The Industry's First Mass-Produced "Full SiC" Power Modules

ROHM now offers SiC power devices featuring a number of characteristics, including: high breakdown voltage, low power consumption, and high-speed switching operation not provided by conventional silicon devices. In response to the growing demand for SiC products, ROHM has implemented the world's first full-scale, mass production of next-generation SiC components.
SiC - the next generation of compact, energy-saving Eco Devices

The demand for power is increasing on a global scale every year while fossil fuels continue to be depleted and global warming is growing at an alarming rate. This requires better solutions and more effective use of power and resources. ROHM provides Eco Devices designed for lower power consumption and high efficiency operation. These include highly integrated circuits utilizing sophisticated, low power ICs, passive components, opto-electronics and modules that save energy and reduce CO₂ emissions. Included are next-generation SiC devices that promise even lower power consumption and higher efficiency.

Lower power loss and high temperature operation in a smaller form factor

In the power device field for power conversion and control, SiC (Silicon Carbide) is gaining increased attention as a next-generation semiconductor material due to its superior characteristics compared with silicon, including lower ON-resistance, faster switching speeds, and higher temperature operation.

Implementing SiC devices in a variety of fields, including the power, automotive, railway, industrial, and consumer sectors

SiC devices allow for smaller products with lower power consumption that make mounting possible even in tight spaces. Additional advantages include high voltage and high temperature operation, enabling stable operation under harsh conditions—impossible with silicon-based products. In hybrid vehicles and EVs SiC power solutions contribute to increased fuel economy and a larger cabin area, while in solar power generation applications they improve power loss by approximately 50%, contributing to reduced global warming.
**SiC Power Devices**

The industry's first mass-produced SiC makes the previously impossible "possible"

### Full SiC Power Module

**Mass Produced**

Switching loss reduced by 85% (max.)

ROHM has developed low-surge-noise power modules integrating SiC devices produced in-house, maximizing high-speed performance. The result is significantly reduced switching loss compared with conventional Si IGBTs.

- **Features (BSM120D12P2C005)**
  1. Switching loss reduced by 85% (max.)*
  2. 50% less volume*
  3. High-speed switching
  4. 1200V rated voltage / 120A rated current

*Compared with conventional Si IGBT modules

- **Switching Loss Comparison**

- **Internal Circuit Diagram (Half Bridge Circuit)**

- **Lineup**

<table>
<thead>
<tr>
<th>Package</th>
<th>BSS</th>
<th>1200V</th>
<th>1800V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module</td>
<td>BSM120D12P2C005</td>
<td>BSM180D12P2C101</td>
<td></td>
</tr>
</tbody>
</table>

### SiC MOSFET

**Mass Produced**

High speed switching with low ON-resistance

SiC enables simultaneous high speed switching with low ON-resistance - normally impossible with silicone-based products. Additional features include superior electric characteristics at high temperatures and significantly lower switching loss, allowing smaller peripheral components to be used.

- **Lineup**

- **Internal Circuit Diagram**

- **On-Resistance Temperature Characteristics (Compared with 1200V-Class Products)**

- **Turn OFF Characteristics (Compared with 1200V-Class Products)**
SiC SBD (Schottky Barrier Diodes)

Significantly lower switching loss

SBDs were developed utilizing SiC, making them ideal for PFC circuits and inverters. Ultra-small reverse recovery time (impossible to achieve with silicon FID) enables high-speed switching. This minimizes reverse recovery charge (Qrr), reducing switching loss considerably and contributes to end-product miniaturization.

Switching Waveforms (SCS110AG)

- Switching loss reduced by 60%

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**Isolated Gate Driver**

High-speed operation supports SiC

- High-speed operation with a max. I/O delay time of 150ns
- Core-less transformer utilized for 2,500Vrms isolation
- Original noise cancelling technology results in high CMR (Common Mode Rejection).
- Supporting high VGS/negative voltage power supplies
- Compact package (6.5×8.1×2.01 mm)

**Recommended Operating Range (BM6101FVC-C)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Supply Voltage</td>
<td>VCC1</td>
<td>4.5</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Output Supply Voltage</td>
<td>VCC2</td>
<td>14</td>
<td>24</td>
<td>V</td>
</tr>
<tr>
<td>Output VBE Voltage</td>
<td>VBE2</td>
<td>-12</td>
<td>0</td>
<td>V</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>Ta</td>
<td>-40</td>
<td>125</td>
<td>°C</td>
</tr>
</tbody>
</table>

**IPM Operating Waveforms (BM6101FVC-C)**

(Conditions) ROHM SiC IPM VCC1=5.0 VCC2=18V VEE2=5V VDN=800V Ta=25°C

**Lineup**

2nd Generation

<table>
<thead>
<tr>
<th>Package</th>
<th>660V</th>
<th>1200V</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>6A</td>
<td>10A</td>
</tr>
<tr>
<td>TO-220AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TO-220FM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TO-247(3pin)</td>
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<td></td>
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<tr>
<td>LPT1(4pin)</td>
<td></td>
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</tr>
</tbody>
</table>

**Lineup**

Part No.           | Rated Output Current (Max.) | Isolation Voltage | Input Filtered High Current | I/O Delay Time | Driver Current Detection | DEGAT | After Cooling Function | Soft Turn-ON Function | Short-Circuit Output |
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BM6101FVC-C</td>
<td>3.0A</td>
<td>2,500Vrms</td>
<td>○</td>
<td>350ns</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>BM6102FVC-C</td>
<td>3.0A</td>
<td>2,500Vrms</td>
<td>○</td>
<td>200ns</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>BM6104FVC-C</td>
<td>3.0A</td>
<td>2,500Vrms</td>
<td>○</td>
<td>150ns</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
High quality ensured through a consistent production system

Quality first is ROHM’s official corporate policy. In this regard a consistent production system was established for SiC production. The acquisition of SiCrystal (Germany) in 2009 has allowed ROHM to perform the entire manufacturing process, from wafer processing to package manufacturing, in-house. This not only ensures stable production and unmatched quality, but lowers cost competitiveness and enables the development of new products.

SiCrystal AG, the largest SiC monocrystal wafer manufacturer in Europe, became a member of the ROHM Group in 2009.

SiCrystal was established in 1997 in Germany based on a SiC monocrystal growth technology development project launched in 1994. Mass production and supply of SiC wafers began in 2001.

In 2012, SiCrystal relocated to a new plant in Nürnberg to increase production capacity.

With the corporate philosophy “Stable Quality”, SiCrystal has adopted an integrated wafer production system from raw SiC material to crystal growth, wafer processing, and inspection, and in 1999 was granted ISO9001 certification.

**Manufactured Product: SiC Wafers**

Advanced Crystallization Technology

SiC inputs are produced via a crystal growth process utilizing a sublimation method called “Rayleigh’s method” that sublimates SiC powder and recrystallizes it under cold temperatures. Compared with conventional Si inputs which are crystallized in the liquid phase from Si melt, the growth rate using the sublimation method is slow, making crystal defects likely to occur, and therefore requires precision technology for crystal control. SiCrystal utilizes advanced crystallization technology to produce stable quality wafers.

**SiC Wafer Production**

1. Crystal growth
2. External polishing
3. Flat formation
4. Slicing
5. Sanding / Edge polishing / Cleaning

**SiC Power Devices**
**State-of-the-art industry-academia R&D collaboration**

ROHM is actively involved in partnerships with major universities in a variety of fields in order to share expertise, cultivate new technologies, and collaborate on breakthrough R&D.

**Development of mass-produced SiC epitaxial growth equipment**

ROHM, along with Kyoto University and Tokyo Electron, developed mass production SiC epitaxial growth equipment that can process multiple SiC wafers in a single operation. Fast development was made possible by efficiently sharing technologies. These new equipment are currently used for mass producing ROHM SiC devices.

**High performance SiC MOSFET with High-k gate is currently under development**

In 2007 ROHM, along with Kyoto University and Tokyo Electron, developed the industry's first SiC Trench MOSFET utilizing an aluminum oxide (AlOx) layer on the gate insulating film. The result is 1.5x the breakdown voltage and 90% lower leakage current vs. conventional thermally oxidized films (SiOx) for greater reliability with lower loss. Expected to find wide adoption in electric vehicles, industrial equipment, and trains in the near future.

**Development of high temperature operation (Tj=225°C) transfer mold modules**

ROHM has developed SiC modules capable of operating at high temperatures for inverter driving in automotive systems and industrial devices. These transfer mold modules are the first in the industry to ensure stable operation up to 225°C while maintaining the compact, low-cost package configurations commonly used in current Si devices. This contributes to wide compatibility and ensures ready adoption. Modules incorporating 6 devices and featuring 1200V/300A operation at temperatures up to 225°C are available.

**Future solutions for high temperature operation**

- **High temperature SiC gate drivers**
  Gate drivers using SiC wafers are currently under development. They are expected to achieve higher speeds with lower power consumption.

- **SiC High temperature devices**
  Operation has been verified above 200°C. Evaluating reliability at high temperatures is the next step.

- **High temperature capacitors**
  Devices featuring new materials and designs are currently being developed with higher temperature capability.

- **High temperature packaging technology**
  Unique technology was used to develop high-temperature packaging suitable for SiC devices.

**Proprietary technology makes it possible to develop ultra-compact large current SiC IPMs.**

ROHM, in collaboration with major motor manufacturers, is focused on developing SiC modules for next-generation vehicle motors that utilize a number of compact products developed in-house, from gate driver ICs to transistors, diodes, and resistors. Previously, no electronic devices could be built into motors due to the extreme temperatures. However, ROHM SiC module technology allows compact integration of electronic components within the motor, making it possible to produce high efficiency motors with built-in inverters. An ultra-compact large current SiC IPM has been realized by attaching a high-temperature-resistant micro-mold-type SiC module directly to a cooler.
Focusing on cutting-edge SiC technology and leading the industry through innovative R&D

ROHM has been focused on developing SiC for use as a material for next-generation power devices for years, collaborating with universities and end-users in order to cultivate technological know-how and expertise. This culminated in Japan’s first mass-produced Schottky barrier diodes in April 2010 and the industry’s first commercially available SiC transistors (MOSFET) in December. And in March 2012 ROHM unveiled the industry’s first mass production of Full SiC Power Modules.

**SiC Technology Breakthroughs**

- **2002**
  - Begin preliminary experiments with SiC MOSFETs (Jan 2002)
  - Develop SiC MOSFET prototypes (Dec 2004)

- **2005**
  - Ship SiC MOSFET samples (Nov 2005)

- **2007**
  - ROHM, along with Kyoto University and Nippon Riko, announce the development of SiC epitaxial mass-production technology (Jun 2007)
  - Trial manufacture of large current (200A) SiC MOSFETs and SBDs (Schottky Barrier Diodes) (Dec 2007)

- **2008**
  - Develop a new type of SiC diode with Nissan Motors (Apr 2008)
  - Release trench-type MOSFETs featuring the industry’s smallest ON-resistance: 7.0mΩ (Sep 2008)
  - Nissan Motors conducts a driving experiment of a hatchback vehicle equipped with an inverter using ROHM’s SiC diode (Sep 2008)
  - Honda R&D Co., Ltd. and ROHM test prototype SiC power modules for hybrid vehicles (Sep 2008)
  - ROHM tests prototype high-temperature operation power modules for high-power SiC elements and introduces a demo capable of operation at 250 °C (Oct 2008)

- **2009**
  - The ROHM Group acquires S-Ceramic, an SiC wafer manufacturer (Jul 2009)
  - Develop the industry’s first high current, low resistance SiC trench MOSFET (Oct 2009)

- **2010**
  - Successfully develop the industry’s first SiC power module containing trench MOSFETs and SBDs that can be integrated into motors (Oct 2010)
  - Begin mass production of SiC MOSFETs (Dec 2010)

- **2011**
  - Develop the industry’s first transfer-mold SiC power modules capable of high temperature operation (up to 255 °C) (Oct 2011)
  - ARII Inc. (Arkansas Power Electronics International) and ROHM: develop high-power, high-current (1000A-class SiC trench MOS modules (Oct 2011)

- **2012**
  - Launch the industry’s first mass production of Full SiC power modules with SiC SBDs and SiC MOSFETs (Mar 2012)
  - Begin mass production of SiC-MOS Module (Dec 2012)

**SiC Eco Devices**

Reducing environmental load

SiC power devices deliver superior energy savings. ROHM is expanding its lineup of SiC power devices with innovative new products that minimize power consumption in order to reduce greenhouse gas emissions and lessen environmental impact.