次世代工業領域最佳電源方案介紹
(相關控制IC與超高壓SiC產品)

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ROHM Semiconductor
Taiwan Design Center
Outline

• Characteristic of SiC material and SiC device
• Application of SiC
• ROHM SiC device
• SiC MOSFET in Auxiliary power supply
Outline

• Characteristic of SiC material and SiC device
  • Application of SiC
  • ROHM SiC device
  • SiC MOSFET in Auxiliary power supply
Superior Material Properties of SiC

- Compound semiconductor which has 1 x 1 covalent bond of Si and C
- Extremely hard material
  - new mohs hardness: 13 ⋯ Diamond (15)

**Properties Comparison**

- Lower Loss: x1/10
- Higher Voltage: x10
- Electric Breakdown Field (V/cm)
- Melting Point (℃)
- Bandgap (eV)
- Thermal Conductivity (W/cm·℃)
- Electron Saturation Velocity (x10^7 cm/s)
- Higher Temp Operation: x3
- Higher Temp Endurance: x3
- Cooling: x3
- Higher Frequency: x10

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## Comparison Between Si and SiC devices

<table>
<thead>
<tr>
<th></th>
<th>Diode</th>
<th>Transistor</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Si Bipolar</strong></td>
<td>PND (FRD)</td>
<td>IGBT</td>
<td>□ Low Ron by hole injection (conductivity modulation)</td>
</tr>
<tr>
<td><strong>device</strong></td>
<td></td>
<td></td>
<td>× Slow reverse recovery (FRD)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>× Tail current (IGBT)</td>
</tr>
<tr>
<td><strong>Si Unipolar</strong></td>
<td>SBD</td>
<td>MOSFET</td>
<td>□ Fast SW speed</td>
</tr>
<tr>
<td><strong>device</strong></td>
<td>SJ-MOSFET</td>
<td></td>
<td>× High RonA at HV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>× SJ-MOS → 900V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>× Terrible body diode recovery</td>
</tr>
<tr>
<td><strong>SiC Unipolar</strong></td>
<td>SBD</td>
<td>MOSFET</td>
<td>◎ Very low RonA</td>
</tr>
<tr>
<td><strong>device</strong></td>
<td></td>
<td></td>
<td>◎ Fast SW speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>◎ Ultra fast recovery (SBD/ body-diode of MOS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>◎ Operate at 200°C ~</td>
</tr>
</tbody>
</table>
Comparison Between Si and SiC devices

Unipolar Devices (Majority Carrier Device) are available in higher voltage applications by SiC Semiconductor.

- **Minority Carrier Device**: Lower on-Resistance but Lower SW Speed
- **Majority Carrier Device**: Lower on-Resistance & Higher SW Speed
Characteristics SiC SBD
Comparison: Si-FRD vs SiC-SBD
Comparison: Si-FRD vs SiC-SBD

Temperature Dependency

Forward Current Dependency
Characteristics of SiC MOSFET
Why SiC in Higher Voltage Application?

Material Property Comparison between Si and SiC

Breakdown Electric Field (MV/cm): Si 0.3 → SiC 2.8

Si-MOSFET

Si Substrate

Drain Electrode

Voltage Isolation area

Gate

Source

n⁺ n⁻ n⁺ p

SiC-MOSFET

SiC Substrate

Drain Electrode

Gate

Source

n⁺ n⁻ n⁺ p

Lower On-Resistance
(by higher doping and thinner drift layer)

Reduction of Condition loss

1/10 Thinner

1/300 to 1/1,000 Lower Resistance

Higher voltage capability with thinner & lower resistance semiconductor layer

SiC is the most promising material for Power Electronics because of Lower Power Losses

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RonA vs BV

At over 900V, There is no MOSFET having low Ron.
Conduction loss/ switching loss

Conduction Loss (@150°C)

Switching Loss
Si-IGBT

SiC-MOS

Significant difference at low power load conditions

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Reverse recovery of body diode

IXFB44N100P (1000V Si-MOSFET)

- Ir = 28A
- Trr = 163ns
- Err = 41.0μJ

SCT2080KE (1200V SiC-MOSFET)

- Ir = 4A
- Trr = 16ns
- Err = 0.3μJ
Body diode特性

Though $V_F$ of body-diode is high because SiC is a wide band gap semiconductor, it can be reduced by tuning-on MOS channel. (reverse conduction)
**Recommended Gate Voltage of SiC-MOSFET**

$V_{GS} = 18V$ is recommended as driving voltage.

On-resistance v.s. Gate Voltage
SCT2080KE (1,200V 80mΩ)

<table>
<thead>
<tr>
<th>Device</th>
<th>Recommended $V_{GS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si-IGBT</td>
<td>10V - 15V</td>
</tr>
<tr>
<td>Si-MOSFET</td>
<td>16V~20V</td>
</tr>
</tbody>
</table>

18V is recommended as the gate voltage, to get lower on resistance, and to avoid the thermal runaway (under 12V area).
Outline

• Characteristic of SiC material and SiC device
• Application of SiC
• ROHM SiC device
• SiC MOSFET in Auxiliary power supply
SiC in EV/ EV Charger

DC/ DC converter: Weight/ Volume → -20%
Inverter: Weight/ Volume → -70%
Charger: Efficiency → improved 2.5%( OBC)
SiC in PV Inverter

PV Inverter
Increase efficiency $\rightarrow$ exceed 98.5%
Reduce weight/ Volume $\rightarrow$ -85%
SiC in UPS/ Motor driver

PFC block $\rightarrow$ SiC MOS/ SiC SBD
Inverter $\rightarrow$ hybrid IGBT.
Outline

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ROHM SiC SBD

1st gen. & 2nd gen. $\rightarrow$ 3rd gen.

**Structure**
- SBD (Schottky barrier diode)
- JBS (PN diode and SBD)

**Junction**

<table>
<thead>
<tr>
<th>Schottky Barrier</th>
<th>Schottky Barrier and PN junction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Features</strong></td>
<td><strong>Features</strong></td>
</tr>
<tr>
<td>• Low $R_{on}$</td>
<td>• High $I_{FSM}$</td>
</tr>
<tr>
<td>• Low $V_F$ under high temperature</td>
<td>• Low leakage current</td>
</tr>
</tbody>
</table>

**ROHM’s advantage**
- Low $V_F$ under high temperature
ROHM SiC SBD

Surge current robustness vs. Forward voltage (V_F@10A (V))

- 3rd gen. SCS310A
- 2nd gen. SCS210A
- 1st gen. SCS110A

Improvement of I_{FSM} by 2.5 times from previous gen. with low V_F

Realized lower forward voltage characteristic by improvement of fabrication process

650V 10A TO-220AC 2L
# ROHM SiC SBD_2Gen

<table>
<thead>
<tr>
<th>Package / Rated voltage</th>
<th>TO-220</th>
<th>TO-220FM</th>
<th>TO-247</th>
<th>D2pack (LPTL)</th>
<th>Bare dies</th>
</tr>
</thead>
<tbody>
<tr>
<td>650V</td>
<td>6A~20A</td>
<td>6A~20A</td>
<td>20A~40A</td>
<td>6A~20A</td>
<td>6A~20A(MP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30A~100A(DS)</td>
</tr>
<tr>
<td>1200V</td>
<td>5A~20A</td>
<td></td>
<td>10A~40A</td>
<td></td>
<td>5A~20A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30A, 50A</td>
</tr>
<tr>
<td>1700V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10A~50A</td>
</tr>
</tbody>
</table>

**Automotive grade  AEC-Q101 qualified**

<table>
<thead>
<tr>
<th>650V</th>
<th>6A~20A</th>
<th></th>
<th>20A~40A</th>
<th>6A~20A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200V</td>
<td>5A~20A</td>
<td></td>
<td>10A~40A</td>
<td>30A, 40A (Under development)</td>
</tr>
</tbody>
</table>
## ROHM SiC SBD_3Gen

<table>
<thead>
<tr>
<th>650V</th>
<th>P/N</th>
<th>2A~10A</th>
</tr>
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<tbody>
<tr>
<td>TO-220ACP</td>
<td>SCS3□□AP</td>
<td></td>
</tr>
<tr>
<td>TO-263AB (LPTL)</td>
<td>SCS3□□AJ</td>
<td></td>
</tr>
<tr>
<td>TO-252M</td>
<td>SCS3□□AD</td>
<td></td>
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</table>
ROHM SiC MOSFET
ROHM SiC MOSFET

<table>
<thead>
<tr>
<th>Generation</th>
<th>2nd generation SiC-MOSFET</th>
<th>3rd generation SiC-MOSFET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Planner gate (DMOS)</td>
<td>Trench gate (UMOS)</td>
</tr>
</tbody>
</table>

Ron・A reduction about 50%
ROHM SiC MOSFET (Double trench)

Ordinary trench MOSFETs

3G SiC MOSFETs

Eox: 35% lower

Conventional single-trench (Gate trench only)

Double-trench (Gate trench and source trench)
# ROHM SiC MOS (DMOS)

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Type</th>
<th>P/N</th>
<th>80mΩ</th>
<th>160mΩ</th>
<th>280mΩ</th>
<th>450mΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>650V</td>
<td></td>
<td>SCT2120AF</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200V</td>
<td></td>
<td>SCT2xxxKE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCH2080KE</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SBD co-pack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700V</td>
<td></td>
<td>SCT2H12NZ</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCT2xxxNY</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As of Apr 2016
# ROHM SiC MOS (DMOS)

**AEC-Q101 qualified**

<table>
<thead>
<tr>
<th>1200V</th>
<th>P/N</th>
<th>80mΩ</th>
<th>160mΩ</th>
<th>280mΩ</th>
<th>450mΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO-247</td>
<td>SCT2xxxKEAHR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</table>

As of Mar, 2016
# ROHM SiC MOS (UMOS)

<table>
<thead>
<tr>
<th>650V</th>
<th>P/N</th>
<th>17mΩ</th>
<th>22mΩ</th>
<th>30mΩ</th>
<th>60mΩ</th>
<th>80mΩ</th>
<th>120mΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO-247N</td>
<td>SCT3xxxAL</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1200V</th>
<th>P/N</th>
<th>22mΩ</th>
<th>30mΩ</th>
<th>40mΩ</th>
<th>80mΩ</th>
<th>160mΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO-247N</td>
<td>SCT3xxxKL</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

As of Oct, 2015
ROHM SiC Module
ROHM SiC Module

Feature

- Full SiC module
- Equivalent package size as standard IGBT modules
- Built-in thermistor
- Tjmax=175°C

1200V/ 80A~ 1200V/ 180A
1200V/ 300A
Outline

- Characteristic of SiC material and SiC device
- Application of SiC
- ROHM SiC device
- SiC MOSFET in Auxiliary power supply
SiC-MOSFET for Auxiliary power supply

AC 400V

Converter  →  Inverter  →  Motor

Step-down Converter  →  DC 5V~48V

400V AC ⇒ 528~1013V

HV MOSFET

<table>
<thead>
<tr>
<th></th>
<th>SCT2H12NY</th>
<th>2SKxxxxx</th>
<th>STPxxxxx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vds</td>
<td>1700V</td>
<td>1500V</td>
<td>1500V</td>
</tr>
<tr>
<td>Id max</td>
<td>4A</td>
<td>2A</td>
<td>2.5A</td>
</tr>
<tr>
<td>Tjmax</td>
<td>175°C</td>
<td>150°C</td>
<td>150°C</td>
</tr>
<tr>
<td>Rds(on)@25°C</td>
<td>1.2Ω</td>
<td>9Ω</td>
<td>6Ω</td>
</tr>
<tr>
<td>Ciss</td>
<td>184pF</td>
<td>990pF</td>
<td>939pF</td>
</tr>
<tr>
<td>Qg</td>
<td>14nC</td>
<td>75nC</td>
<td>29.3nC</td>
</tr>
</tbody>
</table>

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BD7682xFJ-LB

Feature

- Optimum System for driving SiC-MOSFET
- Quasi – Resonant DC/DC convertor
- Max Frequency Controlled (120kHz)
- Burst function at light load
- VCC Over Voltage Protection
- VCC Under Voltage Locked Out
- Brown IN/OUT Function
- DC/DC Cycle by Cycle current limiter
- 250nsec Leading-Edge Blanking
- Over Load Protection (128ms Timer)

Specification

- Operating VCC Range : 15.0V ~ 27.5V
- DCDC Max Frequency : 120kHz
- Operating current : 800 uA
- Operating Temperature: -40deg. to +105deg.

PIN place / Package

Control IC
1 2 3 4
5 6 7 8
VOUT
AC
85-265Vac
FUSE+
-
Filter
Diode
Bridge
OUT
GND
VCC
CS
ZT
RS
CM
FB
ERROR
AMP
PC
BO
MASK
VD
VP
VS
巻線比:NP
巻線比:NS
巻線比:ND

SOP-J8S
6.00mm x 4.90mm x 1.375mm
Pitch: 1.27mm(Typ.)
BD768xFJ-LB’s Feature

SiC-MOSFET has much larger gate voltage range than Si-MOSFET

Operable gate voltage range
12V ~ 22V

BD7682FJ’s
Operable gate voltage range
16.0V ~ 20.0V

Suitable for driving SiC MOSFET ! !
BM2SCQ121NT

Feature

- Quasi – Resonant DC/DC convertor
- Burst function at light load
- Max Frequency Controlled (120kHz)
- VCC Over Voltage Protection
- VCC Under Voltage Locked Out
- Broun IN/OUT Function
- DC/DC Cycle by Cycle current limiter
- 250nsec Leading-Edge Blanking
- Over Load Protection (128ms Timer)
- 1700V / 4A / 1.2ohm SiC MOSFET

Specification

- Operating VCC Range : 15.0V ~ 29.5V
- Operating DRAIN Range : ~ 1700V
- Drain-Source On resistance : 1.56 ohm( typ.)
- DCDC Max Frequency : 120kHz
- Operating current : 1.20 mA
- Operating Temperature: - 40deg. to +105deg.
- Power Range (Without Heat-Sink) : - 30W
- Power Range (With Heat-Sink) : - 100W