2000 V 6H-SiC PN Junction Diodes

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Acknowledgments

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Research carried out under internal funding by
NASA Lewis Research Center, Cleveland, Ohio
Key development areas for SiC power devices:

• Contact resistivities.
  ⇒ device on-state resistances.

• Thermal oxidation and surface passivation.
  ⇒ SiC MOSFET's, power device reliability.

• SiC wafer growth.
  ⇒ defects limit device areas, current ratings.

• SiC epilayer growth.
  ⇒ background dopings and uniformity.
6H-SiC PN Junction Diodes

<table>
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<th>Unannealed Al</th>
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<td>1 µm P+ 6H-SiC NA &gt; 1018</td>
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N 6H-SiC Epilayer
ND ~ 2 - 5 x 10^15 cm^-3
~ 24 µm

~ 8 µm N+ 6H-SiC Epilayer
ND > 10^18 cm^-3

~ 300 µm N+ 6H-SiC Wafer
ND ~ 10^18 cm^-3

Backside Polycrystalline Epi-Growth

Array of Small-Area Devices

6 µm Etch Depth

1 mm
NASA Lewis 6H-SiC PN Diode

Previous best reported SiC diode blocking voltage: 1400 V

2000 V functional yield greater than 50% on small-area ($\leq 4 \times 10^{-4} \text{ cm}^2$) devices.
6H-SiC PN Diode Characteristics

200 µm x 200 µm Square Device

T = 24 °C in Fluorinert™

\[ J_0 = 5 \times 10^{-22} \text{ A/cm}^2 \]

\[ n = 2.05 \]
6H-SiC Diode after 2200 V Catastrophic Failure

Failure appears to occur at diode periphery.
Measured PN Junction Breakdown Fields

- **NASA Lewis 2000 V 6H-SiC Diode**
- **Other NASA Lewis 6H-SiC Diodes**
- **Cree Research 6H-SiC Data**
- **Silicon**

**Y-axis:** Maximum Electric Field (V/cm)

**X-axis:** Background Doping (cm$^{-3}$)
Summary

• Site Competition Epitaxy has greatly improved dopant control in CVD SiC epilayers.

• Reduced epilayer doping has enabled demonstration of the first 2000 V SiC rectifiers ever reported.

• Surface passivation, crystal defects, and other key issues need to be addressed.

• Further improvements expected as crystal growth and processing technologies continue to mature.