Wolfspeed®

Silicon Carbide Substrates and Epitaxy Catalog

WOLFSPEED MATERIALS

Industry-Leading Portfolio, Innovation and Scale

Wolfspeed is a fully integrated materials supplier with the largest and most diverse product portfolio serving our global customer base with a broad range of applications. We are the technology commercialization leader with the capacity and scale to bring large diameter wafers and high-quality epitaxy to the market in mass production volumes.

Wolfspeed has long-proven expertise in SiC and GaN materials technology advancement with the focus and commitment to bring high-quality solution platforms across all applications.

n-TYPE
SiC Substrates

HPSI
High Purity Semi-Insulating SiC Substrates

SiC EPITAXY
n-type and p-type Epitaxial Layers

NITRIDE EPITAXY
GaN, AlGaN, AlInN Epitaxial Layers

APPLICATIONS

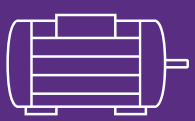
SiC and GaN materials enable faster, smaller, lighter and more powerful electronic systems. Wolfspeed is committed to providing our customers with the materials needed to facilitate the rapid expansion and adoption of the technology within the industry.

Our materials enable devices that power Renewable Energy, Base Stations & Telecom, Traction, Industrial Motor Control, Automotive applications and Aerospace and Defense.

RENEWABLE ENERGY

BASE STATIONS TELECOM

TRACTION



INDUSTRIAL MOTOR CONTROL

AUTOMOTIVE

AEROSPACE AND DEFENSE

PHYSICAL PROPERTIES

Polytype	Single-Crystal 4H
Supported diameters	100 mm*, 150 mm, & 200 mm**
Crystal structure	Hexagonal
Bandgap	3.26 eV
Thermal conductivity (n-type; 0.020 Ω·cm)	a~4.2 W/cm • K @ 298 K
	c~3.7 W/cm • K @ 298 K
Thermal conductivity (HPSI)	a~4.9 W/cm • K @ 298 K
	c~3.9 W/cm • K @ 298 K
Lattice parameters	a=3.073 Å
	c=10.053 Å
Mohs hardness	9

Notes: **Only available for HPSI products.*
***Only available for n-type products*

DIMENSIONAL PROPERTIES, TERMINOLOGY AND METHODS***

DIAMETER

The linear dimension across the surface of a wafer. Measurement is performed using an automated optical micrometer, traceable to the ANSI standard, providing the average value for each individual wafer.

THICKNESS, CENTER POINT

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

SURFACE ORIENTATION

Denotes the orientation of the surface of a wafer with respect to a crystallographic plane within the lattice structure. In wafers cut intentionally “off orientation,” the direction of cut is parallel to the primary flat or notch, away from the secondary flat (if present). Measured with x-ray goniometer on a sample of one wafer per boule in the center of the wafer.

ORTHOGONAL MISORIENTATION

In wafers intentionally cut “off orientation,” the angle between the projection of the surface normal onto a (0001) plane and the nearest $[11\bar{2}0]$ direction.

Notes: **** Please reference SEMI M55.*

Our Products

N-TYPE SiC SUBSTRATE

PRODUCT DESCRIPTIONS

The Materials Business Unit produces an assortment of n-type conductive SiC products. Wolfspeed's industry-leading, high-volume platform process provides our customers with the highest degree of material quality, supply assurance and economies of scale.

Part Number	Description
W4NRG4C-C1-U200	4H-SiC, n-type, Research Grade, 150 mm, 4° Off-Axis, 0.015-0.028 Ω·cm, Ultra Low MPD ≤1/cm², 350 µm Thick w/ 47.5 mm Flat, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate
W4NPG4C-C1-U200	4H-SiC, n-type, Production Grade, 150 mm, 4° Off-Axis, 0.015-0.028 Ω·cm, Ultra Low MPD ≤1/cm², 350 µm Thick w/ 47.5 mm Flat, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate
W4NPG4C-C1-B200	4H-SiC, n-type, Production Grade, 150 mm, 4° Off-Axis, 0.015-0.028 Ω·cm, Ultra Low MPD ≤1/cm², Low BPD ≤1500/cm², 350 µm Thick w/ 47.5 mm Flat, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate
W4NPH4A-N1-0200	4H-SiC, n-type, Production Grade, 200 mm, 4° Off-Axis, 0.015-0.025 Ω·cm, 350 µm Thick w/ Notch, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate

FLAT LENGTH | Linear dimension of the flat measured with automated optical micrometer on a sample of one wafer per boule (see Figure 1).

PRIMARY FLAT | The flat of the longest length on the wafer, oriented such that the chord is parallel with a specified low-index crystal plane.

PRIMARY FLAT ORIENTATION | The primary flat is the $(1\bar{1}00)$ plane with the flat face parallel to the $[11\bar{2}0]$ direction. Measured with XRD back reflection technique.

NOTCH | The notch position is parallel to the $[11\bar{2}0]$ direction, with the notch bisector is in the $(1\bar{1}00)$ plane (see Figure 2).

MARKING | For silicon face polished material, the carbon face of each individual wafer is laser-marked with OCR-compatible font, similar to definitions and characteristics in SEMI M12. The laser markings are positioned upright when the major flat or notch is oriented up, making the scribe easier to read when the wafers are loaded into cassettes. This format includes a wafer supplier identification code, validating the wafer's authenticity. It also includes a checksum, which is an error-detection method that prevents OCR mis-read errors and reduces the instance of processing errors associated with such events.

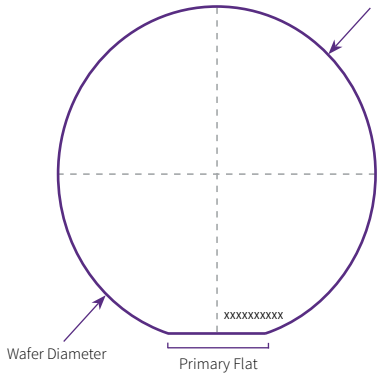


Figure 1. Diameter, primary flat location and marking orientation, carbon face up for silicon face polished 150 mm n-type wafers

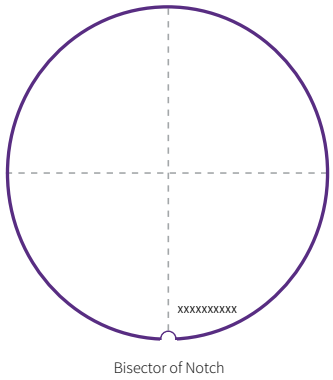


Figure 2. Notch location and marking orientation, carbon face up for 200 mm n-type wafers

PRODUCT SPECIFICATIONS

150 mm Diameter n-type Substrates	
Diameter	150.0 mm ± 0.25 mm
Thickness	350 µm ± 25 µm
Dopant	Nitrogen
Primary flat length	47.5 mm ± 1.5 mm
Secondary flat length	None
Surface orientation	4.0 ° toward [11$\bar{2}$0] ± 0.25 °
Surface finish	Back face optical polish, epi-face CMP
Orthogonal misorientation	± 5 °
Primary flat orientation	[11$\bar{2}$0] ± 5 °
Secondary flat orientation	N/A
TTV	≤10 µm
Warp	≤40 µm
SFQR (max, 1 cm² site)	≤5 µm
LTV (average, 1 cm² site)	
Production-grade	≤2 µm
Research-grade	≤4 µm
Edge chips by diffuse lighting	
Production-grade	None permitted ≥0.5 mm width and depth
Research-grade	Maximum 2 ≤1.0 mm width and depth
Total Usable Area	≥90% area on 2 mm x 2 mm site map
Striations	None permitted
Polytype areas	≤5% area
Area contamination	None permitted
Cracks	None permitted
Hex plates	None permitted
Scratch length	Cumulative ≤150 mm

PRODUCT SPECIFICATIONS

200 mm Diameter n-type Substrates	
Diameter	200.0 mm ± 0.20 mm
Thickness	350 µm ± 25 µm
Dopant	Nitrogen
Notch Depth	1.0 mm +0.25/ -0.0 mm
Notch Orientation	$[1\bar{1}00] \pm 5^\circ$
Surface orientation	4.0° toward $[11\bar{2}0] \pm 0.25^\circ$
Surface finish	Back face optical polish, epi-face CMP
Orthogonal misorientation	$\pm 5^\circ$
TTV	≤8 µm
Warp	≤20 µm
LTV (average, 1 cm^2 site)	≤1 µm
Edge chips by diffuse lighting	None permitted ≥0.5 mm width and depth
Total Usable Area	≥85% area on 5 mm x 5 mm site map
Striations	None permitted
Polytype areas	≤1% area
Area contamination	None permitted
Cracks	None permitted
Hex plates	None permitted
Scratch length	Cumulative ≤100 mm

HIGH PURITY SEMI-INSULATING SiC SUBSTRATE

PRODUCT DESCRIPTIONS

The Materials Business Unit produces a wide assortment of semi-insulating SiC products ranging in wafer diameters up to 150 mm. Wolfspeed's High Purity Semi-Insulating wafers are not vanadium-doped.

Part Number	Description
W4TRF0R-0200	4H-SiC, HPSI, Research Grade, 100 mm, On-Axis, ≥1E6 Ω·cm, Standard MPD, 500 µm Thick w/ 32.5 mm Flat, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate
W4TPF0R-0200	4H-SiC, HPSI, Production Grade, 100 mm, On-Axis, ≥1E6 Ω·cm, Standard MPD, 500 µm Thick w/ 32.5 mm Flat, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate
W4TRG0R-N-0200	4H-SiC, HPSI, Research Grade, 150 mm, On-Axis, ≥1E6 Ω·cm, Standard MPD, 500 µm Thick w/ Notch, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate
W4TPG0R-N-0200	4H-SiC, HPSI, Production Grade, 150 mm, On-Axis, ≥1E6 Ω·cm, Standard MPD, 500 µm Thick w/ Notch, Double-Sided Polish Silicon Face CMP Epi Ready, Bare Substrate

FLAT LENGTH | Linear dimension of the flat measured with automated optical micrometer on a sample of one wafer per boule (see Figure 1).

PRIMARY FLAT | The flat of the longest length on the wafer, oriented such that the chord is parallel with a specified low-index crystal plane. Not applicable to 150 mm wafers.

PRIMARY FLAT ORIENTATION | The primary flat is the $(1\bar{1}00)$ plane with the flat face parallel to the $[11\bar{2}0]$ direction. Measured with XRD back reflection technique.

SECONDARY FLAT | A flat of shorter length than the primary flat, whose position with respect to the primary flat identifies the face of the wafer. Not applicable to 150 mm wafers.

SECONDARY FLAT ORIENTATION | The secondary flat is 90˚ clockwise from the primary flat, ±5˚, referencing the silicon face up.

100 MM HPSI MARKING | HPSI products are silicon face polished, and the carbon face of each individual wafer is laser-marked with OCR-compatible font, similar to definitions and characteristics in SEMI T5 specifications. For 100mm wafers, the laser markings are centered when the primary flat is oriented down (see Figure 1)

150 MM HPSI MARKING | HPSI products are silicon face polished, and the carbon face of each individual wafer is laser-marked with OCR-compatible font, similar to definitions and characteristics in SEMI M12. The laser markings are offset right when looking at the carbon face with the notch oriented down (see Figure 2).

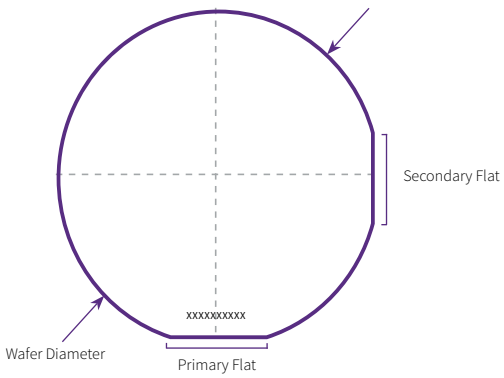


Figure 1. Diameter, primary and secondary flat locations and marking orientation, carbon face up for 100 mm HPSI wafers

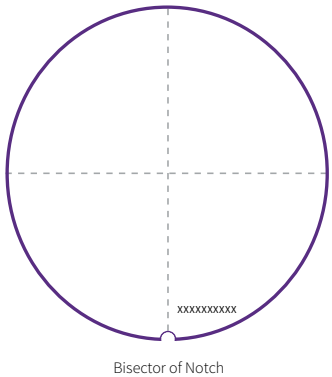


Figure 2. Notch location and marking orientation, carbon face up for 150 mm HPSI wafers

PRODUCT SPECIFICATIONS

100 mm Diameter Semi-Insulating Substrates	
Diameter	100.0 mm +0.0/-0.5 mm
Thickness	500.0 µm ± 25.0 µm
Primary flat length	32.5 mm ± 2.0 mm
Secondary flat length	18.0 mm ± 2.0 mm
Surface orientation	(0001) ± 0.25˚
Surface finish	Back face optical polish, epi-face CMP
Primary flat orientation	$[11\bar{2}0]$ ± 5.0˚
Secondary flat orientation	90.0˚ CW from primary ± 5.0˚, silicon face up
Resistivity	≥1E6 Ω·cm
TTV	≤10 µm
Warp	≤35 µm
LTV (average, 1 cm^2 site)	≤2 µm
Edge chips by diffuse lighting	
Production-grade	None permitted ≥0.5 mm width and depth
Research-grade	Maximum 2 ≤1.0 mm width and depth
Total Usable Area	≥90% area on 2 mm x 2 mm site map
Striations	None permitted
Polytype areas	≤5% area
Area contamination	None permitted
Cracks	None permitted
Hex plates	None permitted
Scratch length	Cumulative ≤150 mm

PRODUCT SPECIFICATIONS

150 mm Diameter Semi-Insulating Substrates	
Diameter	150.0 mm ± 0.25 mm
Thickness	500 µm ± 25 µm
Notch depth	1.0 mm +0.25 mm, -0.00 mm
Notch orientation	$[1\bar{1}00]$ ± 5.0°
Surface orientation	(0001) ± 0.25°
Surface finish	Back face optical polish, epi-face CMP
Resistivity	≥1E6 Ω·cm
TTV	≤10 µm
Warp	≤40 µm
LTV (average, 1 cm^2 site)	≤3 µm
Edge chips by diffuse lighting	
Production-grade	None permitted ≥0.5 mm width and depth
Research-grade	Maximum 2 ≤1.0 mm width and depth
Total Usable Area	≥90% area on 2 mm x 2 mm site map
Striations	None permitted
Polytype areas	≤5% area
Area contamination	None permitted
Cracks	None permitted
Hex plates	None permitted
Scratch length	Cumulative ≤150 mm

SURFACE FINISH DESCRIPTIONS

(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 front-side surface of the wafer to the back-side surface of the wafer. Cracks must exceed 0.25 mm in length under high-intensity illumination in order to discriminate fracture lines from crystalline striations. Fracture lines typically exhibit sharp, thin lines of propagation, which discriminate them from material striations.
EDGE CHIPS	Any edge anomalies in excess of dimensions defined in the product specifications. As viewed under high intensity illumination, edge chips are determined as unintentionally missing material from the edge of the wafer.
EDGE EXCLUSION	The outer annulus of the wafer is designated as wafer handling area and is excluded from surface finish criteria. This annulus is 3 mm for 100 mm, 150 mm , and 200 mm substrates.
HEX PLATE*	Hexagonal-shaped platelets on the surface of the wafer which appear silver in color to the unaided eye, under high intensity light.
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 6H mixed in with a 4H type substrate. Foreign polytype regions may exhibit color changes or distinct boundary lines, and are judged in terms of area percent under UV illumination.
SCRATCHES*	A scratch is defined as a singular cut or groove into the front-side wafer surface with a length-to-width ratio of greater than 5 to 1, and detected and classified by automated optical surface inspection.
STRIATIONS	Striations in silicon carbide are detected under high intensity light and 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 front-side wafer quality area beyond the edge exclusion zone, with regard to a defined grid. The remaining percent value indicates the proportion of the front-side surface to be free of all noted defects, as measured by Lasertec SICA or Candela (does not include edge exclusion).

Notes: **3 mm edge exclusion for 100 mm, 150 mm, and 200 mm substrates.*

SiC EPITAXY

PRODUCT DESCRIPTIONS

Wolfspeed produces n-type and p-type SiC epitaxial layers on SiC substrates, and has the widest range of available layer thickness from sub-micron to >200 µm. Unless noted otherwise on the product quotation, the epitaxial layer structure will meet or exceed the following specifications. Additional comments, terms and conditions may be found in the specification document.

Product Description		
Conductivity	**n-type**	**p-type**
Dopant	Nitrogen	Aluminum
Net doping density	N_D-N_A	N_A-N_D
Silicon face	5E14 – 1E19/cm^3	5E14 – 1E20/cm^3
Tolerance	±20%	±50%
Thickness range	0.2–200 microns	0.2–200 microns
Tolerance	±8% of selected thickness	±10% of selected thickness

PRODUCT SPECIFICATIONS

Characteristics	Maximum Acceptability Limits	Test Methods	Defect Definitions (See pg. 12)	Methodology (See pg. 12)
Scratches	cumulative scratch length ≤150 mm	Diffuse Illumination	D1	M1,M2
Backside cleanliness	95% clean		D2	
Edge chips	See Substrate Specifications		D3	M2
Epi defects*	<3/cm^2	Lasertec SICA	D4-D5	M3
Net doping	See Product Description table	CV	-	M4
Thickness	See Product Description table	FTIR	-	M5

Note: 3 mm edge exclusion, <70 µm thickness

SiC EPIWAFER

DEFINITIONS

D1. SCRATCHES
A scratch is defined as a singular cut or groove into the front-side wafer surface with a length-to-width ratio of greater than 5 to 1, and detected by diffuse illumination with the unaided eye.

D2. BACKSIDE CLEANLINESS
Verified by inspecting for contamination on the wafer backside using diffuse illumination and the unaided eye. Backside cleanliness specified as percent area clean.

D3. EDGE CHIPS
As viewed under diffuse illumination, edge chips are determined as unintentionally missing material from the edge of the wafer.

D4. EPITAXY DEFECTS
The sum of discrete defect counts. These can include triangles, downfall, carrots, particles, and silicon droplets.

D5. AUTOMATED DEFECT CLASSIFICATION & ACCURACY
Defect maps are provided only as representations of wafer quality. Defect classification, location, and count will not be absolutely accurate.

METHODOLOGY

M1. 3 mm edge exclusion.

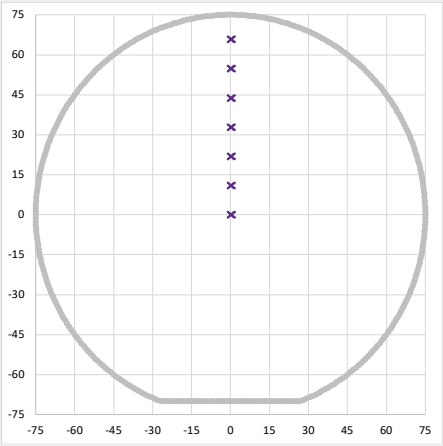
M2. Inspection performed under diffuse illumination.

M3. Automated optical inspection.

M4. Net doping is determined as an average value of multiple points along radius opposite major flat using CV profiling. Rotational symmetry preserved.

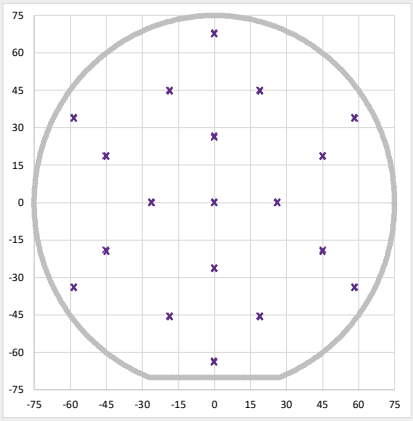
M5. Thickness is determined as an average value across the wafer using FTIR, or mass difference for layers <5 µm.

CV MEASUREMENT POINTS (EPI DOPING)*:



Pt.	x_mm	y_mm
1	0	0
2	0	10.95
3	0	21.90
4	0	32.85
5	0	43.80
6	0	54.75
7	0	65.70

FTIR POINTS (EPI THICKNESS)*:



Pt.	x_mm	y_mm
1	0.00	67.50
2	-58.45	33.76
3	-45.22	18.74
4	-18.74	45.22
5	0.00	26.07
6	18.74	45.22
7	45.22	18.80
8	58.45	33.75
9	45.22	-18.74
10	26.04	0.00

Pt.	x_mm	y_mm
11	0.00	0.00
12	0.00	-26.04
13	-26.04	0.00
14	-45.22	-18.74
15	-58.46	-33.75
16	-18.74	-45.22
17	18.74	-45.22
18	58.45	-33.76
19	0.00	-64.00

Notes: ** Values listed in tables are for 150 mm wafers.*

GaN EPITAXY

PRODUCT DESCRIPTIONS

Wolfspeed produces GaN, $Al_xGa_{1-x}N$ and $Al_{1-y}In_yN$ epitaxial layers on SiC substrates. Unless noted otherwise on the product quotation, the epitaxial layer structure will meet or exceed the following specifications (1). Contact Wolfspeed Materials Sales for specification on custom epitaxy requests. Additional comments, terms and conditions may be found in the specification document.

ELECTRICAL LAYER SPECIFICATIONS

GaN Epitaxial Layer Specifications

Property	Value or Range	Precision	Measurement Technique
Dopant type	n-type (Si) HEMT buffer (Fe and/or C)	-	-
Carrier concentration (unintentionally doped)	< 1E16/cm^3, n-type	-	CV
Carrier concentration (n-type, Si doped)	1E16 to 2E19/cm^3	± 50%	CV (wafer center, room temperature)
Carrier concentration of HEMT structure	>8E12/cm^2 (25 nm $Al_{0.25}Ga_{0.75}N$)	-	Contactless non-destructive carrier concentration
Mobility of HEMT structure	$\mu \geq 1500\ cm^2 V^{-1} s^{-1}$ (25 nm $Al_{0.25}Ga_{0.75}N$)	-	Contactless non-destructive mobility
Sheet Resisitivity	<2% uniformity	-	Contactless non-destructive sheet resisitivity

STRUCTURAL LAYER SPECIFICATIONS

GaN Epitaxial Layer Specifications			
Property	**Value or Range**	**Precision**	**Measurement Technique**
Substrate	On-axis SiC (Semi-Insulating)	-	-
Composition (2)	$Al_xGa_{1-x}N$ or $Al_{1-y}In_yN$	$\Delta x = \pm 0.015$ $\Delta y = \pm 0.02$	XRD peak splitting
	$0 \le x \le 0.3$, $0 \le y \le 0.2$, certain restrictions apply		
Thickness (3)	1.0 µm to 3.0 µm GaN	Average thickness within ± 15% of target thickness and uniformity <10%. (4)	X-ray or white light interferometry
	0.5 nm to 1.0 µm AlN		
	1.0 nm to 1.0 µm $Al_xGa_{1-x}N$		
	1.0 nm to 1.0 µm $Al_{1-y}In_yN$		
	2.0 nm to 5.0 nm GaN (Cap Layer)		
	5.0 nm to 100 nm SiN (Cap Layer)		
GaN Crystallinity	< 250 arcsec (3 µm layer on SiC substrate)	-	XRD (0006) FWHM (center point)
$Al_{0.25}Ga_{0.75}N$	< 500 arcsec (3 µm layer on SiC substrate)	-	XRD (0006) FWHM (center point) (5)
Visible Defects	< 50/cm²	-	Differential interference microscopy at 50x in cross pattern with 5 mm edge exclusion

1. Certain additional restrictions may apply and will be presented on the product quotation
2. Quaternary compositions available upon special request.
3. Range given for undoped layers. Maximum achievable thickness for doped layers or heterostructures will be reduced.
4. Precision specification applies only to layers ≥ 0.01 µm thick.
   Uniformity = (100 x standard deviation / mean).
5. Please specify epitaxy structure details upon submission of RFQ
   (i.e. thickness, doping, composition).
6. Custom structures available. Contact Wolfspeed Materials Sales for more information on custom epitaxy requests.

www.wolfspeed.com/materials | materials_sales@wolfspeed.com

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