

CoreTek 克達科技

Wide Bandgap Semiconductor testing challenge on SiC / GaN

FLEX Test Measure

POMME 禧恩科技股份有限公司
POMME TECHNOLOGIES CO.,LTD

2022

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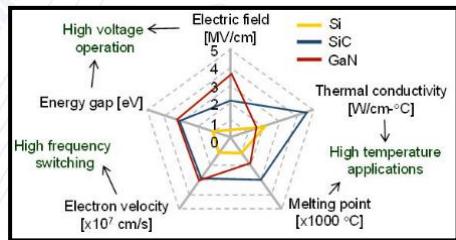
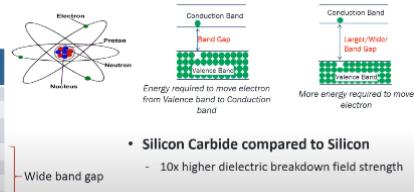
Agenda

- WBG semiconductor advantage
- WBG device test challenge
- Power loss/ Current Collapse/ DPT testing
- POMME WBG fitted solutions
- CoreTech/ POMME introduce and WBG Solutions

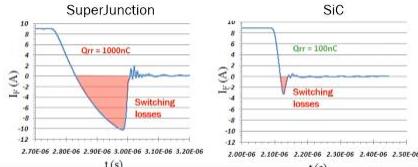
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WBG semiconductor advantage

Material	Symbol	Bandgap Energy (eV)
Germanium	Ge	0.7
Silicon	Si	1.1
Gallium Arsenide	GaAs	1.4
Silicon Carbide	SiC	3.3
Zinc Oxide	ZnO	3.4
Gallium Nitride	GaN	3.4
Diamond	C	5.5



- Low DC power loss
- Higher Operate I/V
- Higher Frequencies
- Higher Thermo-stability

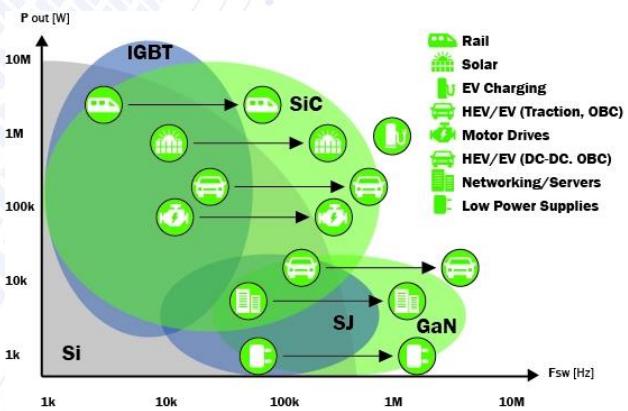
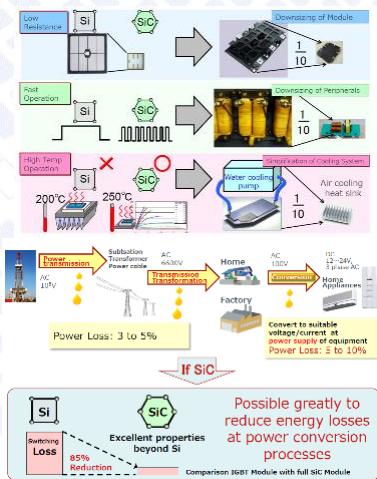


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WBG Market Position



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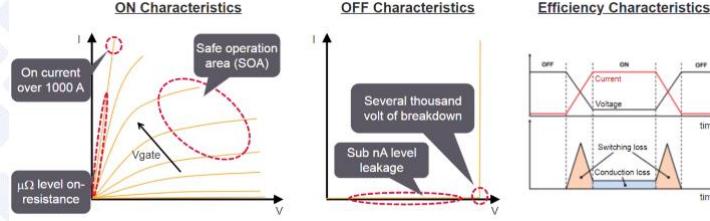
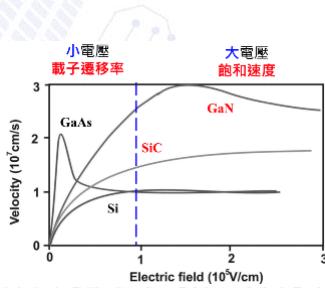


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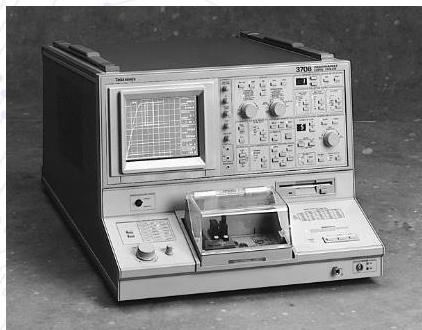
WBG device test challenge

- Power loss($R_{on}/CV/Qg$)
- Current collapse(GaN)
- High DC bias capacitance(GaN)
- DPT testing
- Thermo-testing



Traditional Test Equipment Weakness

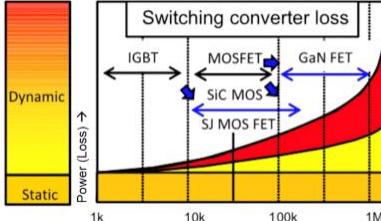
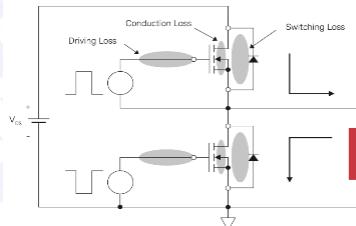
- Poor IV accuracy, non-CV/ Qg/ GaN C.C.
- Hard to prevent self-heating
 - Wide Pulse Width
- No well prepare test fixture
 - Rewire instrument connection
 - Wafer → Die → PKG → Module
- Thermal testing limit
 - Long cabling
 - Hard temperature monitor
 - Thermal chuck as a test pad(Vertical DUT)
- Wafer prober auto-testing
- No switching solution for HV/HC
- WBG DPT solution lack: Higher V/C, Higher speed



Power loss

$$\text{Total Loss} = \text{Conduction Loss} + \text{Switching Loss} + \text{Driving Loss}$$

Key Parameters: R_{on} , R_g , C_{iss} , C_{oss} , Q_g

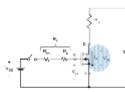


$$\text{Drive Loss} = f * Q_g * V_{gs}$$

$$\text{Switching Loss} \propto f * (V * I * \Delta T)$$

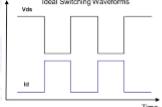
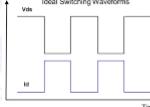
$$\text{Conduction Loss} = R_{on} * (I_{RMS})^2$$

Ron

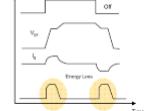
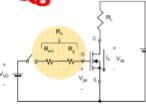


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Rg/CV

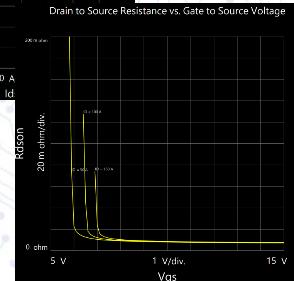
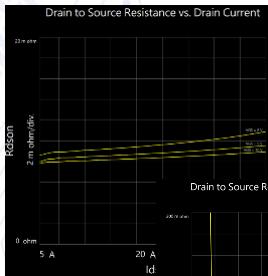
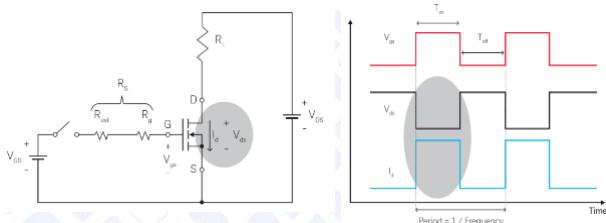


Qg



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On-Resistance: Rdson



- ❑ WBG Rdson is very low so conductive loss can be ignored.
- ❑ How to measure uOhm Rdson is the key:
 - ① Specified test fixture with low R_L
 - ② High current affordable
 - ③ Suitable Rg and duty cycle on Gate/Drain to prevent DUT broken!

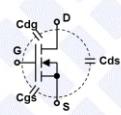
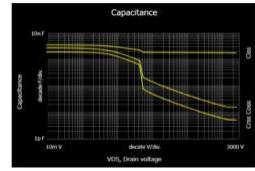
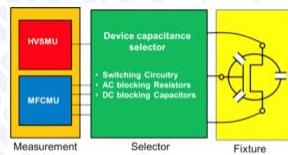
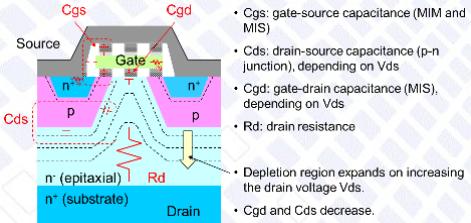


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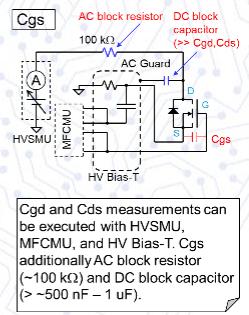
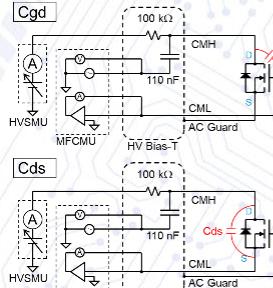
Capacitor: Ciss/ Coss/ Crss



Ciss: Input Capacitance
 $C_{iss} = C_{gs} + C_{gd}$

Coss: Output Capacitance
 $C_{oss} = C_{ds} + C_{gd}$

Crss: Reverse Transfer Capacitance
 $C_{rss} = C_{gd}$

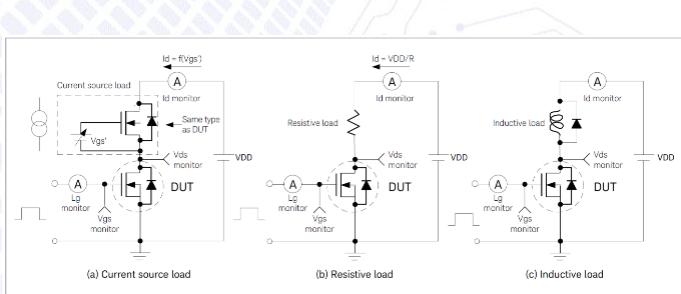
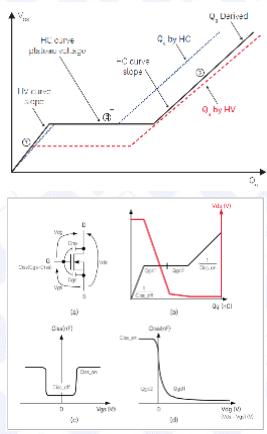


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Gate charge: Qg



Qg measurement difficult

- A stable power supply to provide accurate time dependent output voltage and current.
- A gate drive circuit which can accurately measure time dependent current and voltage.



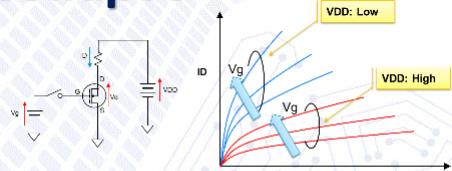
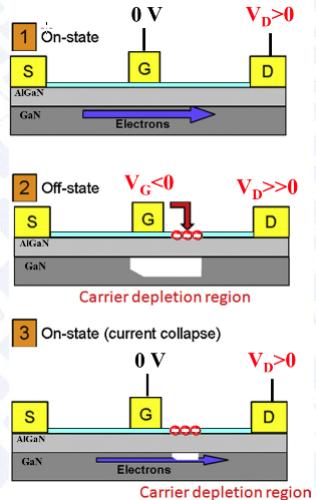
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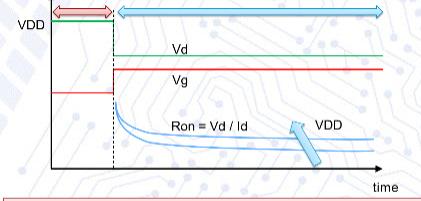
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GaN C.C.: Current Collapse



Drain current at higher VDD is smaller than it at lower VDD!?



- On resistance changes dynamically after changing from off state to on state.
- On resistance is depending on VDD and duration of off-state.
- Caused by the same mechanism with the current collapse phenomena observed at IV measurement.

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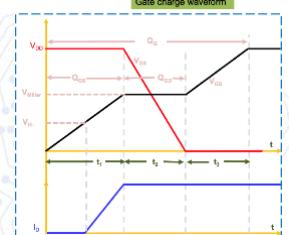
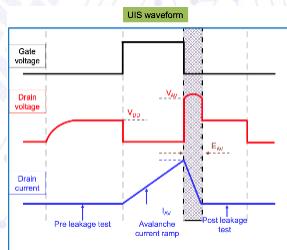
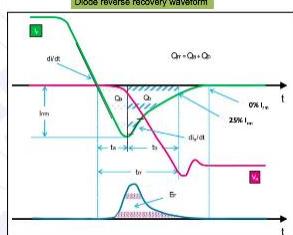
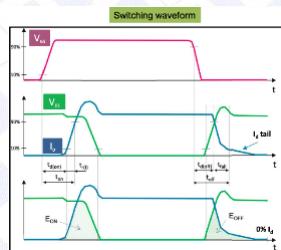
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DPT testing

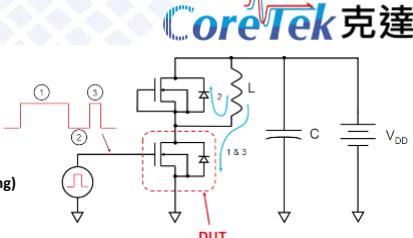
WBG DPT solution:

- ✓ Higher V/C
- ✓ Higher speed
- ✓ Specified fixture



Double pulse testing:

- Switching
- Reverse recovery
- UIS(Unclamped inductive switching)
- Gate charge



Turn-on delay time	$t_{d(on)}$
Rise time	t_r
Turn-off delay time	$t_{d(off)}$
Fall time	t_f

Reverse recovery time	t_{rr}
Reverse recovery charge	Q_{rr}
Peak reverse recovery current	I_{rrm}

Avalanche current	I_{as}
MOSFET dv/dt ruggedness(UIS/EAS)	dv/dt
Reverse diode dv/dt	dv/dt

Gate to source charge	Q_{gs}
Gate to drain charge	Q_{gd}
Gate charge total	Q_g
Gate plateau voltage	$V_{plateau}$

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Coretek / POMME introduce

克達科技/禧恩科技提供了完整的第三代半導體所要求的規格的測試方案：

- DC Power Device Parameter 測試方案
- AC Power Device parameter 測試方案
- Low current device characterization parameter 測試方案

針對寬能隙WBG(Wide Band Gap)Device 設計了加熱器，I/V Curve，C/V Curve 及On-wafer 測試探針及客制的治具，提供一站式的解決方案，大幅減輕您測試環境的架設及測試時間。

針對On-wafer 測試，克達科技提供您完整測試方案從手動、半自動到全自動等，探針/探針卡全面性的解決方案

1. Manual: MF-P/ MF-C series

2. Semi-Auto: SF-P/ SF-C series

3. Fully-Auto: IF series

Probe Station	Tester	Turn-Key System	OST service	Instrument Service
Type Manual ➤ Semi-auto ➤ Fully-auto Function ➤ Low Current/ WBG ➤ LCD/ Vacuum	DC ➤ DC voltage ➤ Keitley ➤ Owned PXI AC ➤ Manual DFT ➤ Surge Current Tester	RDL tester 4PP Tester TEG Tester Reliability Package	Wide Band Gap Low Current Reliability Burn-In	Calibration Loan Repair Used Resell



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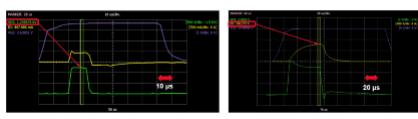


WBG fitted solutions – 1

- Great IV accuracy, non-CV/ Qg/ GaN C.C.
 - B1505A/ B1506A



- Shorter pulses are always better (10 μs in this example)
- It is useful to have some means to visually verify the pulsed waveforms



- Hard to prevent self-heating
 - POMME provide turnkey 10 us level testing



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WBG fitted solutions - 2

- **Thermal testing limit**
 - New high-temp test board
 - Thermal couple for temp-monitor
 - Wafer/Die testing:** 3kV/ 10kV/ 300A thermal chuck(-55~300 °C)
 - Discrete/ SMD:** Thermostream(-80~225 °C)
 - Power Module:** Thermal plate(RT~250 °C)
- **Wafer prober auto-testing**
 - Fully configured probing tips between HV/HC
 - Owned design semiauto/ auto prober
- **No switching solution for HV/HC**
 - Module selector: N1258&9A/ N1265A/ B1506A



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Keysight B1505A/ B1506A

For Power Semiconductor Manufacturers – B1505A

- Very wide range up to 1500 A / 10 kV
- Covering CV, Qg and GaN current collapse measurements
- Supporting both on-wafer and packaged devices
- Automated IV, CV, thermal test capability from -50 °C to +250 °C
- Safe and easy to use



For power electronics engineers using power devices in their products – B1506A

- Fully automated IV, CV and semi-automatic Qg measurements
- Fully automated IV / CV thermal test from -50 °C to +250 °C
- Power loss calculation using IV, CV, Rg, Qg
- Up to 1500 A / 3 kV
- Safe, simple and easy to use



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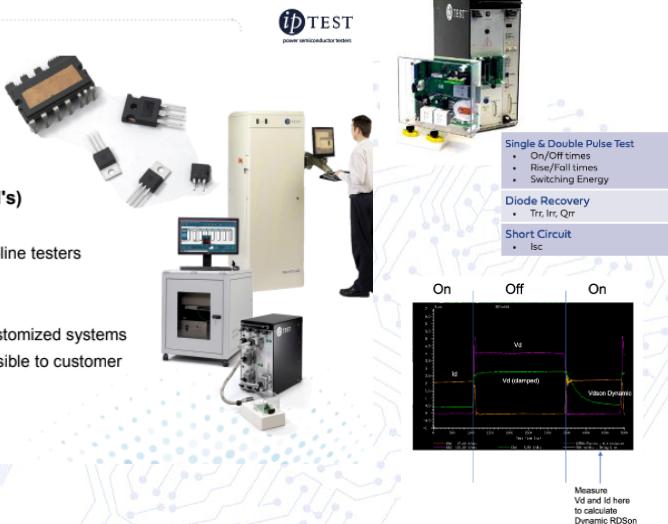


AC: ipTEST DS5

ABOUT ipTEST

ipTEST has become the leading manufacturer of high-speed power discrete test systems to the worlds largest Integrated Device Manufacturers (IDM's)

- We exclusively focus on developing high speed production-line testers
- We have 35 years of high-power discrete testing know-how
- We have more than 500 test systems sold worldwide
- We are flexible to customer demands and deliver highly customized systems
- Our engineering support and R&D teams are openly accessible to customer engineers
- Located in UK, 30km south-west of London



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WBG Manual Probe Station

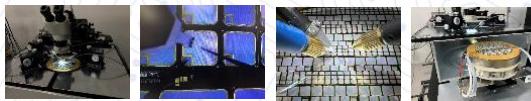


- Model MF-PE2000 is for 8" wafers.
- Model MF-PE3000 is for 12" wafers.



	MF-P2000	MF-P3000
Wafer Size	~ φ100 mm	~ φ150 mm
X-Y travel	X:105mm · Y:200mm	X:160mm · Y:250mm
X-Y repeatability	<±2µm	
X-Y accuracy	<±5µm	
Z travel	20mm	
Z repeatability	<±1µm	
θ travel	±7.5°	
θ repeatability	0.002°	
Unit dimension(Wx Dx H)*	1200x900x1550mm	1250x900x1550mm
Weight*	depending on configuration, 650kg	700kg

- Applications
 - ① Temperature characteristics tests in range from +20°C to +300°C
 - ② Ultra low signal I-V measurements (zoofA level)
 - ③ Various C-V measurements(quasi-static C-V, HF-CV, and RF-CV)
 - ④ RF measurements(up to 67 GHz)
 - ⑤ Ultra high-speed I-V measurements
- Extend Application
 - ① High-power device measurements (**(±300A pulse, ±3kV triaxial, ±10kV coaxial)**)
 - ② Wafer level reliability tests (such as EM, TDDB, HCI, NBTI, and BT)
 - ③ Probe card support (support Multi-site WLR)
 - ④ Built-in laser cutter(Point marking, Exfoliation of protection layer, Metal layer cutting)
 - ⑤ Active vibration isolator and ultra high-accuracy probing through image processing pattern recognition (accuracy: ± 1 um or finer)
 - ⑥ Light-receiving/emitting characteristics evaluation applications for optoelectronics (such as LED, LD, VCSEL, and PD)
 - ⑦ Common gate pad contacts of flat-panel display devices



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OST: Out Source Testing

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- Model AF-OST-AC** is for dynamic testing.
- Model AF-OST-DC** is for DC testing.
- Model AF-OST-WFR** is for on-wafer testing.



Power Device DC Parameters	Symbol
Drain-source breakdown voltage V_{bd}	V_{bd}
Gate threshold voltage V_{th}	V_{th}
Gate-to-drain leakage current I_{gd}	I_{gd}
Gate-source leakage current include Zener diode I_{gss}	I_{gss}
Gate-to-drain reverse bias voltage V_{dg}	V_{dg}
Type output characteristics $Id-Vd$	$Id-Vd$
Type drain source on-state resistance R_{ds}	R_{ds}
Type threshold characteristics $I_{th}-Vg$	$I_{th}-Vg$
Type drain current I_d	I_d
Type Capacitance C_{oss}	C_{oss}
Type Capacitance C_{iss}	C_{iss}
Type Capacitance C_{oss}	C_{oss}
Forward characteristics of reverse diode $IF-Vd$	$IF-Vd$

Power Device AC Parameters	Symbol
Input capacitance C_{iss}	C_{iss}
Output capacitance C_{oss}	C_{oss}
Miller capacitance C_m	C_m
Reverse recovery time t_r	t_r
Forward recovery time t_f	t_f
Peak reverse i_c current i_{rrm}	i_{rrm}
Peak reverse i_v current i_{rrv}	i_{rrv}
Breakdown voltage v_b	v_b
Turn on/off delay time $t_{on/off}$	$t_{on/off}$
Turn on/off time $t_{on/off}$	$t_{on/off}$
Recovery time t_r	t_r
Q _{rr} or Q _{rrv}	Q_{rr}
Turn on/off recovery time $t_{on/off,r}$	$t_{on/off,r}$
Capacitor compensation t_{cc}	t_{cc}
AC-Test-IDC current i_{idc}	i_{idc}
AC-Test-IDC current derivative $d i_{idc} / dt$	$d i_{idc} / dt$
AC-Test-IDC current rate of change $d^2 i_{idc} / dt^2$	$d^2 i_{idc} / dt^2$

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- Applications**
1. WBG tester Keysight B1506A
2. Dynamic tester: POMME STA
3. ThermoStream Temptronic TPO45000A(-80 °C to 225 °C)
4. 5 probe station with thermo-chuck form -55 °C to 200 °C
5. Oven for 100°C to 300°C
6. LCR meter as CV testing
7. B1500A/4200/B2201A/707A for low current WAT testing

- Extend Application**
 - DC: IGBT/MOSFET/DIODE/GaN**
 - IGBT: I_{ces} , I_{ges} , $V_{ge}(th)$, $V_{ce(on)}$, V_{ces} , V_{ges} , $V_{br(ce)}$
 - MOSFET: I_{dss} , I_{gss} , $V_{gs(th)}$, $R_{ds(on)}$, V_{dss} , V_{gss} , $V_{br(ds)}$, C_{dg} , C_{gs} , C_{gd}
 - DIODE: I_r , I_d , V_r , V_f , V_{sd} .
 - AC: Switching/Recovery/ Q_{rr}/ Roughness**
 - Switching Board: $t_{d(on)}$ / t_r / $t_{d(off)}$ / t_f / $E_{(on)}$ / $E_{(off)}$
 - Tri/Qu Board: t_{rr} / Q_{rr} / I_{rrm}
 - dv/dt for MOSFET and Diode



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Questions

CoreTek 克達科技

- 在電容量測部分，有提到非常低的Crss，我們公司在GaN開發時也常遇到無法測試封裝好元件到低於1pF的結果，但換算起來的確GaN Crss的確會這麼低，請問是用什麼方式克服的：
 ➤ GaN的切換速度非常的快，其中很關鍵的因子就是非常低的Crss(Qg也是非常低)，在量測過程中，除了需要考慮線路的補償(capacitor compensation)外，還需要想辦法去除測試電路的耦合作用，禧恩科技有針對DFN8*8/ DFN5*6封裝推出專用版，可以讓GaN封裝元件正確量測低至300fF，有興趣的朋友可以跟克達科技/禧恩科技業務洽詢。
- 請問貴司所設置的委測實驗室，有哪些配置，是否對外開放：
 ➤ 禧恩科技委測實驗室有下列配置: DC部分備有4156C/ B1500A/ B1505A/ B1506A數套，以及針對不同電壓電流的探針台(fA~300A/ 3,000V)；AC部分有手動以及自動化(建置中)Double Pulse Tester數套。可以提供客戶非常完整的靜態/動態datasheet測試項目，熱阻部分也有配合廠商可以提供完整方案，在禧恩科技可以得到非常完整的WBG datasheet特性分析，有興趣的朋友可以跟克達科技/禧恩科技業務洽詢。
- 請問貴公司所提供的探針台方案，是否有特別針對SiC/ GaN有特殊的配置， R_{dson} 可以測到多低：
 ➤ 禧恩科技開發的探針台MF/SF系列，針對WBG的GaN/ SiC分別有不同PKG/on-wafer配件，可以讓客戶快速選擇或切換需要測試的元件(高電壓/高電流/快速切換等)， R_{dson} 的部分，PKG可以測試到700u ohm，探針可以到500u ohm。
- 剛演講中有提到Keysight B1505A/ B1506A，這兩個型號功能相近，實驗室建置時，該怎麼選擇：
 ➤ 剛開始開發設計時，B1505A會比較合適，因為彈性比較大，但後期需要製作datasheet時，B1506A可以快速產生datasheet來的更為便利。以功能面來說，B1505A可以擴增10kV/ GaN C.C.(50us)功能，是有需要測試特殊車用模組或快充時，B1505A則提供一個更好擴增的平台。不管B1505A/ B1506A，禧恩科技都有非常完整的配套方案，有興趣的朋友可以跟克達科技/禧恩科技業務洽詢，來幫您配置最好最合適的方案。

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