電源供應器熱模擬案例
-電晶體熱阻量測與模擬

易富迪科技研討會講義

2019/06/14

康舒科技 隸屬於

新金寶集團

NEW KINPO GROUP

全方位電源專業領導廠商

易富通科技研討會講義

主要產品- 消費性電源

AcBel Power

消費性電源產品(資通訊)

- 個人電腦 (桌上型/筆記型/一體成型機)
- 機上盒
- 印表機
- 監控系統

AcBel Power

消費性電源產品(其他)

- 智慧家庭裝置
- 智慧型手機
- 無人機
- 機器人

國富通科技研討會簡報

主要產品- 工業用電源

www.acbel.com

資料中心電源解決方案

- 超級電腦
- 企業級儲存器
- 中 / 高階伺服器
- 機架式電源分配器

網通電源

- 路由器
- 交換器
- 網路伺服器

技研討會講義

主要產品- 醫療及通信用電源

www.acbel.com

AcBel Power

醫療電源

- 核磁共振
- 超音波
- 生理監護儀
- 睡眠呼吸治療機
- 體外心臟去顫器
- 家用型醫療器械

AcBel inside

通信電源

- DC-DC模組
- 通信電源機櫃 (AC/DC & DC/DC)
- 高頻開關電源
- 切換式整流器

勝富達科技研討會講義

主要產品- 綠色能源電源

潔淨/新能源:
燃料電池/太陽能發電

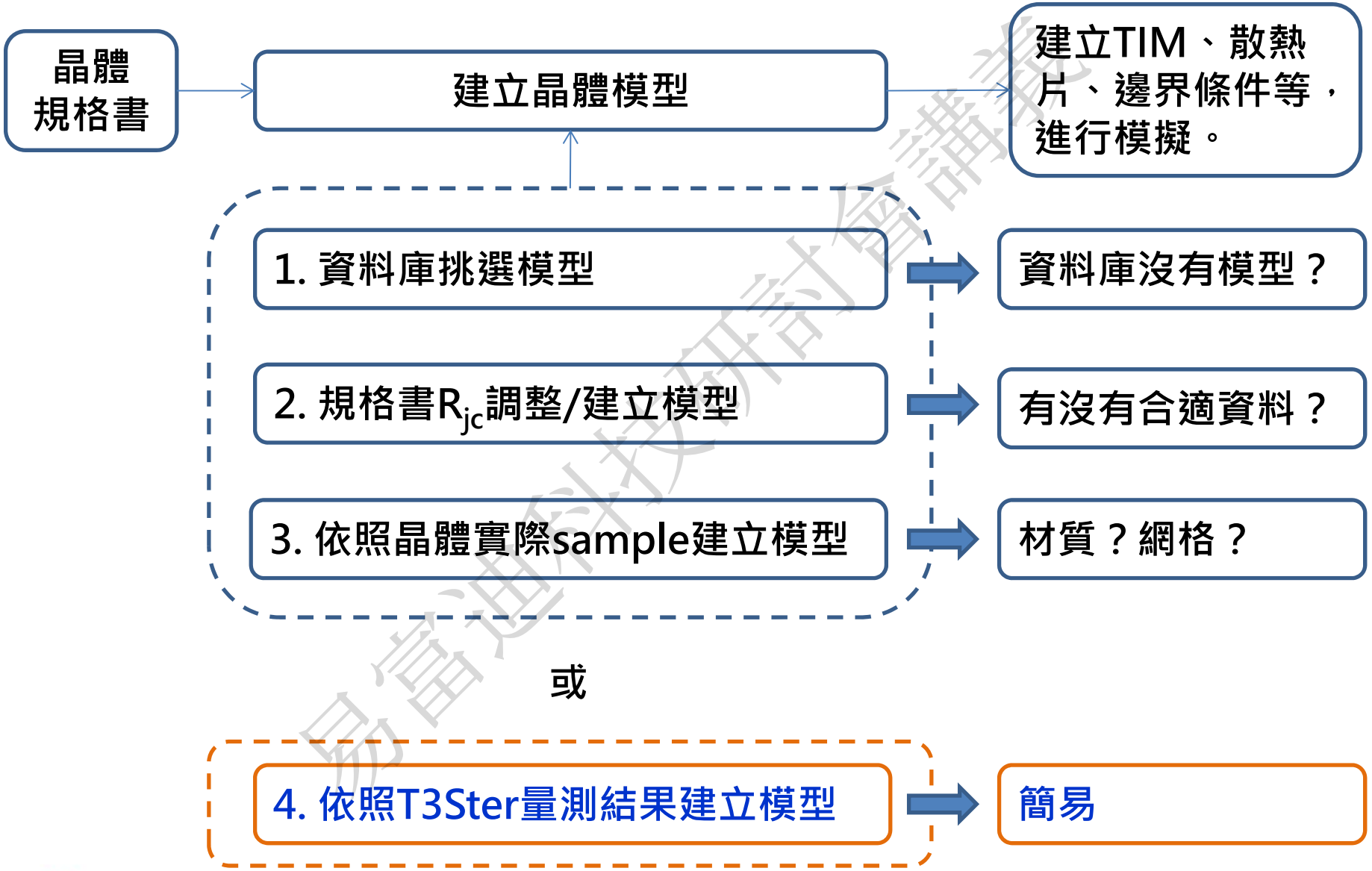
智慧電網

電動車電源

智能LED 照明

晶體溫度熱模擬流程

www.acbel.com



易富通科技研討會講義

晶體熱傳路徑

晶體接合點溫度計算

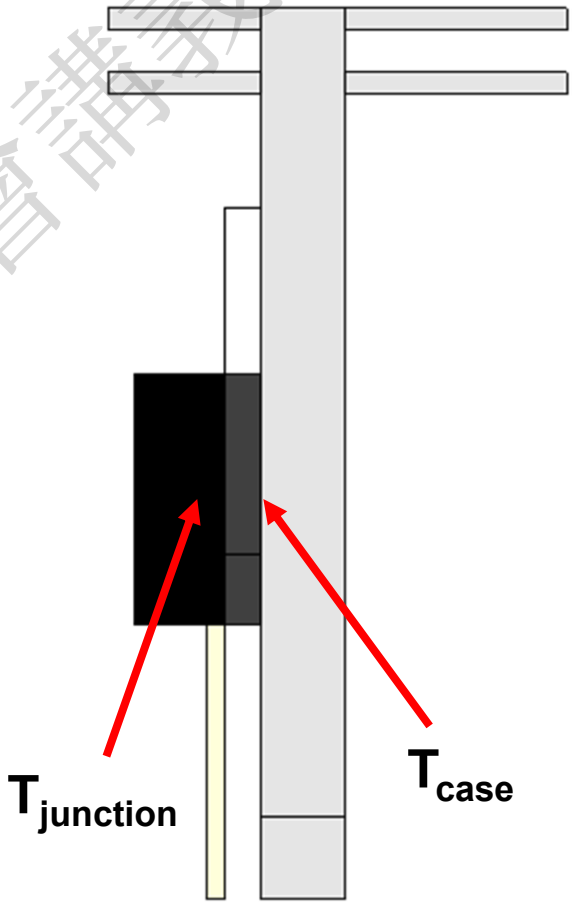
$$T_{junction} = T_{case} + R_{jc} \times P$$

$T_{junction}$: 晶體接合點溫度

T_{case}: 晶體外殼溫度

R_{jc}: 晶體接合點到外殼間的熱阻

P: 功耗

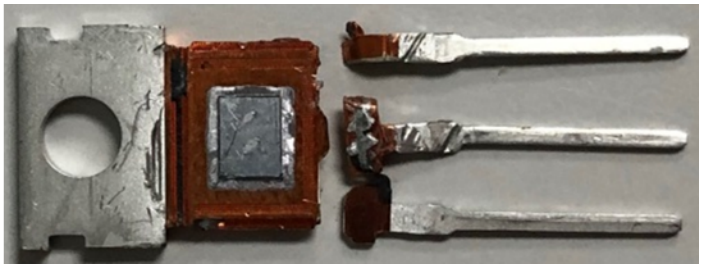


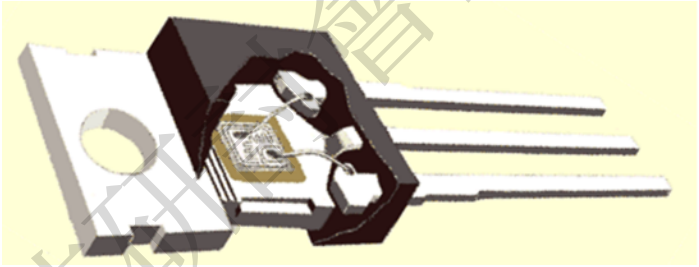
易富迪科技研討會講義

晶體規格

TO220 MOSFET

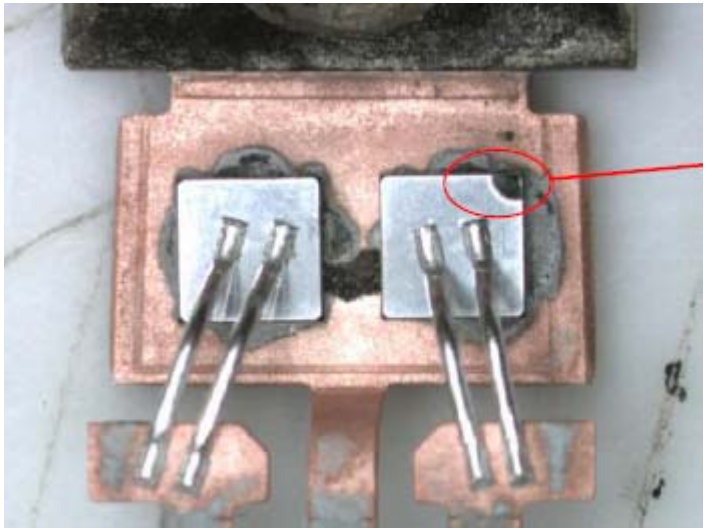
Thermal Resistance-Junction to Ambient (TO-220/TO-220F)		
$R_{\theta JC}$	1.2	℃/W





TO220 Diode

Typical Thermal Resistance (Note 5) Package = TO220AB (Generic)* Package = ITO220AB (Type HE)**		
$R_{\theta JC}$	* 2 ** 4	℃/W



易富世科技股份有限公司講義

Thermal Pad 熱阻

www.acbel.com

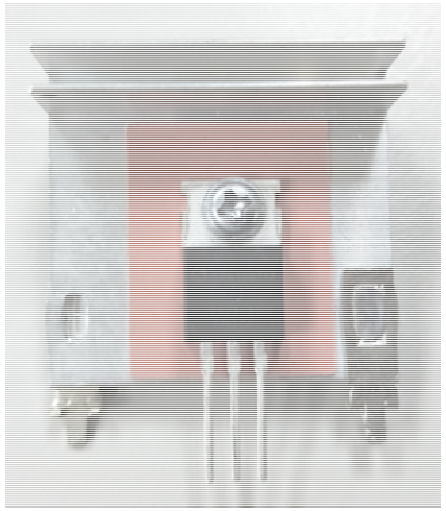
Thermal Pad 規格

Pad顏色	灰	粉紅
厚度(mm)	0.3+-0.03	0.25+-0.03
熱傳導率(W/mK)	1.38	1.9
熱阻係數(℃-in²/W)*	0.34	0.20

* 熱阻係數 = 厚度 / 熱傳導率

鎖固後

項目	A	B	C	D
Pad顏色	灰	粉紅	灰	粉紅
鎖固扭力值(kgf-cm)	5		7.5	
壓縮後厚度(mm)**	0.19	0.20	0.16	0.20
熱傳導率(W/mK)	1.38	1.9	1.38	1.9
熱阻係數(℃-in²/W)*	0.21	0.17	0.18	0.17



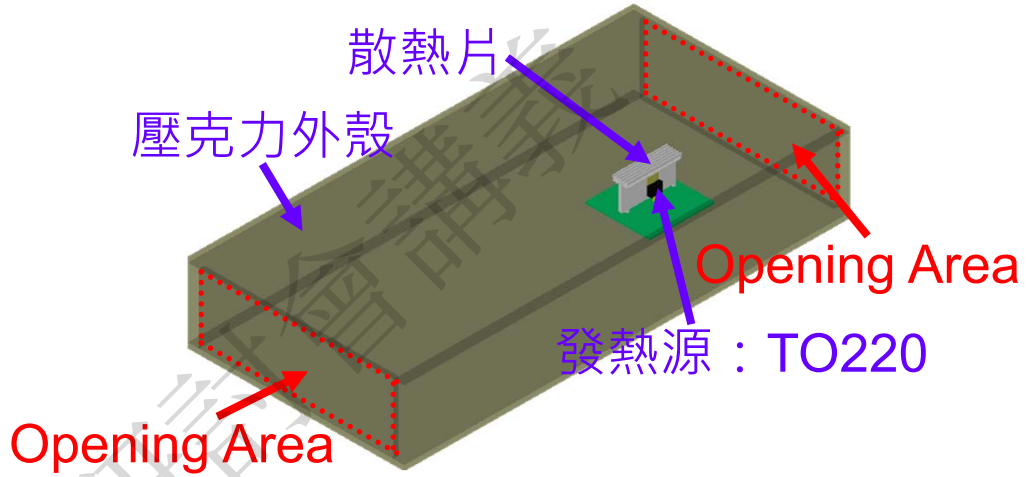
**鎖固後在100℃烘烤24小時量測之厚度。

易富迪科技研討會講義

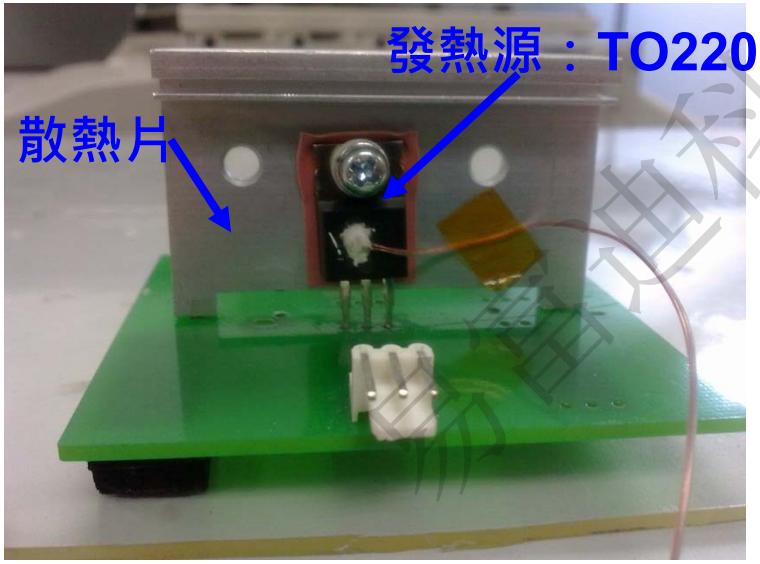
單一晶體實測溫度與模擬比對

假設條件

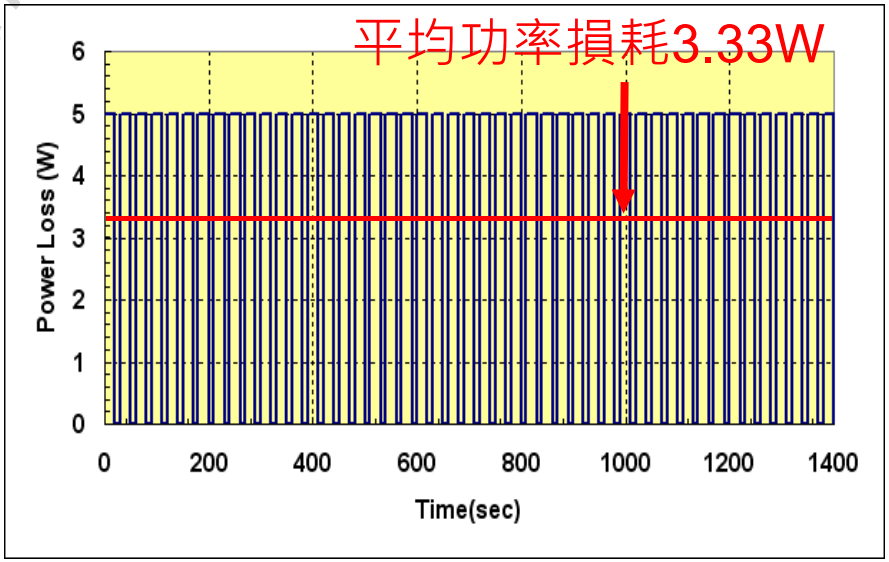
- 高度：海平面
- 環溫：25 deg. C
- 冷卻機制：自然對流
- 暫態功率損耗：
  a. 0~20 sec.：5W
  b. 20~30 sec.：0W



模擬模型示意圖



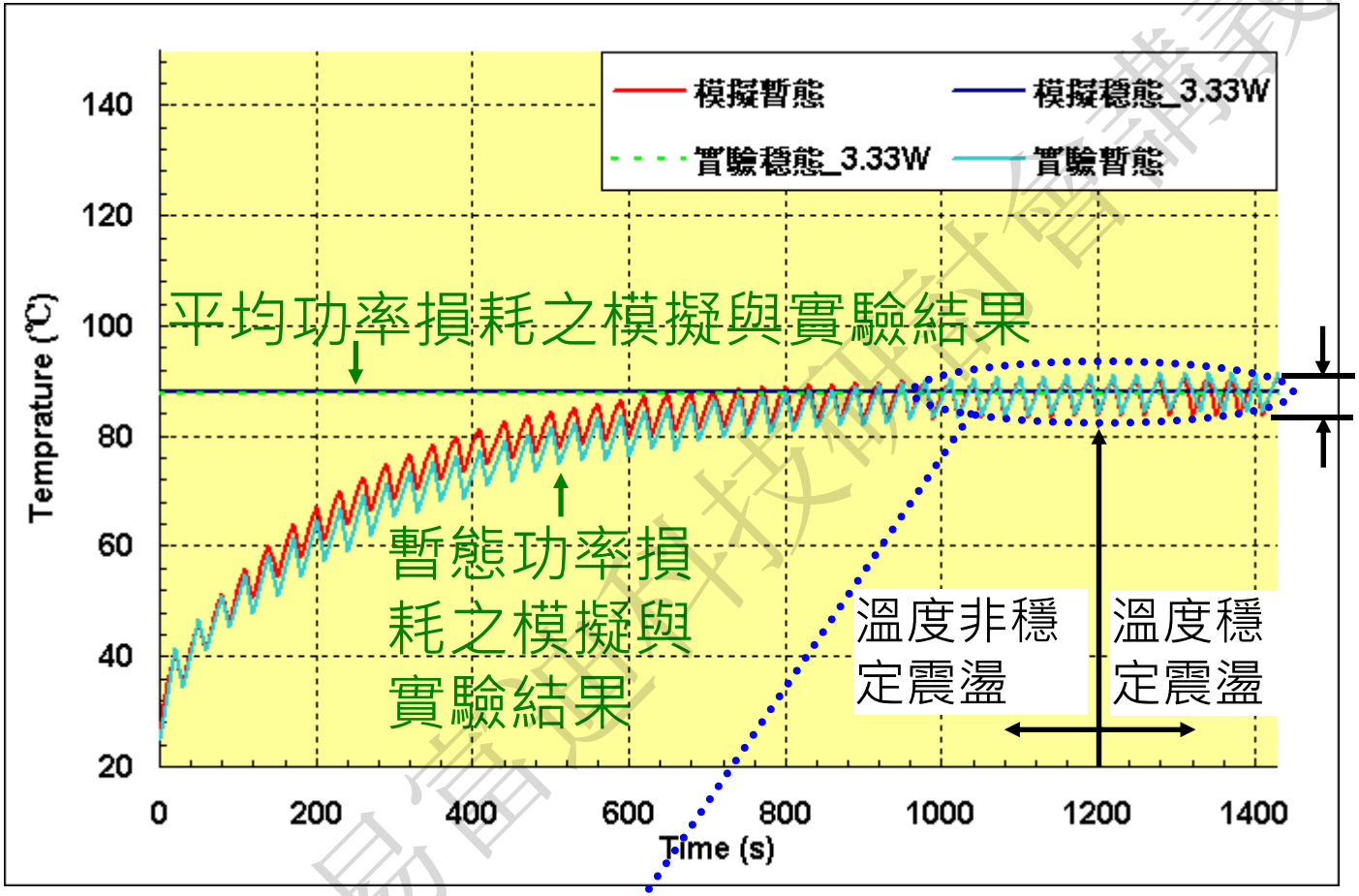
實驗測試設置



時間與功率損耗對應示意圖

晶體實測溫度與模擬比對

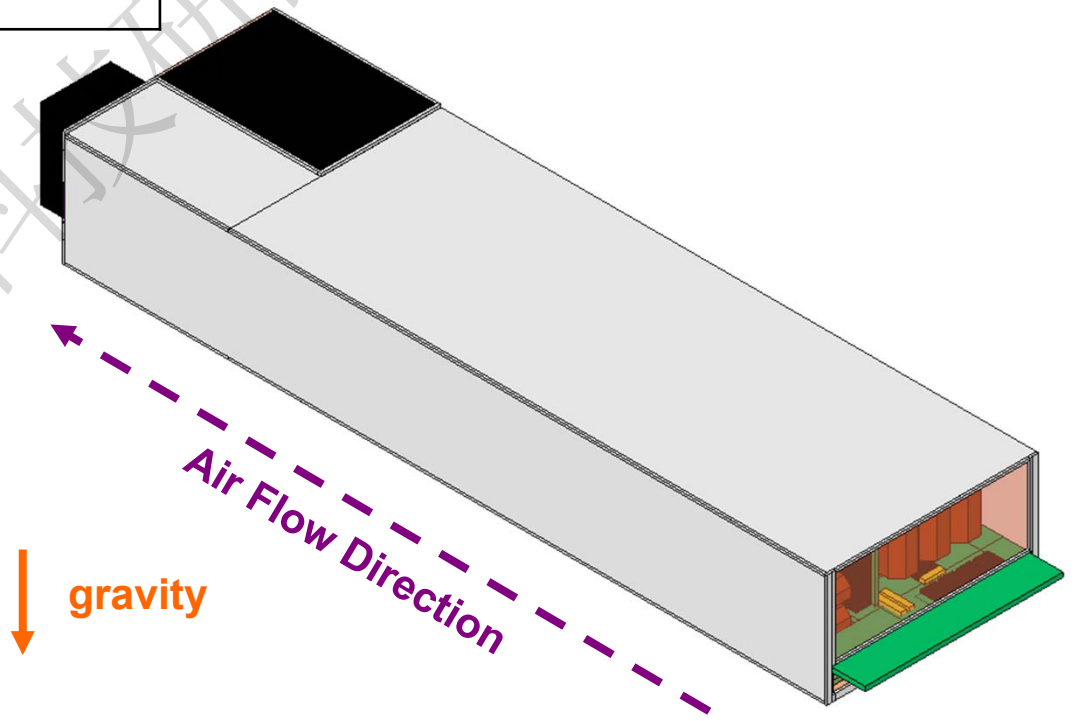
模擬與實驗結果



- 以平均功率損耗的方法進行模擬與實驗，其溫度結果會落在實際功率損耗的溫度震盪區間。

1U 電源供應器熱模擬案例

Worst Condition	
Ambient (ºC)	50
Altitude (m)	0
Cooling Type	Forced Convection
Outline (mm^3)	265 x 73.5 x 39
Sim. Airflow Rate (CFM)	15.79
Test Airflow Rate (CFM)	15.75



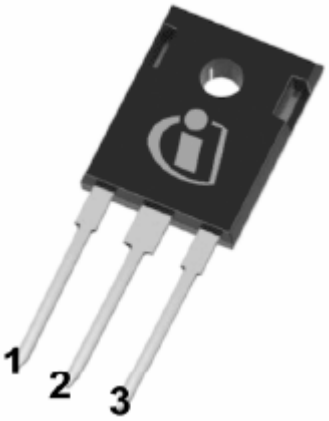
易富迪科技研討會講義

晶體熱阻規格與量測比較1

Table 3 Thermal characteristics

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Thermal resistance, junction - case	R_{thJC}	-	-	1.0	°C/W
Thermal resistance, junction - ambient	R_{thJA}	-	-	62	°C/W
Thermal resistance, junction - ambient for SMD version	R_{thJA}	-	-	-	°C/W
Soldering temperature, wavesoldering only allowed at leads	T_{sold}	-	-	260	°C

PG-TO 247-3



Summary-
60R090F7-Rthjc and Rthja

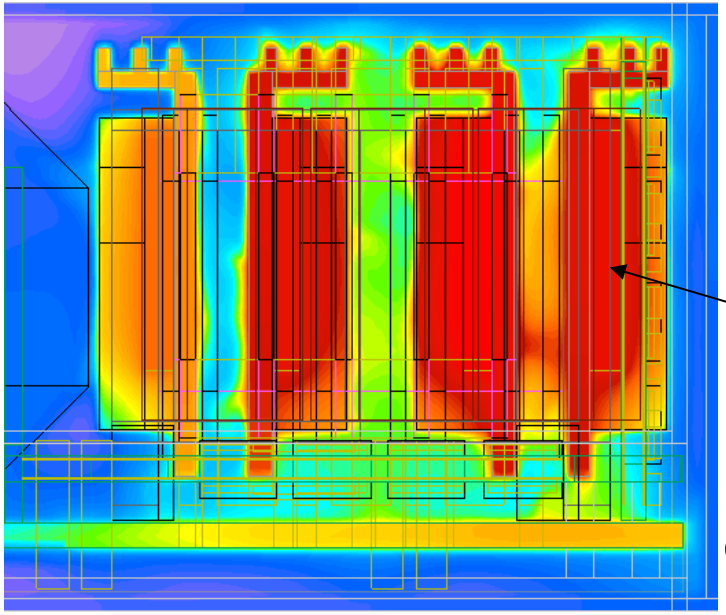
EFD CORPORATION

Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthjc (K/W)
60R090F7 MOSFET	0.488	39.45	64.45	0.5248

Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthja (K/W)
60R090F7 MOSFET	0.488	57.02	80.22	4.732

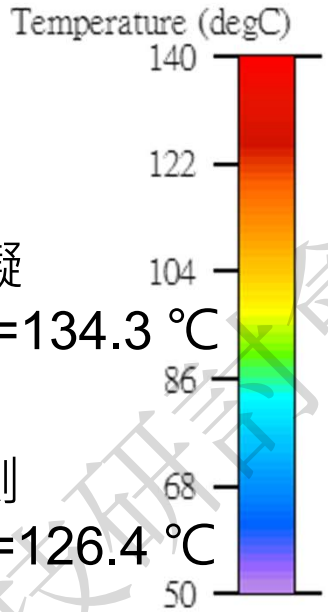
易富半導體科技研討會講義

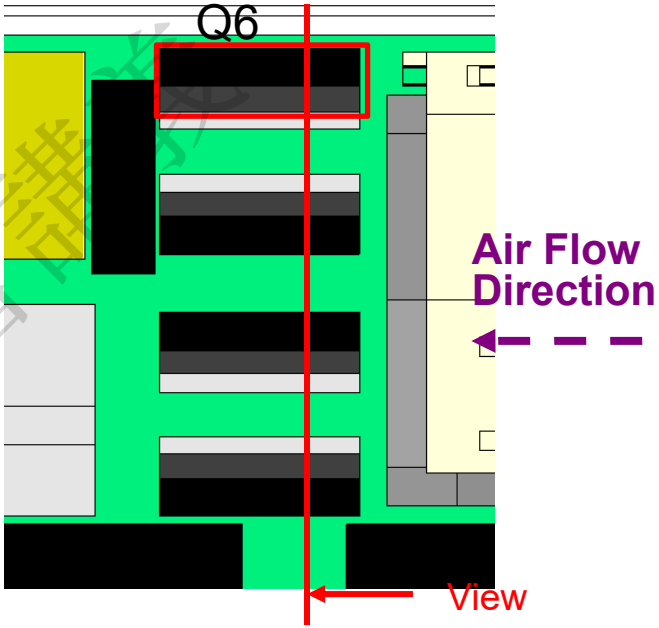
晶體熱阻規格與量測比較1(原始模型)

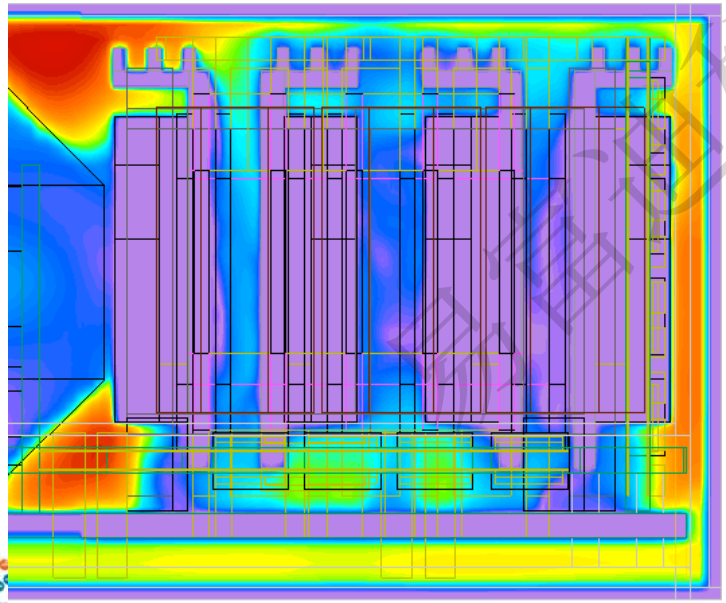


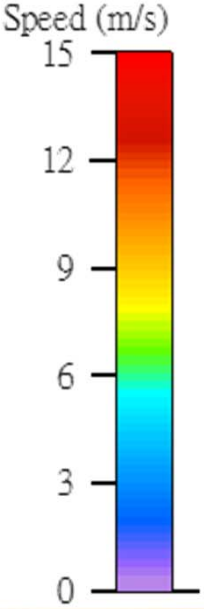
模擬
Q6=134.3 ℃

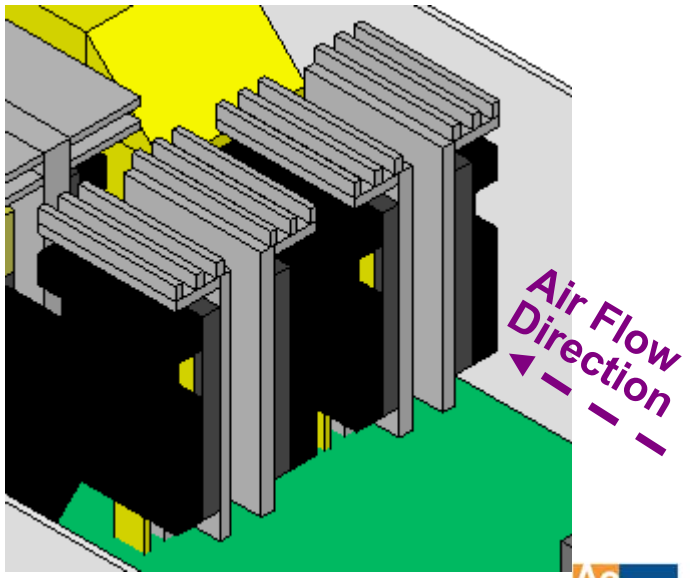
實測
Q6=126.4 ℃





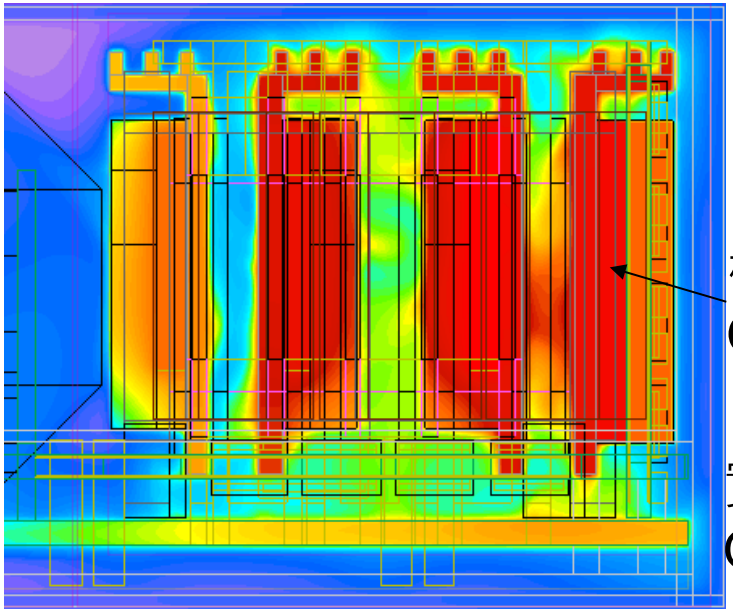






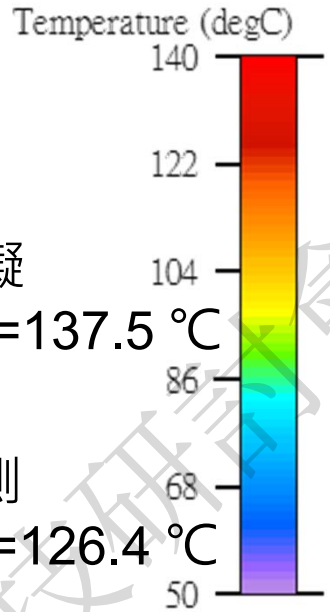
研華通訊科技研討會講義

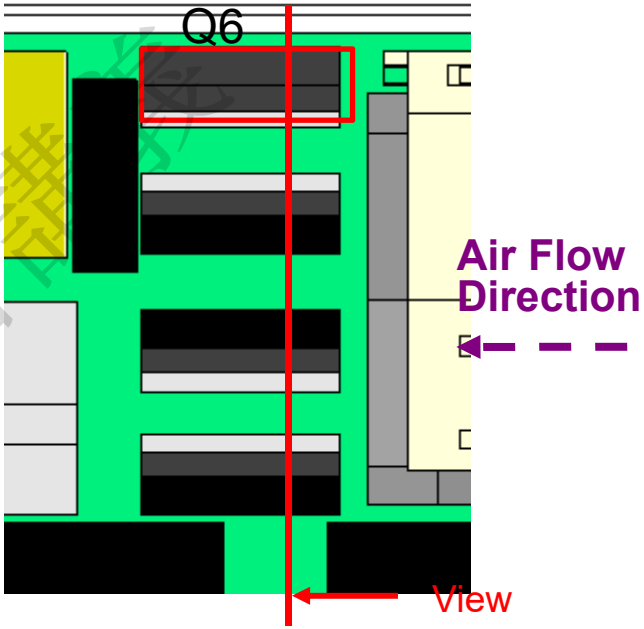
晶體熱阻規格與量測比較1(T3Ster)

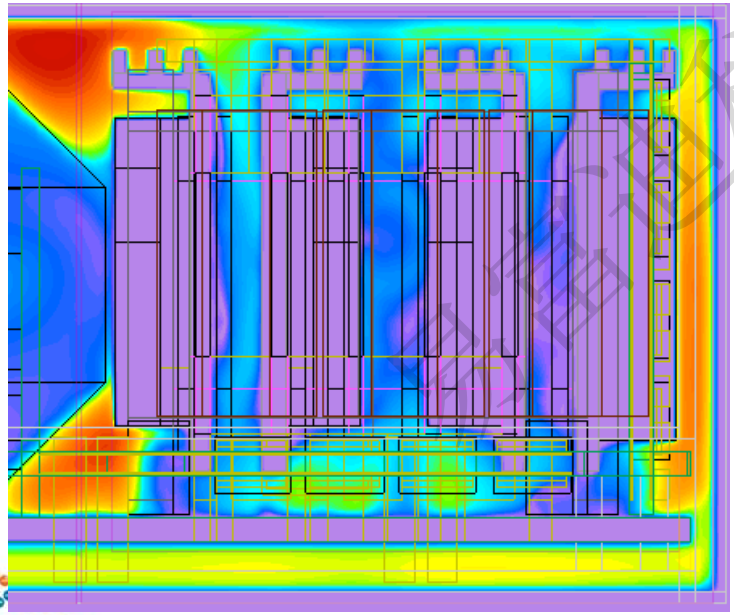


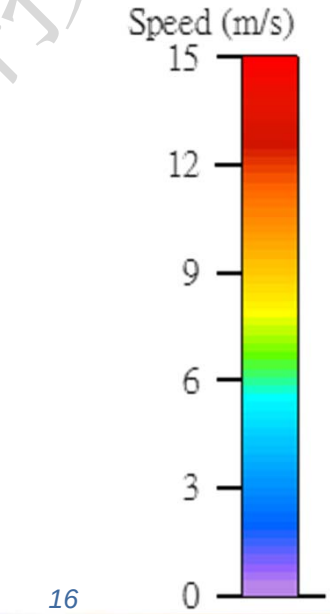
模擬
Q6=137.5 ℃

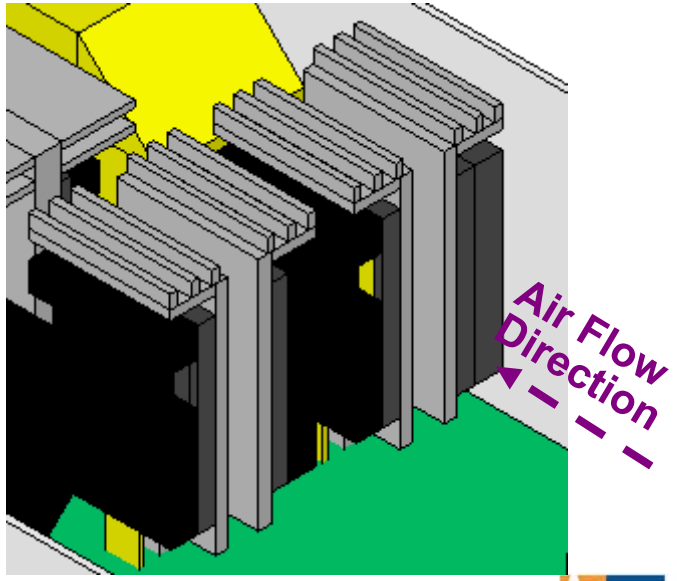
實測
Q6=126.4 ℃





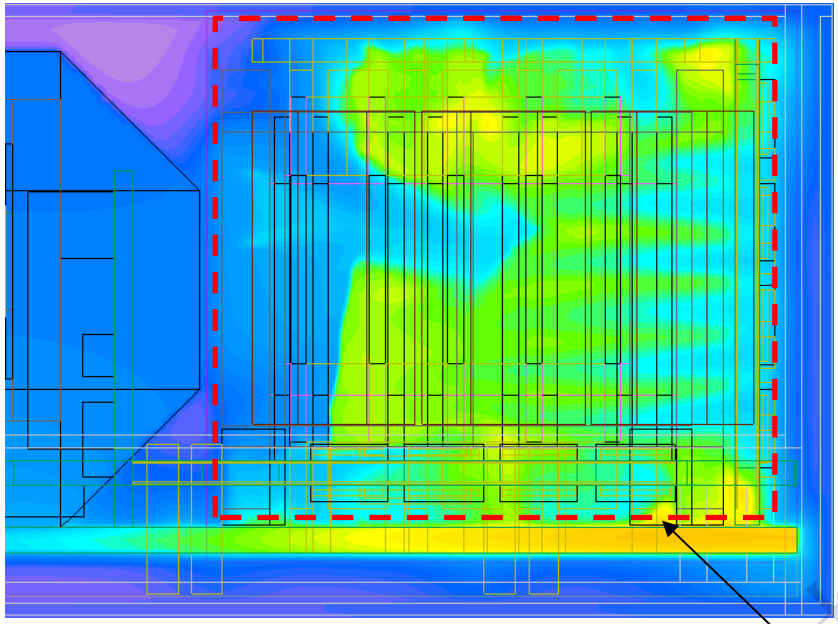


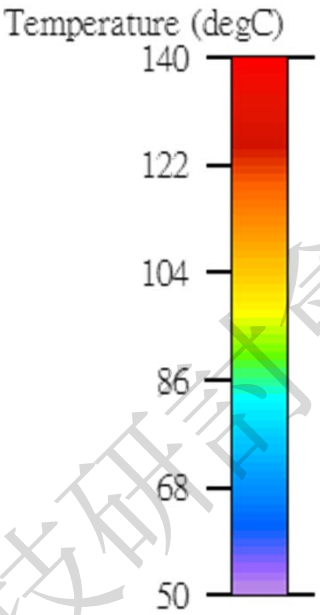


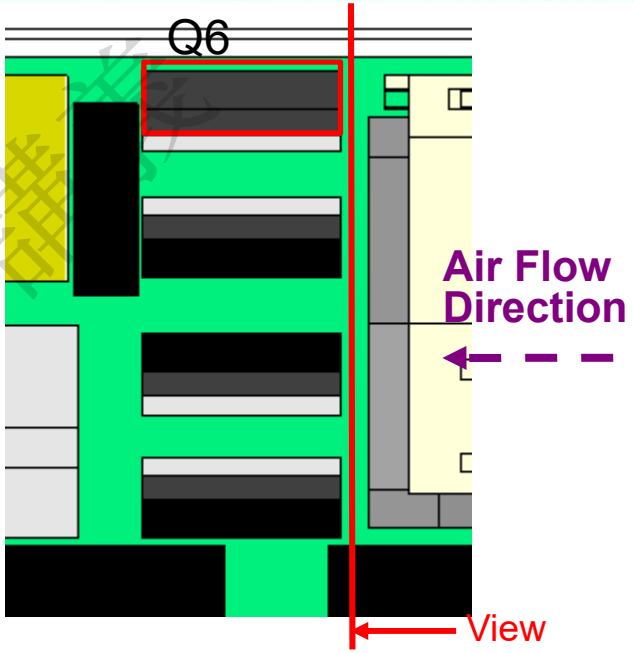


台電電源科技研討會講義

晶體熱阻規格與量測比較1(T3Ster R_{ja}估算)





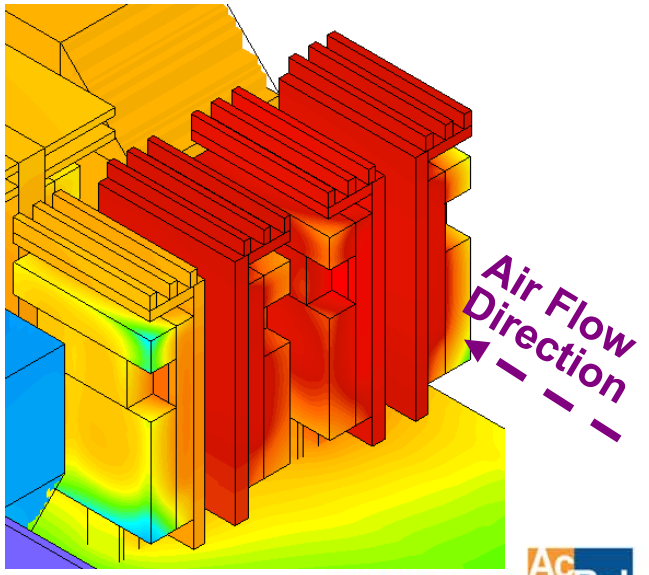


平均溫度81.4 ℃

晶體溫度估算：

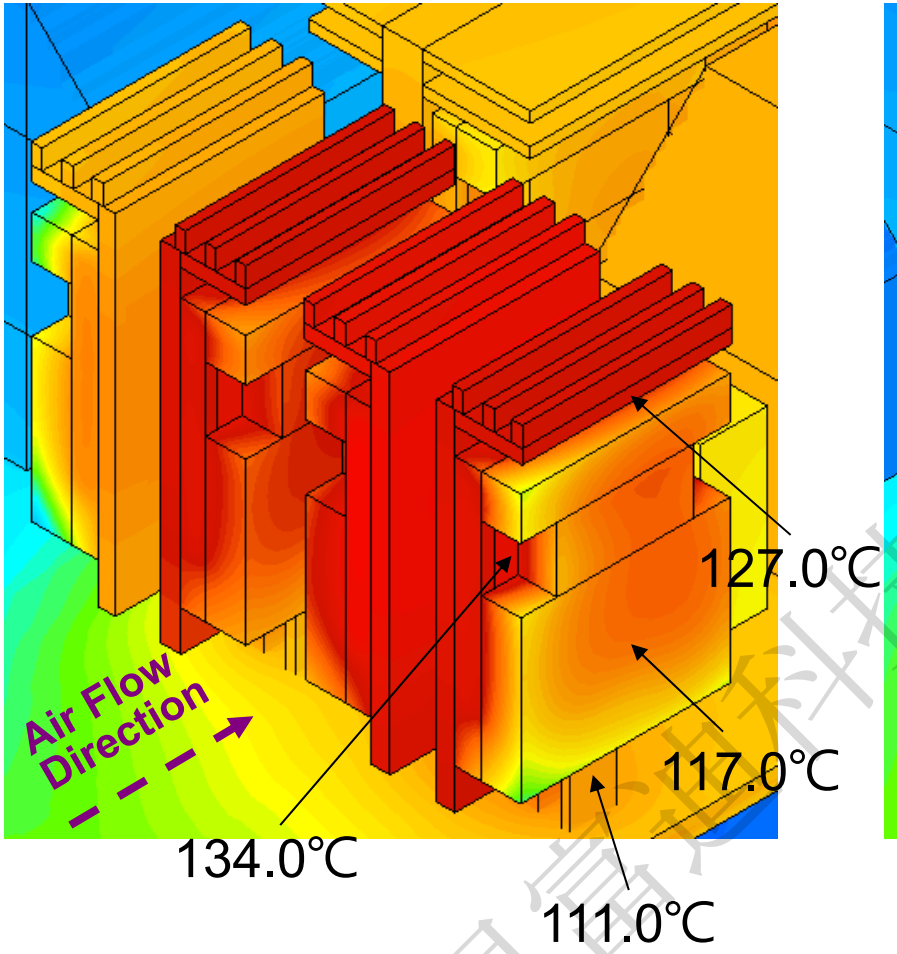
81.4 + 4.732 * 8.2 = 120.2 ℃

實測 Q6 = 126.4 ℃

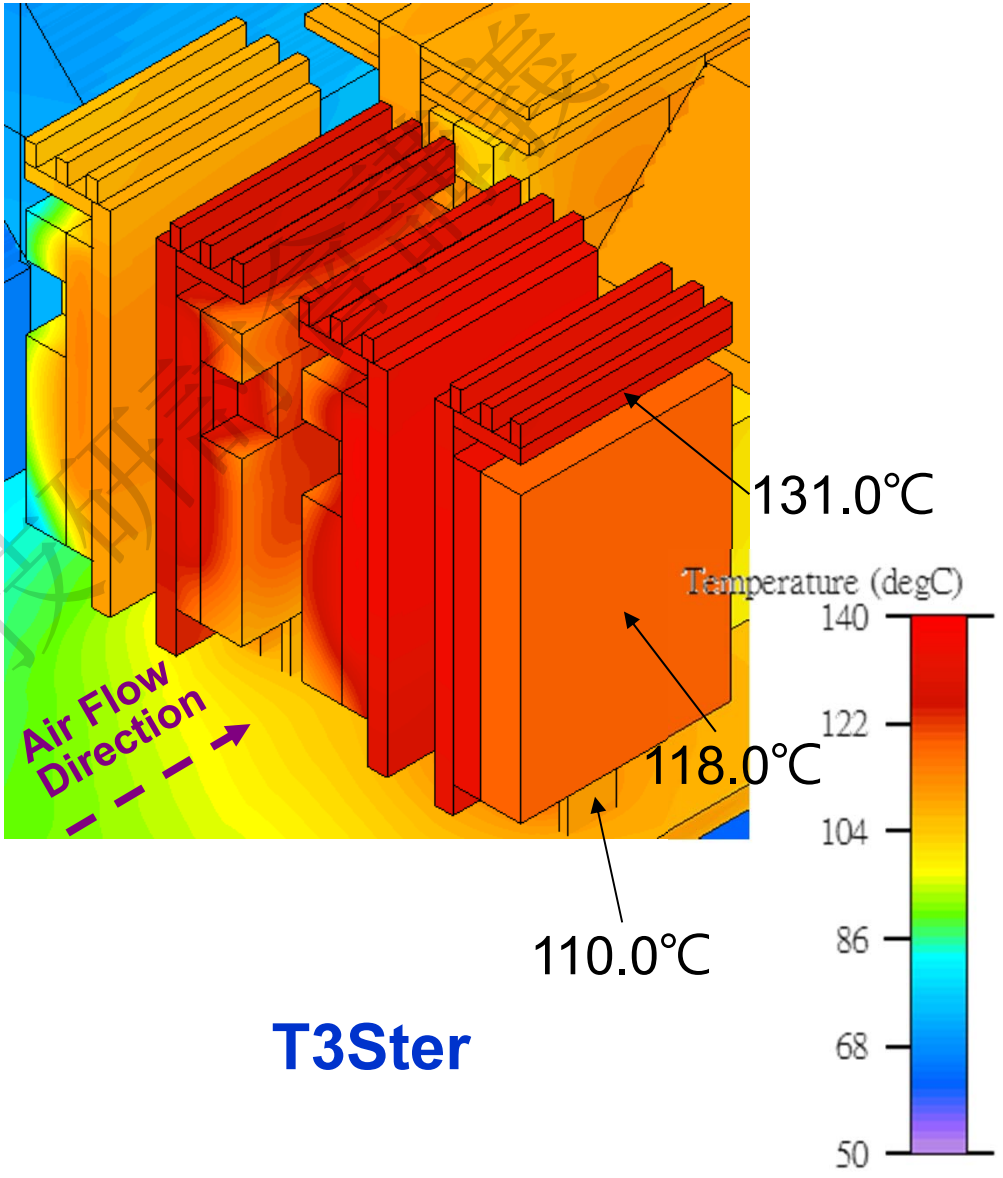


易富迪科技研討會講義

晶體原始模型與T3Ster量測結果模型



原始模型



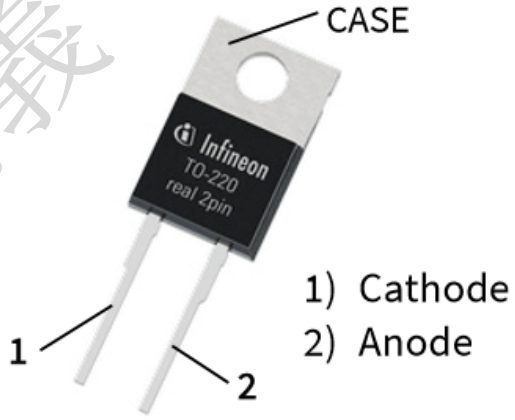
T3Ster

易富通科技研究

晶體熱阻規格與量測比較2

Table 4 Thermal characteristics (PG-TO-220-2)

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Thermal resistance, junction-case	R_{thJC}	–	1.1	1.9	K/W
Thermal resistance, junction-ambient	R_{thJA}	–	–	62	
Soldering temperature, wavesoldering only allowed at leads	T_{sold}	–	–	260	°C



Summary- IDH12G-Rthjc and Rthja

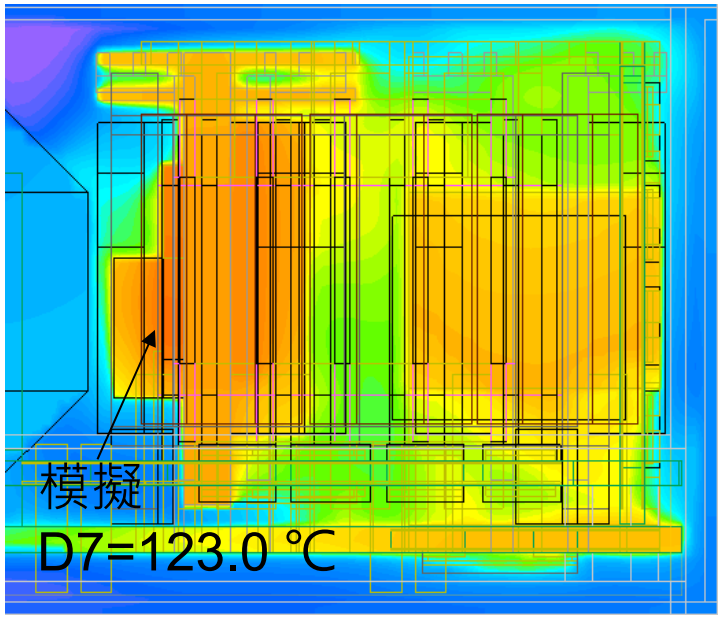
EFD CORPORATION

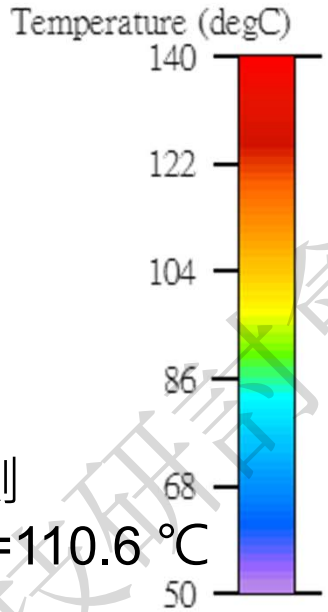
Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthjc (K/W)
IDH12G DIODE	-1.263	49.44	74.44	1.167

Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthja (K/W)
IDH12G DIODE	-1.263	61.92	87.02	5.789

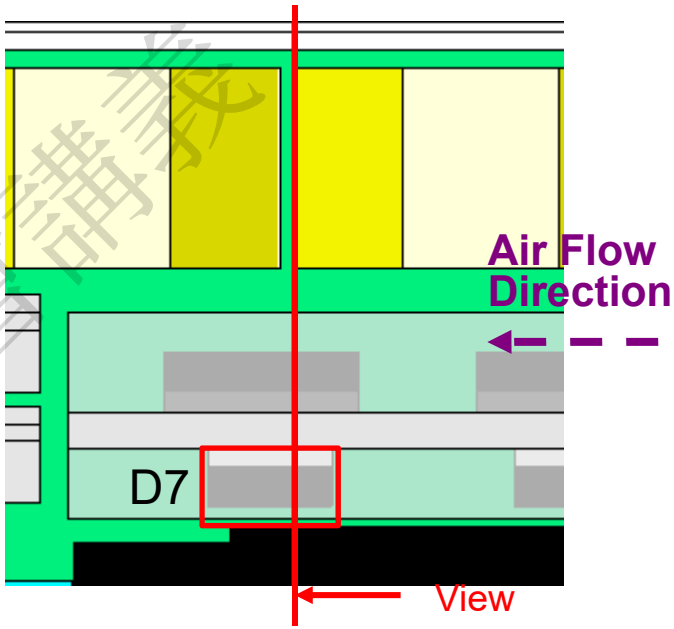
易富迅科技研討會講義

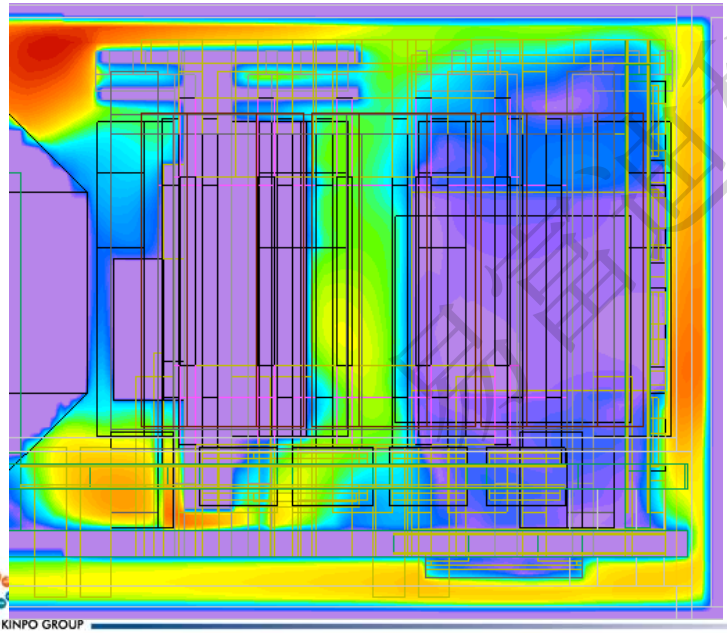
晶體熱阻規格與量測比較2(原始模型)

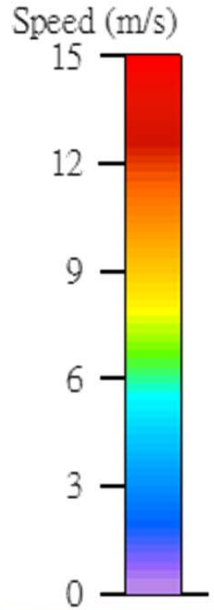


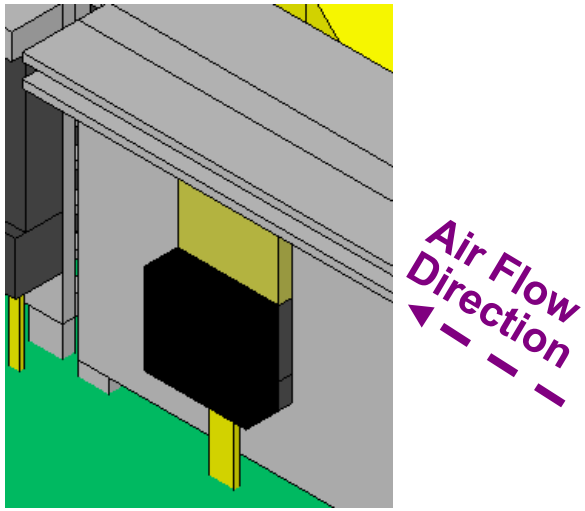


實測
D7=110.6 ℃



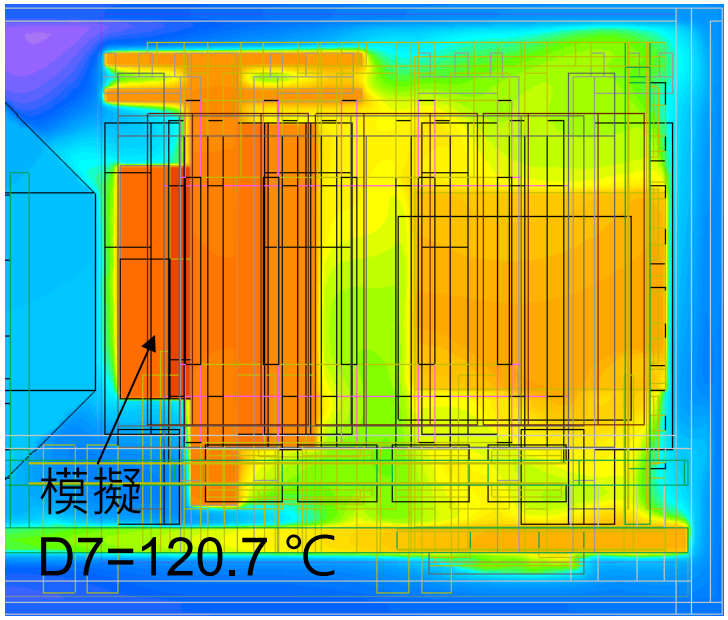




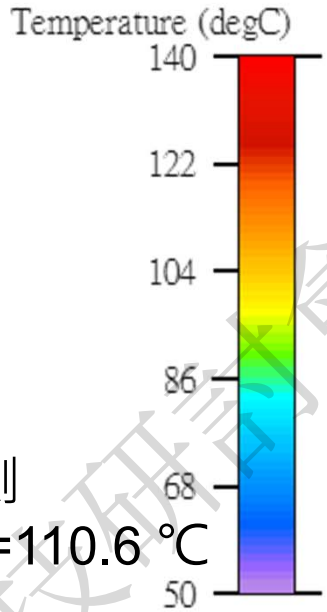


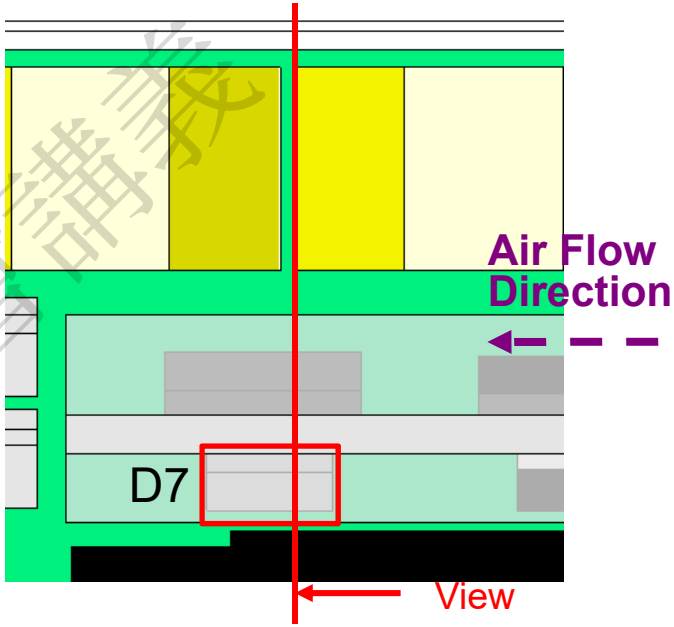
高雄科技研討會講義

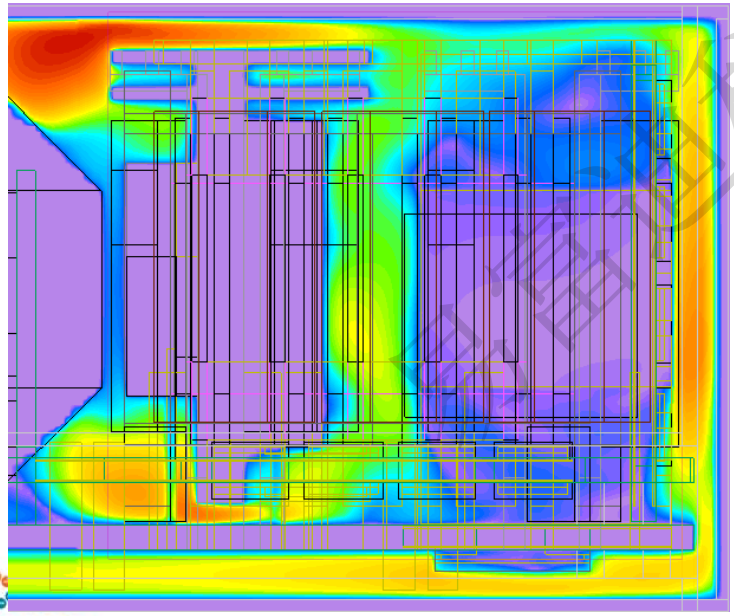
晶體熱阻規格與量測比較2(T3Ster)

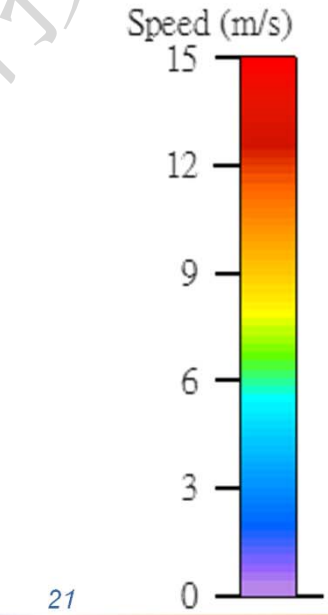


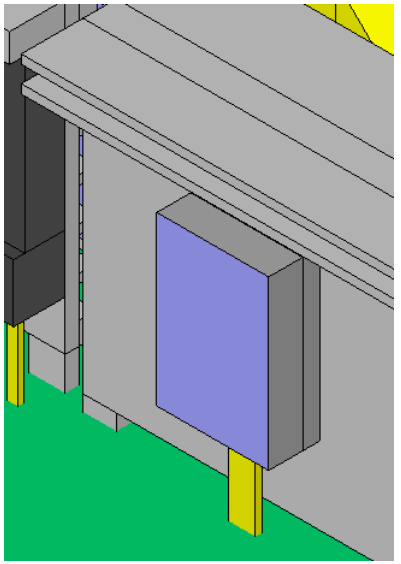
實測
D7=110.6 ℃





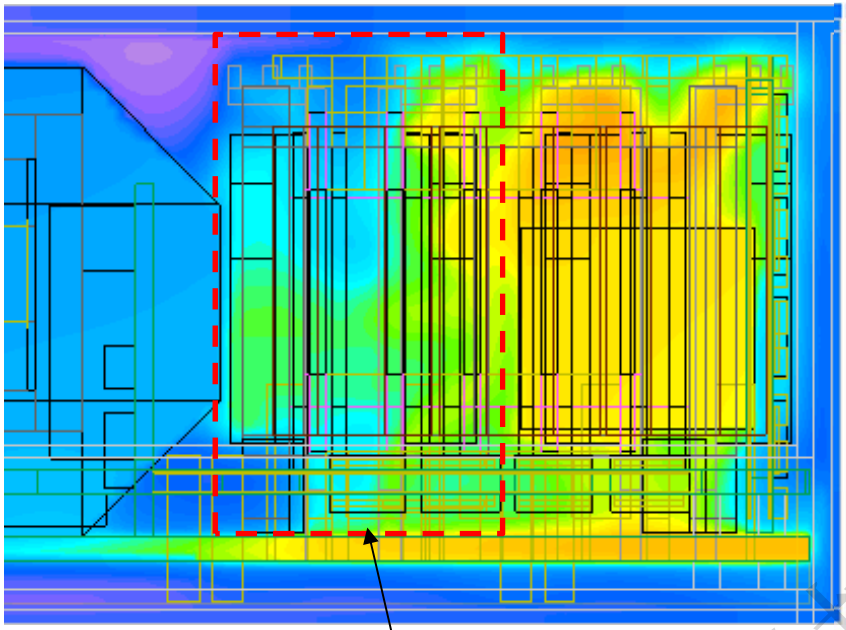


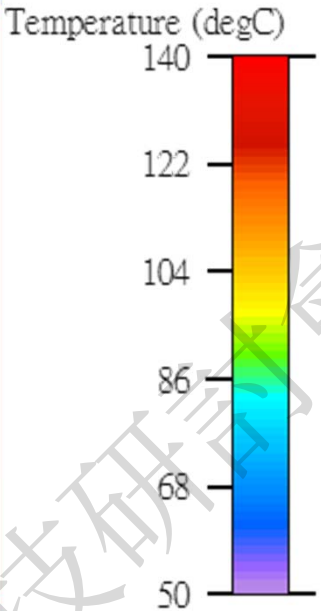


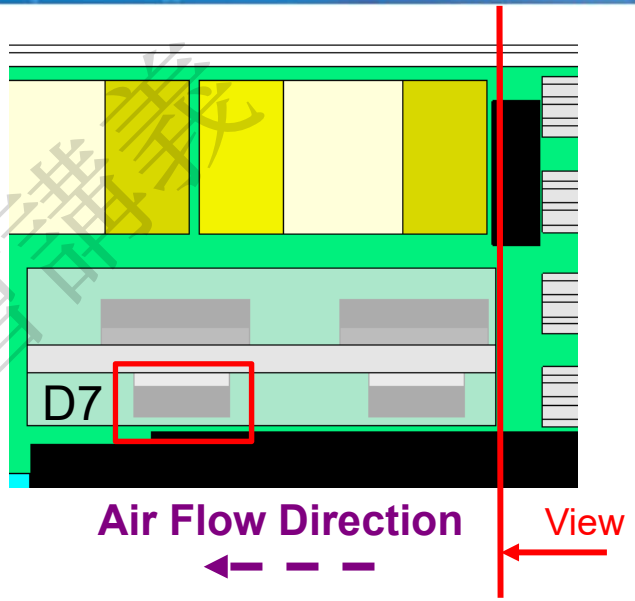


台電綠能科技研討會講義

晶體熱阻規格與量測比較2(T3Ster R_{ja}估算)





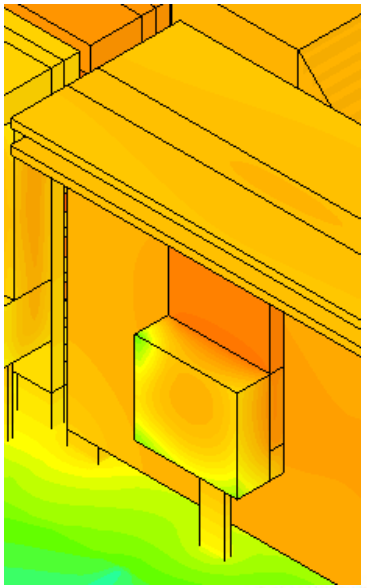


平均溫度83.9 ℃

晶體溫度估算：

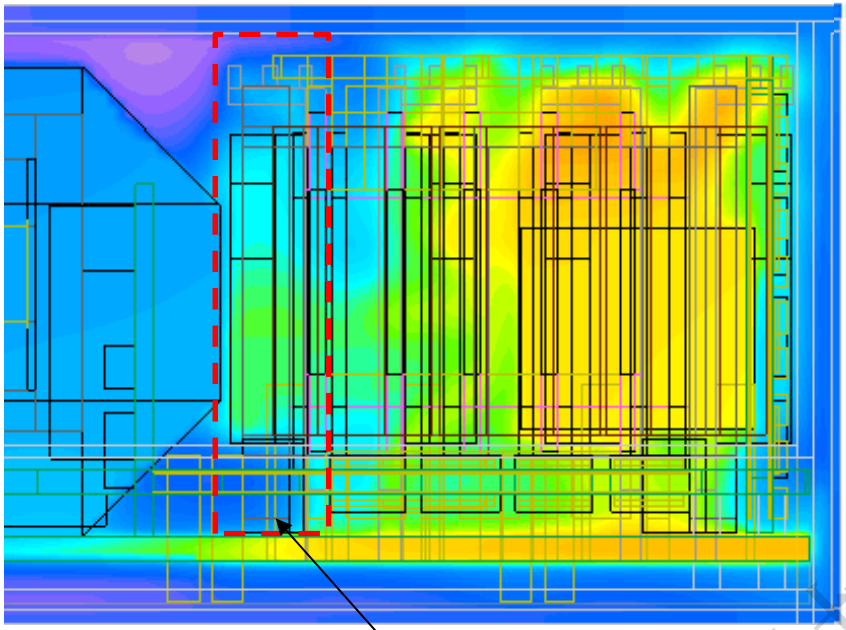
83.9 + 5.789 * 5.8 = 117.5 ℃

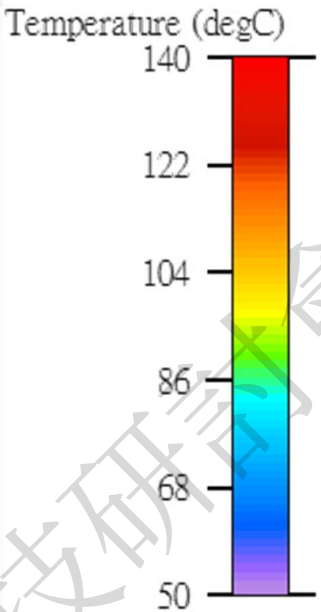
實測 D7 = 110.6 ℃

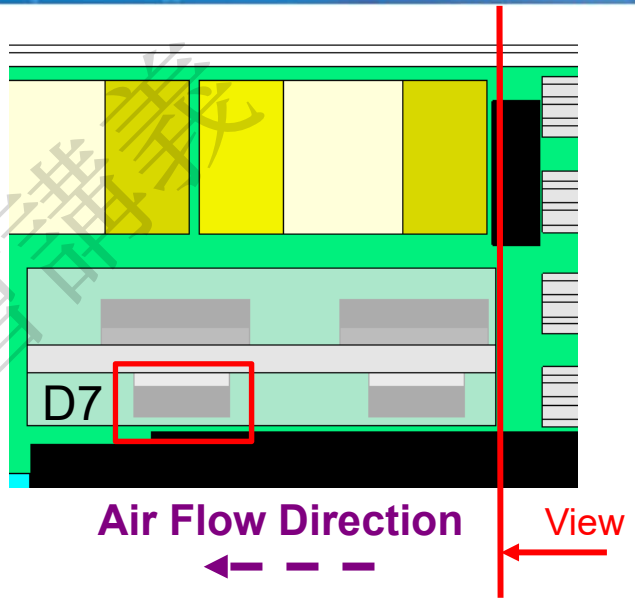


易富迪科技研討會講義

晶體熱阻規格與量測比較2(T3Ster R_{ja}估算)





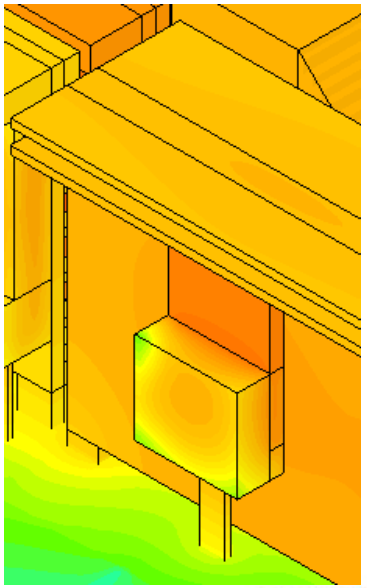


平均溫度77.7 ℃

晶體溫度估算：

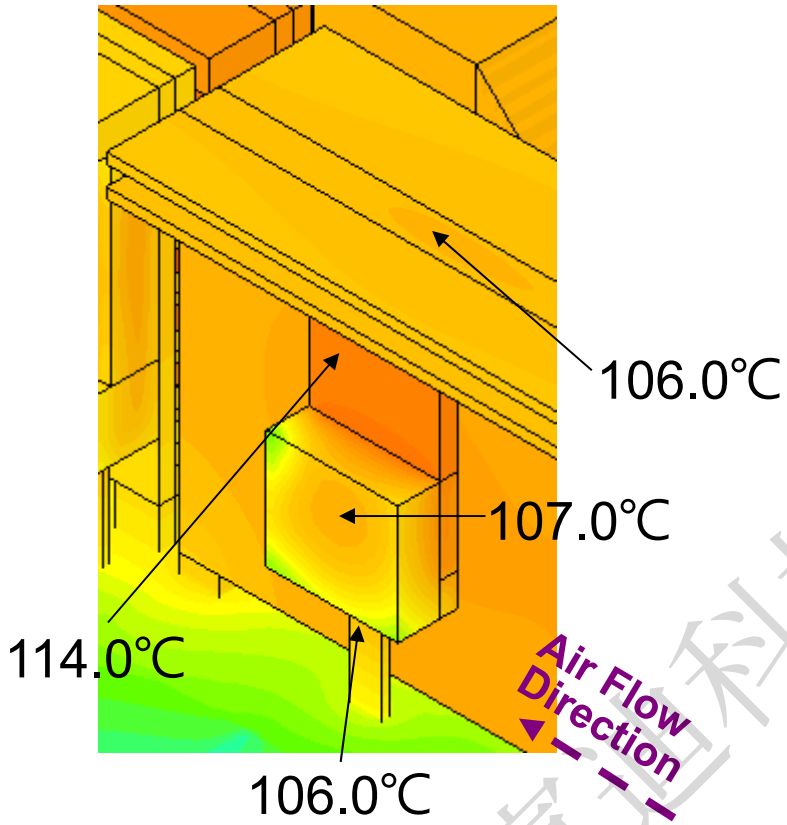
77.7 + 5.789 * 5.8 = 111.3 ℃

實測 D7 = 110.6 ℃

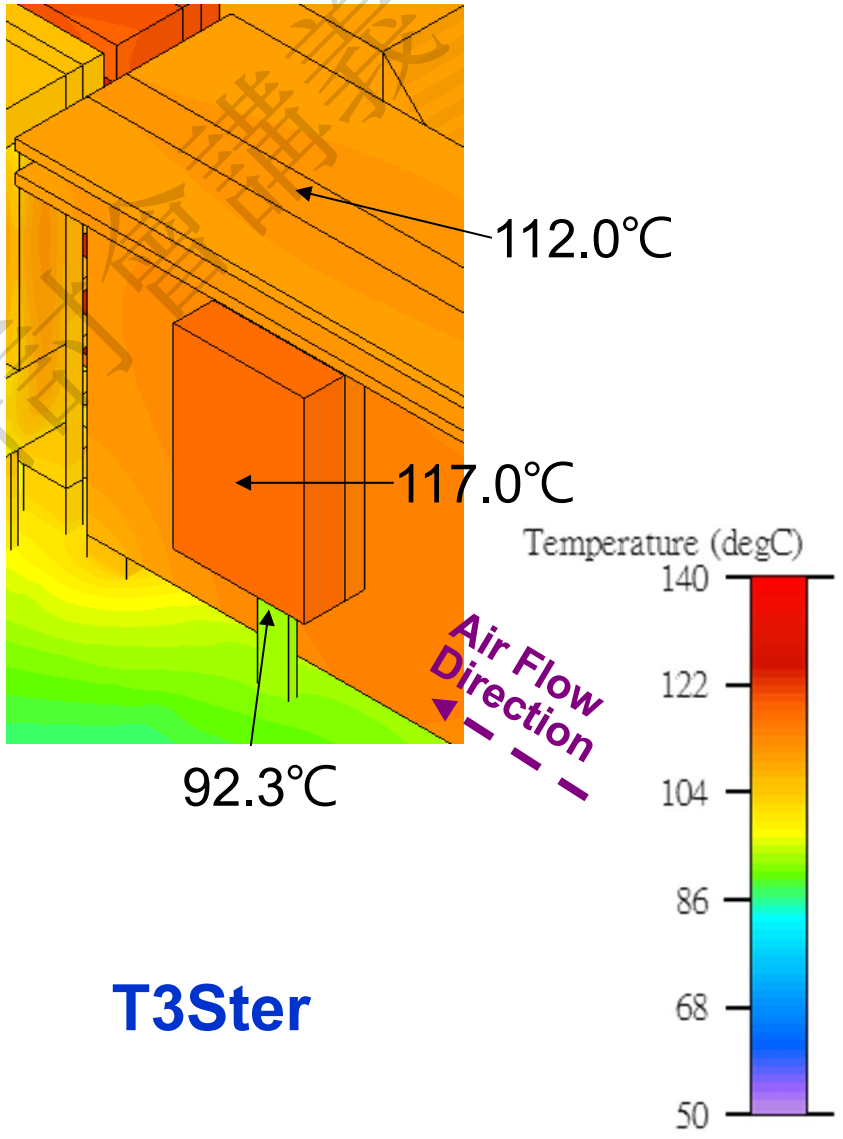


易富迪科技研討會講義

晶體原始模型與T3Ster量測結果模型



原始模型



T3Ster

易富通科技研討會簡報

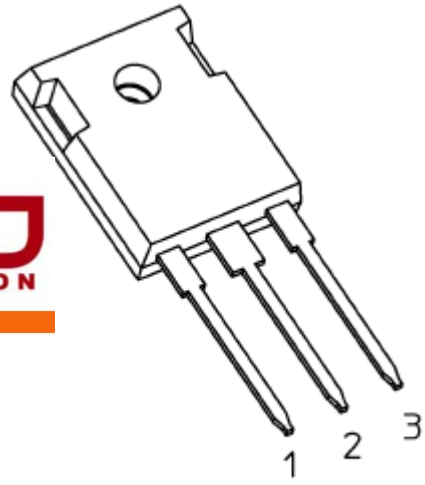
晶體熱阻規格與量測比較3

5. Thermal Characteristics

Characteristics	Symbol	Max	Unit
Channel-to-case thermal resistance	$R_{th(ch-c)}$	0.463	°C/W
Channel-to-ambient thermal resistance	$R_{th(ch-a)}$	50	

Summary-
TK39N60X-Rthjc and Rthja

EFD CORPORATION



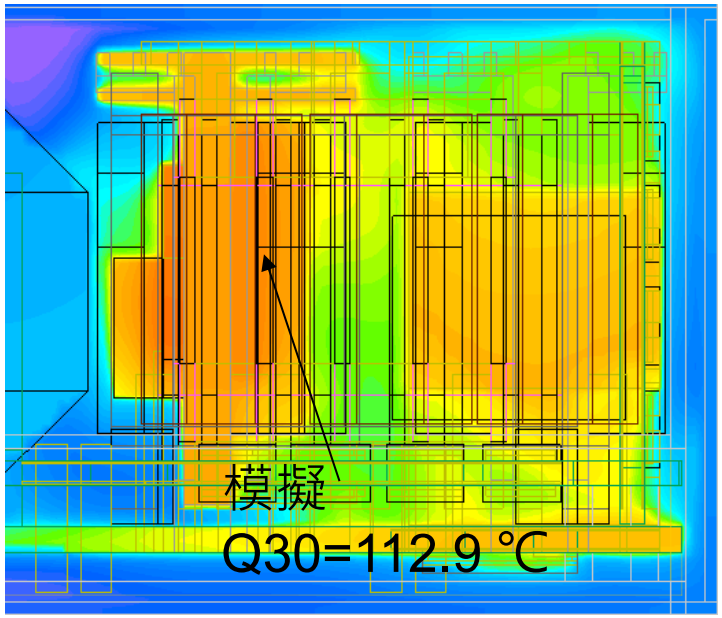
TO-247

Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthjc (K/W)
TK39N60X MOSFET	-7.43	16.86	41.86	0.2992

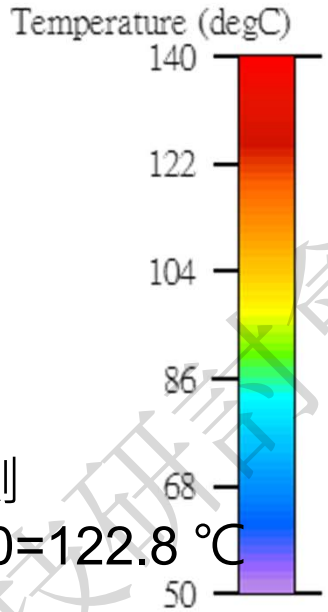
Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthja (K/W)
TK39N60X MOSFET	-7.43	38.01	61.71	3.073

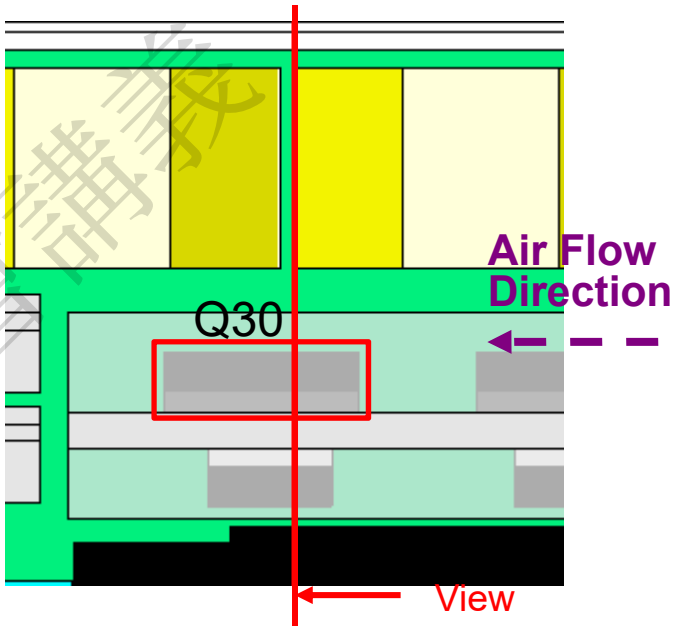
易富迪科技研討會講義

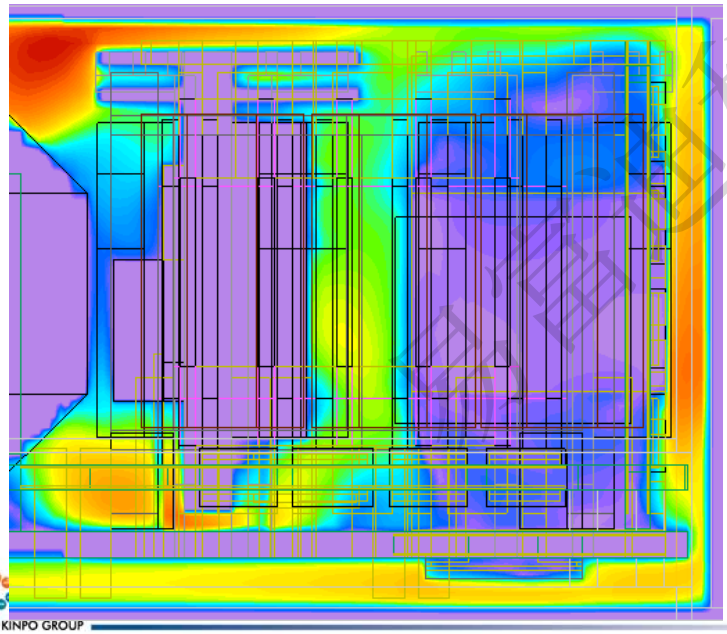
晶體熱阻規格與量測比較3(原始模型)

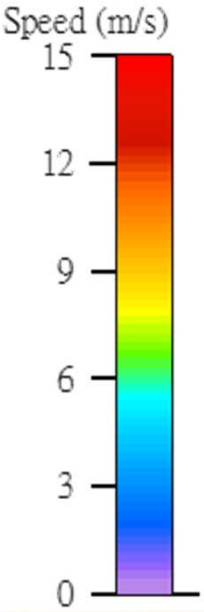


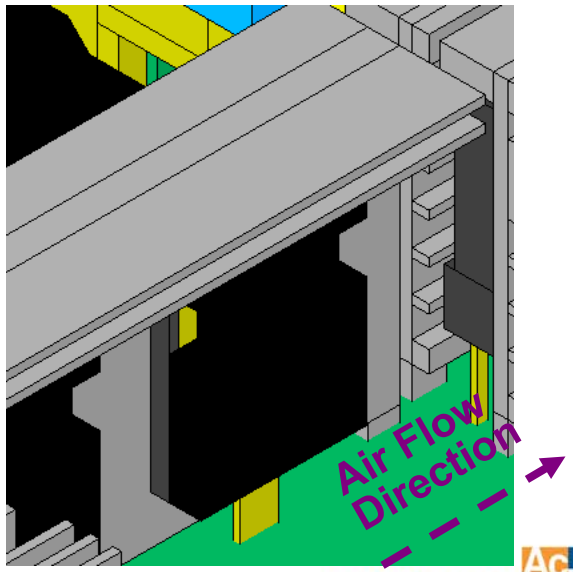
實測
Q30=122.8 ℃





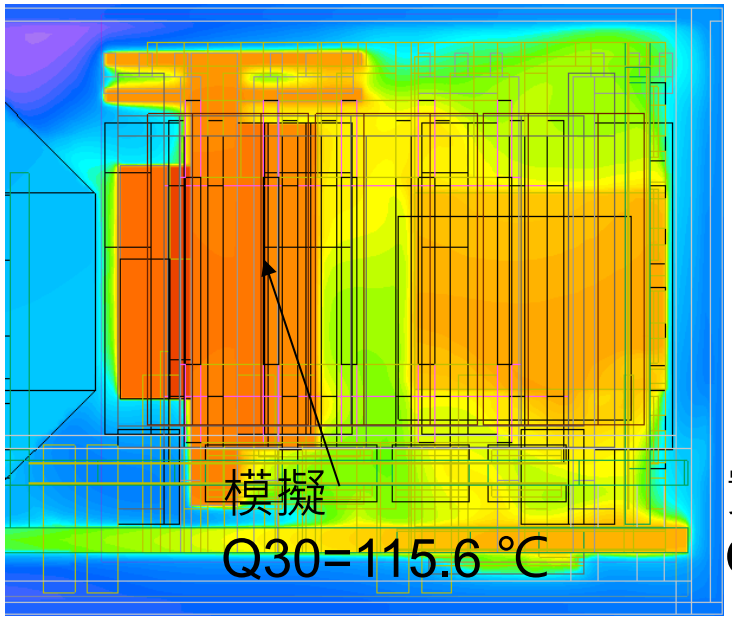




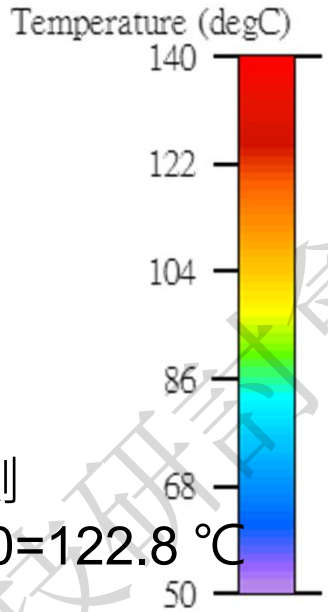


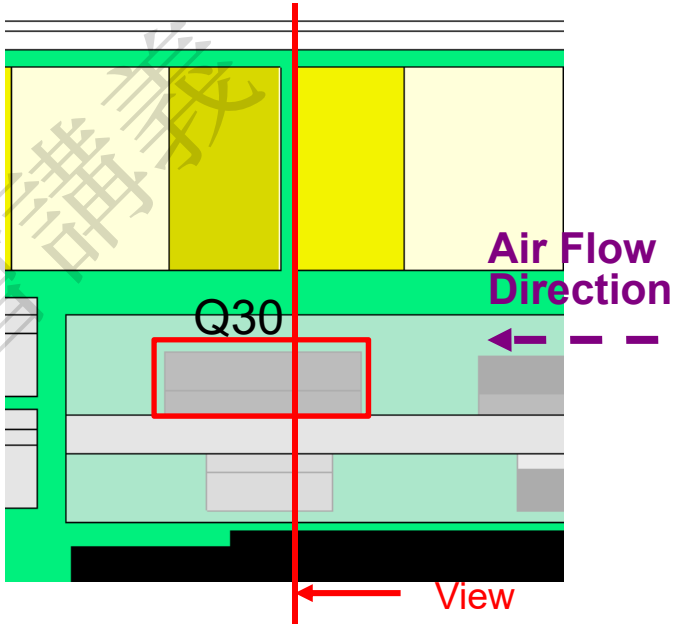
台達電子科技研討會講義

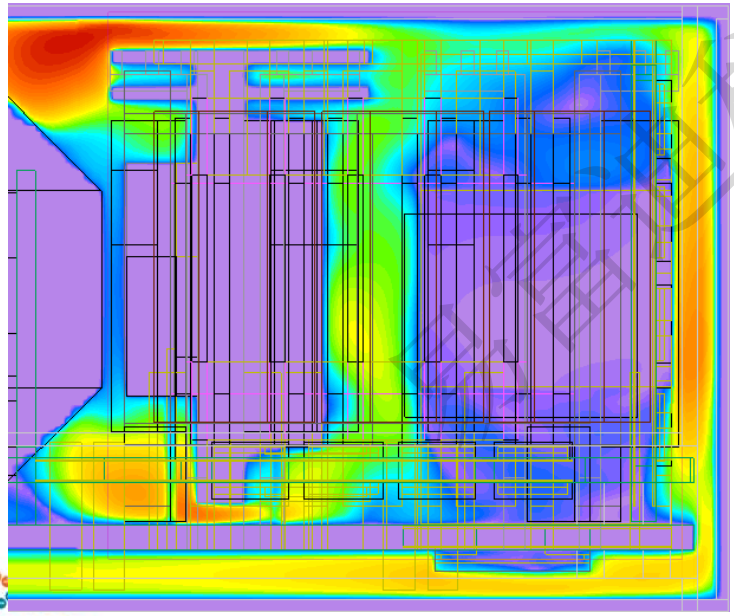
晶體熱阻規格與量測比較3(T3Ster)

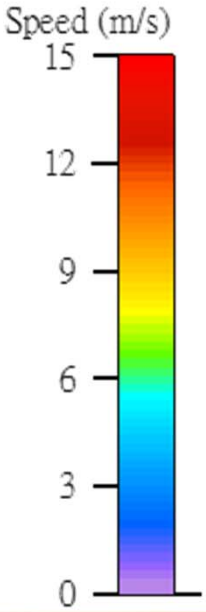


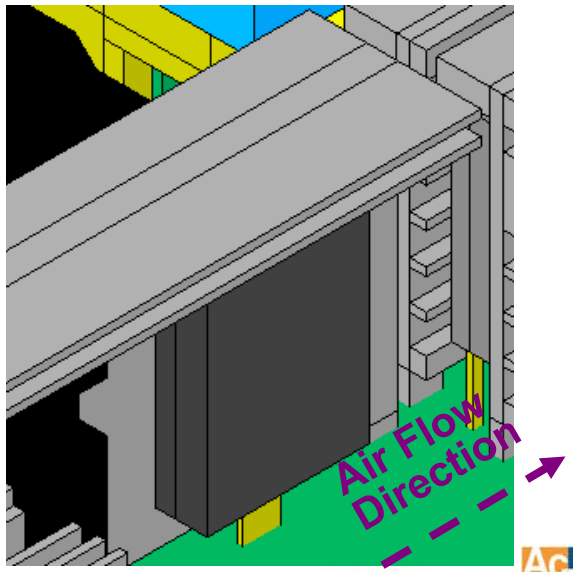
實測
Q30=122.8 ℃





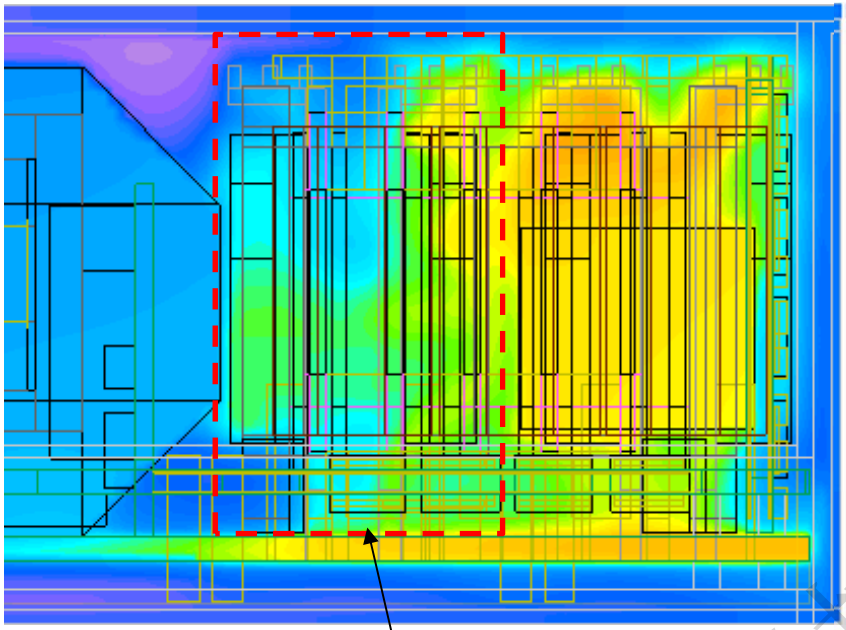


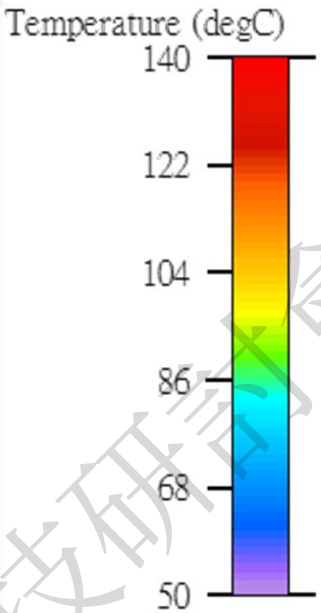


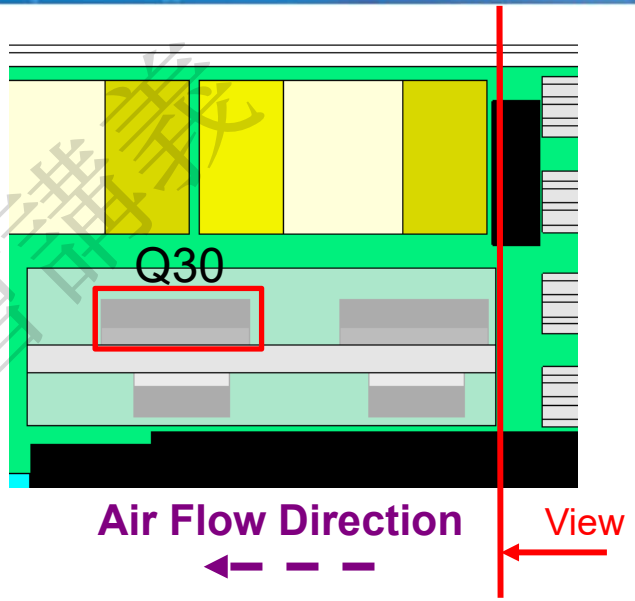


台灣區科技研討會講義

晶體熱阻規格與量測比較3(T3Ster R_{ja}估算)





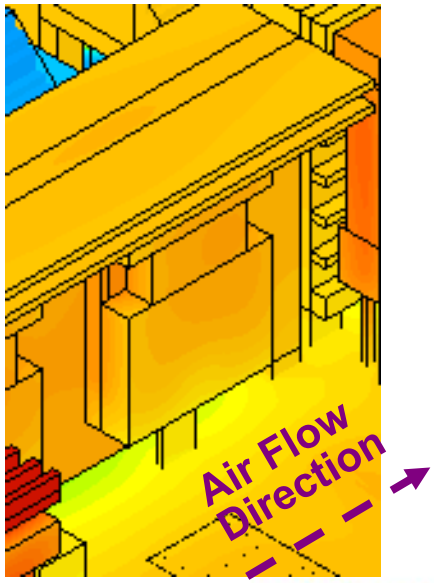


平均溫度83.9 ℃

晶體溫度估算：

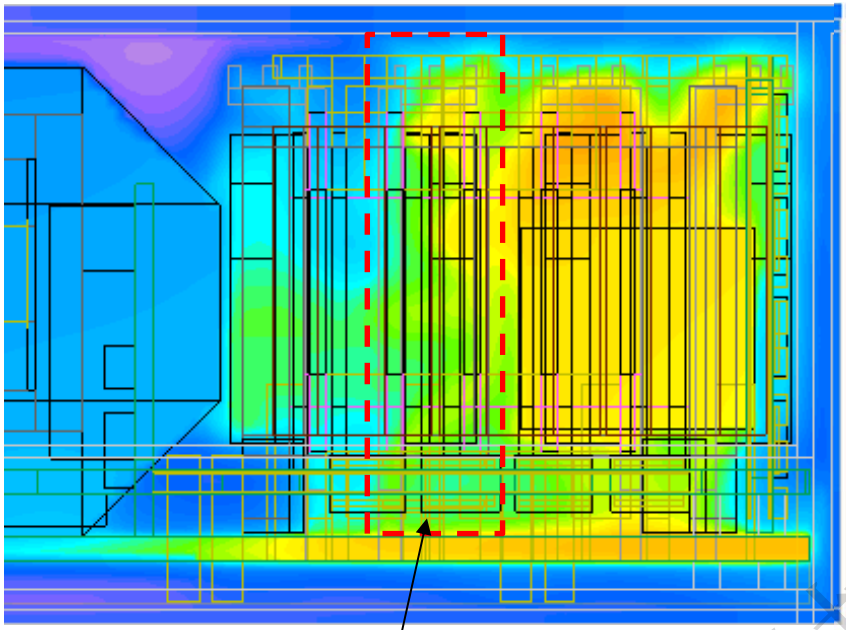
83.9 + 3.073 * 5.928 = 102.1 ℃

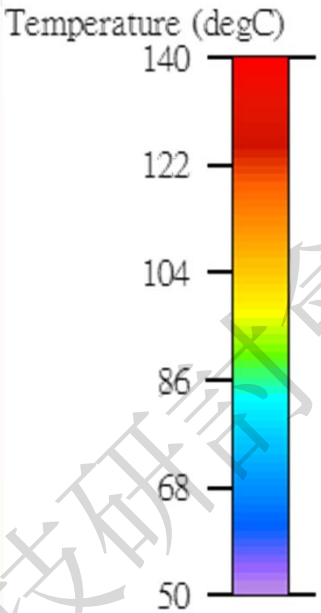
實測 Q30 = 122.8 ℃

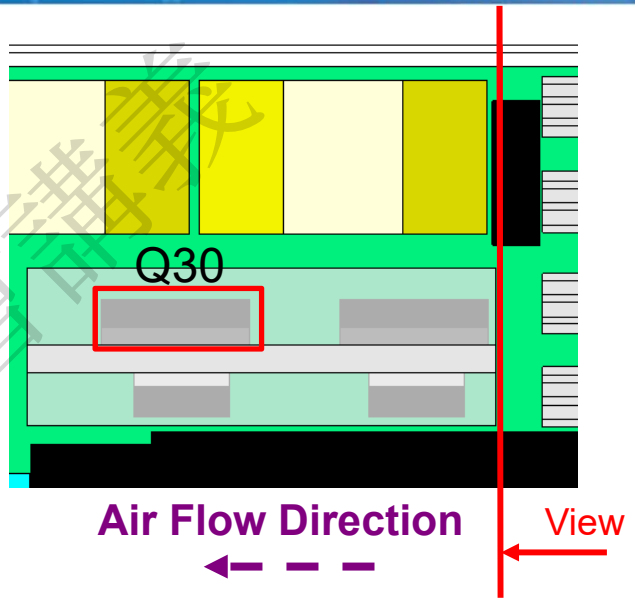


易富迪科技研討會講義

晶體熱阻規格與量測比較3(T3Ster R_{ja}估算)





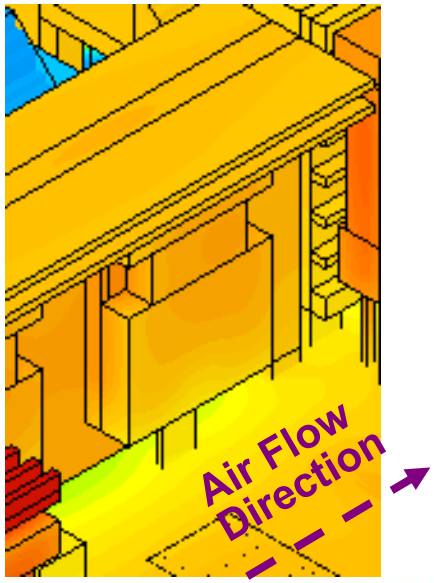


平均溫度88.7 ℃

晶體溫度估算：

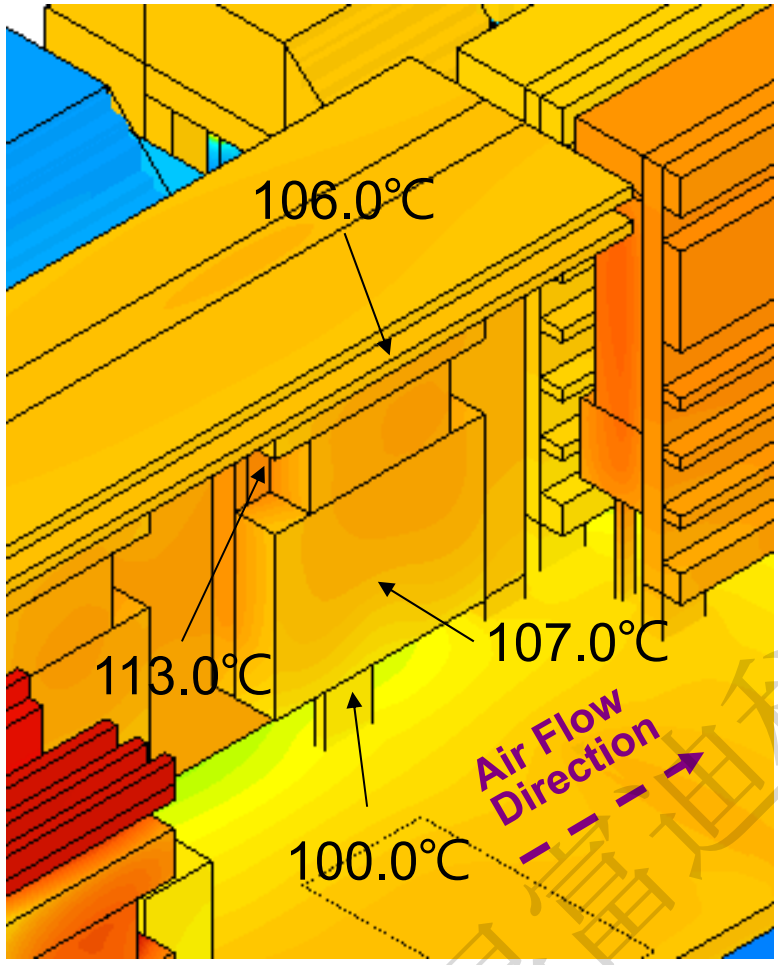
88.7 + 3.073 * 5.928 = 106.9 ℃

實測 Q30 = 122.8 ℃

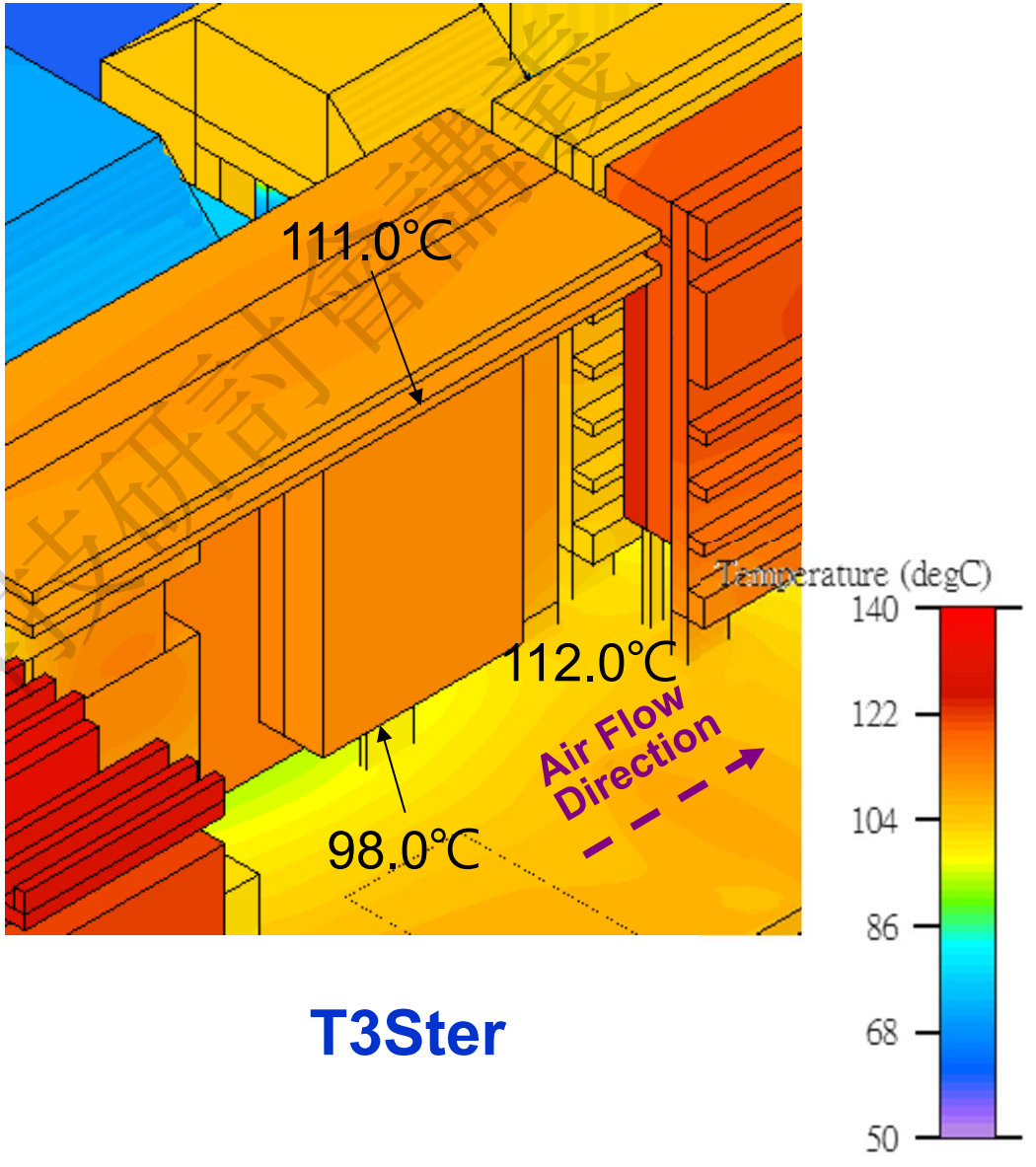


易富迪科技研討會講義

晶體原始模型與T3Ster量測結果模型



原始模型



T3Ster

易富通科技研討會講義

晶體熱阻規格與量測比較4

●電気的・熱的特性　Electrical Characteristics（指定のない場合は Tc=25℃／unless otherwise specified）

順電圧 Forward Voltage	V_F	I_F=12.5A, パルス測定，1素子当たりの規格値 Pulse measurement, per diode	TYP 0.87	MAX 0.92	V
逆電流 Reverse Current	I_R	V_R=600V, パルス測定，1素子当たりの規格値 Pulse measurement, per diode		MAX 10	μA
逆回復時間 Reverse Recovery Time	trr	I_F=0.1A, I_R=0.1A, 1素子当たりの規格値 per diode		MAX 3.0	μs
熱抵抗 Thermal Resistance	θjc	接合部・ケース間，フィン付き Junction to Case, With heatsink		MAX 0.8	℃/W
	θjl	接合部・リード間，フィンなし Junction to Lead, Without heatsink		MAX 5.0	
	θja	接合部・周囲間，フィンなし Junction to Ambient, Without heatsink		MAX 25	

Summary-
LL25XB60-Rthjc and Rthja

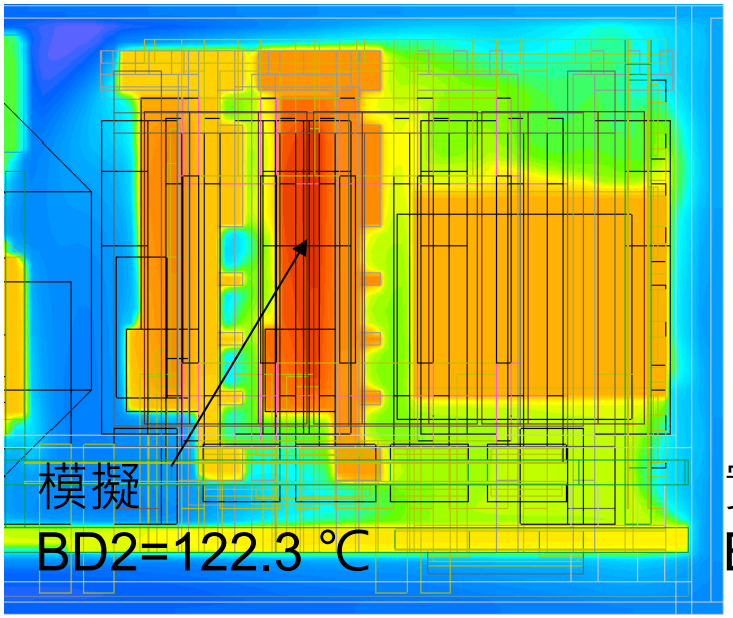
EFD CORPORATION

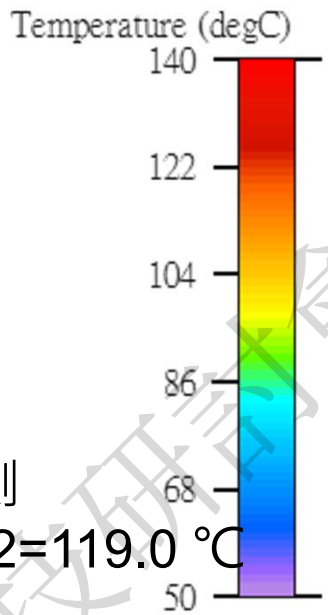
Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthjc (K/W)
LL25XB60 Bridge Diode	-3.916	39.45	64.45	0.9806

Final Data	TSP (mV/K)	ΔTj (°C)	Tj (°C)	Rthja (K/W)
LL25XB60 Bridge Diode	-3.916	55.16	78.76	3.445

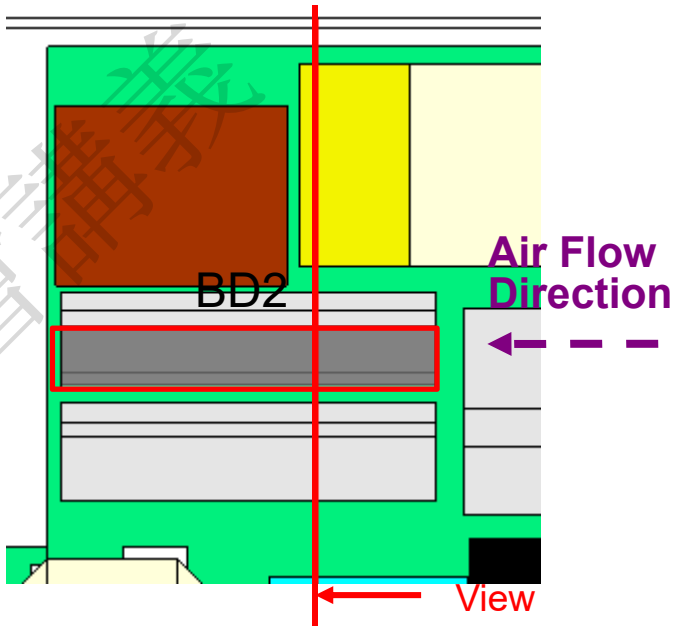
易富迪科技研討會講義

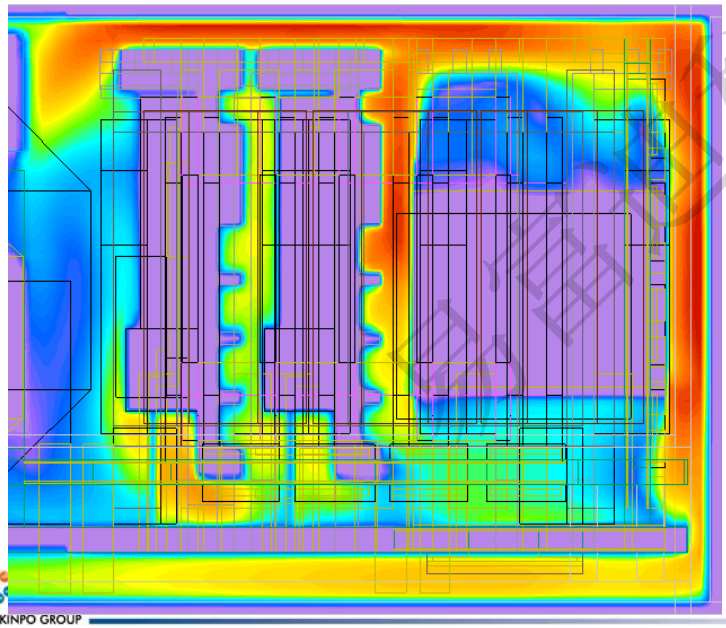
晶體熱阻規格與量測比較4(原始模型)

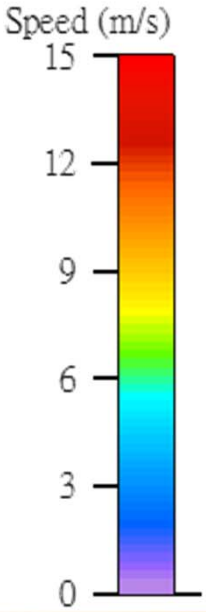




實測
BD2=119.0 ℃

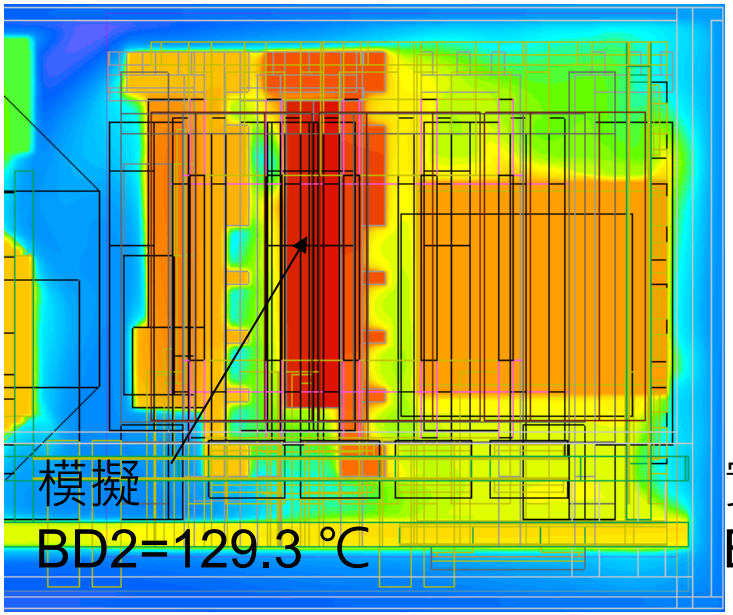




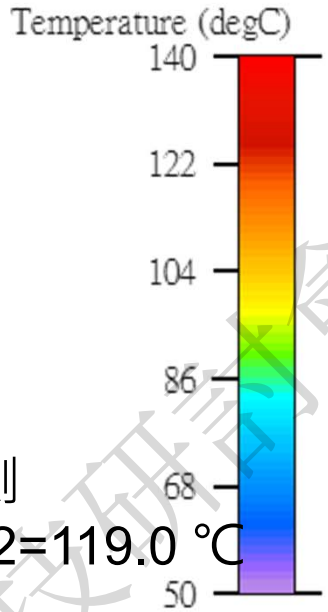


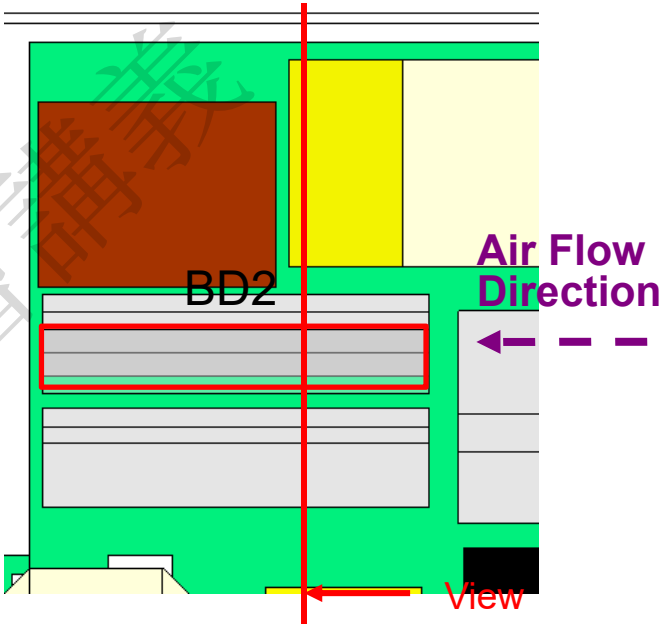
晶富世科技研討會講義

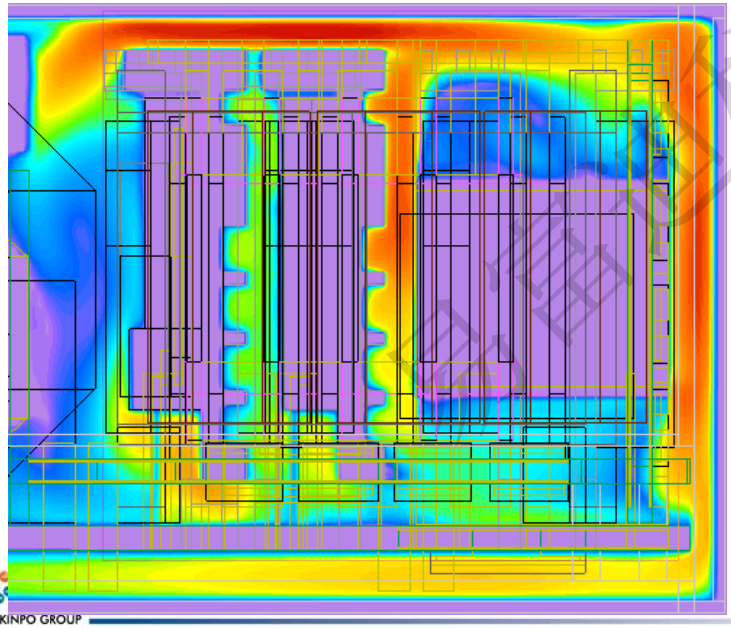
晶體熱阻規格與量測比較4(T3Ster)

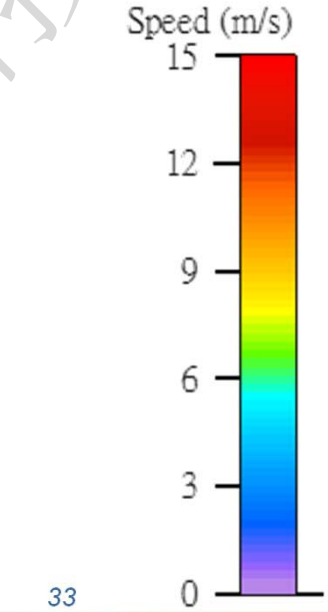


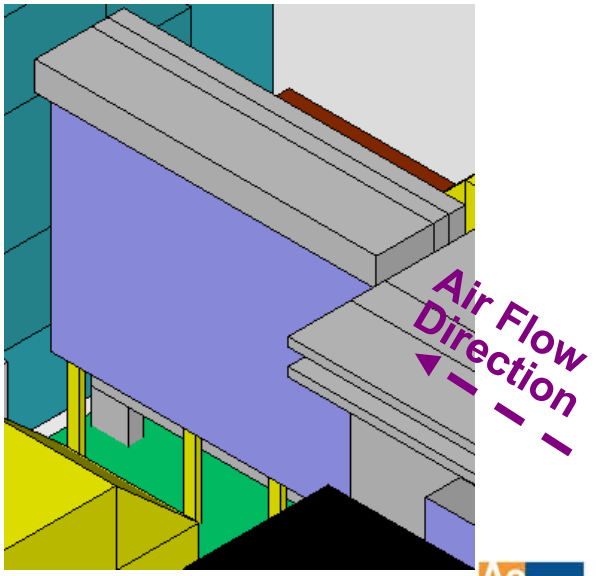
實測
BD2=119.0 ℃











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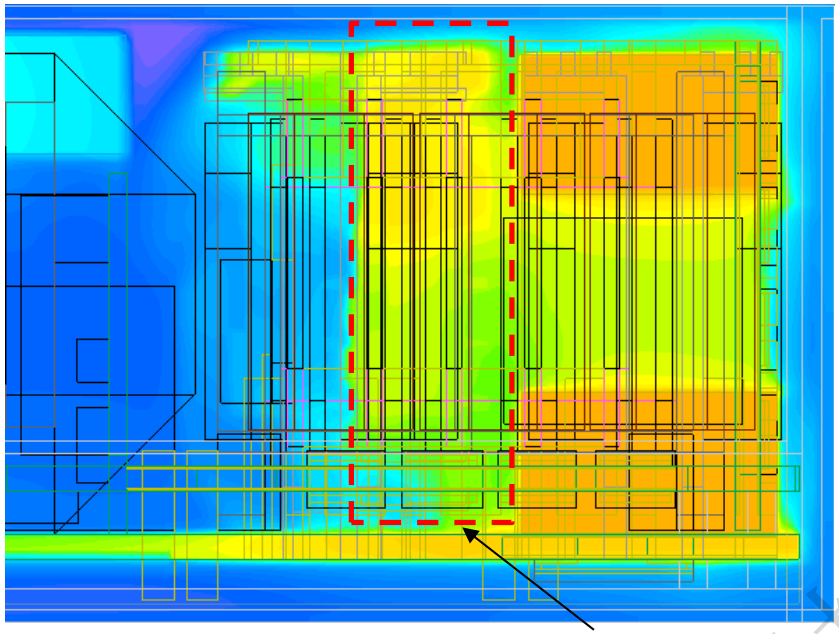
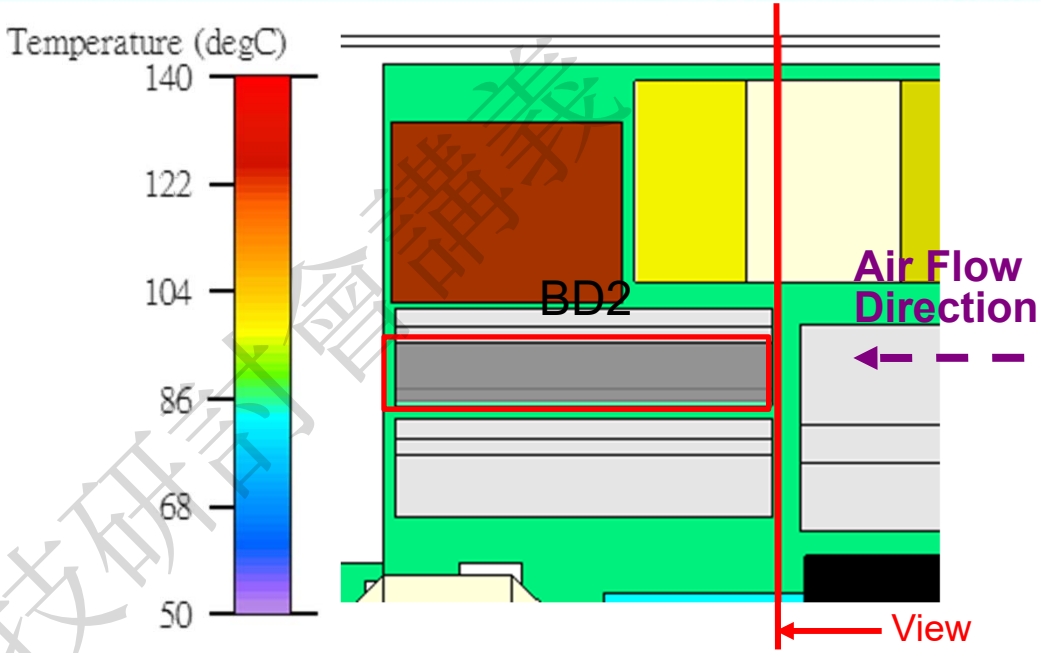
晶體熱阻規格與量測比較4(T3Ster R_{ja}估算)



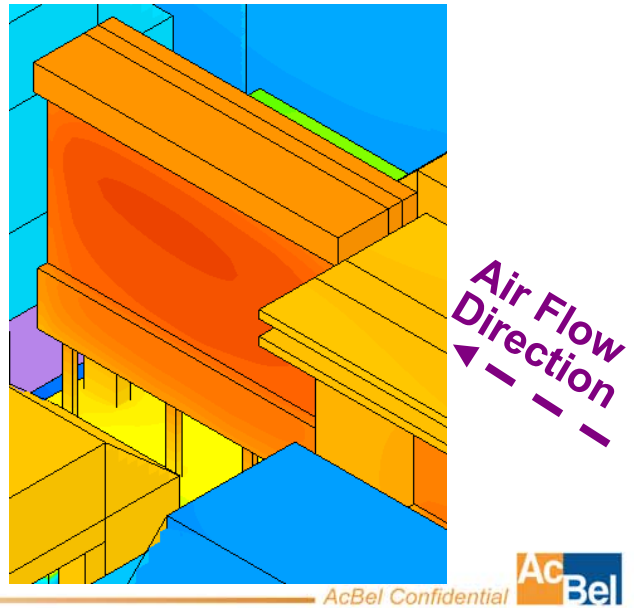


平均溫度91.7 ℃

晶體溫度估算：

91.7 + 0.9806 * 11.4 = 102.8 ℃

實測 BD2 = 119.0 ℃



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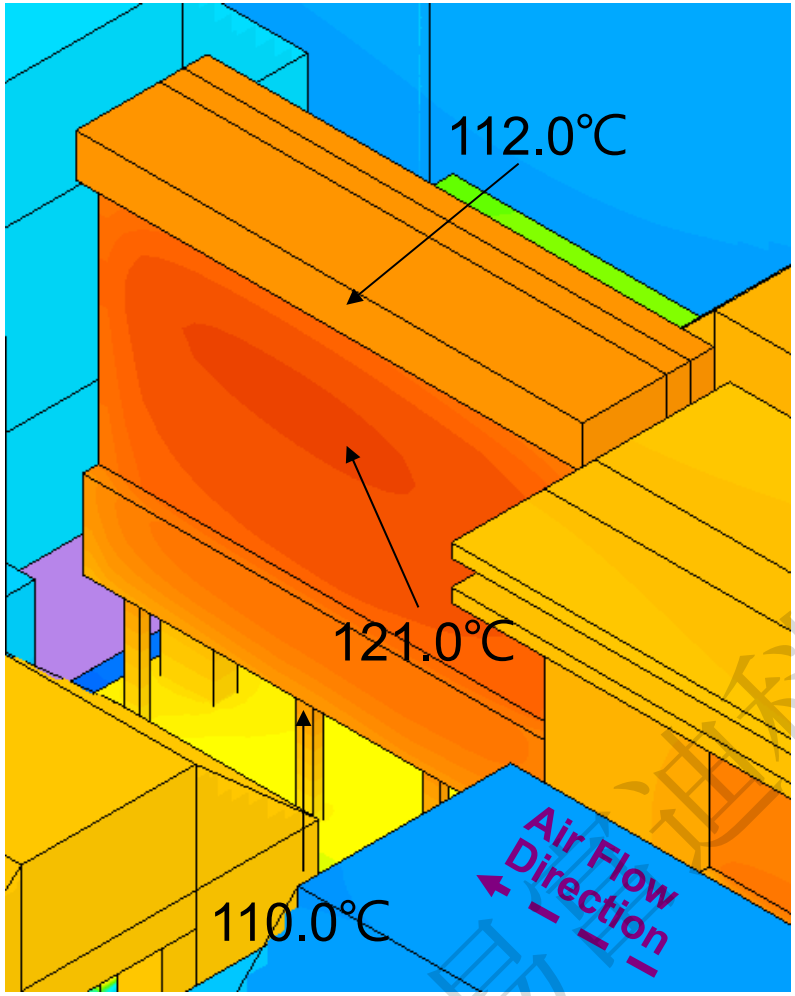
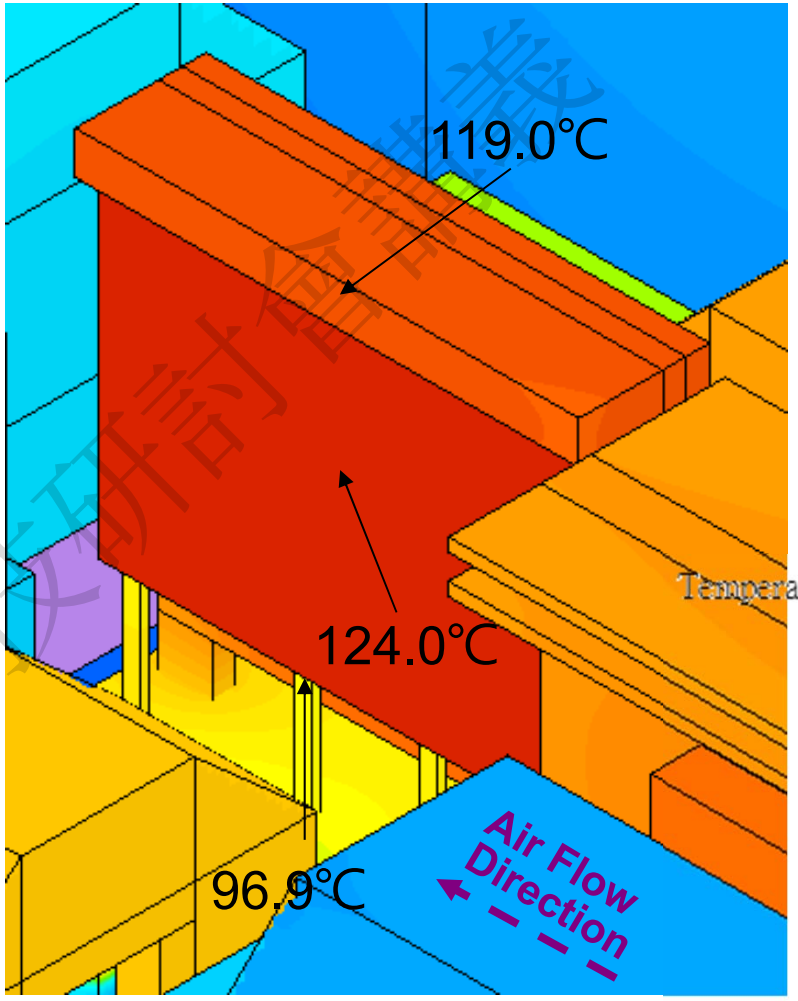
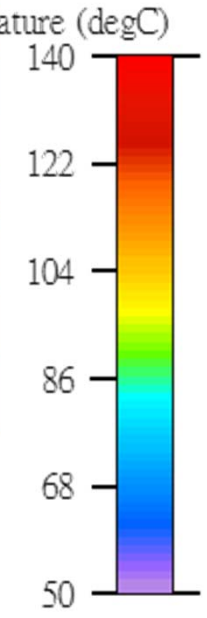
晶體原始模型與T3Ster量測結果模型



原始模型



T3Ster



結論

$T_{junction}$(℃)	Q6	D7	Q30	BD2
實測	126.4	110.6	122.8	119.0
原模型	134.3	123.0	112.9	122.3
T3Ster R_{jc} 2R模型	137.5	120.7	115.6	129.3
T3Ster R_{ja}估算	120.2	111.3	102.1	102.8

T_{pin}(℃)	Q6	D7	Q30	BD2
原模型	111.0	106.0	100.0	110.0
T3Ster R_{jc} 2R模型	110.0	92.3	98.0	96.9

- 使用T3Ster量測晶體R_{jc}結果代入Flotherm 2R模型，與原建立方式之結果在6%以內，可以幫助模型簡化。
- D7與BD2的pin溫度差異較大，調整後能與原模型模擬結果更為接近。

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THANK YOU!

康舒科技
ACBEL POLYTECH INC.

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