ROHM
SEMICONDUCTOR

SiC Power Devices

vol.3

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.

Full SiC Power Module

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 CO_2 emissions. Included are next-generation SiC devices that promise even lower power consumption and higher efficiency.

Industrial equipment
Reduces power loss and size

Consumer electronics
Energy-saving air conditioners and IH cooktops

Servers
Reduce data center power consumption by minimizing server power loss

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 garnering 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.

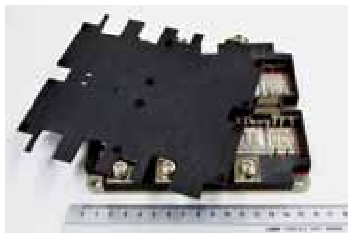
■Performance Comparison: SiC vs. Si

Breakdown Electric Field (MV/cm)	Bandgap (eV)	Thermal Conductivity (W/cm℃)
Si 0.3 / SiC **3.0**	Si 1.1 / SiC **3.2**	Si 1.5 / SiC **4.9**
High voltage Low ON-resistance High-speed switching	High temperature operation (over 250°C)	High heat dissipation

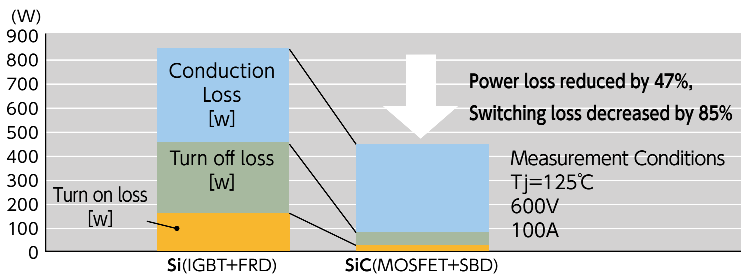
- Higher voltages & currents
- Low conduction loss
- Reduced switching loss
- Smaller cooling systems
- Higher power density
- System miniaturization

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

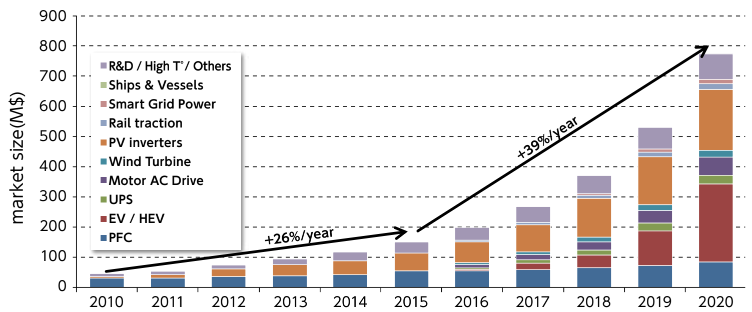
SiC devices allow for smaller products with lower power consumption that make mounting possible even in tight spaces. Additional advantages include high voltage and high temperature operation, enabling stable operation under harsh conditions—impossible with silicon-based products. In hybrid vehicles 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.



■Power Loss Comparison



■long - term market forecast for SiC devices in various power applications



Market forecast for SiC power devices Source: Yole Développement

Power transmission systems
Reduce power loss

Railway
Reduce inverter size and weight

EV (i.e. hybrid/electric vehicles)
Reduce cooling system size, decrease weight, and increase fuel economy

Photovoltaics
Increase power conditioner efficiency

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

SiC Power Device

Full SiC Power Module

Mass Produced

Switching loss reduced by 85% (max.)

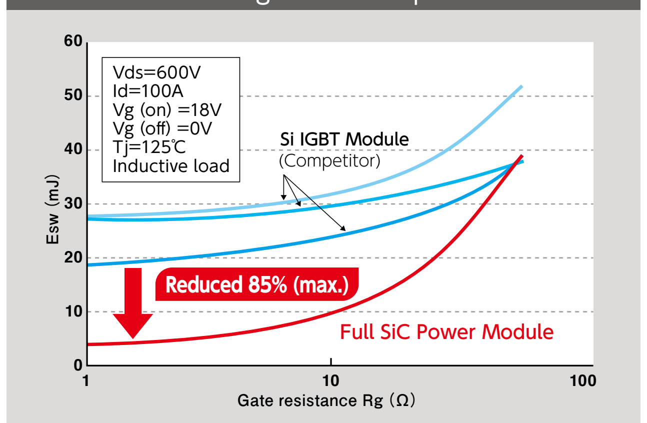
ROHM has developed low-surge-noise power modules integrating SiC devices produced in-house, maximizing high-speed performance. The result is significantly reduced switching loss compared with conventional Si IGBTs.

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

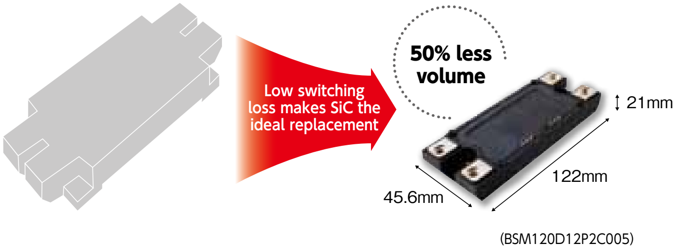
Switching Loss Comparison



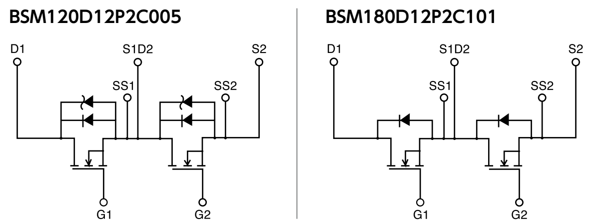
Reference values evaluated under the same conditions

■ Ideal replacement for Si IGBT modules

ROHM SiC power modules reduce switching loss considerably, making them ideal for replacing Si IGBT modules (depending on the operating conditions).



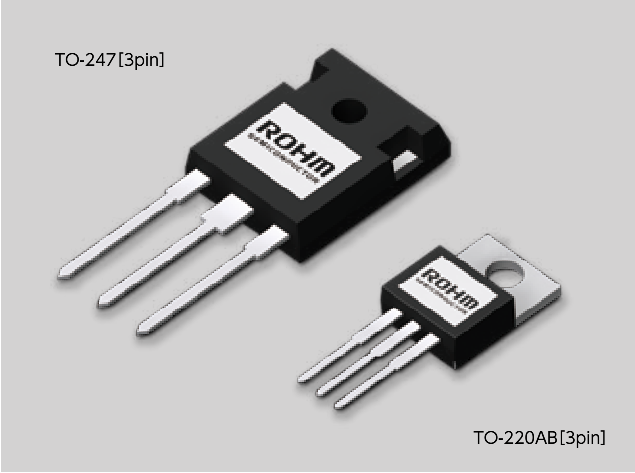
■ Internal Circuit Diagram (Half Bridge Circuit)



■ Lineup

Package	BVDSS 1200V	
	ID 120A	180A
Module	BSM120D12P2C005	New BSM180D12P2C101

SiC MOSFET

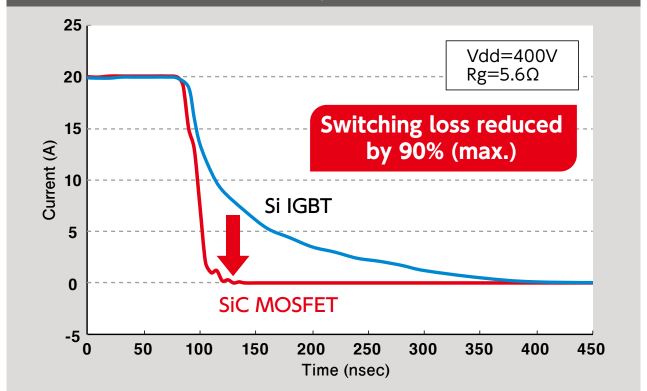


Mass Produced

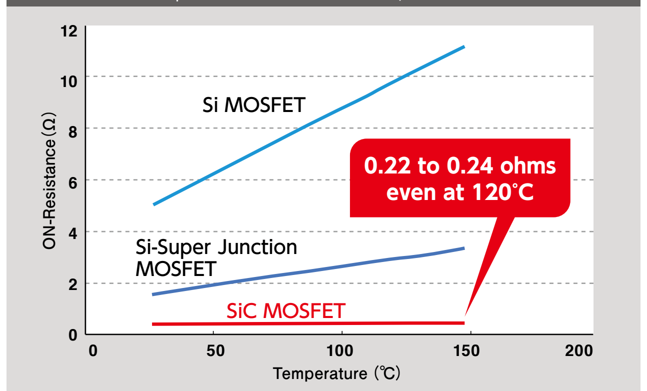
High speed switching with low ON- resistance

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.

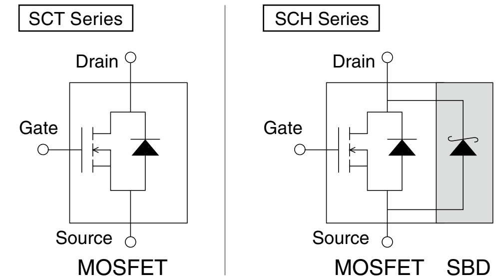
Turn OFF Characteristics (Compared with 1200V-Class Products)



ON-Resistance Temperature Characteristics (Compared with 650V-Class Products)



■ Internal Circuit Diagram



■ Lineup

Package	BVDSS 400V	650V	1200V			
	RDS (on) 120mΩ	120mΩ	80mΩ	160mΩ	280mΩ	450mΩ
TO-220AB [3pin]	New SCTMU001F	New SCT2120AF	—	—	—	—
TO-247 [3pin]	—	—	SCH2080KE / SCT2080KE	New SCT2160KE	New SCT2280KE	New SCT2450KE

ROHM's unique IC technology maximizes SiC characteristics

DRIVER

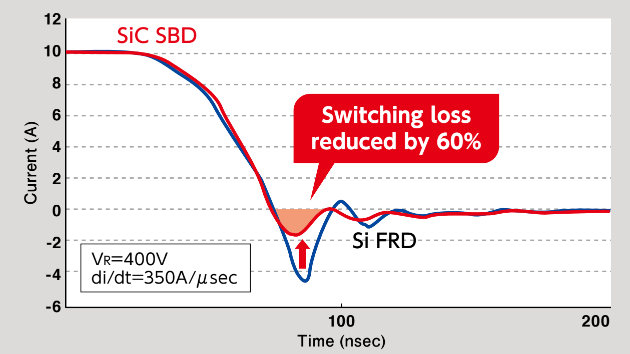
SiC SBD (Schottky Barrier Diodes)

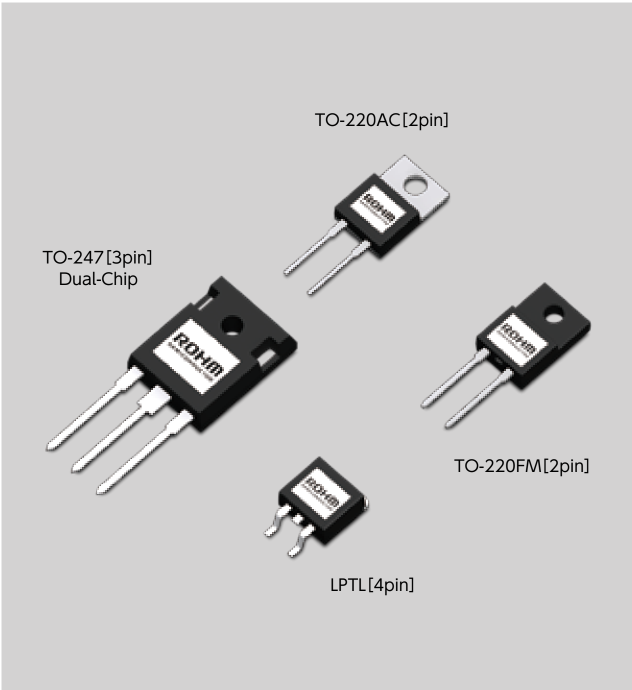
Mass Produced

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 FRDs) enables high-speed switching. This minimizes reverse recovery charge (Qrr), reducing switching loss considerably and contributes to end-product miniaturization.

Switching Waveforms (SCS110AG)





Lineup

2nd Generation

Package	650V								1200V					
	6A	8A	10A	12A	15A	20A	30A	40A	5A	10A	15A	20A	30A	40A
TO-220AC[2pin]	SCS206AG	SCS208AG	SCS210AG	SCS212AG	New SCS215AG	SCS220AG	—	—	SCS205KG	SCS210KG	SCS215KG	SCS220KG	—	—
TO-220FM[2pin]	SCS206AM	SCS208AM	SCS210AM	SCS212AM	New SCS215AM	New SCS220AM	—	—	—	—	—	—	—	—
TO-247[3pin]	—	—	—	—	—	SCS220AE2	New SCS230AE2	SCS240AE2	—	SCS210KE2	—	SCS220KE2	New SCS230KE2	New SCS240KE2
LPTL[4pin]	New SCS206AJ	New SCS208AJ	New SCS210AJ	New SCS212AJ	New SCS215AJ	New SCS220AJ	—	—	—	—	—	—	—	—

Isolated Gate Driver

Under Development

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* *BM6101FV-C, BM6104FV-C
- Compact package (6.5×8.1×2.01 mm)

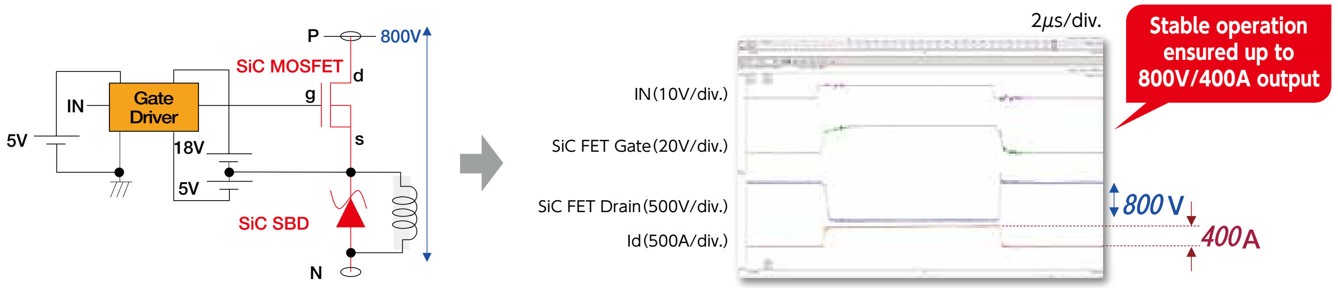
SSOP-B20W

Recommended Operating Range (BM6101FV-C)

Parameter	Symbol	Min.	Max.	Unit
Input Supply Voltage	VCC1	4.5	5.5	V
Output Supply Voltage	VCC2	14	24	V
Output VEE Voltage	VEE2	-12	0	V
Operating Temperature Range	Ta	-40	125	℃

IPM Operating Waveforms (BM6101FV-C)

〈Conditions〉 ROHM SiC IPM VCC1=5.0 VCC2=18V VEE2=-5V VPN=800V Ta=25℃



Lineup

Part No.	Features								
	Rated Output Current (Peak)	Isolation Voltage	Negative Power Supply Compatibility	I/O Delay Time	Over current Detection	DESAT	Mirror Clamp Function	Soft Turn OFF Function	Error Status Output
BM6101FV-C	3.0A	2,500Vrms	○	350ns	○	○	○	○	○
BM6102FV-C	3.0A	2,500Vrms	—	200ns	○	○	○	○	○
BM6104FV-C	3.0A	2,500Vrms	○	150ns	○	○	○	○	○

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.

100% in-house production system

DISCRETE

Diodes

Transistors

ASSYLINE

In-house production equipment

High quality, high volume, and stable manufacturing are guaranteed utilizing in-house production equipment.

MODULES

Low inductance module

A low inductance module utilizing SiC's high-speed characteristics was developed

WAFER PROCESS

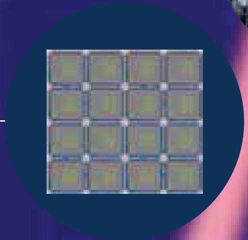
SiC processes

High quality lines integrating SiC's unique processes are utilized.

ON SITE PLANT

Cutting-edge, self-sufficient manufacturing facility

In addition to in-house power generation, all materials required for manufacturing, such as hydrogen, oxygen, and nitrogen, are included on site.



CHIP DESIGN

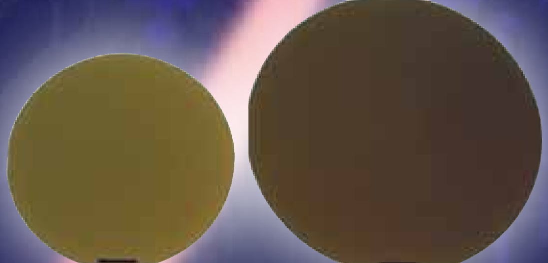
High quality design

Master engineers are on hand to ensure high quality designs.

CAD

In-house photo masking

Enabling uniform quality control from SiC chip design to photo masking



WAFER

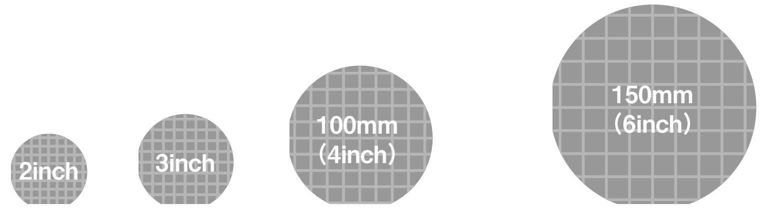
SiC wafer manufacturing

ROHM acquired SiCrystal (a German SiC substrate manufacturer), resulting in stable supply of high-quality SiC substrates.

SiCrystal AG

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 Nüremberg 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



Mass Production

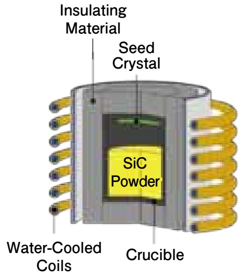
Preparing for mass production

Acquired ISO9001 Certification

SiC Wafer Production

Advanced Crystallization Technology

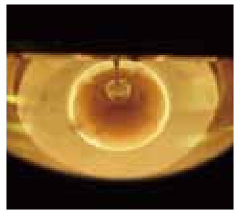
SiC ingots are produced via a crystal growth process utilizing a sublimation method called "Rayleigh's method" that sublimates SiC powder and recrystallizes it under cold temperatures. Compared with conventional Si ingots which are crystalized in the liquid phase from Si melt, the growth rate using the 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.



For SiC:

Temperature: 2,000 to 2,400°C

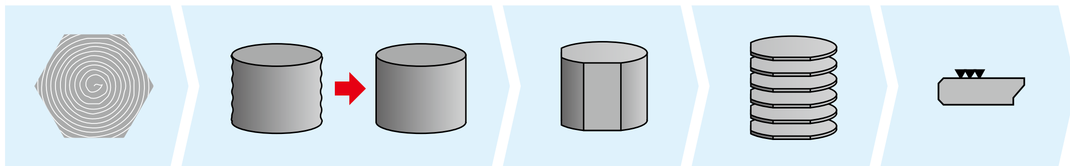
Principle: Transports sublimated gas to the surface of the seed crystal by a heat gradient in order to recrystallize it. Crystal control is difficult and the growth rate is slow compared with liquid phase growth.



For Si:

Temperature: 1,230 to 1,260°C

Principle: Liquid-phase growth during which Si melt is solidified on the seed crystal. This method is characterized by fast crystal growth.



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

SiC Wafer

Research & Development

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

Kyoto University × Tokyo Electron × ROHM

3-institution technological collaboration enables rapid development of high-quality SiC devices

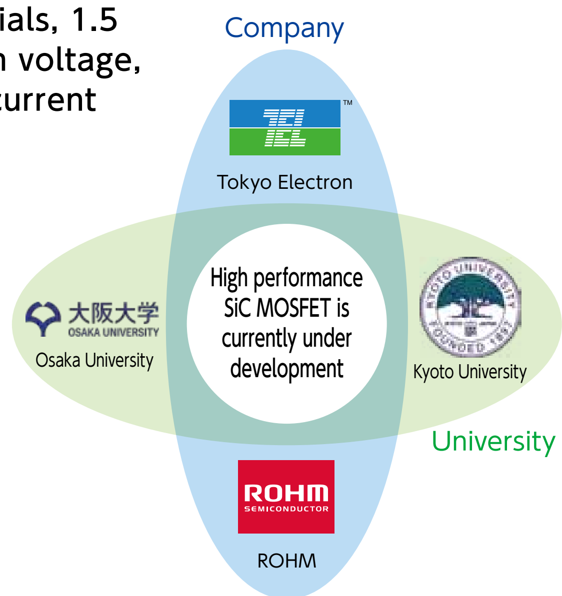
In 2007 ROHM, along with Kyoto University and Tokyo Electron, developed mass production SiC epitaxial growth equipment that can processes multiple SiC wafers in a single operation. Fast development was made possible by efficiently sharing technologies. These new equipment are currently used for mass producing ROHM SiC devices.

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

Osaka University × Kyoto University × Tokyo Electron × ROHM

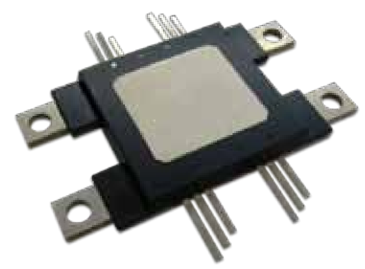
Characteristics improvement based on new materials, 1.5 times the breakdown voltage, 90% lower leakage current

Developed the industry's first SiC Trench MOSFET utilizing an aluminum oxynitride (AlON) layer on the gate insulating film. The result is 1.5x the breakdown voltage and 90% lower leakage current vs. conventional thermally oxidized films (SiO_2) for greater reliability with lower loss. Expected to find wide adoption in electric vehicles, industrial equipment, and trains in the near future.

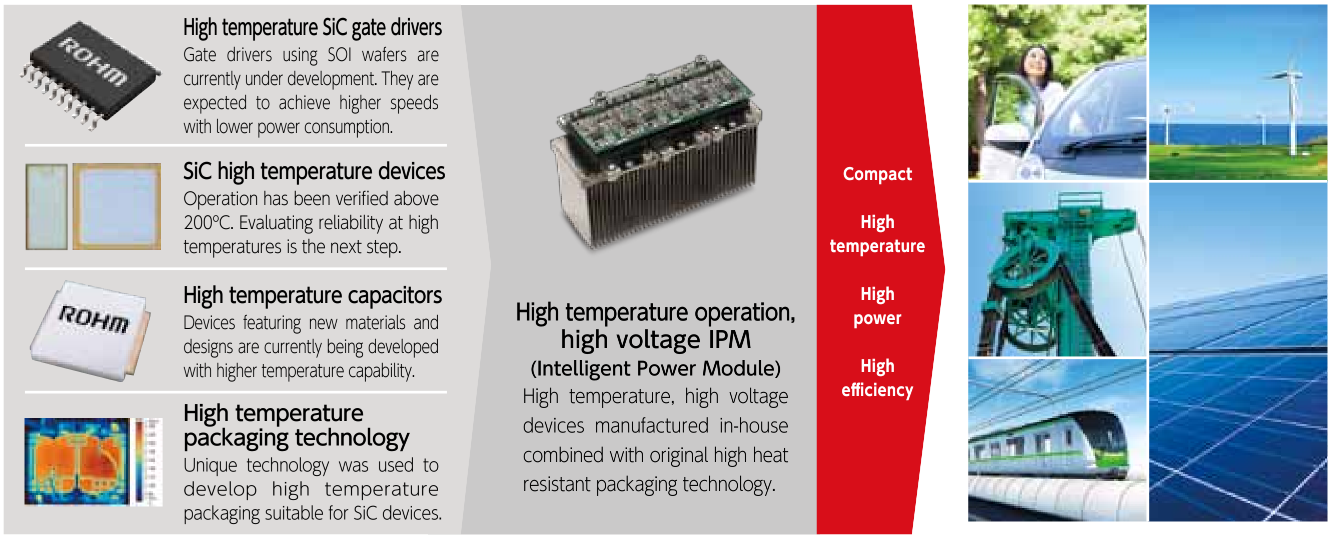


Development of high temperature operation (Tj=225°C) transfer mold modules

ROHM has developed SiC modules capable of operating at thigh 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



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

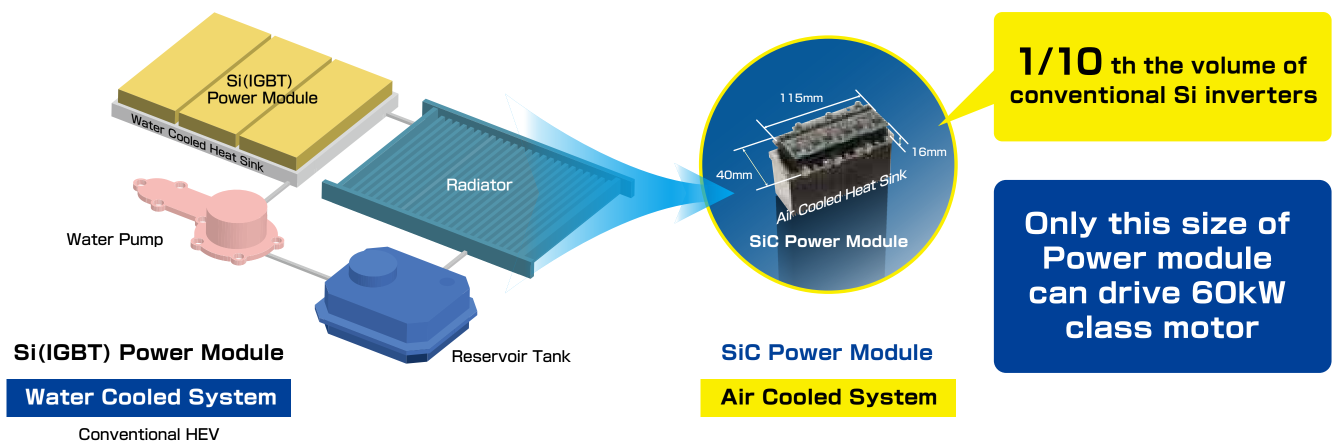
New TOPICS

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.

Significantly downsizing of the inverter

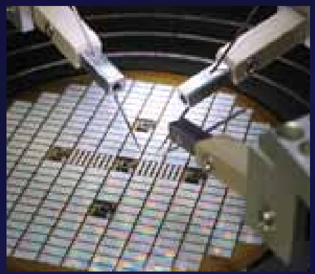


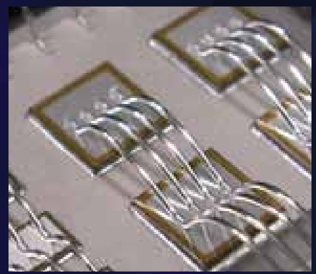
Focusing on cutting-edge SiC technology and leading the industry through innovative R&D

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.

History

SiC Technology Breakthroughs





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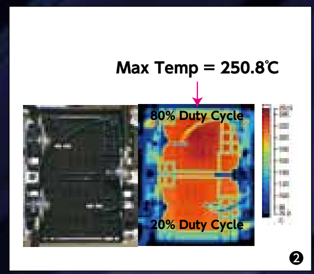

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2002

Begin preliminary experiments with SiC MOSFETs
(Jun 2002)

Develop SiC MOSFET prototypes
(Dec 2004)

2005

Ship SiC MOSFET samples
(Nov 2005)

Announce the development of SiC MOSFETs with the industry's smallest ON-resistance ($3.1m\Omega cm^2$)
(Mar 2006)

2007

ROHM, along with Kyoto University and Tokyo Electron, announce the development of SiC epi film mass-production technology
(Jun 2007)

Trial manufacture of large current (300A) 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: $1.7m\Omega cm^2$
(Sep 2008)

Nissan Motors conducts a driving experiment of a fuel-cell 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 ❶
(Sep 2008)

ROHM tests prototype high temperature operation power modules that utilize SiC elements and introduces a demo capable of operation at 250 °C ❷
(Oct 2008)

❸

❹

❺

❻

2009

The ROHM Group acquires SiCrystal, an SiC wafer manufacturer ❸
(Jul 2009)

Develop the industry's first high current low resistance SiC trench MOSFET
(Oct 2009)

2010

Establish an integrated SiC device production system. Begin mass production of SiC SBDs ❹
(Apr 2010)

Successfully develop the industry's first SiC power modules 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 225℃) ❺
(Oct 2011)

APEI Inc. (Arkansas Power Electronics International) and ROHM develop high-speed, 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 ❻
(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.

R1093A

ROHM Sales Offices

Contact us for further information about the products.

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Atlanta	+1-770-754-5972	**Germany**	+49-2154-921-0	**Dalian**	+86-411-8230-8549	**India**	+91-44-4352-0008
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