Oct 2014

SiC Power Devices

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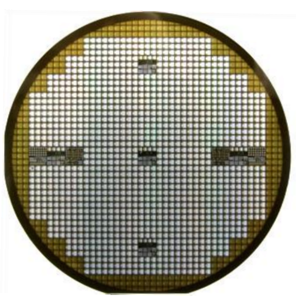
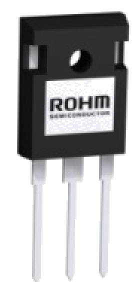
ROHM's Power Devices (High Breakdown Voltage items)

ROHM has Silicon based Super Junction MOSFETs, FRDs and IGBTs. SiC devices cover Schottky diodes and MOSFETs

Material	Si			SiC	
Item	Super Junction MOSFET	FRD	IGBT	SBD	MOSFET
Breakdown Voltage	500V ~800V	300V ~800V, ~1200V*	430V ~650V, ~1200V*	650V, 1200V, 1700V*	650V, 1200V, 1700V*

***Under development**

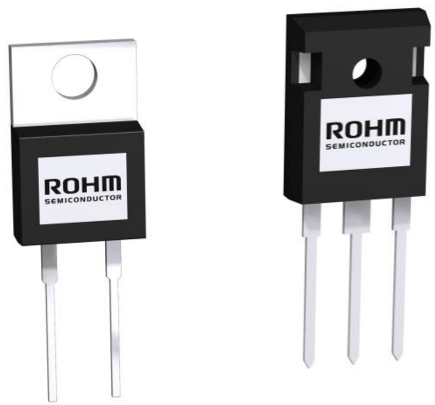


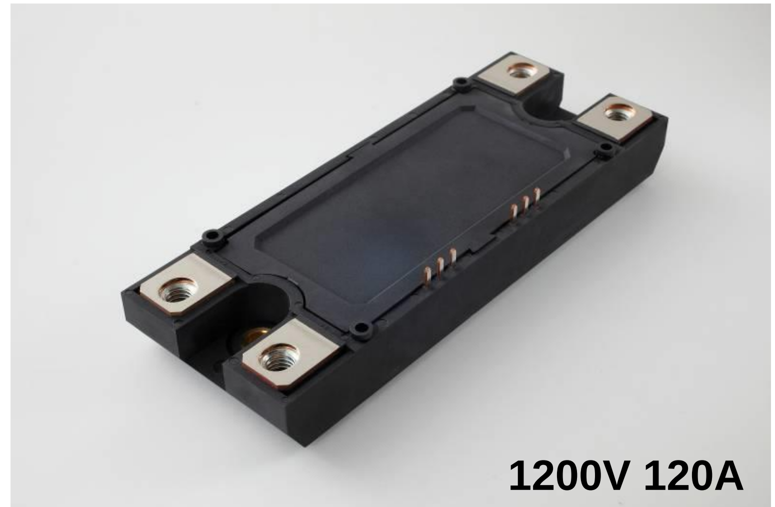


The table shows a product development plan as of today and is subject to change without notice.

As of Nov, 2014

ROHM SiC Power Devices Lineup





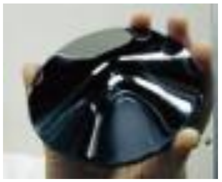
Apr 2010 SiC-SBD mass production start — First in Japan

Dec 2010 SiC-DMOS mass production start — World's first

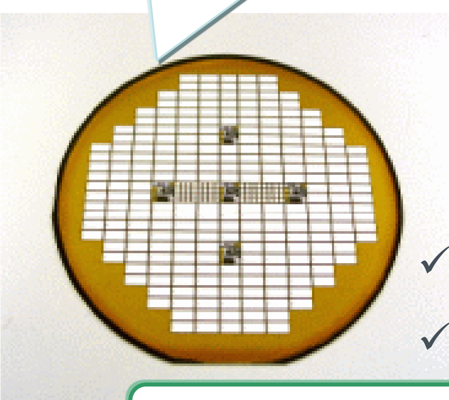
Mar 2012 Full SiC module mass production start — World's first

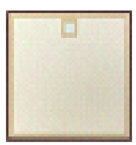
Why SiC Power Devices ??

SiC Material



High breakdown field（Si X10）
Wide band-gap （Si X 3）
High thermal conductivity（SiX 3）



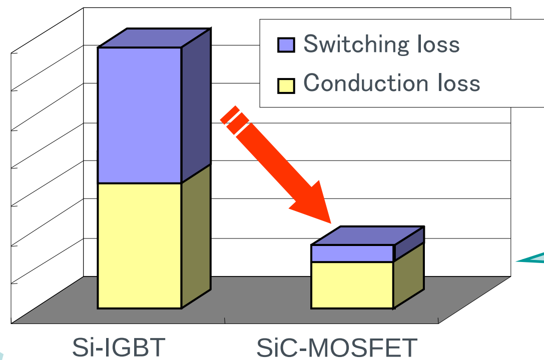


✓ **Lower Power Loss**

✓**High Temp. Operation**

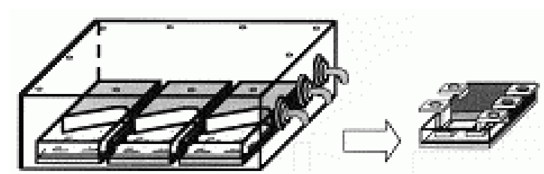
SiC Power Devices

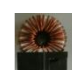
Application



- Higher Efficiency (Lower Power Loss)
- Smaller Size in Modules, Cooling System, and Passive Components
- High Frequency Operation
- High Temp. Operation

Improvement of efficiency and reduction of power loss



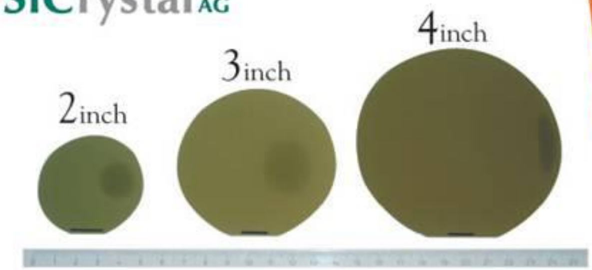


Downsizing of module, passive components and cooling system

Supply Chain of ROHM SiC Power Devices

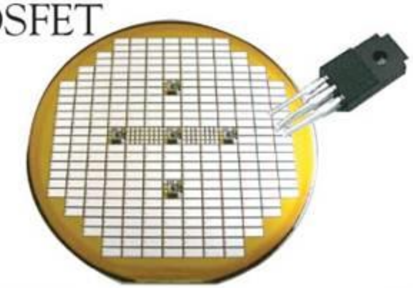
SiC epitaxial substrate

SiCrystal AG

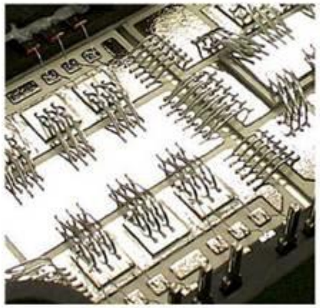


SiC discrete devices

DMOSFET
SBD



SiC power modules



Consistent Production System

The production system of the consistent SiC power semiconductor

2007		ROHM kyoto Univ. and Tokyo Electron Establishment of SiC epitaxial equipment
2009		SiCystal AG. is purchased.
2011	4inch	Mass production start
2013	6inch	Mass production start plan

SiC-SBD
2010.4 MP.

SiC-DMOS
2010.12 MP.

Power Module
2012.3 MP.

Germany
SiCrystal AG

Fukuoka
ROHM Apollo Co., Ltd.

Kyoto
ROHM Co., Ltd. Kyoto HQ.

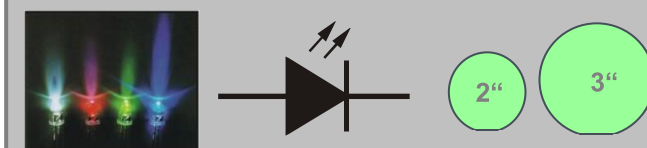
SiCrystal Facts

Company location： Nürnberg, Germany

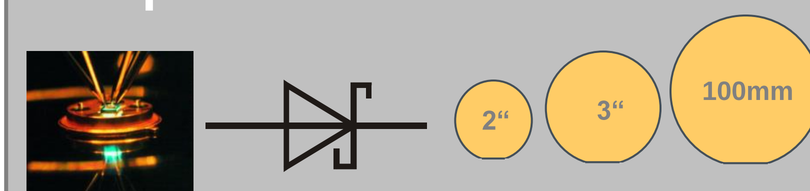
Head count： 79（incl. 10 PhD holders）

Products： SiC wafers

For lighting devices



For power devices



Mass production of 6" wafers started in 2013

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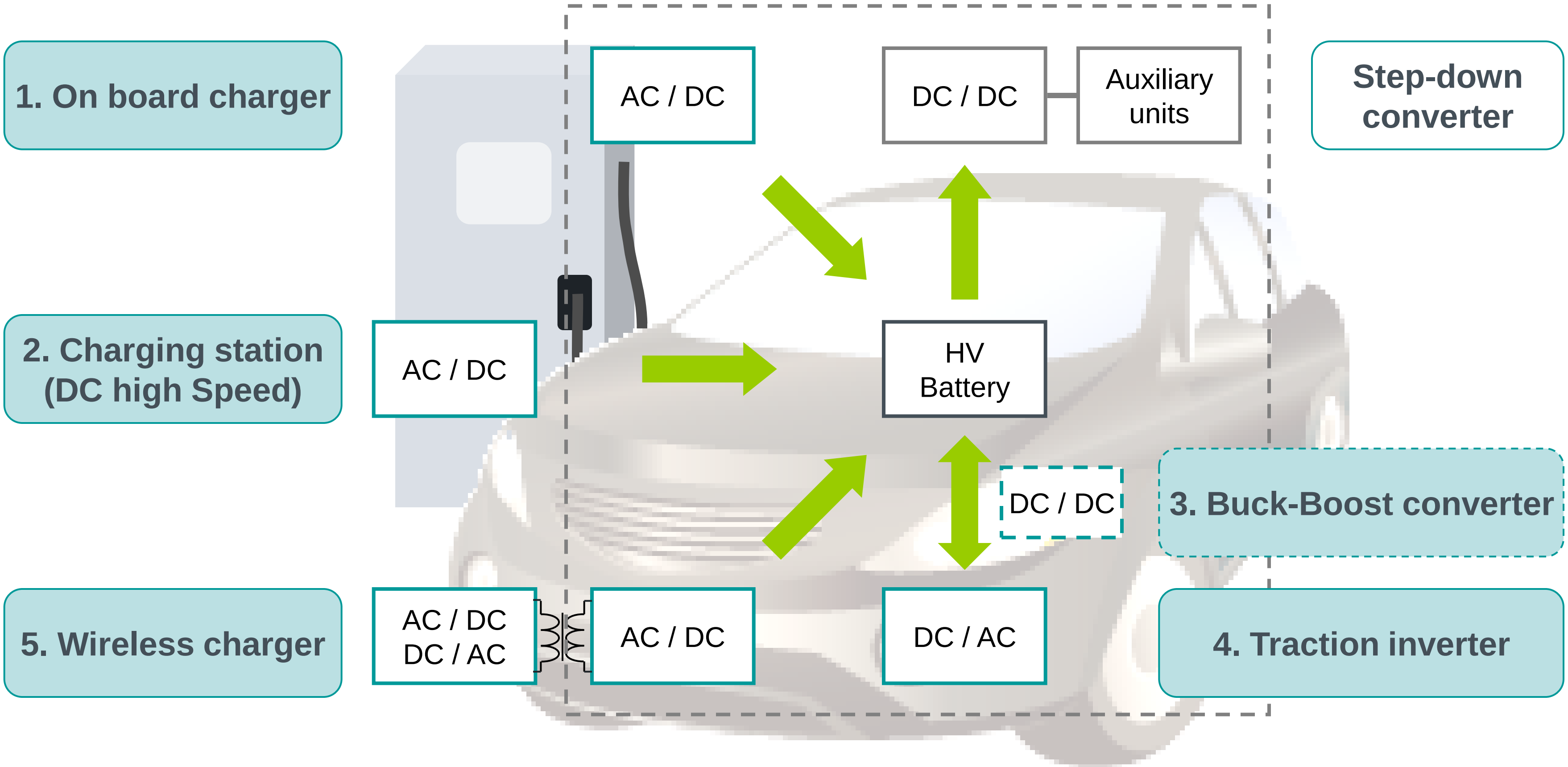
SiC Devices for EV/HEV

High voltage converters are used in EV/HEV – typically SiC devices will be used in chargers, DC-DC converters and traction inverters



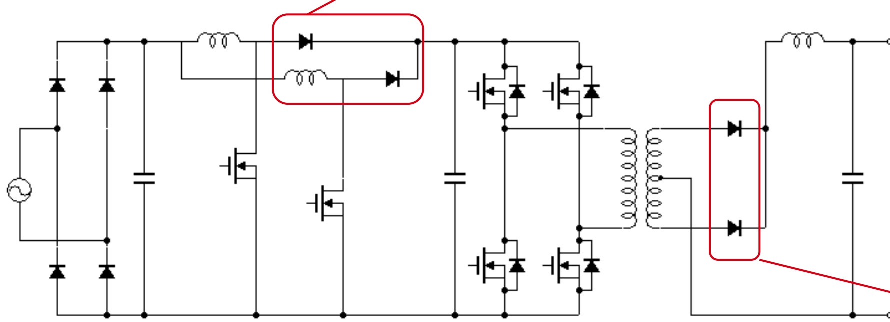
SiC SBDs & MOSFETs contribute to downsizing of the system and its efficiency improvement

SiC Devices in EV / HEV

SiC SBDs are already used in on board chargers & charging stations due to its extremely low switching loss, which leads to higher efficiency and downsizing of the system

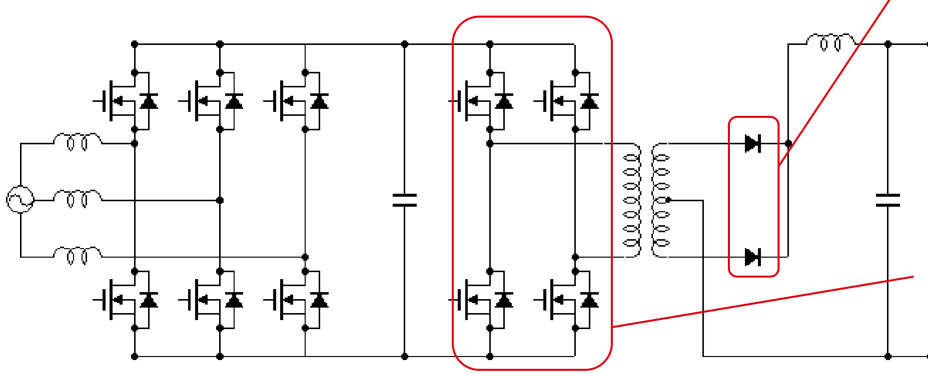
1. On board charger

PFC Boost Diode
SiC SBD 650V



Secondary side rectification
SiC SBD 1200V

2. Charging Station (DC high Speed)



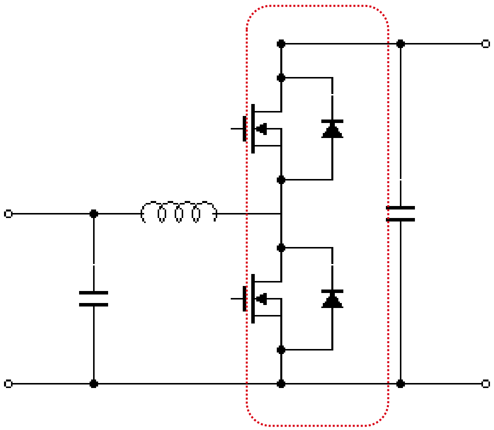
Phase shift full bridge inverter
SiC MOSFET /SBD 1200V

SiC Devices in EV / HEV

SiC MOSFETs will contribute to develop a breakthrough product by enabling smaller module size and downsizing of cooling system

DC / DC converter

3. Buck-Boost converter

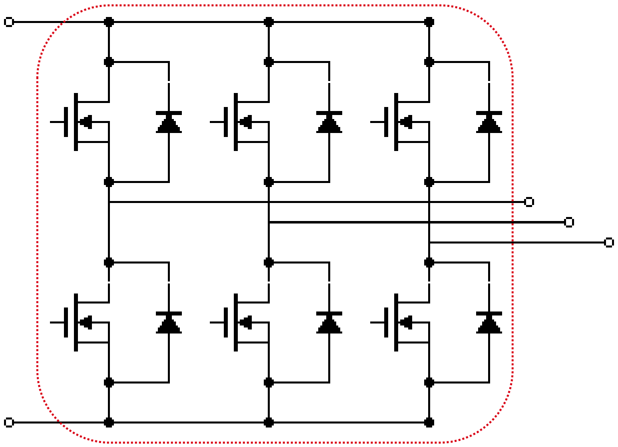


SiC MOSFET / SBD 900V or more

DC / AC inverter

4. Traction inverter

SiC MOSFET / SBD (Module) 600V or more



+ high temp operation (Tj 200C or more)

SiC MOSFET Bi-directional DC/DC Converter

ROHM SiC-MOSFET successfully reduced the size of 5kW bi-directional DC/DC converter by ca. 90%, compared with a conventional design using IGBTs

Non-Insulated Bi-Directional DC-DC Converter “pOCEAN” [product of Myway Plus Corporation]

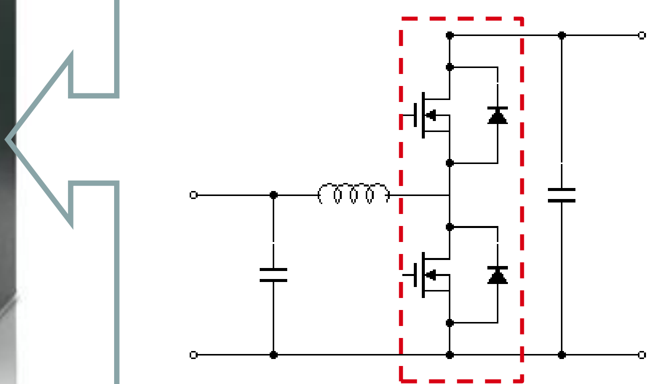
CEATEC AWARD 2013

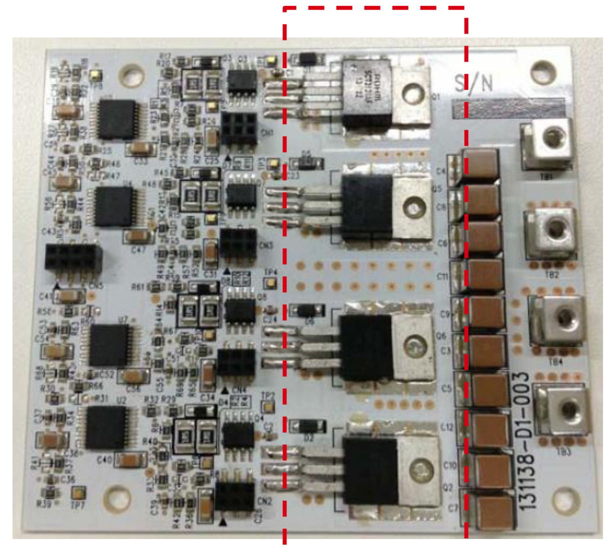
Rated power	5kW
Maximum efficiency	98%
Switching frequency	100kHz
Voltage range	10 – 450V
Dimensions	100(W)×180(H)×117(D) mm

Bi-directional DC/DC Converter: Topology

4 pieces of SCT2120AFC, 650V 120mΩ SiC-MOSFETs are used in the newly developed 5kW bi-directional DC/DC converter

Non-insulated
bi-directional DC-DC x 2





ROHM SIC-MOSFET
SCT2120AFC

Package	TO-220-3L
V_{DSS}:	650V
I_D	29A (T_C25C°)
R_{DSON}	120mΩ (Tj25C°)

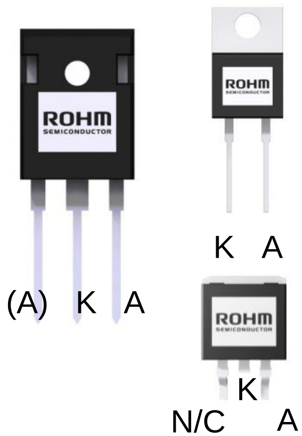
SiC SBD

★ : Available for Automotive
☆ : Planed for Automotive

2nd Gen. -Low VF- SiC-SBD product lineup

650V	6A	8A	10A	12A	15A	20A	30A	40A	Comment
TO220AC SCS2☐☐AGC	★✓	★✓	★✓	★✓	★✓	★✓			
TO220FM SCS2☐☐AM	✓	✓	✓	✓	✓	✓			
TO247 SCS2☐☐AEC					✓	✓			
TO247 SCS2☐☐AE2C						★✓	★✓	★✓	Dual Chip
D2PAK SCS2☐☐AJ	☆✓	☆✓	☆✓	☆✓	☆✓	☆✓			

1200V	5A	10A	15A	20A	30A	40A	Comment
TO220AC SCS2☐☐KGC	★✓	★✓	★✓	★✓			
TO247 SCS2☐☐KE2C		★✓		★✓	☆✓	☆✓	Dual Chip



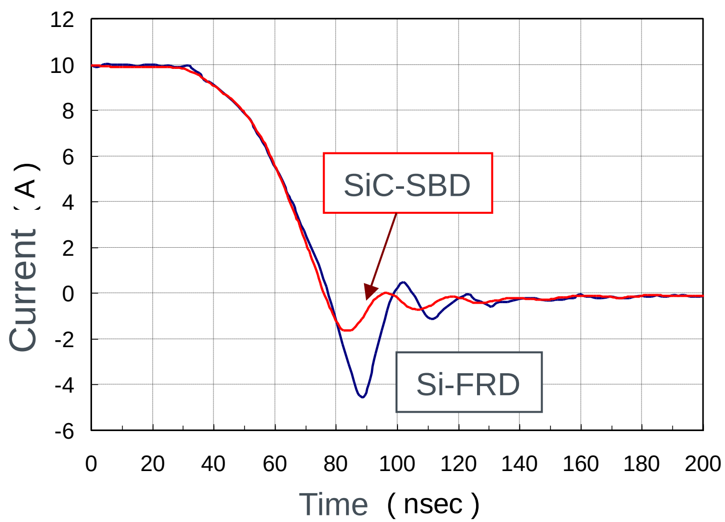
Feature:
1. No reverse recovery current
2. ROHM 2nd Generation SBD realised the lowest Vf

As of Nov, 2014

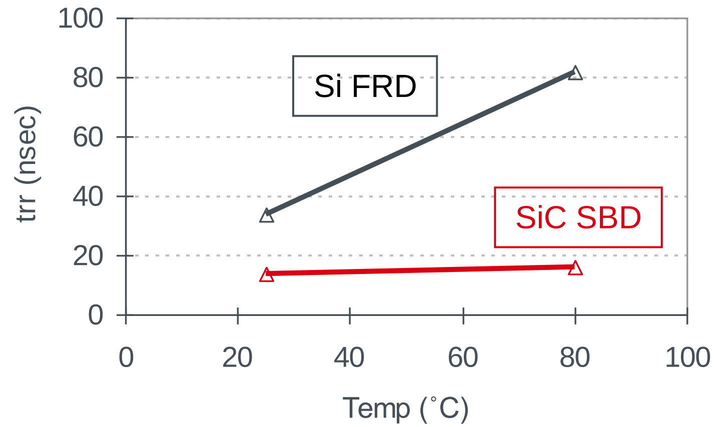
Recovery Characteristics and Dependency on Temp and Current

Low switching loss due to no reverse recovery current.
Also, Dependency on temp and current are far lower than that of Si FRD

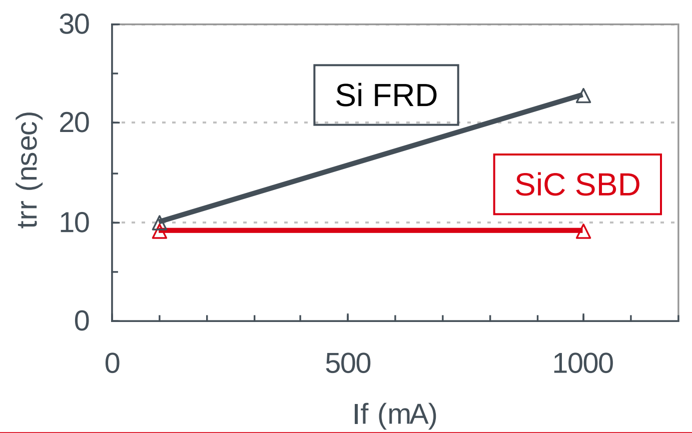
Switching waveform (600V 10A)



Temperature dependency (600V 5A)



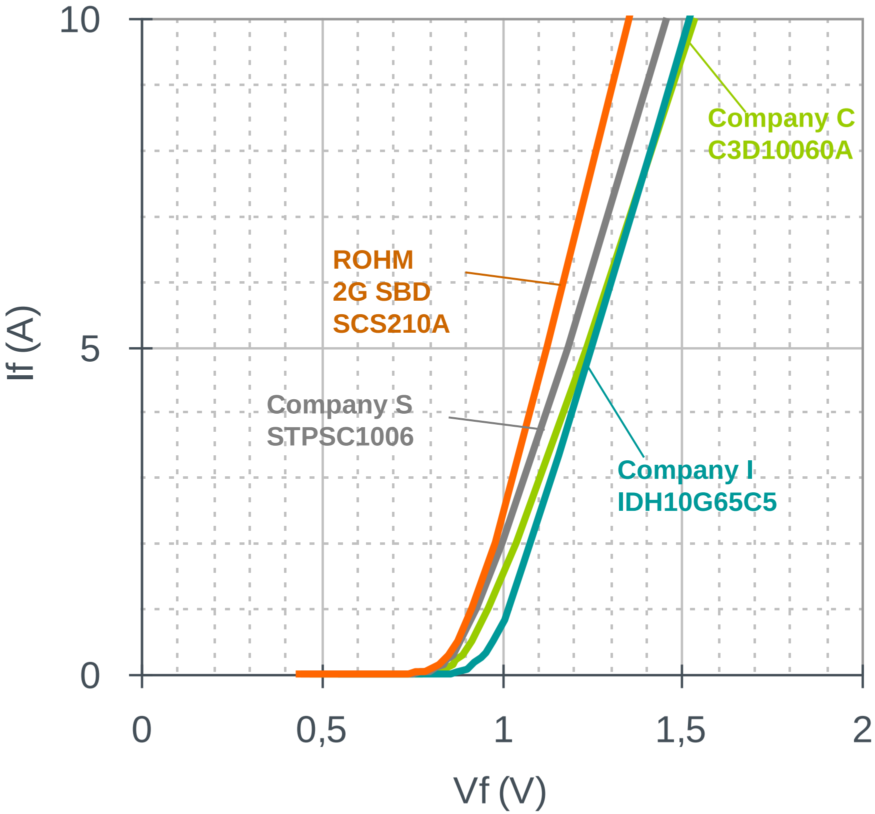
Current dependency (600V 5A)



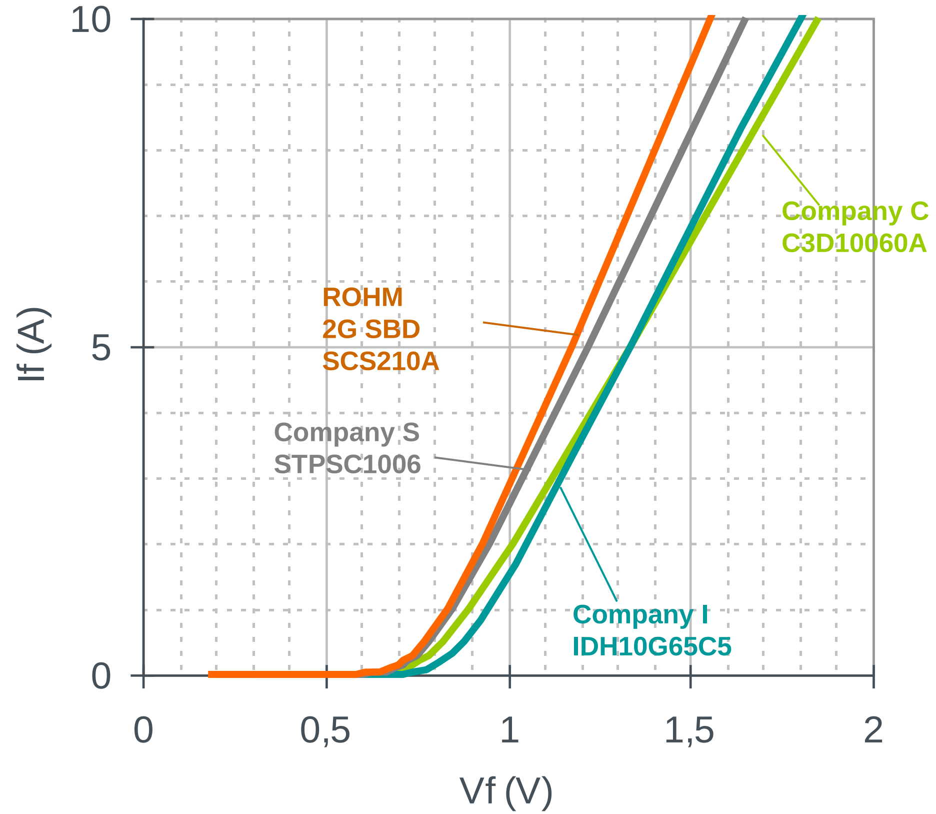
Comparison of Forward Characteristics of SiC SBDs

2nd Gen SiC-SBDs realize lower Vf, which leads to better efficiency

Forward Characteristics （at T=25˚C）



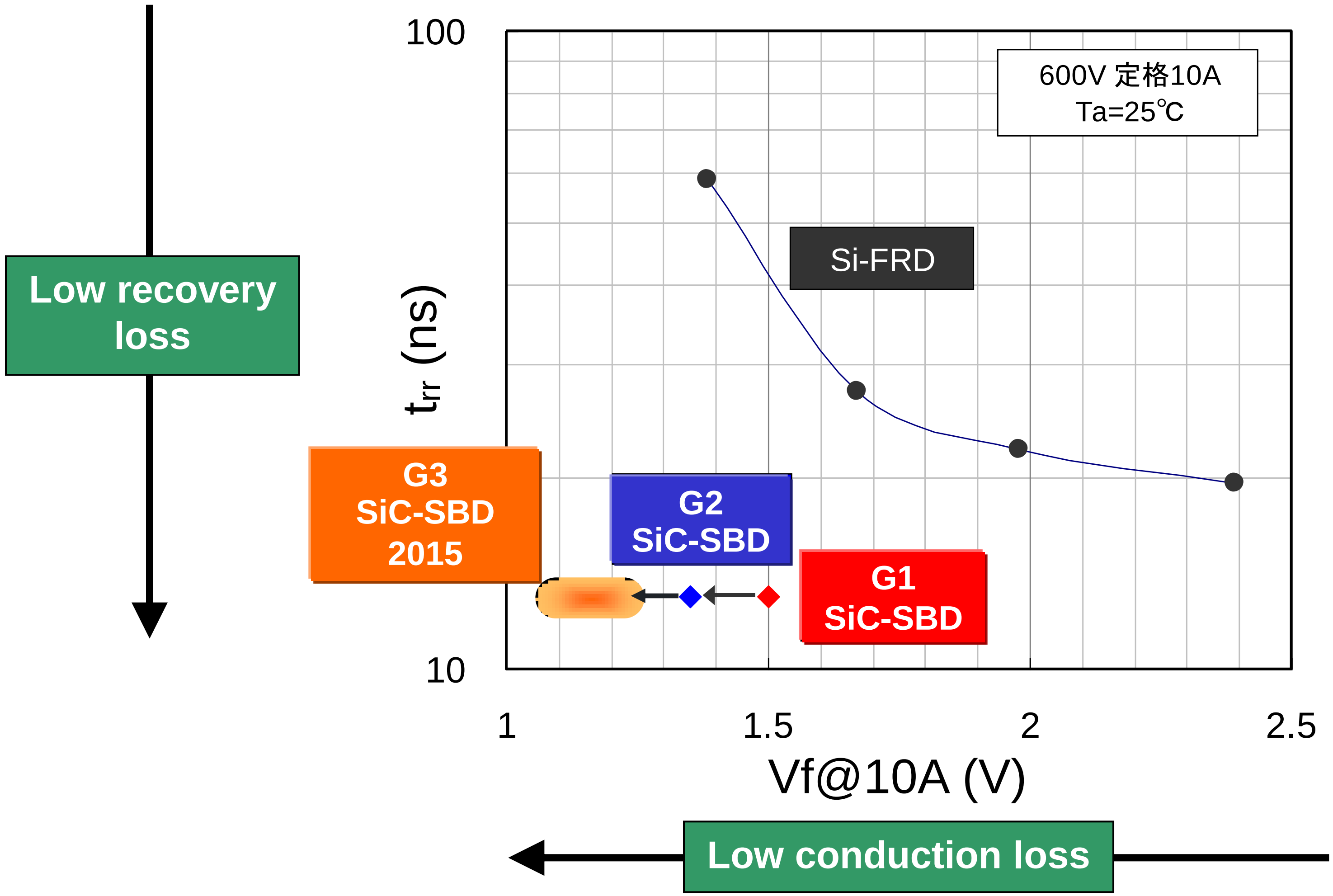
Forward Characteristics （at T=125˚C）



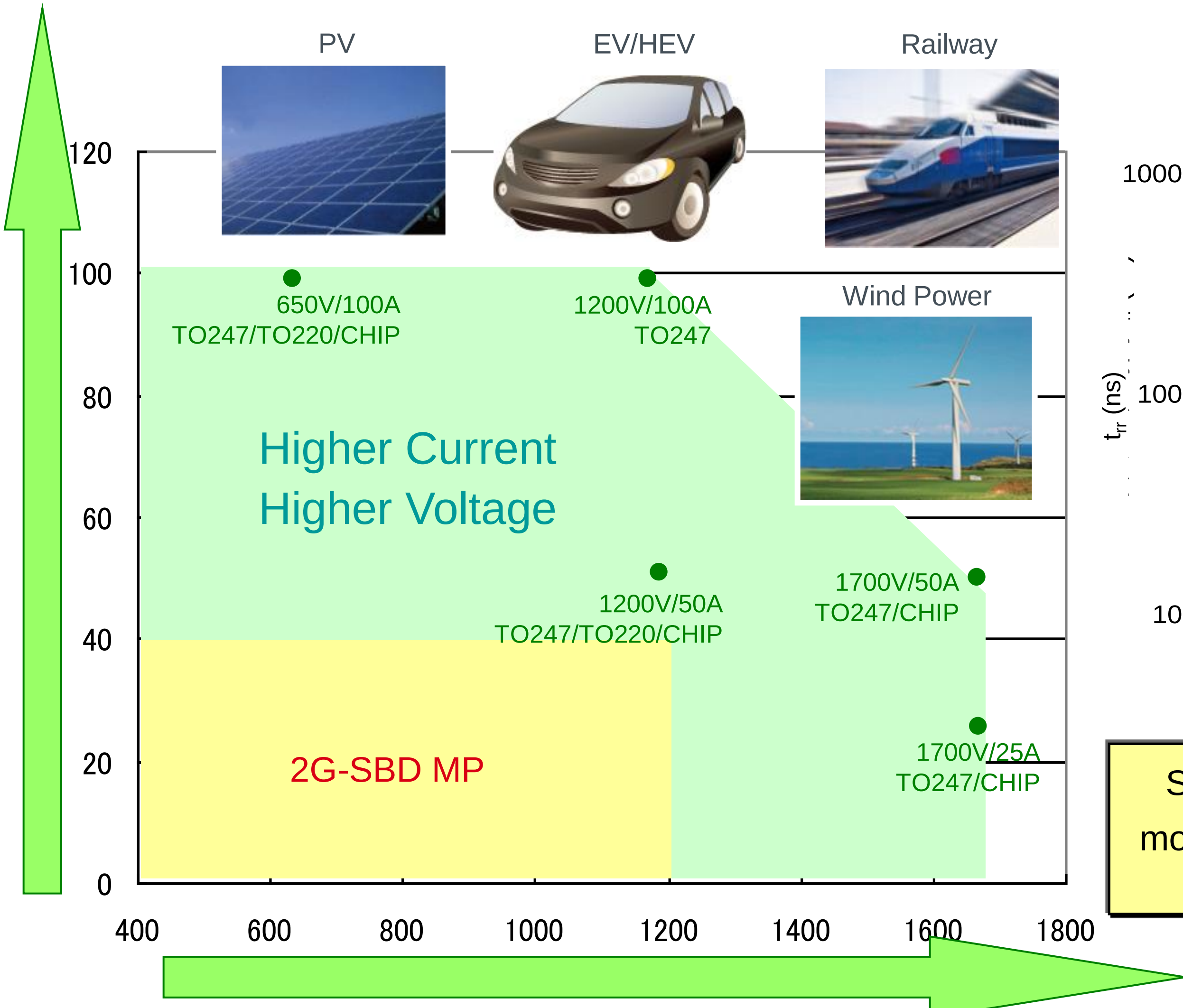
※These data are provided to show a result of evaluation done by ROHM for your reference. ROHM does not guarantee any of the characteristics shown here.

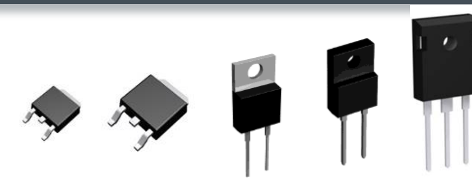
Comparison between Si-FRD and SiC-SBD

High voltage is possible in SiC with “ultra fast” SBD structure
=>negligible recovery loss

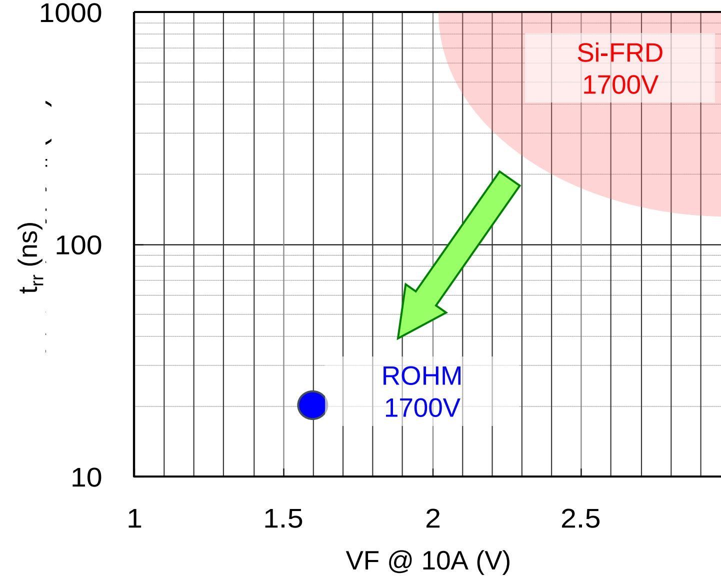


Expansion of ROHM's SiC-SBD





VF vs. trr



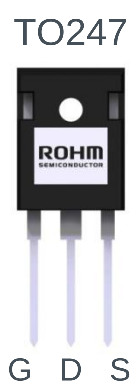
SiC superior characteristics become more significant at higher voltage range

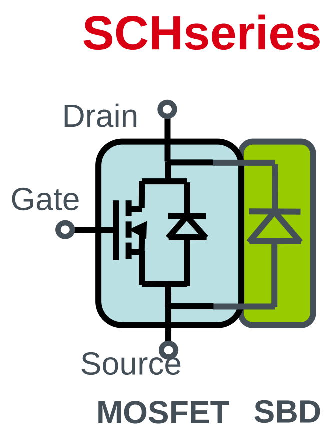
1 order of magnitude lower t_{rr}

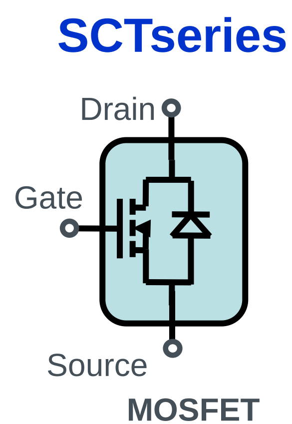
SiC MOSFET

2^{nd} Gen DMOSFET Product Lineup

BV_{DSS}	P/N	Package	$R_{DS}on$	I_D max	SBD	Status
1200V	SCT2080KEC	TO247	80mΩ	40A	-	MP
1200V	SCH2080KEC	TO247	80mΩ	40A	Co-packed	MP
1200V	SCT2160KEC	TO247	160mΩ	22A	-	MP
1200V	SCT2280KEC	TO247	280mΩ	14A	-	MP
1200V	SCT2450KEC	TO247	450mΩ	10A	-	MP
650V	SCT2120AFC	TO220AB	120mΩ	29A	-	MP
400V	SCTMU001F (For Audio)	TO220AB	120mΩ	20A	-	MP



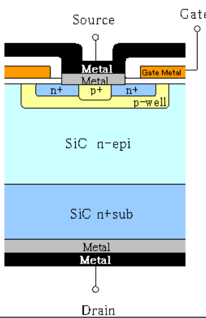
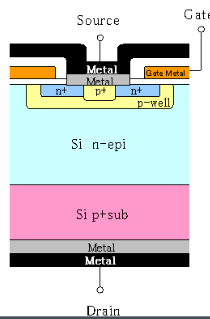
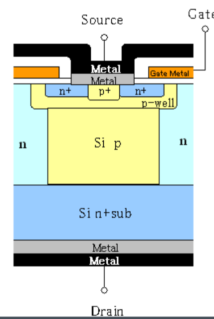




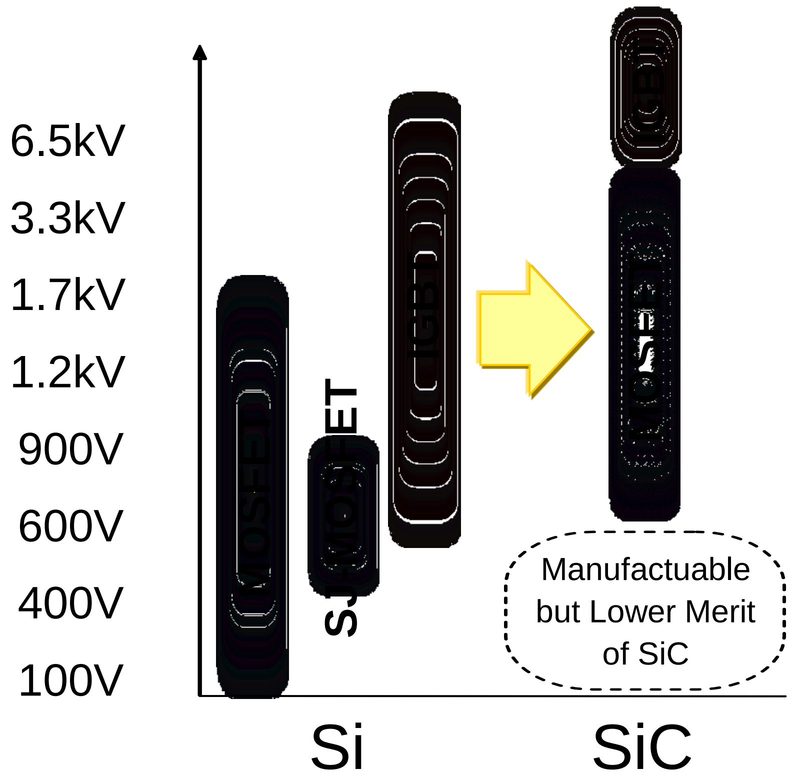
As of Oct 24, 2013

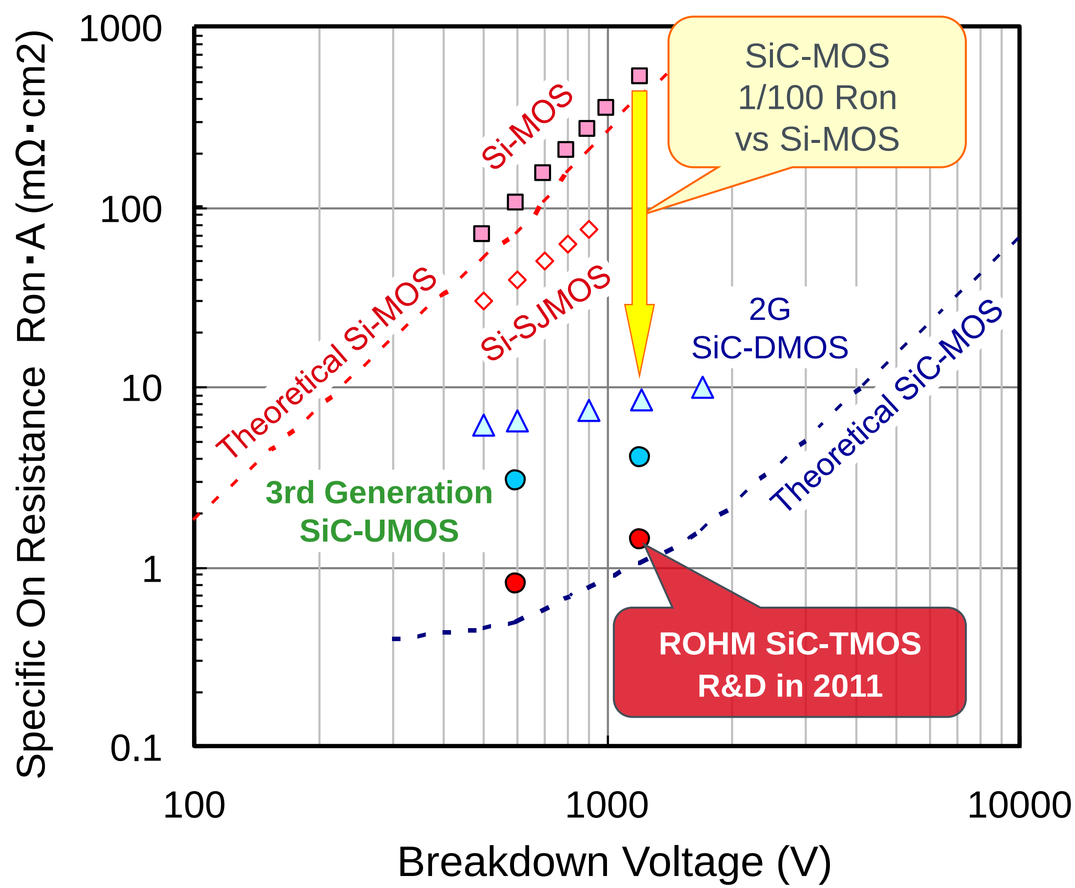
SiC MOSFET – Ideal Switching Device

Only SiC MOSFET combines all 3 desirable features of an ideal switching device

	SiC MOSFET	Si IGBT	Si Super-junction MOSFET
Structure			
Breakdown voltage	High	High	Up to around 900V
Ron	Low	Low but has on-set voltage	Low but increasing at high temperature
Switching speed	Rapid	Limited switching frequency due to tail current at turn-off	Rapid

Comparison between SiC Devices and Si Devices



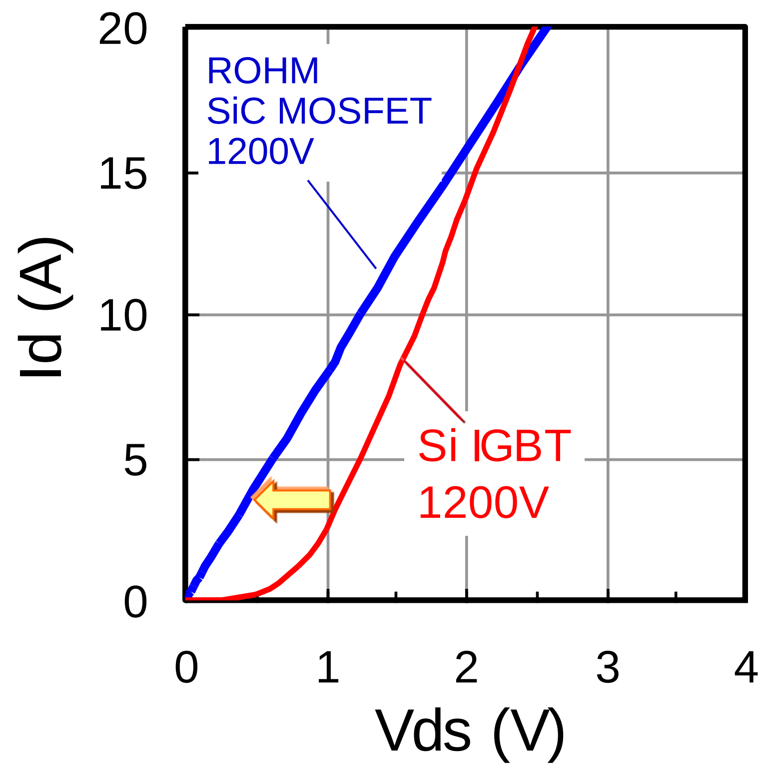


	Si-MOS	**SiC**-MOS	**Si**-IGBT
Conduction Loss	**100 ⇒ 300**	1	2～4 ⇒ ~10
Switching Loss	1	1	**10**

(in the range V_B>1000V)

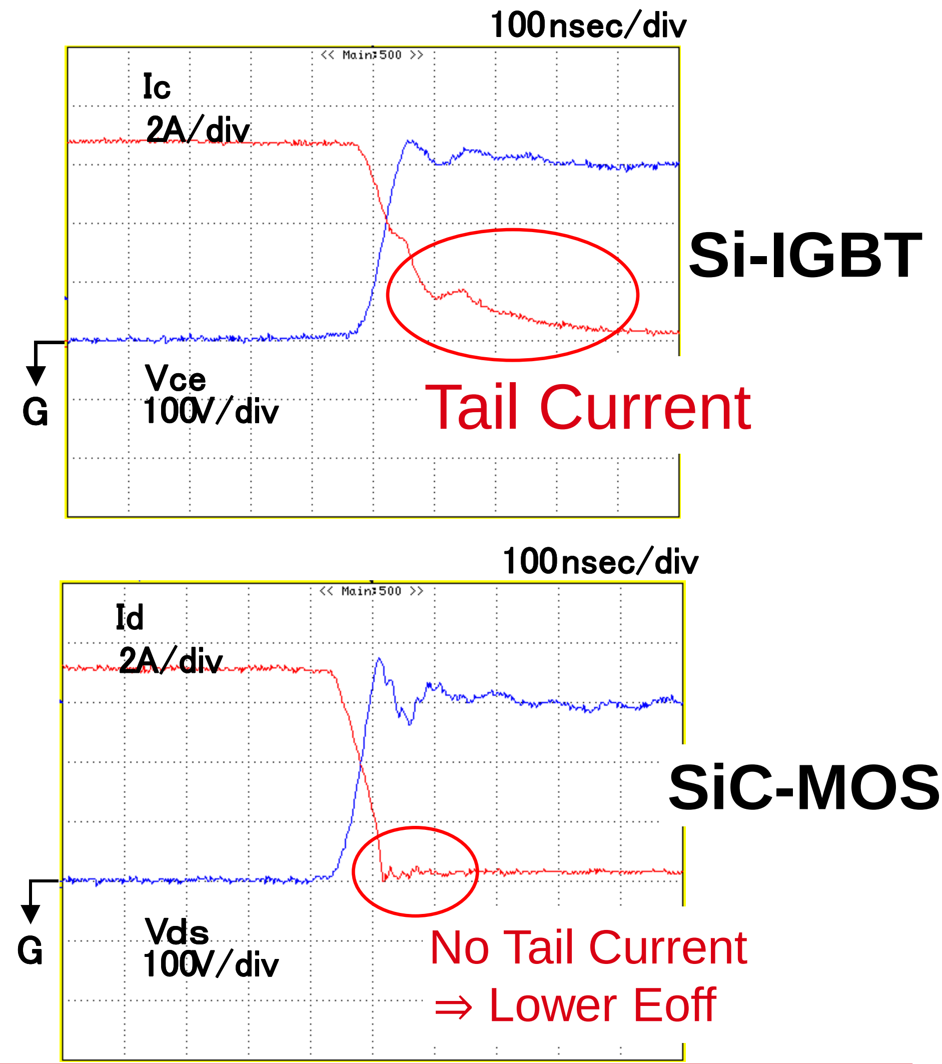
Power Loss Comparison between SiC-MOSFET & Si-IGBT

Conduction Loss（@150˚C）



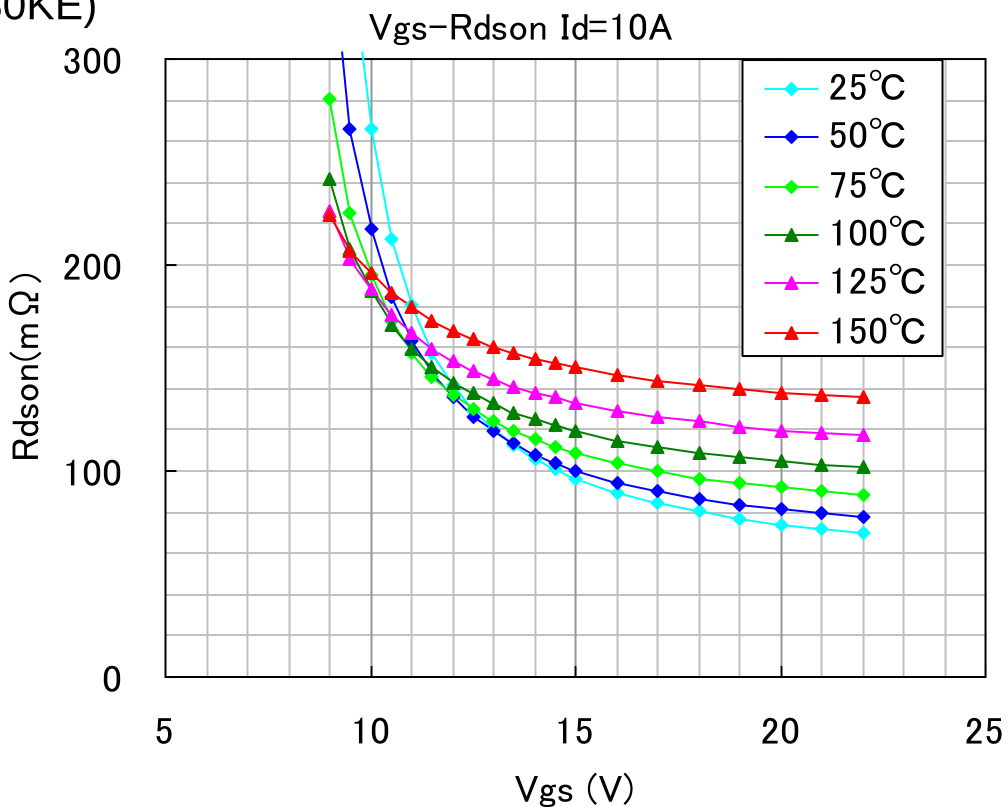
Under lower load condition (lower current condition) the much lower conduction loss can be achieved by its linear characteristic of SiC-MOS.

Switching Loss



Vgs of SiC-DMOS

Ron-Vgs (SCH2080KE)



!

- Recommend to use Vgs=15-18V to get low Ron.
- Not recommend to use below 13V as Vgs because of thermal runaway.

Reliability of ROHM SiC MOSFET

ROHM SEMICONDUCTOR 2G

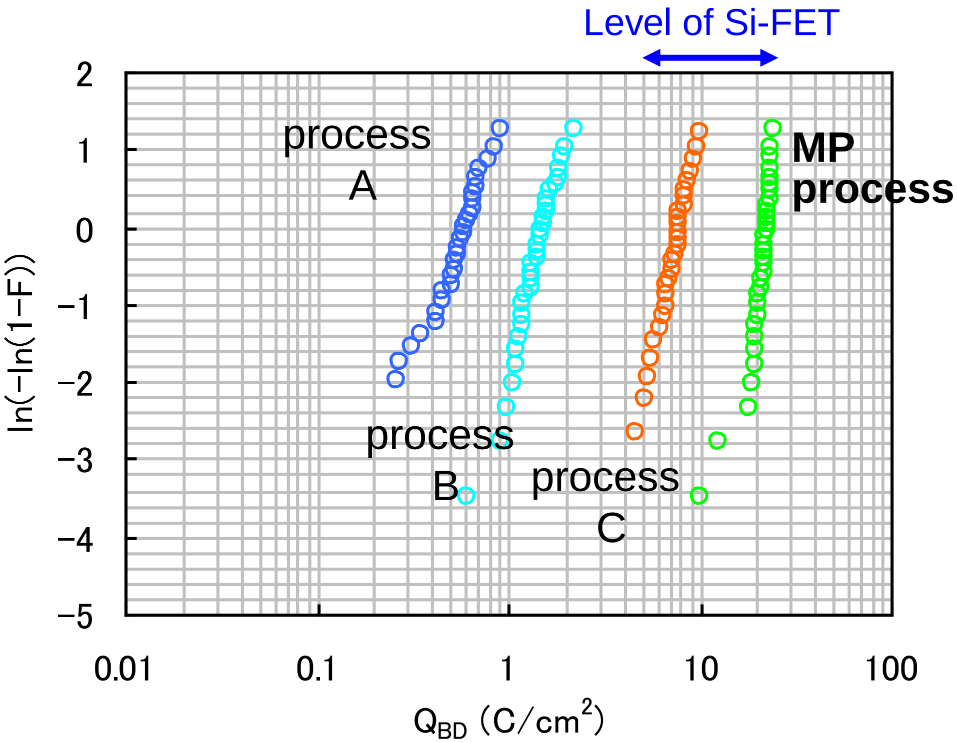
TEST	Condition	SCT2080KE
HTGB+	Vgs; +22V Ta=150℃	Passed (1000h, Pn=0/1000) ⊿Vth=+0.2~0.3V
HTGB-	Vgs; -6V Ta=150℃	Passed (1000h, Pn=0/500) ⊿Vth=-0.2~0.3V
Gate-Oxide CCS-TDDB	Ig=0.5~5mA/cm^2	Qbd=15~20C/cm^2 (Equivalent to Si-MOS)
Body-diode Conduction	Is=8A, Ta=25℃	Passed (1000h, Pn=0/20)
Cosmic-Ray Ruggedness (SEB)	Vds=1200V	4000m: 10FIT 0m: 0.5FIT

Gate Oxide Reliability HTGB +22V 150℃

CCS TDDB (24mA/cm²)

DMOSFET 2.2mmx2.4mm, n=50 each

TDDB: Constant current is injected into gate oxide layer and compare how much charge can be injected before oxide breakdown.



Si-FET-equivalent Qbd: 15～20C/cm²

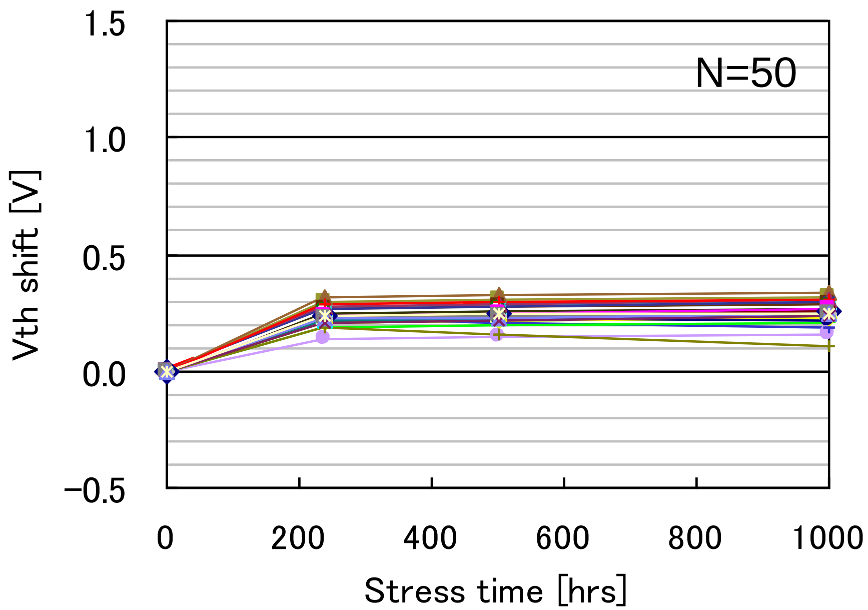
HTGB (+22V, 150℃)

1000h : Pn/N = 0/1000

3000h : Pn/N = 0/300

HTGB (+22V, **175℃**)
3000h : Pn = 0/265

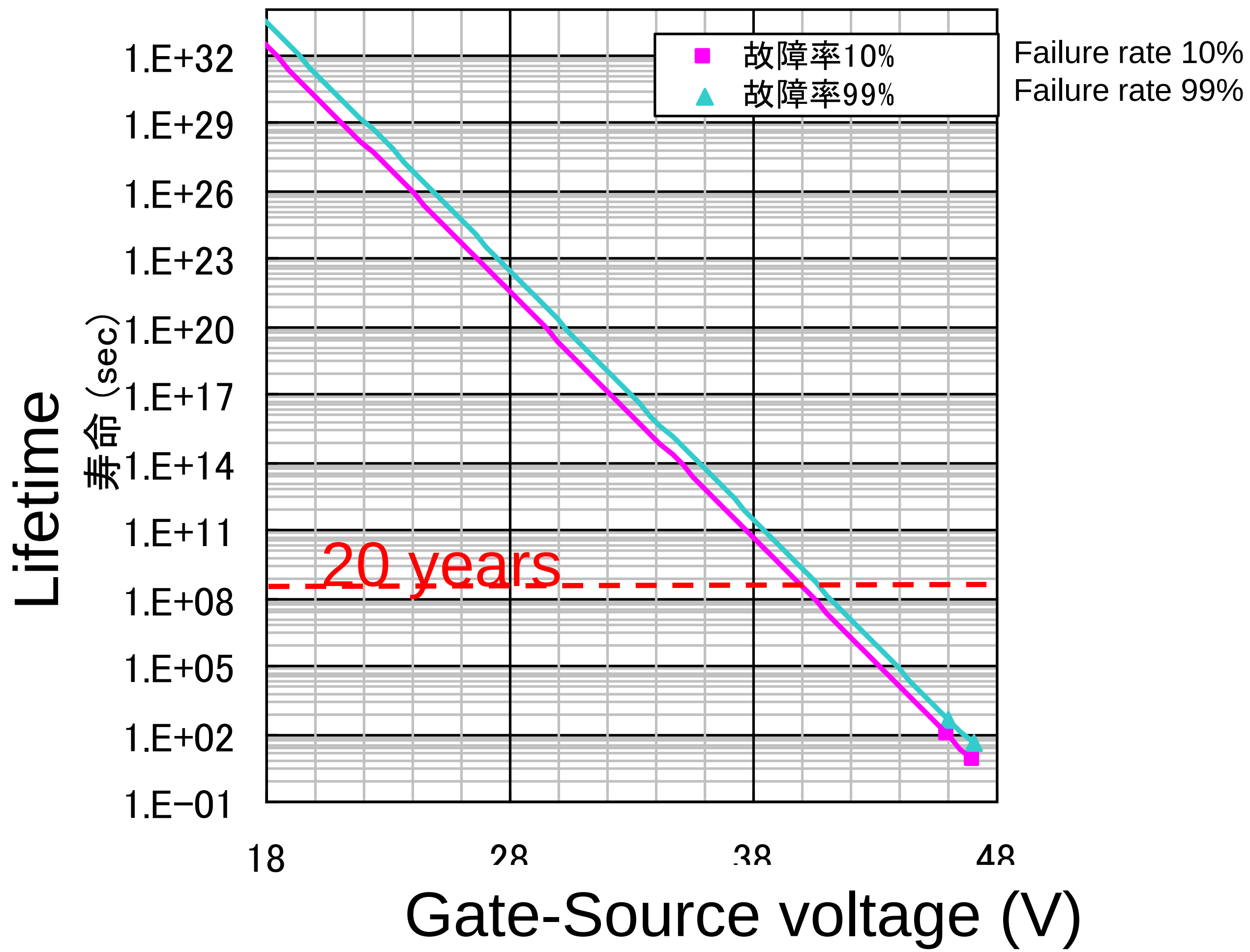
HTGB (+22V, **200℃**)
3000h : Pn = 0/25



Vth shifts only 0.2~0.3V

Lifetime expectation from CCS TDDB

Lifetime of gate-oxide film is more than 20 years with Vgs of 22V at 175℃



Single Event Burn-out for Si Power Devices

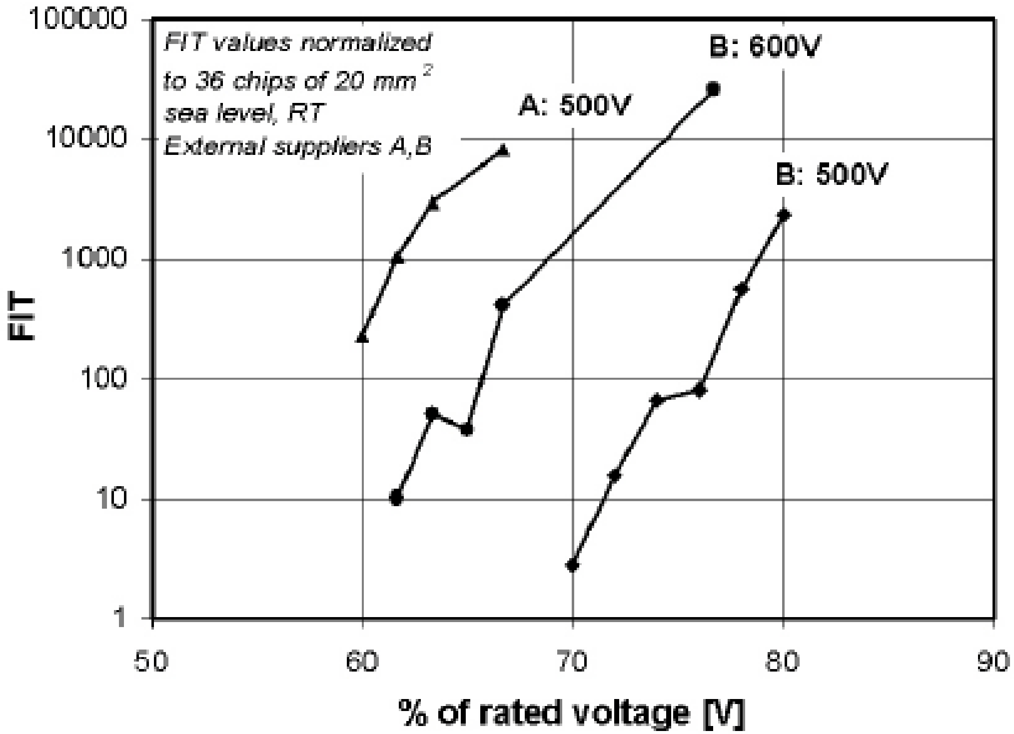


Fig. 7. Failure rates for MOSFETs in fig. 5 plotted as function of the percentage of rated voltage.

Si–MOSFET

In order to achieve ～10FIT, the lower operating voltage (50-80% of rated voltage) is necessary for Si MOSFET's.

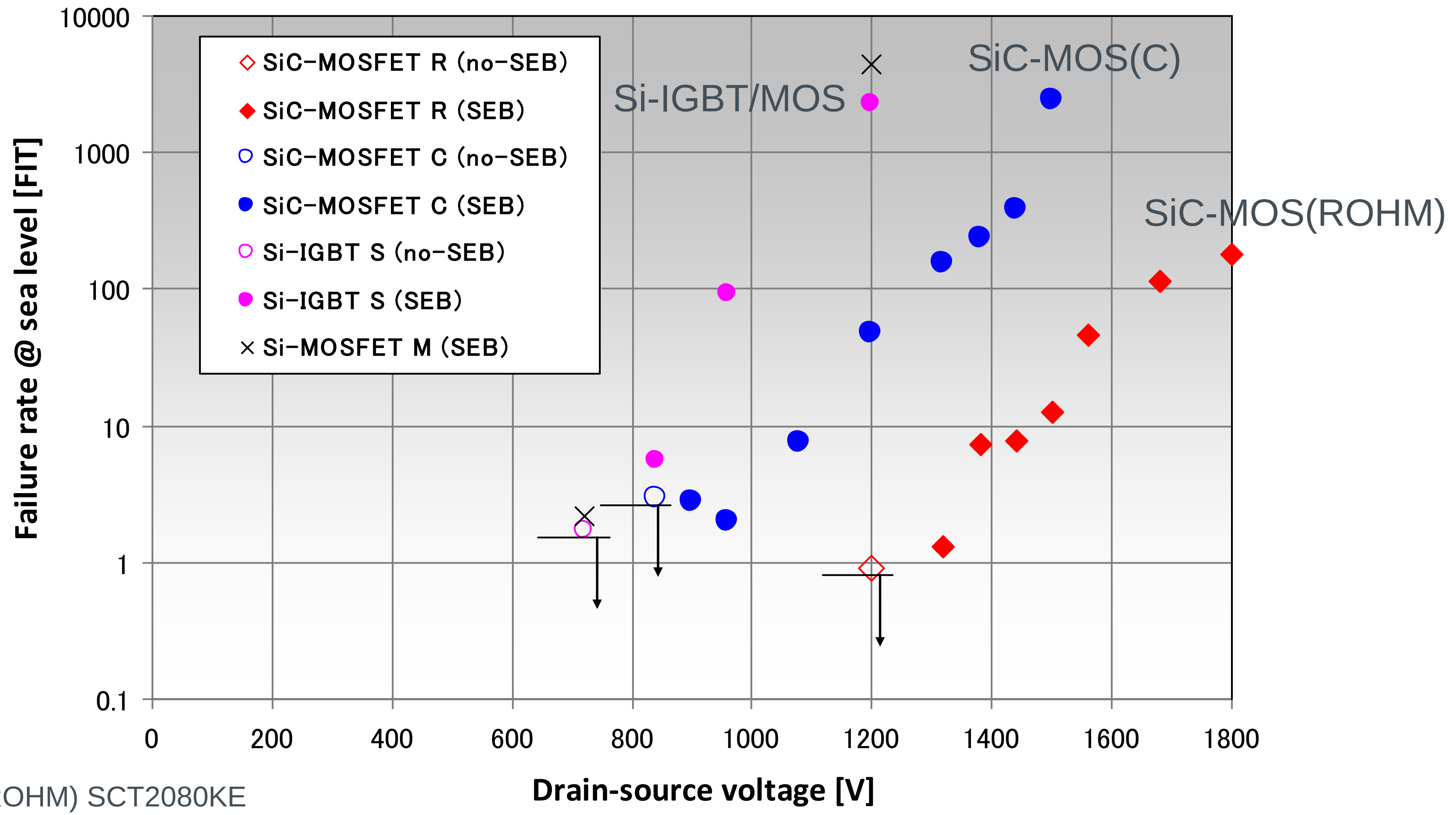
Reference)

Reliability of power electronic devices against cosmic radiation-induced failure

G. Soelkner[a], W. Kaindl[b], H.-J. Schulze[a], G. Wachutka[b]

[a] *Infineon Technologies, Automotive & Industrial, Balanstr. 59/2, 81730 Munich, Germany*
[b] *Inst. for Physics of Electrotechnology, Munich Univ. of Technology, Arcisstr. 21, 80290 Munich, Germany*

1200V FET Failure rate @ Tokyo sea level



SiC-MOS(ROHM) SCT2080KE
SiC-MOS(C) C2M0080120D
Si-MOS(M) APT28M120B2-ND
Si-IGBT(S) STGW35NC120HD

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Full SiC Power Module

W: 122mm
D: 45.6mm
H: 21.1mm

BSM120D12P2C005 MP

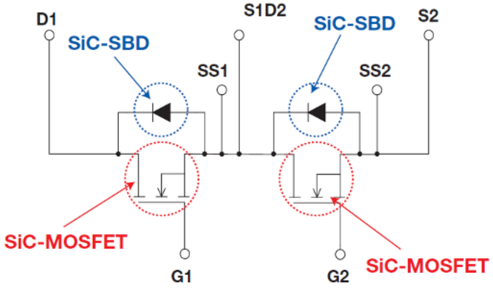
H-Bridge
（MOSFET+SBD 2in1）
VDSS Max **1200V**
ID Max(Tc=60℃) **120A**

BSM180D12P2C101 MP

H-Bridge
（MOSFET only 2in1）
VDSS Max **1200V**
ID Max(Tc=60℃) **180A**

NEW

W: 152mm
D: 62.0mm
H: 20.8mm



BSM300D12P2E001 DS OK

H-Bridge
（MOSFET+SBD 2in1 with NTC-thermistor inside）
VDSS Max **1200V**
ID Max(Tc=60℃) **300A**

We plan to release Full-SiC module, 1200V/300A, in Winter 2014.
Modules with higher voltage and current rating are planed with the same module package.

As of Nov, 2014

Full SiC Power Module

- BSM120D12P2C005
- BSM180D12P2C101

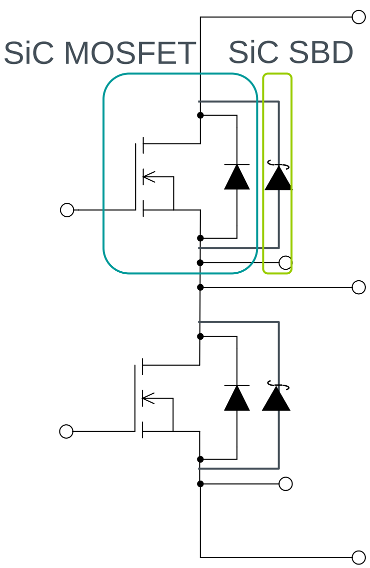
Spec

Rating voltage: 1200V

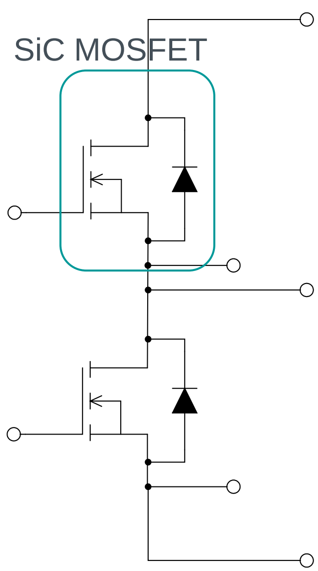
Rating current: 120A / 180A

Circuit diagram

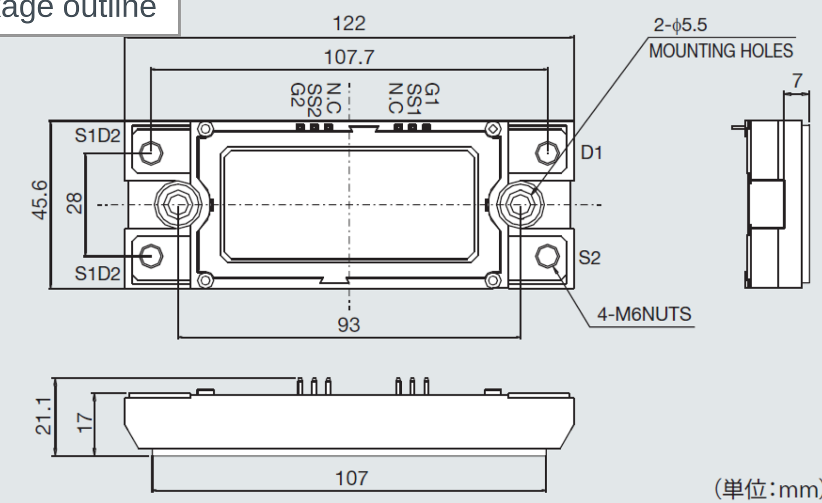
BSM120D12P2C005



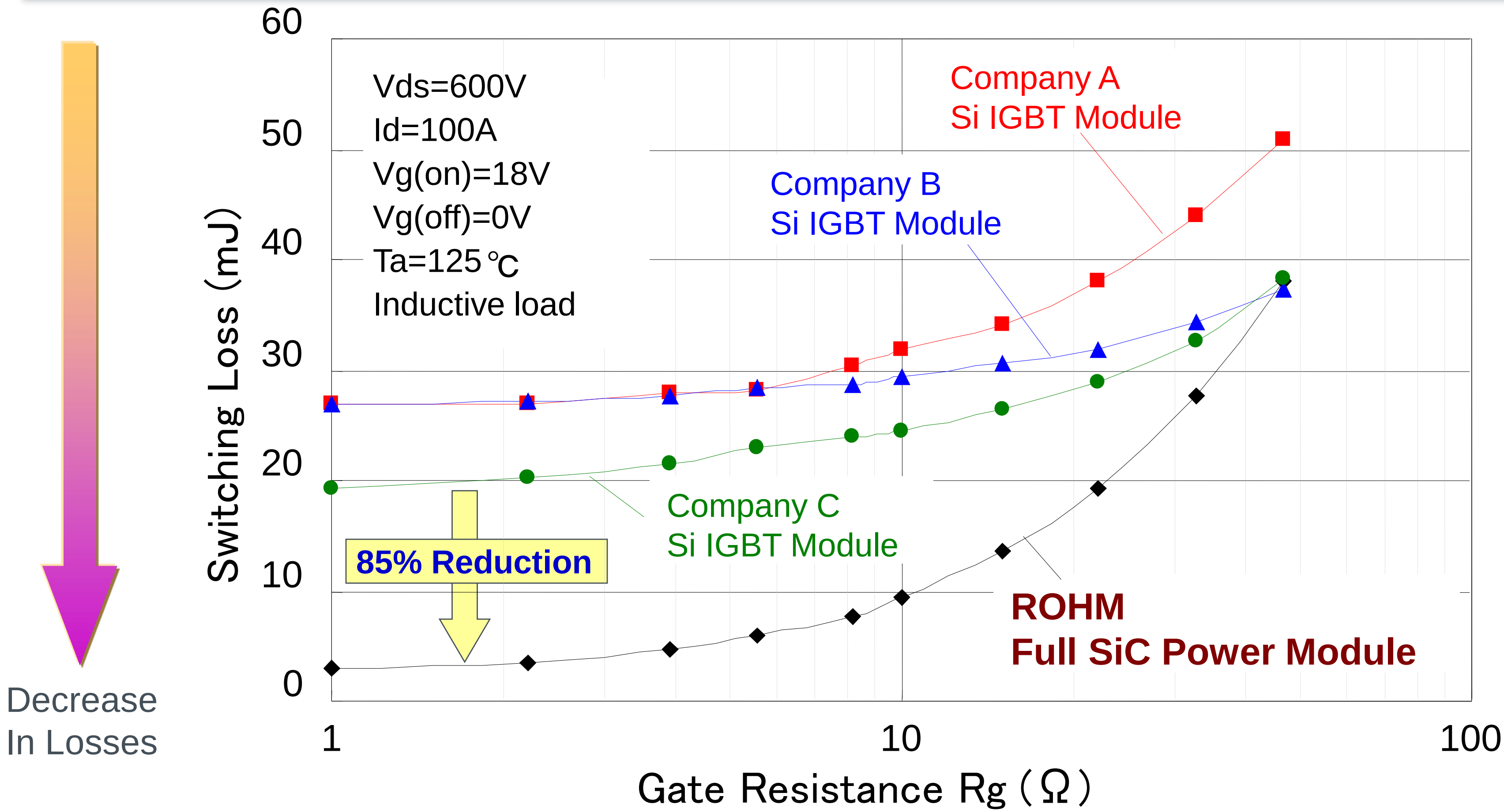
BSM180D12P2C101



Package outline



Comparison of SW loss with IGBT Modules

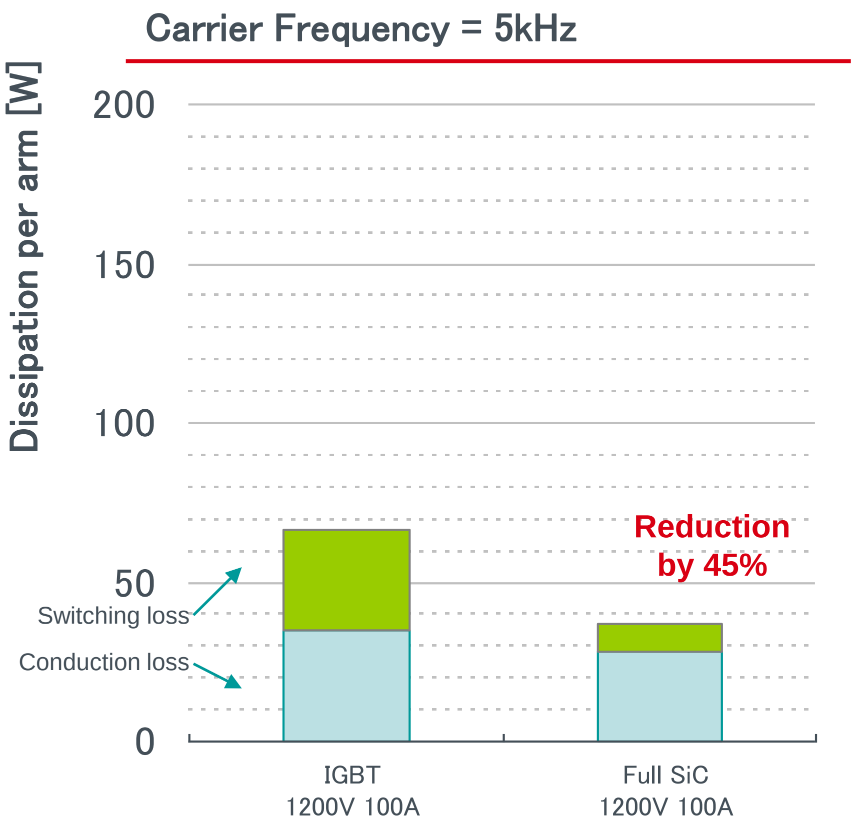


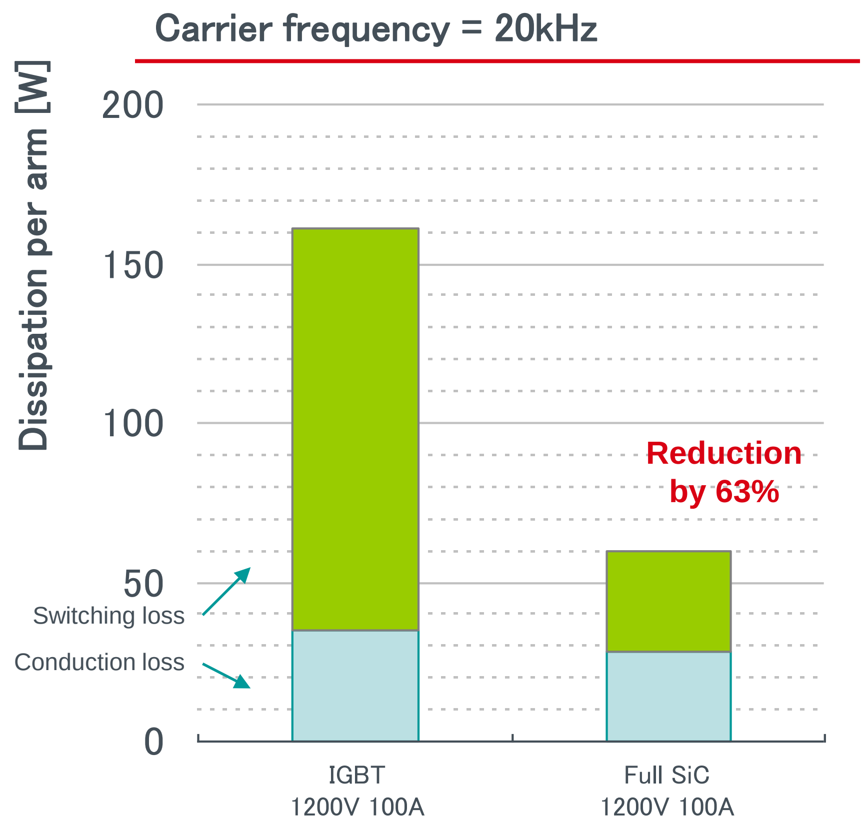
Compared with Si IGBT, SiC Module reduces switching loss by 85% in total.

SiC Power Modules – Comparison in Power Dissipation

SiC power modules realize lower switching loss than IGBT. The effect is significant when used in inverters / converters with high switching frequency

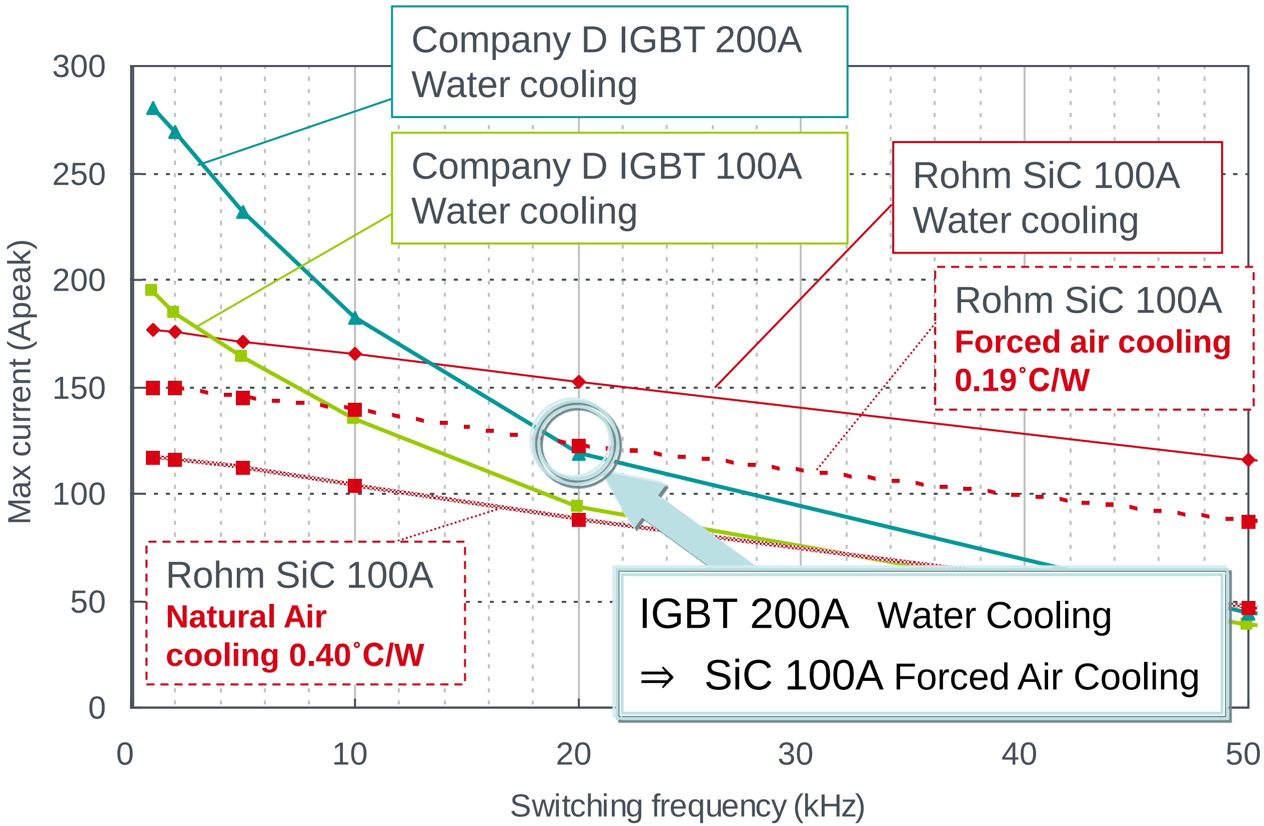
Simulation: Comparison in dissipation per arm, when used in 3 phase PWM inverter
Input voltage = 600V, Output current = 50A rms, Tj=125℃, Power factor = 0.9, Modulation rate = 1.0





Performance of SiC Power Module： Max. Peak Current

In the zone of high switching frequency, cooling system could be downsized by replacement by SiC modules



PWM
Ta=40˚C
Tj=125˚C

Heat sink 0.10˚C/W
(Water cooling)

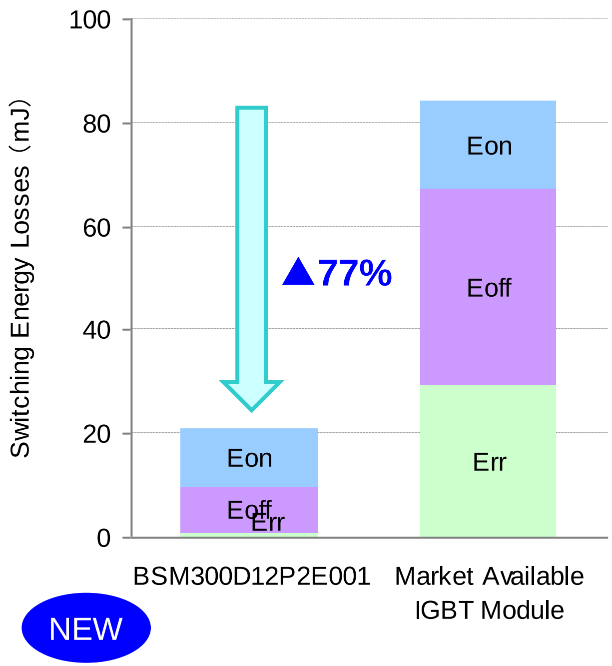
Contact thermal resistance 0.07˚C/W

V=600V
Power factor 1
Modulation rate 0.9

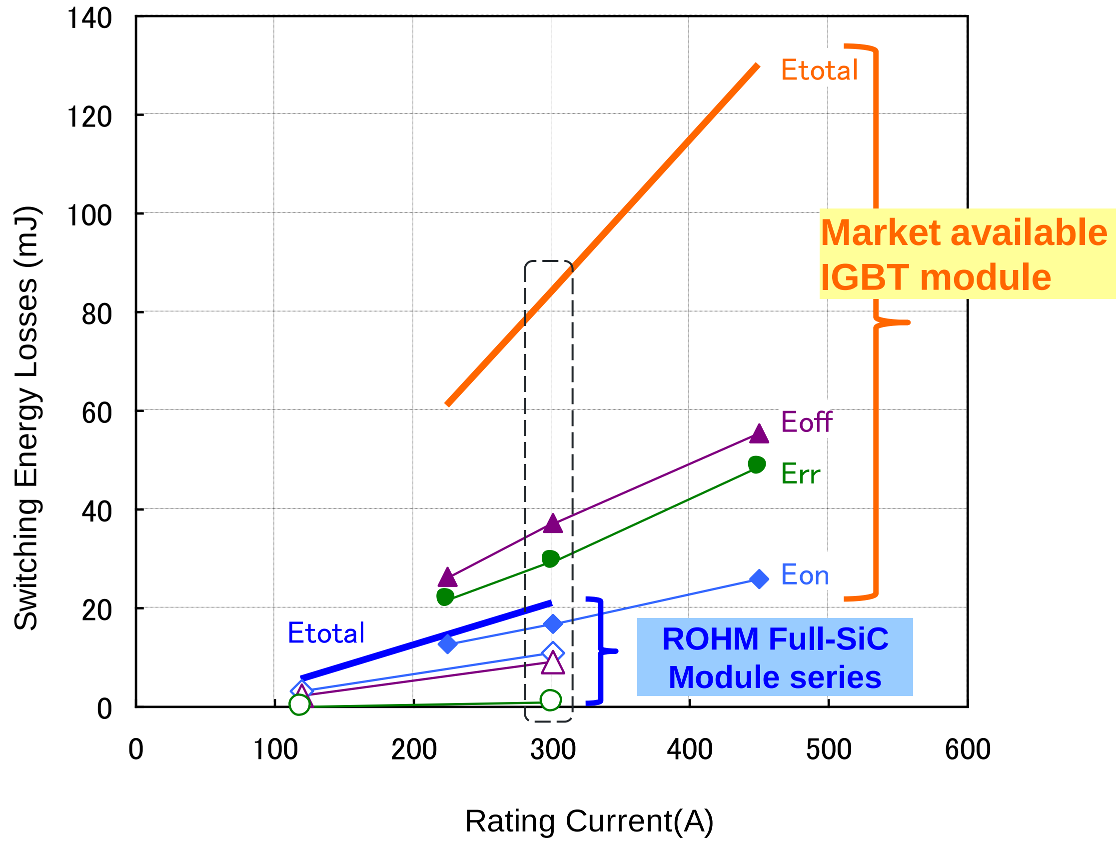
※These data are provided to show a result of evaluation done by ROHM for your reference. ROHM does not guarantee any of the characteristics shown here.

Switching Loss of New SiC-Module

ROHM's new Power module achieved reduction in switching loss by 77%, compared with market available 1200V/300A IGBT modules



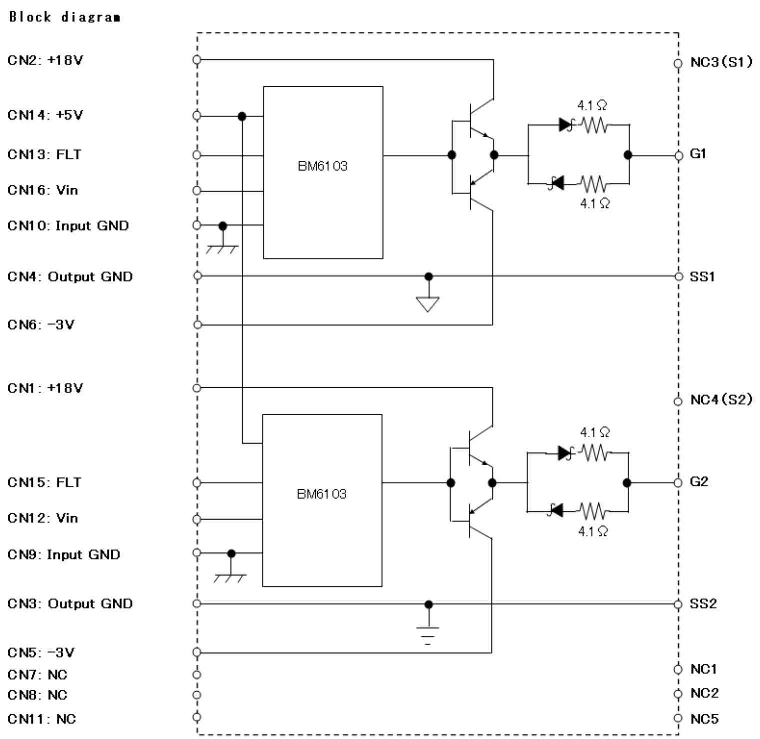
	BSM300D12P2E001	IGBT Module
V_{DS}, V_{CE}	600V	600V
I_D, I_C	300A	300A
V_{GS}, V_{GE}	18V / 0V	15V / -15V
R_G	Recommended R_G	

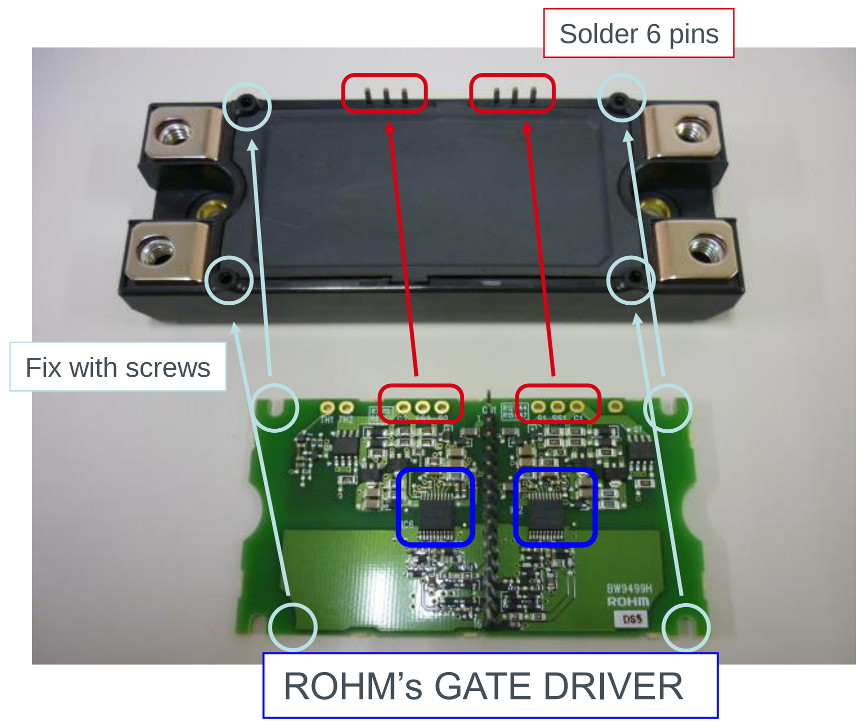


※These data are provided to show a result of evaluation done by ROHM for your reference. ROHM does not guarantee any of the characteristics shown here.

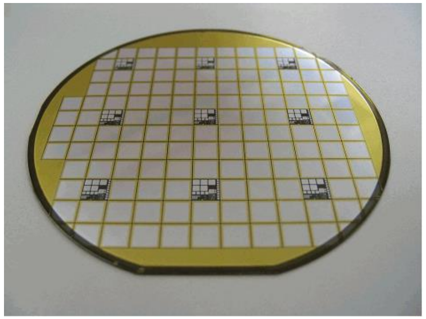
Gate Drive Circuit Board BW9499H

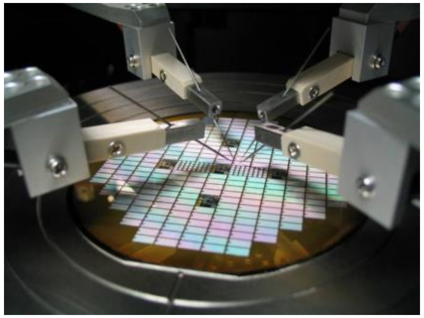
Now Gate drive circuit board BW9499H to evaluate BSM120D12P2C005 / BSM180D12P2C101 is available. For inquiry, please contact our sales rep.





<u>Note: This board is not designed as a commercial product. Please use this board for evaluation purpose only.</u>





Thank you for your attention !!