Among all renewable energies photovoltaic benefits from many environment and economic advantages:
• Unlimited renewable source of energy
• Increasingly cost competitive
• Decentralized power source
• Peak power at peak time of usage
• Environment friendly

The sun, an energy available for free...
Photovoltaic systems use cells to convert sunlight directly into electricity.
When sunlight strikes a PV cell, electrons are dislodged, creating an electrical current.
The most common semiconductor material used in photovoltaic cell is silicon, an element most commonly found in sand.
The crystalline silicon technology, which distinguishes monocrystalline, multicrystalline and ribbon sheets processes, represents approx. 90% of the market today.

Thanks to its outstanding properties graphite is the unique and only material to withstand high temperature, corrosion and the severe conditions on the silicon production process.

Other photovoltaic processes are now available on the market such as the thin film technology where modules are constructed by depositing extremely thin layers of photosensitive materials onto glass, plastic or stainless steel.

Mersen is a world leader in isostatic graphite production, and proposes proven solutions to each step of the photovoltaic production chain, from polysilicon feedstock to cells antireflective coating via thin film process.
Its range of materials covers graphite, Carbon/Carbon composite as well as insulation materials.

Benefits of Mersen materials:
• Grade consistency (inert and non-wetting to most chemicals)
• Large diameters available up to 1.5 m in graphite and 2.2 m in Carbon/Carbon composites for the whole range of products
• High purity (less than 5 ppm), which avoids contamination and allows high quality products
• Dedicated high performance solutions to increase lifetime and efficiency
• Mersen materials offer strong benefits...

“Photovoltaic” is the combination of two words: “photo” from Greek origin, which means light, and “voltaic”, from “volt”, the unit used to measure electricity.
Silica all along the photovoltaic production chain

Mersen

- Large size rounds up to dia. 1500 mm in isostatic graphite 2020.
- Trays or tubes up to dia. 2200 mm in Carbon/Carbon composite AM252
- Rigid carbon thermal insulation CALCARB® and ISOLOR®
- Machining capacity and purification capabilities for large dimensions
- Dedicated solutions to reduce chemical reaction with molten silicon

Photovoltaic production:

1. Silica: Raw material, glass, plastic or stainless steel.
3. TCS: Siemens reactor & converter.
4. Isostatic graphite grade 2191 UHP5: The best combination with high thermal conductivity, high strength & high purity!

Benefits of Mersen materials:

- High purity (less than 5 ppm)
- Large diameters up to 1.5 m in graphite and 2.2 m in Composite AM252
- Grade consistency (inert and non-wetting to most chemicals)
- Environment friendly
- Peak power at peak time of usage
- Decentralized power source
- Increasingly cost competitive
- Unlimited renewable source of energy

Photovoltaic processes:

- Crystalline silicon technology distinguishes monocrystalline and multicrystalline processes.
- Silicon melting.
- Pulling.
- Slicing.
- Antireflective coating.
- Adapting CTE.

Materials:

- UHP5 Metallurgical silicon
- Polysilicon
- Isostatic graphite grade 2123PT, 2020PT
- UHP5 Silicon
- UHP5 Si3 N4
- AM252 carbon/Carbon bolts & nuts
- AM252 carbon/Carbon carriers
- 2020 graphite carriers
- Isostatic graphite grades 2124 UHP5, 2450 UHP5
- Heat shields AM252
- Stabilized properties and excellent wear performance vs. silicon environment

Evaluation, Authorization and Restriction of Chemical Substances (REACH) to all its plants, guarantees the application of the European Community REACH-Regulation (Registration, Evaluation, Authorization and Restriction of Chemical Substances) to all its plants. Our materials are in conformity with the RoHS-Directive (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment) and certain other regulations. Mersen reserves the right to modify, at any time, the technology and product specifications contained herein. Accordingly, Mersen reserves the right to modify, at any time, the technology and product specifications contained herein. Duplication, reproduction or translation of any information contained herein, in whole or in part, is strictly prohibited without prior written consent of Mersen. Data herein contained are provided for general information purpose only and are not binding. Mersen shall have no liability whatsoever with respect to information contained herein.
Photovoltaic systems use cells to convert sunlight directly into electricity. When sunlight strikes a PV cell, electrons are dislodged, creating an electrical current. The sun, an energy available for free, represents a sustainable and easily accessible source of energy. Photovoltaic systems can be used in both decentralized and central power generation, providing a flexible and cost-effective solution for energy needs.

Benefits of Mersen materials:
- High purity (less than 5 ppm), which avoids contamination and extends the lifetime of the product.
- Large diameters available up to 1.5 m in graphite and 2.2 m in carbon/carbon composites.
- Grade consistency (inert and non-wetting to most chemicals).
- Excellent price to performance.

Mersen all along the photovoltaic production chain:
- 2020 graphite crucibles, holders, heaters.
- Rigid carbon thermal insulationCALCARB® and ISOLOR®.
- AM252 carbon/carbon bolts & nuts.
- Large sizes.

Dedicated solutions to reduce chemical reaction with molten silicon.
- Isostatic graphite grades 2124 UHP5, 2450 UHP5.
- Rigid carbon thermal insulation CALCARB® and ISOLOR®.
- Ultra high precision machining to ensure process stability.
- Non wetting to silicon.

Data herein contained are provided for general information purpose only and are not binding. Mersen shall have no liability whatsoever with respect to information contained herein. Duplication, reproduction or translation of any information contained herein, in whole or in part, is strictly prohibited without prior written consent of Mersen. Our materials are in conformity with the RoHS-Directive (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment). Besides Mersen guarantees the application of the European Community REACH-Regulation (Registration, Evaluation, Authorization and Restriction of Chemical substances) to all its plants located in Europe. We are constantly involved in engineering and development. Accordingly, Mersen reserves the right to modify, at any time, the technology and product specifications contained herein.
Materials

### Graphite grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density (MPa)</th>
<th>FS (MPa)</th>
<th>CTE ((10^{-6}°/°C))</th>
<th>Resistivity (µΩcm)</th>
<th>Thermal conductivity (W/m°C)</th>
<th>Permeability (cm²/s)</th>
<th>Standard sizes (mm)</th>
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<tbody>
<tr>
<td>2191</td>
<td>1.75</td>
<td>44</td>
<td>4.2</td>
<td>1.000</td>
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<td>540x540x1,830</td>
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<td>2450</td>
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### Purity

<table>
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<tr>
<th></th>
<th>Unpurified</th>
<th>PT : &lt; 20 ppm</th>
<th>Purified</th>
<th>UHP : &lt; 5 ppm</th>
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</thead>
<tbody>
<tr>
<td>Density</td>
<td>290 ppm</td>
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### SiC coating

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<tr>
<th>T max (°C)</th>
<th>Density (MPa)</th>
<th>Open porosity</th>
<th>RF (MPa)</th>
<th>CTE ((10^{-6}°/°C))</th>
<th>Coating thickness</th>
<th>Hardness</th>
<th>Young modulus (GPa)</th>
<th>Permeability (cm²/s)</th>
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<tr>
<td>1700°C</td>
<td>3.2</td>
<td>Impervious to most gases (H₂) and liquids</td>
<td>350</td>
<td>4.8</td>
<td>50-250 µm</td>
<td>2280</td>
<td>2950</td>
<td>63</td>
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### Rigid carbon insulation

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<th>Density</th>
<th>Thermal conductivity at 400°C (W/m°C)</th>
<th>Thermal conductivity at 2,200°C (W/m°C)</th>
<th>Standard Dimensions (mm)</th>
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</thead>
<tbody>
<tr>
<td>ISOLOR® S10</td>
<td>0.1</td>
<td>2.4</td>
<td>2.2</td>
<td>1,500x1000x40 Rounds &amp; special sizes on request</td>
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<tr>
<td>CALCARB® CBCF 18-2000</td>
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<td>1.0</td>
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### Carbon / Carbon composite

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<th>Density</th>
<th>FS (MPa)</th>
<th>Flexural modulus (GPa)</th>
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<tr>
<td>AM252</td>
<td>1.70</td>
<td>100</td>
<td>10</td>
<td>Ring Ø 2,200 Tube length 3,000</td>
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</tbody>
</table>
A WORLD EXPERT
in materials and solutions for high temperature processes

A GLOBAL PLAYER
Global expert in materials and solutions for extreme environments as well as in the safety and reliability of electrical equipment. Mersen designs innovative solutions to address its clients’ specific needs to enable them to optimize their manufacturing process in sectors such as energy, transportation, electronics, chemical, pharmaceutical and process industries.

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ML1 4XL, UNITED KINGDOM
Tel.: +44 1698 838710
Fax: +44 1698 838711
calcarb@mersen.com

www.mersen.com
# Purified Graphite

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density (g/cm³)</th>
<th>Grain size (µm)</th>
<th>Porosity (%)</th>
<th>FS (MPa)</th>
<th>CTE, 10⁻⁶°C⁻¹</th>
<th>Resistivity (µΩ·cm)</th>
<th>Thermal Conductivity (W/m·K)</th>
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<tbody>
<tr>
<td>ø610x1830</td>
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<td>12</td>
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<td>116</td>
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<td>ø1500x635x1830</td>
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<td>15</td>
<td>12</td>
<td>44</td>
<td>4.2</td>
<td>1090</td>
<td>116</td>
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<tr>
<td>ø1030x1080x325</td>
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<td>15</td>
<td>12</td>
<td>44</td>
<td>4.2</td>
<td>1090</td>
<td>116</td>
</tr>
</tbody>
</table>

## Reference

- **Thickness (mm)**
- **Width (mm)**
- **Density (g/cm³)**
- **Emissivity (Vacuum)**
- **Coefficient (Vacuum)**
- **Size (mm)**

## Soft graphite

- **Density (g/cm³)**
- **Open porosity (%)**
- **CTE, 10⁻⁶°C⁻¹**
- **Size (mm)**

## Ultra High Purity

- **Al**, **B**, **Fe**, **CA**, **Cu**, **Mg**, **Ni**, **Ti**, **V**, **Si**, **Pb**, **Sn**, **Mo**, **W**, **Zn**, **Cr**, **Total**
- **Unpurified**
- **<5 ppm**
- **<0.2 ppm**
- **<0.8 ppm**
- **<0.5 ppm**
- **ND** (not detectable)
- **<0.1 ppm**
- **<0.5 ppm**
- **<0.1 ppm**
- **<0.5 ppm**

## High density graphite grades with small grain size ensure that no particle contamination occurs in ultra high vacuum systems and environment. Mersen drastically reduces molecular contamination to a minimum with appropriate additional treatments, from outgassing to closing the packages in a glove box after impregnation.

Gas tight, hermetic coatings, are renowned specialties of Mersen to prevent unintended water doping.

Mersen's clean room packaging allows a direct use in customer's clean rooms. High purity graphite grades with small grain size ensure that no particle contamination occurs in ultra high vacuum system, from outgassing to closing the packages in a glove box after impregnation. Gas tight, hermetic coatings, are renowned specialties of Mersen to prevent unintended water doping.

Mersen is qualified as a supplier for spare parts used in the electronic industry. High purity graphite production equipment is single crystal growing furnace, silicon epitaxy, MOCVD reactors, dry etchers, ion implanters, etc.

Mersen offers to OEM and electronic component makers an innovative and wide range of ultra and near ultrapure high temperature graphite based solutions. Mersen's clean room packaging allows a direct use in customer's clean rooms. High purity graphite grades with small grain size ensure that no particle contamination occurs in ultra high vacuum system, from outgassing to closing the packages in a glove box after impregnation. Gas tight, hermetic coatings, are renowned specialties of Mersen to prevent unintended water doping.

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From semiconductor material making...

...to wafer processing...

Graphite a light refractory material

Mersen graphite compounds, with their steady and reliable behavior versus temperature, interface nicely with any mechanical interface.

Mersen provides engineering services to help customers simulate and design the best solution to perform the desired functions.

Mersen graphite compounds are suitable for any given environment at high temperature, with the most aggressive etchants, resistance to oxidation can be drastically increased with optimal treatments and coatings, leading to the lowest cost of ownership.

Most of the functions offered by Mersen graphite-based products have a high service to value ratio. This one-size-fits-all solution compared to most refractory metals. Ease of fabrication, mass-graphite materials are a real alternative at the lowest cost, according to the highest quality standards.

Mersen is a worldwide group, and is a local partner to every customer: its affiliates provide close service and quick delivery to every customer throughout the world.

FUNDAMENTAL REASONS FOR YOU TO GET THE BEST VALUE FROM THE BEST SOLUTION:

1. Mersen puts chemical reactions with the graphite and C/C product range under control. Mersen provides optimal and effective solutions to simulate and design the best solution to perform the desired functions.

2. Mersen guarantees the application of the European Community data therein contained are provided for general information purpose only and are not binding. Mersen shall have no liability whatsoever with respect to information.

3. Mersen’s quality graphite, as most of the functions offered by Mersen graphite-based products have a high service to value ratio. This one-size-fits-all solution compared to most refractory metals. Ease of fabrication, mass-graphite materials are a real alternative at the lowest cost, according to the highest quality standards.

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16. Mersen is a worldwide group, and is a local partner to every customer: its affiliates provide close service and quick delivery to every customer throughout the world.
Mersen graphite products offer a range of properties that make them ideal for high-temperature applications. Here’s how they perform across various metrics:

**Thermal Conductivity**
- Graphite materials are known for their high thermal conductivity, which helps in efficient heat transfer in high-temperature environments.

**Thermal Expansion**
- Graphite materials exhibit low thermal expansion, ensuring dimensional stability at high temperatures.

**Density**
- Graphite materials come in varying densities, allowing for customization based on specific application requirements.

**Electrical Resistance**
- Graphite materials have low electrical resistance, which is crucial for high-voltage applications.

**Specific Weight**
- Graphite materials have a low specific weight, making them ideal for applications requiring lightweight components.

** Specific Flexural Strength**
- Graphite materials have high specific flexural strength, providing durability and structural integrity.

**Specific Volume**
- Graphite materials have a high specific volume, which can be advantageous in space-constrained applications.

**Transmission of Primary Electromagnetic Radiation**
- Graphite materials are effective in shielding against electromagnetic radiation, making them ideal for aerospace and military applications.

**Mechanical Properties**
- Graphite materials exhibit excellent mechanical properties, including high compressive strength and impact resistance.

**Cost-Effective**
- Mersen graphite products are cost-effective solutions that offer high performance at an affordable price.

**Dimetric**
- Graphite materials are highly corrosion-resistant, ensuring longevity in harsh environments.

**Surface Hardness**
- Graphite materials have high surface hardness, providing durability and wear resistance.

**Optical Properties**
- Graphite materials are ideal for applications requiring optical clarity and transparency.

**Resistance to Oxidation**
- Graphite materials are resistant to oxidation, making them suitable for high-temperature environments.

**Chemical Resistance**
- Graphite materials are highly chemically resistant, ensuring stability in corrosive environments.

**Dimensional Stability**
- Graphite materials maintain dimensional stability over a wide temperature range, ensuring reliable performance.

**Ease of Machining**
- Graphite materials are easy to machine, allowing for precise shaping and finishing.

**Thermal Shock Resistance**
- Graphite materials are resistant to thermal shock, preventing damage in rapidly changing temperature conditions.

**Thermal Expansion Coefficient**
- Graphite materials have a low thermal expansion coefficient, ensuring dimensional stability at high temperatures.

**Electrical Conductivity**
- Graphite materials have high electrical conductivity, making them suitable for various electrical applications.

**Specific Conductivity**
- Graphite materials have high specific conductivity, which is crucial for high-current applications.

**Dielectric Strength**
- Graphite materials have high dielectric strength, providing protection against electrical breakdown.

**Thermal Conductive Polymer (TCP)**
- Graphite materials are used in thermal conductive polymer (TCP) composites, which are ideal for heat dissipation in electronic applications.

**Graphite Systems**
- Graphite systems offer a wide range of applications, including thermal insulation, heat dissipation, and electrical conductivity.

**Graphite and Graphite-Based Products**
- Graphite and graphite-based products offer a range of properties that make them ideal for high-temperature applications.

**Graphite Materials**
- Graphite materials are used in various applications, including thermal insulation, heat dissipation, and electrical conductivity.

**Graphite and Graphite-Based Products**
- Graphite and graphite-based products offer a wide range of applications, including thermal insulation, heat dissipation, and electrical conductivity.

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FROM SEMICONDUCTOR MATERIAL MAKING

... TO WAFER PROCESSING

FUNDAMENTAL REASONS FOR YOU TO GET THE BEST VALUE FROM THE BEST SOLUTION:

OEIC and electronic component makers have 8 good fundamental reasons to order Mersen graphite products for High Temperature applications:

1. Mersen graphite components, with their steady and reliable behavior versus temperature, are ideal for centrifugal treatments. A high thermal conductivity of graphite makes it an ideal material for high temperature applications.

2. Resistant to oxidation, and with a low thermal expansion rate, Mersen graphite products can be processed at high temperatures and pressures, ensuring consistent quality and performance.

3. Mersen graphite is a strong material, with high mechanical strength and a low coefficient of thermal expansion. It is ideal for use in high-temperature environments, such as in silicon and III-V crystal growth furnaces.

4. Mersen graphite is also a good electrical conductor, with a high electrical conductivity and high thermal conductivity. This makes it ideal for use in high-temperature electrical applications.

5. Mersen graphite is a light refractory material, with low density and high strength. This makes it ideal for use in high-temperature applications, such as in silicon crystal growth furnaces.

6. Mersen graphite is resistant to contamination, with a low contamination rate and a high purity grade. This makes it ideal for use in high-temperature applications, such as in silicon crystal growth furnaces.

7. Mersen graphite is resistant to erosion, with a high erosion resistance and a low erosion rate. This makes it ideal for use in high-temperature applications, such as in silicon crystal growth furnaces.

8. Mersen graphite is resistant to corrosion, with a low corrosion rate and a high corrosion resistance. This makes it ideal for use in high-temperature applications, such as in silicon crystal growth furnaces.

When one of refractory metals contaminates and collapses at high temperatures, Mersen’s quality graphite, as the least refractory natural element, stands mechanically in high-temperature processes.

Best Choice Application conductivity along C/C materials C/C AEROLOR A252 Medium or cylindrical shapes impregnated very low CTE to resist stress flexibility of assembly. C/C AEROLOR is a rigid felt, gets the widest prevent contain hot melt and reduce number lower thermal substitute dusty Polysilicon reactors Crystal growing furnace equipment low porosity composite layering prevents heat exchanger chucks Si SiGe AsGa InP Crystals, insulation 2191 Below 5 ppm for computer simulation below 2 ppm increase lifetime homogeneous heavy loads and cylindrical form AEROLOR components resistivity to lower A252 C/C at high temperature lower contact slow SiC conversion and chemical inertia thermal radiation highly purified diminish reactive SiC coating reduces on A252 heat conduction get the avoid hot spots 2020, 2450 SiC coating at low temperature soft material, high FS and appropriate medium FS to allow for high FS: PAPYEX® WPTX
**Purified Graphite**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density (g/cm³)</th>
<th>CTE (10⁻⁶/°C)</th>
<th>Resistivity (µΩ.cm)</th>
<th>Thermal Conductivity (W/m°C)</th>
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<tbody>
<tr>
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</table>

**Flexible graphite**

- **Rigid carbon insulation**
- **CALCARB®**
- **Pyrocoating and bulk pyrocarbon**
- **Glassy carbon**
- **Silicon Carbide coating**
- **Vitreous carbon impregnation**

**A WORLD EXPERT in materials and solutions for high temperature processes**

Mersen offers to OEM and electronic component makers an innovative and wide range of high purity graphite-based solutions. Mersen provides the lowest level of elemental contamination with its 99.9995% purified grades and allows its customers to manufacture and to process defect-free materials into containers.

**FOR YOUR WAFER QUALITY GET OUR ULTRA HIGH PURITY**

Mersen’s clean room packaging allows a direct use in customer’s clean rooms. High purity graphite grades with small grain size ensure that no particle contamination occurs in ultra high vacuum. All relevant Mersen materials are produced to a minimal contamination level with appropriate additional treatments, from outgassing to closing the production until final polishing of the materials by impregnation.

Gas tight, hermetic coatings, are identified by a special symbol to prevent undesired wafer doping.

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