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CRRC

# Introduction of CRRC IGBT Products

# Content


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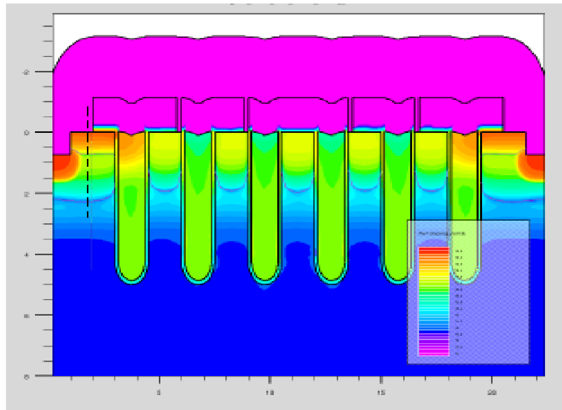
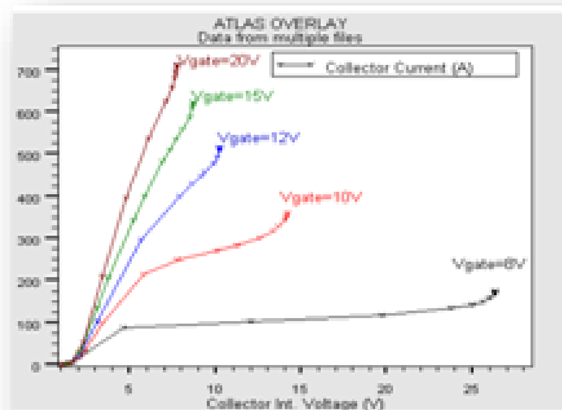
# The only Professional 8inch IGBT production line in China

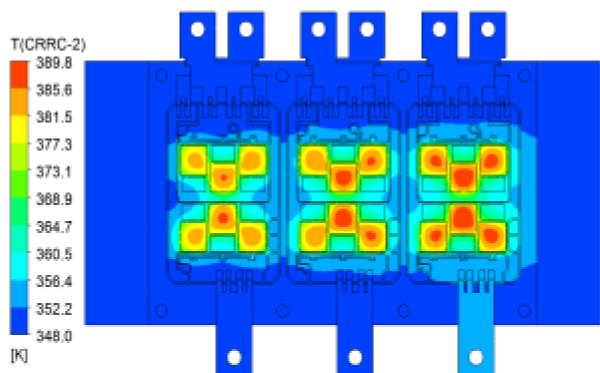
- High Precision 2D&3D power semiconductor Design & Simulation Workshop
- 8inch 0.35um process capability to ensure parameter uniformity
- Advanced ion implantation to get precise control of carrier lifetime
- Excellent etching to realize fine geometry trench gate
- Grinding to thickness of 50um to ensure production of LV series
- Copper Metallization to increase reliability

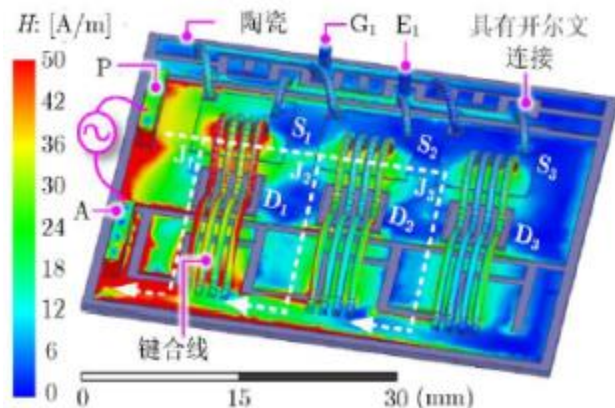




# 750V～6500V IGBT assembly & testing capability

- Automatic process to ensure the yield and quality
- MES manufacturing system to monitor process and predict trend
- Intelligent storage, automatic material distribution
- 3D X-ray to inspect soldering quality
- Lead free soldering
- Customized design and double side cooling module available

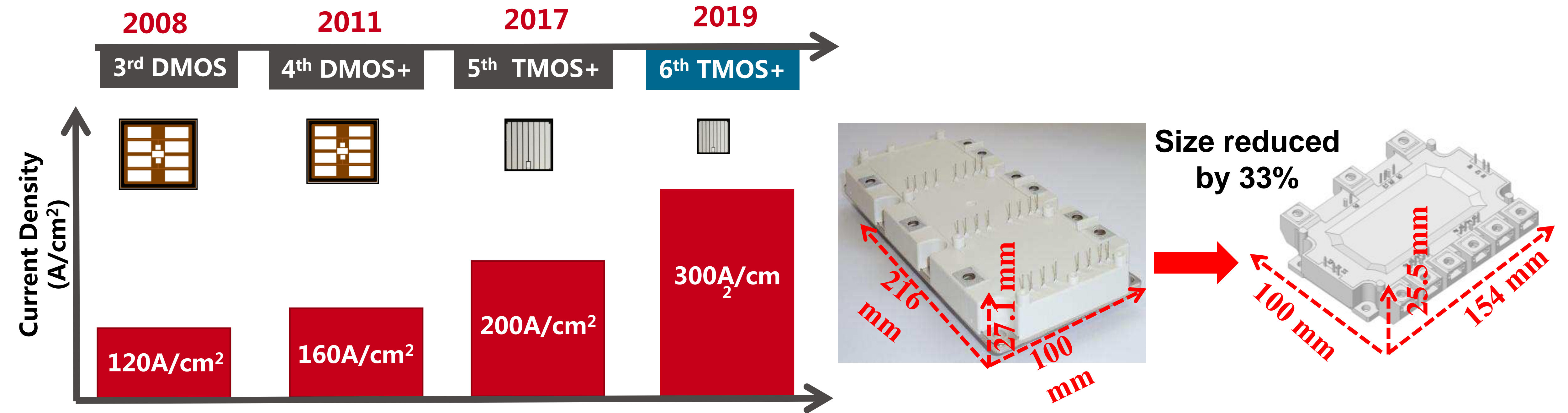


# Part 1 CRRC IGBT Platform

## IGBT Die Technology

- Current density of CRRC IGBT die has been kept increasing
- CRRC IGBT Technology has evolved to 4th DMOS+(Enhanced planar gate) and 5th TMOS+(Trench + Field Stop + Carrier Storage )
- 6th TMOS+ based on Fine Geometry-trench gate technology released by end of 2018





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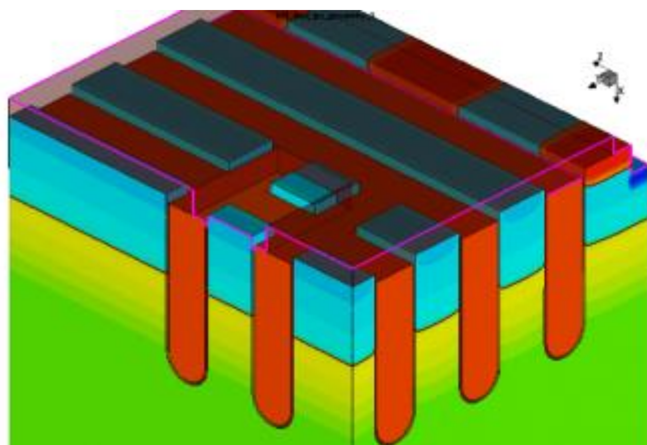
# Part 1 CRRC IGBT Platform

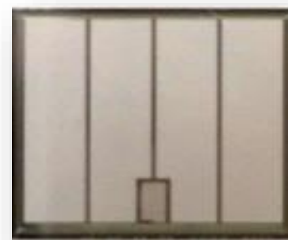


## The **5th-generation TMOS** --- (Infineon IGBT4 )

- Already apply to 750V-1200V IGBTs, will cover full voltage range
- Trench+FS+Carrier Storage (TMOS+)technology
- High power density, low conduction loss



TMOS+ 3D model



750V/200A IGBT die

1200V/200A IGBT die

# Part 1 CRRC IGBT Platform



**The 6th-generation** trench IGBT --- (**Infineon EDT2** )

- based on Fine Geometry-trench gate technology to improve power density
- Recessed Emitter Trench (RET) Technology applied, decreasing process difficulties
- Process width down to sub-micron level, power density improved greatly.

A Novel 1700V RET-IGBT (Recessed Emitter Trench IGBT) Shows Record Low $V_{CE(ON)}$, Enhanced Current Handling Capability and Short Circuit Robustness

CRRC RET technology

IGBT4
CRRC: 5th
CRRC: 6th

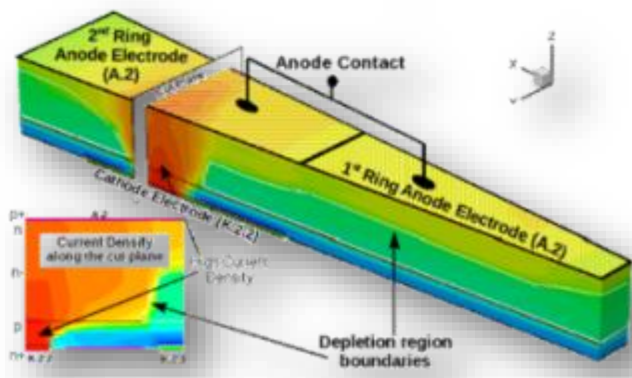
$E_{OFF}$ (mJ)

$V_{CE(ON)}$ (V)

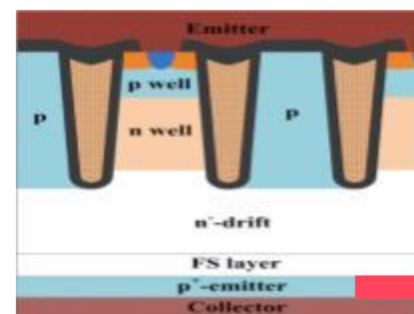
Performance compare

## The 7th-generation

- Fine Geometry-trench gate + Reverse Conducting : **Beyond competitor**
- Reverse Conducting : **Integrate IGBT and FRD** in one chip, improve power density and module reliability
- Module temperature fluctuations reduced



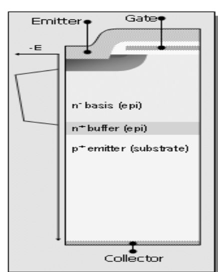

Reverse conducting IGBT 3D simulation



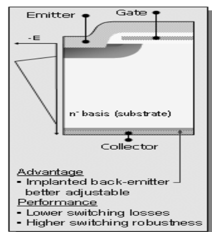

Fine Geometry-trench gate + Reverse Conducting

# Part 1 CRRC IGBT Platform

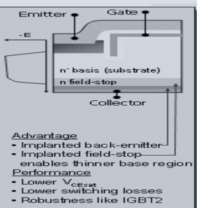
## IGBT Die Technology



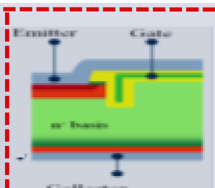
Siemens Era



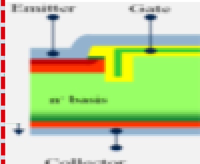
IGBT1/2



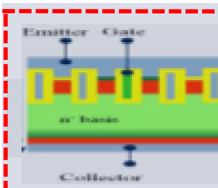
IGBT3



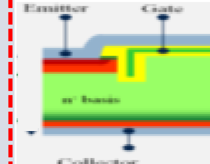
IGBT4



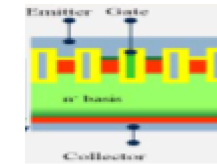
IGBT5 (Copper)



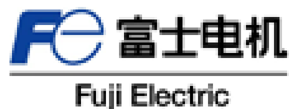
EDT2

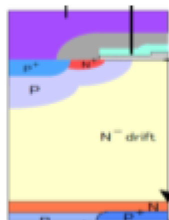


IGBT6 (IR Tech)

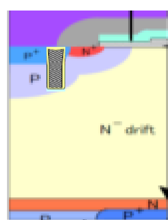


IGBT7 (EDT2 for Industry)

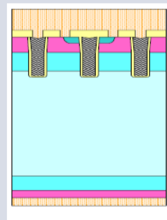




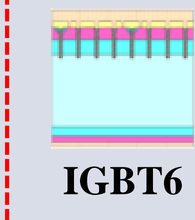
IGBT1-3 Plannar



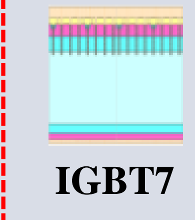
IGBT4 Trench



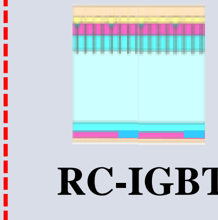
IGBT5



IGBT6

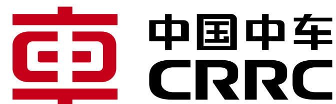


IGBT7



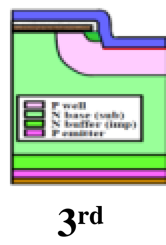
RC-IGBT7

Automotive IGBT



1st PT

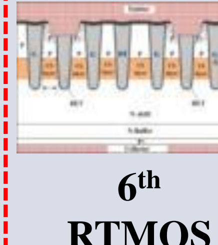
2nd NPT



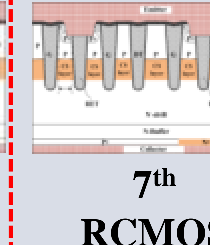
3rd DMOS

4th DMOS+

5th TMOS



6th RTMOS



7th RCMOS

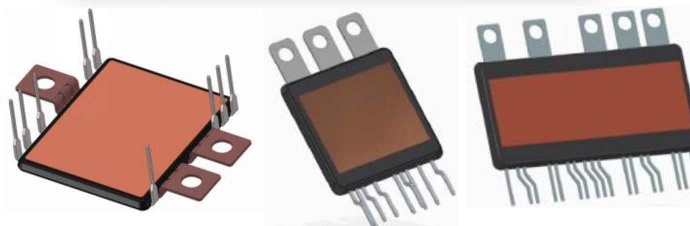
# Part 1 CRRC IGBT technique platform



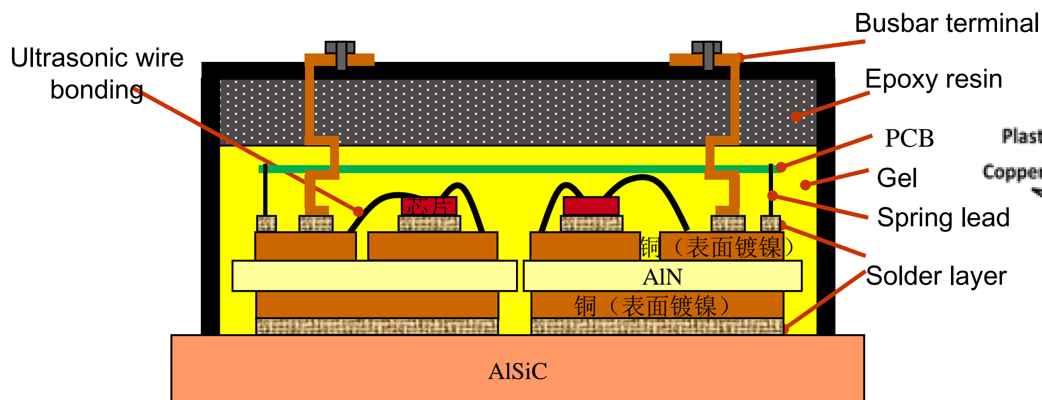
- Fully mastered Single-sided soldering, Double-sided soldering and press-pak packaging technology
- Continue to study in key technologies such as package interconnection, soldering, and heat dissipation

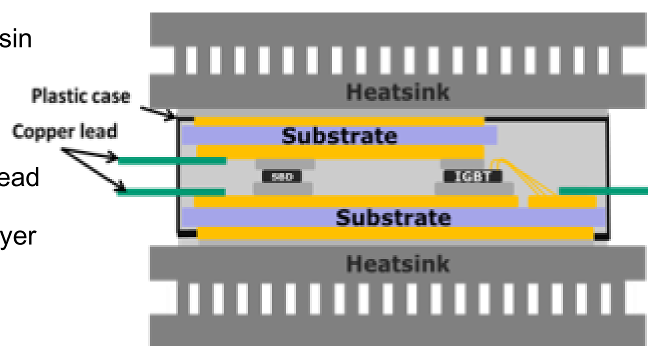
## Single-sided soldering

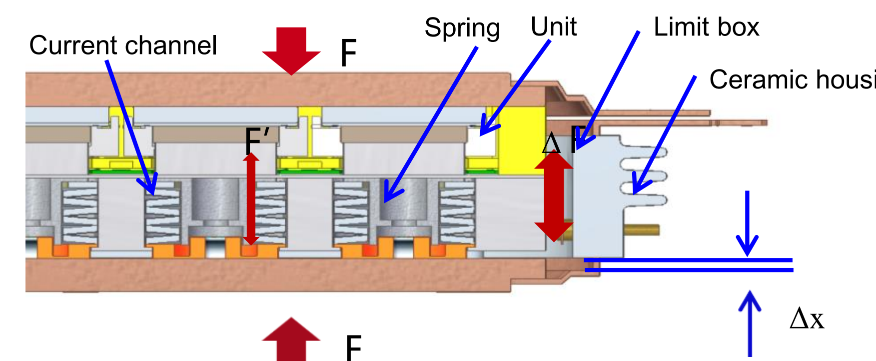
## Double-sided soldering



## Press-pak packaging



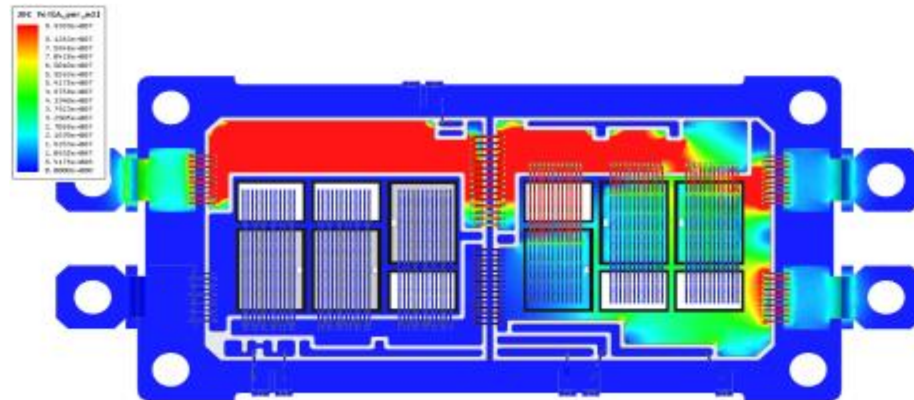
Interconnection technology

Soldering technology

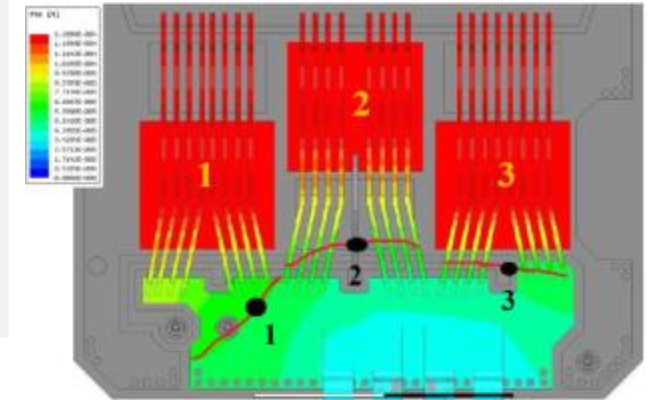
Thermal dissipation technology

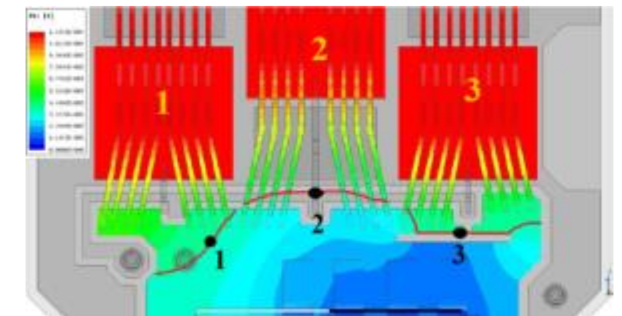
## Optimize interconnect layout design

- Half bridge module of upper and lower voltage drop difference (at rated current) <0.02V , Symmetry of upper and lower side
- Loop parasitic inductance <20nH , effectively suppress overvoltage
- Uniform stray parameters between parallel chips ensure device current sharing characteristics
- Common-emitter inductance optimization, effectively suppressing short-circuit current concentration



Current distribution simulation results of 600A/1200V M1 IGBT module DC current




Common-emitter inductance optimization comparison of 820A/750V S3+

# Part 1 CRRC IGBT technique platform

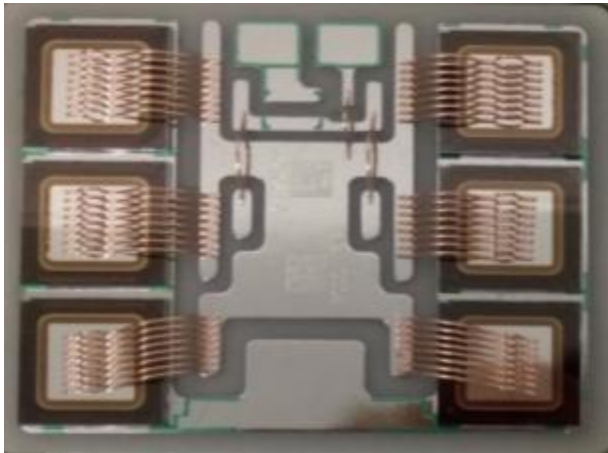




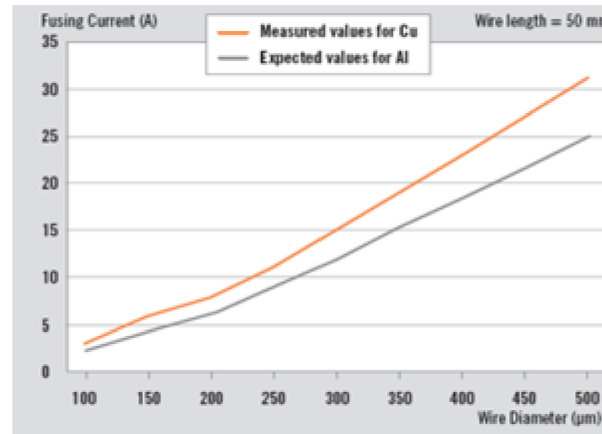
- **Copper bonding Vs AL bonding**
- Copper wire fuse current is about **25%** higher than aluminum wire
- Power cycle capability of copper wire is **10 times** than aluminum wire
- Excellent conductivity and heat transfer performance

| Material characteristic | Copper | Aluminum |
|---|---|---|
| Conductivity (%IACS) | 103.1 | 64.5 |
| Resistivity (μΩcm) | 1.7 | 2.66 |
| Thermal conductivity (W/m K) | 398 | 243 |
| Thermal expansion coefficient (μm/m K) | 16.5 | 23.6 |
| Young's modulus (GPa@300K) | 130 | 75 |

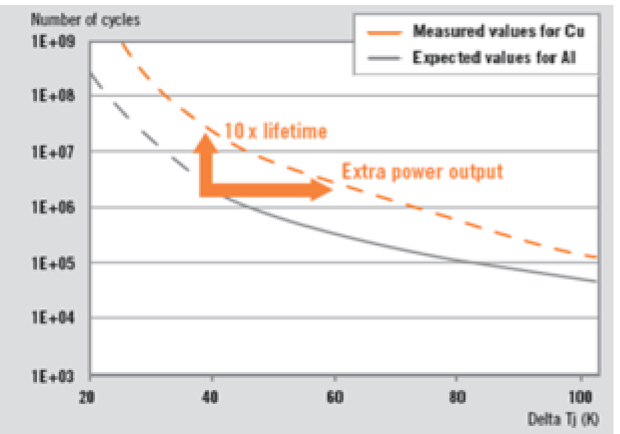
* Data from Heraeus Copper Data Sheet



Copper wire bonding sample




Fuse current



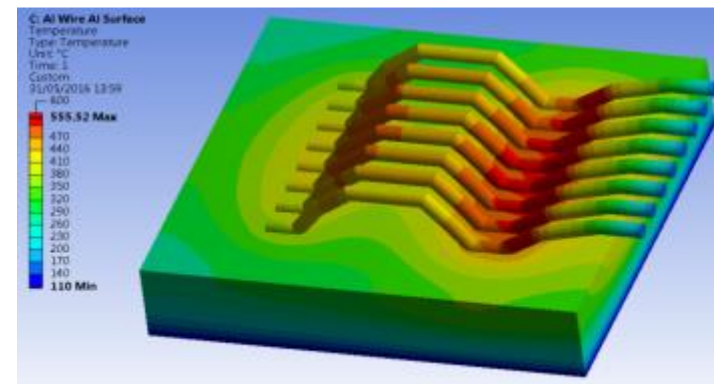

Power cycle capability

# Part 1 CRRC IGBT technique platform

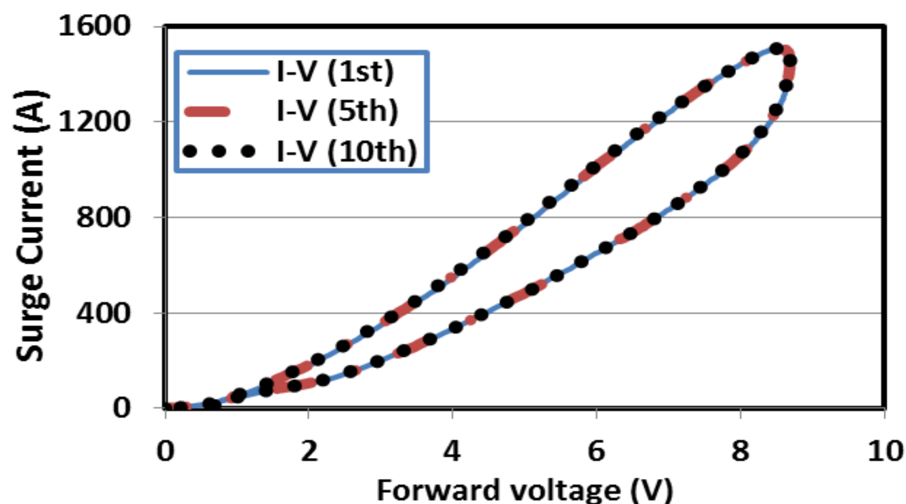




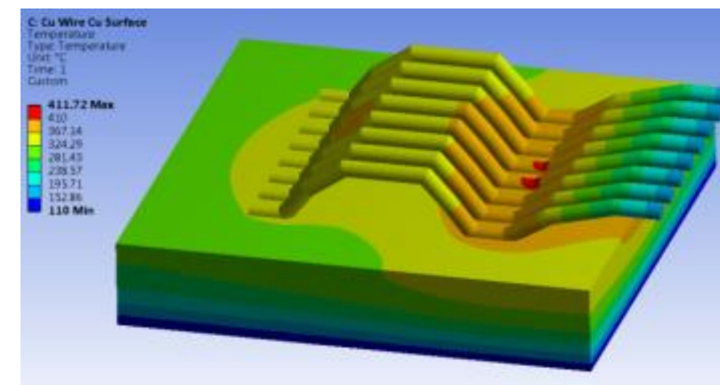
- **FRD surge and IGBT short circuit capability significantly improved**
  - Chip copper metallization + copper wire bonding technology
  - Optimized bonding parameters and layout
  - Surge current increased by 1.5 times , $I^2t$ increased by 2.2 times



Temperature distribution of aluminum metallization layer + aluminum wire bonding at 1000A surge current, , Tmax=**552**°C




Copper metallization + copper wire bonding test sample after 10 surge tests (1.5 times conventional surge current), I-V characteristics remain unchanged



Temperature distribution of copper metallization layer + aluminum wire bonding at 1000A surge current , Tmax=**411**°C

# Part 1 CRRC IGBT technique platform

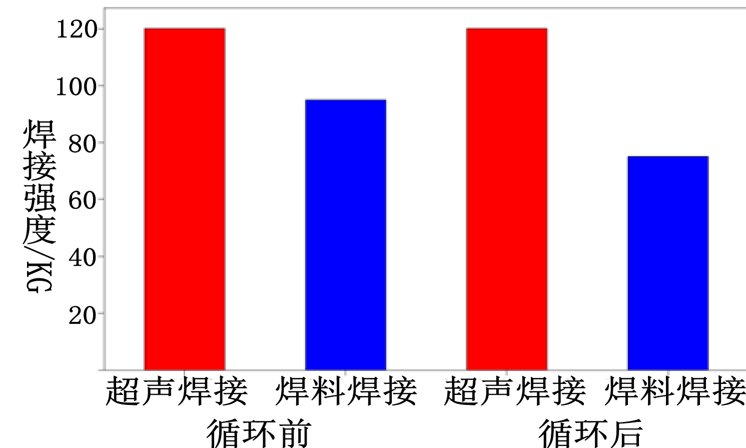


Interconnec-tion technology

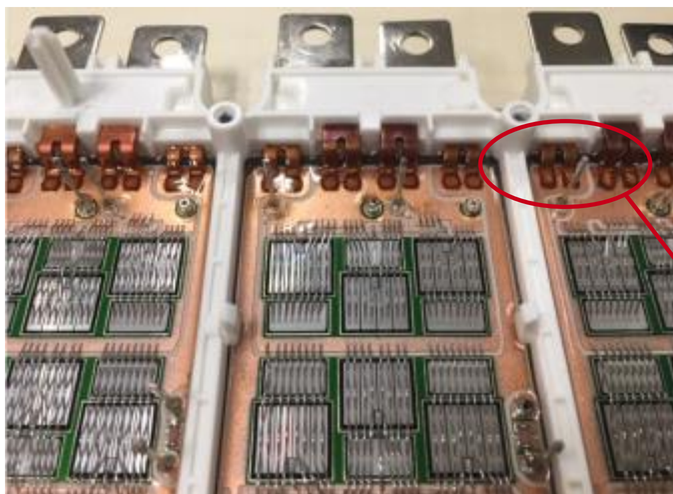
Soldering technology

Thermal dissipation technology

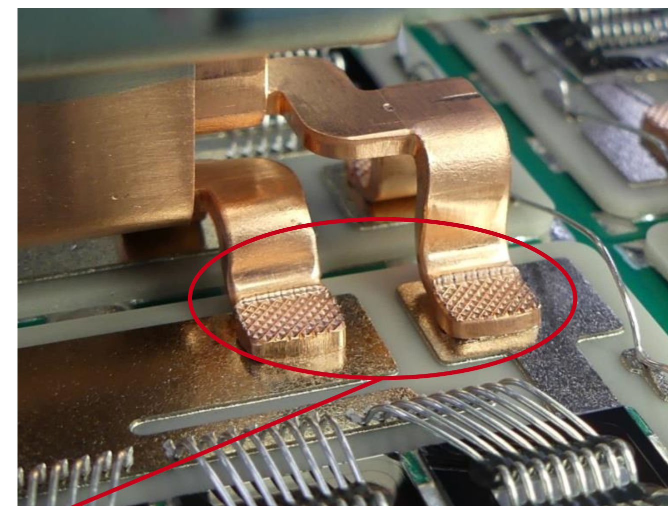
- **Power terminal ultrasonic welding technology**
  - High bonding strength and strong current carrying capacity
  - Lower contact resistance, lower loss
  - Withstand harsher mechanical environments and improve life expectancy




Comparison of welding strength after 100 temperature cycles ( -40 ° C - 150 ° C)



820A/750V S3+ module



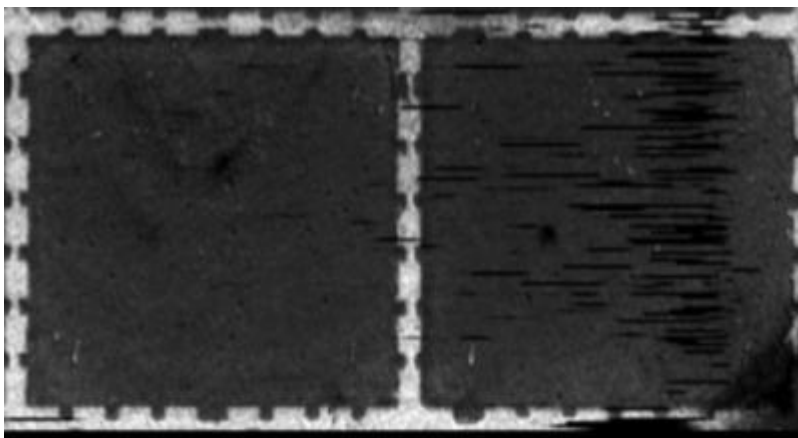
1500A/3300V E2 module

Ultrasonic welding terminal

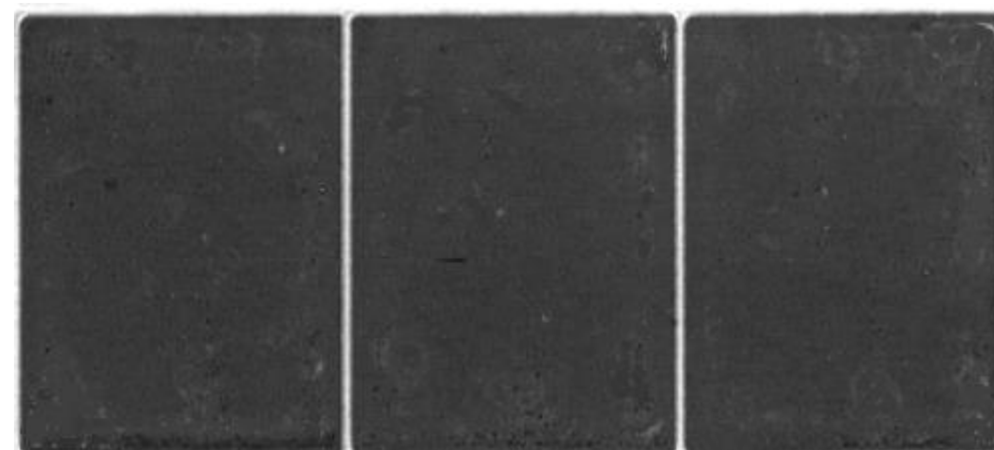
# Part 1 CRRC IGBT technique platform



- **Solder layer thickness control and optimization technology**
  - Special process control of weld thickness uniformity
  - Dimple technology to control weld thickness uniformity
  - Highly reliable solder system to improve thermal fatigue resistance by >2 times



Passive thermal cycle：△T=80 ℃，solder layer after 20000 times



Temperature shock：△T=200 ℃，solder layer after 300 times

# Part 1 CRRC IGBT technique platform



Interconnection technology

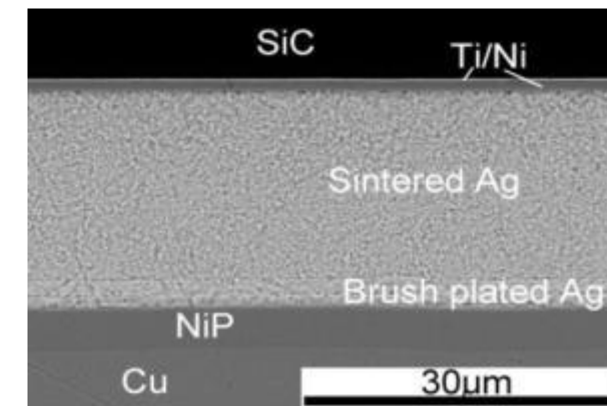
Soldering technology

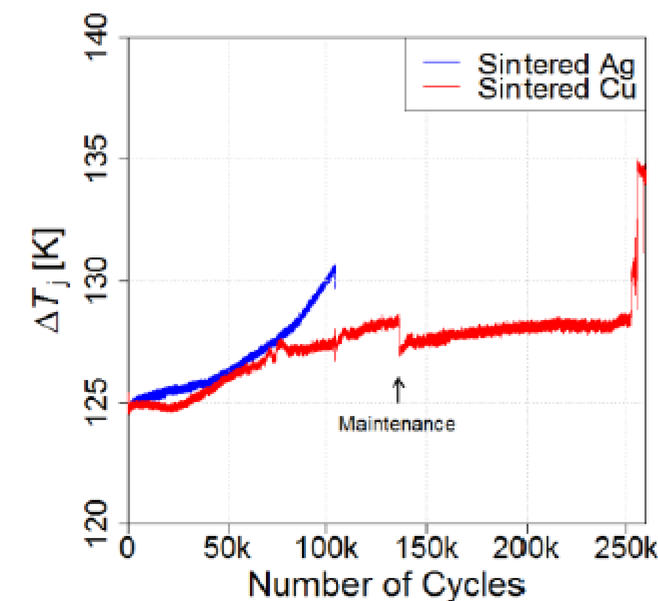
Thermal dissipation technology

- **Nano silver sintering technology**
- Characteristic：low temperature (~250℃)、low pressure (~5MPa)、short period (~5min)
- Silver sintered layer has high melting point, high electric / thermal conductivity and other characteristics
- Highly improved thermal shock and reliability lifetime capability

| Material characteristic | Silver sintering layer | Sn-Pb solder layer | Sn-Ag solder layer |
|---|---|---|---|
| Process temperature (°C) | <300 | 217 | 260 |
| Maximium operation temperature (°C) | 710 | 183 | 221 |
| Melting point (°C) | 961 | 183 | 221 |
| Conductivity (MS/m) | 41 | 6.8 | 7.8 |
| Thermal conductivity (W/mK) | 250 | 51 | 70 |
| Thermal expansion rate (ppm/K) | 19 | 25 | 28 |

Comparison of characteristics between silver sintered layer and ordinary solder layer




Power cycling capability using silver sintering technology

# Part 1 CRRC IGBT technique platform

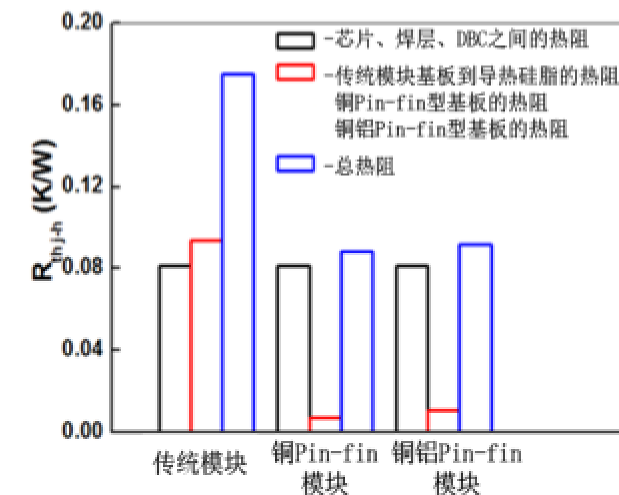


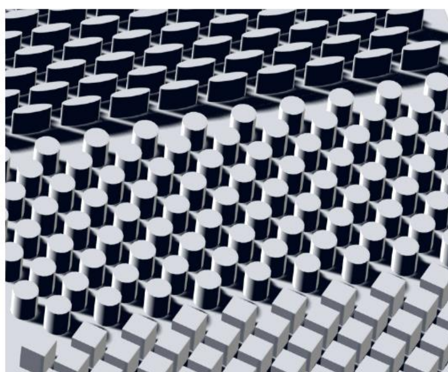
**Interconnection technology**

Soldering technology

Thermal dissipation technology

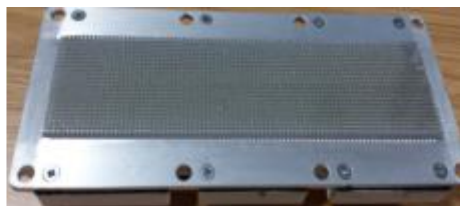
- **Pin-Fin direct liquid cooling technology**
- Direct liquid cooling, eliminating thermal grease
- Lower thermal resistance, lower 40% than conventional modules
- Integrated heat dissipation structure integrated with the heat sink



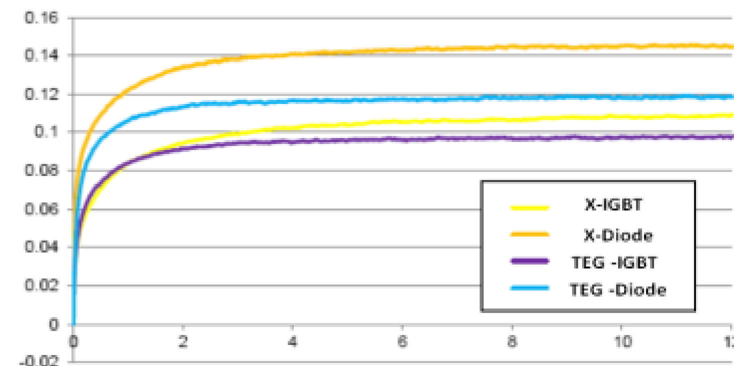



Pin-fin structure

Copper Pin-fin structure



Copper-Al Pin-fin structure




Comparison test result of thermal resistance with the same degree module from X company

# Part 1 CRRC IGBT technique platform

## Packaging technology

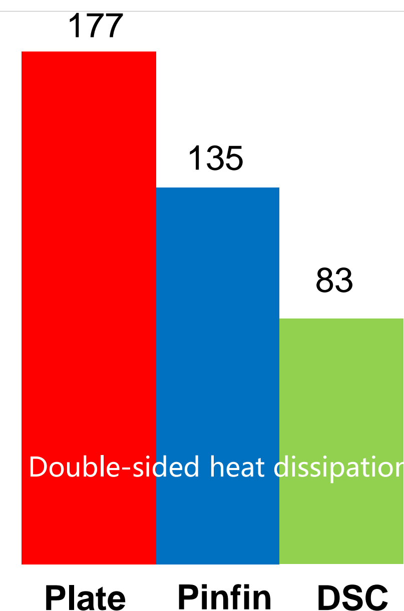
Interconnec-tion technology

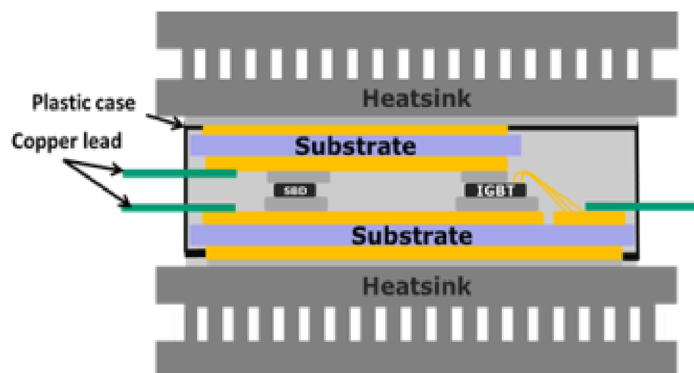
Soldering technology

Thermal dissipation technology

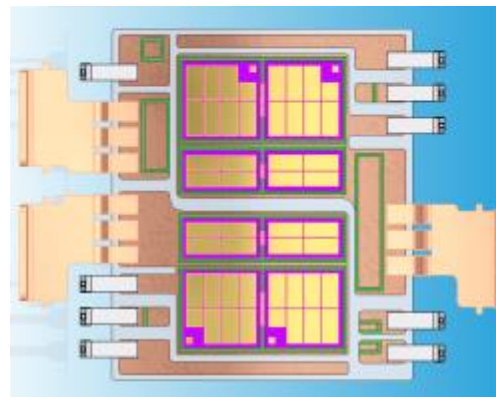
■ **Double side cooling technology**

- Double-sided mountable heat sink cooling, extremely low thermal resistance, high power density
- Optimize the welding process to overcome the double-sided stress distribution and control technology problems
- Double-sided heat dissipation is reduced 50% compared to traditional standard flat panel modules

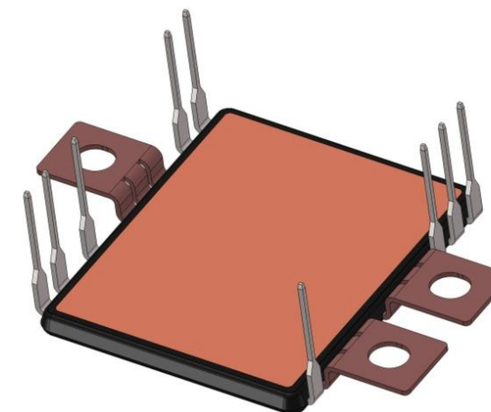



Double-sided heat dissipation structure



L1 module internal structure



600A/750V half bridge L1 module

# Content


Part 1 CRRC IGBT technique platform

Part 2 CRRC IGBT product profile

Part 3 CRRC IGBT nomenclature

Part 4 CRRC IGBT product plan

# 2. IGBT product portfolio

**Covering 750V ~ 6500V, used in railway, EV, power transmission, new energy**

## Railway

750A single

500A single
**6500V**

2400A single

1600A single

800A dual
**1700V**

1800A single

1500A single

1000A single

500A dual
**3300V**

1200A single
**4500V**

## EV

400A six pack

400A six pack

820A ( 600A ) six pack

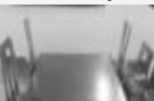
800A six pack

600A half
**750V**

800A half-b

600A half-b

450A half-b

600A six pack

200A half
**1200V**

## Industry

1400A half-b

1000A half-b

650A half-b

600A half-b

450A half-b
**1700V**

1400A half-b

900A half-b

800A half-b

600A half-b

450A half-b
**1200V**

## Grid

1800A single

1500A single
**3300V**

3000A/2000A

1500A

1200A single
**4500V**

# 2. IGBT product portfolio



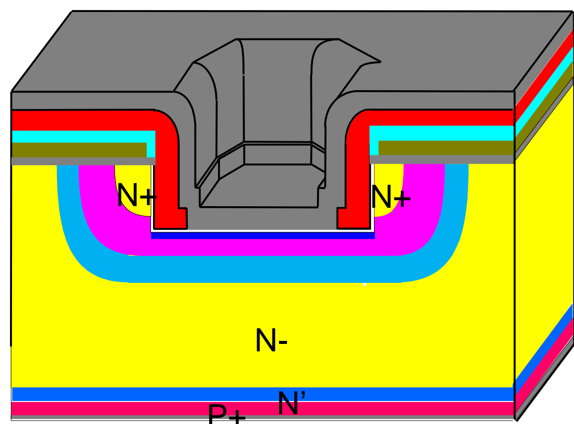
## High V IGBT tech spec

- single-side soldering package
- volume application in China EMU, power transmission, high-tech industry
- Over 1 million times power cycling（ΔT=60℃）
- With the uniformity control of welding layer, no obvious degradation of welding layer was observed after 20,000 passive thermal cycles （ ΔT=80℃ ）.
- AlSiC baseplate+ AlN substrate to achieve good thermal shock and passive thermal cycle capability

# 2. IGBT product portfolio

## High V IGBT module

- 4th Gen DMOS chip technology
- Apply to 1700V-6500V IGBT
- Combination of world’s mainstream SPT and Carrier Storage Technology
- 6500V/750A temperature rise same as Infineon（water cooling variance<2° C）




| Product | Characteristics | CRRC | Infineon | Mitsubishi | ABB |
|---|---|---|---|---|---|
| 1600A/1700V | IGBT Vces（V） | 2.4 | 2.4 | 2.4 | 2.6 |
| | Esw（J） | 1.6 | 1.6 | 1.4 | 1.8 |
| | FRD Vf（V） | 1.8 | .8 | 2.5 | 1.7 |
| 1500A/3300V | IGBT Vces（V） | 3.3 | 3.2 | 3.2 | 3.2 |
| | Esw（J） | 6.4 | 6.1 | 6.0 | 5.4 |
| | FRD Vf（V） | 2.5 | 2.8 | 2.3 | 2.3 |
| 1200A/4500V | IGBT Vces（V） | 3.0 | 3.3 | 4.4 | 3.3 |
| | Esw（J） | 11.3 | 8.1 | 9.8 | 8.9 |
| | FRD Vf（V） | 2.9 | 2.7 | 2.8 | 3.3 |
| 750A/6500V | IGBT Vces（V） | 4.0 | 3.9 | 4.8 | 3.9 |
| | Esw（J） | 10.2 | 10.3 | 9.3 | 11.7 |
| | FRD Vf（V） | 3.0 | 2.7 | 3.3 | 4 |

# 2. IGBT product portfolio



## 3300V high V IGBT characteristics

- Better Vce(sat) than competitors
- Competitive Eon+Eoff against rivals

TIM1500ESM3-PSA IGBT

| 3300V /1500A IGBT ( @150℃ ) | CRRC (TIM1500ESM3-PSA) (test: Rgoff=1.5Ω ; Rgon=1Ω ; Ls=150nH) | INFINEON (FZ1500R33HE3) (test: Rgoff=1.5Ω ; Rgon=1Ω ; Ls=150nH) | ABB (5SNA1500E330305) (test :Rgoff=1.5Ω ; Rgon=1Ω ; Ls=150nH) |
|---|---|---|---|
| $V_{CE(sat)}$/V@1500A | 2.96 | 3.24 | 3.25 |
| $V_F$/V | 2.22 | 2.81 | 2.21 |
| $E_{ON}$/J | 2.54 | 3.65 | 2.58 |
| $E_{OFF}$/J | 4.46 | 2.70 | 2.83 |
| $E_{rec}$/J | 2.63 | 1.62 | 2.38 |

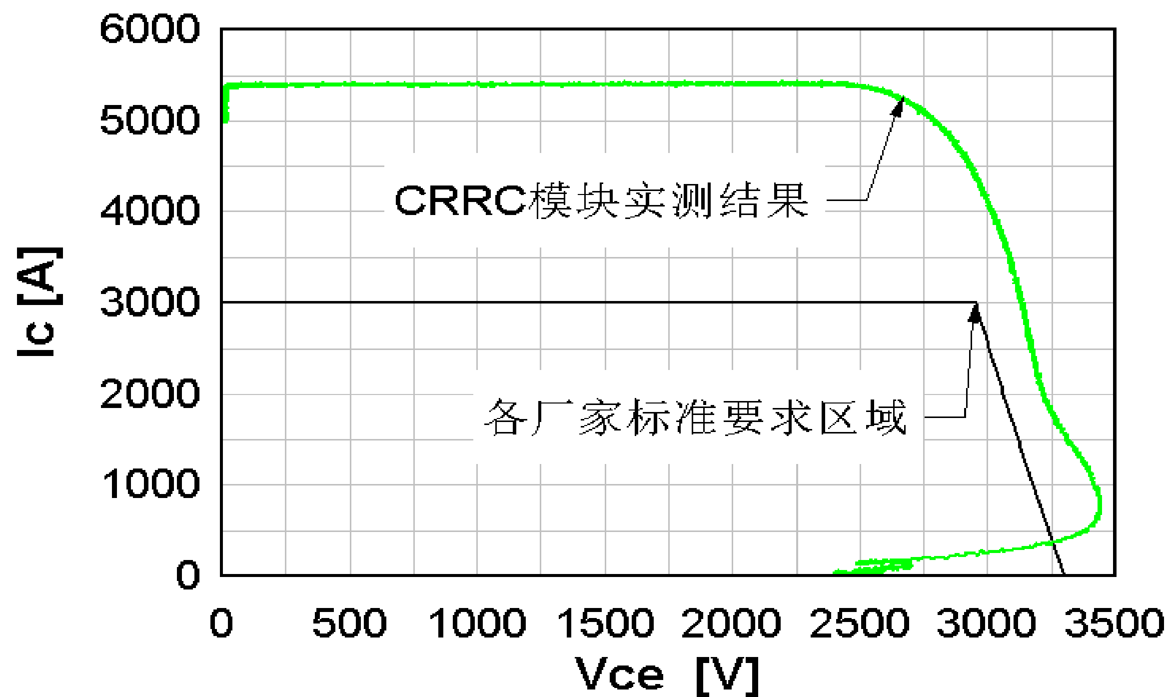
# 2. IGBT product portfolio



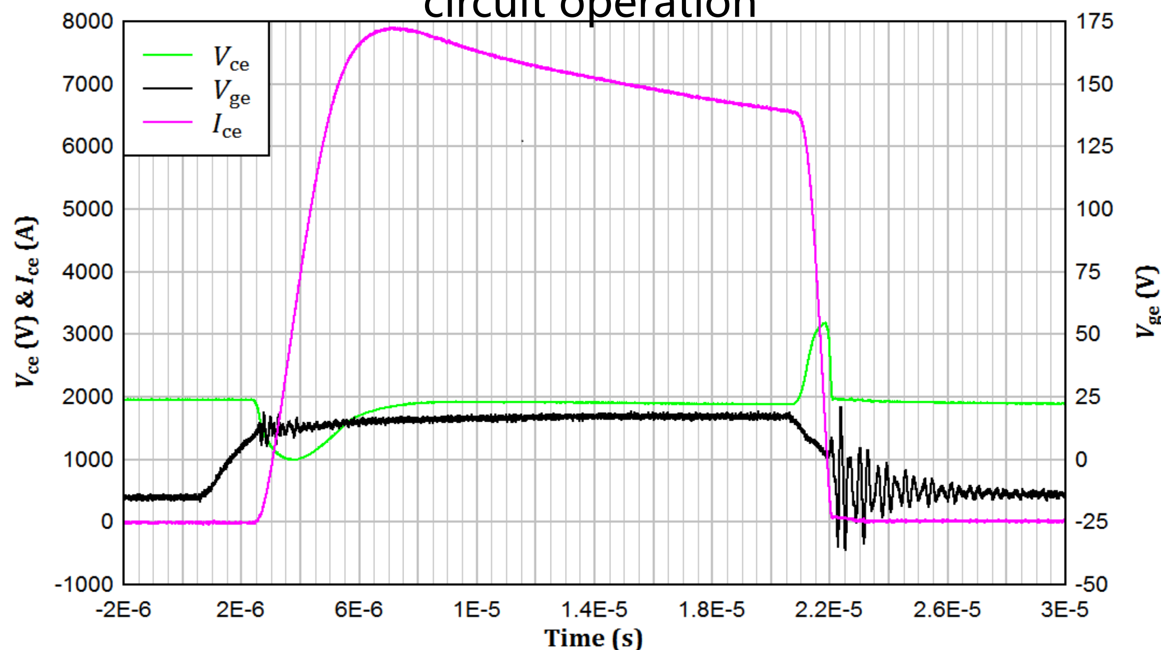
## 3300V high V IGBT high short circuit capability

- Higher safe operating area：wide RBSOA and SCSOA
- Class-leading robustness

RBSOA：2500V, turn off 3.5 times of rated Ic




SCSOA：Vge 18V maintain 20μs short-circuit operation



# 2. IGBT product portfolio



## 4500V high V IGBT characteristics

- Similar Eon+Eoff against rivals, Vce(sat) better than ABB

| 4500V/1200A IGBT Parameters ( @ 125℃ ) | CRRC (TIM1200ASM45-PSA) ( test: Rgon=1.5Ω ; Rgoff=2.7Ω , Ls=180nH) | INFINEON (FZ1200R45KL3) (datasheet :Rgoff=Rgon =5.1Ω, Ls=110nH ) | ABB (5SNA 1200G450350) (datasheet: Rgoff= Rgon=1.5Ω, Ls=150nH) |
|---|---|---|---|
| $V_{CE(sat)}$ /V@1200A | 3.10 | 3.10 | 3.55 |
| $V_F$/V | 2.78 | 2.50 | 3.50 |
| $E_{ON}$/J | 4.53 | 6.15 | 4.35 |
| $E_{OFF}$/J | 6.42 | 5.10 | 6.00 |
| $E_{rec}$/J | 3.62 | 3.55 | 2.73 |

TIM1200ASM45-PSA IGBT

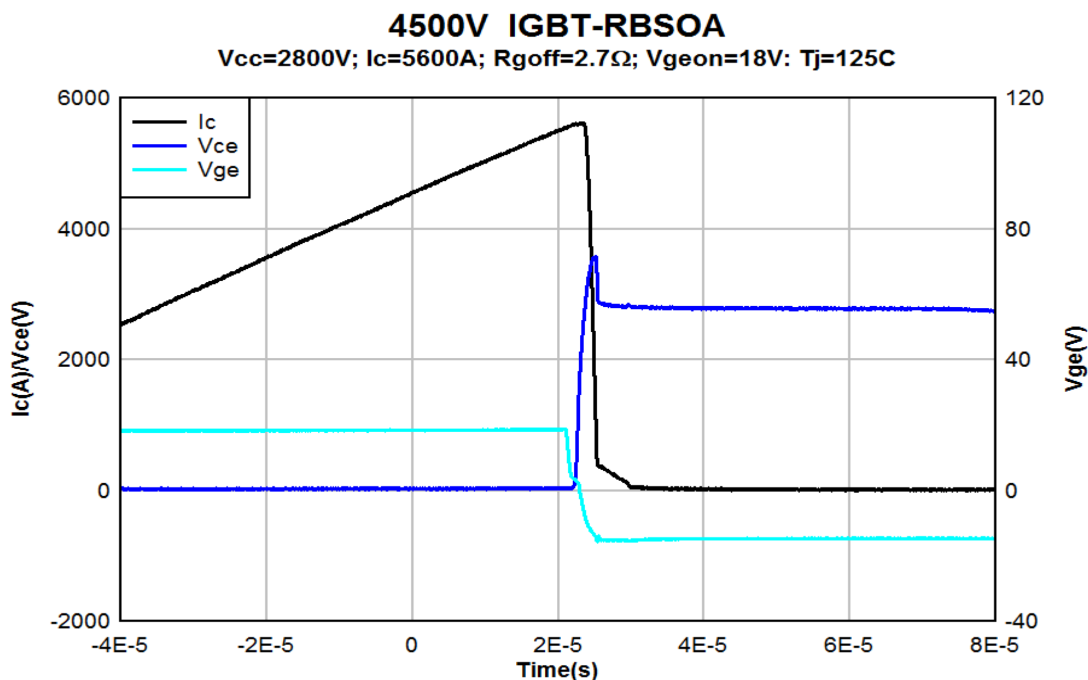
# 2. IGBT product portfolio



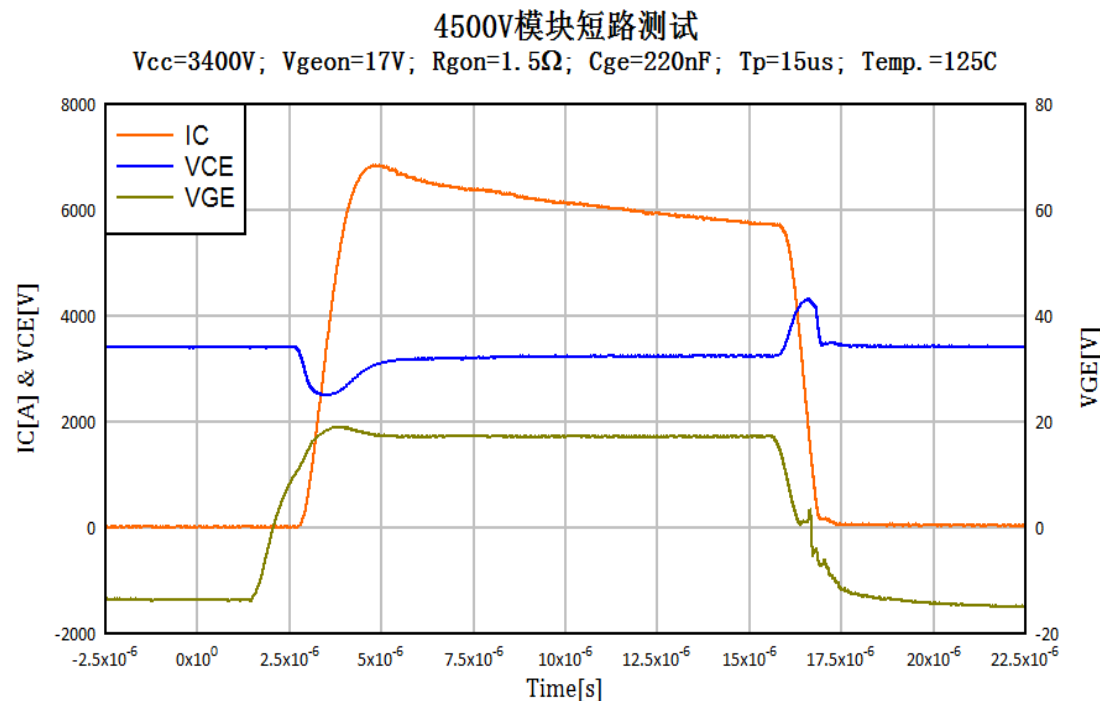
## 4500V high V IGBT high short circuit capability

- Strong current capability, wide RBSOA

RBSOA： turn off 5600A current（5 times rated current）




SCSOA： Vge 17V maintain 15μs, regular short circuit 7000A（5.8 times rated current ）



# 2. IGBT product portfolio



## 6500V high V IGBT characteristics

- Similar total losses

| 6500V/750A IGBT Parameters (@ 125℃) | CRRC (TIM750ASM65-PSA ) ( test: Rgon=1Ω ; Rgoff=6.8Ω , Ls=180nH) | INFINEON (FZ750R65K3) (test:Rgon=1; Rgoff =6.8Ω; Ls=180nH) | ABB (5SNA 0750G650300) (test : Rgon=2.7Ω, Rgoff =15Ω, Ls=180nH) |
|---|---|---|---|
| $V_{CE\,(sat)}$ /V@750A | 4.00 | 3.90 | 3.95 |
| $V_F$/V | 3.01 | 2.61 | 3.48 |
| $E_{ON}$/J | 5.98 | 4.69 | 4.62 |
| $E_{OFF}$/J | 4.20 | 3.77 | 3.62 |
| $E_{rec}$/J | 4.26 | 4.01 | 2.96 |
| $E_{total}$ /J | 14.44 | 12.47 | 11.2 |

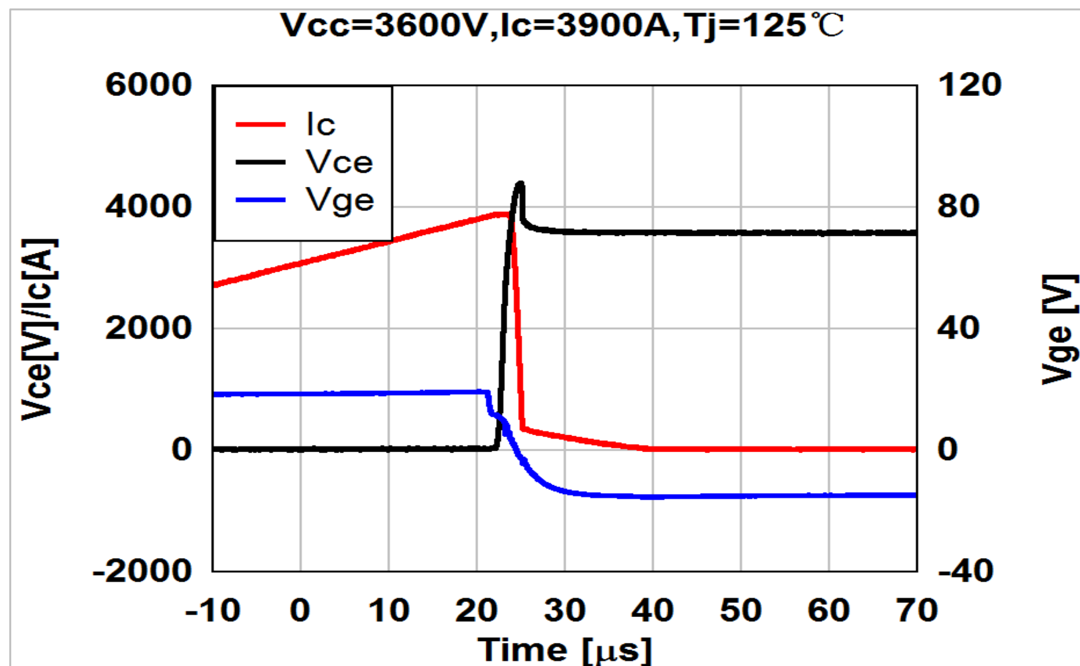
TIM750ASM65-PSA IGBT

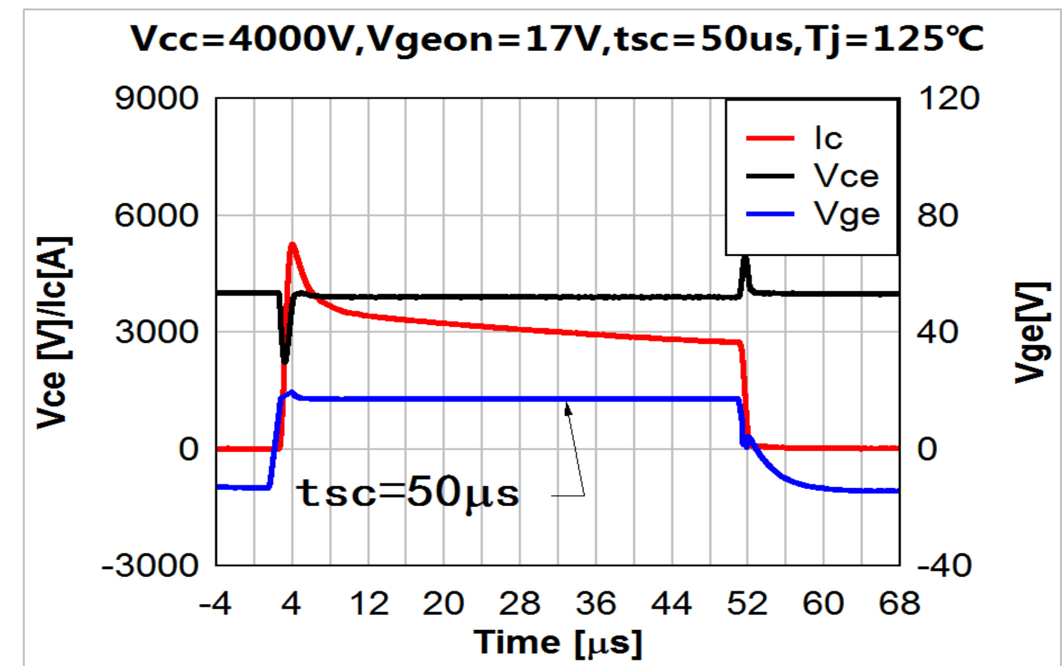
## 6500V high V IGBT high short circuit capability

- Meet SOA requirements

RBSOA：turn off 5.2 times rated current

SCSOA：Vge 17V maintain 50μs short-circuit operation

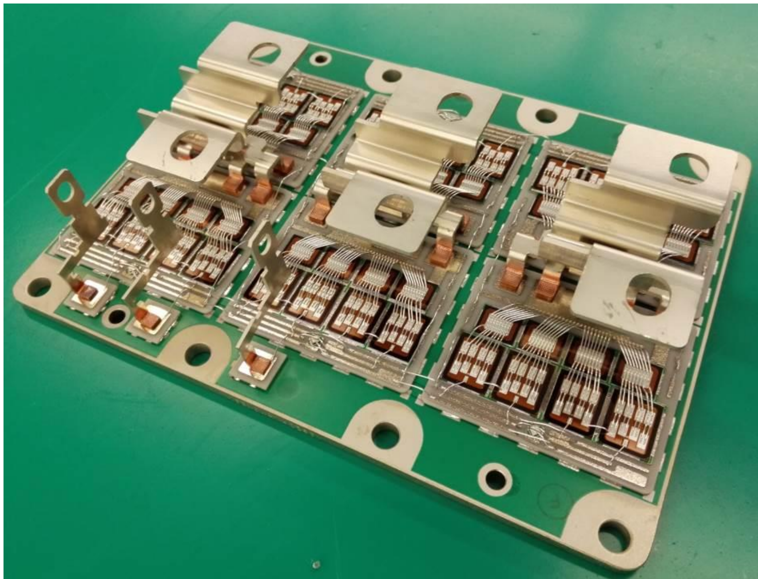


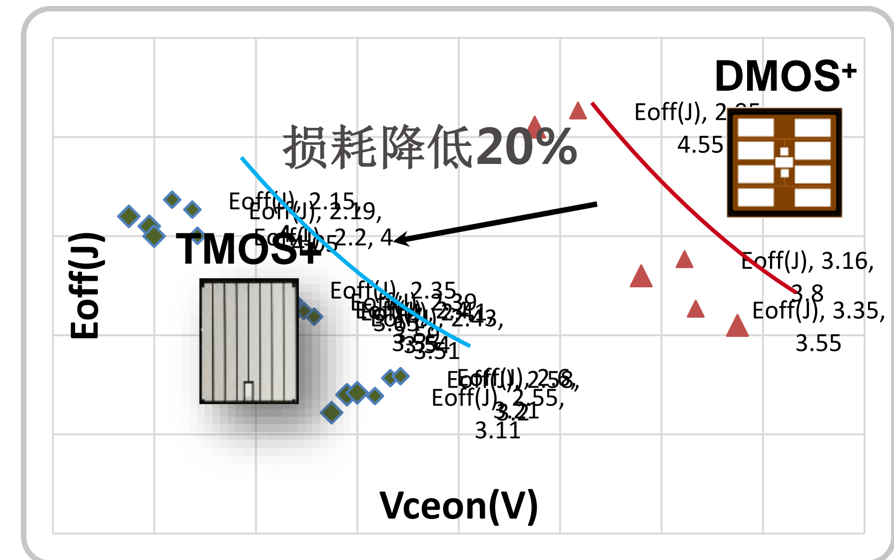



# 2. IGBT product portfolio



- **3300V/1800A trench gate E2 module**
- Power density increase by 20%
- Low inductance design, uniform heat dissipation, lower thermal resistance
- better anti-explosion



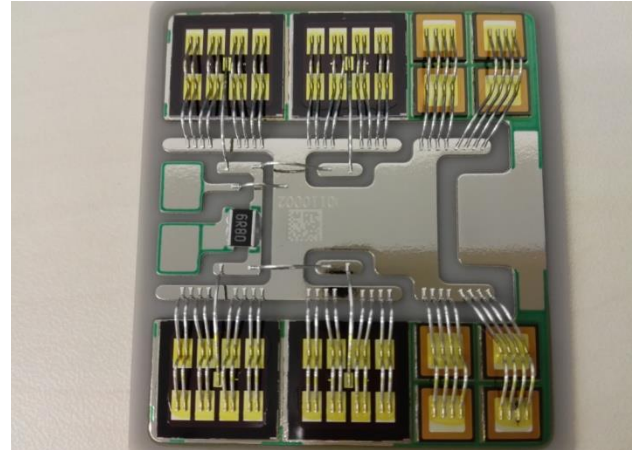


# 2. IGBT product portfolio



## 3300V/1500A Hybrid-SiC E Module

- Replace Si-FRD with SiC-SBD
- With out diode reverse recovery loss
- Available to replace IGBT E Module

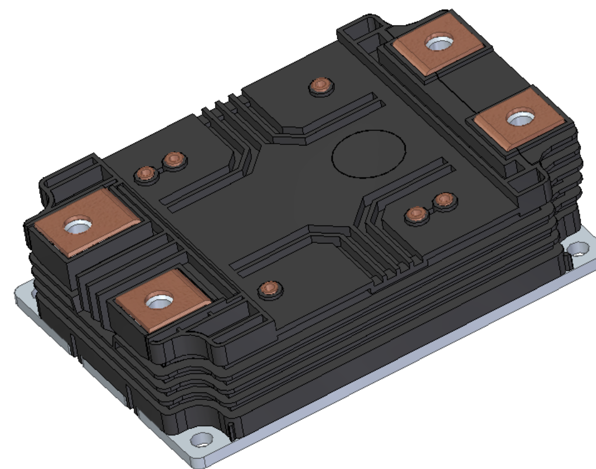


| Module | Vce(sat)/V | Vf/V | Eoff/J | Eon/J | Erec/J | Etot/J | Voltage/V |
|---|---|---|---|---|---|---|---|
| CRRC Hybrid SiC E Module | 2.96 | 3.85 | 4.45 | 2.56 | 0 | 7.01 | 3300 |
| CRRC Si-IGBT E Module | 2.96 | 2.22 | 4.46 | 2.54 | 2.63 | 9.64 | 3300 |
| Hitachi Hybrid SiC Module | 2.79 | 3.91 | 3.97 | 3.08 | 0 | 7.05 | 3300 |

# 2. IGBT product portfolio



- **Open source module**
- Basic structure design to target XHP3
- Trench gate chip technology, current capacity 450A
- Standard package
- Low inductance design to fit high efficiency application
- Ultrasonic bonding of power terminals to improve module reliability
- based on same structure to develop SiC module



# 2. IGBT product portfolio

## High V IGBT module





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# 2. IGBT product portfolio



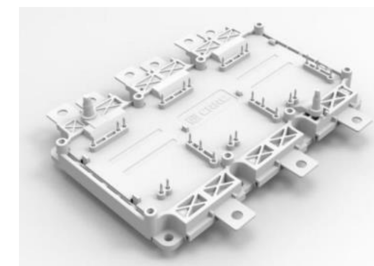
## Auto IGBT characteristics

- Both Gen5 and Gen6 IGBT chip
- Six pack module, operation temperature 150°C, Tvjm 175℃
- Enhanced ceramic substrate, high reliable soldering and stronger temperature cycling capability
- Ultrasonic bonding of power terminals, lower impedance, Strong resistance to mechanical vibration ,improved module reliability
- Assembly type： S0、S1、S2、S3、 S3+

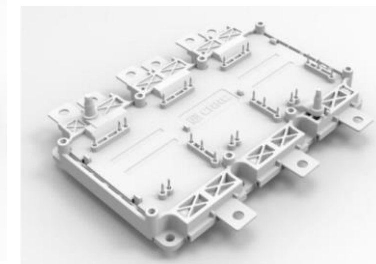
750V/400A S0

750V/800A S1

750V/400A S2



750V/600A S3
1200V/450A S3
1200V/540A SiC S3



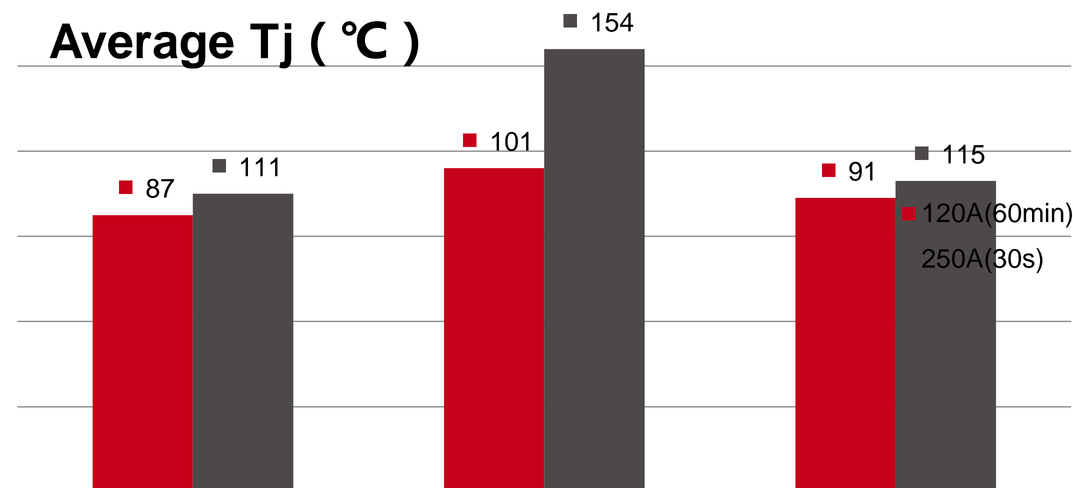
750V/820A S3+
750V/950A S3+

# 2. IGBT product portfolio

Automotive IGBT module

## 750V/400A S0/S2 module

- Compared with Infineon products, the loss is equivalent, the thermal resistance is the lowest, and the highest withstand voltage
- Suitable for 70KW below A0、A00 type automobile or logistic bus




Temperature rise of CRRC S2 is lower than DC6 and M652

| 模块 | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J-F)}$/K/KW |
|---|---|---|---|---|
| CRRC S2 | 1.70 | 1.50 | 28 | 140 |
| Infineon DC6-H6 | 1.60 | 1.65 | 31.7 | 190 |
| Fuji M652 | 1.63 | 1.58 | 26 | 210 |

# 2. IGBT product portfolio



## 750V/800A S1 module

- Higher withstand voltage
- Lower thermal resistance
- Suitable for 150KW below, A type、SUV type automobile

| Module | Vceon/V | Vf/V | Eoff/mJ | Eon/mJ | Erec/mJ | Etot/mJ | R(J-F)/K/kW | Withstand voltage/V |
|---|---|---|---|---|---|---|---|---|
| CRRC S1 | 1.45 | 1.45 | 35 | 7.2 | 13 | 55.2 | 86 | 750 |
| Infineon HP2 | 1.3 | 1.5 | 21 | 10.5 | 4 | 35.5 | 97 | 650 |

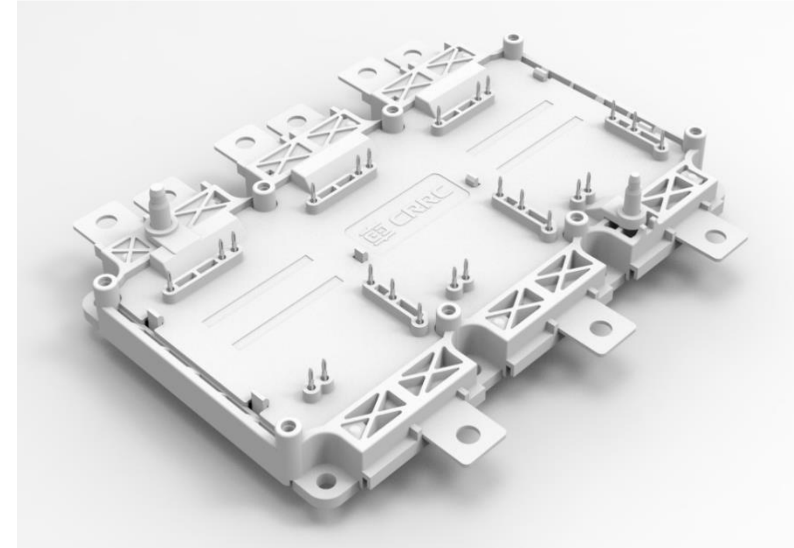
# 2. IGBT product portfolio



## 750V/600A S3 module

■Series product

■Suitable for 100KW below, A type、A0 type automobile



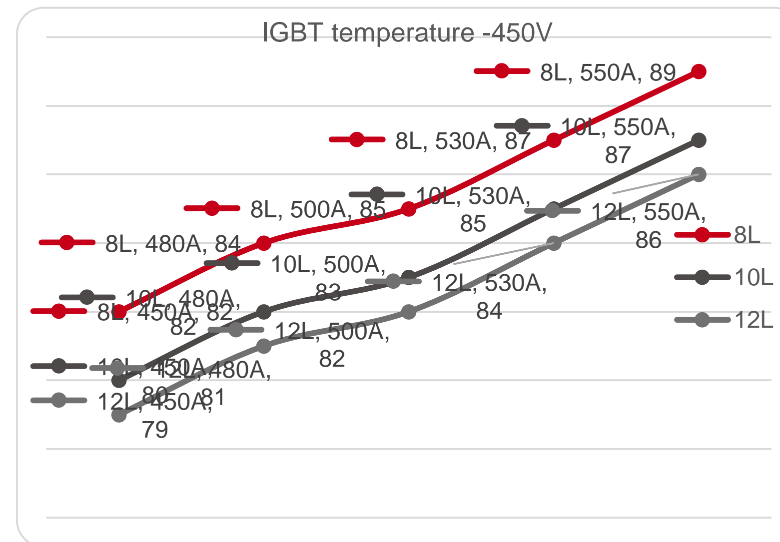
| Module | Vceon/V | Vf/V | Eoff/mJ | Eon/mJ | Erec/mJ | Etot/mJ | R(J-F)/K/kW | Withstand voltage/V |
|---|---|---|---|---|---|---|---|---|
| CRRC S3 | 1.55 | 1.45 | 16 | 2.4 | 8.4 | 26.8 | 115 | 750 |

# 2. IGBT product portfolio



## 750V/820A S3+ module status

- Advanced packaging materials with higher heat dissipation efficiency
- Thermal resistance is lower than Infineon HP-Drive
- 950A Version will be released at the end of 2019



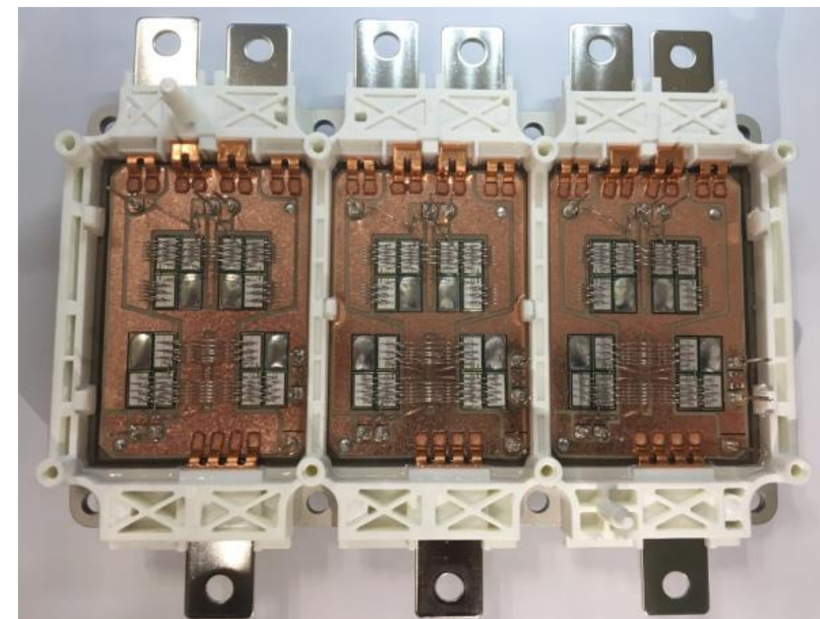

750V/820A S3+ device temperature rise test

| 模块 | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J\text{-}F)}$/K/KW |
|---|---|---|---|---|
| CRRC S3+ | 1.25 | 1.49 | 59.2 | 115 |
| Infineon HP Drive | 1.16 | 1.51 | 56 | 120 |

# 2. IGBT product portfolio

## 1200V/540A Full-SiC S3 Module

- Low inductance design; improved current sharing
- Si3N4 substrate，Pin-fin base-plate; higher heat dissipation efficiency
- Room for current improvement (30%)
- Lower dynamic power loss than Starpower module



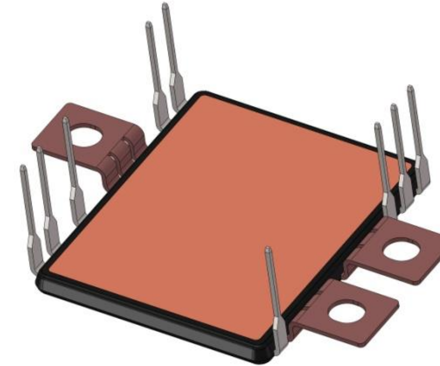
| Module | Vds(on)/V | Vf/V | Eoff/mJ | Eon/mJ | Erec/mJ | Etot/mJ | 耐压/V |
|---|---|---|---|---|---|---|---|
| CRRC | 0.68 | 3.2 | 18.5 | 21 | 1.31 | 40.8 | 1200 |
| S Competitor | 0.67 | 3.2 | 23.9 | 32 | 1.41 | 57.3 | 1200 |

# 2. IGBT product portfolio

Automotive IGBT module

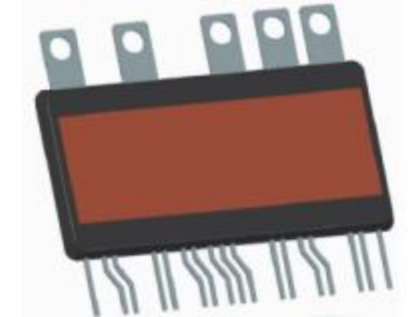
**750V/300-600A double side cooling module**

- Half bridge or 6-pak , built in NTC resistance
- Double side soldering
- Double side water cooling
- Suitable for hybrid automotive



750V/600A 2in1 L1 module

750V/400A 2in1 module



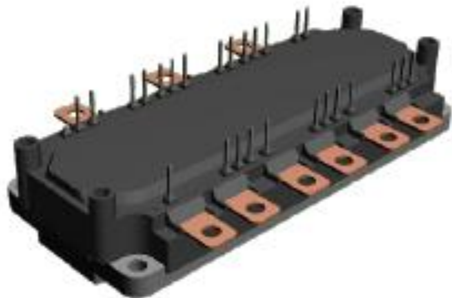
750V/200A 6in1 module

| Module | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J-F)}$/K/KW |
|---|---|---|---|---|
| 750V/600A 2in1 | 1.78 | 1.7 | 19 | 120 |
| 750V/400A 2in1 | Developing：2019Q4 Prototype, 2020Q2 SOP | | | |
| 750V/200A 6in1 | Developing：2019Q4 Prototype, 2020Q2 SOP | | | |

# 2. IGBT product portfolio



- HIPA series double-sided cooling module, customized package
- Matching CRRC intelligent gate drive, can realize dI/dt, dV/dt loss and surge control, IGBT health status monitoring, etc., to meet the needs of automotive functional safety design

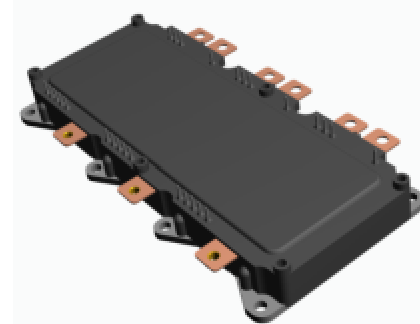


**450A/750V**

- $R_{thJF_IGBT}$ : 0.21K/W
- $R_{thJF_FRD}$ : 0.33K/W
- Parasitic inductance : 11.7nH

**900A/750V**

- $R_{thJF_IGBT}$ : 0.09K/W
- $R_{thJF_FRD}$ : 0.15K/W
- Parasitic inductance : 12.5nH



**1200A/750V**

- $R_{thJF_IGBT}$ : 0.07K/W
- $R_{thJF_FRD}$ : 0.11K/W
- Parasitic inductance : 9.5nH

# CRRC IGBT Overview

## Roadmap for EV/HEV IGBTs

Legend: Sampling | MP

| Product | Rating | Sampling | MP |
|---|---|---|---|
| M1 Half-bridge | 450A/1200V S3A00 | | 2019Q1 |
| M1 Half-bridge | 600A/1200V G3A00 | 2019Q1 | 2019Q3 |
| M1 Half-bridge | 800A/1200V | 2019Q3 | 2020Q1 |
| S0 6-in-1 | 400A/750V | 2019Q1 | 2019Q4 |
| S1 6-in-1 | 800A/750V | 2019Q1 | 2019Q2 |
| S2 6-in-1 | 400A/750V w or w/t pin-fin | 2019Q1 | 2019Q4 |

2019Q1 | 2019Q2 | 2019Q3 | 2019Q4 | 2020Q1 | 2020Q2

# CRRC IGBT Overview

## Roadmap for EV/HEV IGBTs

Sampling | MP

600A/750V

820A/750V

950A/750V

600A/750V
2in1 DSC

300A/1200V

400A/750V
2in1

300A/750V
6in1

900A/750V
6in1

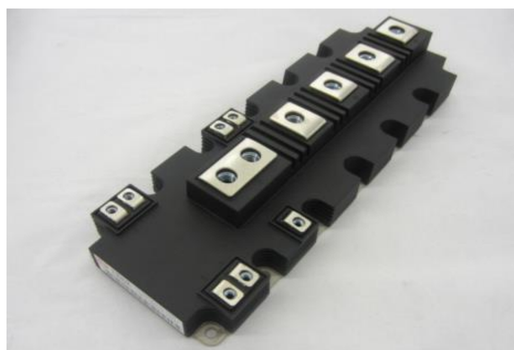
| 2019Q1 | 2019Q2 | 2019Q3 | 2019Q4 | 2020Q1 | 2020Q2 |
|---|---|---|---|---|---|

# CRRC IGBT Overview

## Characteristics of Industrial IGBTs

- 5th generation trench gate IGBT and soft turn-off FRD, NTC integrated
- Half-bridge module, operating temperature 150C, maximum junction temperature 175°C, good positive temperature coefficient
- High reliability soldering system, solder layer uniformity control technology to strengthen thermal cycling capability
- Ultrasonic terminal welding technology, with low impedance, large load capacity, strong resistance to mechanical shock, and higher reliability
- Package Size: 158x62x25mm (M1 Series), 250x89x38mm (H1), 172*89*38mm (H2)

M1 Package



H1 Package

H2 Package

# CRRC IGBT Overview

1200V/450A IGBT

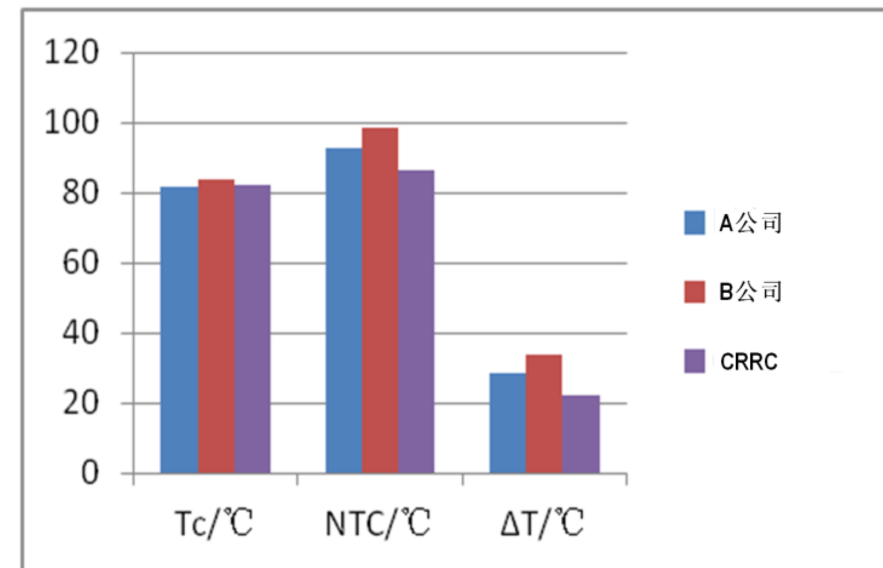
## 1200V/450A M1 Module

◆Equivalent to Infineon EconoDUAL package

◆150° C operating temperature, 175° C maximum junction temperature

◆Half-bridge IGBT with built-in NTC resistor

◆High thermal cycling capability




Comparison of Temperature Rise of 1200V/450A M1 Module

| Module | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J-F)}$/K/KW |
|---|---|---|---|---|
| CRRC 1200V/450A M1 | 1.65 | 1.65 | 133 | 52 |
| Infineon 1200V/450A ME4 | 1.75 | 1.65 | 145 | 66 |

# CRRC IGBT Overview

**1200V/600A IGBT**

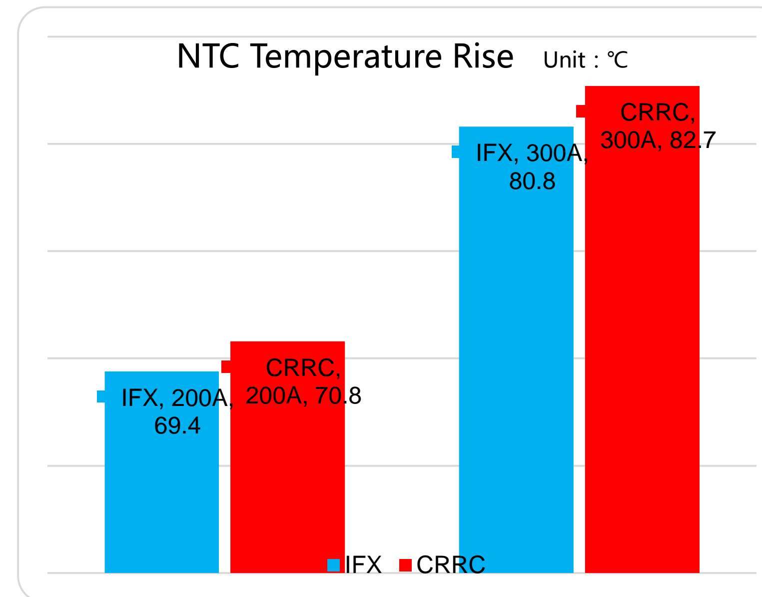
## 1200V/600A M1 Module

◆Equivalent to Infineon EconoDUAL package

◆150° C operating temperature, 175° C maximum junction temperature

◆Half-bridge IGBT with built-in NTC resistor

◆High thermal cycling capability




Temperature Rise of 1200V/600A Module
Vcc=540V,fsw=8kHz,Tf=45℃

| Module | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J-F)}$/K/KW |
|---|---|---|---|---|
| CRRC 1200V/600A M1 | 1.85 | 1.90 | 171 | 49 |
| Infineon 1200V/600A ME4A | 1.75 | 1.90 | 186 | 45 |

# CRRC IGBT Overview

## 1700V/450A IGBT

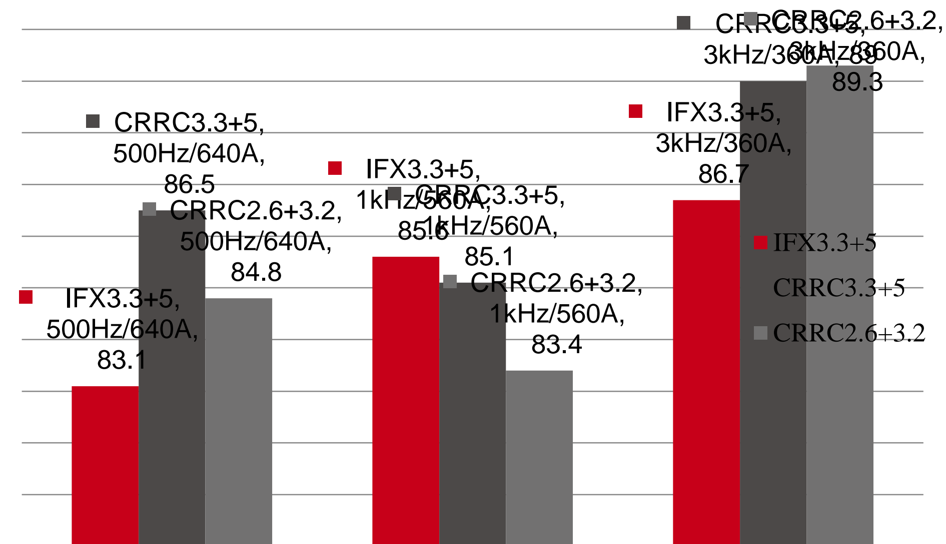
### 1700V/450A M1 Module

◆Equivalent to Infineon EconoDUAL package

◆150° C operating temperature, 175° C maximum junction temperature

◆Half-bridge IGBT with built-in NTC resistor

◆High thermal cycling capability




Temperature Rise of 1700V/450A Module

| Module | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J-F)}$/K/KW |
|---|---|---|---|---|
| CRRC 1700V/450A | 1.80 | 2.05 | 381 | 55 |
| Infineon 1700V/450A | 1.95 | 1.80 | 440 | 60 |

# CRRC IGBT Overview

**1700V/600A IGBT**

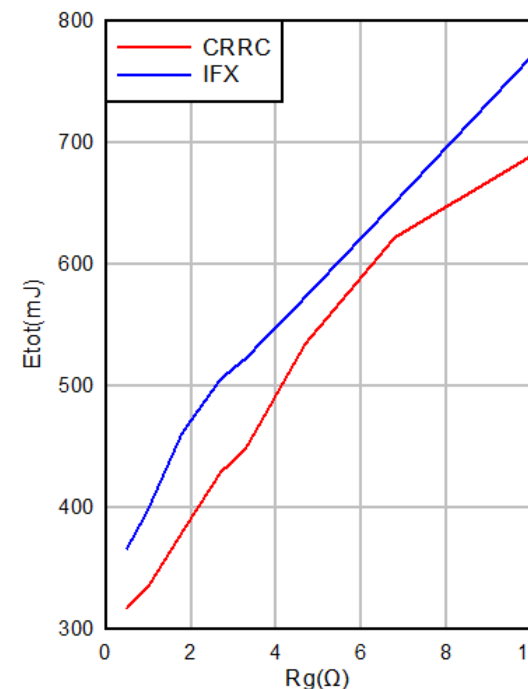
## 1700V/600A M1 Module

◆Equivalent to Infineon EconoDUAL package

◆150° C operating temperature, 175° C maximum junction temperature

◆Half-bridge IGBT with built-in NTC resistor

◆High thermal cycling capability




Total loss comparison
@Vcc=900V，T=150℃

| Module | $V_{CE(sat)}$ /V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J-F)}$ /K/KW |
|---|---|---|---|---|
| CRRC 1700V/600A | 1.85 | 2.15 | 458 | 44 |
| Infineon 1700V/600A | 1.95 | 1.80 | 595 | 37 |

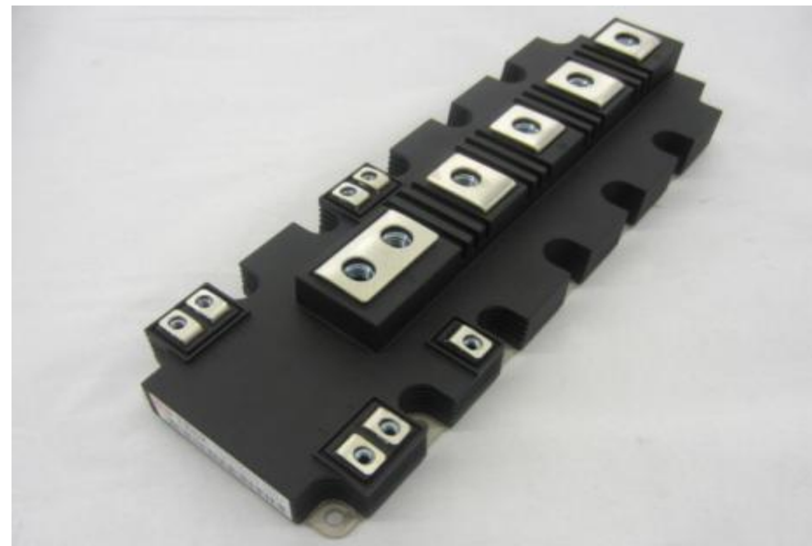
## 1700V/1000A H1 Module

◆Equivalent to Infineon PrimePack package

◆150° C operating temperature, 175° C maximum junction temperature

◆Half-bridge IGBT with built-in NTC resistor

◆Low thermal resistance



| H1 | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J\text{-}IGBT)}$/K/KW | $R_{th(J\text{-}FRD)}$/K/KW |
|---|---|---|---|---|---|
| CRRC 1700V/1000A | 1.85 | 1.80 | 980 | 20 | 36 |
| IFX 1700V/1000A | 2 | 1.85 | 990 | 24 | 48 |

# CRRC IGBT Overview



## 1700V/650A H2 Module

- ◆Equivalent to Infineon PrimePack package
- ◆150° C operating temperature, 175° C maximum junction temperature
- ◆Half-bridge IGBT with built-in NTC resistor
- ◆Low thermal resistance

| H1 | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J\text{-}IGBT)}$/K/KW | $R_{th(J\text{-}FRD)}$/K/KW |
|---|---|---|---|---|---|
| CRRC 1700V/650A | 1.85 | 1.8 | 610 | 30 | 54 |
| Infineon 1700V/650A | 2 | 1.85 | 610 | 36 | 71.5 |

# CRRC IGBT Overview

## H-Series IGBT Module

## 1200V/900A H2 Module

- ◆Equivalent to Infineon PrimePack package
- ◆150° C operating temperature, 175° C maximum junction temperature
- ◆Half-bridge IGBT with built-in NTC resistor
- ◆Lower Vf parameter

| H2 | $V_{CE(sat)}$/V | $V_F$/V | $E_{tot}$/mJ@150C | $R_{th(J\text{-}IGBT)}$/K/KW | $R_{th(J\text{-}FRD)}$/K/KW |
|---|---|---|---|---|---|
| CRRC 1200V/900A | 1.75 | 1.85 | 344 | 30 | 55 |
| IFX 1200V/900A | 1.75 | 1.90 | 300 | 26.5 | 53.5 |

# CRRC IGBT Overview

## Roadmap for Industrial IGBTs

| Product | Rating | Sampling | MP |
|---|---|---|---|
| H1 Half-Bridge | 1000A/1700V | 2019Q1 | 2019Q3 |
| H1 Half-Bridge | 1400A/1700V | 2019Q2 | 2020Q1 |
| H1 Half-Bridge | 1400A/1200V | 2019Q1 | 2019Q4 |
| H2 Half-Bridge | 650A/1700V | 2019Q1 | 2019Q3 |
| H2 Half-Bridge | 900A/1200V | 2019Q2 | 2019Q4 |
| M1 Half-Bridge | 600A/1700V | 2019Q1 | 2019Q4 |
| M1 Half-Bridge | 450A/1700V | | 2019Q1 |

# CRRC IGBT Overview



## Press-pak IGBT module characteristic

### ABB Press-pack IGBT

- Flexible spring press
- Sub-module structure (multi-chips)
- Non-hermetic package structure
- The current maximum capacity is 3000A/4500V(including anti-parallel diodes)

### CRRC Press-pack IGBT

- Flexible spring press
- Sub-module structure (single-chip)
- Hermetic package structure
- The current maximum capacity is 3000A/4500V(including anti-parallel diodes)

### Toshiba Press-pack IGBT

- Rigid press
- Hermetic ceramic package
- The current maximum capacity is 3000A/4500V (no anti-parallel diode)

# CRRC IGBT Overview

## Press-Pack IGBT Modules

- The fourth-generation DMOS+ chip technology, free-floating packaging process, which is widely used in the production of thyristors in HVDC application.

Wafer

Dies(21*21mm)

Sub-Module

Assembling&Welding

Press-pack IGBT module

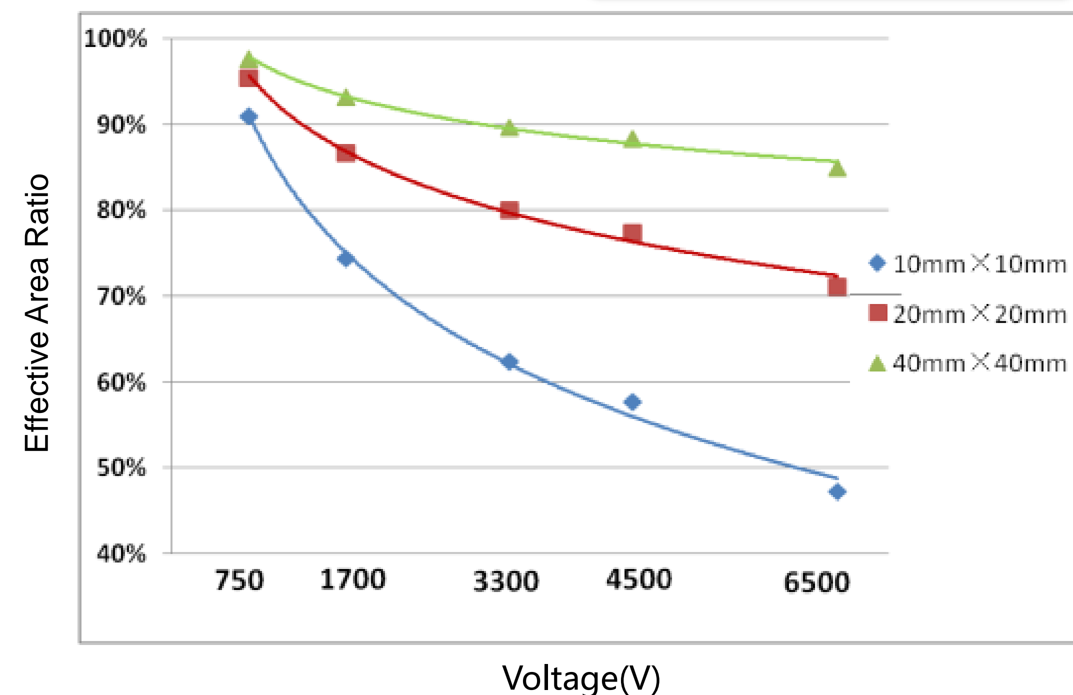
# CRRC IGBT Overview

## Press-Pack IGBT Modules

- Large scale chip, larger effective area, and higher current capability;
- Reduce number of parallel dies, improve reliability.

| Manufacturer | CRRC<br>( TG3000SW45ZC-P200 ) | ABB<br>( 5SNA 3000K452300 ) |
|---|---|---|
| Chip size/mm$^2$ | 21*21 | 14*14 |
| Effective Size /mm$^2$ | 18.4*18.4 | 12*12 |
| IGBT Dies Quantity | 24 | 48 |
| Effective Area/mm$^2$ | 8125 | 6912 |
| | 117.5% | 100% |

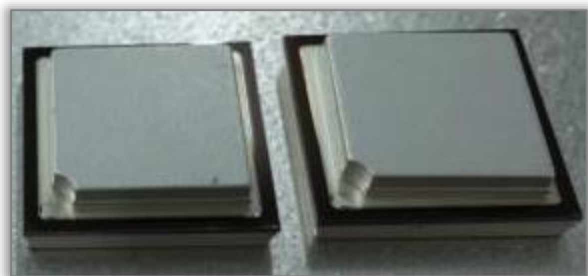
Comparison of Effective Area



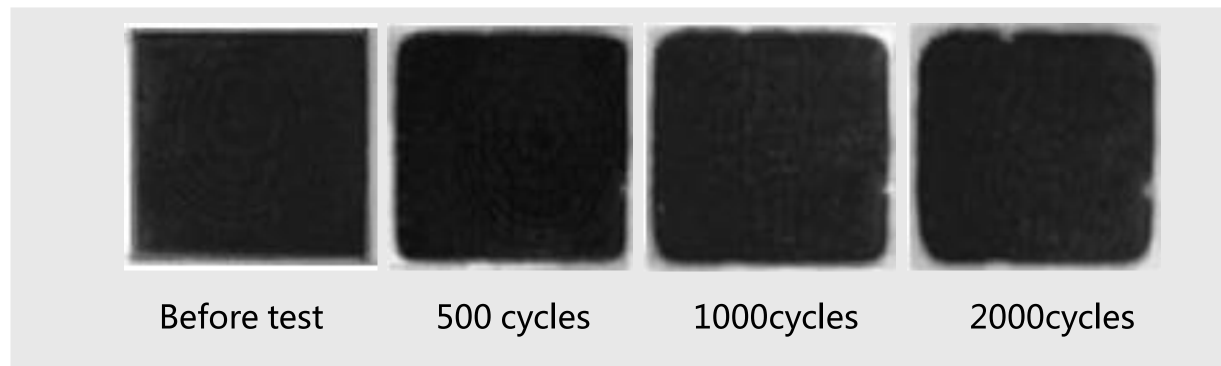

Effective Area Ratio vs Voltage

## Electric Interconnection

- Low-temperature nano-silver sintering technology, realize low-stress electrical interconnection between chip and molybdenum sheet;
- Compared with traditional soldering technology, better thermal shock capability



Demo of nano-silver sintering

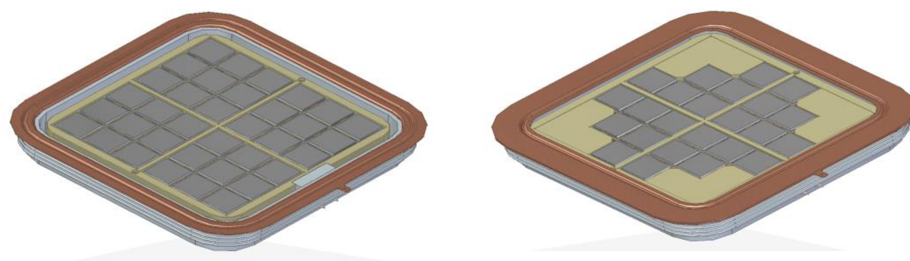



Thermal Shock Test
（-40℃~+125 ℃ ）

# CRRC IGBT Overview



- Hermetic ceramic package structure
- A mature thyristor structure of hermetic ceramic package is adopted, the filling of nitrogen and inert gas is able to prevent moisture from entering;
- In ABB package structure, there is potential gap between sub-module and module due to the structure of coating plate and silicone encapsulation



CRRC Press-packIGBT

ABB Press-pack IGBTs



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# CRRC IGBT Overview



- Key Parameters Comparison

- Eoff and Erec are lower than ABB modules, Eon is slightly higher than ABB modules;
- Overall loss is slightly lower than ABB modules.

| Key Parameters ( 25℃ ) | Symbol | Unit | CRRC | ABB |
|---|---|---|---|---|
| Turn-on Loss | $E_{on}$ | J | 19.70 | 17.73 |
| Turn-off Loss | $E_{off}$ | J | 16.40 | 20.95 |
| Reverse Recovery Loss | $E_{rec}$ | J | 4.01 | 4.36 |
| **Overall Switching Loss** | $E_{tot}$ | J | 40.01 | 43.04 |

# CRRC IGBT Overview

## Roadmap of Press-Pack IGBT Modules

Sampling | MP

Square

3000A/4500V Co-pack

2000A/4500V Co-pack

4500A/4500V All-IGBT

3000A/5200V Co-pack

4000A/5200V Co-pack

6000A/5200V All-IGBT

Round

1500A/3300V Co-pack

1500A/4500V Co-pack

| 2019Q3 | 2019Q4 | 2020Q1 | 2020Q2 | 2020Q3 | 2020Q4 |
|---|---|---|---|---|---|

# Content


Part 1 — CRRC IGBT technique platform

Part 2 — CRRC IGBT product portfolio

Part 3 — CRRC IGBT nomenclature

Part 4 — CRRC IGBT product plan

# IGBT Module Roadmap

High Voltage IGBT

**2017**
- E 1200A/4500V
- E 1500A/3300V

**2018**
- A 1200A/4500V
- x 800A/4500V
- K1 1500A/3300V
- E 1000A/3300V
- A 750A/6500V
- E2 1500A/3300V

**2019**
- PressPack 3000A/4500V
- E2 1800A/3300V
- N 1000A/3300V
- open-Source 450A/3300V
- PressPack 2000A/4500V
- N 1200A/3300V
- G 500A/3300V
- P 250A/3300V

**2020**
- PressPack 3000A/6500V
- A 1000A/6500V
- x 1200A/4500V
- PressPack 3000A/5200V
- E2 3600A/1700V
- N2 2400A/1700V

# IGBT Module Roadmap

**Low Voltage/Medium Voltage IGBT**

**2017**
- M1(2016) 600A/1200V
- M1(2017) 450A/1700V
- S1 (2017) 800A/750V

**2018**
- H2 650A/1700V
- H1 650A/1700V
- H2 900A/1200V
- M1 800A/1200V
- S3 600A/750V
- L1 600A/750V
- S2 400A/750V
- M1 450A/1200V

**2019**
- HIPA2 900A/750V
- S3+ 950A/750V
- S3+ 820A/750V
- S3 600A/1200V
- L2 400A/750V
- M1 600A/1700V
- L3 (6in1) 200A/750V

**2020**
- HIPA2 1200A/750V
- S3 (SiC) 400A/750V
- HIPA2 450A/750V
- L1(SiC) 300A/750V 300A/1200V

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# 〔Thanks！〕