# SUPERSiC® Silicon Carbide

*Products for semiconductor front end processes*

## OVERVIEW

SUPERSiC® is Entegris' trade name for silicon carbide products. Within this family of silicon carbide materials there are a number of grades that have been tailored to offer semiconductor customers optimum performance for their application. These grades offer material solutions coupled with a unique manufacturing method that provides design flexibility, faster delivery times, lower cost of ownership and higher quality than are typically seen in the production of conventional silicon carbide products.

## CORE STRENGTH

Entegris, formerly known as Poco Graphite, has been in the business of manufacturing premium graphites for over 40 years with a reputation for producing the best graphites in the world. The development of Entegris graphite materials and post processing techniques has often been linked with changes in the semiconductor industry. Entegris has built its reputation as a manufacturer of semiconductor grade materials by controlling the manufacturing process to deliver quality products that provide consistent performance year after year.

Entegris used this graphite expertise to refine its conversion process to develop multiple grades of SUPERSiC for semiconductor applications.

## MANUFACTURING

Entegris materials and finished parts are produced at the North Texas manufacturing facility. Entegris starts with a graphite material that has been designed and manufactured to be used as the precursor in the conversion process. This is not a commercially available grade of graphite. Parts are machined from this unique material to near net shape and then purified to less than 5 ppm ash. The purified parts are then subjected to a proprietary process, converting the graphite to high-purity silicon carbide.

## ADVANTAGES OF THE ENTEGRIS PROCESS

Customer parts are machined to near net shape while still in the graphite form, which is easier and less costly than machining in silicon carbide. There are no expensive molds or additional design costs associated with the Entegris manufacturing process. This allows for custom designs and changes to existing parts can be achieved quickly and with minimum impact to the customer. No significant retooling is ever necessary, which allows design changes to occur in a timely manner. The bottom line is that prototypes can be placed in process in a time frame which meets the demanding requirements of the semiconductor industry. All this translates into lower cost of ownership.

## UNIQUE MATERIAL STRUCTURE OF SUPERSiC SILICON CARBIDE

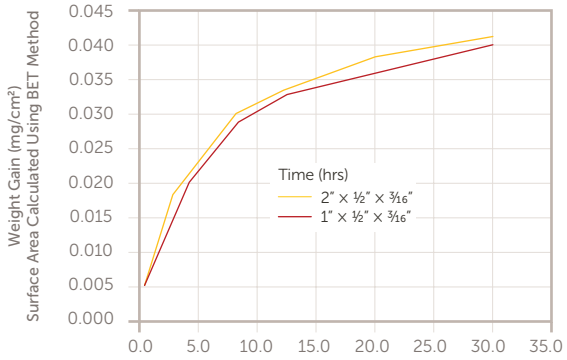
The resulting Silicon Carbide (SiC) is stoichiometric-SiC. Because there is no sintering operation, binding agents, or interfaces, the contamination levels in the converted SiC are typically below 5 ppm, as measured by LA-ICP-MS. The 1:1 ratio of silicon to carbon in the material matrix translates into a product that is impervious to acid attack. Sintered or slip cast silicon carbides, which backfill the voids in the SiC matrix with silicon, must be coated to protect the excess silicon from the common acids found in the semiconductor fab.

## FULLY CONVERTED PARTS

SUPERSiC silicon carbide parts are fully converted by the Entegris process. Our design specialists design for the conversion depth limitations of the process. Finished products are designed with features that reduce thermal mass while retaining high strength.

## OXIDATION RESISTANCE

Oxidation Resistance of Entegris SUPERSiC




*Oxidation resistance of SUPERSiC at 1200°C in an ambient air environment. The surface area was calculated using the BET method, which takes into account the surface area of individual grains.*

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## PURITY AND MOBILE IONS

SUPERSiC silicon carbide is purer than conventional sintered Si/SiC materials. Independent user tests indicate that SUPERSiC is of equal or higher purity than quartz as measured by LA-ICP-MS. Major semiconductor fabs using SUPERSiC carriers found through various metrology tests, reduced atomic contamination at the wafer level.

Typical Purity of SUPERSiC Silicon Carbide

| LA-ICP-MS ELEMENTAL DATA ANALYSIS | |
|---|---|
| **Element** | **SUPERSiC** |
| Na | 0.10 ppm |
| Mg | 0.10 ppm |
| Al | 0.20 ppm |
| K | 0.30 ppm |
| Ca | 0.30 ppm |
| Ti | 0.08 ppm |
| V | 0.17 ppm |
| Mn | 0.12 ppm |
| Fe | 0.30 ppm |
| Ni | 0.30 ppm |
| Cr | 0.20 ppm |
| Zn | 0.01 ppm |

## REDUCED PARTICLE GENERATION

A major semiconductor manufacturer performed a qualification study of particle generation comparing standard quartz to SUPERSiC silicon carbide. The SUPERSiC silicon carbide carriers reduced particle counts by 10 – 40%.

### BETTER FILM ADHESION/IMPROVED YIELD

Deposited films, poly-silicon and silicon nitride contract and expand at the same rate as silicon carbide carriers due to a closer Coefficient of Thermal Expansion (CTE) than quartz, which has a lower CTE. Typical run cycles between cleans using SUPERSiC carriers are 60 – 100% longer than quartz carriers.

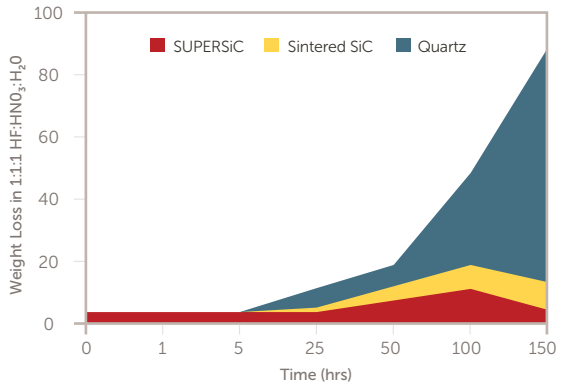
### REDUCED DOWNTIME

Increased production can be gained by reducing downtime for cleaning, SUPERSiC carriers can complete more run cycles between cleanings than quartz. The carriers remain dimensionally stable at high temperatures during their lifetime.

Yield improvement can be seen due to reduced particle generation.

### SEMICONDUCTOR WET CHEMISTRIES

SUPERSiC silicon carbide is virtually unaffected by typical semiconductor wet chemistries. Lesser grades of silicon carbide (i.e. sintered) cannot be used in wet chemistries if the protective coating is chipped during normal handling. This chipping will expose the underlying filler impurities used in the bulk sintered material, creating a contamination source for semi-conductor devices. SUPERSiC silicon carbide is still impervious to acid attack, even if the coating is chipped. SUPERSiC can continued to be deployed in these applications since it is fully stoichiometric silicon carbide without any contaminating fillers.




## SUPERSiC GRADES

SUPERSiC is Entegris' silicon carbide material. The silicon carbide has some porosity. Typical applications are high temperature anneals and drive-ins. Typical fab cleaning methods may be used.

SUPERSiC-3C is the SUPERSiC material with a 75 µm SiC coating that seals and eliminates the underlying porosity while smoothing the surface. Depending on the application this coating can be applied up to 200 µm. Typical applications are Chemical Vapor Deposition (CVD) and Low-pressure Chemical Vapor Deposition (LPCVD). Typical fab cleaning methods may be used.

| Property | SUPERSiC |
|---|---|
| Apparent density: | 3.13 g/cm³ (0.113 lb/in³) |
| Bulk density: | 2.53 g/cm³ (0.092 lb/in³) |
| Total porosity: | 20% |
| Open porosity: | 19% |
| Total impurity level: | <10 ppm |
| Flexural strength: | 155 MPa (22,400 psi) |
| Tensile strength: | 129 MPa (18,700 psi) |
| Elastic modulus: | 216 GPa (31 $10^6$ psi) |
| Specific stiffness: | 85 kN.m/g |
| Poisson's ratio: | 0.17 |
| Dynamic shear modulus: | 96 GPa (14 $10^6$ psi) |
| Fracture toughness: | 2.3 MPa.$m^{0.5}$ |
| Hardness knoop: | 1992 kg/mm² |

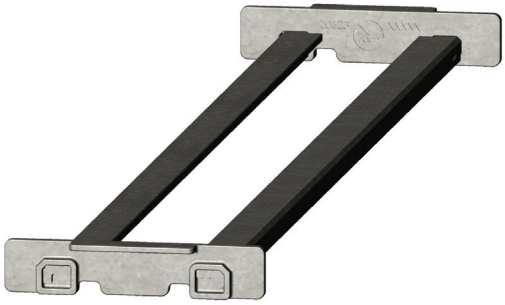
| Property | SUPERSiC |
|---|---|
| Thermal diffusivity: | 100 $mm^2/s$ |
| Thermal conductivity: | 170 W/m.K<br>(98 Btu/hr/ft°F) |
| Electrical resistivity: | 4000 μΩ-cm<br>(1570 μΩ-in) |
| Instantaneous CTE at RT: | 2.4 $10^{-6}$/K<br>(1.3 $10^{-6}$/°F) |

## HORIZONTAL COMPONENTS

Entegris offers wafer carrier solutions that fit all horizontal furnace systems. SUPERSiC silicon carbide products include intermediate carriers, baffle assemblies, LTO cages, horizontal carriers and pickup tools and tips. Entegris' manufacturing process allows for design flexibility so that customers can order special slotting configurations and carriers to fit existing autoloader nests and paddle/cantilever systems.

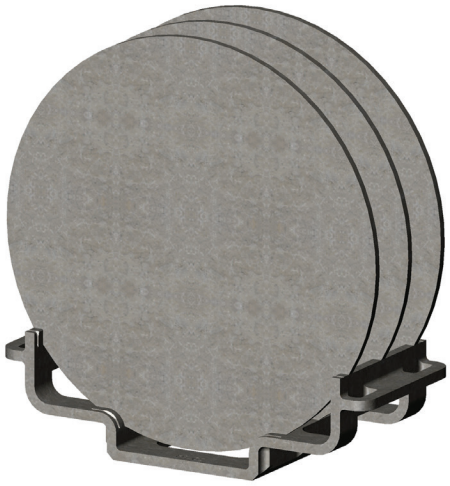
### INTERMEDIATE CARRIERS

Carriers are available in standard and custom configurations. Entegris carriers have lower thermal mass and weight than sintered silicon carbide products. This lightweight characteristic can be advantageous depending upon the application or configuration of the system.



### BAFFLE ASSEMBLIES

Customer specified slotting is available on both half or standard size baffle boats. Boats can be specified for 100 mm, 125 mm, 150 mm or 200 mm wafer size. Standard half boat baffles are available with 3 baffle wafer slots or with 3 baffle wafer slots and 2 monitor wafer slots. Standard full baffle boats have either 6 or 7 baffle wafer slots. Standard baffle disks are 2.54 mm (0.1") thick. Other thicknesses can be specified.

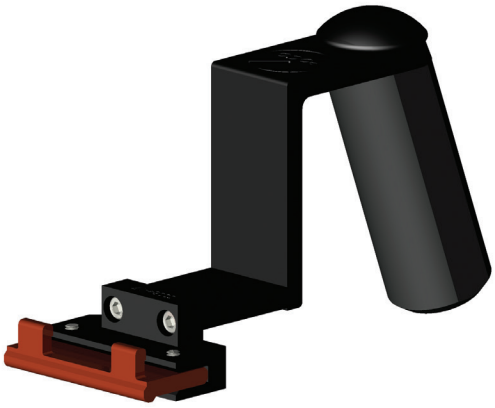


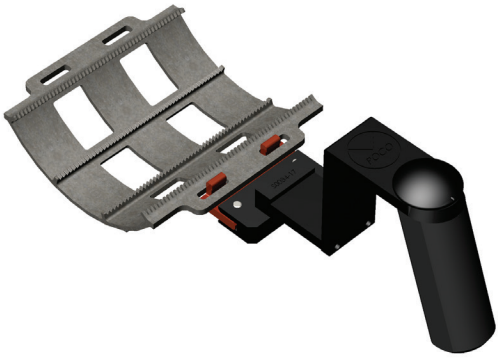
## WAFER CARRIERS

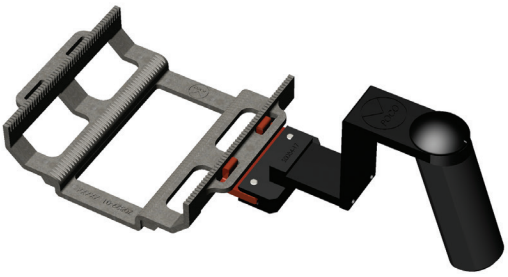
Several styles of horizontal carriers are available in contiguous or non-contiguous styles in 100 mm, 125 mm, 150 mm and 200 mm sizes. Entegris standard styles are one-third round and monolithic carriers. SEMI® standard or custom slotting is available. The base of the carrier can be modified to fit existing autoloaders and paddles.

## PICKUP TOOLS

Entegris' lifting tools are ergonomically designed. This is especially advantageous for operators loading upper furnace tubes as improved stability lowers risk of accidents. Styles include side or end pickup.







## PICKUP TOOL TIPS

A variety of fab approved materials are available to choose from when ordering tools or replacement tips. Selected materials offer temperature and price range to fit most applications.

| Material | Max Temperature |
|---|---|
| ULTEM® | 200°C |
| Vespel® | 300°C |
| Duratron® | 250°C |
| Peek | 250°C |
| SUPERSiC | 900°C |

## DUMMY WAFERS

Entegris' portfolio of SUPERSiC, silicon carbide dummy and baffle wafers provide the user with maximum flexibility while meeting SEMI standard wafer dimensions.

Wafers can be specified as full round, notched or with user defined flats. They are available in sizes up to 300 mm. Entegris offers user defined serialization on each wafer regardless of size or thickness. Custom engraving eliminates the risk of cross contamination in the fab.

Produced from SUPERSiC-3C, dummy wafers contain no silicon backfill and have high purity and durability. Due to their acid resistance, SUPERSiC wafers can be cleaned and reused indefinitely in LPCVD or diffusion processes and can withstand extended high temperature cycling.

| SEMI Standard Dummy Wafers | |
|---|---|
| 125 mm SiC wafers | 0.625 mm (0.0250") thick |
| 150 mm SiC wafers | 0.675 mm (0.0265") thick |
| 200 mm SiC wafers | 0.724 mm (0.0285") thick |
| 300 mm SiC wafers | 0.625 mm (0.0250") thick |

## SUPERSIC BENEFIT

It is still common for silicon dummy wafers to be made from reclaimed Si material. Si reclaimed wafers require recovery, cleaning, protection, and tracking. Costs for reclaimed Si wafers can exceed $100,000 per year, depending on the size of the fab.

The lifetime of a Si reclaimed dummy wafer is determined by its cleaning frequency. Each cleaning cycle reduces the life of the Si reclaimed wafer which results in the continuous purchase of more reclaimed Si wafers to replace those lost. SUPERSiC silicon carbide dummy wafers remain unchanged cycle after cycle. Lifetimes for SUPERSiC dummy wafers have been reported to be in excess of 3 years.

Due to the better match between the CTE of SiC and typical depositions, the film thickness that can be deposited is thicker for SiC than reclaimed Si. Also the surface roughness of SUPERSiC silicon carbide dummy wafers is higher than that of reclaimed Si which improves adhesion of the deposited film to support the growth of thicker deposits before a clean is needed. Depending upon material and process, deposition films of up to 10x the thickness of those produced with reclaimed Si wafers can be grown using SUPERSiC dummy wafers.

SUPERSiC silicon carbide dummy wafers can be custom engraved to avoid any crossover of dummy wafers between various processes which helps to avoid cross-contamination. Engraving is done by laser for easy reading and recognition. In contrast to reclaimed Si dummy wafers, this engraving is not affected by the cleaning cycles and never needs to be redone throughout the lifetime of the wafer.

## EXAMPLE FOR A 200 MM CUSTOMER WITH A POLYSILICON PROCESS

| | | |
|---|---|---|
| **RECLAIMED Si DUMMY WAFER** | | |
| **wafer costs + cleaning costs** | $26*15*365/30 + $10*15*365/1 | |
| | = $4,745 + $54,750 = $59,495 | each year |
| **SUPERSiC DUMMY WAFER** | | |
| **wafer costs + cleaning costs** | $350*15*365/365 + $10*15*365/5 | |
| | = $5,250 + $10,950 = $16,200 | 1st year |
| | = $0 + $10,950 = $10,950 | 2nd year |
| | = $0 + $10,950 = $10,950 | 3rd year |

Consider a reclaimed Si dummy wafer cost of $26 and a SUPERSiC silicon carbide dummy wafer cost of $350. A set of side dummies contains 15 dummy wafers. Lifetime of the reclaimed Si dummy wafer is 30 days and the SUPERSiC dummy wafer is more than 36 months (3 years). Assume a conservative 5x the runs with SUPERSiC dummy wafers when compared with reclaimed Si wafers before cleaning with the reclaimed Si dummy wafers being cleaned every day. Cleaning costs of $10 per wafer were reported equally for reclaimed Si and SUPERSiC silicon carbide.

In the first year of usage, the SUPERSiC silicon carbide dummy wafers saved more than $43,200 for this customer. (This may vary for other customers depending on their specific costs.)

In the following two years, new reclaimed Si dummy wafers must be purchased but the SUPERSiC silicon carbide dummy wafers can continue to be reused. The respective costs in the formula above are then the same annually for reclaimed Si dummy wafers but only $10,950 annually for SUPERSiC dummy wafers, as only cleaning costs need to be paid. This increases the annual saved costs to more than $48,500 per tube, so the costs multiply again by the number of tools in use at the facility. With a total of 18 tools for this customer, the costs for Si dummy wafers sum up to more than $1 million per year. For SUPERSiC silicon carbide dummy wafers the cost is only about $291,000 in the first year and about $197,000 in the two following years. Over a period of three years this customer saved $2.3 million for these side dummies.

## EXAMPLE FOR A 300 MM CUSTOMER WITH A SILICON NITRIDE PROCESS

| | | |
|---|---|---|
| **RECLAIMED Si DUMMY WAFER** | | |
| **wafer costs + cleaning costs** | $65*12*365/20 + $17*12*365/1 | |
| | = $14,235 + $74,460 = $88,695 | each year |
| **SUPERSiC DUMMY WAFER** | | |
| **wafer costs + cleaning costs** | $800*12*365/365 + $17*12*365/4 | |
| | = $9,600 + $18,615 = $28,215 | 1st year |
| | = $0 + $18,615 = $18,615 | 2nd year |
| | = $0 + $18,615 = $18,615 | 3rd year |

Consider a reclaimed Si dummy wafer cost of $65 and a SUPERSiC silicon carbide dummy wafer cost of $800. The set of dummy wafers contains 12 wafers. Lifetime of the reclaimed Si dummy wafer is 20 days and the SUPERSiC dummy wafer is about 30 months (2.5 years). Consider a conservative 4x the runs with SUPERSiC wafers when compared to reclaimed Si wafers before cleaning with the reclaimed Si wafers being cleaned every day. Cleaning costs of $17 per wafer were reported equally for reclaimed Si and SUPERSiC silicon carbide.

In the first year the usage of SUPERSiC silicon carbide dummy wafers saved costs of more than $60,400 for this customer. (Again, this may vary for other customers depending on their specific costs.)

In the following two years new reclaimed Si dummy wafers must be purchased, but the SUPERSiC silicon carbide dummy wafers can continue to be reused. The respective annual costs in the formula above are then the same for reclaimed Si dummy wafers but only $18,615 annually for SUPERSiC dummy wafers, as only cleaning costs need to be paid. This increases the annual saved costs to more than $70,000 per tube, so the costs multiply again by the number of tools in use at the facility. With a total of 24 tools for this customer, the costs for Si dummy wafers sum up to more than $2.1 million per year. For SUPERSiC silicon carbide dummy wafers the cost is only about $677,000 in the first year and about $447,000 in the two following years. Over a period of three years this customer saved more than $4.7 million on dummy wafers.

## LIMITED WARRANTY

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