AN221012

Thermal characteristics of GaN power transistors

AMPLEON

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Document information

Info	Content
Keywords	Thermal Resistance, Characterization, Simulation, GaN, lifetime
Abstract	This application note describes the methodology for thermal evaluation of high-power GaN RF power amplifier devices. The proper understanding and interpretation of data sheet specifications are essential to predict the operation temperature and evaluate the transistor lifetime.

Revision history

Rev	Date	Description
AN221012#1	20220310	Initial version.

Contact information

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1. Introduction

Performance and reliability of Gallium Nitride (GaN) power amplifier (PA) devices highly depend on the operating temperature. This Application note is to review the basis of thermal resistance figures and to specifically define the measurement and modeling use to derive thermal resistance and explain the basis for the figure. Furthermore, it will highlight thermal resistance connections to data sheet maximum channel temperature and reliability predictions.

2. Methodology for thermal evaluation

Ampleon's methodology for GaN thermal characteristics represented in datasheets follows the process illustrated in Figure 1. The surface temperature (Ts) of the active die is measured using an Infrared (IR) camera and the case temperature (Tc) with a thermocouple, to extract the thermal resistance of surface to case (Rth(s-c)). The calibrated finite element analysis (FEA)-based thermal model is used to predict the channel temperature (Tch) for thermal resistance of channel to case (Rth(ch-c)). In addition, the lifetime tool can predict the Median-Time-To-Failure (MTF is the time that 50 % of the population has failed) vs power and channel temperature in a device. For specific calculation, we refer to the Lifetime Calculator on the Ampleon's website. Pulse thermal impedance and temperature dependency of thermal resistance can be presented in the datasheet for specific devices.

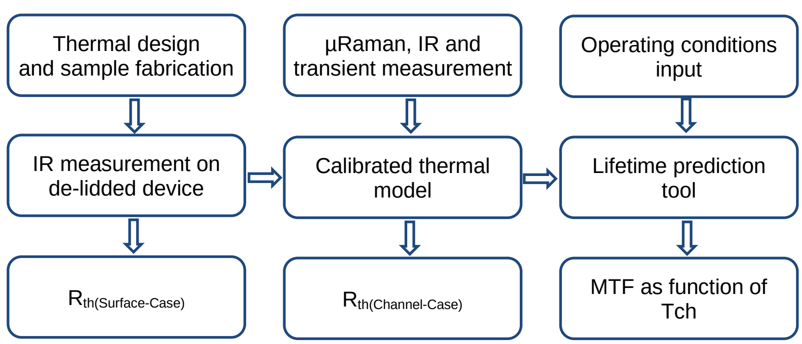


Figure 1. GaN thermal characterization process

3. IR measurement for $R_{th(s\text{-}c)}$

The commonly used technique to measure the temperature of a power amplifier device under operation is using IR thermography. However, we should consider the limitations of averaging the temperature over optical spot size on surface and sample preparation. Ampleon's datasheets present Rth(s-c) based on IR measurements to enable application of customers' system-level IR measurement data, and comparison with the other thermal data.

The schematic of the IR measurement setup is illustrated in Figure 2. For visibility of die, packaging layer of ceramic lead is removed or overmold compound is etched away. The exposed die is coated with a high emissivity coating to obtain an accurate fixed emissivity value. The surface temperature (T_S) of sample is measured by the high-resolution IR camera from top view and the case temperature (T_C) of the package is measured by a spring-loaded thermocouple. The thermal resistance between surface to case is calculated as:

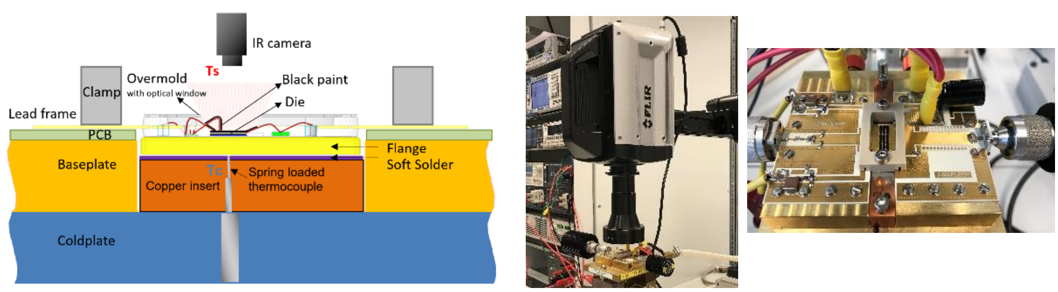
$$R_{th(s-c)} = (T_s - T_c)/P_D \qquad (1)$$

where the dissipated power (P_D) is calculated as:

$$P_D = P_{in} + P_{DC} - P_{out} \qquad (2)$$

where P_{in} and P_{out} are the RF input and output power and P_{DC} is the DC input power.

Due to the nonlinearity of material properties, the thermal resistance slightly depends on heat dissipation and case temperature. Please refer to the specific product data sheet for the conditions under which the devices are measured.



(a) (b) (c)

Figure 2. (a) Schematic, (b) image of setup and (c) board of the IR measurement

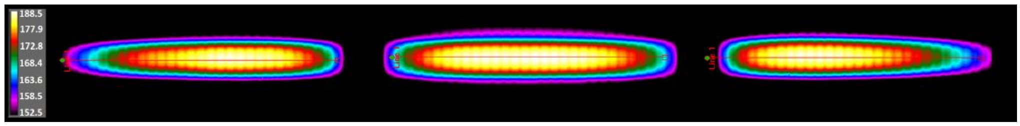
4. Thermal model for $R_{th(ch-c)}$

Accurate determination of the channel temperature relies on finite element thermal modeling calibrated with measurement. Ampleon's datasheets present $R_{th(ch-c)}$ based on thermal modeling to enable lifetime prediction and ensure to keep the device within thermal safe operation area.

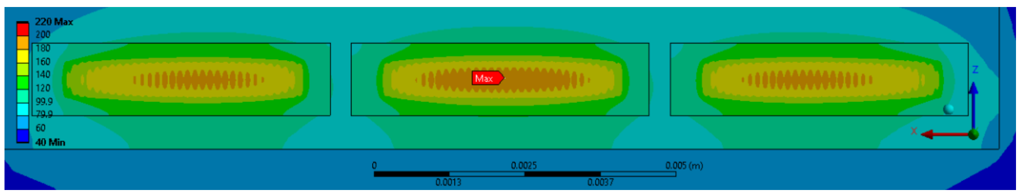
For each process technology, the thermal model is calibrated on material properties and geometry with accurate IR and µRaman measurements on various steady heat dissipations, beside to transient electrical-based measurement. The calibrated model is benchmarked to make sure about the versatility and range of applicability. Figure 3 shows the measured IR image and modelled temperature of device surface with 3 dies.

The model geometry is used to reproduce the IR measurement by averaging the simulated temperatures inside the IR focus spot. The highest channel temperature (T_{ch}) of the device which is the maximum temperature of the model is used to calculate the thermal resistance between channel to case as following:

$$R_{th(ch-c)} = (T_{ch} - T_c)/P_D \quad (3)$$



(a)



(b)

Figure 3. (a) IR-measured and (b) FEM-modelled of device temperature

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