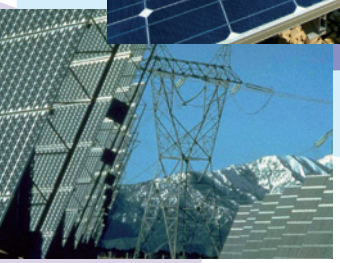
CARBON AND GRAPHITE FOR PHOTOVOLTAIC INDUSTRY

Innovation & Efficiency for a competitive PV energy

ISO 9001: 2000 | ISO 14001

CARBONE LORRAINE

Carbone Lorraine all along the photovoltaic production chain



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.

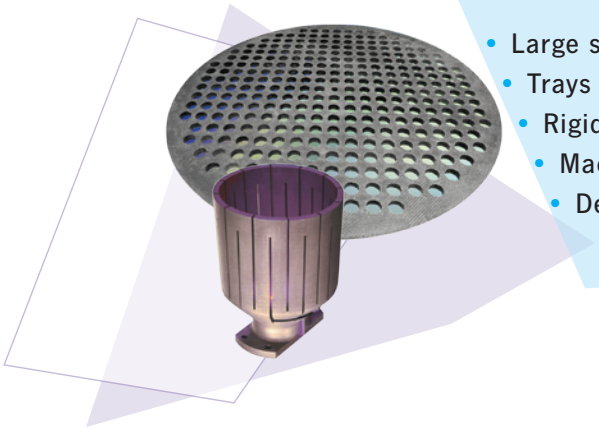
"**Photovoltaic**" is the combination of two words: "**photo**" from Greek origin, which means **light**, and "**voltaic**", from "**volt**", the unit used to measure electricity.

Carbone Lorraine 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.

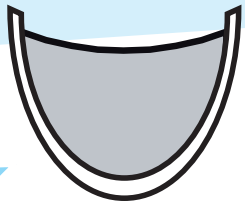
Benefits of Carbone Lorraine materials:

- 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
- Carbone Lorraine materials offer strong benefits...

Carbone Lorraine all along the

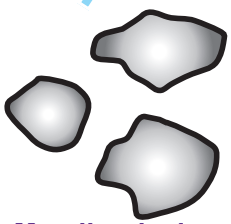


- Large size rounds up to dia. 1500 mm in isostatic graphite 2020.
- Trays or tubes up to dia. 2200 mm in Carbon/Carbon composite AM252
- Rigid carbon thermal insulation CALCARB® and ISOLOR®
- Machining capacity and purification capabilities for large dimensions
- Dedicated solutions to reduce chemical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

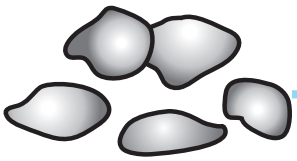


Silicon refining

Silica

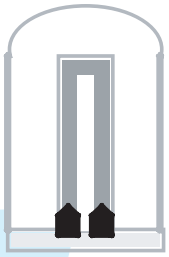


Metallurgical silicon



Polysilicon

TCS Siemens reactor & converter



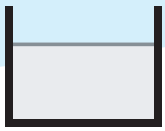
Isostatic graphite grade 2191 UHP5

The best combination with high thermal conductivity, high strength & high purity!

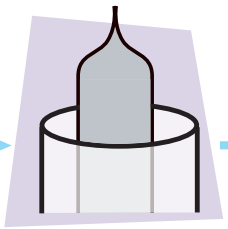
- Purified graphite grades 2123PT, 2450PT, 2020PT
- SiC coating
- Rigid carbon thermal insulation CALCARB® and ISOLOR®
- Heat shields AM252
- Stable properties and excellent wear performance vs. silicon environment

photovoltaic production chain

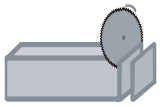
- 2020 graphite crucibles, holders, heaters
- Rigid carbon thermal insulation CALCARB® and ISOLOR®
- AM252 carbon/carbon bolts & nuts
- Large sizes
- Excellent price to performance



Multicrystalline silicon melting



Monocrystalline silicon pulling

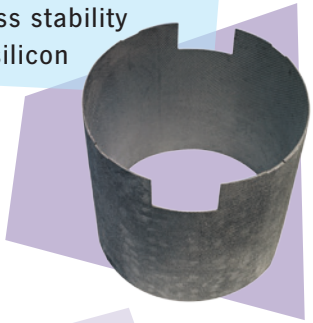


Wafer slicing

Solar cell

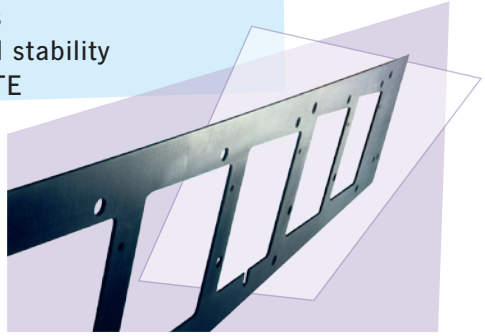
Si - Ribbons process

- 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

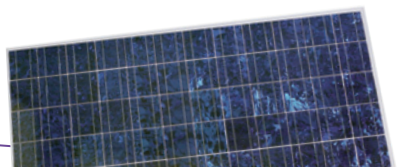


Anti-reflective coating
$Si_3 N_4$

- 2020 graphite carriers
- AM252 carbon/carbon carriers
- Large sizes
- Mechanical stability
- Adapted CTE



Our materials are in conformity with the RoHS-Directive (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment). Besides CARBONE LORRAINE guarantees the application of the European Community REACH-Regulation (Registration, Evaluation, Authorization and Restriction of Chemical substances) to all its plants located in Europe.



MATERIALS

Graphite grades

Grade	Density	FS (MPa)	CTE (10^{-6}/°C)	Resistivity (µΩcm)	Thermal conductivity (W/m°C)	Permeability (cm^2/s)	Standard sizes (mm)
2191	1.75	44	4.2	1,000	116	0.5	540x540x1,830
2020	1.77	45	4.3	1,550	85	0.4	530x635x1,830 1,030x1080x325 Ø 610x1,830 Ø 915x760 Ø 1,500 on request
2123	1.84	58	5.5	1,140	112	0.3	305x620x915
2160	1.86	76	6.0	1,270	102	0.2	305x305x915
2450	1.86	45	4.5	1,550	85	0.04	On request
6503	1.74	23	3.3	800	200	1	550x550x1,830

Purity

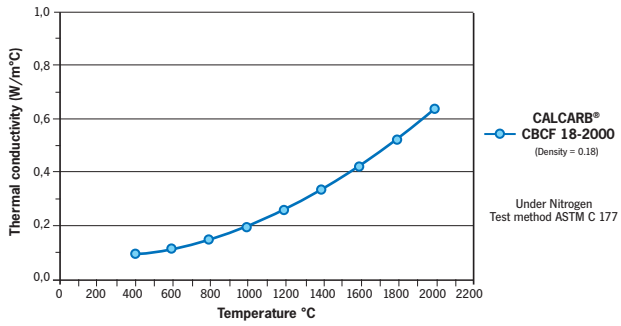
Unpurified	Purified	
290 ppm	PT : < 20 ppm	UHP : < 5 ppm

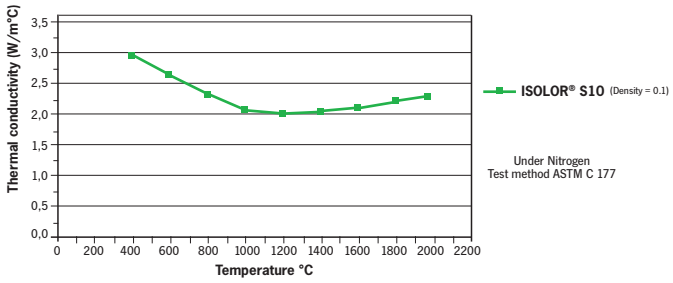
SiC coating

T max	Density	Open porosity	RF (MPa)	CTE 10^{-6}/°C	Coating thickness	Hardness	Young modulus (GPa)	Permeability (cm^2/s)
1700°C	3.2	Impervious to most gases (H2) and liquids	350	4.8	50-250 µm	2280 2950 Knoop	63	< 10^{-4}

Rigid carbon insulation

	Density	Thermal conductivity at 400°C (W/m°C)	Thermal conductivity at 2,200°C (W/m°C)	Standard Dimensions (mm)
ISOLOR® S10	0.1	2.4	2.2	1,500x1000x40 Rounds & special sizes on request
CALCARB® CBCF 18-2000	0.18	0.1	1.0	





Carbon/Carbon composite

	Density	FS (MPa)	Flexural modulus (GPa)	Max sizes (mm)
AM252	1.70	100	10	Ring Ø 2,200 Tube length 3,000

CUSTOMER-ORIENTED INTERNATIONAL NETWORK

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PARTNER IN INNOVATION

Carbone Lorraine harnesses prime expertise in industrial applications to deliver innovative solutions – involving graphite, other high-performance materials,and key components for electric motors and electronic equipment – for many high-technology markets.

As world number-one its main business specialities, Carbone Lorraine fields an extensive industrial and commercial network covering around 40 countries, working hand in hand with its clients to pursue permanent innovation through a broad range of top-class products and services.

CARBONE LORRAINE

Contact in North America
CARBONE OF AMERICA
Ultra Carbon Division
900 Harrison Street
Bay City, MI 48708
USA
Tel. : +1 989 894 29 11
Fax : +1 989 895 77 40
solar.us@carbonelorraine.com

Contact for Europe
CARBONE LORRAINE COMPOSANTS
41 rue Jean Jaurès - BP 148
F-92231 GENNEVILLIERS CEDEX
FRANCE
Tel. : +33 (0)1 41 85 45 14
Fax : +33 (0)1 41 85 43 53
solar.fr@carbonelorraine.com

Contact for Asia
Le Carbone Advanced Graphite Co., Ltd
#29 South Taihu Road,
Kunshan Development Zone,
Kunshan, Jiangsu Province,
215334, PR China
Tel.: +86 512 5763 9808
Fax: +86 512 5763 9811
www.carbonelorraine-ht.cn

www.carbonelorraine.com

HT 26 GB 9010