MITSUBISHI ELECTRIC
Changes for the Better

6th and 7th Generation IGBT Module for Industrial Applications

Mitsubishi Electric Corporation

T.Radke K.Masuda

MITSUBISHI ELECTRIC CORPORATION

C-140917-01

MITSUBISHI ELECTRIC
Changes for the Better

Outline

1. Background

2. 6th generation IGBT module

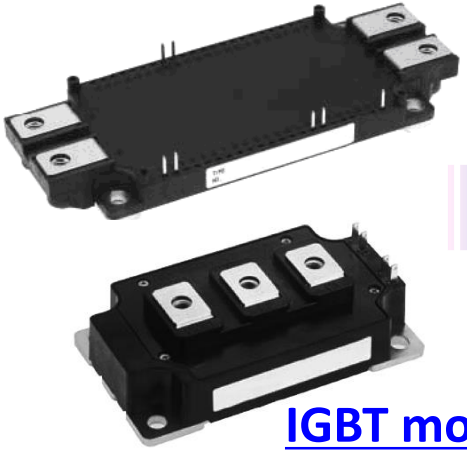
2.1 Thermal resistance
2.2 ΔTj-c Performance Benchmark
2.3 Chip comparison between 6th and 6.1th

3. 7th generation IGBT module

3.1 Package technologies
3.2 Chip technologies
3.3 Power Loss
3.4 Summary

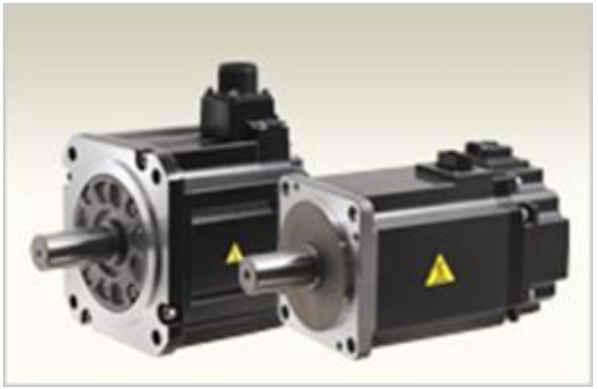
1. Background

Industrial applications



IGBT module

Renewable power generation



Motor control

Medical device

UPS

Robotics

Lift

Common requirements are “High reliability”, “Low loss”, “Compact” and “Lightweight”.

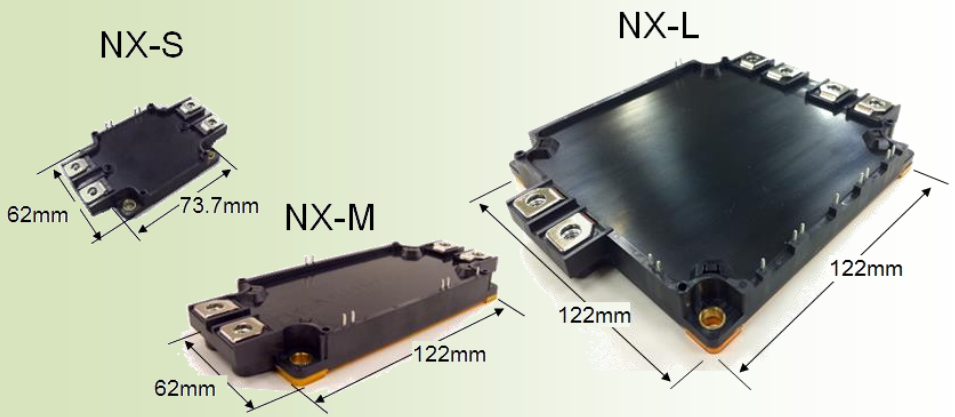
2. 6th generation IGBT module

Features

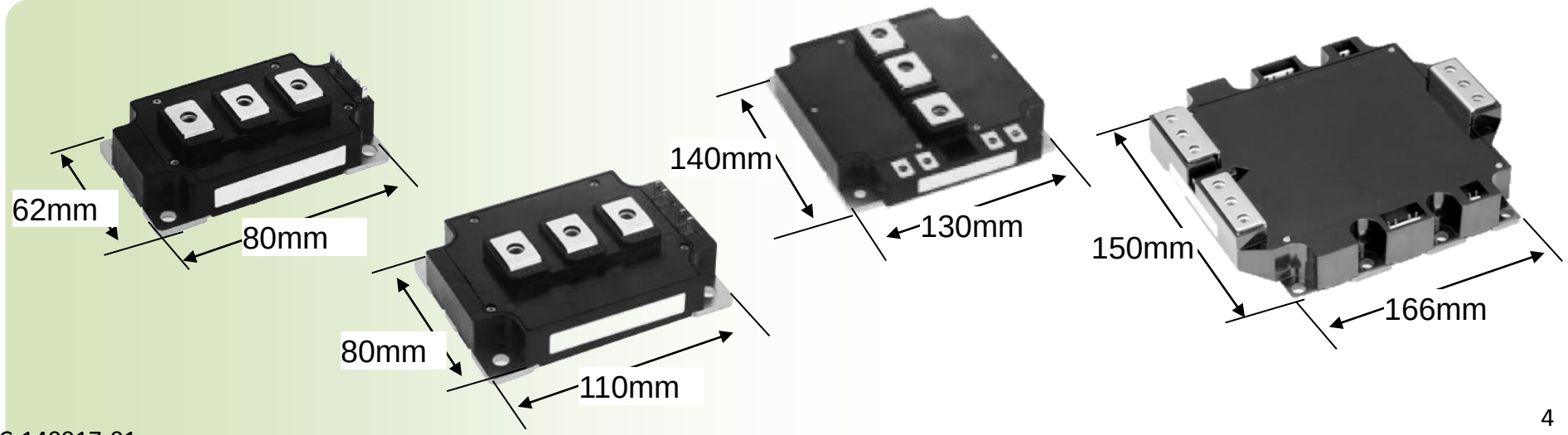
Feature

- **Low Rth(j-c) by AlN isolation**
- **2 types of chip technologies appling 6th gen. and 6.1th gen. chip**
- Tjmax=175degC
- Low gate capacitance

Package type NX-Series

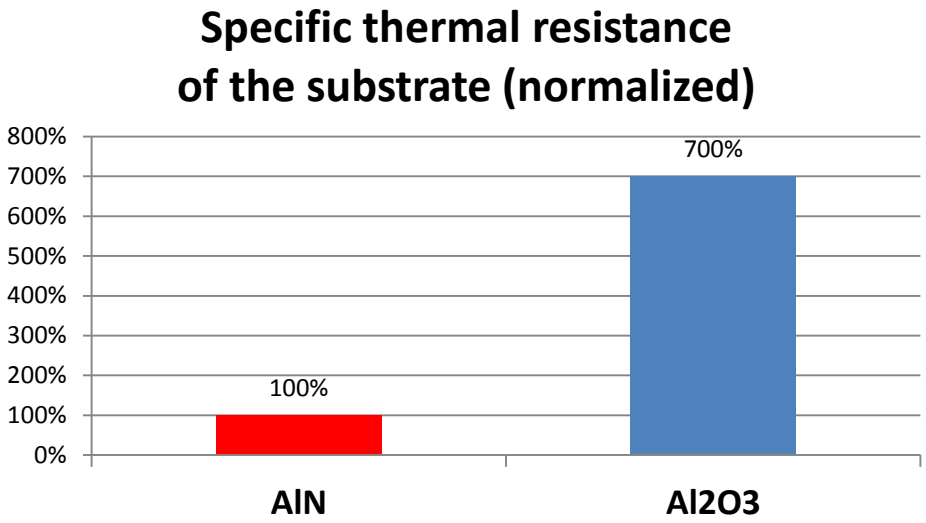


Package type MPD, S-Series



C-140917-01

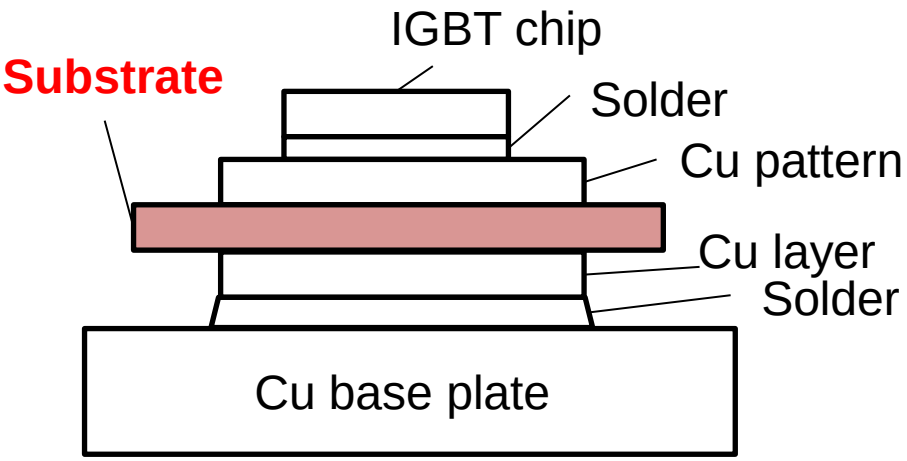
2.1 Thermal resistance



Mitsubishi 6th Gen. → AlN

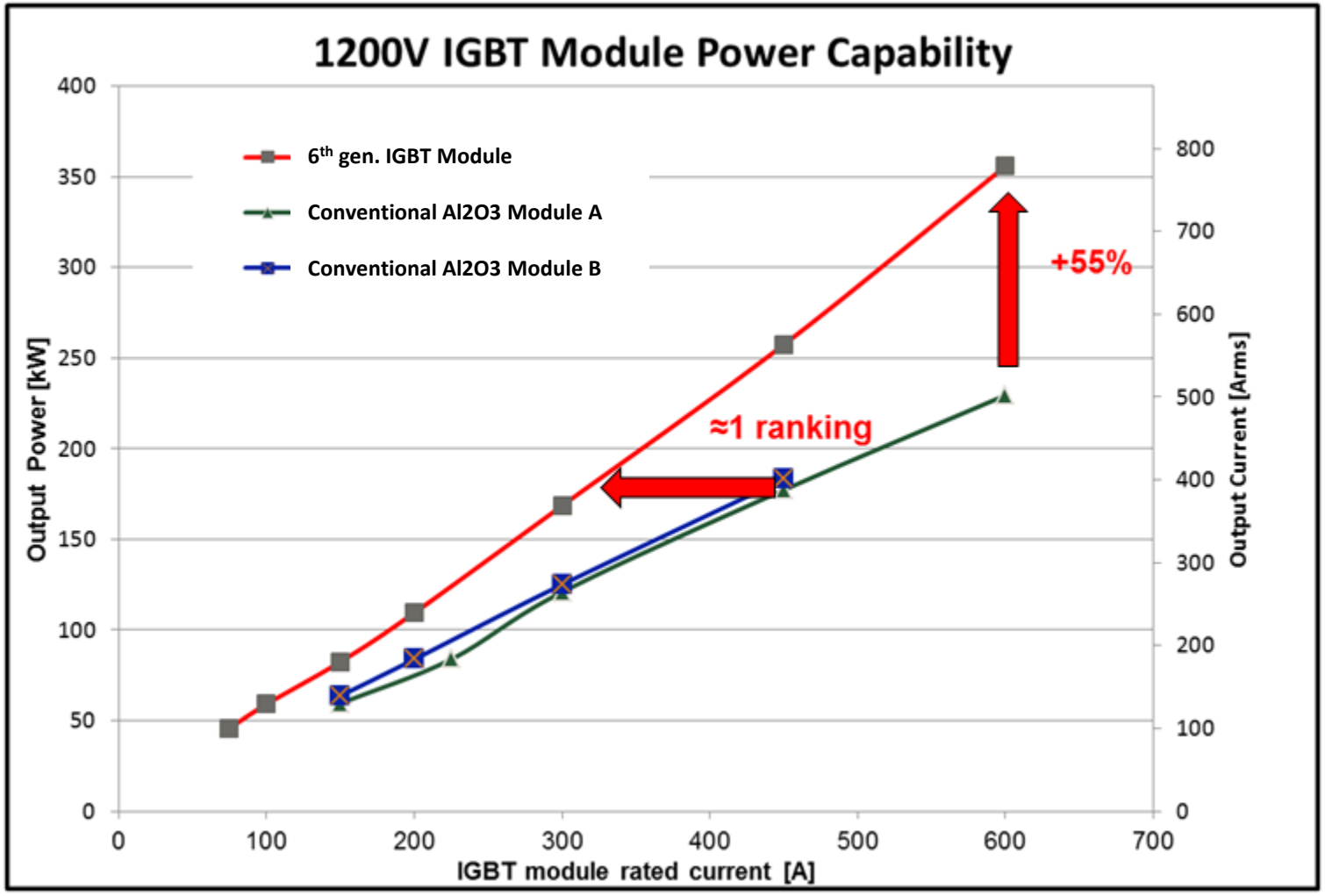
Conventional module→ Al_2O_3

Structure of IGBT module



Module Rating	6th Gen. $R_{th(j-c)}Q$	Al_2O_3 Module $R_{th(j-c)}Q$	Al_2O_3 Module is x % Higher
100A / 1200V CIB	0.20 K/W	0.29K/W	+45%
150A / 1200V (6in1)	0.013 K/W	0.02 K/W	+54%
450A /1200V (2in1)	0.044 K/W	0.066 K/W	+50%

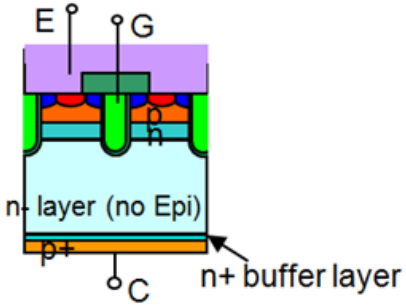
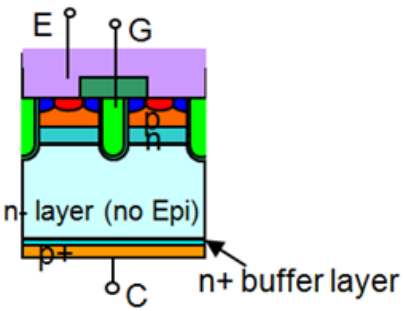
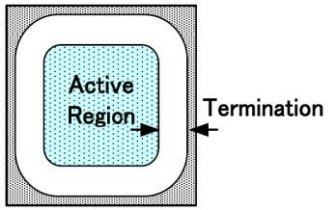
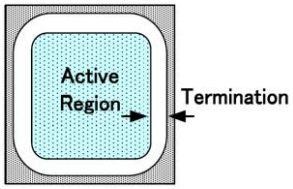
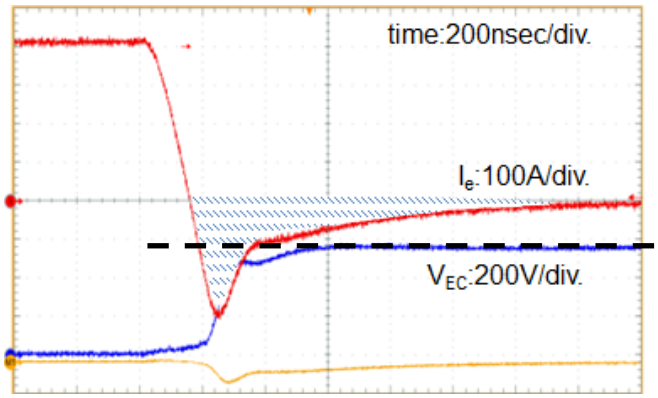
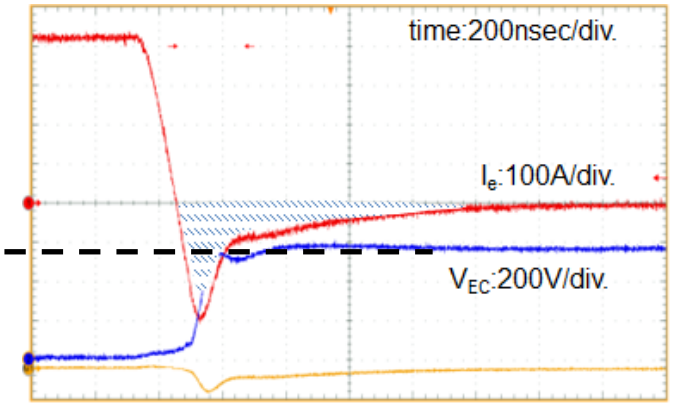
2.2 ΔT_{j-c} Performance Benchmark



ΔTj-c=35℃（T_{case}=115℃, T_j=150℃) , f_c=5kHz , cos(φ)=0.8 , V_{CC}=600V , m=0.9

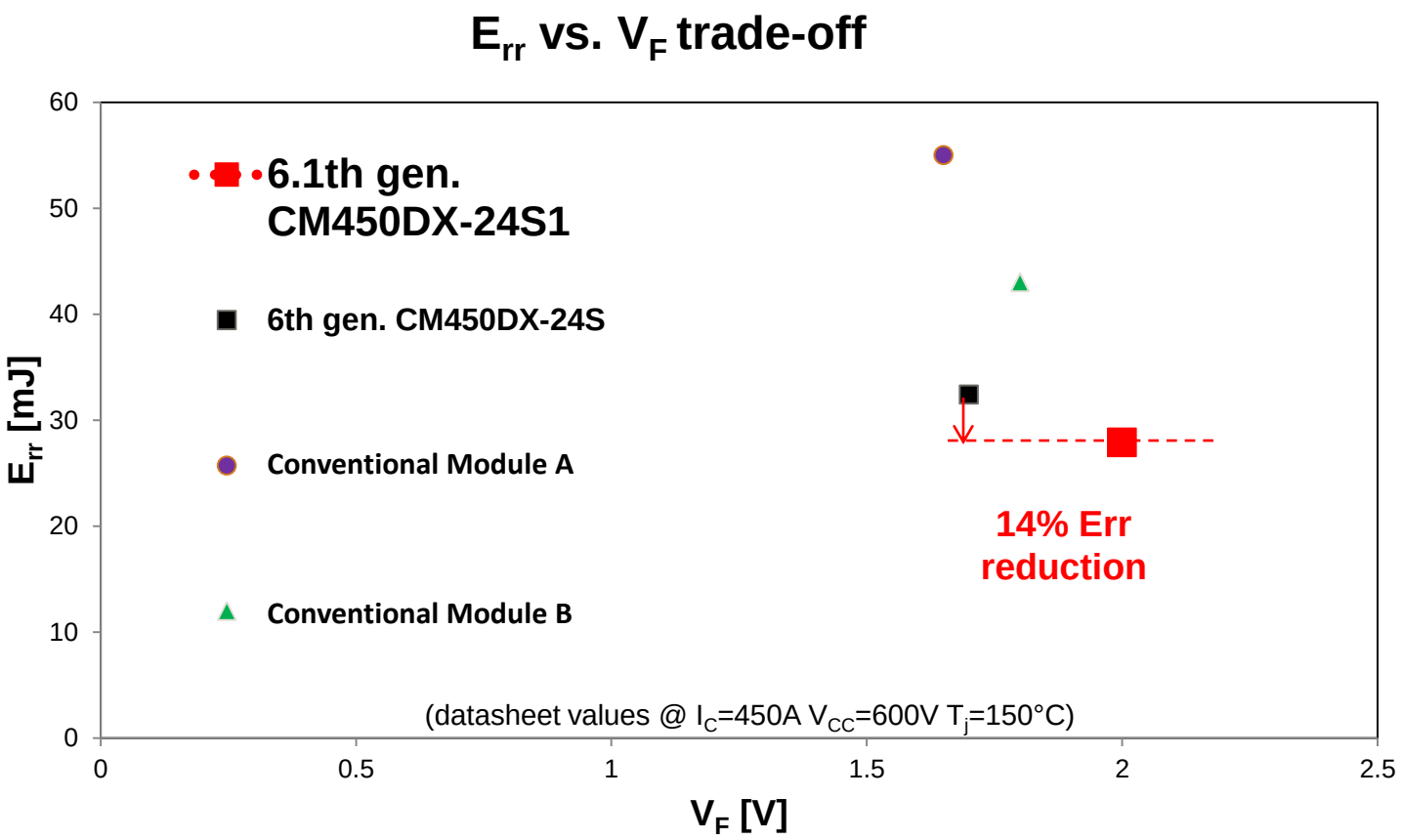
C-140917-01

2.3 Chip comparison between 6th and 6.1th

	6th Gen.	6.1th Gen.
IGBT structure		
	no change	
IGBT Termination		
	Shrinking	
Diode		
	Err is reduced	
	CM450DX-24S(6th gen.)	CM450DX-24S1(6.1th gen.)

Condition : V_{CC}=600V, I_c=450A, V_{GE}=+15/-15V, R_G=0Ω, T_j=150℃

2.3 Diode Chip trade-off



6.1th gen. diode trade-off is optimized for lower switching losses

2. 6th generation IGBT module

■6th gen. IGBT module

1.Package technologies

Low Rth(j-c) by AlN isolation

→High power capability compared with Al_2O_3 module.

→Same ΔTj as Al2O3 module by 55% more power @600A

2. Chip technologies

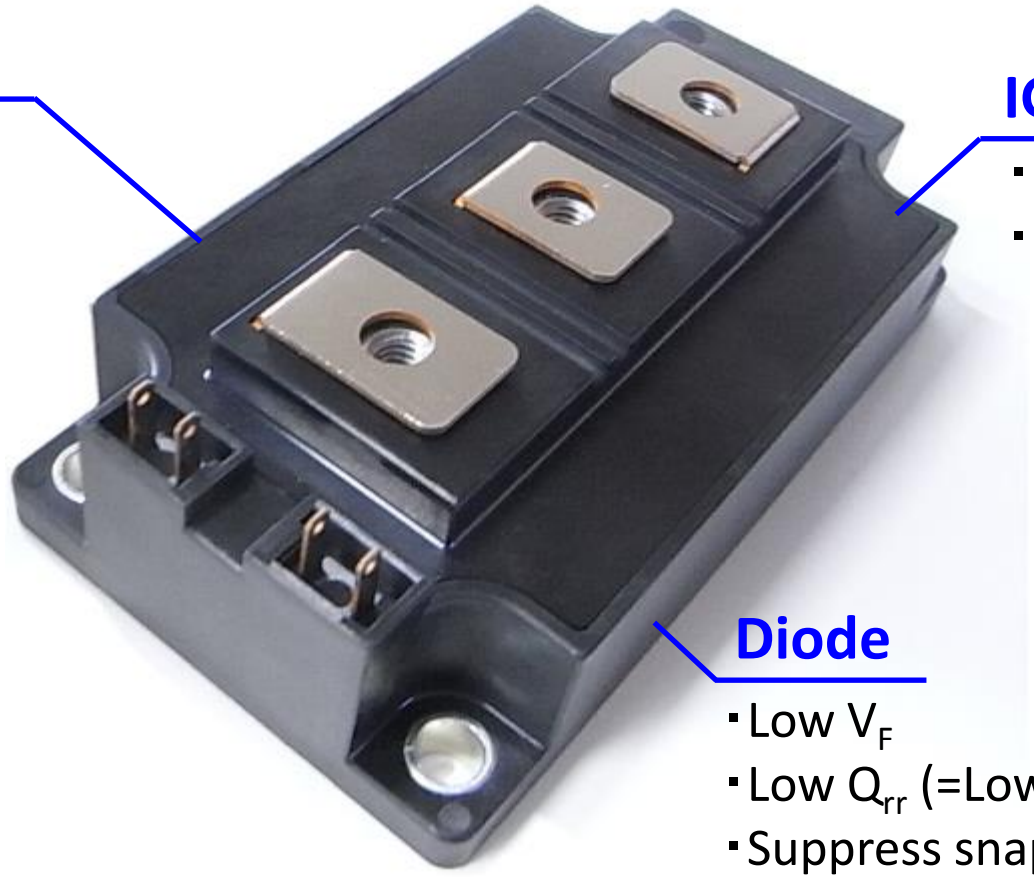
→6.1th is optimized for high fc application

- Package optimization
- Chip technology improvement

7th gen. IGBT module

3. 7th generation IGBT module

■Concept of 7th gen. IGBT module



Package

- High reliability
- Low inductance
- Compact
- Lightweight

IGBT

- Low V_{CEsat}
- Low E_{off}

Diode

- Low V_F
- Low Q_{rr} (=Low E_{on} + E_{rr})
- Suppress snap-off recovery

High reliability, Low losses, Compact and Lightweight.

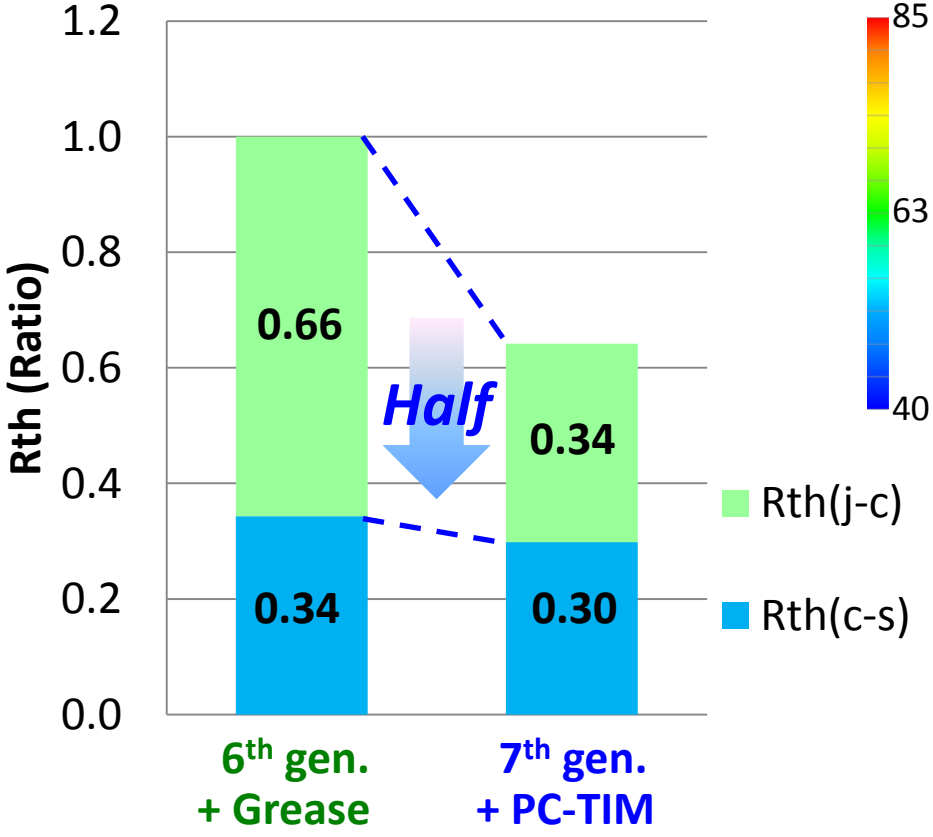
3.1.1 Substrate

■Thermal resistance

※PC-TIM: Phase Change – Thermal Interface Matrial

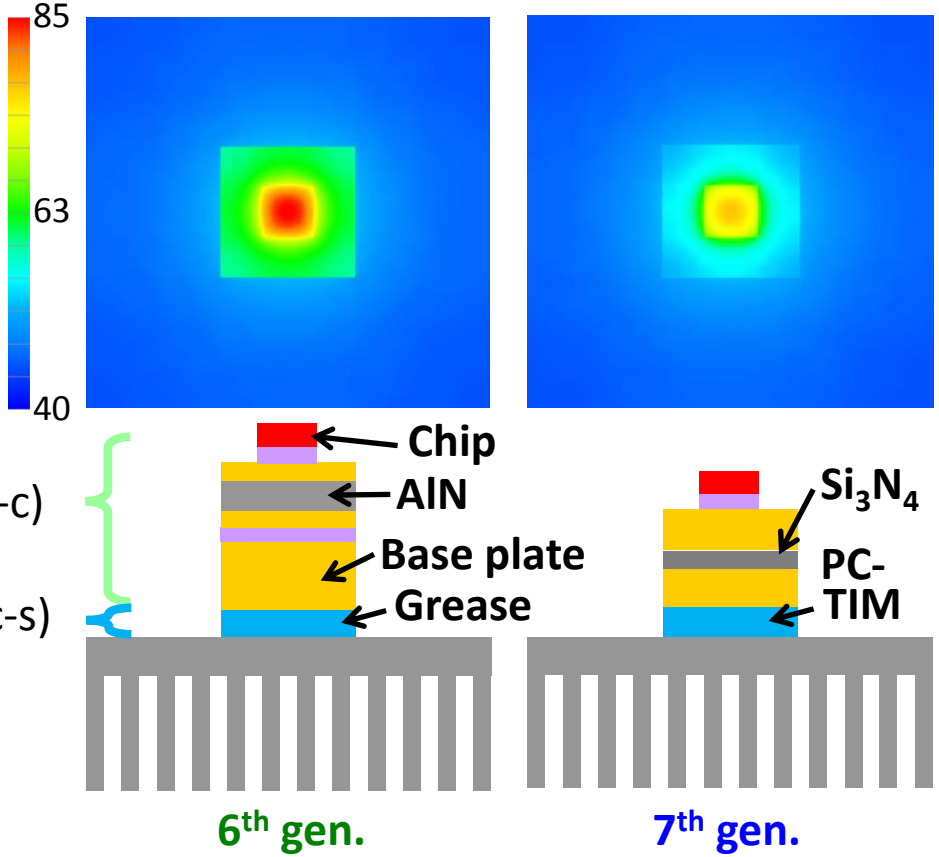
Thermal resistance simulation

Condition: Same chip size.



Heat dissipation simulation

Condition: Ta=25 ℃, U=800 W/m²・K, Same chip size.

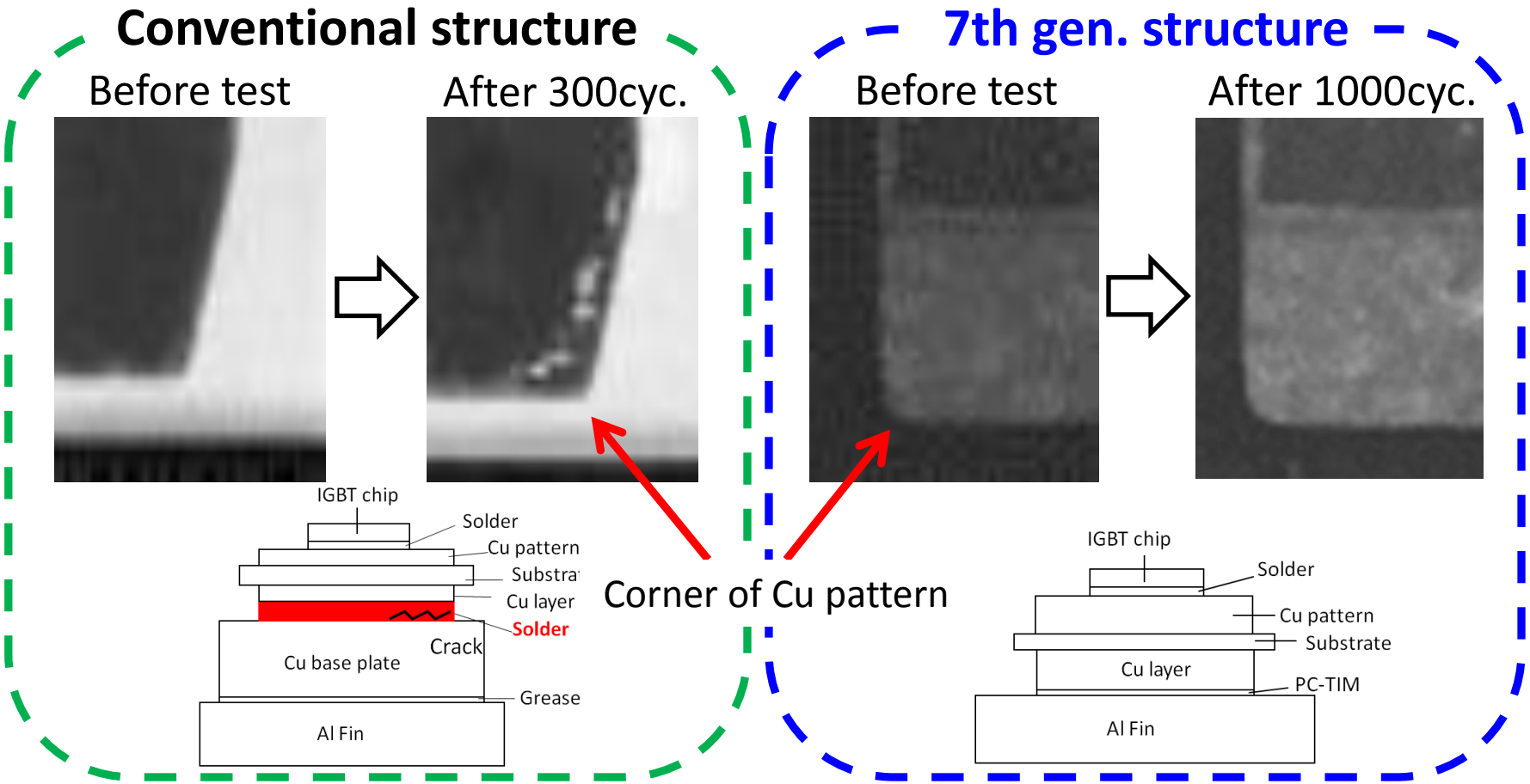


The Internal thermal resistance of the 7th gen. is a half of the 6th gen.

3.1.1 Substrate

■ Experimental result

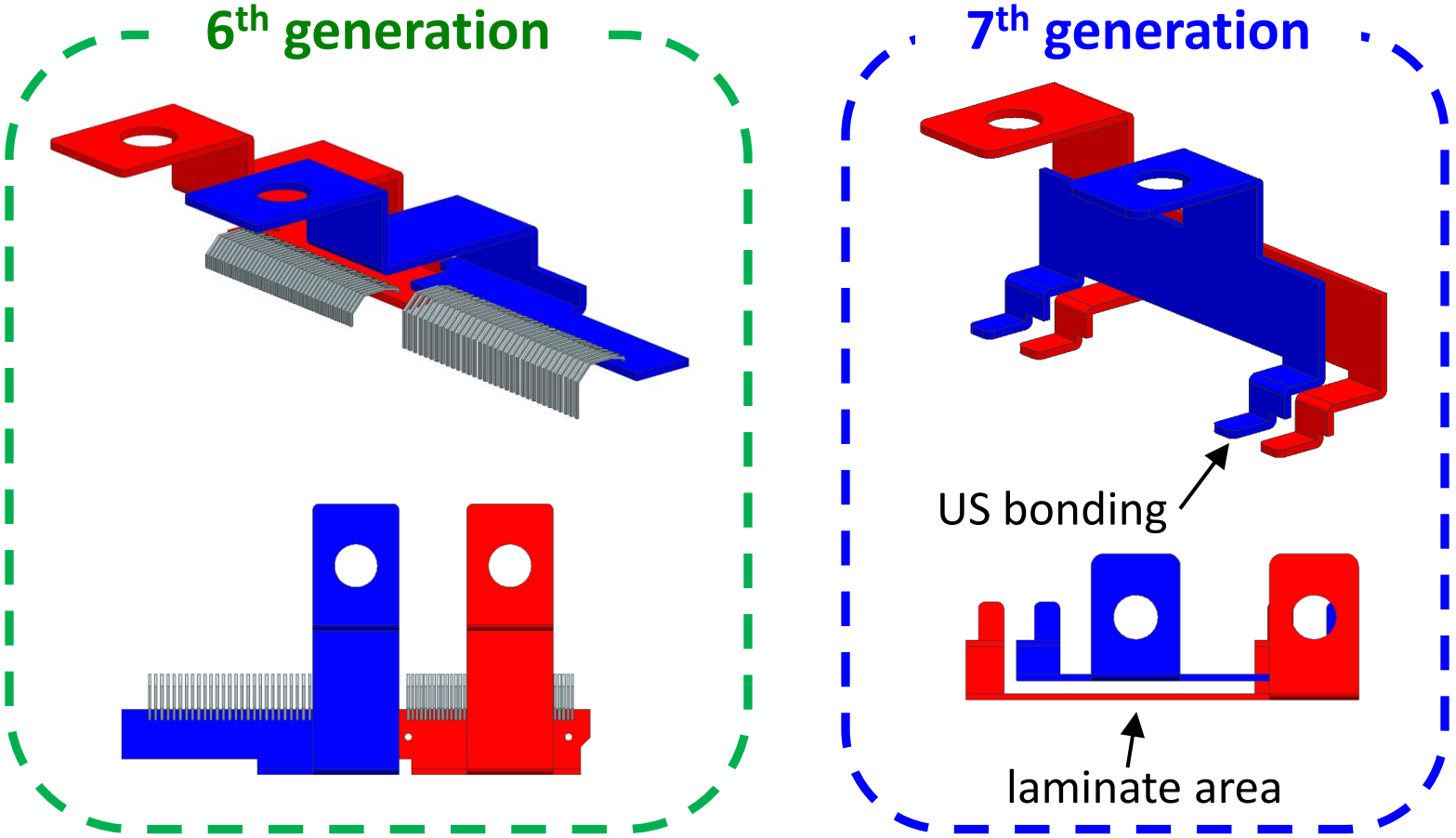
SAT pictures before and after thermal cycling test (-40～125℃)



No crack had been observed until 1000cyc., which is 3 times larger.

3.1.2 Main terminal

■ Package inductance



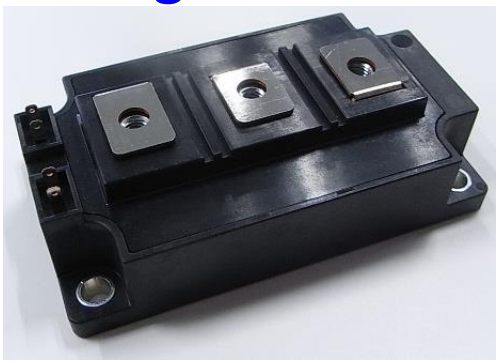
By using laminated main terminals, package inductance is reduced by 30%.

3.1.3 Results

■1200V/600A, dual

6th generation

7th generation



Item	6th gen.	7th gen.	Improvement
Thermal resistance (Ratio)	1	0.5	Reduction of **50**%
Thermal cycling (Ratio)	1	3 ～	Increasing **3** times
Inductance (Ratio)	1	0.7	Reduction of **30**%
Package size (W*D*H)	110 × 80 × 29 mm	**108 × 62** × 30mm	Reduction of **20**%
Weight	580 g	320 g	Reduction of **45**%

New compact and lightweight package is realized.

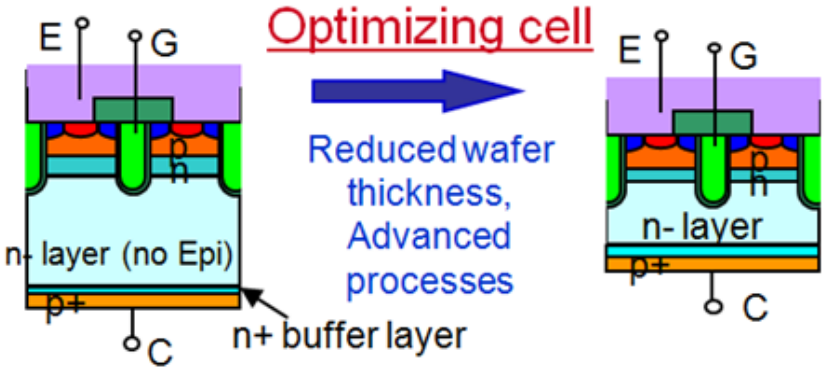
3.2 Chip technologies

3.2.1 IGBT chip

■ Cross section structure

6th/6.1th gen.

7th gen.



Key point

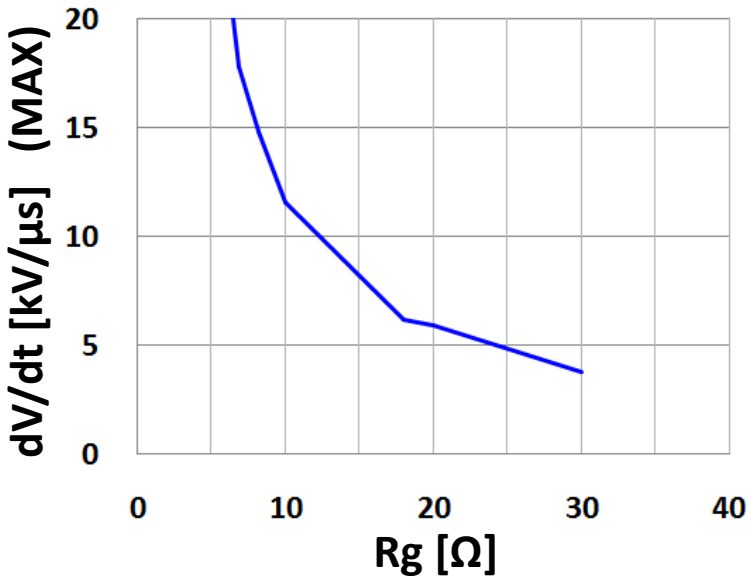
1. Thin N^- drift layer

Low V_{CEsat}

Low E_{off}

2. Optimized cell design

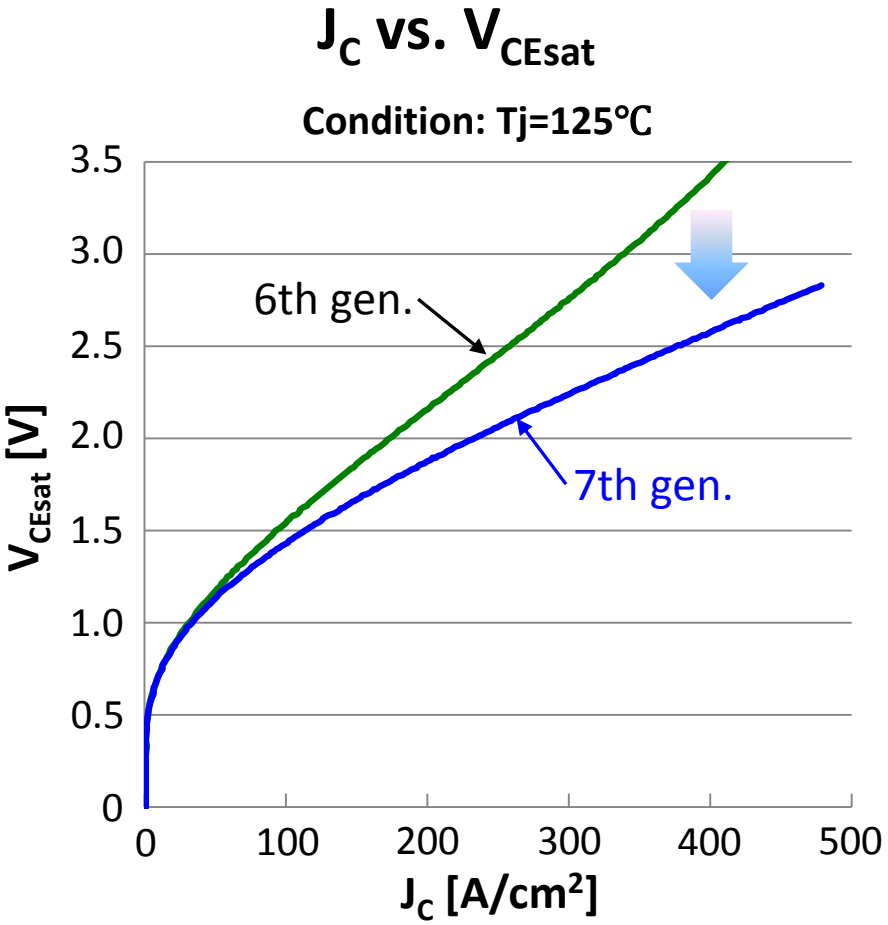
easier controllability of dV/dt by Rg

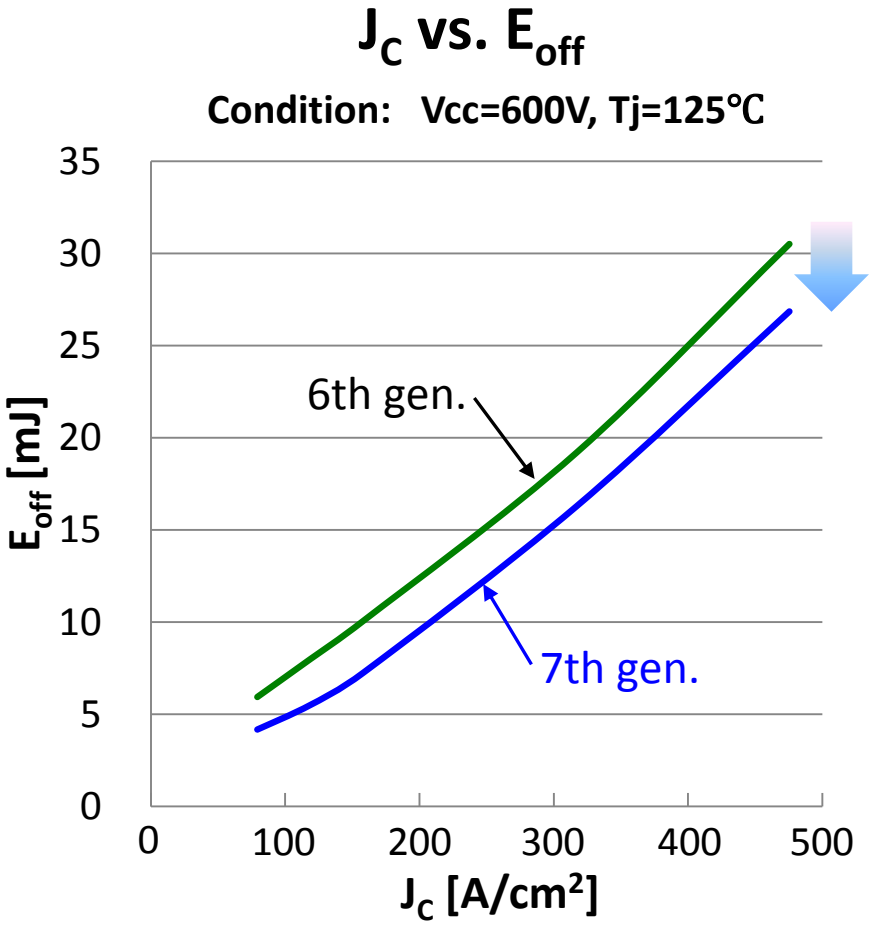


7th gen. IGBT has better static and dynamic characteristics.

3.2.1 IGBT chip

Experimental result





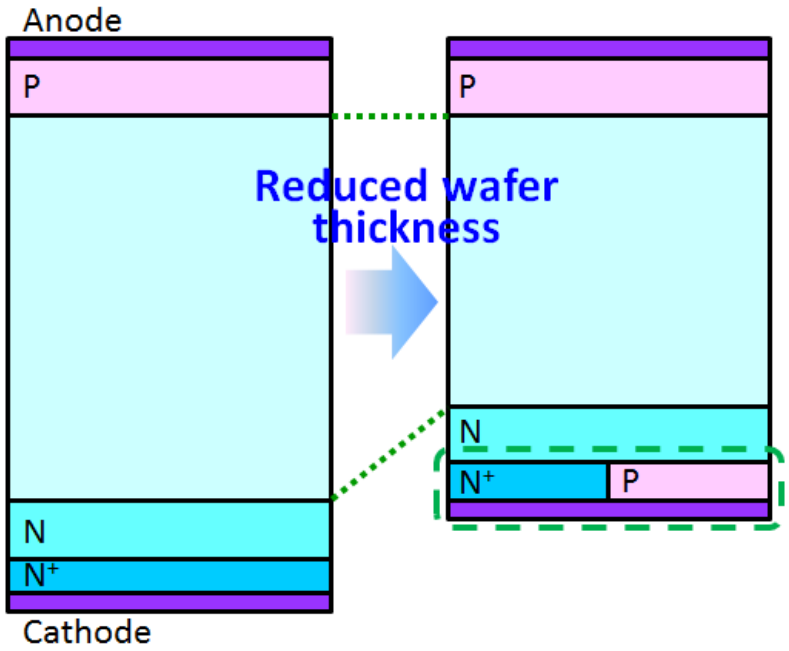
The 7th gen. IGBT has the better V_{CEsat} and E_{off}.

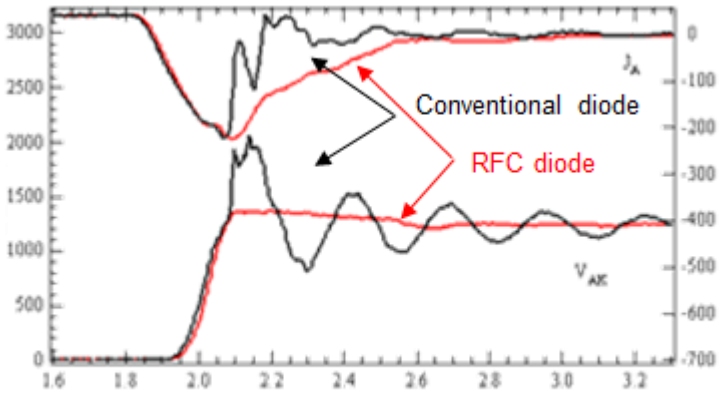
3.2.2 Diode chip

■Cross section structures

※RFC - diode: **R**elaxed **F**ield of **C**athode - diode

6th gen.: N buffer diode　　7th gen.: RFC diode



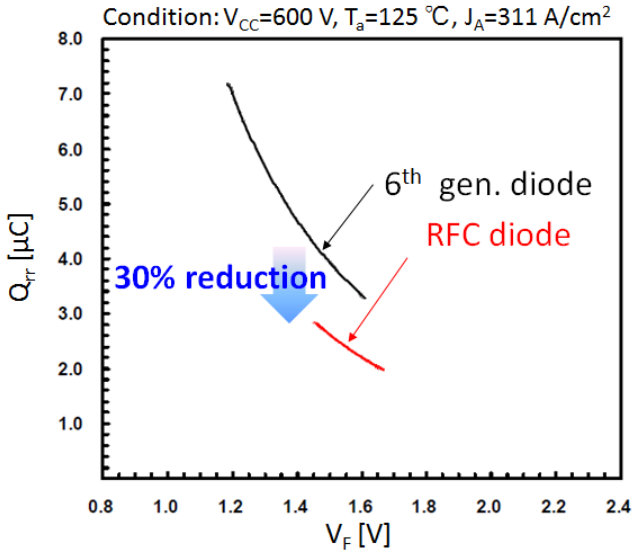


Key point

1. Thinner N drift layer

Low V_F

Low Q_{rr} → Low (E_{rr} + E_{on})



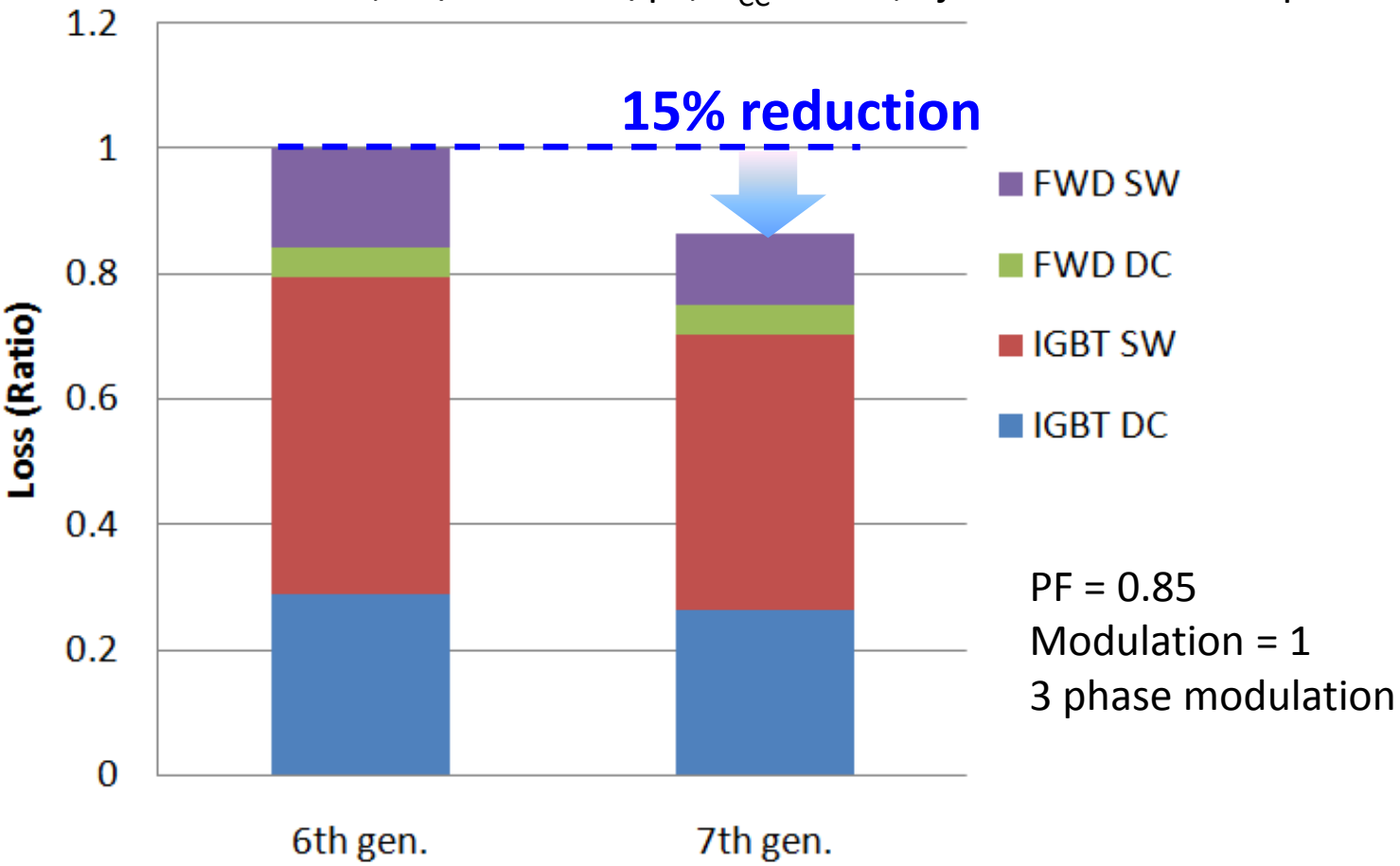
2. N^+/P cathode structure

Suppress snap-off recovery

3.3 Power Loss

Power loss simulation

Condition: fc=10 kHz, dv/dt =10 kV/μs, V_{CC}=600 V, Tj=125 ℃, Same chip size



PF = 0.85
Modulation = 1
3 phase modulation

In 7th gen. IGBT module, the power loss is reduced by 15%.

3.4. Summary

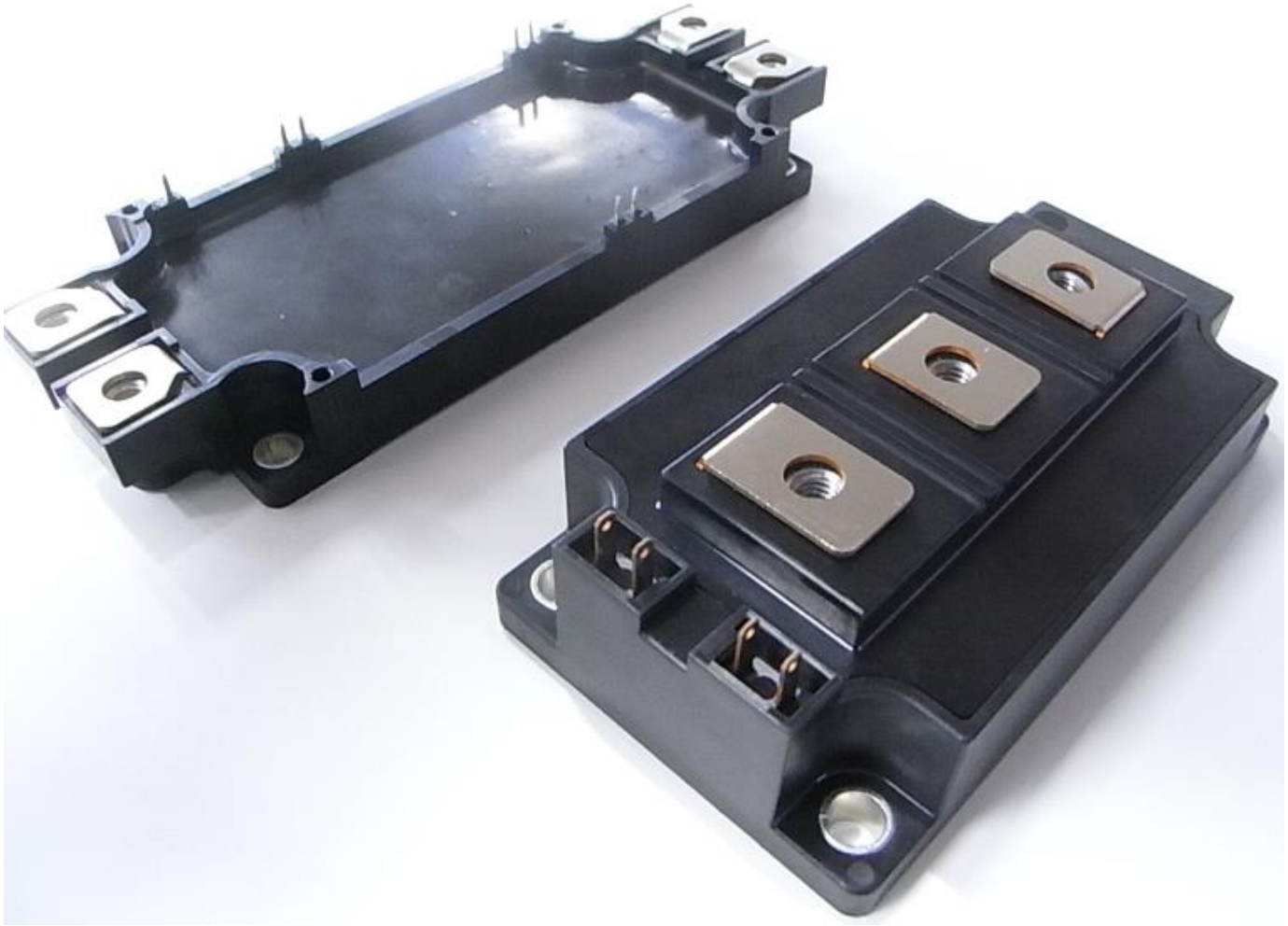
Package technologies

New Compact and Light weight package
50% reduction of internal thermal resistance
3 times higher thermal cycle capability or more
30% reduction of package inductance

Chip technologies

30% reduction of Q_{rr}-V_F trade-off
15% reduction of total loss in inverter operation

High performance in a **Compact** and **Light weight** module.



Thank you for your kind attention!

Innovative Power Devices for a Sustainable Future