Characterization of Channel Temperature in Ga_2O_3 MOSFETs

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Knowledge of the channel temperature (T_{ch}) in high power Ga_2O_3 metal-oxide-semiconductor field effect transistors (MOSFETs) is essential for device reliability studies. In this work, the T_{ch} and thermal resistance (R_{th}) of field-plated β-Ga_2O_3 (010) MOSFETs [1] were systematically determined through electrical measurements complemented by 2-D device simulations that incorporated experimental Ga_2O_3 thermal parameters. The technique was based on a comparison between DC and pulsed drain currents (I_{DS}) at known applied drain biases (V_{DS}), where negligible self-heating under pulsed conditions enabled approximation of T_{ch} to the ambient temperature (T_{amb}) and consequently calibration of I_{DS} as a function of T_{ch} ($\approx T_{amb}$) over a range of V_{DS}. Reduction in I_{DS} from the calibrated values arises from DC operating conditions that induce significant self-heating. The reduced I_{DS} at a given V_{DS} uniquely determines a $T_{ch} = T_{amb} + \Delta T$ (where ΔT is the temperature rise due to self-heating) from the I_{DS}-T_{ch} calibration data obtained from pulsed measurements.

The measured and simulated temperature-dependent DC characteristics of the Ga_2O_3 MOSFET are shown in Fig. 1. A room temperature electron mobility of 75 cm^2/Vs and a thermal resistance of 1°C·mm^2/W at the channel/buffer interface were obtained by calibrating the device model against the DC data. Temperature-dependent pulsed characteristics – measured at quiescent drain/gate biases of 0 V with a pulse width of 5 μs and a duty cycle of 0.005% – were then simulated by disabling self-heating in the calibrated DC model (Fig. 2). A good match between measured and simulated values at low powers confirmed insignificant power dissipation, whereas compression of measured I_{DS} toward higher powers was attributed to self-heating. The low power pulsed data unaffected by self-heating were translated into an I_{DS}-T_{ch} calibration plot, from which T_{ch} as a function of DC dissipated power ($P_D = I_{DS} \times V_{DS}$) was extracted as described above. Reasonable agreement between the measured T_{ch} (averaged along the channel) and the simulated peak T_{ch} (under the gate) was obtained (Fig. 3). A large experimental R_{th} of 48°C·mm/W extracted at T_{amb} = 20°C highlights the importance of thermal analysis for understanding the degradation mechanisms of Ga_2O_3 devices.

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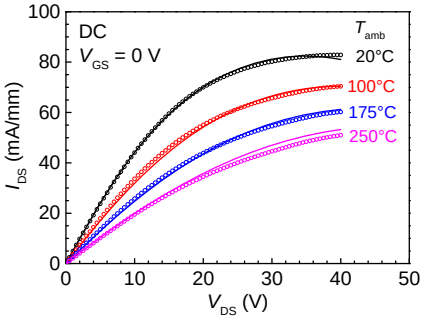

Fig. 1. Measured (symbol) and simulated (line) temperature-dependent DC I_{DS}-V_{DS} characteristics. Good agreement lent support to a well-calibrated DC device model.

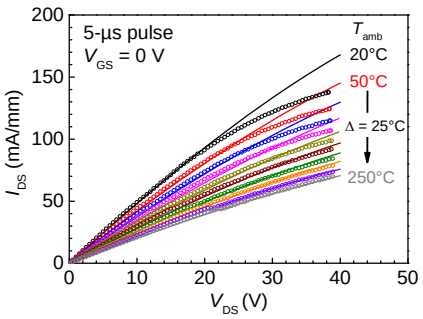

Fig. 2. Measured (symbol) and simulated (line) temperature-dependent pulsed I_{DS}-V_{DS} characteristics. Good agreement at low powers indicated negligible self-heating.

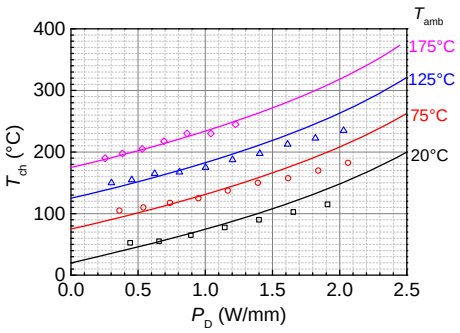

Fig. 3. Measured average T_{ch} (symbol) and simulated peak T_{ch} (line) vs. P_D. The slope corresponds to R_{th}.