Silicon Carbide: a new frontier for radiation detectors?

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April 2001: first commercial SiC Diode

Applications
Compact Switched Mode Power Supplies

600 V - 4 A
300 V - 10 A
Today industrial SiC devices

Industrial World is already producing and using SiC devices

**MOSFETs and Diodes**
600 V – 1.2 kV, up to 150 A

**High efficiency**
DC/DC Converters, Inverters

**Automotive**

**Renewable energy**
USA R&D for SiC & GaN industrial applications

https://poweramericainstitute.org

Accelerating the next generation of power electronics.
SiC detector prototypes

Processed SiC Wafer

Microstrip

Pad

Interdigitated

Pixel

Quad
Strength of SiC for Radiation Detection

Wide Bandgap
3.2 eV

High Critical Field
(2 MV/cm)

**Experimental Data**

Reverse Current Density

Mean electric field (kV/cm)

J = 1 pA/cm² @ +27°C → sub-electron ENC
J = 1 nA/cm² @ +127°C → High-T operation
E=100 kV/cm → very fast, no charge trapping

**Strength of SiC for Radiation Detection**

- **Wide Bandgap**
  - 3.2 eV

- **High Critical Field**
  - (2 MV/cm)

**Graphical Data**

- **SiC**
- **4H-SiC**
- **GaAs**
- **Si**

- **E_g** (eV)
- **E_c** (MV/cm)
- **E_b** (x10 eV)
- **V_s** (10^7 cm/s)

- **J = 1 pA/cm² @ +27°C → sub-electron ENC**
- **J = 1 nA/cm² @ +127°C → High-T operation**
- **E=100 kV/cm → very fast, no charge trapping**
High Resolution X-Ray Spectroscopy with SiC pixel

- FWHM 177 eV (9.6 e\(^-\) rms) +100 °C
- FWHM 120 eV (6.5 e\(^-\) rms) +28 °C
SiC detector under floating temperature

Bandgap energy (e-h pair creation energy) : minimum temperature coefficient

SiC microstrip detector

ΔT_{max} 140 K

T_{max} +110 °C

T_{min} -30 °C

Counts

Energy (keV)

0 10 20 30 40 50 60

10h floating T (ΔT=140°C)

1 h constant T=30°C

SiC Microstrip Detector
LPE - SM1

Pulser
V_{DET} = 80 V

τ_{peak} = 12.8 μs

G. Bertuccio, Silicon Carbide Detectors for Ionizing Radiation: history, state of the art and perspectives
CPAD Instrumentation Frontier Workshop 2021, 18 - 22 March 2021, Stony Brook, NY, USA
Strength of SiC for Radiation Detection

High Atom Displacement Energy
(22 / 35 eV)

Experimental Data

Before irradiation

After 23 MGy of $^{137}$ Cs

$^{238}$Pu alpha spectra

46 keV FWHM

62 keV FWHM

Courtesy of F. H. Ruddy, Westinghouse
Strength of SiC for Radiation Detection

High Atom Displacement Energy
(22 / 35 eV)

SiC
GaAs
Si

Experimental Data
Plasma radiation

Asterix – PALS (Prague)
High Power Laser
3 TW / 1 J / 350 ps Laser

SiC detector signal

80 V on 50 Ω (1.6 A)

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Strength of SiC for Radiation Detection

- High Critical Field (2 MV/cm)
- High Saturation Velocity (200 μm/ns)

**Experimental Data**
Plasma radiation

Asterix – PALS (Prague)
High Power Laser
3 TW / 1 J / 350 ps Laser

SiC detector signal

- Amplitude (V)
- Time (ns)

![Graph showing SiC, GaAs, and Si strengths and parameters](image)

- $E_g$ (eV)
- $E_c$ (MV/cm)
- $E_D$ (x10 eV)
- $V_s$ ($10^7$ cm/s)

- Strength of SiC for Radiation Detection
- High Saturation Velocity (200 μm/ns)
- High Critical Field (2 MV/cm)

Experimental Data
Plasma radiation

Asterix – PALS (Prague)
High Power Laser
3 TW / 1 J / 350 ps Laser

![Graph showing SiC detector signal](image)

- Amplitude (V)
- Time (ns)

1 ns 50 V
SiC detectors: a wide and successful R&D

Silicon carbide detector for laser-generated plasma radiation
Giuseppe Bertuccio\textsuperscript{a,b}, Donatella Puglisi\textsuperscript{a,b}, Lorenzo Torrisi\textsuperscript{c,d}, Claudio Lanziere\textsuperscript{a}
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High-Resolution Alpha-Particle Spectrometry Using 4H Silicon Carbide Semiconductor Detectors
Frank H. Ruddy, John G. Seidel, Huygian Chen, Abdul R. Dallio, Member, IEEE, and Sei-Hyung Ryu, Member, IEEE

\textbf{What next?}
Large format detectors R&D

\textbf{What is needed now?}
A significant application

SiC detectors: a wide and successful R&D

Simultaneous Measurement of Neutron and Gamma-Ray Radiation Levels from a TRIGA Reactor Core Using Silicon Carbide Semiconductor Detectors
A.R. Dallio\textsuperscript{a}, J.H. Ruddy\textsuperscript{b}, J.G. Seidel\textsuperscript{c}, C. Davison\textsuperscript{d}, T. Finchbaugh\textsuperscript{e} and T. Drexelensepeck\textsuperscript{f}
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What next?
Large format detectors R&D

What is needed now?
A significant application

Additional information:
see presentation at CPAD Solid State Session
Thursday, 18 March 2021
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