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Application Note

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Through-the-Substrate Imaging Enables Flip Chip Thermal Analysis

The Future of Thermal Imaging is Here!!!

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Introduction

Flip chip mounting is a method for interconnecting a semiconductor device or integrated circuit to its surrounding circuitry by means of solder bumps that are added to the topside of the device when the wafer is processed. The device is connected to the external circuitry by flipping it upside down and aligning the solder bumps on the device with the appropriate connecting pads on the substrate or circuit board. This interconnection technique is an alternative to mounting the device right side up and using wire-bonding techniques to connect the device pads to the external circuitry. The flip chip mounting approach virtually eliminates the parasitic inductance common with wire-bonding and it requires less space on the substrate on which it is mounted.

Eliminating the parasitic inductance is a key benefit for high frequency performance and the size reduction is important for portable devices. With continued emphasis on increased operating speed and size reduction in today's electronic systems, the flip chip mounting approach is being more widely used.

Since the active area of the device or IC is hidden from view, flip chip assemblies add another challenge for those wishing to analyze the thermal properties of the mounted device. Thru-the-substrate imaging with thermoreflectance can address this challenge.

Thru-the-Substrate Thermal Imaging

A common substrate material to provide the external circuitry to which the flip chip is connected is silicon. Silicon, it turns out, is transparent for an illumination wavelength of about 1100 nm and longer. These wavelengths are in the near infrared (NIR) range and are convenient for thermal imaging of the active layer of a flip chip mounted device by viewing the device through the silicon substrate.

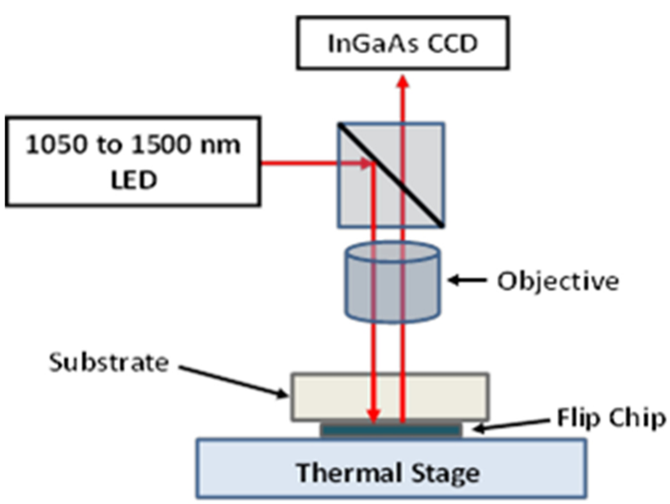

Figure 1: Thru-the-substrate thermal imaging

Implementing the thermoreflectance technique in the NIR range is straightforward. It employs much of the same equipment and uses the same image data processing techniques. The differences are in the optics, which are optimized for NIR transmission; the imaging sensor, which is InGaAs rather than Si; and the LED wavelength. Illumination wavelengths typically used with the Microsanj Nanotherm-Series analyzers having thru-the-substrate imaging capability are: 1050 nm, 1200 nm, 1300 nm, or 1500 nm.

Applications for thru-the-substrate imaging:

The ability to thermally characterize flip chip assemblies is just one of many applications for thru-the-substrate thermal imaging. Many semiconductor devices have layers that may obstruct thermal analysis of a specific junction or region of interest on a specific device.

Figure 2, for example, shows the structure for an array of silicon lateral double-diffused metal oxide (LDMOS) transistors designed for high power operation. [1] As can be seen in the figure, the top side of the device has multiple metallic contact layers and a passivation layer. The uneven surface with different materials having different thermoreflectance coefficients complicates imaging with visible light on the top side if the goal is to analyze the thermal characteristics of the transistor itself. The back side of the silicon however, is smooth and uniform and with NIR illumination provides a better solution for analyzing junction thermal behavior.

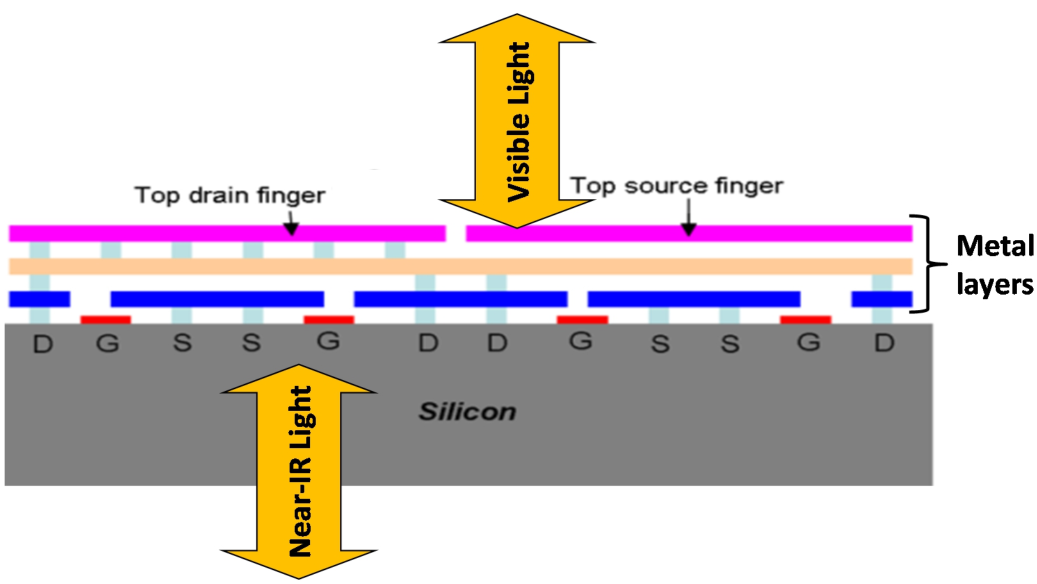

Figure 2: Cross-sectional view of LDMOS power transistor array

The topside and backside thermal images obtained with thermoreflactance are shown in Figure 3. The top side image shows the temperature distribution for the metal layer of the device while the backside image shows the thermal image for the transistor array observed with NIR illumination through the silicon susbstrate.

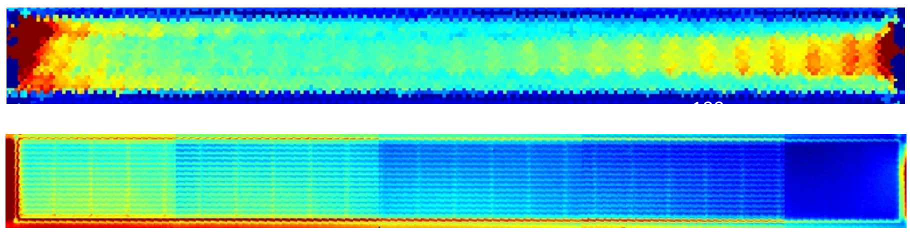

Figure 3: Topside metal surface thermal image for 3.175 mm array and transistor thermal image obtained with NIR thru-the-substrate

Each short line on the backside image corresponds to a specific transistor in the array, clearly showing the temperature distribution between drain and source contacts.

Conclusion

Thru-the-Substrate imaging adds another dimension to thermal imaging and thermal characterization based on the thermoreflectance principal. Obviously the use of illumination wavelengths in the NIR range, in contrast with wavelengths in the visible range, will compromise the spatial resolution somewhat [2], but what is gained, is valuable thermal information that would, otherwise, go undetected. With the growing use of flip chip assemblies and the development of multi-layer structures, similar to the one described above, thru-the-substrate thermal imaging will be an essential capability to analyze and fully understand the thermal behavior these devices.

Thru-the-substrate thermal imaging is a standard feature for the Microsanj NT300 series and the NT410A.

References

[1] Yazawa, K., Kendig. D., Hernandez, D., Maize, K., Alavi, S., and Shakouri, A., “High Speed Transient Thermoreflectance Imaging of Microelectronic Devices and Circuits”, *EDFA Magazine*, Vol. 15, 2013, pp. 12-22. http://edfas.asminternational.org/portal/site/edfas/AsmStore/ProductDetails/?vgnextoid=25b39e7c72d6c310VgnVCM100000621e010aRCRD

[2] AN-003: Understanding the Thermoreflectance Coefficient
http://www.microsanj.com/application-notes/understanding-thermoreflectan...

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