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To cite this version:

Rémy Ouaida, Cyril Buttay, Anh Dung Hoang, Raphaël Riva, Dominique Bergogne, et al.. Thermal Runaway Robustness of SiC VJFETs. CSCRM, Sep 2012, Saint-Pétersbourg, Russia. 2p. hal-00759975v2

HAL Id: hal-00759975

https://hal.science/hal-00759975v2

Submitted on 12 Mar 2013

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Thermal Runaway Robustness of SiC VJFETs

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One of the key advantage of SiC power devices over their Si counterparts is their ability to operate at higher temperature (in theory up to 1000 K for a 1000 V-rated SiC device as compared to less that 500 K for a comparable Si device [1]). Practical tests have already demonstrated operation at elevated temperature. For example, in [2], SiC JFET and diode operate at 450°C (723 K) ambient temperature, although with considerable de-rating in saturation current and blocking voltage.

The high-junction-temperature uses of power devices can be divided in two sets of applications: operation in harsh environment (aerospace, oil exploration...), and operation with reduced cooling (small heatsink, confined system...). An example of this latter application is given in [3], with a converter designed to operate at an ambient temperature of 150°C with a junction temperature of its power devices as high as 250°C. This large drop between the junction and ambient temperatures allows for the use of a less sophisticated cooling system.

However, it has been demonstrated in [4] that the high temperature advantage of SiC might be limited because of thermal run-away issues. In a recent article [5], we studied this phenomenon on SiC diodes, and showed that purely unipolar diodes are prone to thermal runaway, whereas Merged PiN-Schottky (MPS) diodes are not.

A schematic explaining the thermal run-away mechanism is visible in figure 1: if we consider a simple cooling system (the plain line), it divides the Power/Temperature domain in two regions: in region A, above the plain line, the power dissipated is higher than what the cooling system can extract. Any system in region A will then tend to heat-up. On the oposite, a system in region B would tend to cool down, as the power it dissipates is lower that what the cooling system can extract. If we assume the imaginary device plotted in figure 1 (dashed line), we can see that there are two equilibrium points, where the power dissipated by the device is equal to what the cooling system can extract. However, the topmost equilibrium point is unstable: in particular, a small increase in the device junction temperature puts it in region A, where its temperature will increase indefinitely (that is, until the destruction of the device). *(more explanations will be given in the full paper)*

In this paper, we performed I(V) measurements on a SiC JFET (SiCED 1200 V, 2.4x2.4 mm die) over a wide temperature range (from -70 to +200°C). A model [6] was then fitted to these measurements and used to draw the graph in figure 2. (*the details on the measurement method, and on the model will be added to the paper)*

As a results, it appears that the thermal phenomenon can be observed (for example, the "8 A" device characteristic and the "2 K/W" cooling system in figure 2 look very similar to the example in figure 1). Furthermore, the upward bend exhibited by the device characteristic in figure 2 is more pronounced than expected in theory. In [4], the increase in dissipated power with temperature is associated with the

increase in electrical resistivity of the drift layer. For the JFET studied here, the increase in dissipated power (i.e in voltage drop) is not only caused by this increase in resistivity, but also by the decrease in the saturation current with temperature.

As a conclusion, it appears that in spite of its satisfying performance at elevated temperature, the cooling system of a JFET must be carefully designed in order to avoid thermal run-away.

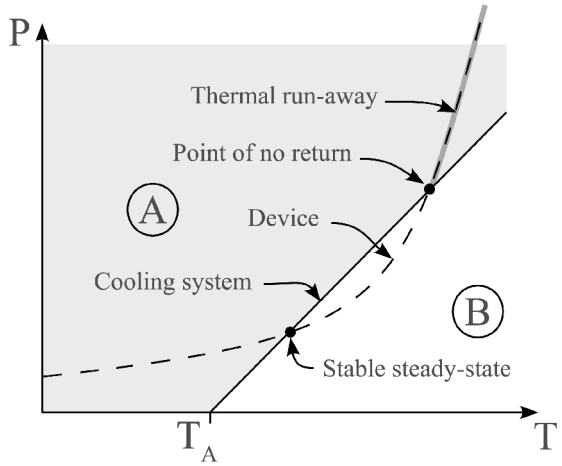

Figure 1: power dissipated by a device as a function of its temperature (dashed line), and cooling performance of its associated cooling system (plain)

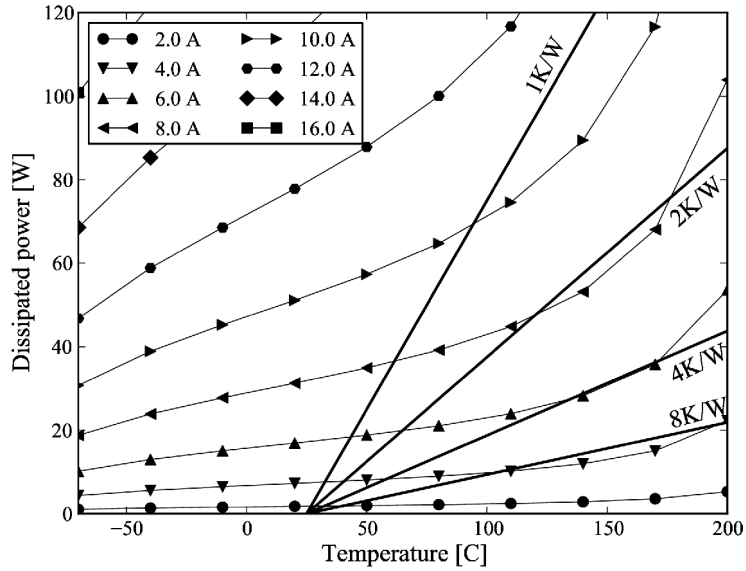

Figure 2: Power dissipated by a 2.4x2.4 mm die SiC JFET (SiCED), with a V_{GS}=0 V, for drain currents ranging from 2 to 16 A (thin lines). The thick lines are different thermal resistances (different cooling systems). Note that 1 K/W corresponds to a very efficient cooling system.

References

[1] Raynaud, C. et al. "Comparison of high voltage and high temperature performances of wide bandgap semiconductors for vertical power devices" Diamond and Related Materials, 2010, 19, p. 1 - 6

[2] Funaki, T. et al. "Power Conversion With SiC Devices at Extremely High Ambient Temperatures" IEEE Transactions on Power Electronics, 2007, 22, p 1321-1329

[3] Hornberger, J. M. et al. "A High-Temperature Multichip Power Module (MCPM) Inverter utilizing Silicon Carbide (SiC) and Silicon on Insulator (SOI) Electronics" Proceedings of the 37th PESC Conference, IEEE, 2006, p 9-15

[4] Sheng, K. "Maximum Junction Temperatures of SiC Power Devices" IEEE Tr. Elec; Dev., 2009, 56, p 337-342

[5] Buttay, C. et al. "Thermal Stability of Silicon Carbide Power Diodes" IEEE tr. Elec. Dev., 2012, 59, p. 761-769

[6] Ben Salah, T. et al. "Toward SiC-JFETs modelling with temperature dependence" Eur. Phys. J. App. Phys., 2010, 52, 8p