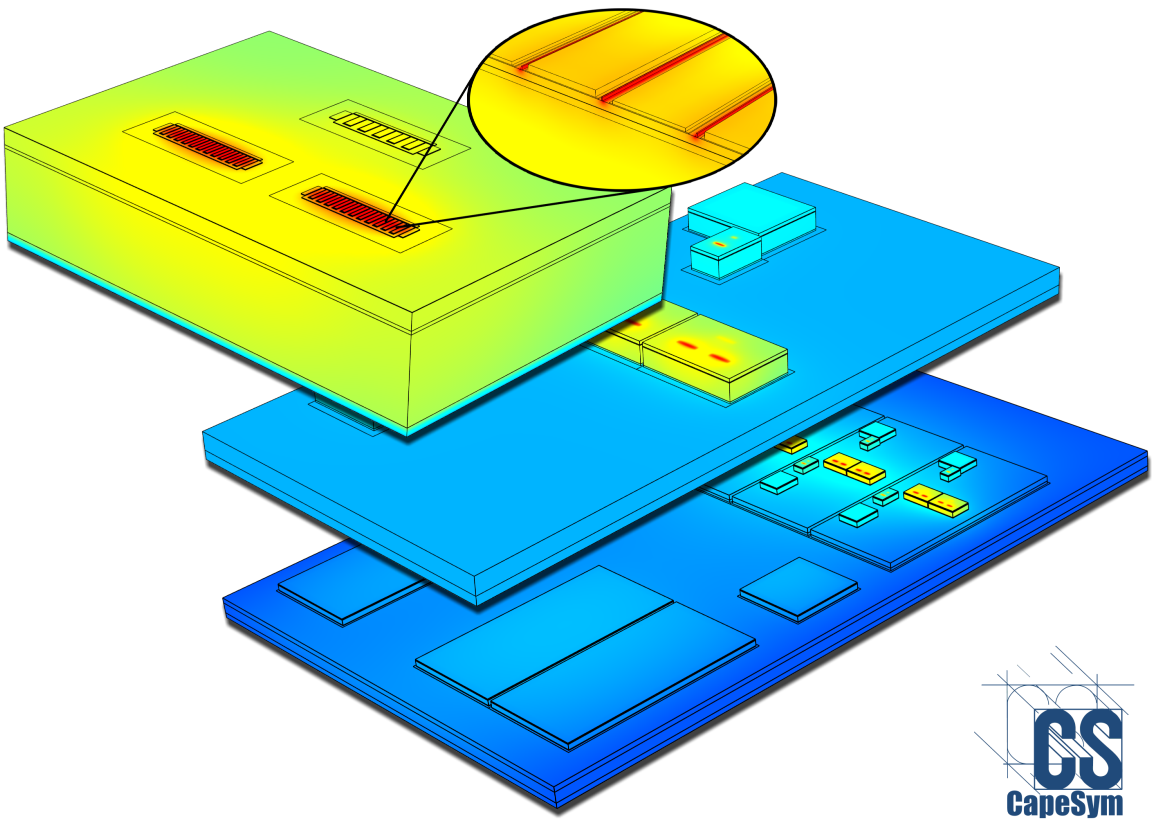
SYMMIC™ Application Note:

Simulations Versus IR Measurements



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Simulations Versus IR Measurements

Infrared (IR) measurements are frequently used to assess the thermal performance of microwave transistors, but this technology substantially underestimates the peak temperatures of most devices [1]. Most IR thermography has a spatial resolution on the order of 5 µm. The dimensions of active channels in these devices are often less than 5 µm in length. The effective averaging of temperatures over the channel by IR thermography therefore fails to capture the peak temperatures. When the distribution of current in the channel is reasonably well-known, high-resolution simulations such as those computed by SYMMIC can provide a better estimate of peak junction temperatures.

As one example, consider the IR thermography used by Winslow to measure temperatures in a high voltage, field plate-based MESFET [2]. In this study, an IR thermal scan across the 10 channels of 0.4mm FET cell revealed a inverted-U shaped temperature profile with the hottest temperatures in the center channels. Sharp peaks were not evident within the channels from this data. The hottest measured temperatures reached about 140°C, but Winslow estimated that the actual peaks were at least 15°C hotter. The pixel size of the IR scanner was about 7 µm, meaning that the each measured temperature was an average over a 7 µm square area on the device.

SYMMIC's template-based approach to thermal analysis allowed the **Generic FET Template** to be rapidly reconfigured to match the MESFET layout in Winslow's study (Figure 1). Thermal analysis of this configuration revealed the hottest temperatures in the middle of the center channels, as expected. The peak channel temperature in the device was calculated to be 159.6°C, much hotter than obtained from IR measurements.

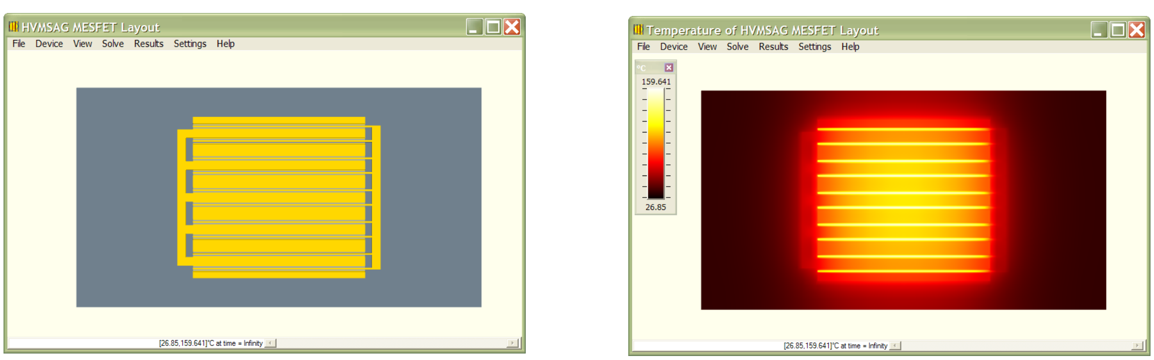

Figure 1: A MESFET model and its solution in SYMMIC.

The temperatures along the channels exhibited a smooth inverted-U shape (Figure 2). The temperatures across the channels however had a multi-peaked distribution with very narrow, high peaks in temperature at the locations of maximum current density. This distribution differs significantly from the IR measurements.

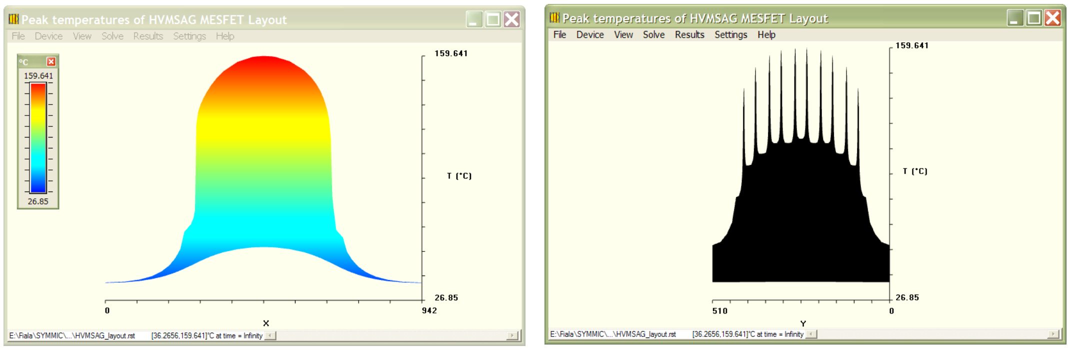

Figure 2: The left image shows the temperaure distribution parallel to the gates. The right image shows the temperature distribution perpendicular to the gates.

To assess the accuracy of the simulation relative to IR measurements, the temperature probe feature in SYMMIC was used to measure average temperatures along a line perpendicular to the gates through the center of the device. The temperature probe was configured to be a 7 µm square region. The probe temperature is an average over the probe region at the surface of the device, mimicing the average value of a pixel in an IR imager. A series of 72 temperature probes were recorded from adjacent, non-overlapping fields through the center of the device (Figure 3). The recorded values had a maximum of 142°C, about 18°C less than the maximum of 159.6°C attained by the sharp peaks, which corroborates Winslow's estimate of actual peak temperatures being much higher than measured by IR thermography.

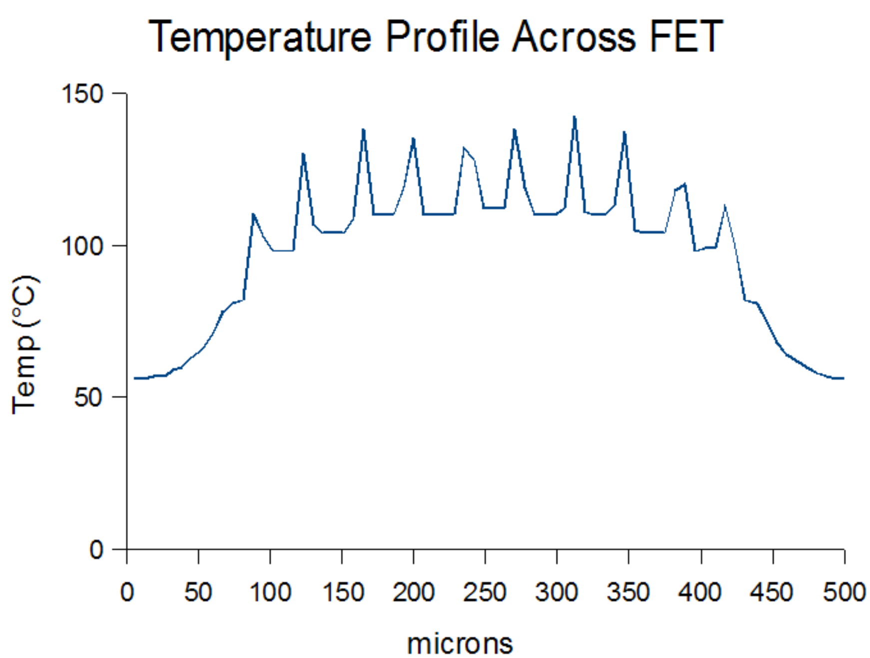

Figure 3: Simulated IR measurements made using a 7 µm square temperature probe in SYMMIC.

The templates provided with SYMMIC are designed to model regions with the large temperature gradients using a high-resolution mesh. In the example just described, SYMMIC calculates temperatures at over 390 locations across the mid-line of the device, with the highest density near the gates. Adjacent pixels in an IR imager, on the other hand, would distinguish temperatures at only about 72 locations. Thus, SYMMIC produces a high-fidelity estimate of peak junction temperatures, much higher than can be obtained through IR thermography.

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References

[1] T. E. Beechem III, Metrology of GaN Electronics Using Micro-Raman Spectroscopy, Doctoral Thesis, Georgia Institute of Technology, 2008, p. 101.

[2] T. A. Winslow, "Robustness of GaAs Field Plate Based MESFETs," 2007 IEEE/MTT-S International Microwave Conference, Honolulu, HI. June, 2007. pp. 315-318.