SiC Power Devices

vol.1

2011

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Accelerating the future of energy

SiC is widely expected to be used for next-generation power devices
due to its superior electric characteristics,
resulting in power devices with lower power loss.
SiC devices save power in a number of ways.
ROHM has performed leading
R&D on SiC power devices and modules,
and recently began mass production in response to increased market demand.

Improved energy savings and device miniaturization

Power demand is growing on a global scale every year while fossil fuels continue to be depleted and global warming is increasing at an alarming rate. ROHM provides Eco Devices designed for lower power consumption and high efficiency operation, including high density IC, passive components, opto electronics and modules, that help save energy and reduce CO_2 emissions. Among them are next-generation SiC devices that promise even lower power consumption and higher efficiency.

Industrial equipment

Reduce power loss and reduce size

Consumer electronics

Energy-saving air conditioners and IH cooktops

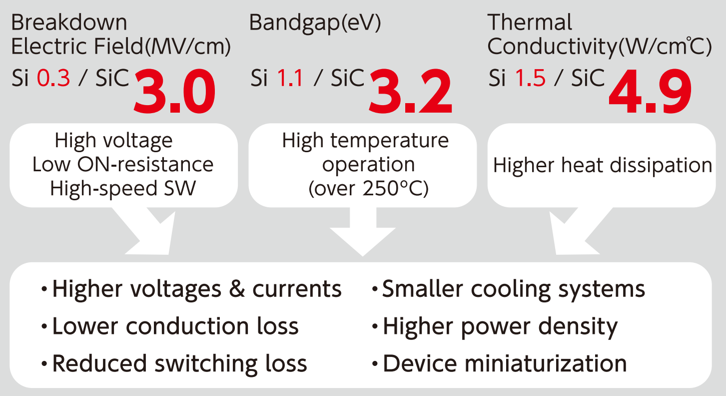
Computers

Compact AC adapters integrated in notebook computers

Achieving lower power loss, high temperature operation, and greater miniaturization

In the power device field SiC (Silicon Carbide) is garnering increased attention due to its superior characteristics, including lower ON-resistance, faster switching, and higher temperature operation.

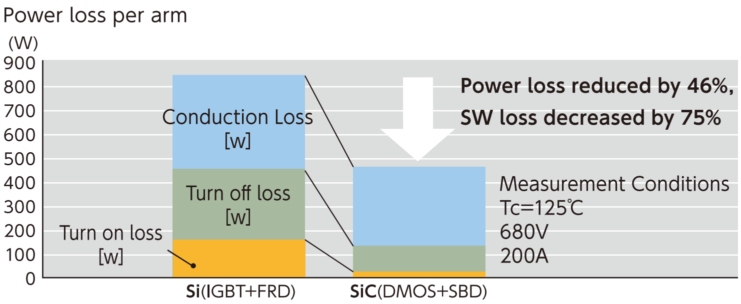
■ Performance Comparison: SiC vs. Si

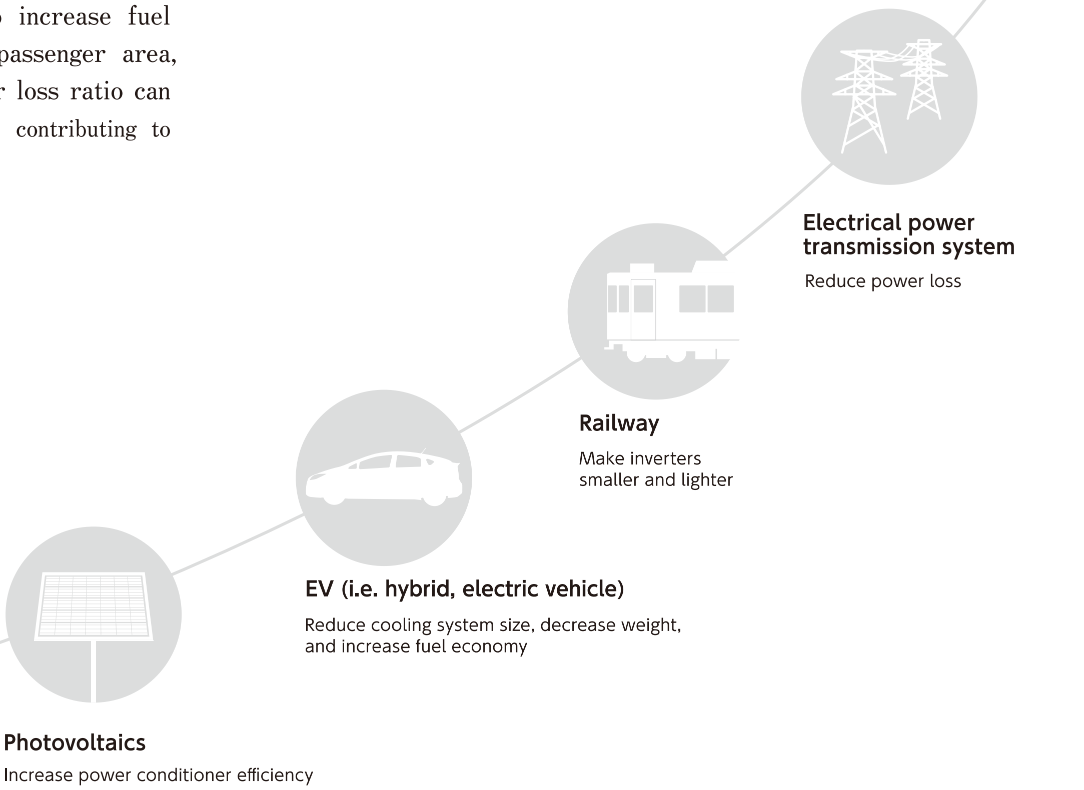


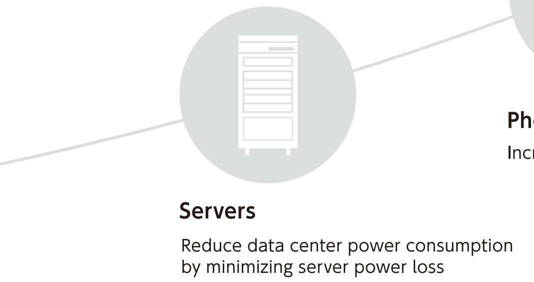
Utilizing SiC devices many applications, including power supplies, automotive, railway, industrial equipment, and consumer products

SiC allows for smaller devices with lower power consumption. Advantages include high voltage and high temperature operation characteristics that enable mounting in tight spaces or under harsh conditions impossible with silicon-based products. In hybrid vehicles and EVs SiC power solutions contribute to increase fuel economy and provide larger passenger area, while in solar power the power loss ratio can be improved by approx. 50%, contributing to reduced global warming.

■ Power Loss Comparison



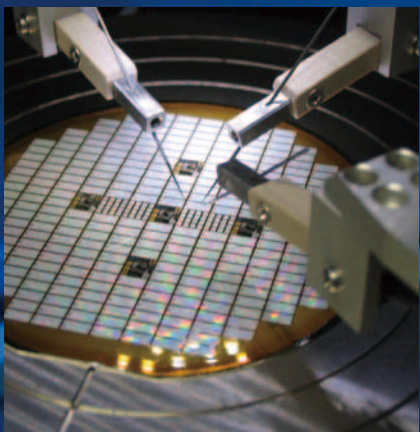


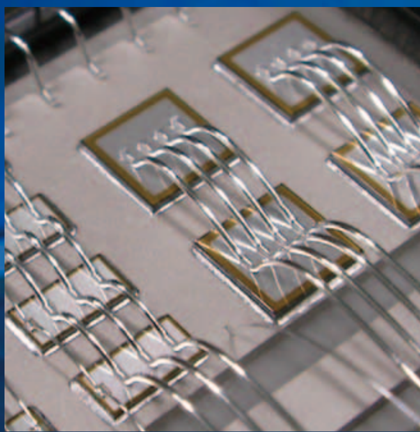


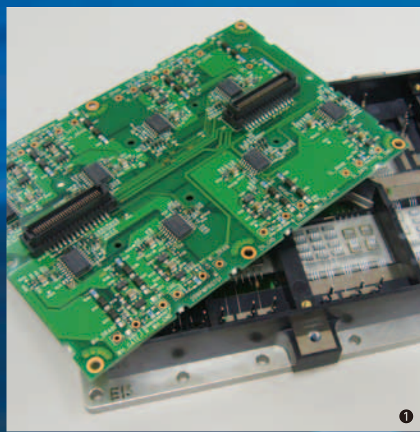
Focusing on cutting-edge SiC technology and leading through innovative R&D

ROHM has been pioneering SiC development from the very beginning, collaborating with universities and end-users to cultivate technological know-how and expertise, culminating in Japan's first mass-produced Schottky barrier diodes in April 2010 and the industry's first commercially available SiC transistor (DMOSFET) in December.

SiC Technology Trends







2002

Begin primary experimentation of SiC MOSFETs (Jun 2002)

Develop SiC MOSFET prototypes (Dec 2004)

2005

Ship SiC MOSFET samples (Nov 2005)

Release SiC MOSFETs with industry's smallest ON-resistance: 3.1mΩcm² (Mar 2006)

2007

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

Test fabrication of high current (300A) MOSFET and SBD (Schottky Barrier Diode) (Dec 2007)

2008

Nissan Motors and ROHM develop a new structure SiC diode (Apr 2008)

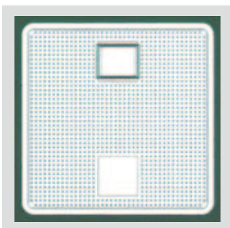
Release a trench type MOSFET featuring the industry's smallest ON-resistance: 1.7mΩcm² (Sep 2008)

Nissan Motors uses an inverter with ROHM's SiC diode fuel-cell vehicle drive test (Sep 2008)

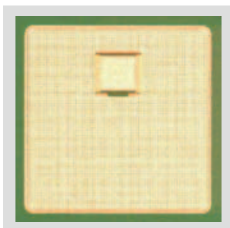
Eco device pioneer

SiC devices are often referred to as key devices in an eco-focused age. SiC diodes for power converters debuted in 2001. A year later, in 2002, ROHM began fundamental testing of SiC MOSFETs, resulting in significant breakthroughs and the industry's first mass production system for SiC products.

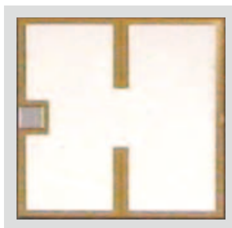
■ Prototype Development



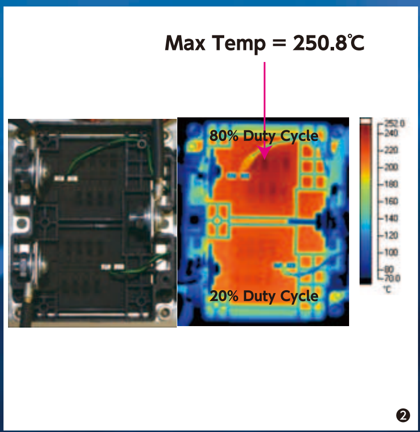
2004
SiC DMOSFET



2007
SiC DMOSFET



2009
SiC Trench MOSFET



❷


❸

❹

2009 — 2010 — 2011

Honda R&D Co., Ltd. and ROHM test prototype SiC power modules for hybrid vehicles ❶ (Sep 2008)

ROHM tests prototype of high temperature power modules using SiC elements and presents an demo operable at 250 °C ❷ (Oct 2008)

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

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

Establish a consistent SiC device production system. Begin mass production of SiC SBDs ❹ (Apr 2010)

Successfully develop the first SiC power module using trench MOSFET and SBD that can be integrated into motors. (Oct 2010)

Begin SiC MOSFET mass production (Dec 2010)

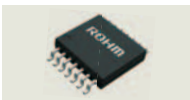
Latest TOPICS

New co-op module development

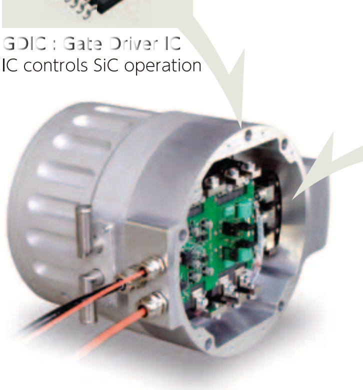
R&D results

ROHM is focused on developing integrated modules for next-generation EV motor in cooperation with motor manufacturers. These SiC modules are designed to operate at temperatures greater than 200℃, 600V blocking voltage, and support current on the order of 1kA – all in a size less than 1/3rd that of conventional Si devices and with a steady-state loss 50% less. (Released in Jan 2011)

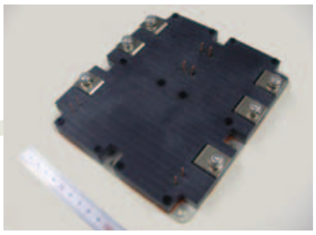
ROHM's GDIC



GDIC : Gate Driver IC
IC controls SiC operation

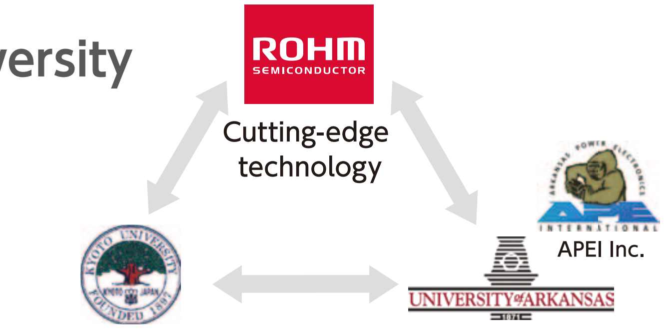


600V/1kA power module integrating SiC trench MOS and SiC SBD



Cutting-edge industry-University R&D collaboration

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



Developing mass produced SiC epitaxial growth equipment

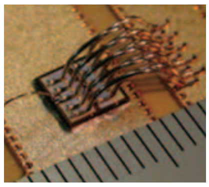
Kyoto University × Tokyo Electron × ROHM

Rapid development of high quality SiC epi film through 3-institution technological collaboration

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. This new technology is currently implemented in the mass production of ROHM SiC devices.

Developing high current trench gate MOSFETs

Kyoto University × ROHM



R&D aimed towards large current SiC devices and maximum energy savings

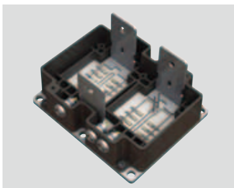
Joint collaboration with Kyoto University has yielded dramatic current increases in SiC vertical trench gate MOSFETs, with 300A drive successfully achieved from a single chip. This represents the industry's lowest loss, with further reductions in ON-resistance possible, and has expanded the potential of SiC device application to high current power conversion modules. It is expected to see wide use in hybrid / electric vehicles.

Developing high temperature operation (Tj=250°C) intelligent power modules (IPM)

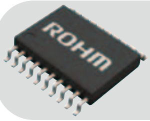
University of Arkansas × ROHM

R&D of module compatible to operate at high temperature, and collaboration with highly acclaimed world-class University

Research conducted by ROHM in collaboration with the University of Arkansas has led to the development of a modules that can operate at temperatures up to 250°C, and was selected as one of three in the R&D 100 Electric Device Category by USA's R&D Magazine in 2009. The module features a high temperature operation package and die attachment technology, resulting in 150A-class operation. A high temperature operation gate driver has also been successfully developed.

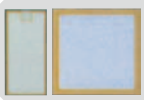


■ Further challenges to high temperature operation



High temperature SiC gate driver

Gate drivers using SOI wafers are currently under development. They are expected to achieve higher speeds and lower power consumption.

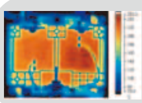


SiC high temperature devices

Operation has been verified above 200°C. Evaluating reliability at high temperature is the next step.

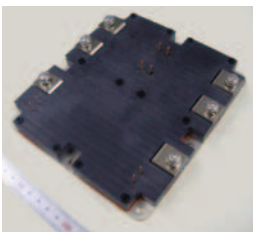
High temperature capacitor

Devices featuring new materials and designs are currently being developed with higher temperature capability.



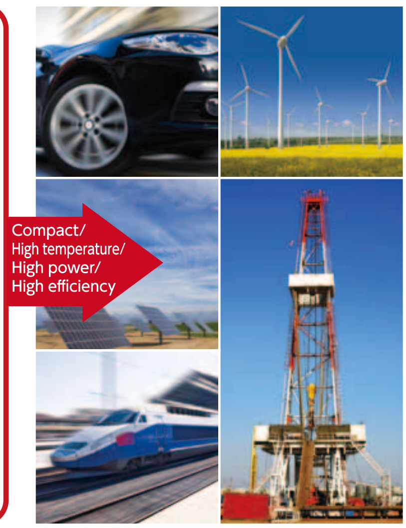
High temperature operation packaging technology

Unique technology was used to develop high temperature operation packaging.



High temperature operation, high voltage IPM (Intelligent Power Module)

In-house high voltage, high temperature devices are combined with unique high heat resistance packaging technology.



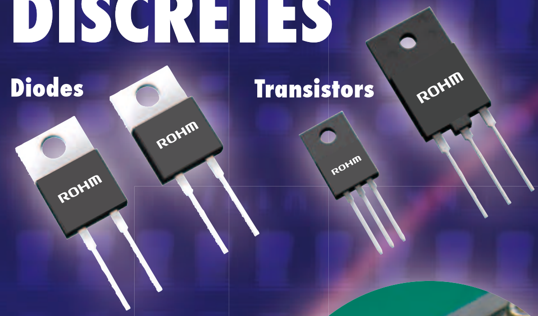
High quality ensured through a consistent production system

Quality First is ROHM's official corporate policy. In this regard a consistent production system was established for SiC production. The acquisition of SiCrystal (German) 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.

DISCRETES

Diodes

Transistors



MODULES

Low inductance module

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

100% in-house production system

SiCrystal

ASSYLINE

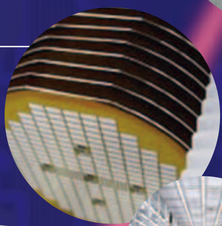
In-house production equipment

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

WAFER PROCESS

SiC processes

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



Epi Process

Industry-university joint partnerships resulted in the development of high quality epitaxial equipment

ON SITE PLANT

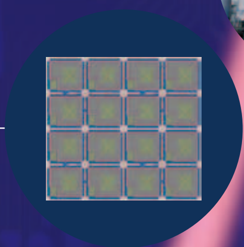
Cutting-edge, self-sufficient manufacturing facility

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

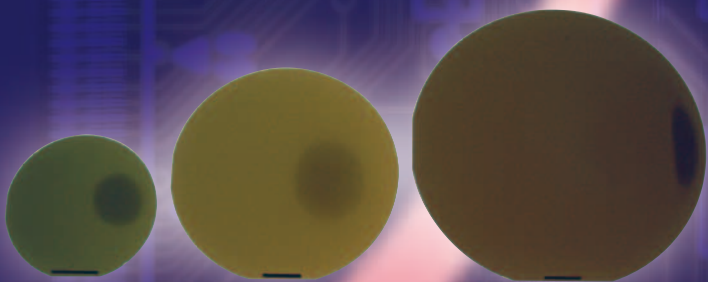
Master engineers are on hand to ensure high quality designs.



CAD

In-house photo masking

Enabling uniform quality control from SiC chip design to photo masking



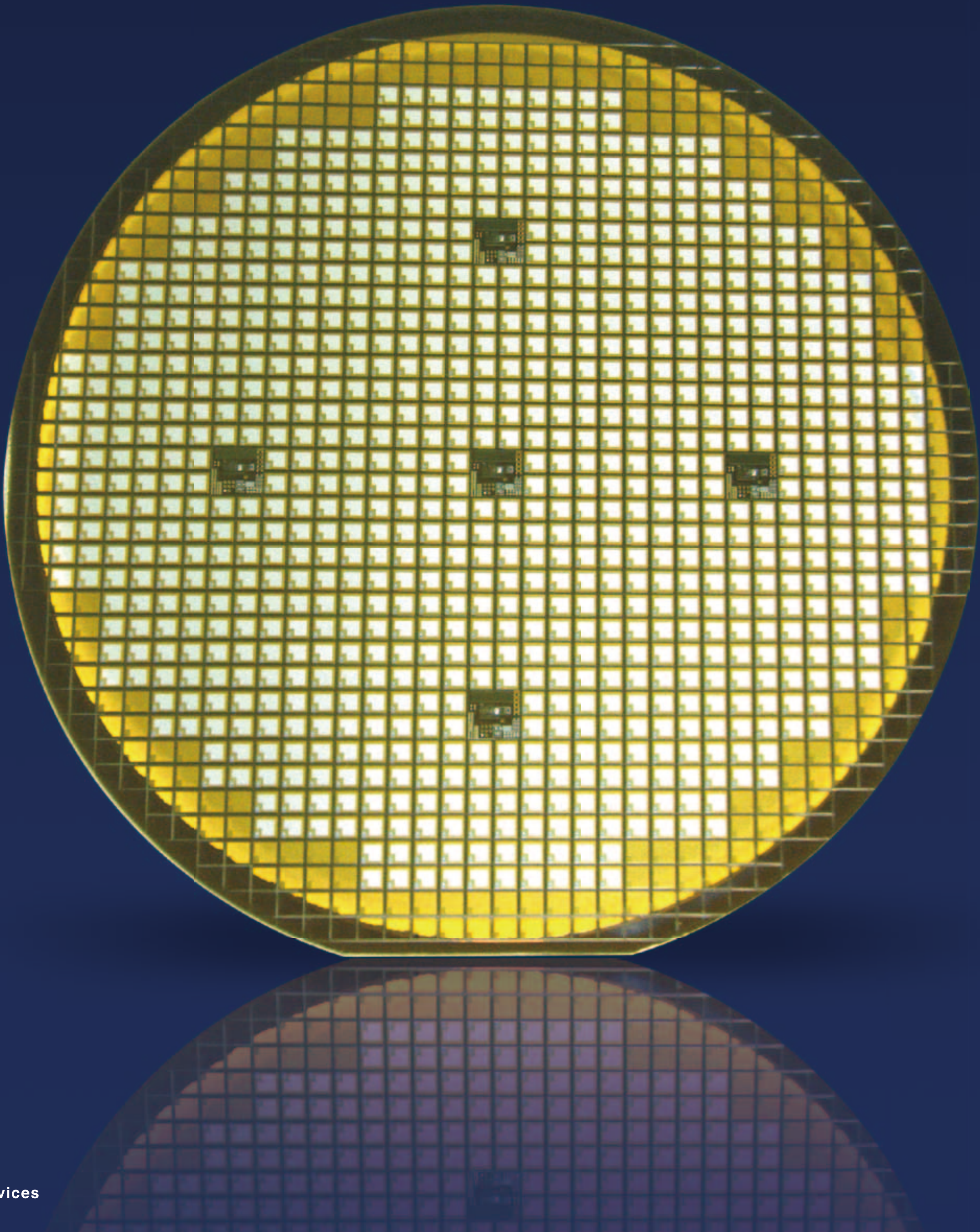
WAFER

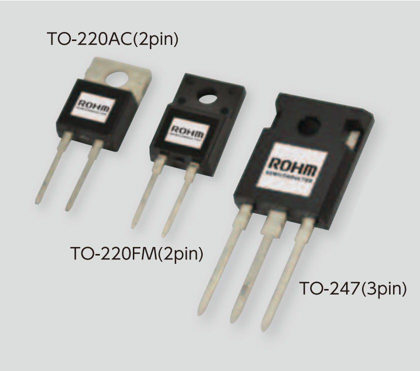
SiC wafer manufacturing

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

Leading the industry
in the mass-production of SiC

SiC Power Devices





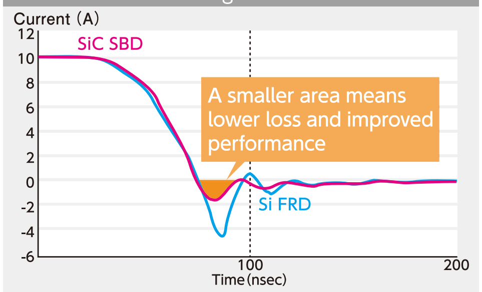
SiC Schottky Barrier Diodes (SBD)

Mass Produced

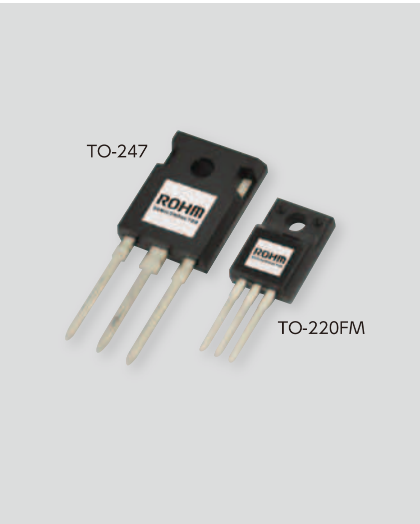
Dramatically lower switching loss

SiC SBDs were developed, optimized for PFC circuits and inverters. Ultra-short reverse recovery time (impossible to achieve with silicon) enables high-speed switching. This minimizes the reverse recovery charge (Qrr), significantly reducing switching loss while contributing to end-product miniaturization.

Switching Waveforms



Package	V_R(V)	600						1200			
	Io(A) 6	8	10	12	20	24	40	5	10	20	40
TO-220AC (2pin)	SCS106AG	SCS108AG	SCS110AG	SCS112AG	SCS120AG			SCS105KG	SCS110KG	SCS120KG	
TO-220FM (2pin)	SCS106AM	SCS108AM	SCS110AM	SCS112AM	SCS120AM						
TO-247 (3pin)					SCS120AE2	SCS124AE2	SCS140AE2		SCS110KE2	SCS120KE2	SCS140KE2



SiC MOSFETs

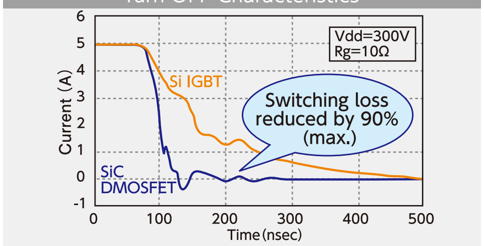
Mass Produced

High speed and low ON- resistance

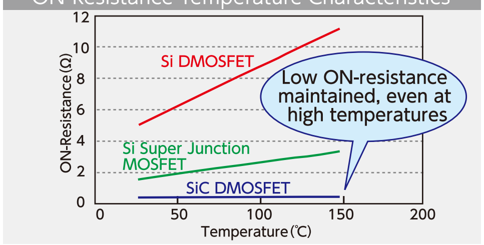
SiC enables simultaneous high speed switching and low ON-resistance – normally impossible with silicon-based products. Additional features include superior electric characteristics at high temperatures and significantly lower switching loss, allowing smaller peripheral components to be used.

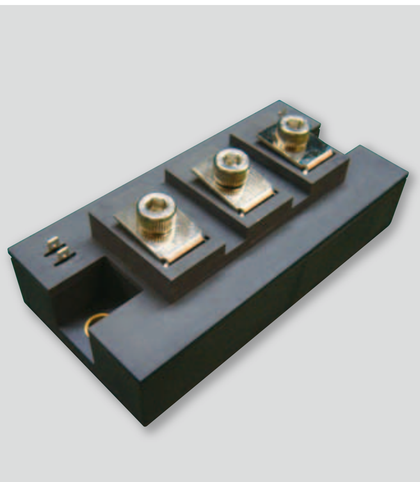
Primary ratings⇒
Rated voltage: 600V to 1200V,
Rated current: 5A to 20A

Turn OFF Characteristics



ON-Resistance Temperature Characteristics





SiC Power Module

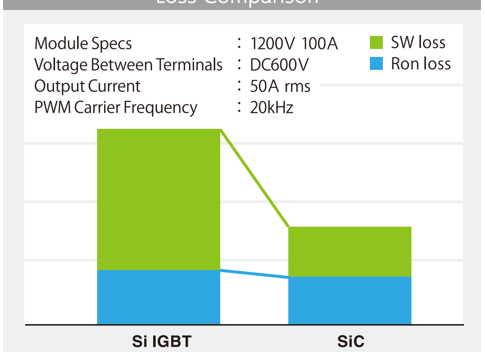
Sample

Reducing loss by more than half

Original device technology was used to develop low surge noise power modules that take advantage of SiC's high speed characteristics. The result is reduced steady-state loss (ON-resistance) and less than half the switching loss compared with Si devices.

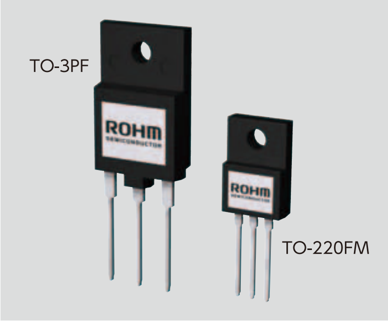
Primary ratings⇒
Rated voltage: 1200V,
Rated current: 100A

Loss Comparison



ROHM high performance power devices offer unparalleled versatility

Si Transistors

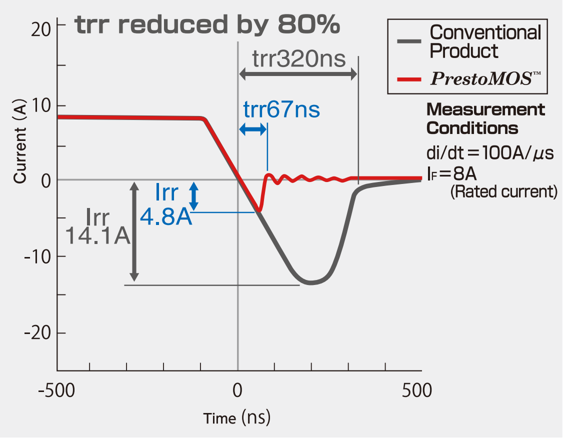


MOSFET
PrestoMOS™ Series

500 to 600V
8 to 46A

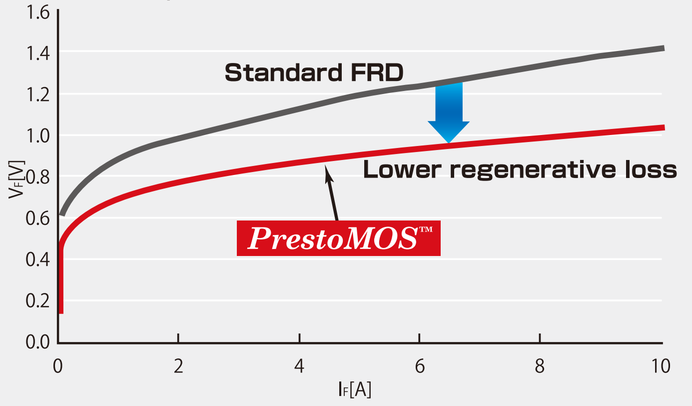
Features

ROHM's PrestoMOS™ series provides low R_{DS} (on), low Qg, high speed switching, and high blocking voltage, and integrates a diode with high-speed trr.



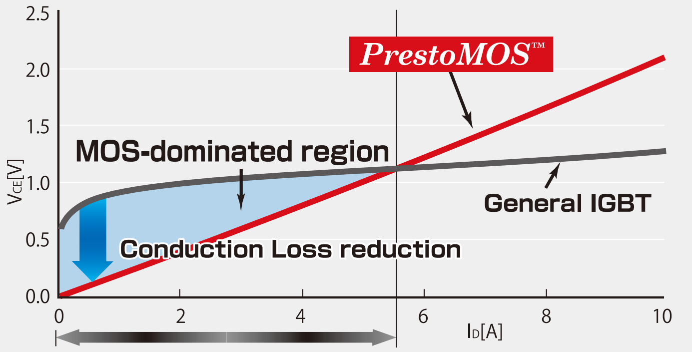
Power Conditioner Circuit

● Loss Comparison



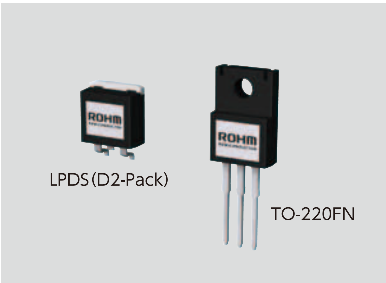
Motor Driver Circuit

● Loss Comparison



Consumer electronics predominately use this range.
Reduces annual power consumption.

Si Diodes



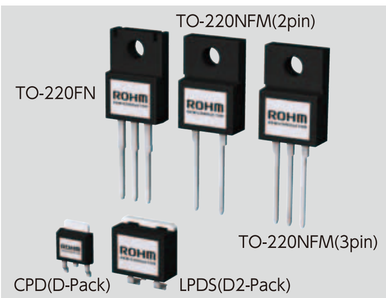
SBD RBQ Series

150V/30A
100V/30A

Features

·New processes utilized for ultra-low I_R
·Prevents thermal runaway at high temperatures

Package	Part No.	V_R(V)	Io(A)	V_F(V)		I_R(mA)	
				Max.	I_F(A)	Max.	V_R(V)
TO-220FN	RBQ10T45A	45	10	0.65	5	0.15	45
	RBQ20T45A	45	20	0.65	10	0.3	45
	RBQ30T45A	45	30	0.65	15	0.45	45
	RBQ10T65A	65	10	0.69	5	0.15	65
	RBQ20T65A	65	20	0.69	10	0.3	65
	RBQ30T65A	65	30	0.69	15	0.45	65
LPDS(D2-Pack)	RBQ10NS45A	45	10	0.65	5	0.15	45
	RBQ20NS45A	45	20	0.65	10	0.3	45
	RBQ30NS45A	45	30	0.65	15	0.45	45
	RBQ10NS65A	65	10	0.69	5	0.15	65
	RBQ20NS65A	65	20	0.69	10	0.3	65
	RBQ30NS65A	65	30	0.69	15	0.45	65
CPD(D-Pack)	RBQ10B45A	45	10	0.65	5	0.15	45
	RBQ10B65A	65	10	0.69	5	0.15	65

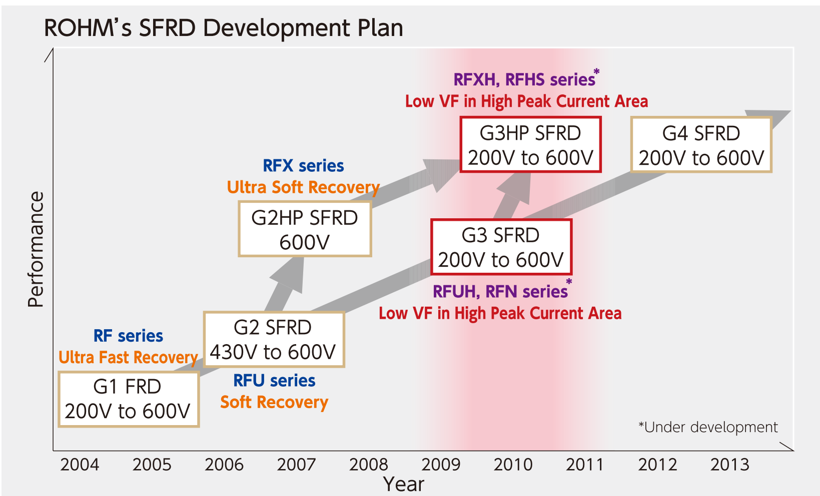


FRD RF Series

200 to 800V
1 to 20A

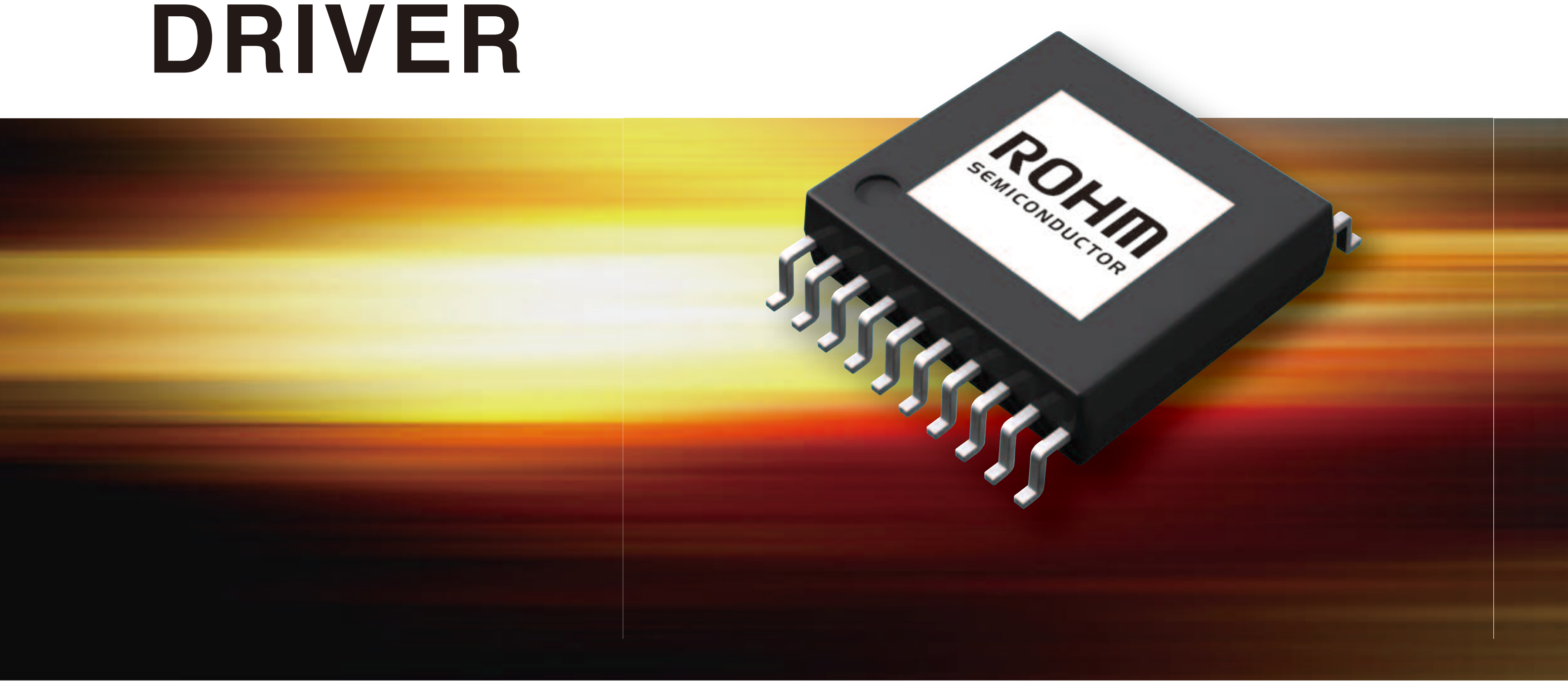
Features

·Unique technology ensures high-speed trr
·Low heat generation even under high temperatures

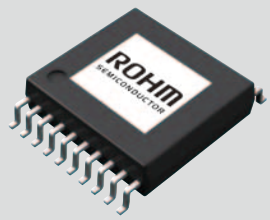


ROHM's unique IC technology maximizes SiC characteristics

DRIVER



Isolated Gate Driver



SSOP-B20W

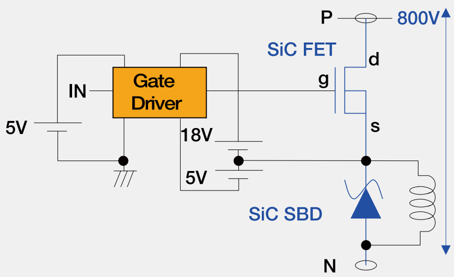
Maximizes SiC performance

Features

- ·Core-less transformer with 2,500Vrms isolation
- ·Original noise cancelling technology results in high CMR
- ·Supporting high VGS/negative voltage power supplies
- ·Compact package

Recommended Operating Range	Symbol	Min	Max	Unit
Output Ground Voltage	GND2	-1.2	1.2	kV
Input Supply Voltage	VCC1	4.5	5.5	V
Output Supply Voltage	VCC2	12	24	V
Output VEE Voltage	VEE2	-12	0	V
Operating Temperature Range	Ta	-40	125	℃

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



SiC is ECO Device

Reducing environmental load

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

ROHM Sales Offices

Contact us for further information about the products.

R1041A

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