

# Silicon Carbide Substrates

## **Product Specifications**

4H Silicon Carbide  
(n/p-type)

6H Silicon Carbide  
(n/p-type)



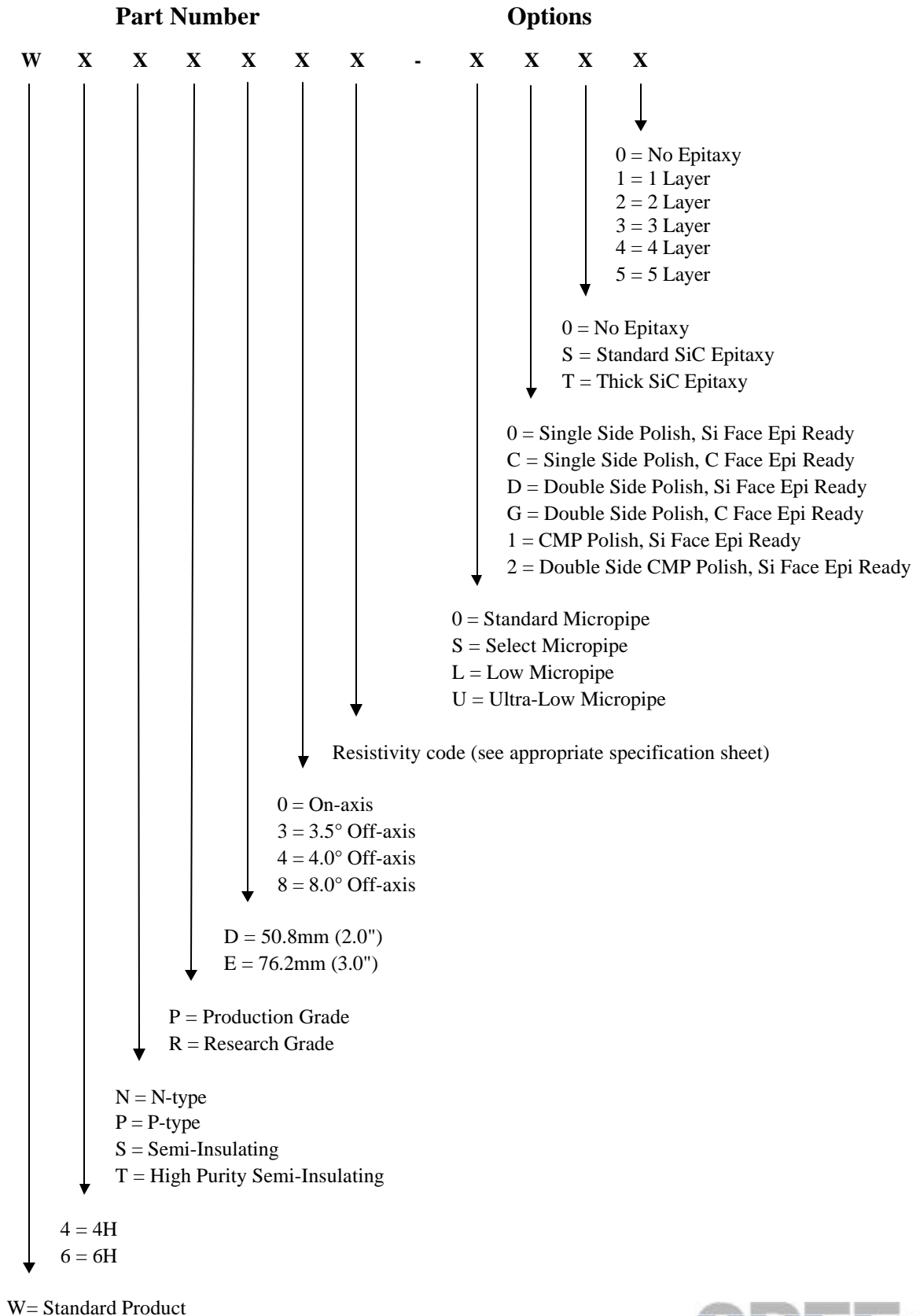
# Properties and Specifications for Silicon Carbide

- Applications:
- High Frequency Power Devices
  - High Power Devices
  - High Temperature Devices
  - Optoelectronic Devices
  - III-V Nitride Deposition

## Physical Properties

<b>Polytype</b>	Single Crystal 4H	Single Crystal 6H
<b>Crystal Structure</b>	Hexagonal	Hexagonal
<b>Bandgap</b>	3.26 eV	3.03 eV
<b>Thermal Conductivity</b> (Typical Range)	3.0-3.8 W/cm • K @ 298K (2.3-2.8 W/cm • K @ 373K)	3.0-3.8 W/cm • K @ 298K (2.3-2.8 W/cm • K @ 373K)
<b>Lattice Parameters</b>	a=3.073 Å c=10.053Å	a=3.081 Å c=15.117Å
<b>Mohs Hardness</b>	~9	~9

# Product Descriptions



# Product Descriptions

## 4H-Silicon Carbide

### 50.8mm Diameter

#### STANDARD MICROPIPE DENSITY

Part Number	Type	Orientation	Micropipe Density	Resistivity Ohm-cm Range	Bin
W4NXD8C-0000	n	8° off	31-100 micropipes/cm <sup>2</sup>	0.015-0.028	C
W4NXD8D-0000	n	8° off	31-100 micropipes/cm <sup>2</sup>	0.028-0.065	D
W4PXD8G-0000	p	8° off	N/A	2.50-8.50	G

#### SELECT MICROPIPE DENSITY

W4NXD8C-S000	n	8° off	16-30 micropipes/cm <sup>2</sup>	0.015-0.028	C
W4NXD8D-S000	n	8° off	16-30 micropipes/cm <sup>2</sup>	0.028-0.065	D

#### LOW MICROPIPE DENSITY

W4NXD8C-L000	n	8° off	≤15 micropipes/cm <sup>2</sup>	0.015-0.028	C
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#### ULTRA-LOW MICROPIPE DENSITY

W4NRD8C-U000 <sup>†</sup>	n	8° off	≤5 micropipes/cm <sup>2</sup>	0.015-0.028	C
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#### SEMI-INSULATING

W4SRD0R-0D00	SI	on-axis	N/A	≥1E5	R
W4SRD8R-0D00	SI	8° off	N/A	≥1E5	R
W4TRD0R-0D00	HPSI	on-axis	N/A	≥1E5	R
W4TRD8R-0D00	HPSI	8° off	N/A	≥1E5	R

#### LCW SUBSTRATES

W4NRD0X-0000	n	on-axis	N/A	0.013-0.500	N/A
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<sup>†</sup> - Contact Cree for availability

# Product Descriptions

## 4H-Silicon Carbide

### 76.2mm Diameter

#### STANDARD MICROPIPE DENSITY

Part Number	Type	Orientation	Micropipe Density	Resistivity Ohm-cm Range	Bin
W4NXE4C-0D00	n	4° off	31-100 micropipes/cm <sup>2</sup>	0.015-0.028	C
W4NXE8C-0D00	n	8° off	31-100 micropipes/cm <sup>2</sup>	0.015-0.028	C
W4NRE0X-0D00	n	on-axis	N/A	0.013-0.500	N/A

#### SELECT MICROPIPE DENSITY

W4NXE4C-SD00	n	4° off	16-30 micropipes/cm <sup>2</sup>	0.015-0.028	C
W4NXE8C-SD00	n	8° off	16-30 micropipes/cm <sup>2</sup>	0.015-0.028	C

#### LOW MICROPIPE DENSITY

W4NXE4C-LD00	n	4° off	≤15 micropipes/cm <sup>2</sup>	0.015-0.028	C
W4NXE8C-LD00	n	8° off	≤15 micropipes/cm <sup>2</sup>	0.015-0.028	C

#### SEMI-INSULATING (PROTOTYPE)

W4TXE0X-0D00	HPSI	on-axis	N/A	N/A	N/A
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# Product Descriptions

## 6H-Silicon Carbide

### 50.8mm Diameter

Part Number	Type	Orientation	Resistivity Ohm-cm Range	Bin
W6NXD3J-0000	n	3.5° off	0.020-0.040	J
W6NXD3K-0000	n	3.5° off	0.040-0.090	K
W6NXD0K-0000	n	on-axis	0.040-0.090	K
W6NXD0KLSR-0000	n	on-axis	0.040-0.090	K
W6NXD3L-0000	n	3.5° off	0.090-0.150	L
W6PXD3O-0000	p	3.5° off	1.00-5.00	O

### LCW SUBSTRATES

W6NRD0X-0000	n	on-axis	0.020-0.200	N/A
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### 76.2mm Diameter

Part Number	Type	Orientation	Resistivity Ohm-cm Range	Bin
W6NRE0X-0000	n	on-axis	0.020-0.200	N/A

# Standard Specifications

## DEFINITION OF DIMENSIONAL PROPERTIES, TERMINOLOGY AND METHODS

### Diameter

The linear dimension across the surface of a wafer. Measurement is performed manually with ANSI certified digital calipers on each individual wafer (see Figure 1).

### Thickness, Center Point

Measured with ANSI certified non-contact tools at the center of each individual wafer.

### Flat Length

Linear dimension of the flat measured with ANSI certified digital calipers on a sample of one wafer per ingot (see Figure 1).

### Surface Orientation

Denotes the orientation of the surface of a wafer with respect to a crystallographic plane within the lattice structure. Measured with x-ray goniometer on a sample of one wafer per ingot in the center of the wafer.

### Orthogonal Misorientation

In wafers cut intentionally “off orientation,” the angle between the projection of the normal vector to the wafers surface onto a  $\{0001\}$  plane and the projection on that plane of the nearest  $\langle 11\bar{2}0 \rangle$  direction.

### Primary Flat

The primary flat is the  $\{10\bar{1}0\}$  plane with the flat face parallel to the  $\langle 11\bar{2}0 \rangle$  direction.

### Primary Flat Orientation

The flat of the longest length on the wafer, oriented such that the chord is parallel with a specified low index crystal plane. Measured on one wafer per ingot using Laue back-reflection technique with manual angle measurement.

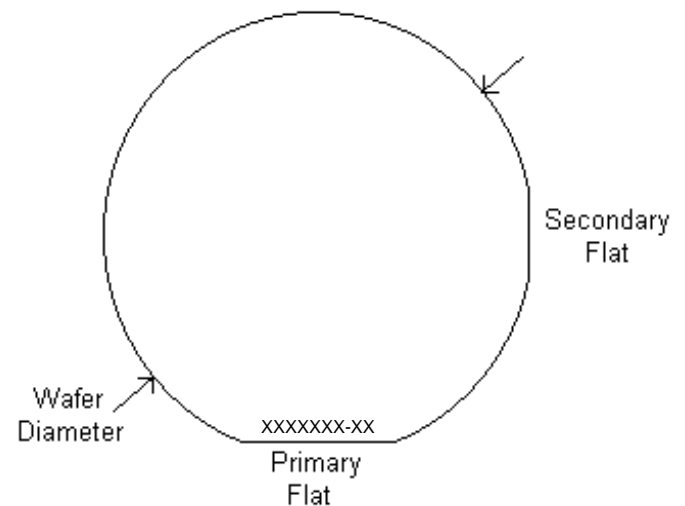
### Secondary Flat Orientation

A flat of shorter length than the primary orientation flat, whose position with respect to the primary orientation flat identifies the face of the wafer.

### Marking

The carbon face of each individual wafer is laser marked with OCR compatible font (similar to definitions and characteristics in SEMI M12).

**Figure 1. Diameter and Primary and Secondary Flat Dimension**



# Standard Specifications

## 50.8mm Diameter Substrate Specifications

SUBSTRATE PROPERTY	CREE STANDARD	
<b>Diameter</b>	2.000" $\pm$ 0.015" 50.8mm $\pm$ 0.38mm	
<b>Thickness, Centerpoint</b>		
4H and 6H On-Axis	<b>Standard</b> 0.010" $\pm$ 0.001" 254.0 $\mu$ m $\pm$ 25.4 $\mu$ m	<b>Laser (6H only)</b> 0.0055" $\pm$ 0.0015" 140.0 $\mu$ m $\pm$ 38.0 $\mu$ m
4H and 6H Off-Axis; Semi-Insulating	0.0145" $\pm$ 0.0025" 368.0 $\mu$ m $\pm$ 64.0 $\mu$ m	
<b>Dopant</b>	n-type: Nitrogen p-type: Aluminum	
<b>Primary Flat Length</b>	0.625" $\pm$ 0.065" 15.88mm $\pm$ 1.65mm	
<b>Secondary Flat Length</b>	0.315" $\pm$ 0.065" 8.0mm $\pm$ 1.65mm	
<b>Cleaved Flat Length</b> (laser substrate only)	Nominal 0.4" (10mm)	
<b>Surface Orientation</b>		
6H and 4H On-Axis	{0001} $\pm$ 0.5°	
6H Off-Axis	3.5° toward $\langle 11\bar{2}0 \rangle \pm 0.5^\circ$	
4H Off-Axis	8.0° toward $\langle 11\bar{2}0 \rangle \pm 0.5^\circ$	
<b>Surface Treatment</b>	Silicon face polish unless otherwise specified	
<b>Orthogonal Misorientation</b>	$\pm 5^\circ$	
<b>Primary Flat Orientation</b>	$\langle 11\bar{2}0 \rangle \pm 5^\circ$	
<b>Secondary Flat Orientation</b>		
Carbon Face	90° CCW from Primary $\pm 5^\circ$	
Silicon Face	90° CW from Primary $\pm 5^\circ$	
<b>Cleaved Flat Orientation</b> (laser substrate only)	180° from primary flat is {10 $\bar{1}$ 0} face	
<b>Package</b>	FLUOROWARE® Single Wafer Container	



# Standard Specifications

## 76.2mm Diameter Substrate Specifications

SUBSTRATE PROPERTY	CREE STANDARD
<b>Diameter</b>	3.000" $\pm$ 0.015" 76.2mm $\pm$ 0.38mm
<b>Thickness, Centerpoint</b>	
4H On and Off-Axis	0.0138" $\pm$ 0.001" 350.0 $\mu$ m $\pm$ 25.4 $\mu$ m
Semi-Insulating	0.0145" $\pm$ 0.0025" 368.0 $\mu$ m $\pm$ 64.0 $\mu$ m
6H On-Axis	0.010" $\pm$ 0.001" 254.0 $\mu$ m $\pm$ 25.4 $\mu$ m
<b>Dopant</b>	n-type: Nitrogen
<b>Primary Flat Length</b>	0.875" $\pm$ 0.125" 22.22mm $\pm$ 3.17mm
<b>Secondary Flat Length</b>	0.440" $\pm$ 0.060" 11.18mm $\pm$ 1.52mm
<b>Surface Orientation</b>	
4H and 6H On-Axis	{0001} $\pm$ 0.5°
4H Off-Axis	4.0° toward $\langle 11\bar{2}0 \rangle \pm 0.5^\circ$ 8.0° toward $\langle 11\bar{2}0 \rangle \pm 0.5^\circ$
<b>Surface Treatment</b>	Silicon face polish unless otherwise specified
<b>Orthogonal Misorientation</b>	$\pm 5^\circ$
<b>Primary Flat Orientation</b>	$\langle 11\bar{2}0 \rangle \pm 5^\circ$
<b>Secondary Flat Orientation</b>	
Carbon Face	90° CCW from Primary $\pm 5^\circ$
Silicon Face	90° CW from Primary $\pm 5^\circ$
<b>Package</b>	FLUOROWARE® Single Wafer Container

# Standard Specifications

## STANDARD SPECIFICATIONS FOR POLISHED SILICON CARBIDE SUBSTRATES - Surface Finish

Characteristics	Production Grade	Research Grade
<b>Edge Chips/Indents by diffuse lighting<sup>†</sup></b>	None Permitted	$2 \leq 1.5$ mm width & depth
<b>Orange Peel/Pits by diffuse lighting<sup>*◇</sup></b>	$\leq 10\%$ area	$\leq 30\%$ area
<b>Polytype Areas by diffuse lighting<sup>*</sup></b>	$\leq 5\%$ area	$\leq 20\%$ area
<b>Striations by diffuse lighting<sup>*</sup></b>	3 allowed $\leq 3$ mm each	20 allowed $\leq 7$ mm each
<b>Area Contamination (stains) by high intensity light</b>	None Permitted	None Permitted
<b>Cracks by high intensity light</b>	None Permitted	None Permitted
<b>Hex Plate by high intensity light<sup>*</sup></b>	Cumulative area $<10\%$	Cumulative area $<30\%$
<b>Scratches by high intensity light<sup>*</sup></b>	5 scratches to 1x wafer diameter cumulative length.	8 scratches to 1.5x wafer diameter cumulative length.
<b>Masking Defects (Mounds)<sup>*</sup></b> Quantitative by 200X Microscopic Inspection	10 defects in 3 or less of the 9 fields inspected in a cross pattern	10 defects in 5 or less of the 9 fields inspected in a cross pattern
<b>Contamination</b> Quantitative by 200X Microscopic Inspection	None in inspected fields	None in inspected fields
<b>Cumulative Area Defects<sup>*</sup></b>	$\leq 10\%$ area	$\leq 30\%$ area

### Notes:

\* Defect limits apply to entire wafer surface except for a 2mm edge exclusion area

◇ Pits must be  $< 2$ mm in distance from one another to be considered a reject cause

† Edge chips must be  $> 0.5$ mm on R grade material to be considered a reject cause

# Standard Specifications

## STANDARD SPECIFICATIONS FOR POLISHED SILICON CARBIDE SUBSTRATES - Surface Finish

### Definition of Terminology and Methods

#### (Area) Contamination

Any foreign matter on the surface in localized areas which is revealed under high intensity (or diffuse) illumination as discolored, mottled, or cloudy appearance resulting from smudges, stains or water spots.

#### Cracks

A fracture or cleavage of the wafer that extends from the frontside surface of the wafer to the back-side surface of the wafer. Cracks must exceed 0.010" in length under high intensity illumination in order to discriminate fracture lines from allowable crystalline striations. Fracture lines typically exhibit sharp, thin lines of propagation, which discriminate them from material striations.

#### Edge Chips

Any edge anomalies (including wafer saw exit marks) in excess of 1.5 mm in either radial depth or width. As viewed under diffuse illumination, edge chips are determined as unintentionally missing material from the edge of the wafer.

#### Edge Exclusion

The outer 2 mm annulus of the wafer is designated as wafer handling area and is excluded from surface finish criteria (such as scratches, pits, haze, contamination, craters, dimples, grooves, mounds, orange peel and saw marks).

#### Hex Plate

Hexagonal shaped platelets on the surface of the wafer which appear silver in color to the unaided eye, under diffuse illumination.

#### Masking Defects (also referred to as "Mound")

A distinct raised area above the wafer frontside surface as viewed with diffuse illumination.

#### Orange peel

Visually detectable surface roughening when viewed under diffuse illumination.

#### Pits

Individual distinguishable surface anomalies, which appears as a depression in the wafer surface with a length-to-width ratio less than 5 to 1, and visible under high intensity illumination.

#### Foreign Polytypes (also referred to as "Inclusions" or "Crystallites")

Regions of the wafer crystallography which are polycrystalline or of a different polytype material than the remainder of the wafer, such as 4H mixed in with a 6H type wafer. Poly regions frequently exhibit color changes or distinct boundary lines, and are judged in terms of area percent under diffuse illumination.

#### Scratches

A scratch is defined as a singular cut or groove into the frontside wafer surface with a length-to-width ratio of greater than 5 to 1, and visible under high intensity illumination.

#### Striations

Striations in silicon carbide are defined as linear crystallographic defects extending down from the surface of the wafer which may or may not pass through the entire thickness of the wafer, and generally follow crystallographic planes over its length.

#### Total Usable Area

A cumulative subtraction of all noted defect areas from the frontside wafer quality area within the edge exclusion zone. The remaining percent value indicates the proportion of the frontside surface to be free of all noted defects (does not include 2mm edge exclusion).

# Epitaxial Specifications for Silicon Carbide

## STANDARD SPECIFICATIONS FOR SILICON CARBIDE EPITAXIAL WAFER - 50.8mm and 76.2mm SUBSTRATES

<b>Substrate Orientation:</b> Epitaxy is only available for off-axis substrates.		
<b>Conductivity</b>	n-type	p-type
<b>Dopant</b>	Nitrogen	Aluminum
<b>Net Doping Density</b>	$N_D - N_A$	$N_A - N_D$
Silicon Face	9E14 – 1E19/cm <sup>3</sup>	9E14 – 1E19/cm <sup>3</sup>
Carbon Face	1E16 – 1E19/cm <sup>3</sup>	Not Available
Tolerance	± 50%	± 50%
<b>Thickness Range- Silicon Face</b>		
0.2-1.0 microns	± 25% of selected thickness	± 25% of selected thickness
1.1-20.0 microns	± 15% of selected thickness	± 15% of selected thickness
20.1-50.0 microns	± 10% of selected thickness	± 10% of selected thickness
<b>Thickness Range- Carbon Face</b>		
0.2-1.0 microns	± 25% of selected thickness	Not Available
1.0-10.0 microns	± 15% of selected thickness	Not Available

Notes: • 2mm edge exclusion

- N-type epi layers <20 microns are preceded by n-type , 1E18, 0.5 micron buffer layer
- N-type epi layers ≥20 microns are preceded by n-type , 1E18, 1.0 micron buffer layer
- No buffer layer for p-type epitaxial layers
- Not all doping densities are available in all thicknesses
- Epitaxy on 6H polytype is limited to 10 microns
- Contact Cree Sales for specifications on multi-layer or unique epitaxy requests

# Epitaxial Specifications for Silicon Carbide

## STANDARD SPECIFICATIONS FOR SILICON CARBIDE EPITAXIAL WAFER - 50.8mm and 76.2mm SUBSTRATES

Characteristics	Maximum Acceptability Limits		Test Methods	Defect Definitions (see pgs. 14-15)	Methodology
Large Point Defects	50.8mm	30	Diffuse Illumination	D1	M1, M2
	76.2mm	60		D2	M1, M2
Scratches	10 lines < 2x wafer diameter			D3	M1, M2
Dimpling	< 5% affected			D4	M1, M2
Step Bunching	4° off-axis	N/A		D5	M1, M2
	8° off-axis	< 10% affected			
Backside Cleanliness	95% clean			D6	M1, M2
Edge Chips	2 with radius 1.5mm			D7	M2
ID Correct/Legible	Yes			D7	M2
Wafer Flats	Yes			D7	M2
Epi Defects	50.8mm, 4H	75	Microscopic	D8-D12	M3
	50.8mm, 6H	135			
	76.2mm, 4H	113			
	76.2mm, 6H	203			
Net Doping	See Specification Table		Hg Probe CV	-	M4
Thickness	See Specification Table		FTIR, SIMS, SEM	-	M5

Notes: • 2mm edge exclusion

# Epitaxial Specifications for Silicon Carbide

## STANDARD SPECIFICATIONS FOR SILICON CARBIDE EPITAXIAL WAFER, DEFINITIONS, EPITAXY DEFECT DESCRIPTIONS, AND METHODOLOGY

### Definitions

#### D1. Large Point Defects

Defects which exhibit a clear shape to the unassisted eye and are > 50 microns across. These features include spikes, adherent particles, chips and craters. Large point defects less than 3 mm apart count as one defect.

#### D2. Scratches

Grooves or cuts below the surface plane of the wafer having a length-to-width ratio of greater than 5 to 1. Scratches are specified by the number of discrete scratches times the total length in fractional diameter.

#### D3. Dimpling

A texture resembling the surface of a golf ball. Specified in % affected area.

#### D4. Step Bunching

Step bunching is visible as a pattern of parallel lines running perpendicular to the major flat. If present, estimate the % of specified area affected.

#### D5. Backside Cleanliness

Verified by inspecting for a uniform color to the wafer backside. Note there is a darker region near the center of some higher doped wafers. Backside cleanliness specified as percent area clean.

#### D6. Edge Chips

Areas where material has been unintentionally removed from the wafer. Do not confuse fractures in epi crown with edge chips.

#### D7. ID Correct and Major Wafer Flat

Both should be readily discernible.

### Epitaxy Defects

The sum of discrete microscopic defects counted in specified area. These include 3C inclusions, comet tails, carrots, particles and silicon droplets.

#### D8. 3C Inclusions

Regions where step-flow was interrupted during epi layer growth. Typical regions are generally triangular although more rounded shapes are sometimes seen. Count once per occurrence. Two inclusions within 200 microns count as one.

#### D9. Comet Tails

Comet tails have a discrete head and trailing tail. These features are aligned parallel to the major flat. Usually, all comet tails tend to be of the same length. Count once per occurrence. Two comet tails within 200 microns count as one.

#### D10. Carrots

Similar to comet tails in appearance except they are more angular and lack a discrete head. If present, these features are aligned parallel to the major flat. Usually, any carrots present tend to be of the same length. Count once per occurrence. Two carrots within 200 microns count as one.

#### D11. Particles

Particles have the appearance of eyes and if present are usually concentrated at the wafer edges and not within the specified area. If present, count once per occurrence. Two particles within 200 microns count as one.

#### D12. Silicon droplets

Silicon droplets can appear as either small mounds or depressions in the wafer surface. Normally absent, but if present are largely concentrated at perimeter of wafer. If present, estimate the % of specified area affected.

# Epitaxial Specifications for Silicon Carbide

## STANDARD SPECIFICATIONS FOR SILICON CARBIDE EPITAXIAL WAFER, DEFINITIONS, EPITAXY DEFECT DESCRIPTIONS, AND METHODOLOGY

### Methodology

**M1.** 2mm edge exclusion.

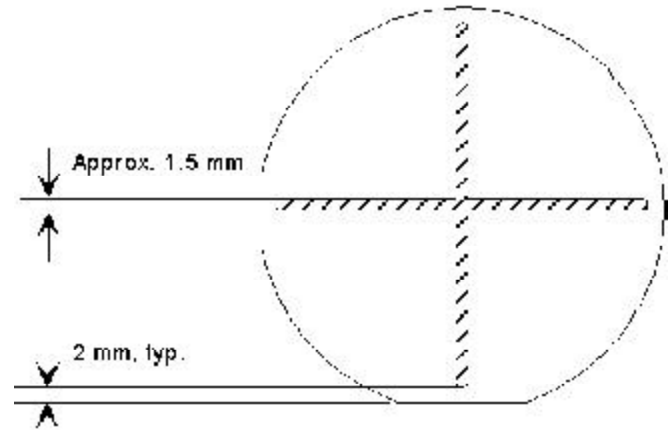
**M2.** Inspection performed under diffuse illumination.

**M3.** Microscopic inspection performed at 100X, on an Olympus BH2 UMA Optical Microscope, or comparable. Inspection pattern detailed in Figure 2.

**M4.** Net doping is determined in the center of the wafer using Hg probe CV.

**M5.** Thickness is determined in the center of the wafer using FTIR, SIMS, or cross-sectional SEM on available monitor wafers.

**Figure 2. Epi Inspection Pattern**





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