Power Electronic Devices Stress Test system

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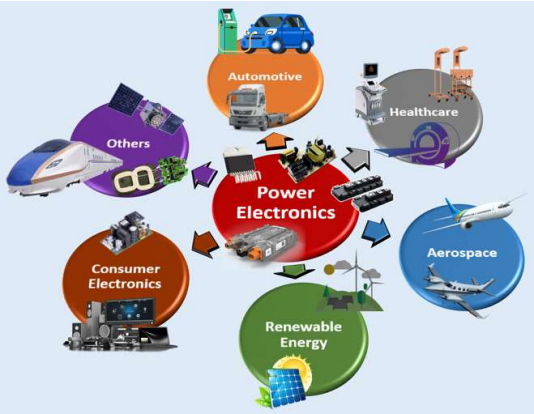


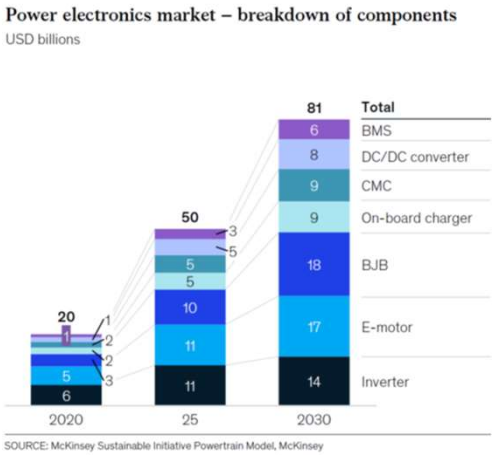
Introduction – 1

- Eurofins Testing for Life: 940 labs, 59 countries, 61K employees, revenue > €6B; pharma/chemical/medical/food/agro services
- Company Profile eurofins|MASER

1993	25+	55	NL	2	MIDS
Founded Eurofins | MASER is an Independent Service Provider founded in 1993	**Experience** 25+ years of experience in reliability test and failure analysis of semiconductors, electronic components and electronic systems	**Employees** Staff 55 employees (45 FTE), half with engineering degree (PhD/MSc/BSc)	**Location** Main office & laboratory: Auke Vleerstraat 26, Enschede, The Netherlands	**Certification** ISO-9001:2015 certification by Lloyds ISO-17025:2005 accreditation according to scope L388 www.rva.nl	**CMIDS** MIDS internal track and trace system Secure customer interface for project tracking and download/upload function (cmids.maser.nl)

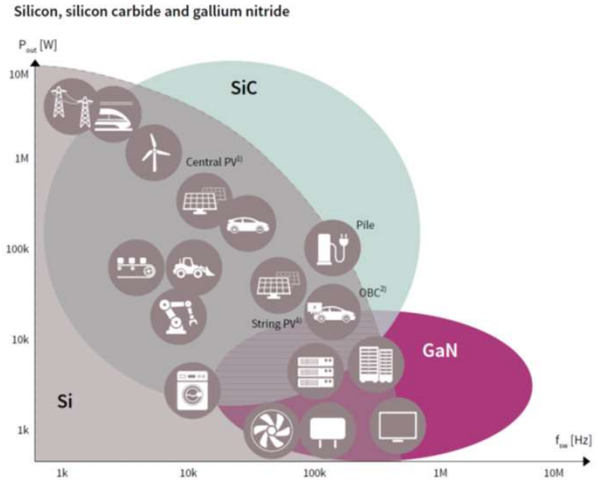
Introduction – 2

- Power Semiconductor markets
  - CAGR: +10%
- Sustainable Energy
  - PV cell and Wind generator convertors
  - DC power Storage and Transportation
- Mobility
  - E-motor drivers and battery chargers
  - ADAS and in-car entertainment
- Consumer Electronics
  - Battery Chargers
  - SMART home applications and LED



Power Electronic Semiconductors – 1

- **Silicon (Si)**
  - V-range 25V to 1700V
  - Low to High Power
- **Gallium Nitride (GaN)**
  - V-range 80V to 650V
  - Medium Power
  - Highest switching freq.
- **Silicon Carbide (SiC)**
  - V-range 650V to 3300V
  - High Power
  - Mid to High switching freq.

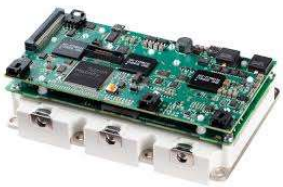


Power Electronic Semiconductors – 2

- **Non-controllable devices**
  - Power diodes
- **Controllable devices**
  - Transistors Bipolar
  - Transistors PowerMOS
  - Thyristors
  - IGBT
  - Half H-bridge modules
  - Full H-bridge modules

Power Diodes

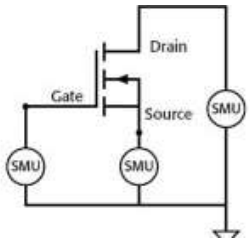
Power Thyristors



Full Bridge & controller

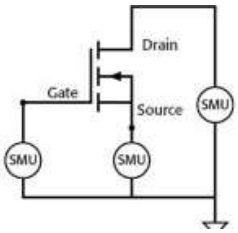
IGBT modules

Reliability Stress Tests – 1



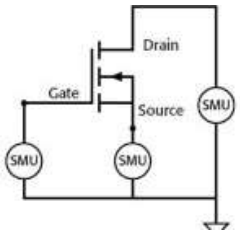
- **High Voltage, Low Current Stress Tests**
  - High Temperature Reverse Bias (HTRB)
    - Vds:Vmax – Vgs:0V/-10V – Ta:+150°C/+175°C
  - High Temperature Gate Bias (HTGB)
    - Vds:0V – Vgs:0,8 Vmax – Ta:+150°C/+175°C
  - High Humidity, High Temperature Reverse Bias (H3TRB)
    - Vds:0,8Vmax – Vgs:0V/-10V – Ta:+85°C/85%rh
- **Purpose of HVLC Stress Tests**
  - Off-state robustness at high temperature and time
  - Enclosure leakage stability

Reliability Stress Tests – 2



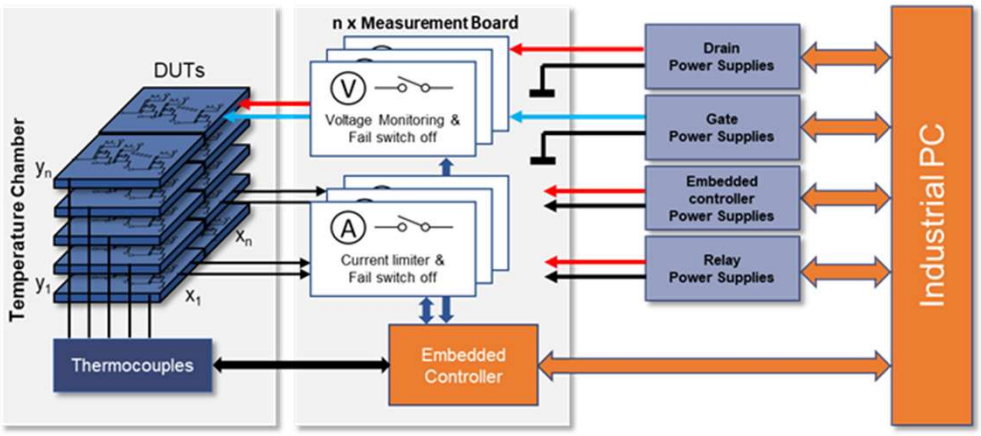
- **Low Voltage, High Current Stress Test**
  - High Temperature Operating Life (HTOL)
    - Functional mode – Ta:+100°C/+125°C
  - Intermitted Operating Life (IOL)
    - 2min.ON / 4min.OFF with Tj monitoring – Tj >+125°C – 7.500 cycles
  - Power Cycling Test (PCT)
    - ON/OFF state with Tj monitoring – delta Tj <100K – 15.000 cycles
- **Purpose of LVHC Stress Tests**
  - Off-state robustness at high temperature and time
  - Enclosure leakage stability

Reliability Stress Tests – 3



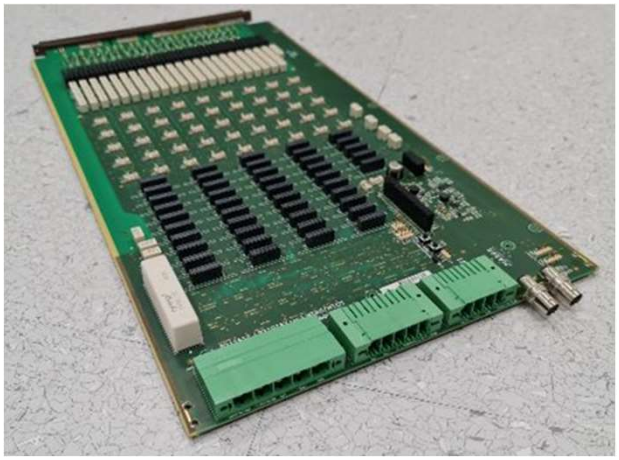
- **Other Reliability Stress Tests**
  - Preconditioning Test
  - Unbiased High Accelerated Stress Test (UHAST)
    - Ta:+130°C/85%rh
  - Temperature Cycling (TC)
    - 2 chamber non bias – Ta:-55°C to +150°C – 1.000 cycles
  - Resistance to solder heat
    - 3x 10 sec solder dip @ +260°C or 3x convection reflow @ +250°C peak
  - ESD test
    - 4kV HBM and 1kV CDM or 8kV system level

HTRB / HTGB Stress Test System – 1



HTRB / HTGB Stress Test System – 2

Specification for values/monitoring @ HTRB/HTGS test equipment			
Monitoring on stress board level	Typical values during testing	Accuracy	Remark
Voltage	0 V – 600 V	0.1%	
Temperature	150 °C, 175 °C	1%	
Monitoring on device-level @ HTRB			
Drain-Source/Collector-Emitter leakage current	0 mA – 3 mA /device	< 0.5%	Current measured in source line of device
Monitoring on device-level @ HTGS			
Gate-Source/Gate-Emitter leakage current	0 µA – 300 µA /device	< 0.5%	Current measured in source line of device
Capturing of data	< 1 per second, < 20 sec / board		
Turn off device/board	< 70 µs		
Number of devices per LOT	45		



HTRB / HTGB Stress Test System – 3

- **Voltage Monitoring & Fail switch off**
  - Monitoring of individual High Voltage bias during test.
  - Voltage blocker absorber and switch off.
  - Protects test boards, other DUT, monitoring circuit and HV power supplies.
  - Prevents defect device from explosion, burning or other severe damage
- **Current Limiter & Fail switch off**
  - Monitoring of individual OFF state current.
  - Fast response (<70µs) current limiter and switch off.
  - Protects test boards, other DUT, monitoring circuit and HV power supplies.
  - Prevents defect device from explosion, burning or other severe damage

HTRB / HTGB Stress Test System – 4

- **HV measurement issue**
  - Single HV MOSFET
  - H-bridge measurement
  - HV and HF
  - Isolated and Differential probe
- **HV protection solution**
  - Low-side current limit/sense
  - Active I/V convertor
  - HV switch off and fuse
  - 70µs response to HV overload

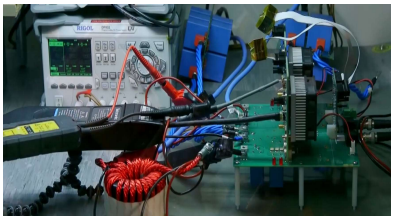
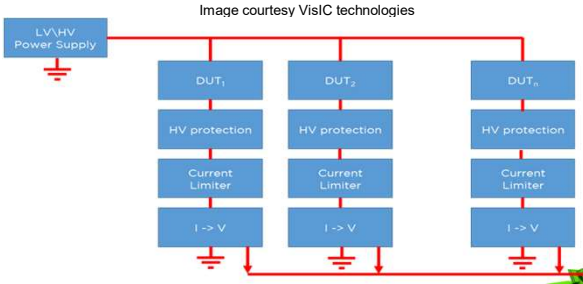


Image courtesy VisIC technologies



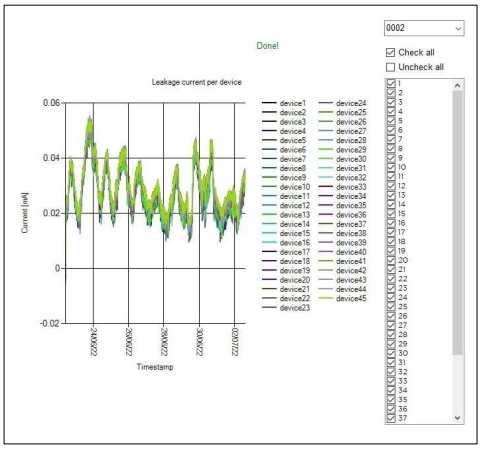
HTRB / HTGB Stress Test System – 5

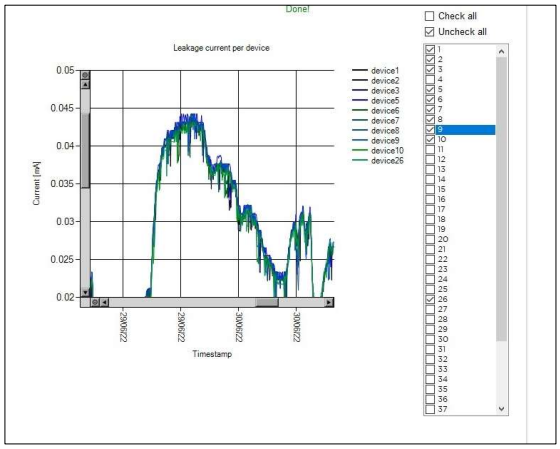
24 DUT boards in oven

DUT board

Thermal chamber, PS & monitoring cabinet

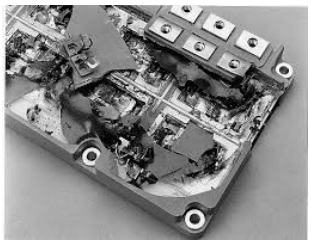
Stress Test Results





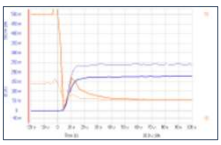
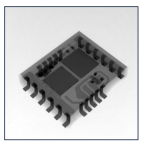
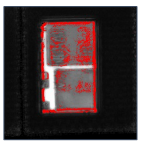
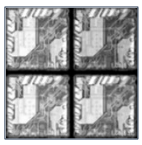
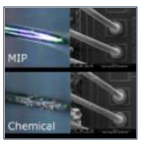
Failure Analysis Challenges – 1

- **Major issues with F/A on defect Power Electronic devices**
  - High power application, limited protection
  - Uncontrolled / unlimited current flow → overheating
  - Key is to limit power when entering defect mode
  - Wide range of application specific packages
  - Cooling is key, resulting in integrated heatsinks
  - High Voltage induced breakdowns form new paths
  - High power discharge can result in explosions and missing material
  - High temperature applications → use of plastics resistant to chemicals
  - SiC is a very hard and brittle material → mechanical cross section is hard



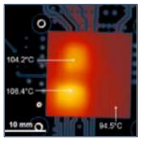
Failure Analysis Challenges – 2

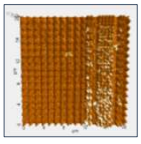
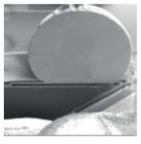
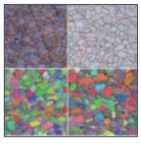
- **Major tools for F/A on defect PE devices**
  - Electrical Verification
    - B1505A power device analyzer, range 3.000V / 500A
  - Non Destructive Analysis
    - 2D/3D XRAY – Scanning Acoustic & Optical Microscopy – Lock-In Thermography
  - Sample preparation
    - Laser Ablation – MIP decap – Sawing, Grinding, Polishing – Ion Beam milling

Failure Analysis Challenges – 3

- **Major tools for F/A on defect Power Electronic devices**
  - Fault localization
    - 3D Lock-InThermography – Probing – EMMI – OBIRCH – Voltage Contrast SEM
  - Defect Imaging and Material Analysis
    - Optical – SEM – FIB/SEM – sTEM – AFM
    - SEM/EDX – SEM/EBSD – FTIR



Summary

- Power Electronic Semiconductors show a fast rise in applications
- Voltage, Power and Speed levels are increasing with GaN & SiC
- High Safety and Reliability levels required for critical applications
- New Stress Test systems fulfil the demanding requirements
- Proper monitoring and protection circuitry → improved test data, F/A on defects still possible, System hardware protected
- Special F/A techniques developed for the dedicated packages of Power Electronic Semiconductor devices and modules.

More information

Visit us at the WOTS 2022 Test & Meet paviljoen, Booth # 9B020

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