pcim
ASIA Hybrid Platform
All SiC Module for Traction Inverters with 1st Generation Trench Gate SiC MOSFETs
Chen Song, Fuji electric China Co., Ltd

# Outline

*1. Introduction*

*2. Future of Package for Traction*

*3. 3.3kV 1st gen trench gate MOSFETs technologies*

*4. Electrical performance for SiC MOSFETs*

4-1 Static characteristics
4-2 Improvement of leakage current
4-3 Dynamic characteristics
4-4 PWM simulation results
4-5 Calculation results for relationship between Tvj and Io

*5. Line up plan*

*6. Conclusion: Down sizing*


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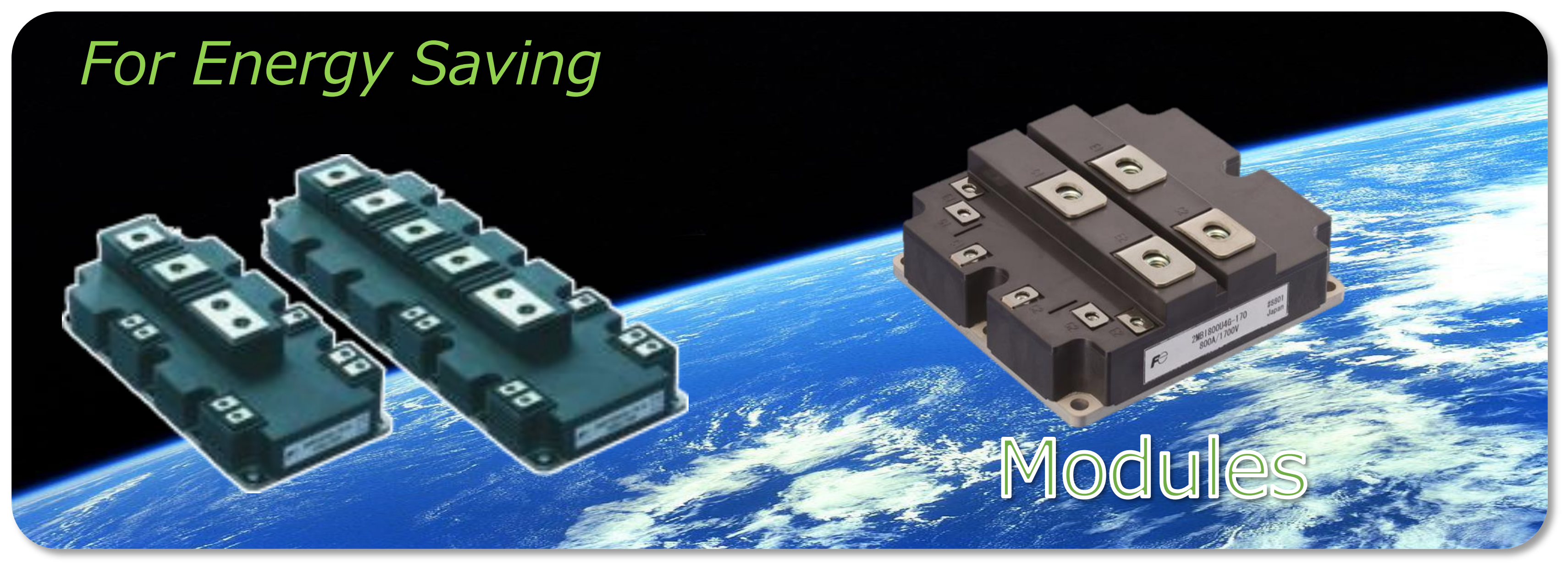
## *Power semiconductor Module's Market Demands*

- ✓ *High current density*
- ✓ *Low dissipation*





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*Market demands*

*Downsizing of Power Modules*

*Issues*

*Increment of Losses*

*Rise of Temperature*

*Solutions*

- ✓ *Low static Loss*
- ✓ *Low swiching loss*
- ✓ *High temperature operation*

*Our Solutions*

- ✓ *Trench gate MOSFETs*
- ✓ *SiC MOSFET and SBD*
- ✓ *Low Inductance Package due to High di/dt*
- ✓ *Expansion of Tvj(ope)*

**$Tvj_{(op)}$: Continuous Operating Junction Temperature*


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# 2. Feature of Package for Traction

*HPnC : New PKG*

*HPM : Conventional PKG*

- *Low inductance:10nH*
- *High isolation capability up to 3.3kV*
- *Traction standard:EN50124-1 and EN45545-2*


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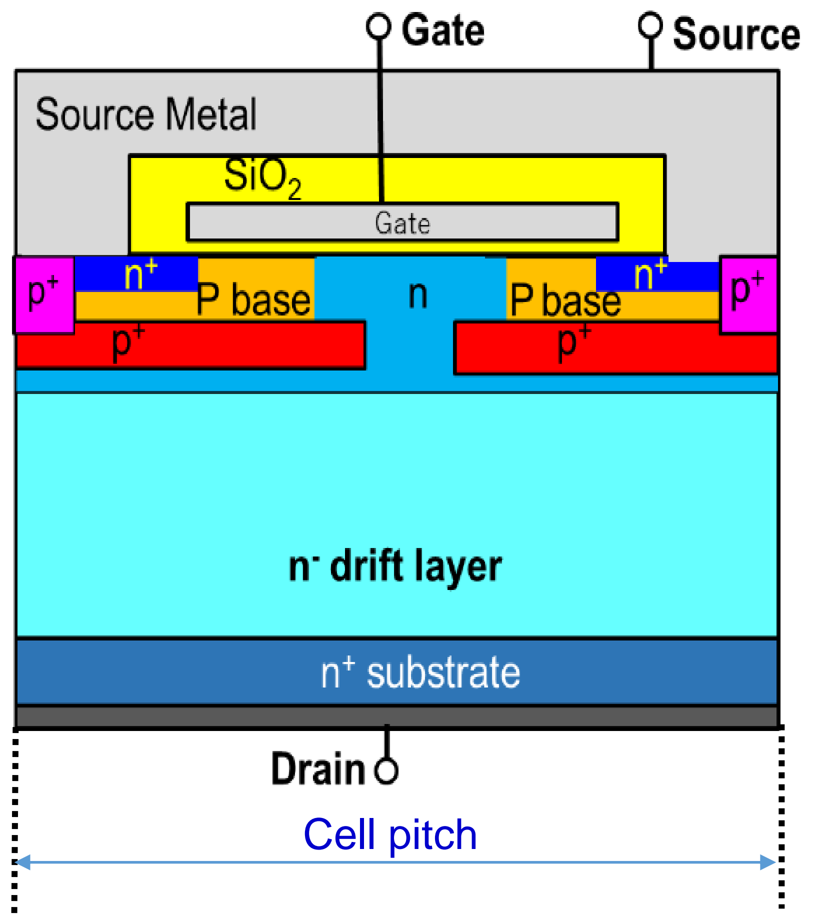
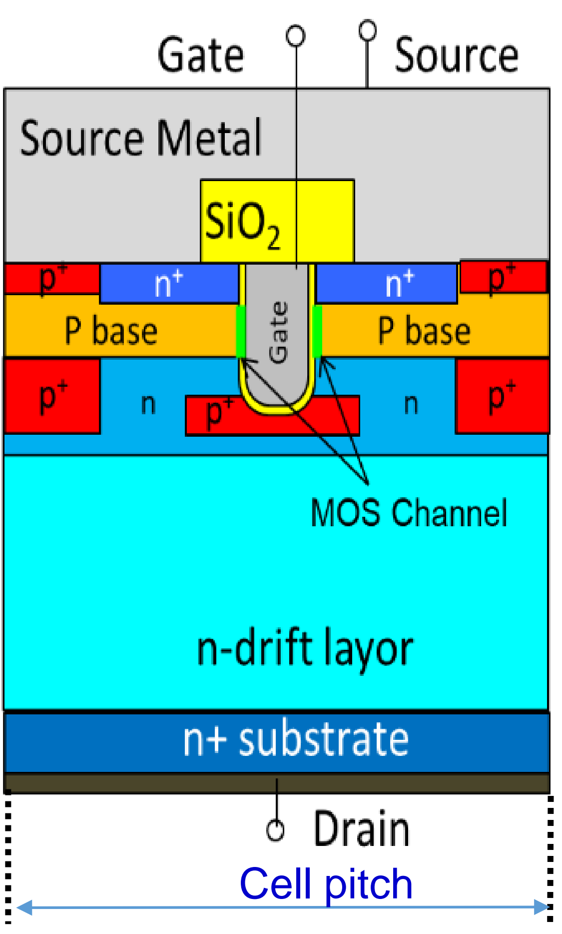
*Cross-Section Structure of MOSFETs*

## Planar SiC MOSFET




## 1G Trench SiC MOSFET




Cell pitch of 1G trench Gate was reduced by 50% and RonA could be reduced 40% compared to planar Gate.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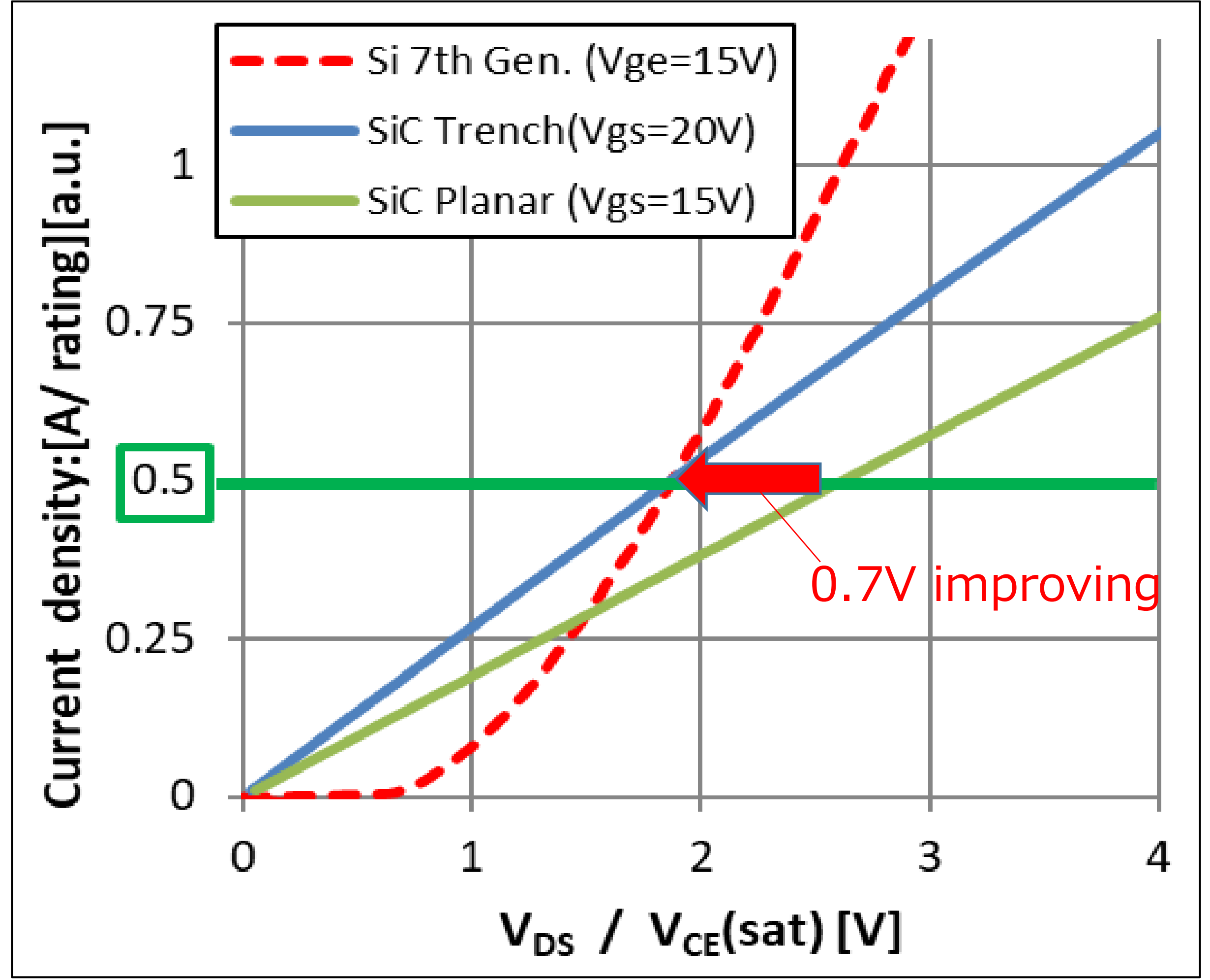
# 4-1. Static characteristics

## Si 7th Gen./SiC1st Gen. trench/SiC planar. output characteristic at 150deg.C




All-SiC trench 1G gate is lower than Vce of Si 7th Gen under half rated current, which is used under general continuous operation condition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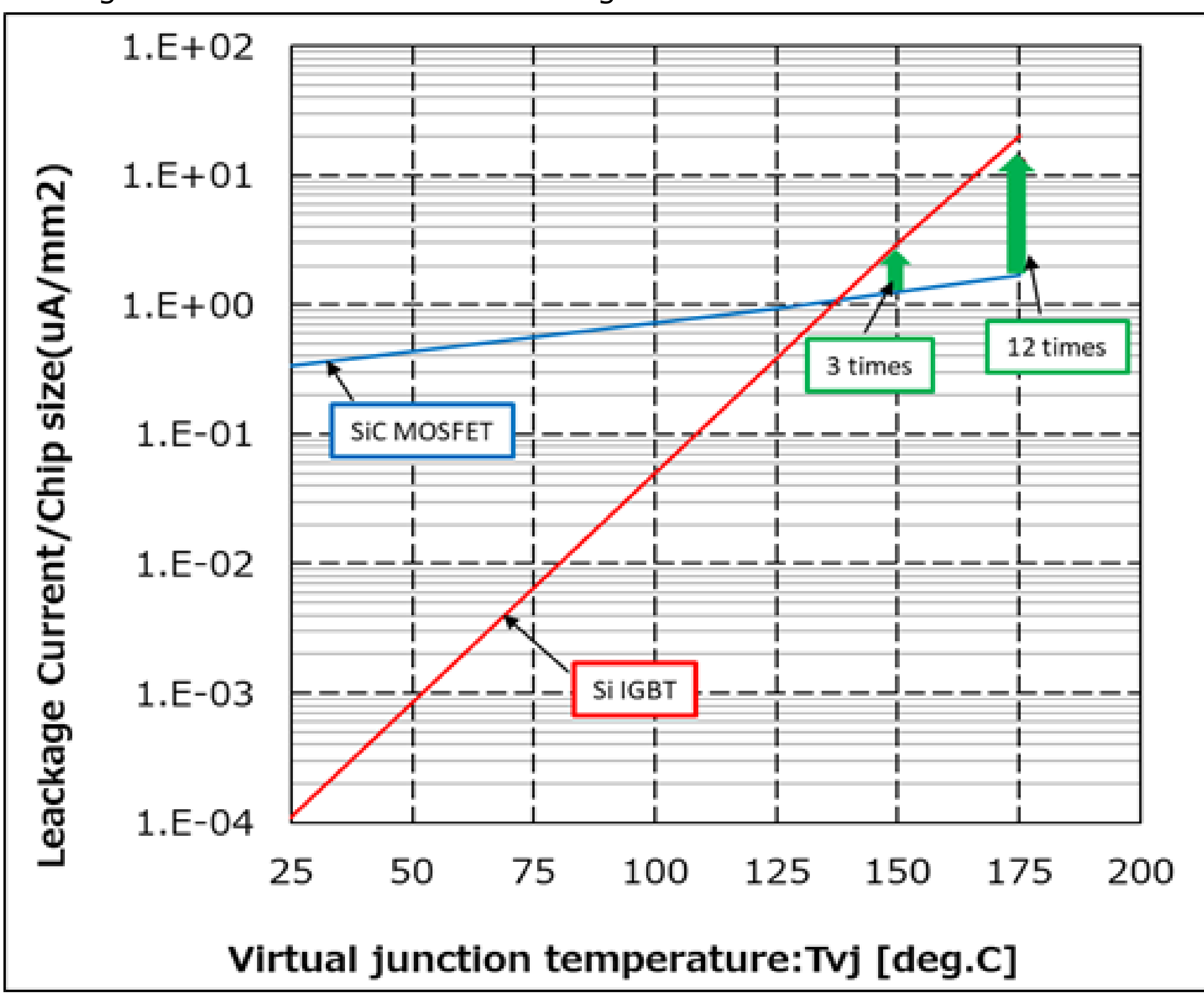
# 4-2. Improvement of leakage current

Si 7th gen IGBT and SiC MOSFET leakage current




- Leakage current of Si IGBT was approximately 3 times larger than SiC MOSFET at 150deg.C and enable to operate under higher temperature.
- Maximum temperature is limited to 175deg.C due to Package reliability.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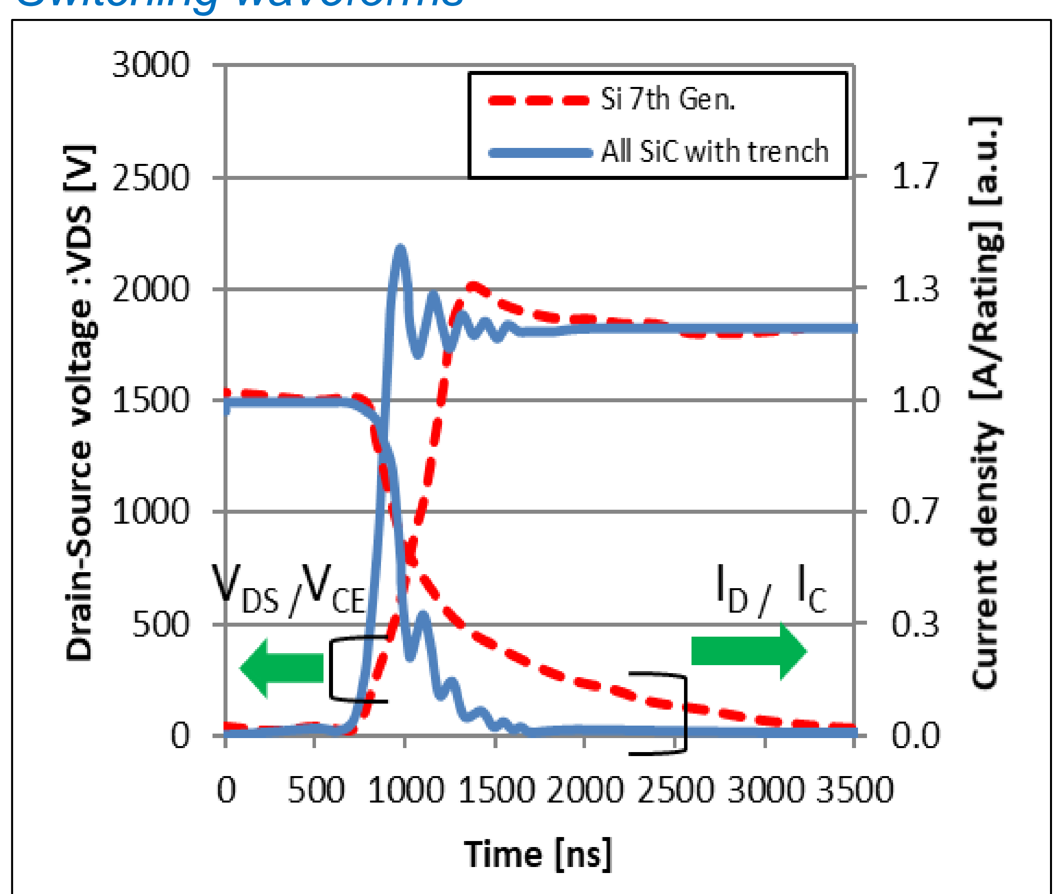
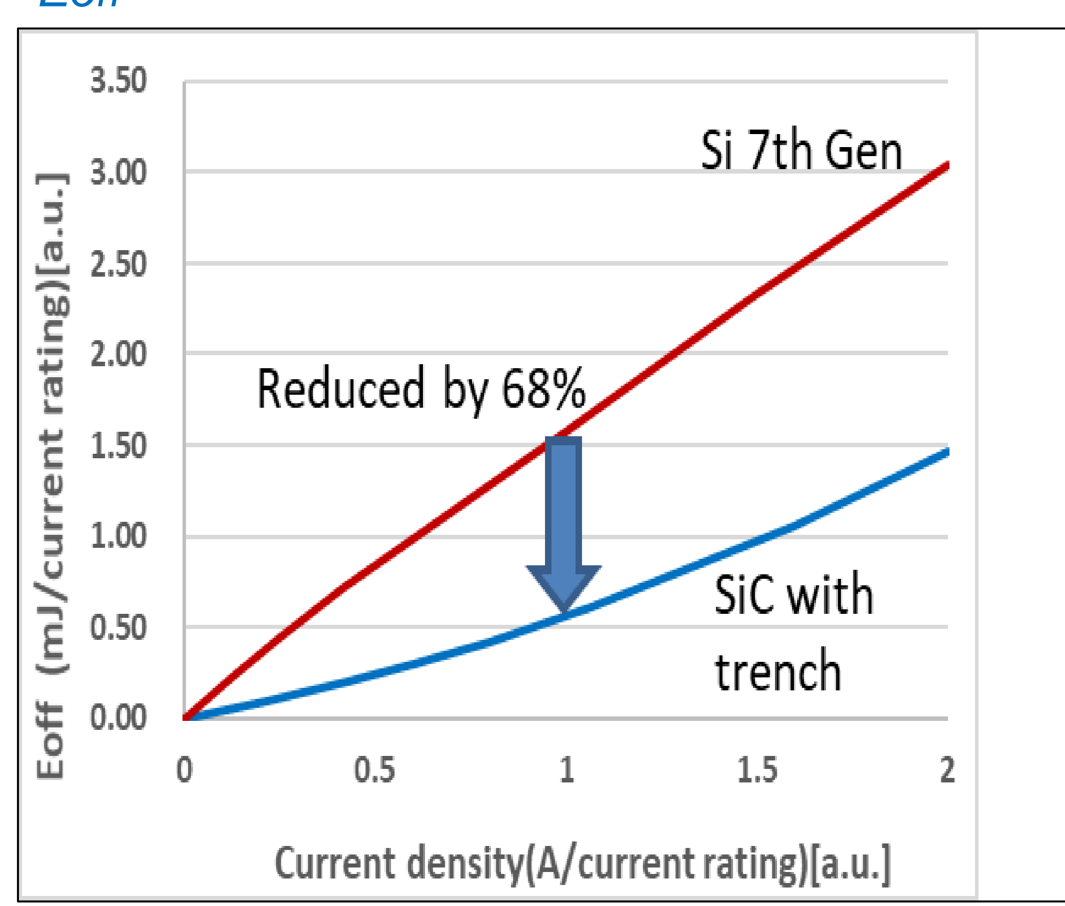
# 4-3. Dynamic characteristics Turn off

$V_{cc}$=1800V, $I_D$=same current density(A/rating), $R_g$=2.7Ω for Si 7$^{th}$ Gen , $R_g$=10Ω for All SiC

*Switching waveforms*




*Eoff*




The tail current of all-SiC module was reduced and the rising voltage was also faster compared to 7th generation Si IGBT module.

→ Eoff was reduced by 68%.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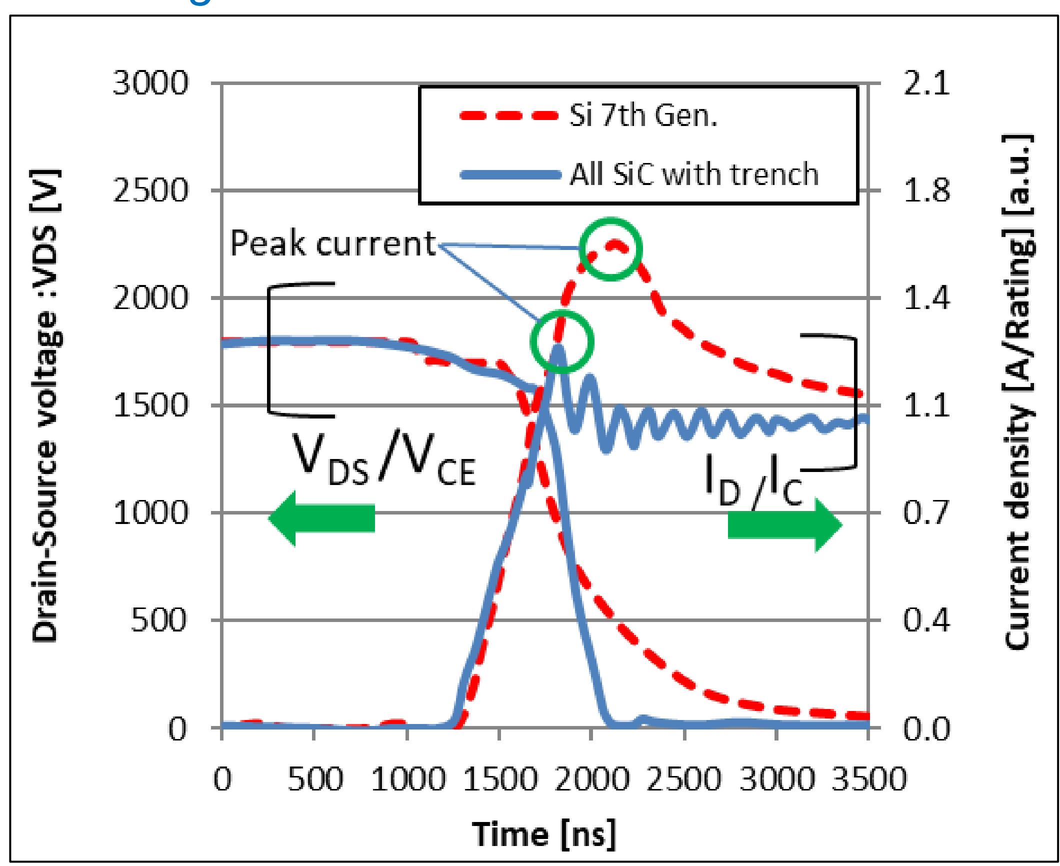
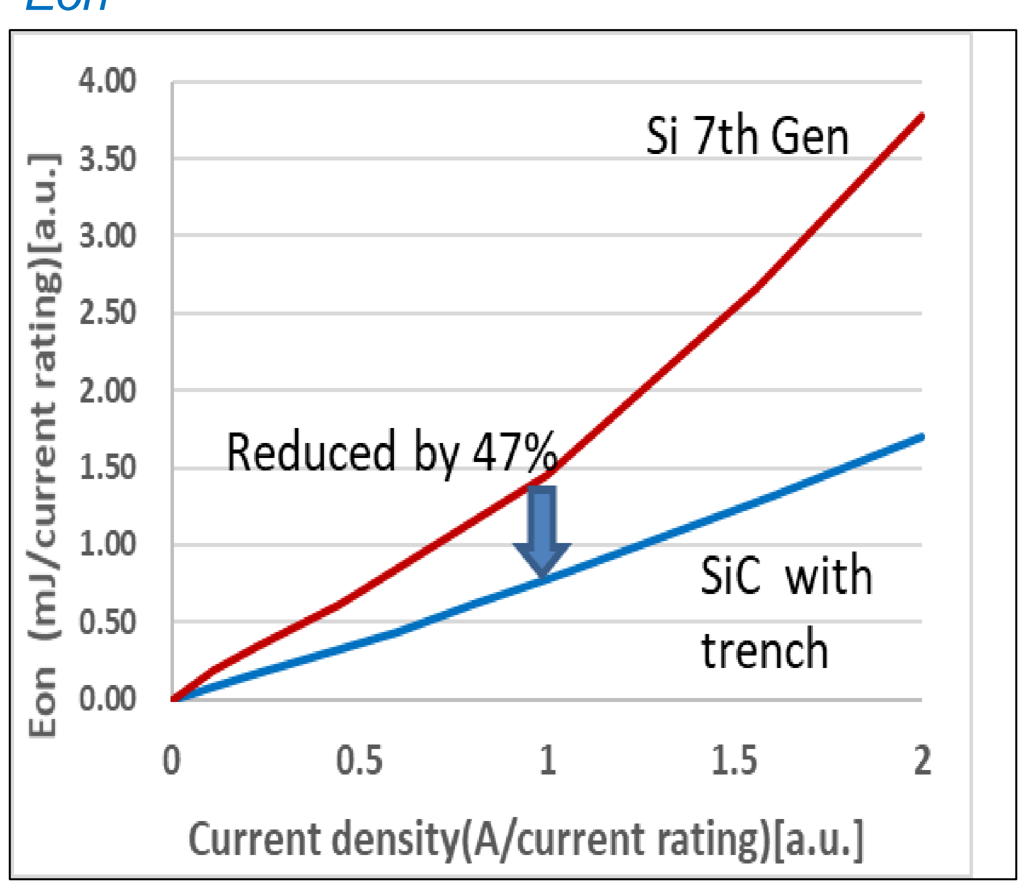
# 4-3. Dynamic characteristics Turn on

$V_{cc}$=1800V, $I_D$=same current density(A/rating), $R_g$=0.68Ω for Si 7th Gen , $R_g$=20Ω for All SiC

*Switching waveforms*




*Eon*




The peak current at turn on of the all-SiC module was reduced compared to 7th generation Si IGBT module.

→ Eon was reduced by 47%.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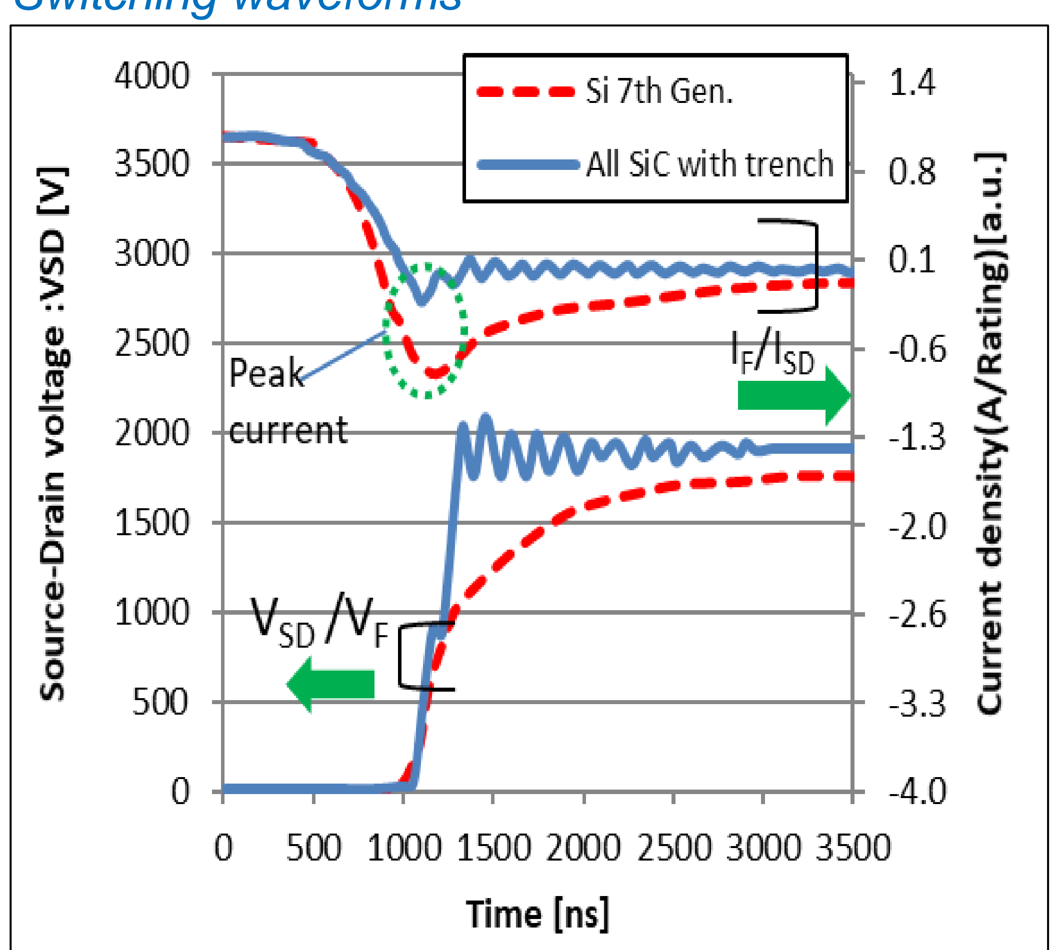
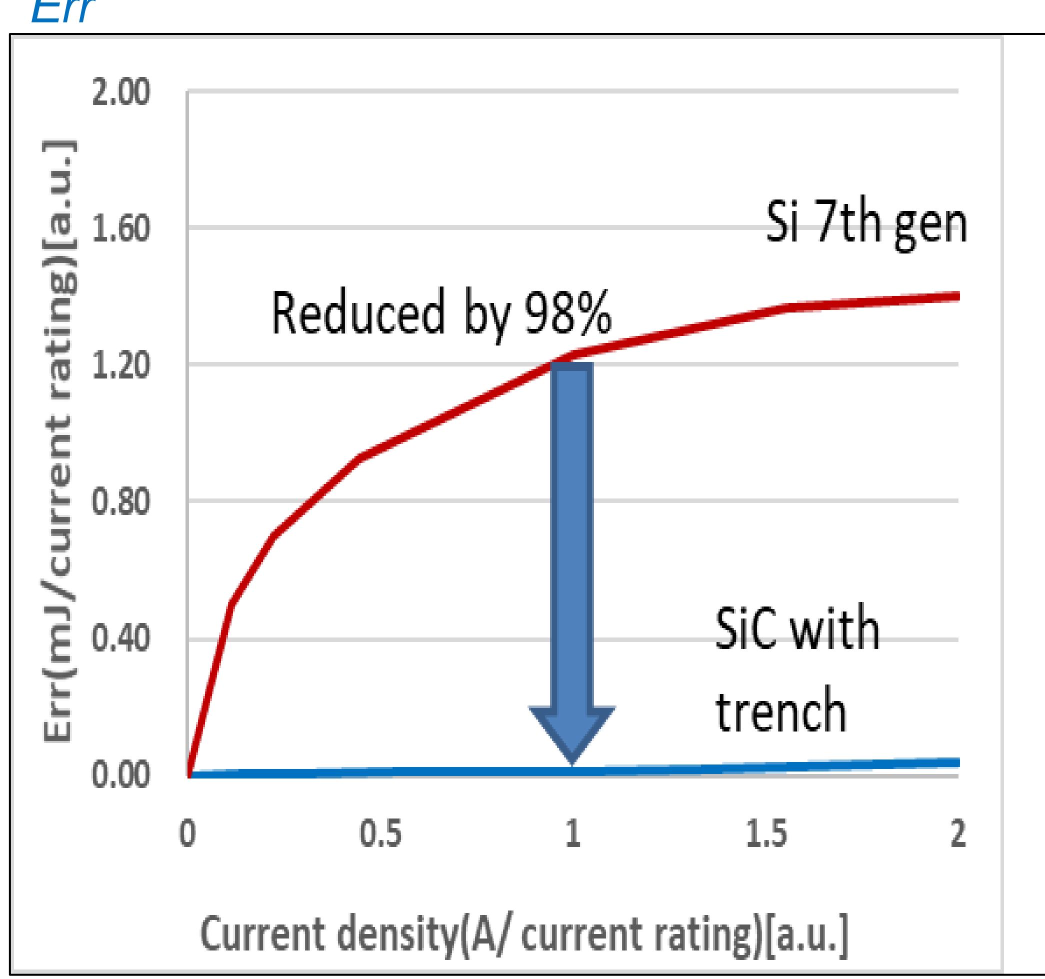
# 4-3. Dynamic characteristics Recovery

$V_{cc}$=1800V, $I_D$=same current density(A/rating), $R_g$=0.68Ω for Si 7th Gen , $R_g$=20Ω for All SiC

*Switching waveforms*



*Err*




The tail current of all-SiC module was reduced compared to the 7th generation Si IGBT module.

→ Err was reduced by 98%.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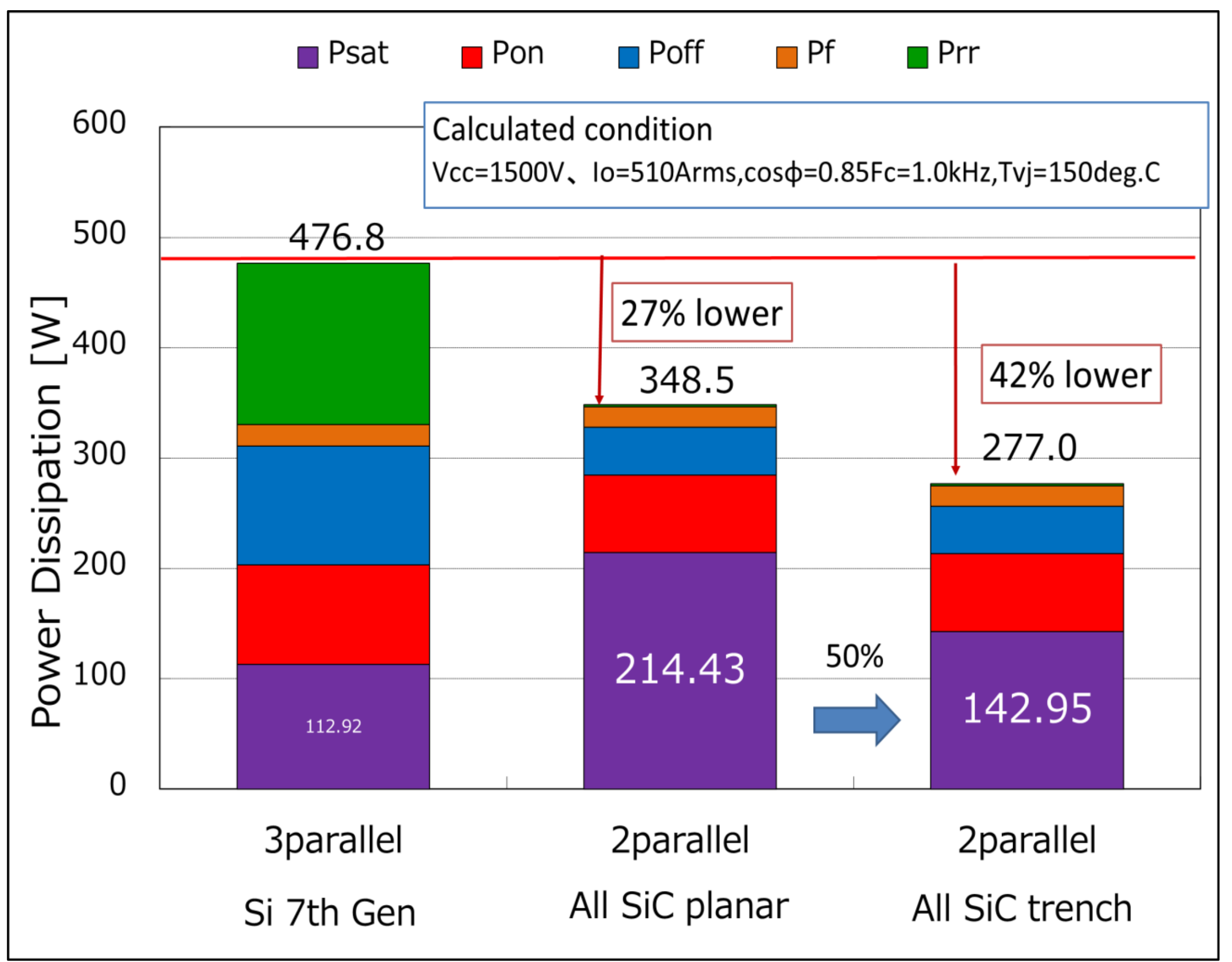
# 4-4. PWM simulation results

Calculate condition :Vcc=1500V,Io=510Arms,cosφ=0.85、λ=1.0,Fc=1kHz、Tvj=150deg.C

Sample rating :450A/3300V(Si maximum rating) , 750A/3300V(All SiC maximum rating)




The overall power dissipation for All SiC module with trench gate with 2 modules in parallel was reduced 42% compared to Si 7th Gen.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# 4-5.Calculation results for relationship between Tvj and Io

Virtual Junction temperature : Tvj (deg.C)
200
175
150
125
100
75
50
25
0
0
150
300
450
600
750
900
Out put current : I out (Arms)
25% expanding from planar
Tvj=+25deg.C up
Silicone (450A/3300V)
All SiC Trench (750A/3300V)
All SiC planar
66% expanding from Silicone

All SiC module with Trench gate MOSFET realized to expand the Io by 66% with same package size during overload operation.


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# 5. Lineup plan

| Package | | Small 1B | Small 2B | 62mm STD | HPnC |
|---|---|---|---|---|---|
| size(WxDxH) | | 62.8x33.8x12 mm | 56.7x62.8x12 mm | 62x108x30.5 mm | 100x140x38 mm |
| Rated voltage | Equivalent Circuit | | | | |
| 1200V | 2in1 | ~100A | ~200A | ~600A | - |
| | 6in1 | ~50A | ~100A | - | - |
| 1700V | 2in1 | - | - | ~400A | TBD |
| 3300V | 2in1 | - | - | - | 750A |
| **Application** | | **Auxially equipment** | | | **Propulsion** |

The product lineup will realize coverage of the wide range for traction.


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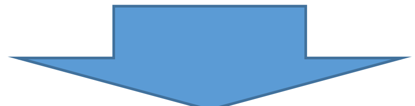
- ***High temperature operation***

→*Operation temperature was expanded to 175deg.C*

- ***Low Power Dissipaption***

→*Dissipation loss was decreased by 42%*



- ***Down sizing (High Power Density)***

→*Output current was expanded by 66%*

→*Maximum rated current was expanded from 450A to 750A*

*All-SiC module will contribute greatly to the high efficiency and miniaturize power conversion systems in the future.*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# *Thank you very much!!*

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