



Power Tester 在功率循環測試 應用案例分享

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Outline



- Mentor and MicReD
- 易富迪科技—熱特性量測實驗室
- IGBT模組測試方式
- Power Tester 原理介紹
- 量測應用案例

MicReD Hardware System



Dyn-TIM
材料導熱係數量測設備



T3Ster
暫態熱阻量測儀



TeraLED
LED光熱耦合量測積分球



Power Tester
功率循環信賴性測試



T3Ster S
簡易暫態熱阻量測儀



T3Ster Booster
增壓穩壓系統

Mentor & MicReD

- ⑩ Hungarian company, spun out of Budapest University of Technology
Department of Electron Devices



- Still maintain strong links with BUTE:
 - innovation in products
 - research behind development

MicReD
Measuring the Real World

Mentor & MicReD



MicReD History

- 1997: Company founded
- 2000: Participate in EU PROFIT project;

- 2008: Merging with Mentor Corporation
- 2004: Mentor MicReD Product Development



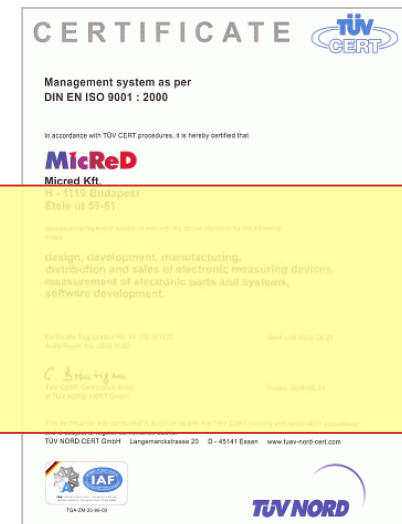
- 2005: SEMI-THERM top 2 partners; and acquired by Flomerics

- 2006: SEMI-THERM Exhibition

- 2016: Mentor Corporation merging with Siemens Business

- 2007: Members of the EU

NANOPACK project

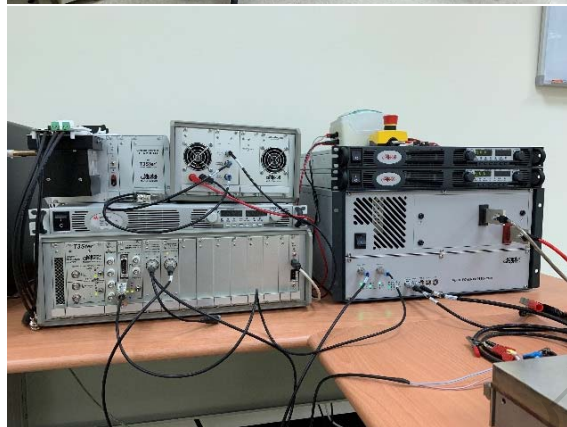


熱特性量測 和功率循環測試



提供給客戶的服務:

1. 完整的Demo及教育訓練
2. 客戶產品熱特性的Benchmark
3. 代測服務
4. 資深工程師和客戶面對面的技術探討



➤可進行的技術支援

- 熱阻測試
- 功率迴圈信賴性測試
- 協助客戶進行前期測試
- 資料解析及技術問題探討
- SI system(設備客制系統) arrangement
- 軟體模擬協助及解析(包含技術探討)



High power module device



- Automotive and transportation
- Power generation and conversion
- Thermal testing and power cycling (reliability)



2011 Ecotec 1.4L I-4 VVT (I4U) and
2011 Volt® Drive Unit 4ET50 (MK)
for Chevrolet Volt



IGBT模組測試方式



一般測試方式

- IGBT testing includes some major branches, like IGBT 主要的測試內容包含
 - Module electrical characterization tests 模組電性測試
 - Environmental tests 環境測試
 - Characterization tests 表徵測試
 - Lifetime tests 壽命測試
 - etc. (mechanical tolerances 機械公差, chemical resistance 耐化學性, ...)

Mentor Graphics expertise covers an important range of these testing branches, especially those which are related to **powering solutions** and **thermal effects**

Mentor Graphics 的專家對於**功率解決方案**和**熱效應**的部分有特別的涉略

Characterization tests (QC) 表徵測試

Using the terminology suggested at ECPE 相關術語取自於ECPE

QC – 01 Determination of parasitic stray inductance (L_p)
— IEC60747-15:2012 Chapter 5.3.2 寄生雜散電感的測定

QC – 02 Determination of thermal resistance
— IEC60747-15:2012 Chapter 5.3.6 熱阻測定

QC – 03 Determination of short-circuit capability 確定短路能力

QC – 04 Determination of isolation behavior 確認隔絕狀況
— IEC 60664-1

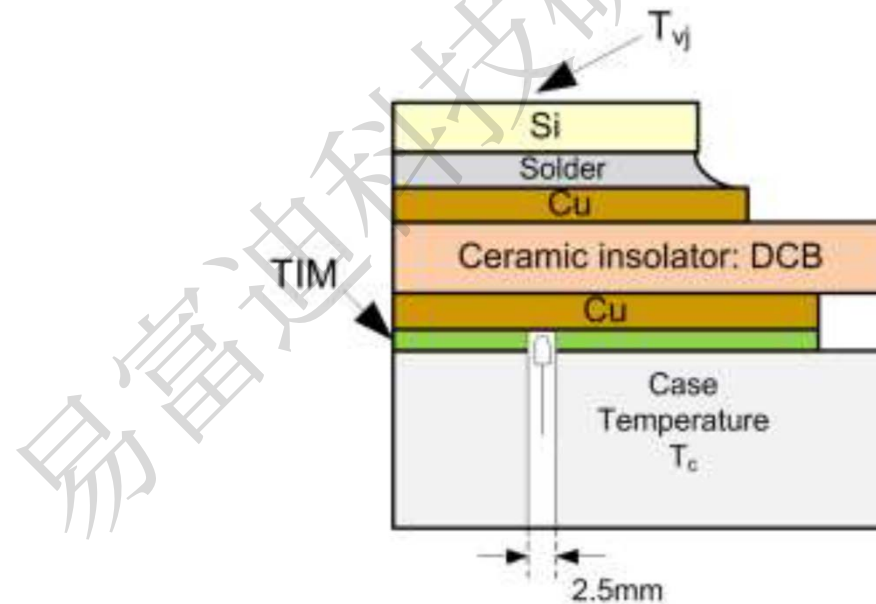
QC – 05 Determination of mechanical data 確認機械資料

IGBT模組測試方式

Determination of thermal resistance (R_{th}) 熱阻測定

Junction to case 結點到殼

(R_{thJ-C} , using Dual interface measurement or aux temp sensor)
利用雙介面量測法或其他溫度感測器



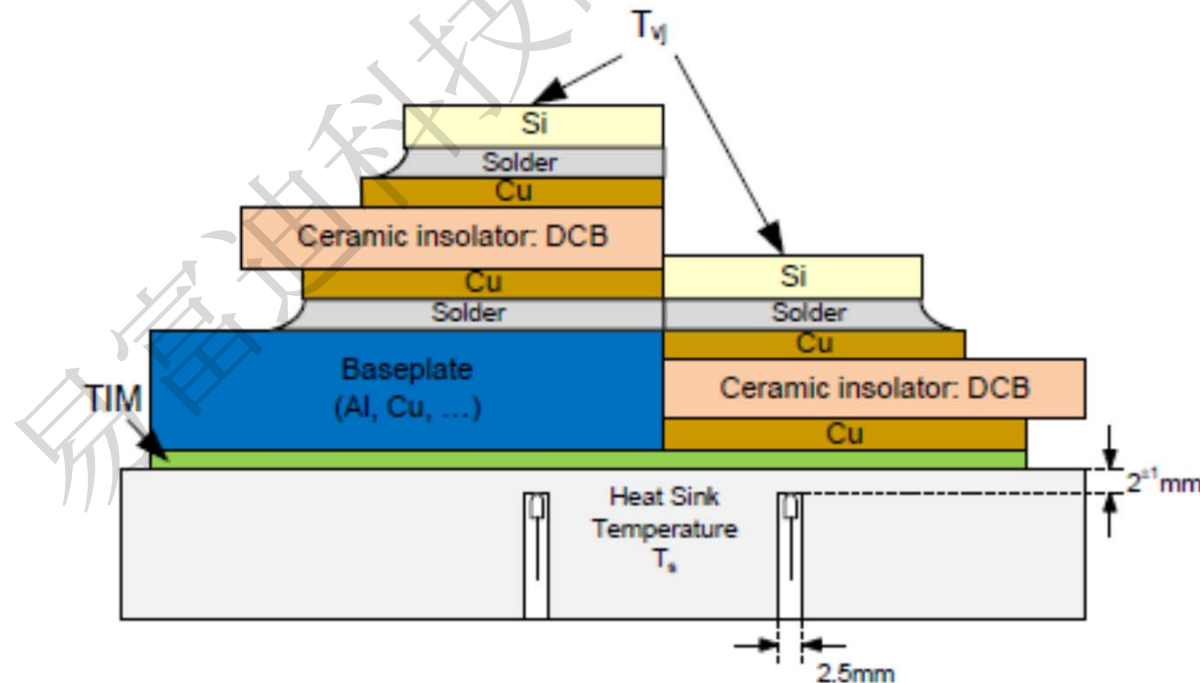
IGBT模組測試方式

Determination of thermal resistance (R_{th}) 熱阻測定

Junction to heat sink 結點到散熱器

(R_{thJ-S} , using embedded Pt100 temperature sensor – where and how many?? customer specific)

利用內置的Pt100 溫度感測器，放置位置和數量由客戶自行定義

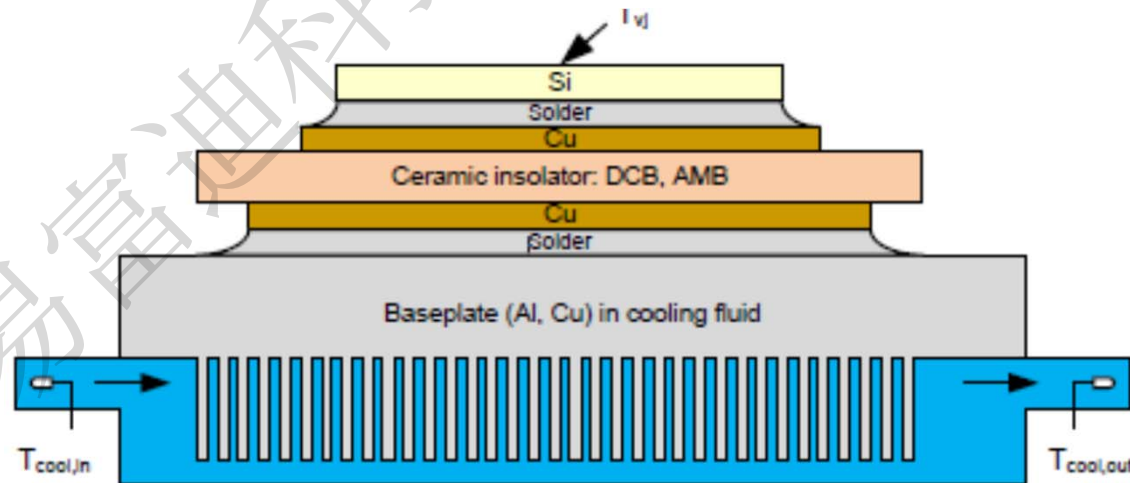


Determination of thermal resistance (R_{th}) 熱阻測定

Junction to ambient 結點到環境

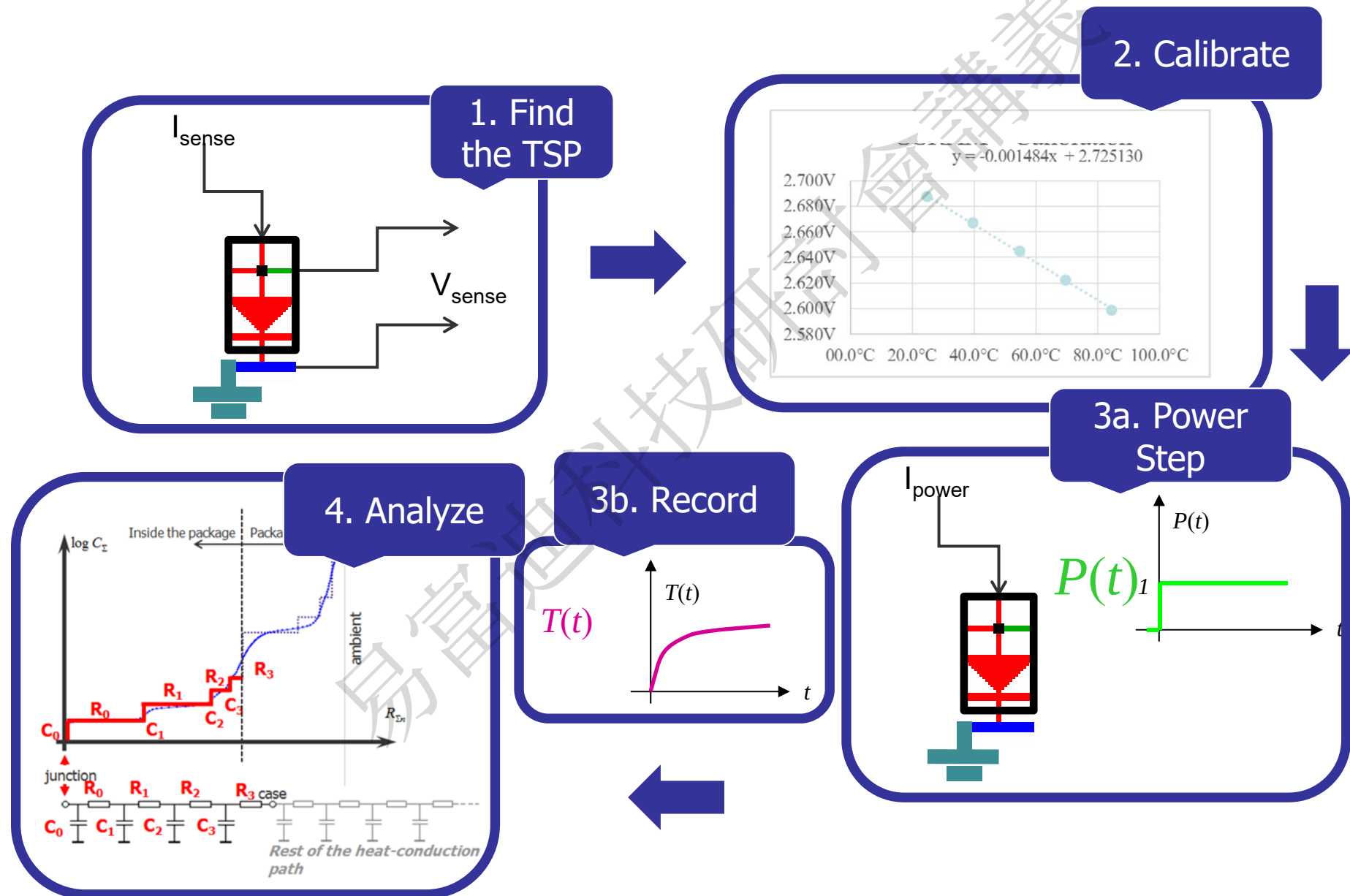
(R_{thJ-A} , its **real effective value** is inherently provided by all other measurements. In case of integrated heat sink; coolant temperatures give additional information for system integration.)

實際有效數值由其他量測所提供，在集成散熱器的情況下，冷卻液的溫度提供額外的訊息



IGBT模組測試方式

T3Ster測試原理



IGBT模組測試方式

T3Ster測試原理

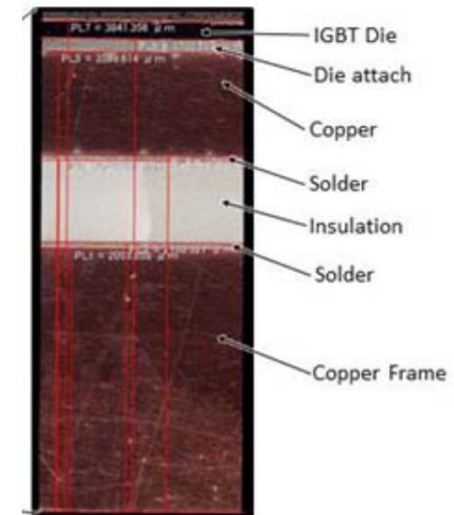
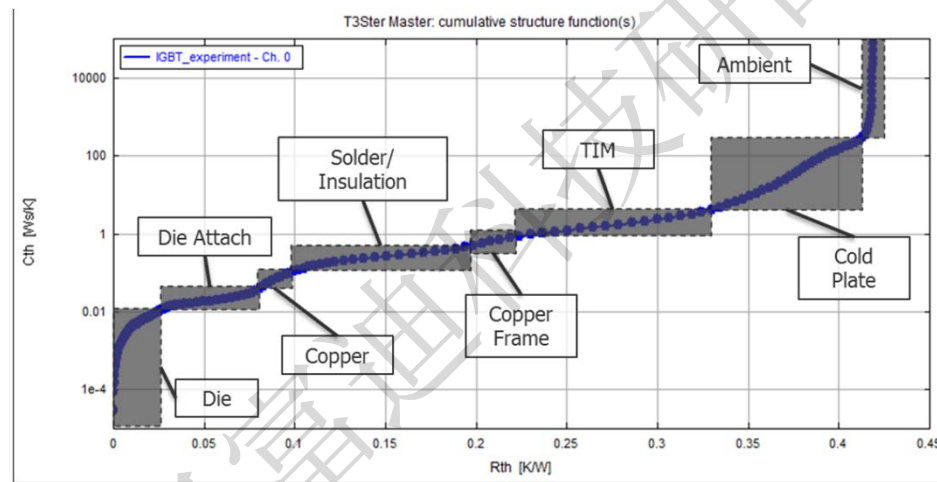


T3Ster - Transient Response Measurements

T3Ster – 瞬態回應量測

Each section of the Structure Function path represents physical objects the heat encounters. There is a correlation between physical objects and sections of the RC path.

“結構函數” 路徑上的每個部分都代表熱所遭遇到的物理物件。物理物件和部分的RC 路徑之間存在相關性。



- Out of these we can focus only on those which induce mechanical damage in the heat conduction path of the power module

在這之中我們只能關注在功率模組的導熱路徑中所引起得機械損傷

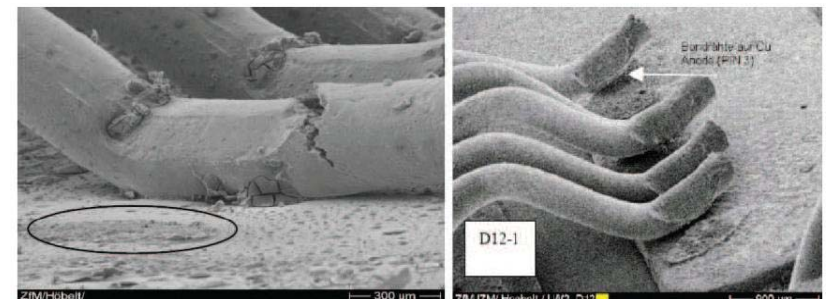
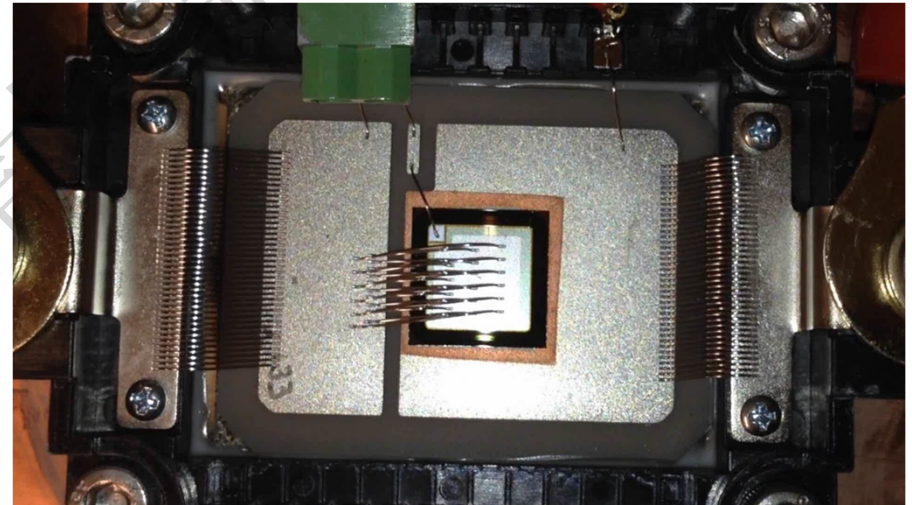
— Combined with structure function evaluation it is a good test method

結合結構函數是很好的測試方式

IGBT模組測試方式

Focus on Power Electronics Module Reliability—Life time test

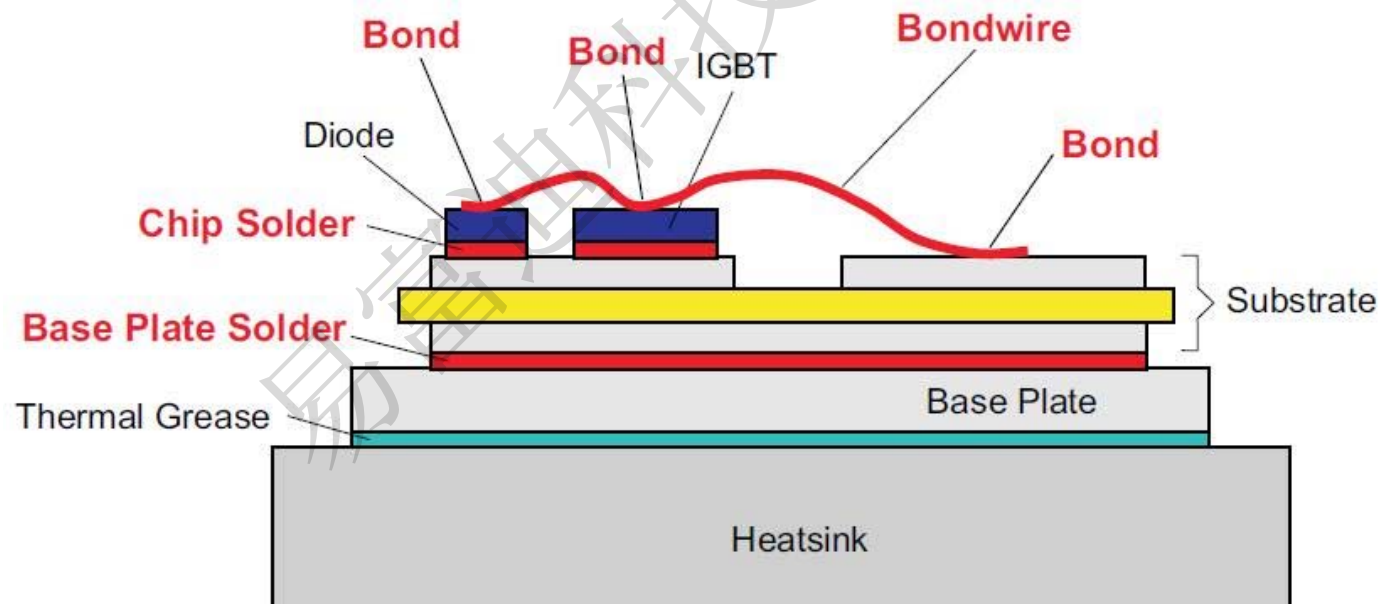
- ∞ Examples:
 - Hybrid & electric vehicle (EV)
 - Railway traction applications – 30+ year expected lifetime
 - Reusable energy production, e.g., wind turbines, solar
- ∞ 10' s of thousands to millions of cycles required
- ∞ Issue is thermally induced degradations due to power cycling & heat
 - Wire bond degradation
 - Metallization layer mismatch
 - Solder fatigue
 - Die and substrate cracks



IGBT模組測試方式

典型功率組件的弱點

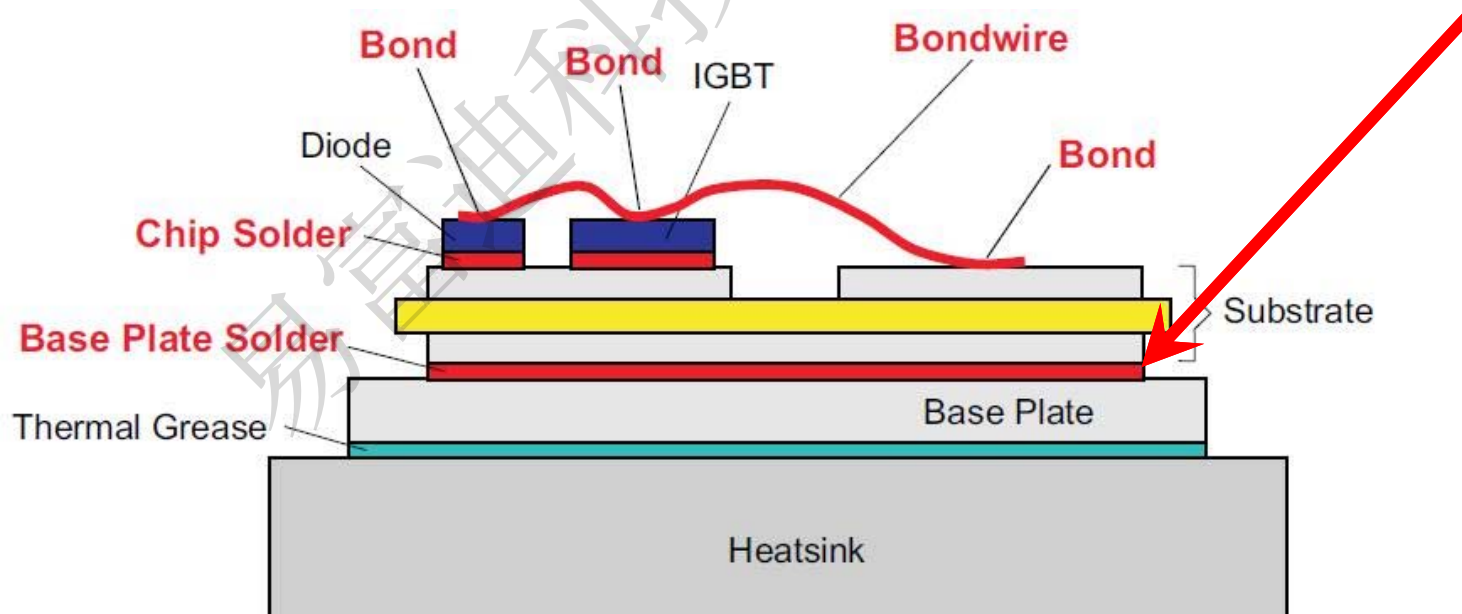
- ∞ The thermo-mechanical stress is the largest when the temperature difference between layers is high and the contact surface is large
- ∞ 各層接觸面和溫度變化劇烈處是熱機應力最顯著的位置



IGBT模組測試方式

典型功率組件的弱點

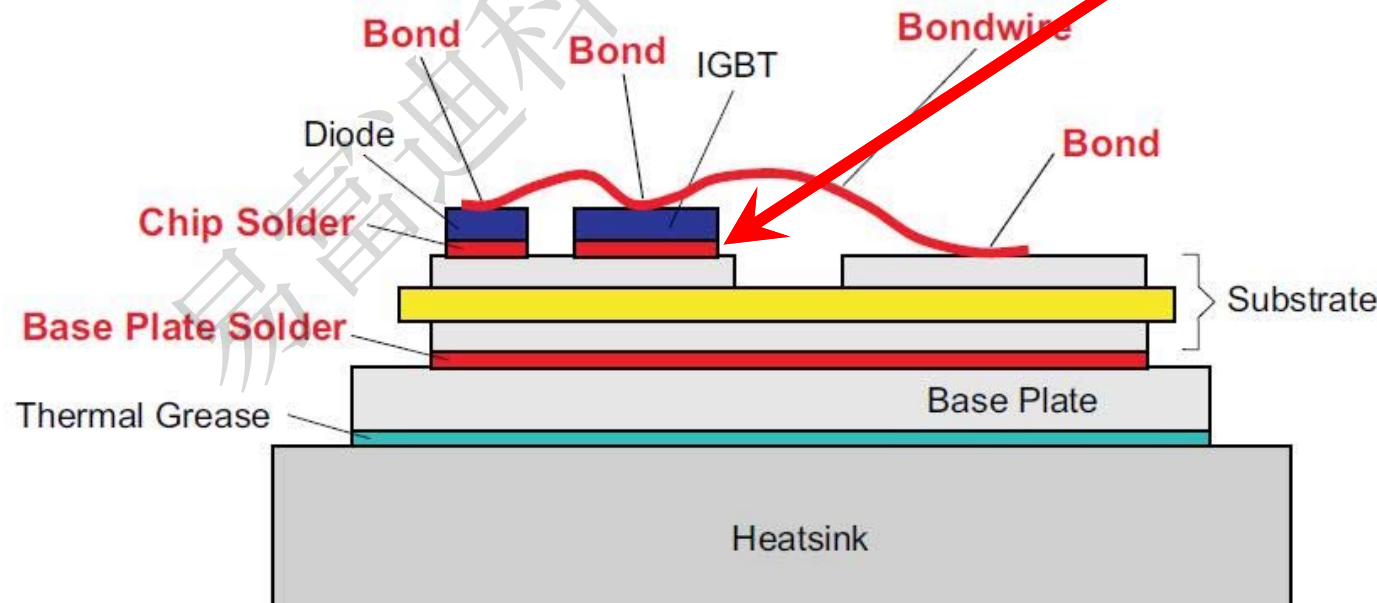
- ∞ The thermo-mechanical stress is the largest when the temperature difference between layers is high and the contact surface is large
- ∞ Solder joint between the base plate and the back-side metallization of the substrate
- ∞ 基板和背面金屬化間的焊點



IGBT模組測試方式

典型功率組件的弱點

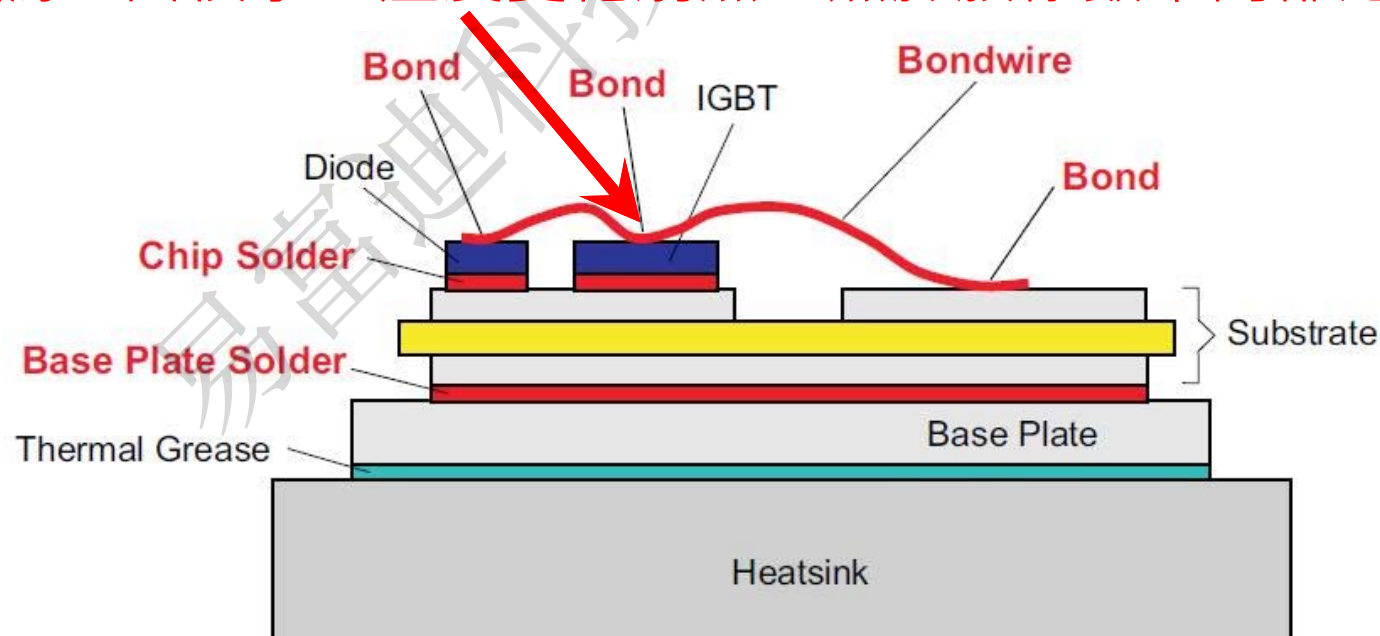
- ∞ The thermo-mechanical stress is the largest when the temperature difference between layers is high and the contact surface is large
- ∞ Die attach – There was extensive research in this field towards better materials and processes
- ∞ 粘結層– 在材料與制程領域上已有廣泛研究



IGBT模組測試方式

典型功率組件的弱點

- ∞ The thermo-mechanical stress is the largest when the temperature difference between layers is high and the contact surface is large
- ∞ Bond wires - Small area but high temperature swing and CTE mismatch make it vulnerable
- ∞ 連接線—面積小且溫度變化劇烈、熱膨脹係數不同都是其弱點

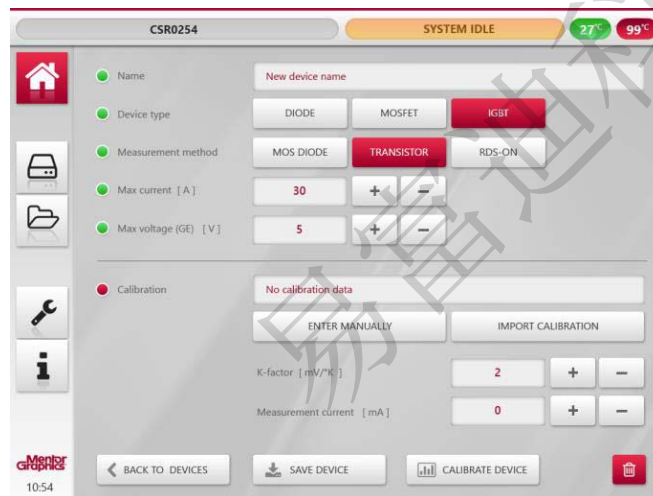


Power Tester 原理介紹



The power cycling and thermal testing of high power semiconductors

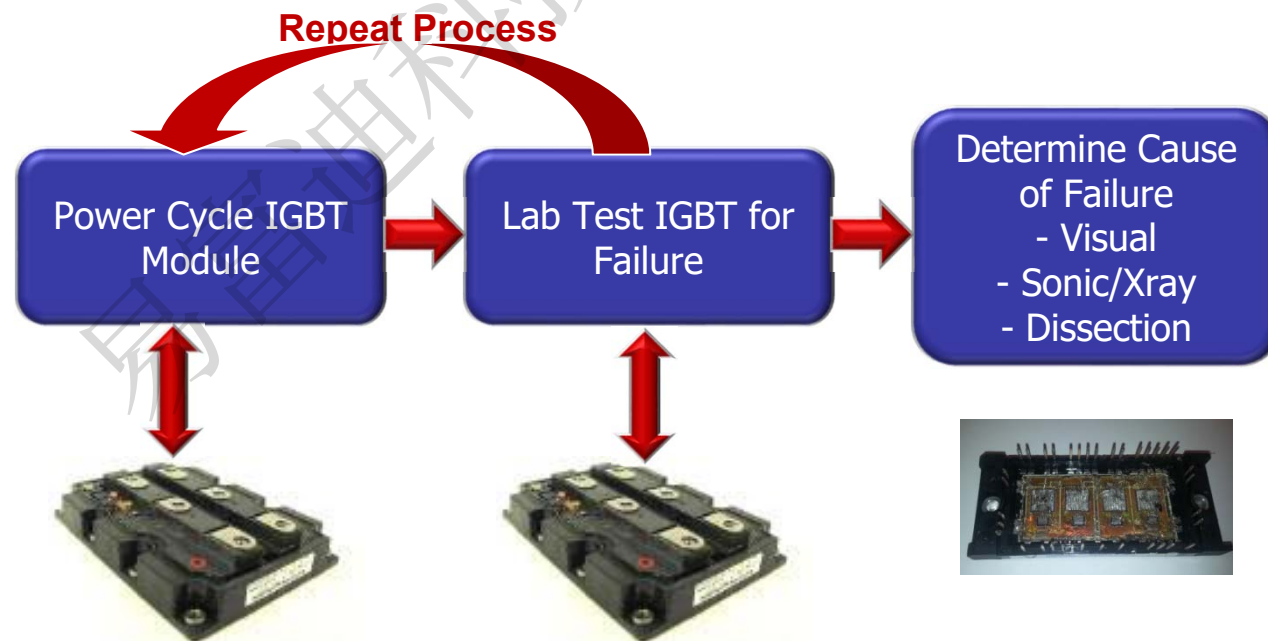
- Industrial implementation of T3Ster+Booster technology
- A new product
 - not a new T3Ster
 - not a new add-on
 - not a new Booster



Traditional Power Cycle Failure Testing



- Traditional Process:
 - Run set number of power cycles
 - Take to lab and test for failure
 - Repeat power cycling/lab testing cycle until failure
 - Take to lab and determine reason for failure
- Issues:
 - Repetitive cycle/lab test process = long times
 - No “real time” indication of failure in progress – only post mortem
 - Failure cause requires lab analysis – typically internal to package



Power Tester 原理介紹



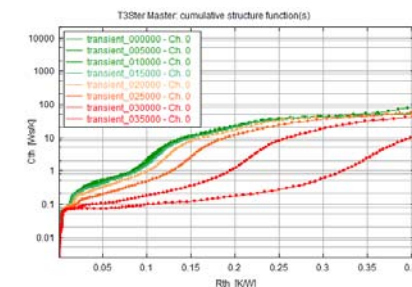
- Industrial implementation of Mentor's industry-unique MicReD T3Ster technology
- Provides fully automated power testing / cycling
- Simple touch-screen user interface
- For MOSFET, IGBT and generic two-pole devices
- Records diagnostic information during test:
 - Current, voltage and die temperature sensing
 - "Structure Function" identifies changes / failures in package structure
- Supports package development, reliability testing, and batch checking of incoming parts before production



Power Tester 1500A

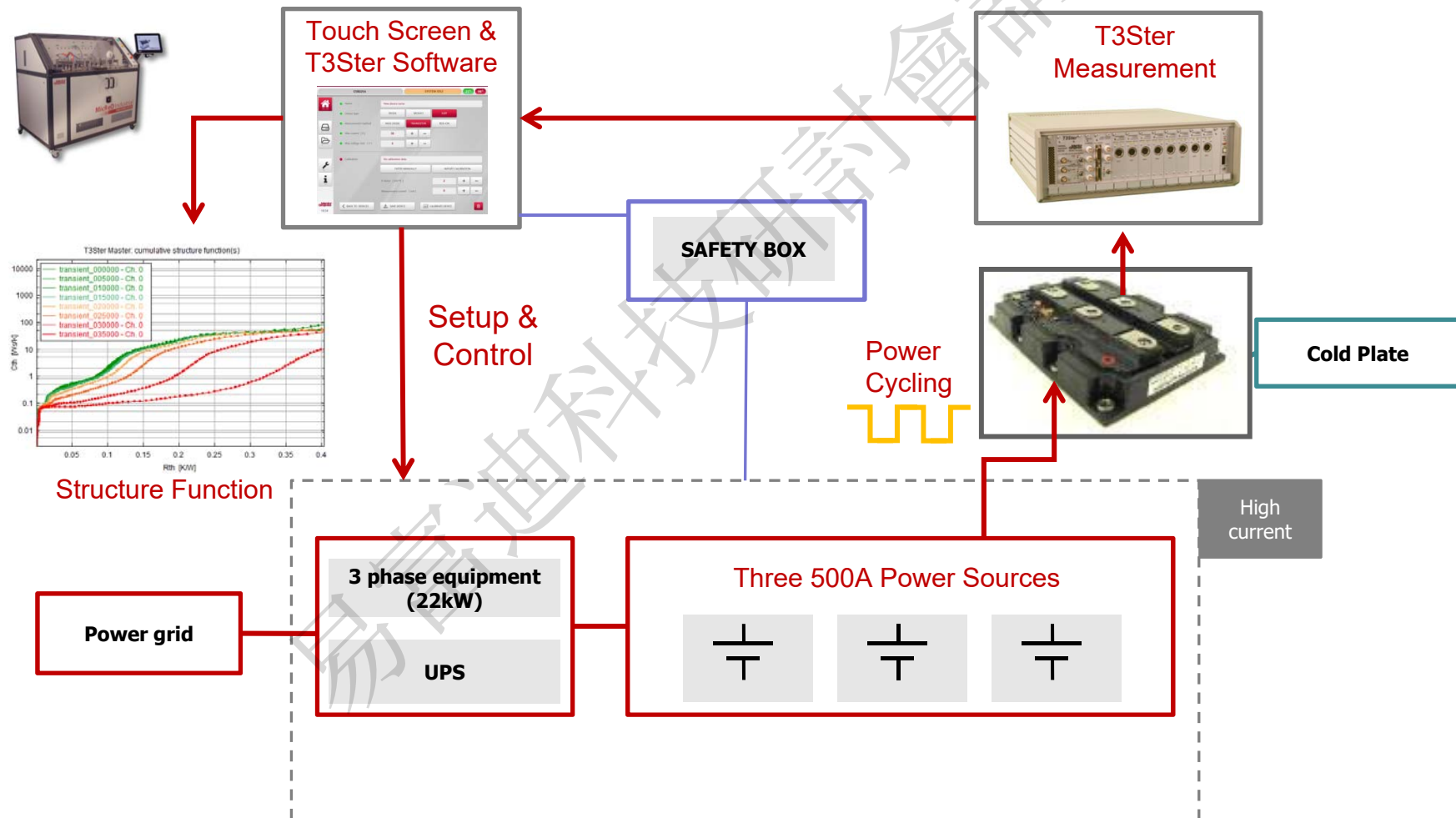


Touch Screen Controls



Structure Function

Power Tester 原理介紹



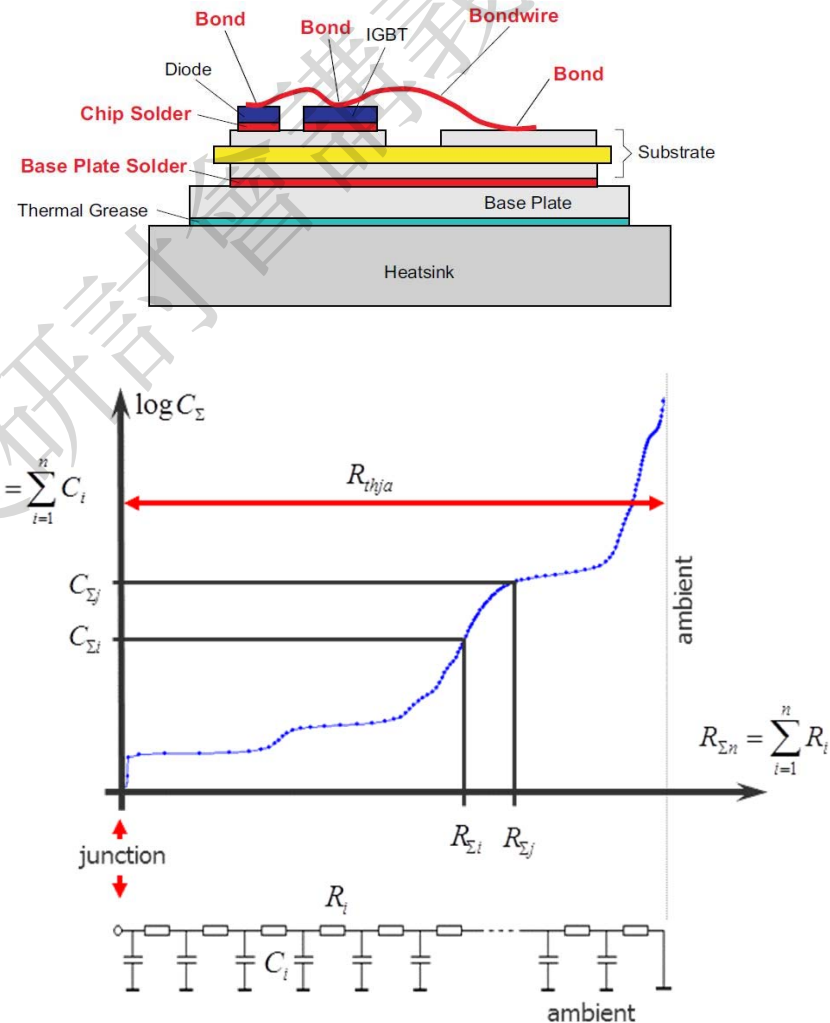
Power Tester 原理介紹



- Thermal transient measurement for junction temperature characterization and Rth identification
 - Following JEDEC JESD 51-1 static test method
 - Structure functions describe the heat conduction path towards the ambient
 - Support of JEDEC JESD 51-14 transient dual interface measurements to determine R_{thJC}
- Combined power cycling + Rth measurement mode
 - Creates stress on the device using power cycles
 - Regular measurement of Rth during the cycling
 - Monitoring of system parameters (voltage, current)
 - Automated increase of Rth measurement frequency

Power Tester 原理介紹

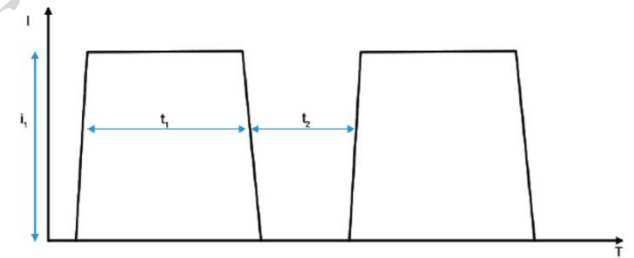
- The Structure Function shows how heat is flowing through a package from junction to ambient
- Reference (good device) Structure Function is saved
- Changes in the Structure Function curve during power cycling identify a specific change in the package
 - Delamination
 - Cracks in substrate
 -



Power Tester 原理介紹



- **Constant current**
 - Degradation has immediate impact on resulting temperature swing, no compensation
 - Most severe strategy
- **Constant current, change of the cold-plate' s HTC**
 - Changes the flow rate of the coolant liquid in sync with the cycles
 - Helps to create a temperature swing at the case to induce failures in the base plate solder
 - For longer cycle times
- **Constant power, PV**
 - Constant ton and toff
 - Power losses are held constant by controlling the driving current
- **Constant $\Delta T_j = \text{Const}$**
 - Driving current control



Power Tester 原理介紹



- Integrated Rth measurement and power cycling
- 1x **1500A** or 3 x 500A heating current, 1-3 devices, 2 cold-plates
- An automated, standalone measurement station
- Simple, task oriented UI
- Alarms and safety features
- **Savings in gross measurement time, complexity**

Power Tester 原理介紹



New Launches

- ☞ PWT 1500A 12C 8V
- ☞ PWT 1800A 12C 12V
- ☞ PWT 3600A 12C 6V
- ☞ PWT 600A 16C 48V
- ☞ PWT 2400A 16C 12V
- ☞ Customers request optimization

Going from 12kW to 29kW

Power Tester 原理介紹

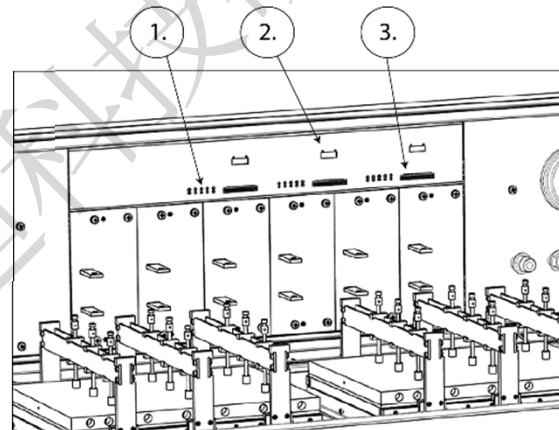


3C HW
PWT 1500A

12C HW
PWT 1500A /1800A/3600A

3-CHANNEL POWER TESTER HW VERSION

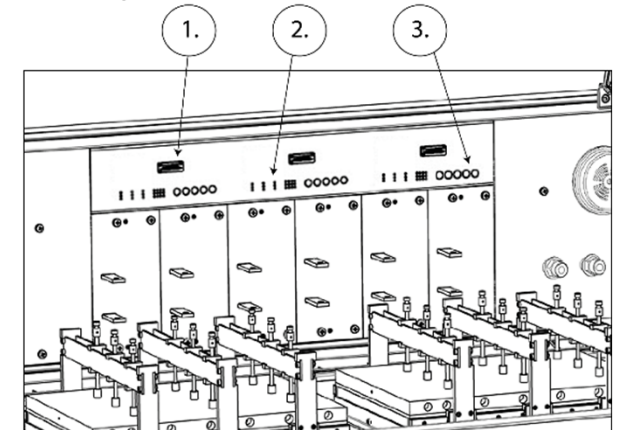
NOT compatible with PWT Control Software 2.1



Number	Element
1.	Measurement channel LED indicators
2.	External temperature sensor connection
3.	DUT connection

12-CHANNEL POWER TESTER HW VERSIONS

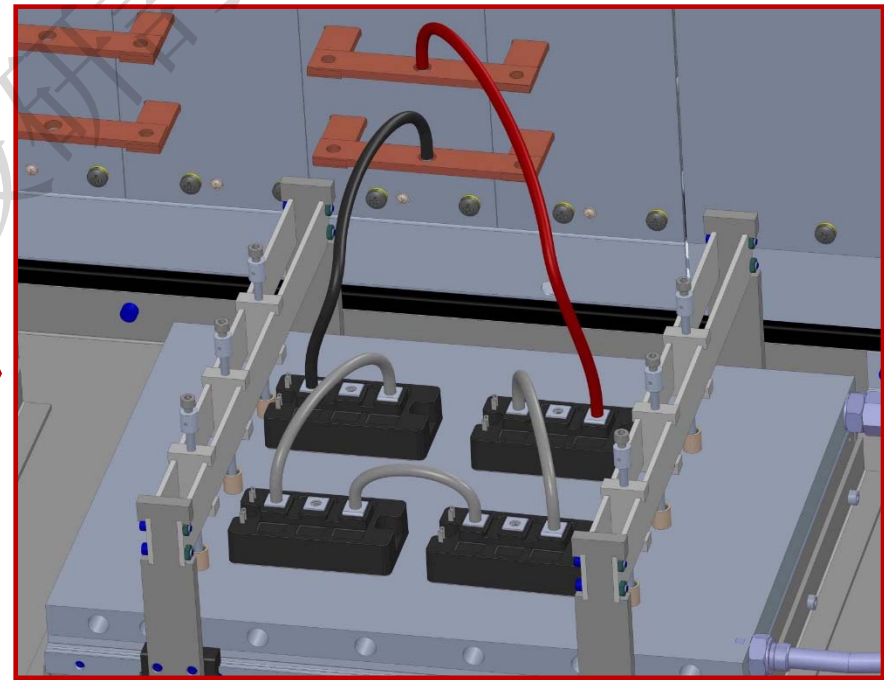
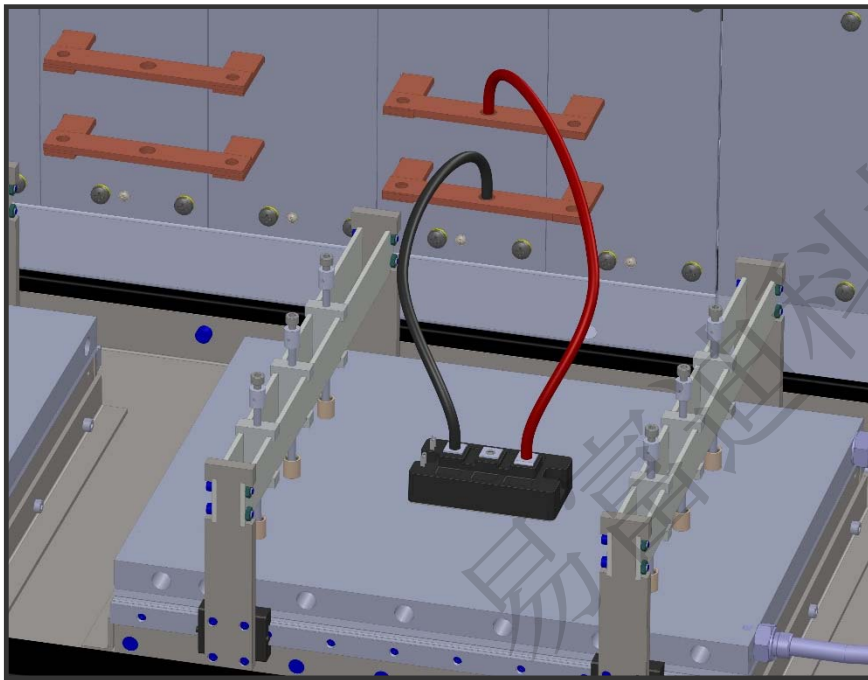
Compatible with PWT Control Software 2.1



Number	Element
1.	External temperature sensor connection
2.	Measurement channel LED indicators
3.	DUT connection

Power Tester 原理介紹

- Up to 12 devices can be measured at the same time
- 4 Devices per Channel using a channel Multiplexer.



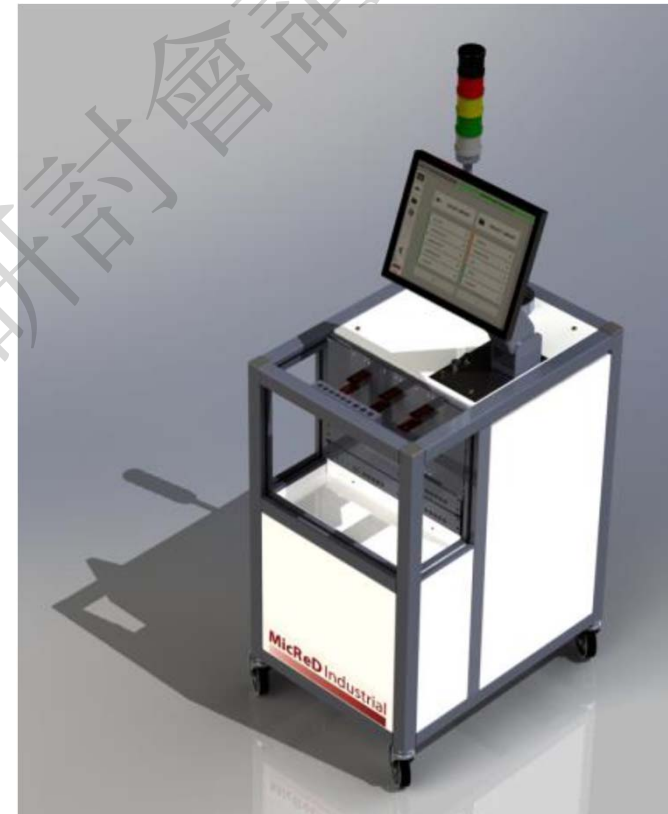
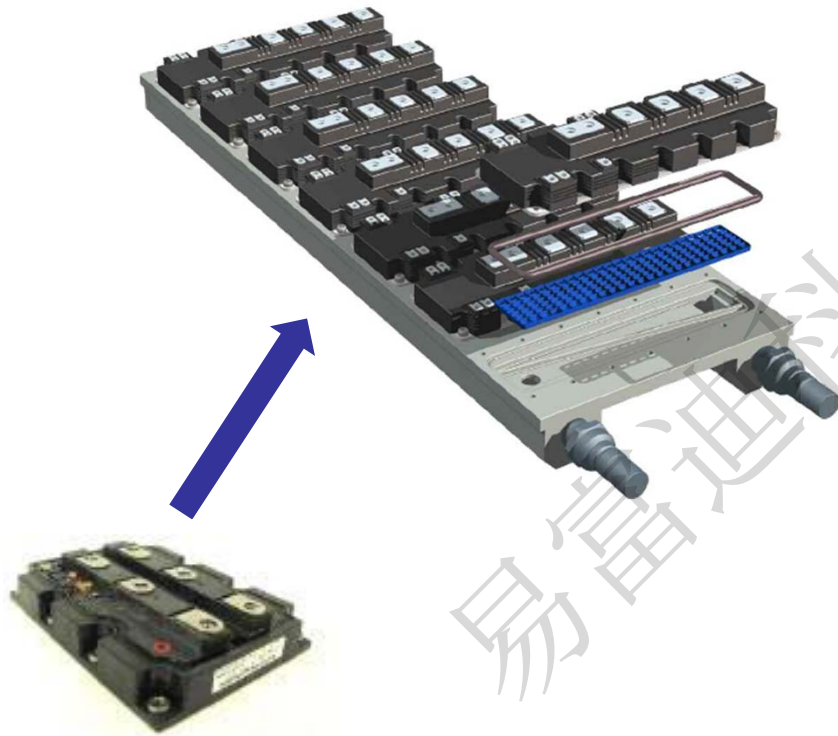
Power Tester 原理介紹



- Lighter mechanics (no cold-plate or cavity)
- Measurement: 16 channels (4x4)
- Output current: 600A (2x300A)
- Output voltage: 48V
- Power Tester 600A 16C 48V (29kW!)

Power Tester 原理介紹

Exploded
view of
IGBT

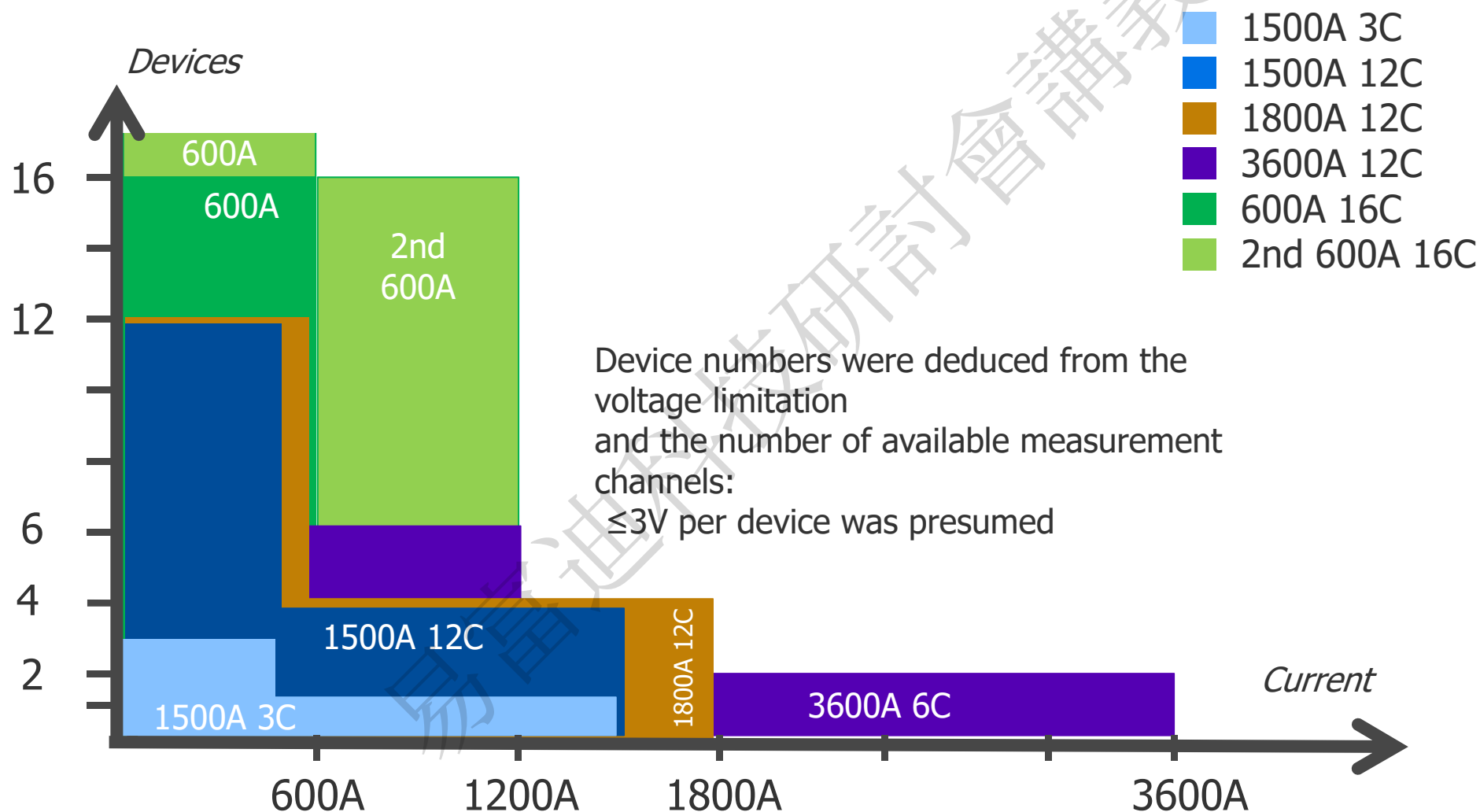


Power Tester 原理介紹



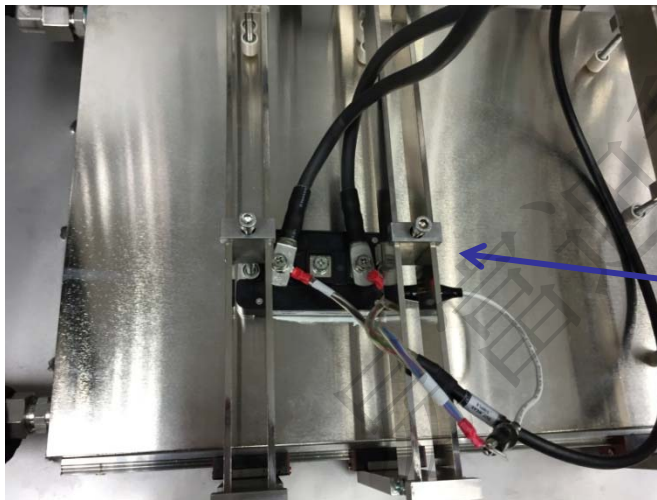
- Up to 8 X 600A Power Testers chained together allows users to power cycle to failure up to 128 IGBTs in series

Power Tester 原理介紹

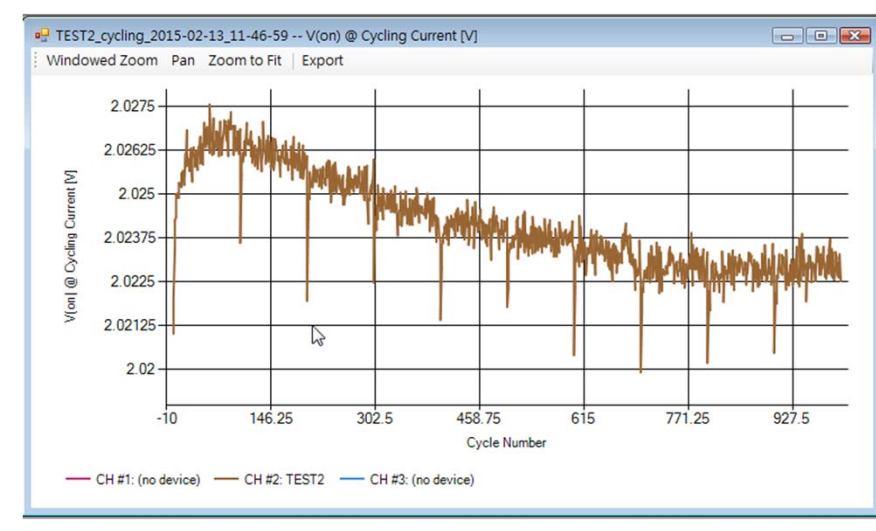
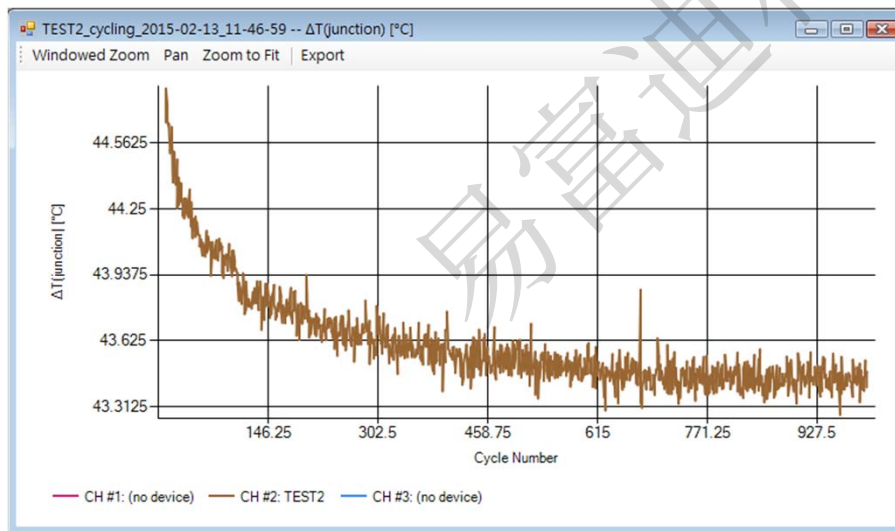
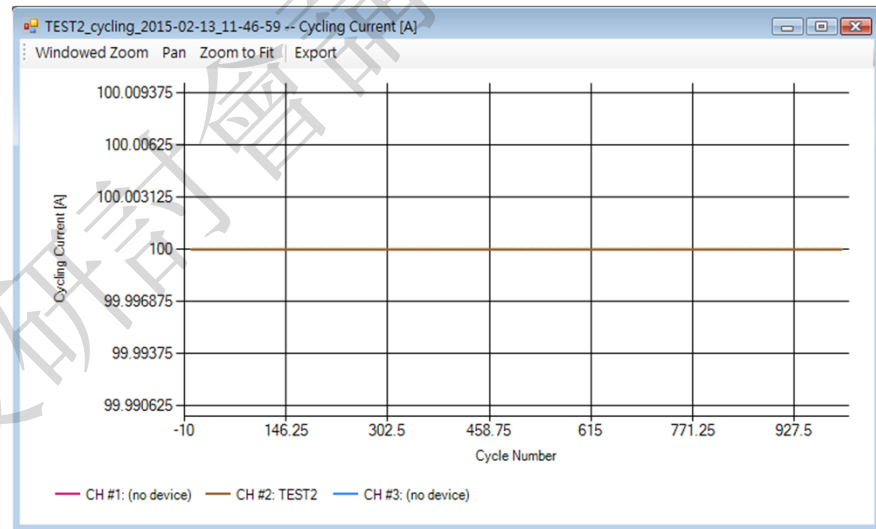
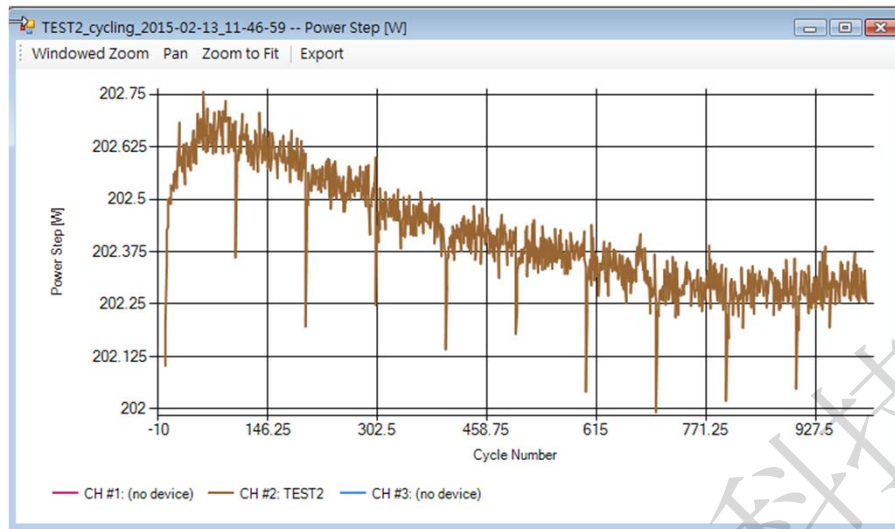


IGBT measurement of Power Tester(1)—constant current

- Base plate temperature: 25 °C
- Input power: 200W @ 100A
- Constant current regardless of the voltage change
- The number of cycles: 1000 cycles
- Transient test after every 100 cycles



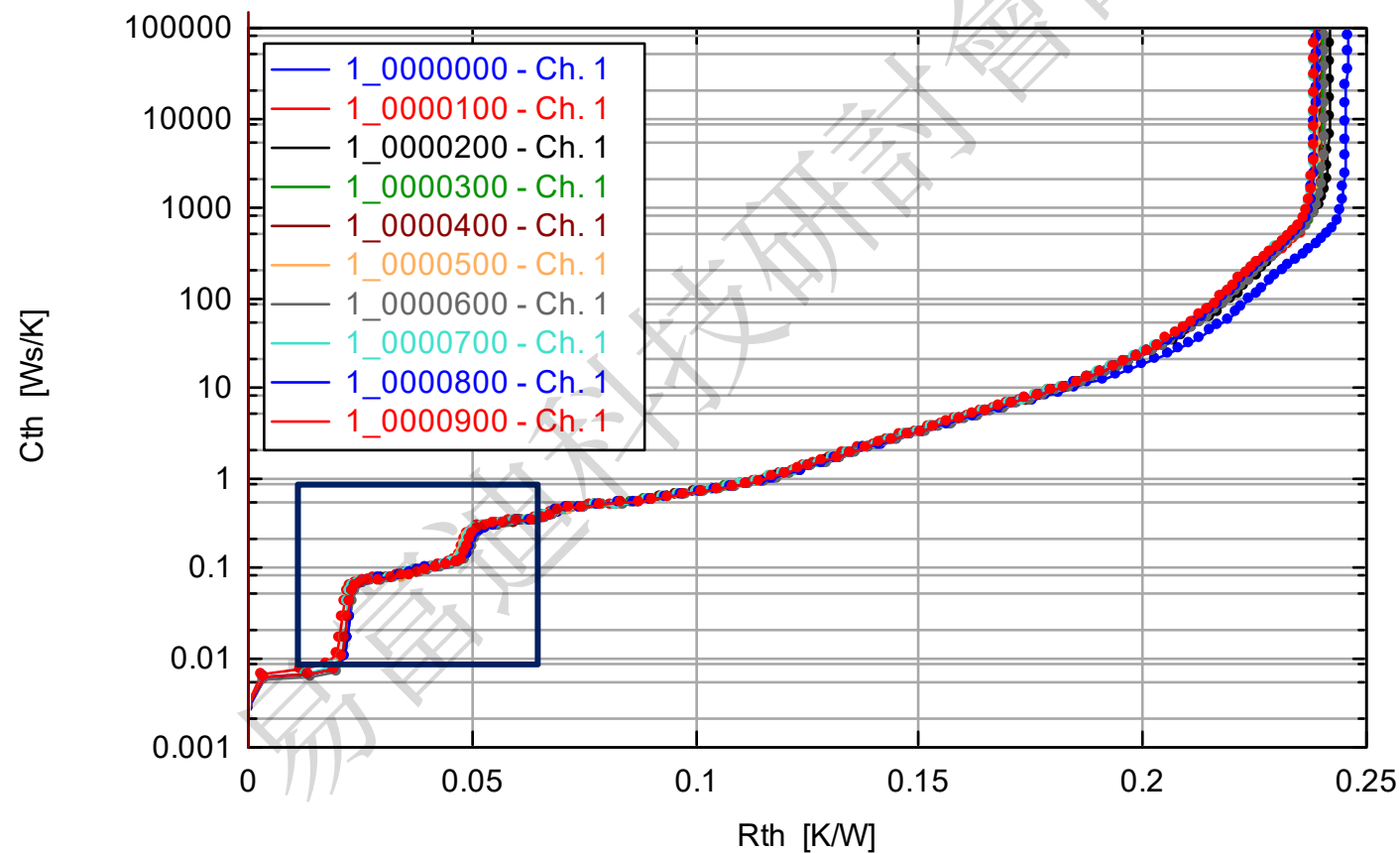
IGBT measurement of Power Tester(1)—constant current



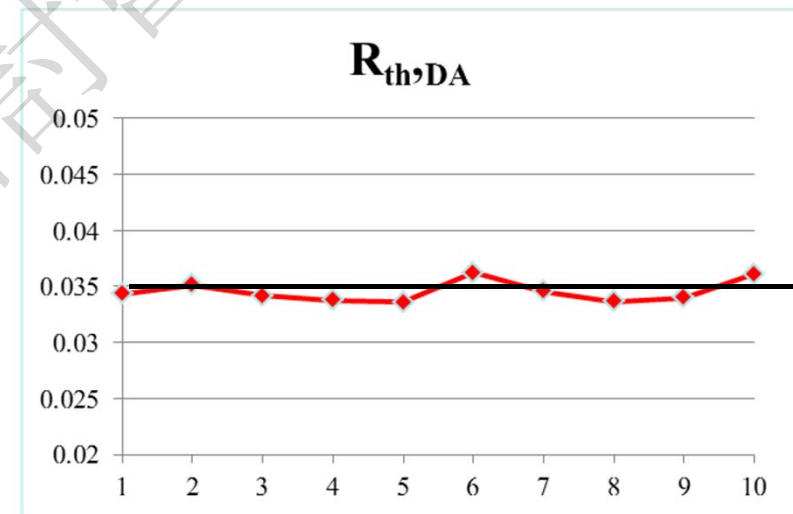
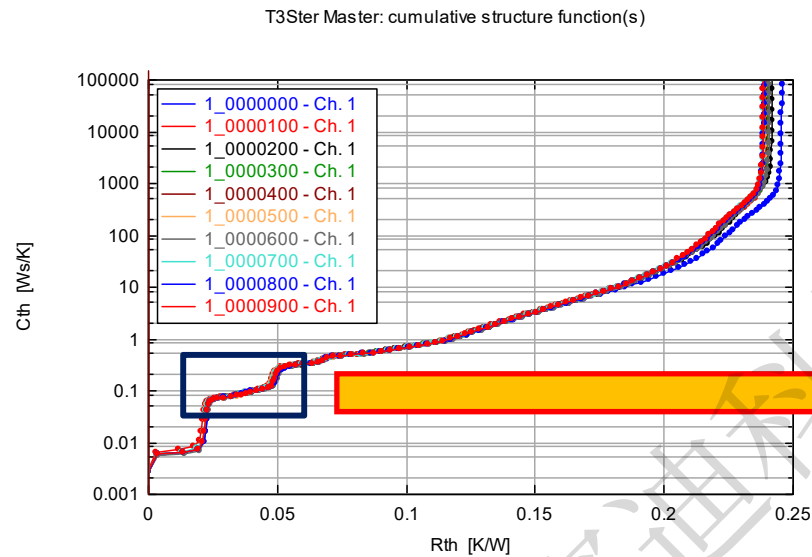
IGBT measurement of Power Tester(1)—constant current



T3Ster Master: cumulative structure function(s)

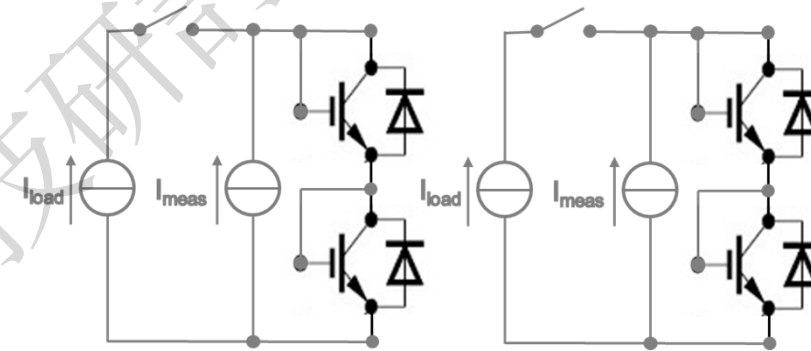
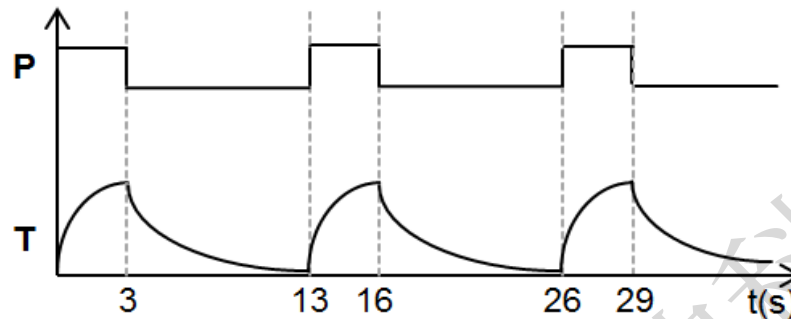


IGBT measurement of Power Tester(1)—constant current



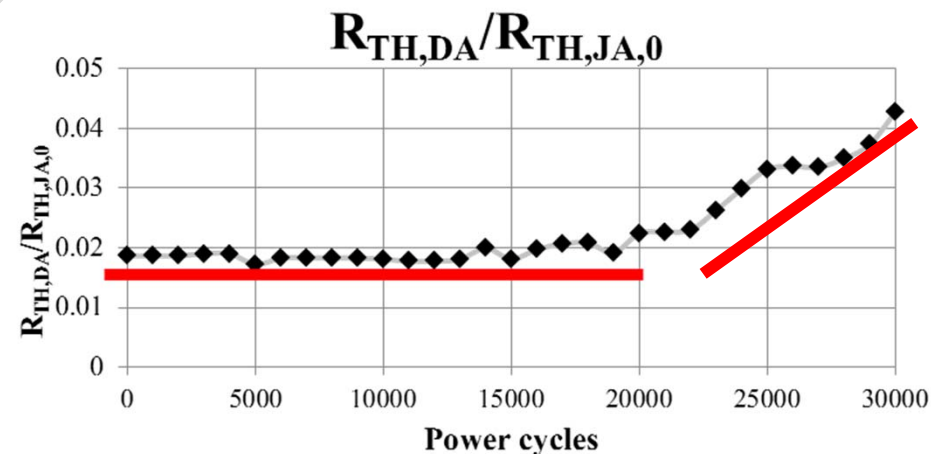
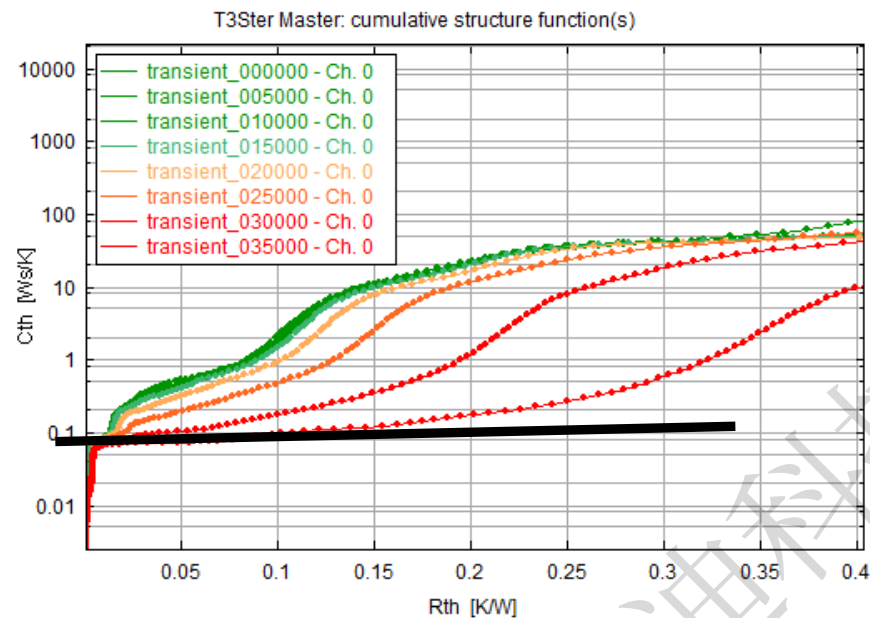
IGBT measurement of Power Tester(2)-constant current

- Base plate temperature: 25 °C
- Targeted junction temperature: 125 °C
- Input power: 200W @ 25A



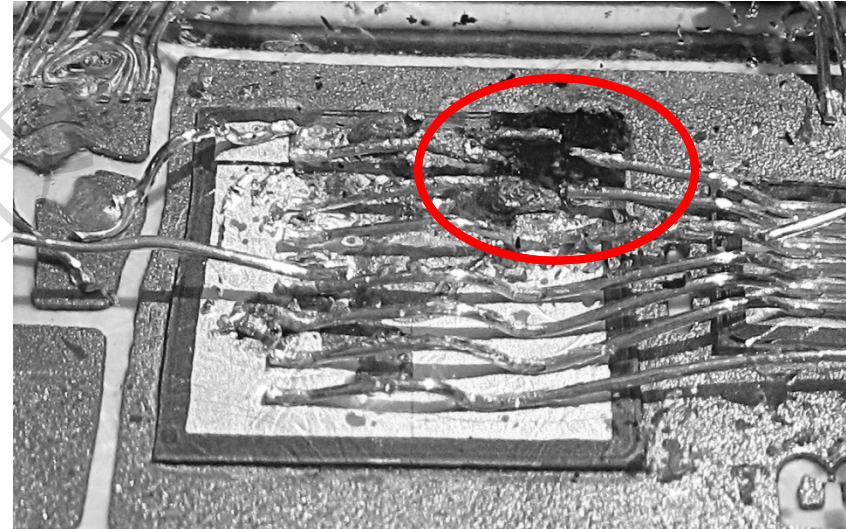
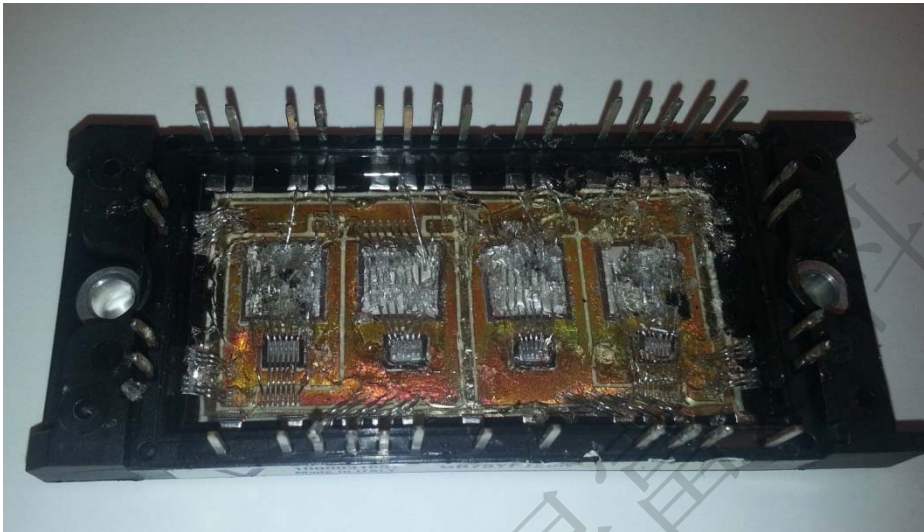
- **Constant current regardless of the voltage change**
- Transient test after every 200 cycles

IGBT measurement of Power Tester(2)-constant current



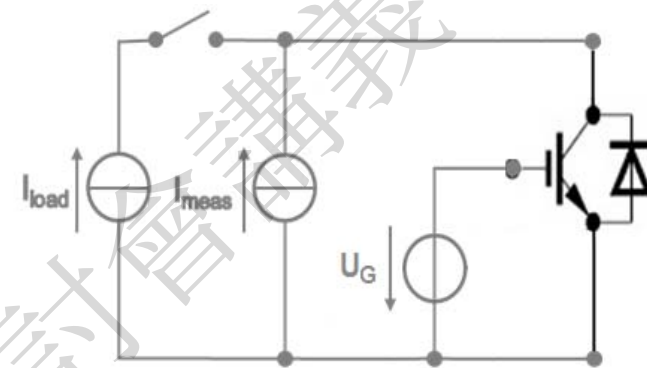
IGBT measurement of Power Tester(2)-constant current

- Broken bond-wires and burnt areas on the chip surface

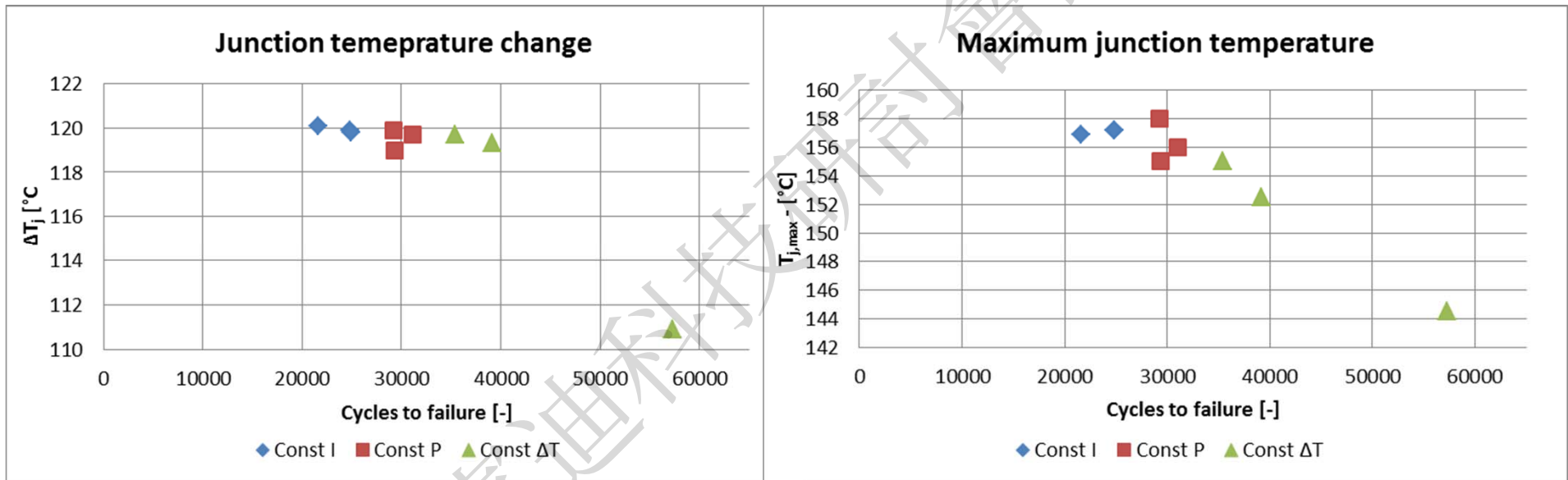


IGBT measurement of Power Tester(3)- Different Strategies to compare

- ∞ Devices mounted on temperature controlled cold plate
- ∞ Base plate temperature: 25 °C
- ∞ Various control strategies*
- ∞ Transient test after every 250 power cycles



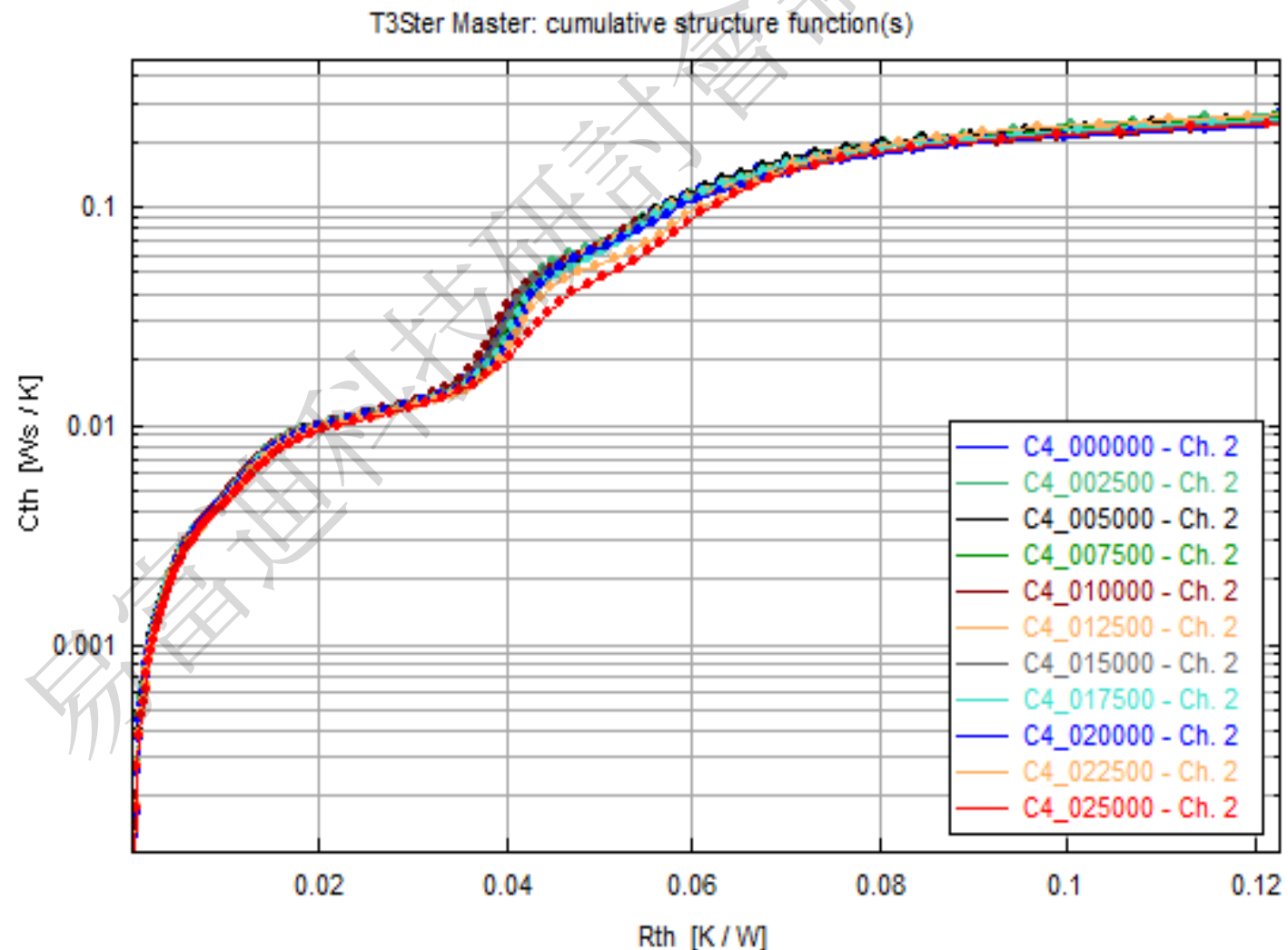
IGBT measurement of Power Tester(3)- Different Strategies to compare



IGBT measurement of Power Tester(3)- Different Strategies to compare



Structure functions to identify die
attach degradation



IGBT measurement of Power Tester(3)- Different Strategies to compare



- ∞ The same parameters used for IGBT cycling
- ∞ ΔT_j is kept constant, but 10°C difference between two cases

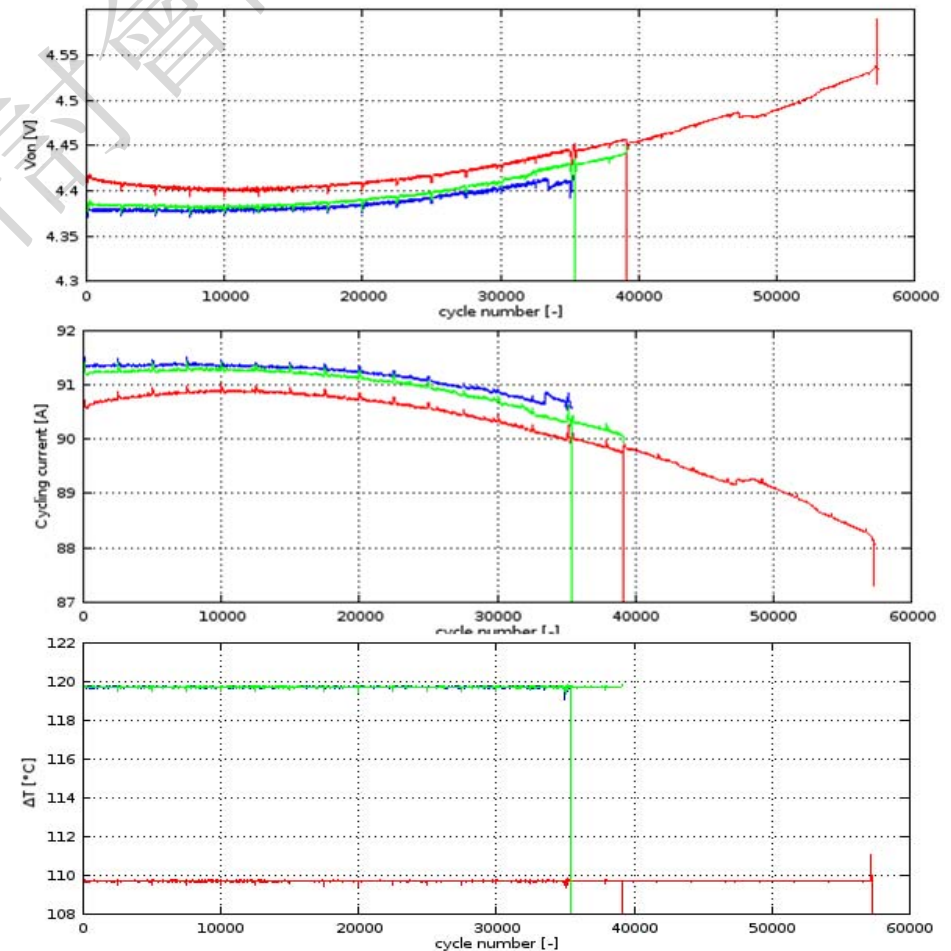


Significant difference in the lifetime

- 120°C: ~36000 cycles
- 110°C: ~58000 cycles

- ∞ 2 points of the lifetime curve are available

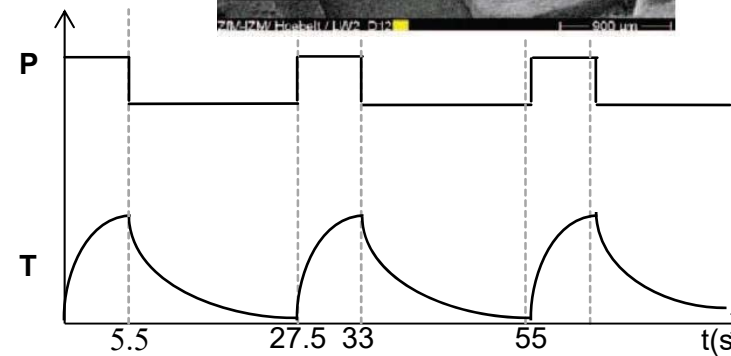
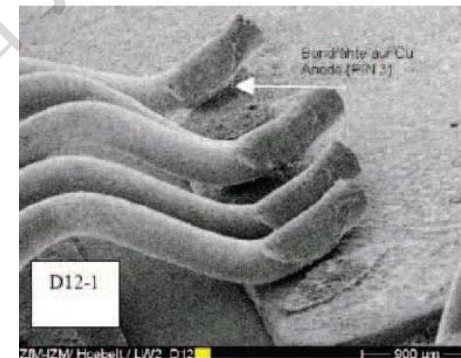
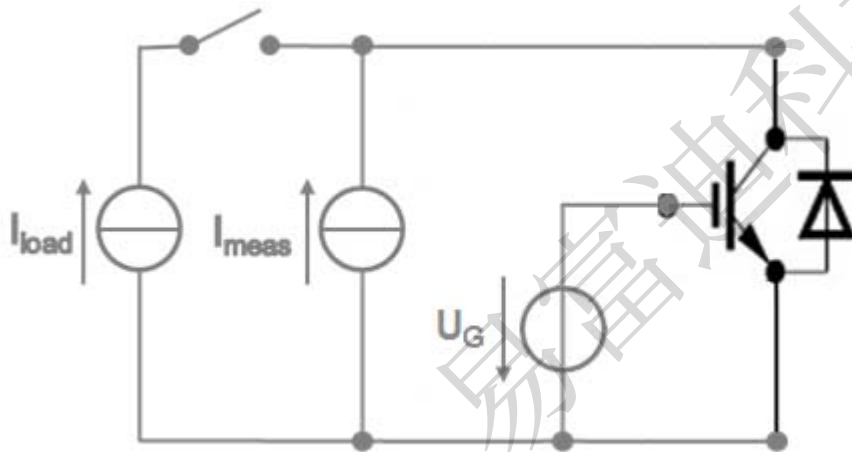
Effect of temperature differences on lifetime



IGBT measurement of Power Tester(4)- Wire Bonding broken check

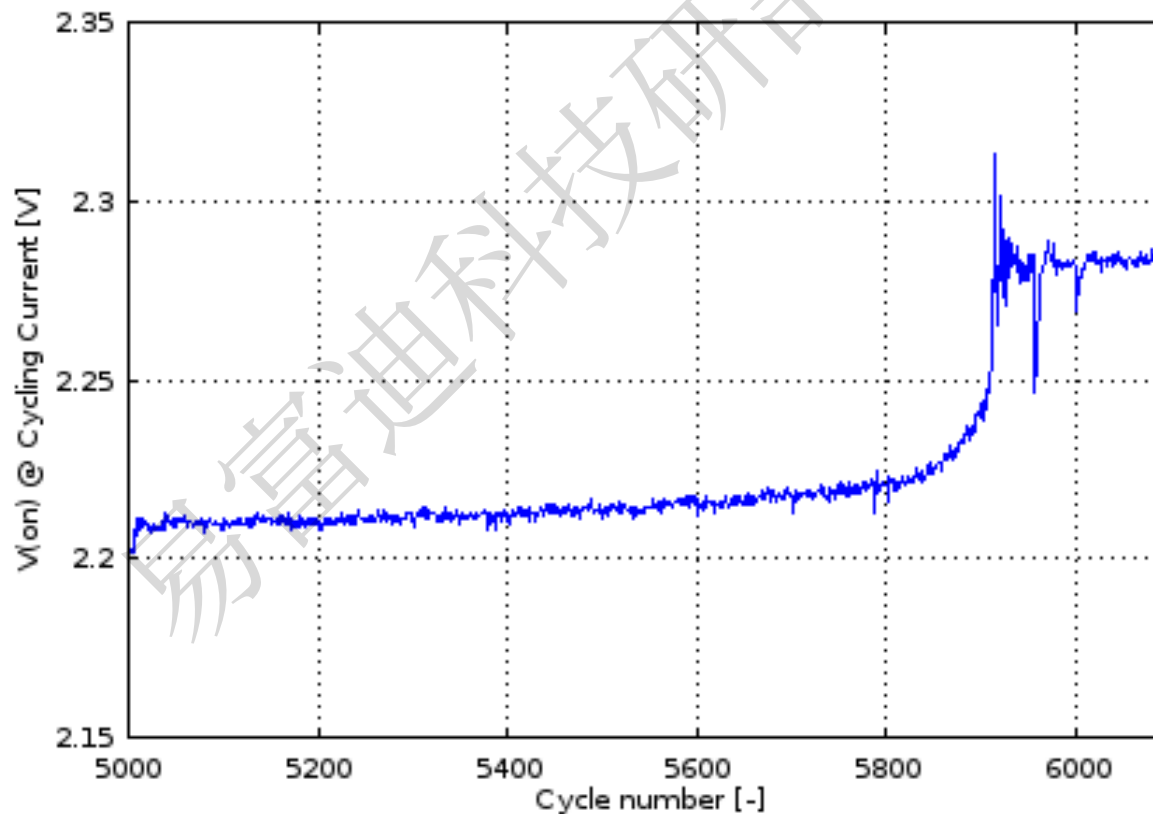
- ∞ $I_{D\max} = 160\text{A}$
- ∞ Device driven is saturation mode, $V_{GS} = 15\text{V}$
- ∞ Target $\Delta T = 100^\circ\text{C}$
- ∞ Constant timing and current regardless of the voltage change

I_{load}	160 A
P	~530 W
ΔT	~100 °C
T_{Heating}	5.5 s
T_{Cooling}	22 s
T_{max}	135 °C

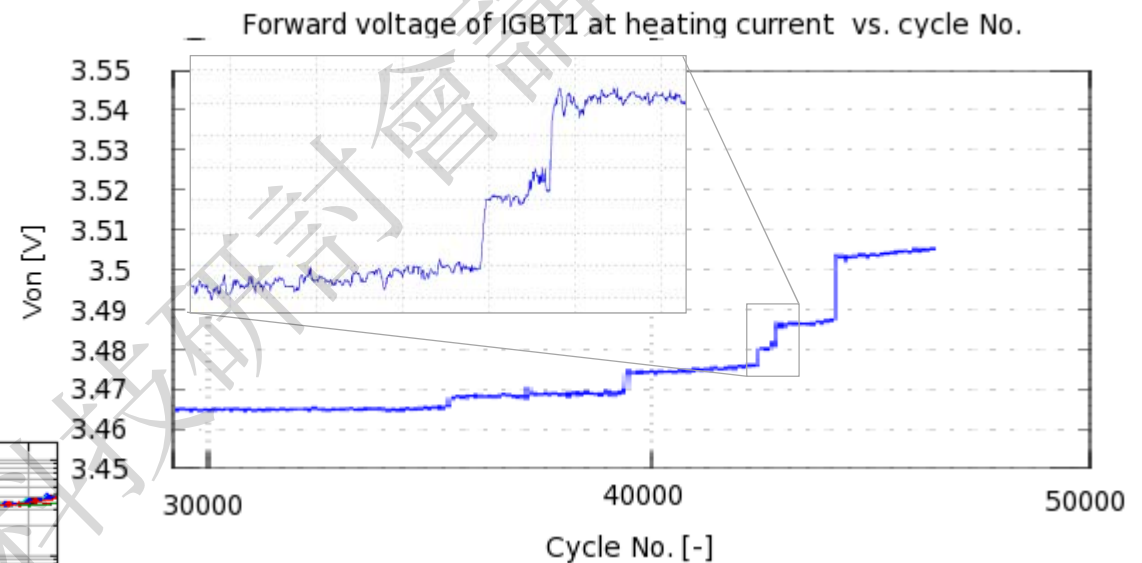
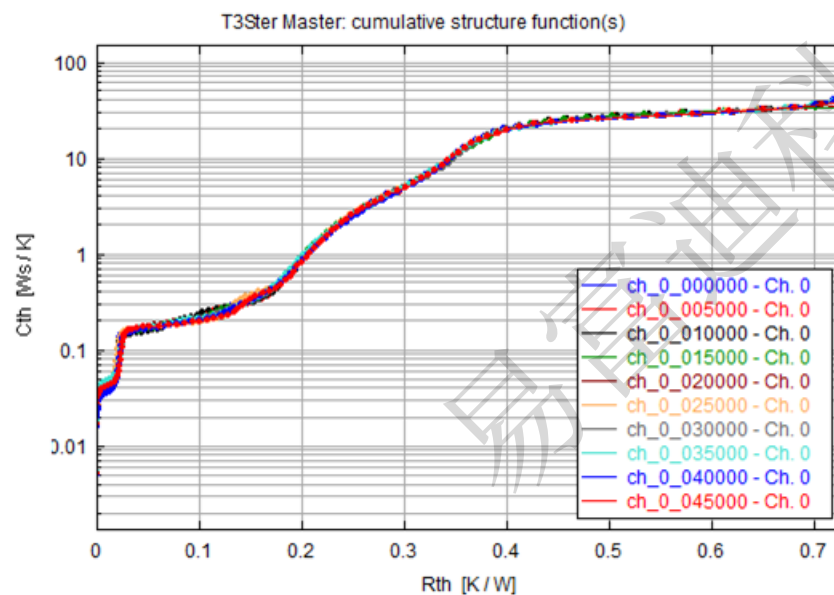


Bond wire degradation

-
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IGBT measurement of Power Tester(4)-Wire Bonding broken check



We could verify that there was no structural change

IGBT measurement of Power Tester(5)- Difference module compare

- 2 IGBT Module compare
- Provide the same test condition and check



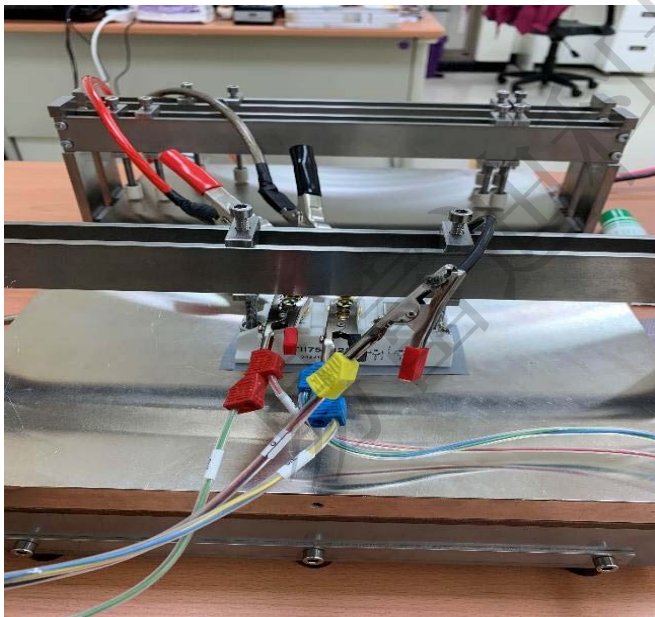
FF75R12RT4



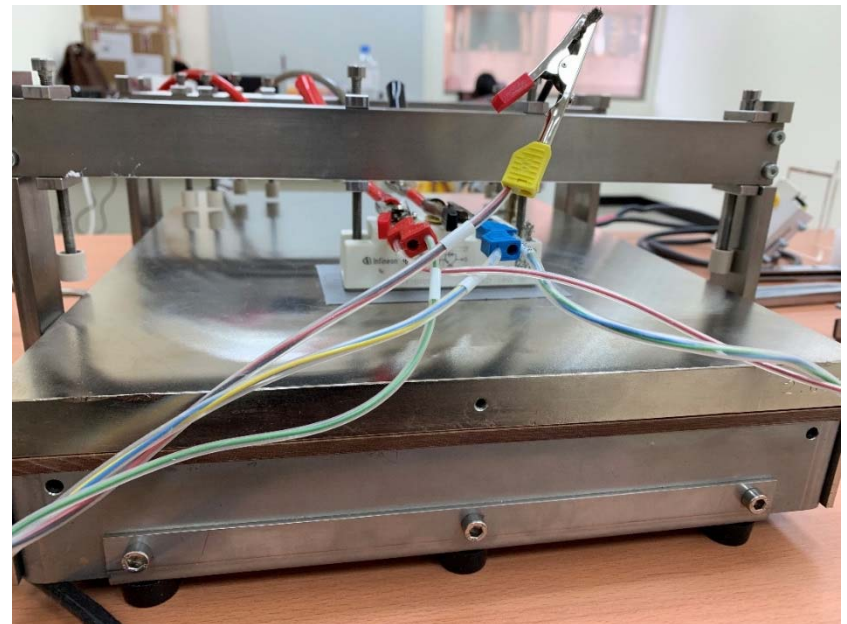
TII75A120

IGBT measurement of Power Tester(5)- Difference module compare

- Base plate temperature: 25 °C
- Input power: about 105W @ 60A
- constant current to measurement
- The number of cycles: 2000 cycles
- Transient test after every 200 cycles @ 30A
- Pulse on /off time: 3 secs. / 5 secs.

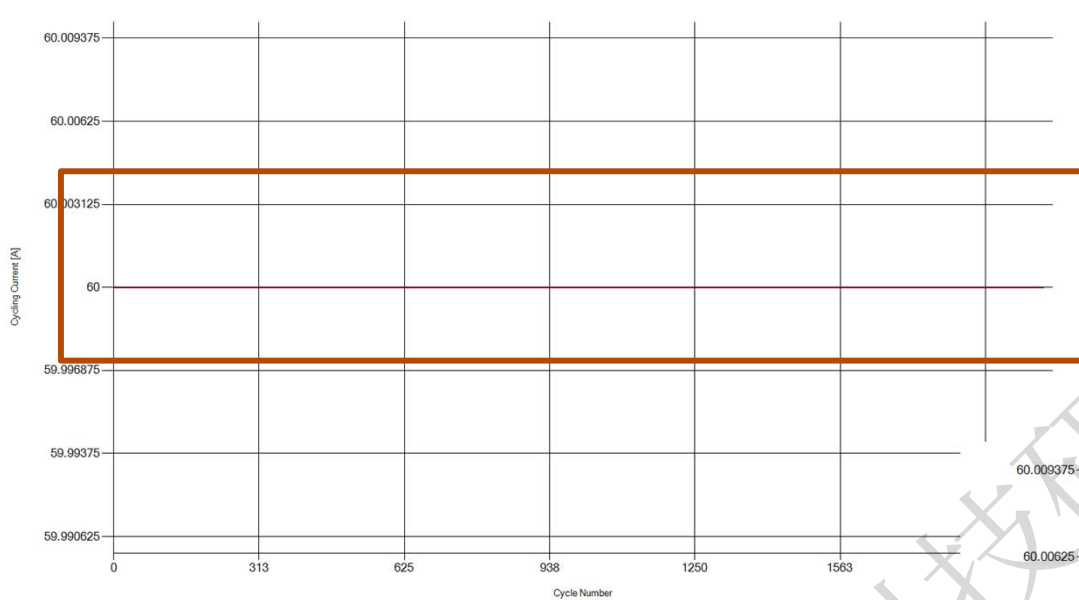


TII75A120



FF75R12RT4

IGBT measurement of Power Tester(5)- Difference module compare

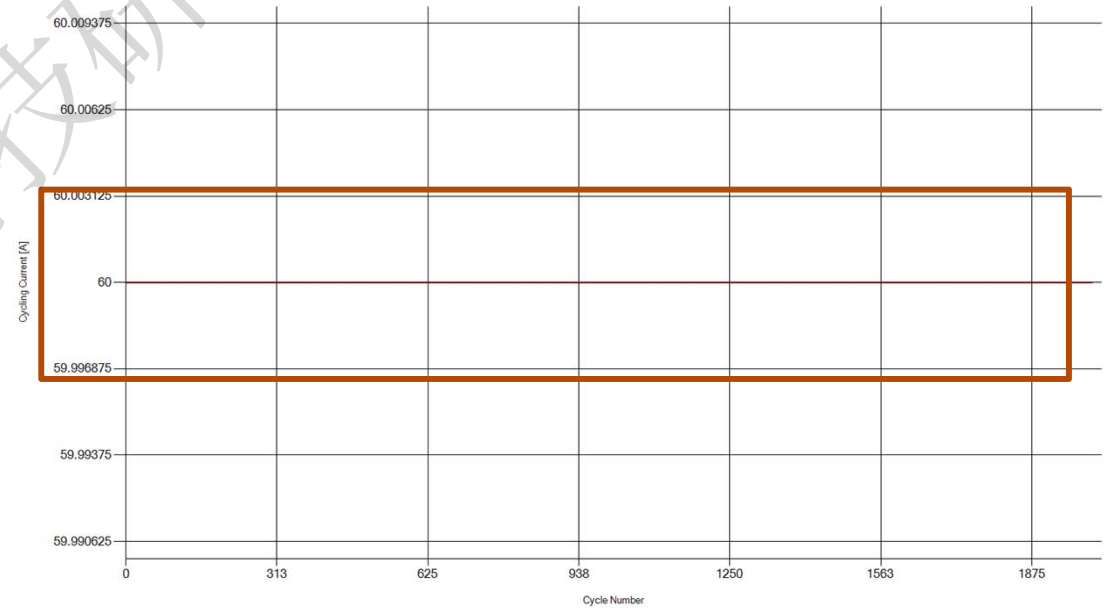


CH #1: FF75R12



FF75R12RT4

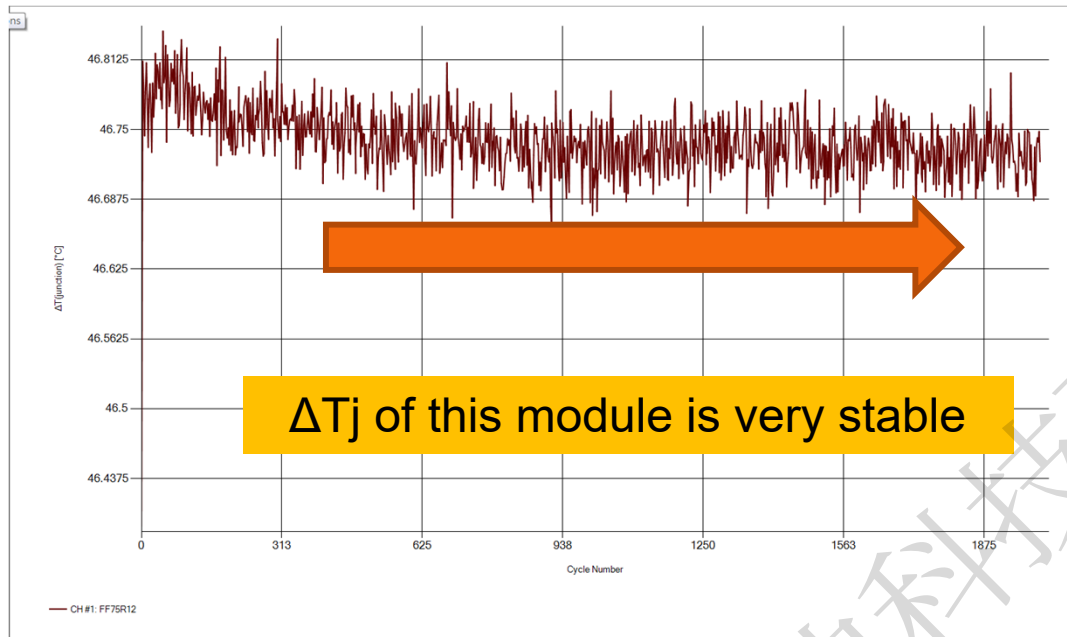
TII75A120



CH #1: TII75A120

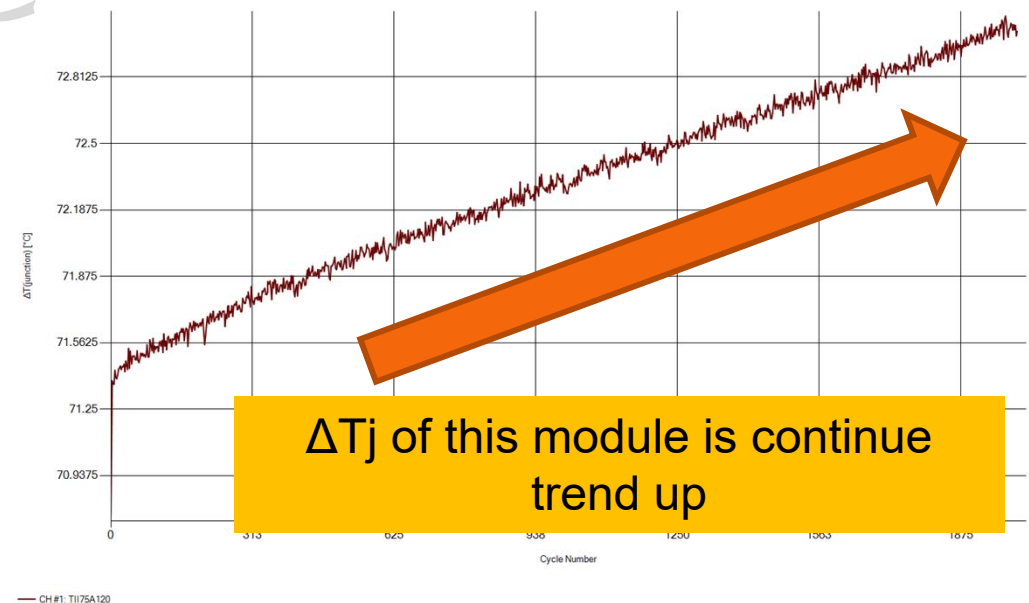
First, we can check the current output of Power Tester to this two module is the same and very stable

IGBT measurement of Power Tester(5)- Difference module compare

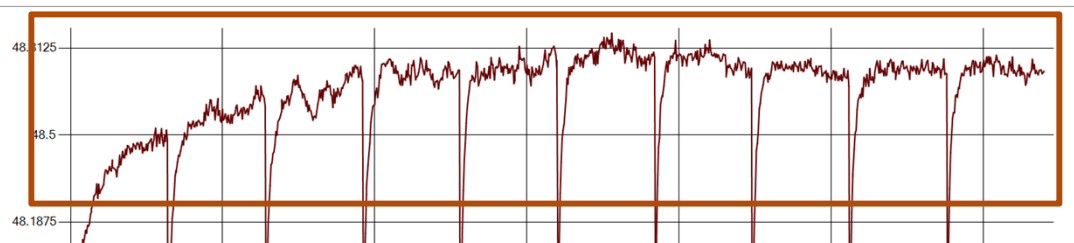


FF75R12RT4

TII75A120

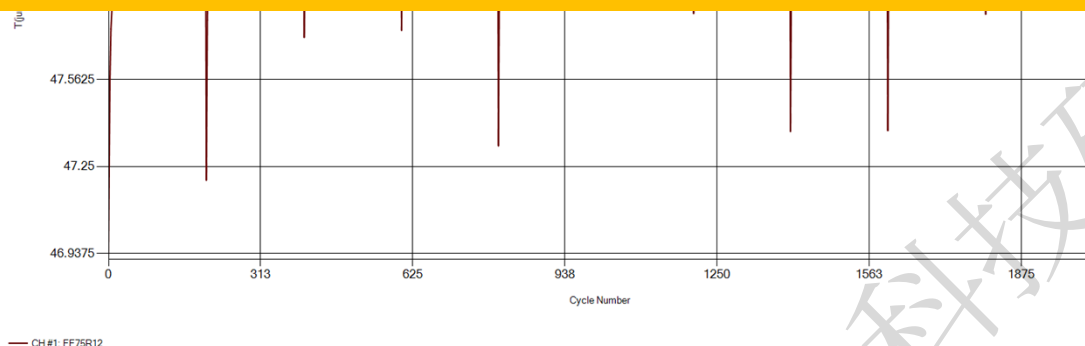


IGBT measurement of Power Tester(5)- Difference module compare

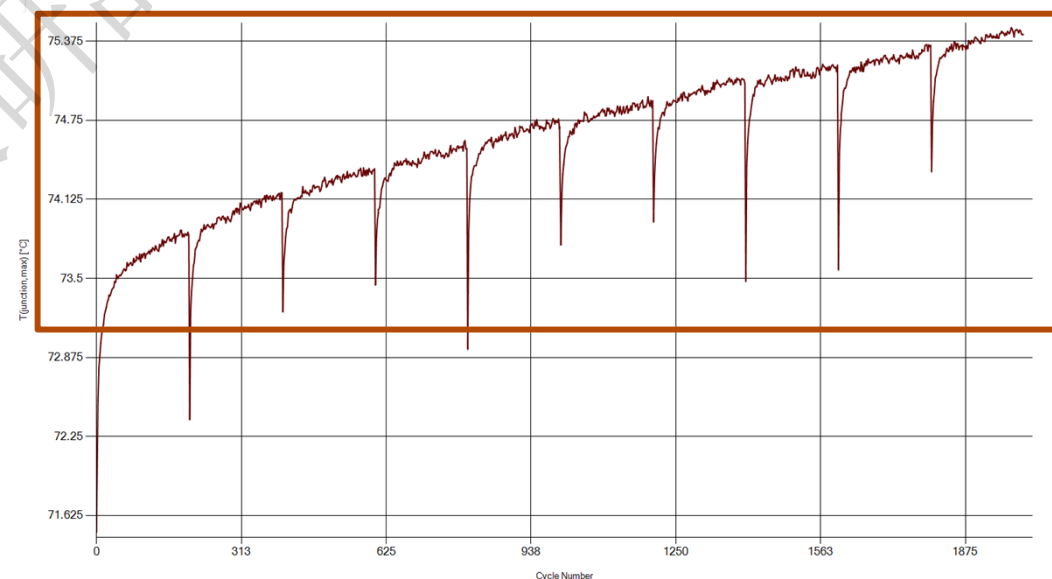


Tjmax of this module just 48.5 degree and very stable

TII75A120

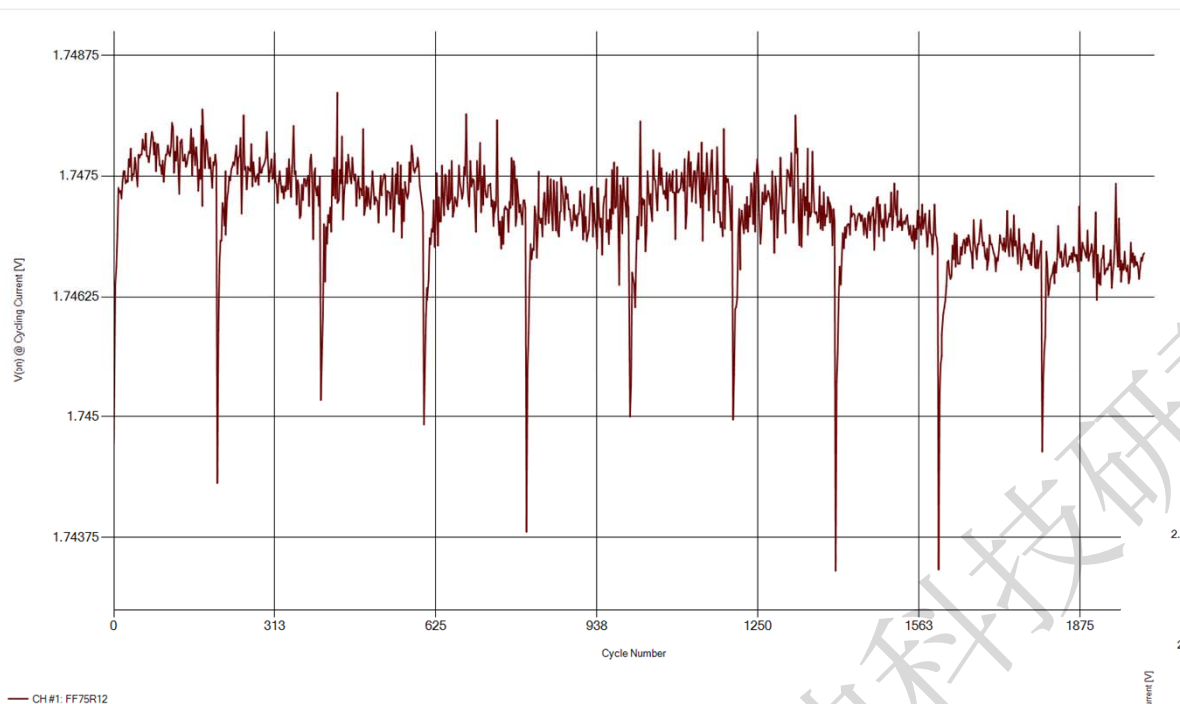


FF75R12RT4

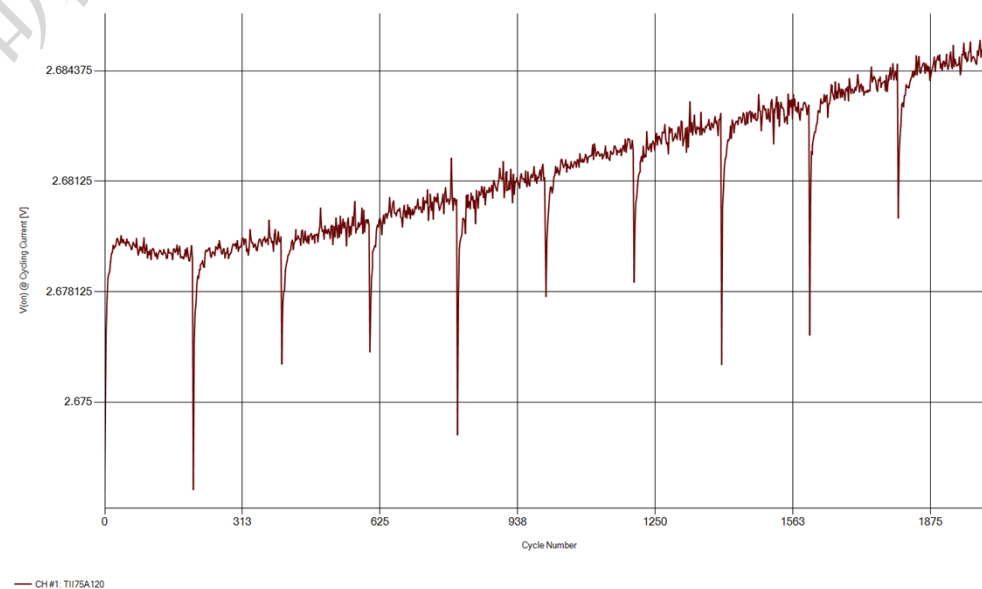


In the same test condition, Tjmax of this module is reach to about 73.5 degree and continue trend up

IGBT measurement of Power Tester(5)- Difference module compare



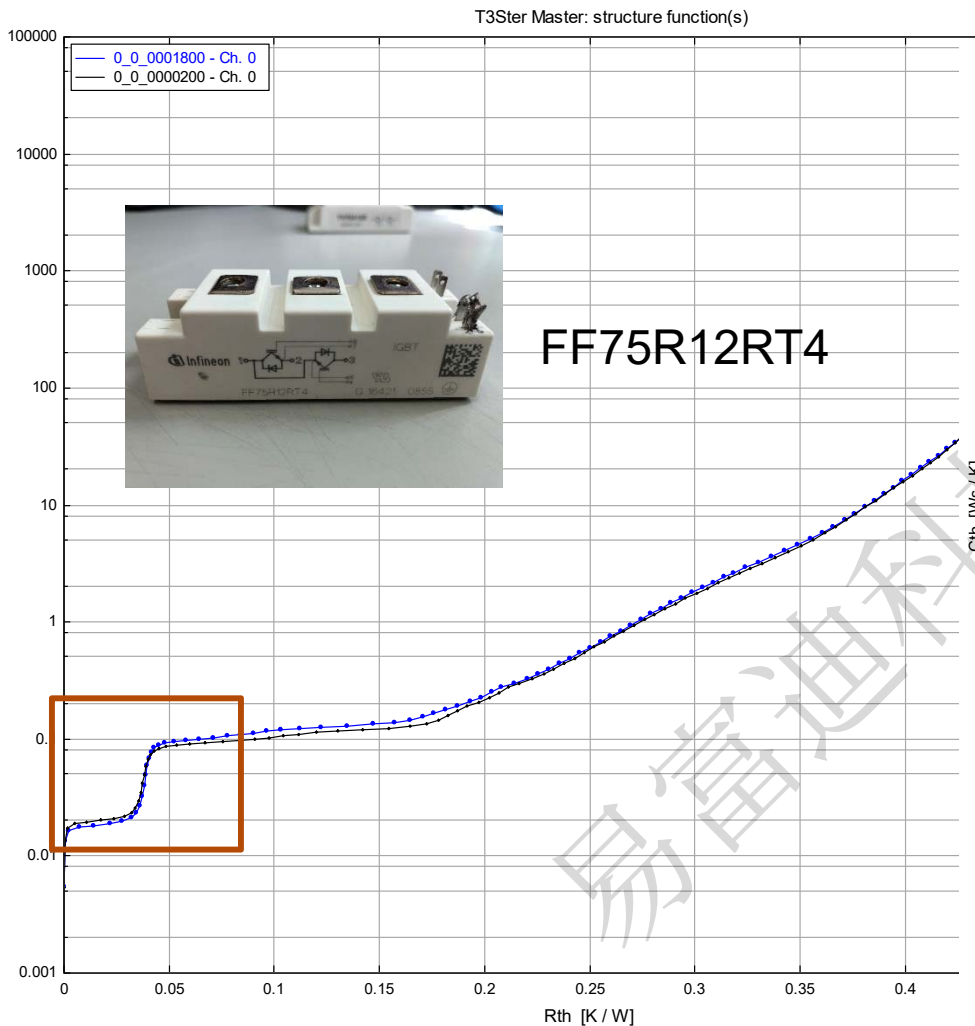
FF75R12RT4



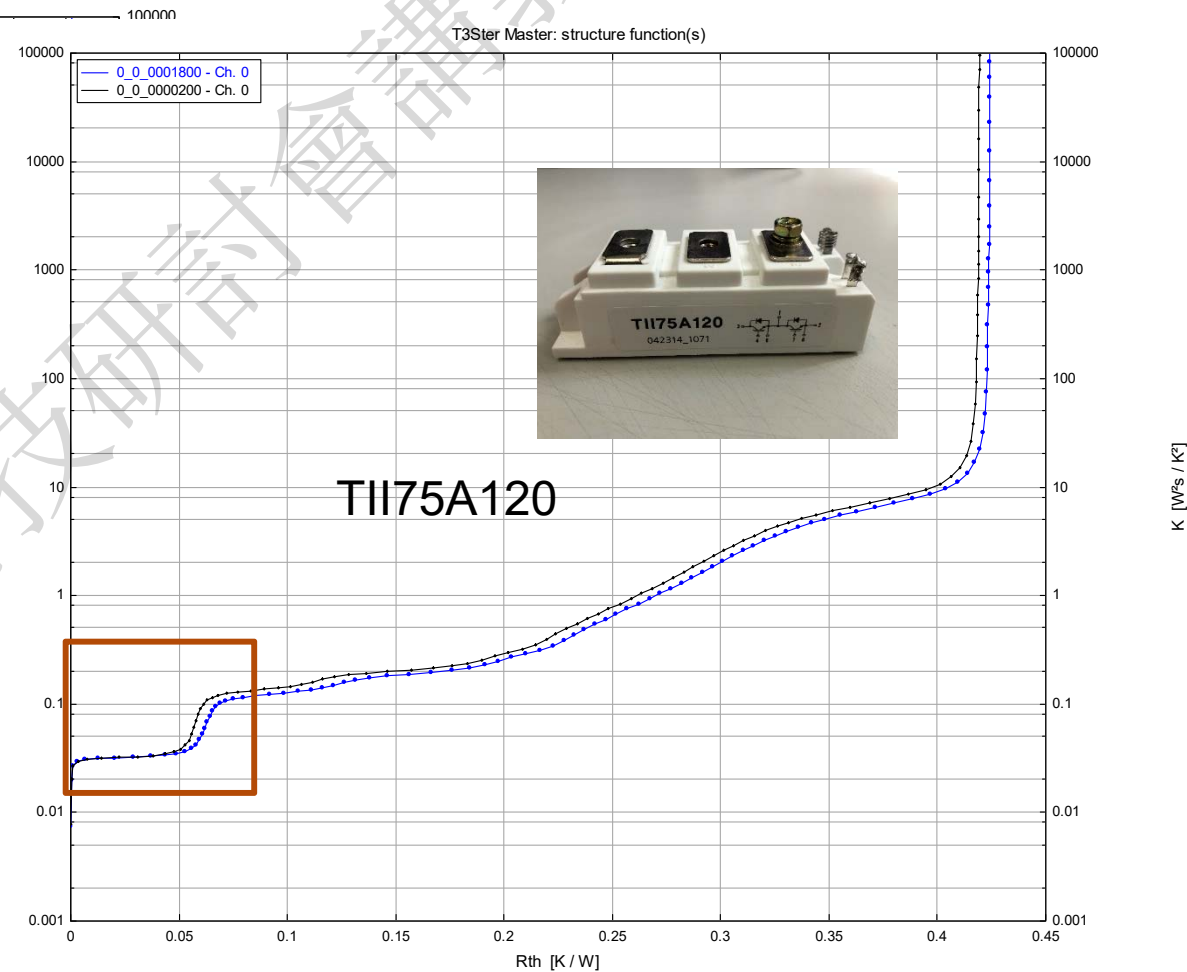
TII75A120

The voltage of two module have the same condition as the ΔT_j

IGBT measurement of Power Tester(5)- Difference module compare



Rth of this module don't have any change after 200 and 1800 cycling



Rth of this module become lager after 200 and 1800 cycling

聯絡我們



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