THE POWER TESTER ACCELERATED TESTING AND DIAGNOSIS OF SEMICONDUCTO

WHITEPAPER

MECHANICAL ANALYSIS

www.mentor.com

INTRODUCTIO

The energy demands of both consumer and industrial electronic systems are increasing, and electronics power component suppliers as well as OEMs are faced with the challenge of providing the highly reliable systems needed for aviation, electric vehicles, trains, power generation, and reusable energy production. The unique MicReD Power Tester 1500A from Mentor Graphics was designed and built to help address this challenge by accelerating testing and diagnosis of possible failure causes of power components. Two examples using IGBT modules illustrate how this issue can be addressed.

THE CHALLENGE OF RELIABILITY UNDER HIGH LOADS AND LONG

Power electronics components such as MOSFETs, diodes, transistors, and IGBTs are used wherever electrical energy is generated, converted, and controlled. As the energy demands in both consumer and industrial applications are on the rise, the challenge for manufacturers of power modules is to increase the maximum power level and current load capability, while maintaining high quality and reliability. For example, railway-traction applications are expected to have a reliable 30-year lifetime, and 50,000 to millions of cycles are required by power modules incorporated into hybrid and electrical vehicles as well as solar and wind turbine energy production systems.

With this increasing pressure, innovation has resulted in new technologies such as ceramic substrates that have an improved heat transfer coefficient, ribbon bonding to replace thick bond wires, and solderless die-attach technologies to enhance the cycling capability of the modules. The new substrates help to decrease temperatures, the ribbons can take more current, and the solderless die-attach can be sintered silver which has extra low thermal resistance. In a nutshell, the thermal path has been improved. However, thermal and thermal-mechanical stress on these systems can still cause failures related to power cycling and heat. These stresses can lead to problems such as bond wire degradation (Figure 1), solder fatigue, delamination of stack-ups, and die or substrate cracks.

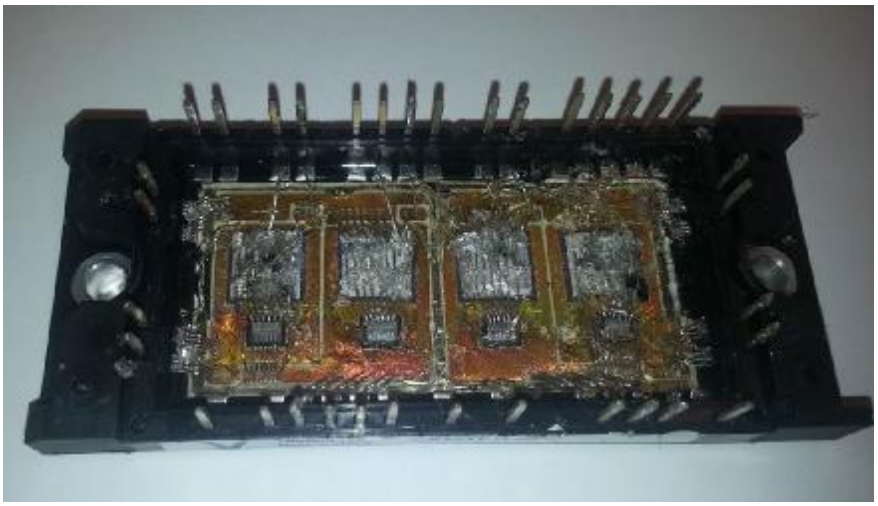

Figure 1: Damaged IGBT modules.

The process traditionally used for power-cycle failure testing is repetitive and time-consuming, it can only be done “post-mortem,” and it has to be done in the lab to analyze the internal condition of the package.

HOW THE POWER TESTER ACCELERATES TESTING AND

The Mentor Graphics MicReD Power Tester 1500A is the only machine built for manufacturing as well as laboratory environments that does automated power cycling while producing analytical data for real-time failure-in-progress diagnosis (Figure 2). It’s designed to accelerate lifetime testing and improve the reliability of applications that use power electronic modules.

Figure 2: The Power Tester 1500A is built for use in semiconductor manufacturing environments.

The Power Tester 1500A is the industrial implementation of the MicReD T3Ster thermal measurement and characterization technology for electronic parts, LEDs, and systems. The Power Tester 1500A is unique in that it provides fully automated power testing and cycling at the same time, on the same machine, without having to remove the device under test during the process. A simple touch-screen interface allows a technician to use it on the manufacturing floor and/or failure analysis engineer to use it in the lab (Figure 3).

Best for analyzing MOSFET, IGBT, and generic two-pole devices, the Power Tester 1500A senses current, voltage, and die temperature while it uses structure function analysis to record changes or failures in the package structure. The machine can be used to enhance and speed up package development, reliability testing, and batch checking of incoming parts before production.

While running power cycles, the real-time structure function analysis shows the failure in progress, the number of cycles, and the cause of the failure, eliminating the need for a lab post-mortem. Conducting lengthy cycling measurements on multiple samples to estimate the cycle count range corresponding to degradation is no longer necessary. Also there's no need for an excess number of thermal measurements in this range to ensure degradation is captured. The device under test only has to be mounted and connected once; cycling and configuration is configured once.

Figure 3: The Power Tester 1500A touch-screen interface (left to right): main screen, device creation, and placing devices on the cold plate.

> "Across all semiconductor devices, ability to pinpoint and quantify degradation in the thermal stack during will greatly assist in the of cost-optimized packaging that are currently hampered by package reliability concerns. Mentor's Power Tester 1500A should be an invaluable tool investigating thermal path degradation in all types of power
>
> MARK JOHNSON, PROFESSOR OF ADVANCED POWER CONVERSION, UNIVERSITY OF

With the Power Tester 1500A, power electronics suppliers will be able to design a more reliable power electronics

customers. Component designers and manufacturers can validate the suppliers' reliability specifications and characterize the package reliability. Those who are designing and manufacturing products with high requirements for reliability over the long-term will be able to test at the system level.

JEDEC Standard JESD 51-1 static test method. Based on the captured transient response, the system can automatically generate structure functions. Structure functions provide an equivalent model of the heat conduction path expressed by thermal resistances and thermal capacitances, and they can be used to detect structural failures or to capture partial thermal resistances in the heat conduction path. The Power Tester 1500A also supports the JEDEC Standard JESD 51-14 transient dual interface measurements to determine RthJC. The process of combined power cycling and Rthmeasurement mode creates stress on the device using power cycles, does regular measurement of Rthduring the cycling, monitors system parameters such as voltage and current, and automatically increases Rthmeasurement frequency.

The testing and characterization data produced by the Power Tester 1500A can be used to calibrate and validate detailed models in FloTHERM and FloEFD thermal simulation software.

EXAMPLES OF TESTING IGBT MODULES THROUGH A LIFETIME OF

Designers of electronics power modules and their related assemblies and systems have to ensure the thermal resistance between the chip and the base plate stays as low as possible, create reliable bonding, and ensure the die-attach layer can withstand significant thermal load during the lifecycle of the product (Figure 4). The relationship between the number of possible load cycles and the temperature/load conditions of the device has to be known to be able to make a good estimate for the power module's lifetime.

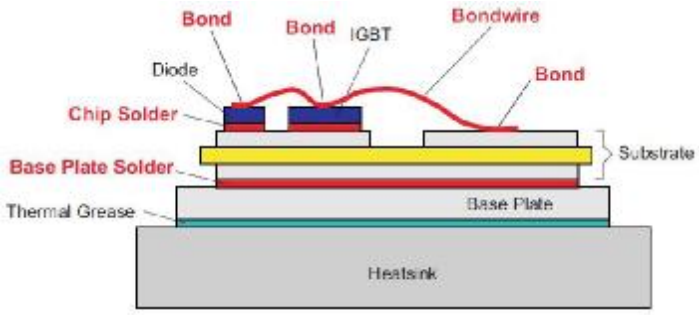

Figure 4: Cross-section of an IGBT module.

With the introduction of electric and hybrid electric vehicles, IGBT devices have gained a leading position in traction and high-voltage converter applications. Dissipated heat in the junction has a major effect on the reliability of these components. High junction temperatures and high temperature gradients during