How To...

Guide to Understanding Power Cycling

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Since the release of MicReD® Power Tester 1500A there is a need for greater knowledge and awareness of Power Cycling.

For Starters

Power Cycling is used to exert thermo-mechanical stress on different materials. Thanks to thermodynamics, we know that a material can expand and contract at different temperatures according to this equation:

$$\alpha_V = \left(\frac{1}{V}\right)\left(\frac{dV}{dT}\right)$$

What this shows is that materials can change size when a temperature change occurs. What does this mean for testing? Well, as we have more than one material in our components and packages, we have what is called a thermal coefficient mismatch. This means that different materials expand or contract at different rates. This creates strain, and when strained enough, the interface or the materials themselves break.

In addition to this some materials age quicker, corrode or stop functioning. In terms of semiconductors the possibilities are endless. Of course all of these effects need to be induced and tested with several methods, before a component is verified and shipped. However, the environment and operational condition of the component may determine which failure occurs first.

Other Issues

Environmental and operational conditions not only bring forth new technology, requirements and conclusions. Ultimately, what everyone is concerned about, is the longevity of their device. Will it last two million cycles? What will the cause be for earlier failure? Is there a difference between

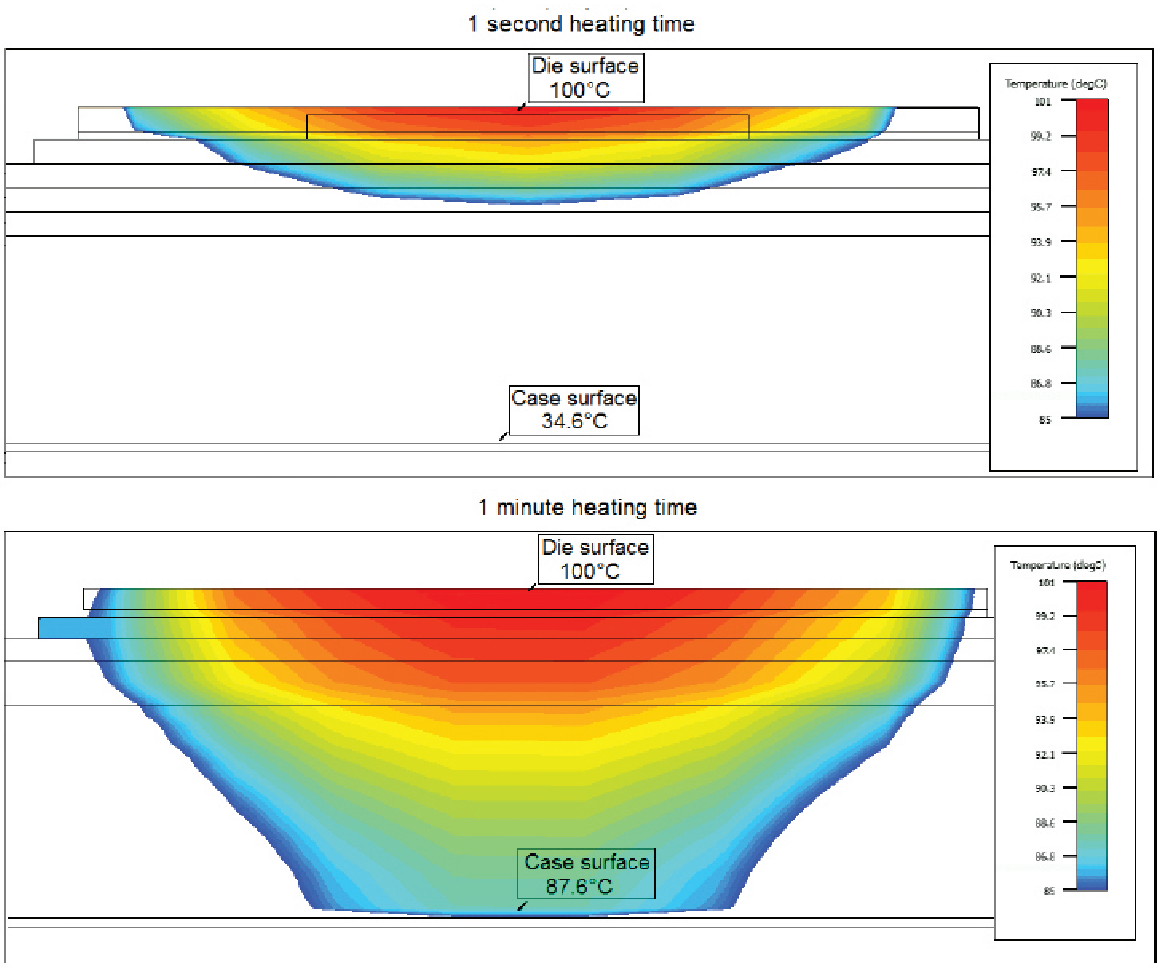

Figure 1. Heat-spreading behavior after 1 seconds (top) and 60 seconds (bottom)

complete failure and accepted failure? For clarification of what these questions entail let us use an electric car as an example. Not only does the automotive industry have some of the toughest reliability standards in the consumer space, but the industry also tends to buy, not fabricate, components. This means that much of the information is provided and then compared.

Going one step further, we want to create our own electric car, and need to purchase IGBTs for our electric motor. Now, aside from all the electric criteria, we would prefer it if the IGBT does not get very hot, performs all functions and has a long life time. Given that we are not in Utopia, we will need to get data from different manufacturers and compare their statements.

one second, might affect it differently than if it's cycled for one minute.

Additionally, different cycling methodologies can be driven to quantify different failure modes. By keeping the change in junction temperature constant over the cycle period, therefore reducing the power as the die attach ages, the system experiences less stress over the entire life span. The other option is to keep the input current constant and not compensating for the degradation.

The effects are relatively straight forward and not all are shown here. In a quick test we can already demonstrate how constant current (blue) differs to constant power (red) and constant temperature change (green). Though the results vary, there is a clear trend and a possibility to "optimize" results.

The reason this is important has several explanations:

1. If you are receiving the IGBTs, make sure you understand the test procedure
2. ΔT seems like a useful solution, although cars driven slower to manage the power levels might not suit everyone.
3. Be sure that the testing method applies to your application – wind turbines might need to withstand a hurricane, while a car has to deal with a novice driver that doesn't know the difference between 'R' and '1st', or believes that a side walk is shared space.

Cycle Time	Short periods - mostly affecting the die attach and wire bonds	Long Periods - Potentially aging other layers of the device
Heating Parameter	Constant Current - Brute Force Method	Constant Tj - Adjusting Power level to compensate for increased thermal resistance
Test Setup	In-situ - Considering your own heat sink and materials	Component - Thermal path from device can be optimized to keep it cooler

Figure 2. Summary of testing parameters to age high power electronics

Thermal Resistance

Thermal resistance is a measurable unit in Kelvin per Watt (K/W) – if a device has 2K/W, the temperature will increase by two degrees for every Watt power. Unfortunately the thermal resistance may increase as the device ages. If the device gets too hot, it ages, as it ages it will deteriorate and in so doing it will then become hotter. This then reduces the longevity of the components.

Cycling Conditions

Another important factor is the conditions at which the device is cycled and stands in direct correlation with the thermal resistance. Turning the device on and off for

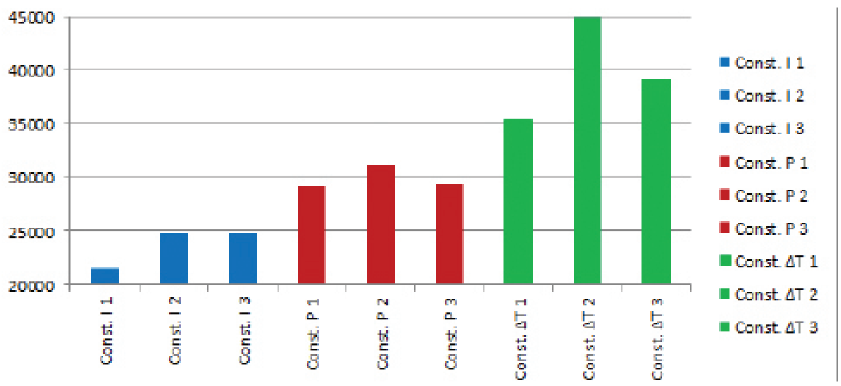

Figure 3. Chart showing the aging of IGBTs after the use of different control strategies. Constant Current (Blue), Constant Power (Red) and Constant change in Junction Temperature (Green)