PULSED POWER OPERATION OF COMMERCIALLY AVAILABLE SILICON CARBIDE MESFETS

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ABSTRACT

Sample devices of commercially available SiC MESFETs were measured under pulsed conditions. The results show significant improvements over traditional III-V devices measured under the same conditions. The measurements indicate that SiC devices may have several advantages for use in pulsed applications such as Phased Array Radar.

INTRODUCTION

Silicon Carbide MESFETs have long been heralded as the future for high power base station applications. The advantages for CW applications of wide bandgap materials (such as SiC, GaN etc.) have long been known (Trew et al (1)). The higher power densities of wide bandgap materials result in significantly smaller devices, and the high thermal conductivity of SiC leads to efficient heat removal, and hence less stringent cooling requirements.

For pulsed operation SiC could offer other significant advantages over traditional III-V materials. Pulse droop (variation in output power, gain, and phase) is a major concern in pulsed power applications, particularly in the long pulses used in PAR applications.

The GaAs IC Group at Roke Manor Research Limited (RMRL) has been involved in the design of high power pulsed amplifiers for several years. These have been fabricated using traditional III-V materials (GaAs MESFET, AlGaAs/GaAs PHEMT etc.). This paper details measurements made at RMRL on commercially available SiC MESFETs and compares these with measurements made on similar GaAs devices.

COMMERCIALLY AVAILABLE SILICON CARBIDE MESFETS

At the time of writing, the only commercial source of SiC MESFETs known to the author is Cree Research Inc. Cree supply the CRF-20010-101 SiC MESFET in sample quantities. The CRF-20010-101 device is a 10W single-stage amplifier, mounted in a standard power amplifier package. The CRF-20010-101 device is supplied with an evaluation board to enable one to make CW measurements on the device. The evaluation kit is relatively simple to use for CW measurements, as it only requires a 2GHz RF input signal and a single +48V bias supply (gate supply is provided by an on-board V_{neg} generator circuit). The gate voltage is controlled by means of a SMT potentiometer.

For pulsed measurements, the evaluation board must be modified to allow independent biasing of the gate and drain of the device. This is easily achieved by removing the series inductors furthest from the device from the on-board bias circuits and attaching the gate and drain directly to PSUs. It is important to retain as much of the original bias circuit as possible to reduce the risk of oscillations.

PULSED MEASUREMENTS

Having made CW measurements to verify the performance of the devices and modified the evaluation board, several types pulsed measurements were made on the devices. Two of these are discussed below. The first measurement was intended to establish the effect on the amplitude of the device of increasing the baseplate temperature (and hence the junction temperature) of the device. The second measurement was to establish the effect on amplitude and phase of the device of increasing the pulse length with a constant duty cycle. Amplitude measurements were made using a test bench based around a HP8990A Peak Power Analyzer and phase measurements were made using a Pulsed HP8510C Vector Network Analyzer.

AMPLITUDE MEASUREMENTS AT VARIOUS BASEPLATE TEMPERATURES

To measure the effect of raising the baseplate (and hence junction) temperature of the device, the evaluation board was placed on a hotplate and the output power measured for temperatures between room temperature and 100°C. In order that the self-heating of the device should not contribute significantly to the temperature of the device, the device was measured with short (100µs) pulses and with a low (10%) duty cycle. The temperature of the hotplate can be adjusted and controlled over the required range, however the temperature of the package baseplate was monitored using a thermistor placed between the top surface of the package and the evaluation board retaining bolt.

The average power was measured against temperature. The results (figure 1) show that for a baseplate temperature rise of 80°C, the output power of the device is only reduced by 0.7dBm. This compares favourably with a GaAs device, which we would expect to have its output power reduced by 1.2dB for the same temperature change.

MEASUREMENTS OF DEVICES WITH VARYING PULSE LENGTHS

The amplitude (gain and output power) and phase of the Cree SiC MESFET devices were measured for pulses of various length from 100µs to 5ms with a 30% duty cycle. The peak power analyzer gives a graphical representation of the input and output power as a function of time. Each device was measured with an input power of 30dBm, gate bias of –7V, and drain voltage of +48V. The devices were measured for pulse lengths of 100µs, 300µs, 500µs, 1ms, 3ms, and 5ms. The devices exhibited around 0.2dBs of power droop for a 5ms pulse length. Figure 2 shows the results for one of the sample devices. The pulsed VNA gives a graphical representation of the phase of the device as a function of time. Each device was measured under the same conditions as for the amplitude measurements. The devices exhibited around 5° of phase droop for a 5ms pulse length. Figure 3 shows the results for the same sample device as before.

DISCUSSION OF RESULTS

The measurement results of five sample SiC MESFET devices have shown that SiC does seem to be a very promising material for high power pulsed applications. They have shown very little amplitude and phase droop when measured under diverse pulse conditions (when compared to GaAs devices) and have exhibited less severe degradation in performance when operated with increasing baseplate temperatures. This, combined with the high power density and high voltage/low current bias conditions, makes the SiC MESFET an ideal candidate for phased array radar applications. Table 1 summarises the important properties and results for the SiC devices.

Property	Result for Cree SiC MESFET	Result for a GaAs MESFET
Power density	Typically 4W/mm	Typically 0.5W/mm
Drain current (10W device)	0.5A	~3A
Chip size (10W device)	~1mm^2	~10mm^2
Power drop for 80°C temp rise	0.7dB	~1.2dB
Power droop (5ms pulse)	0.2dBm	~0.5dBm
Phase droop (5ms pulse)	5°	~15°

Table 1: Summary of important properties and results of SiC MESFETs for high power pulsed applications

CONCLUSIONS

SiC appears to offer several advantages over GaAs for high power pulsed applications, such as phased array radar.

- The high power density of the material results in very small devices (leading to easier integration into PAR antenna faces).
- The high drain voltage results in low currents (removing the need for high current power supplies).
- The power and phase droop is significantly better than for GaAs devices (better tracking between elements in an array).
- The power degradation with increased temperature is less significant than with GaAs devices (leading to less severe constraints on the cooling system).

However, there are some disadvantages with SiC devices

- Several devices have failed due to oscillations. These may be due to a fundamental problem with the SiC material (Hilton et al (2)).
- Supply of SiC is severely limited. Currently Cree are the only commercial source of SiC devices.
- Cree SiC MESFETs are really only research grade parts. Their process has currently been upgraded and no more Gen1 devices are available. Gen1.5 devices are now available in sample quantities and the author will be assessing these imminently.

ACKNOWLEDGMENTS

The author would like to acknowledge David K. Jones of BAE Systems Ltd. for funding this work.

REFERENCES

[1] RJ Trew, JB Yan, PM Mock, “The Potential of Diamond and SiC Electronic Devices for Microwave and Millimeter-Wave Power Applications” May 1991, Proc IEEE, Vol 79, No. 5, pp598-620.

[2] KP Hilton, MJ Uren, DG Hayes, PJ Wilding, BH Smith, “Suppression of Instabilities in 4H-SiC Microwave MESFETs” Nov 2000, Proc. EDMO 2000, pp 67-70.

FIGURES

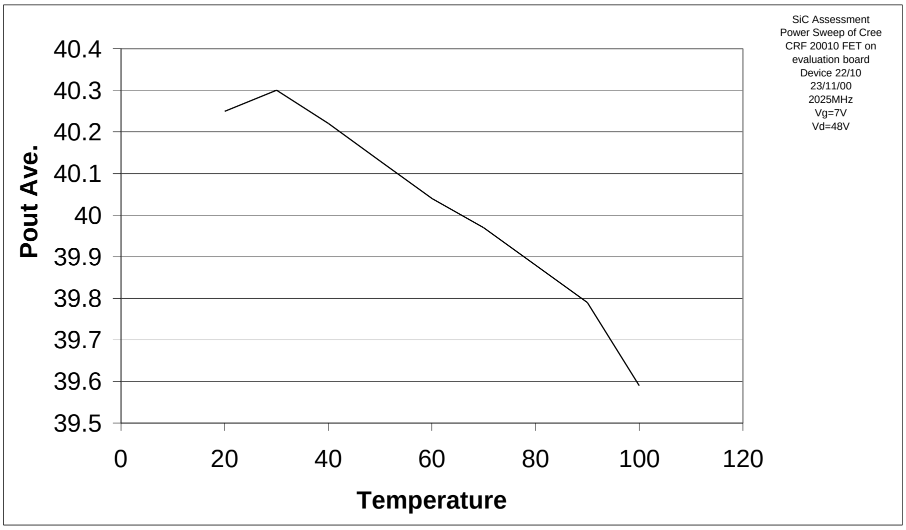

Figure 1: Average output power (dBm) vs. baseplate temperature (°C)

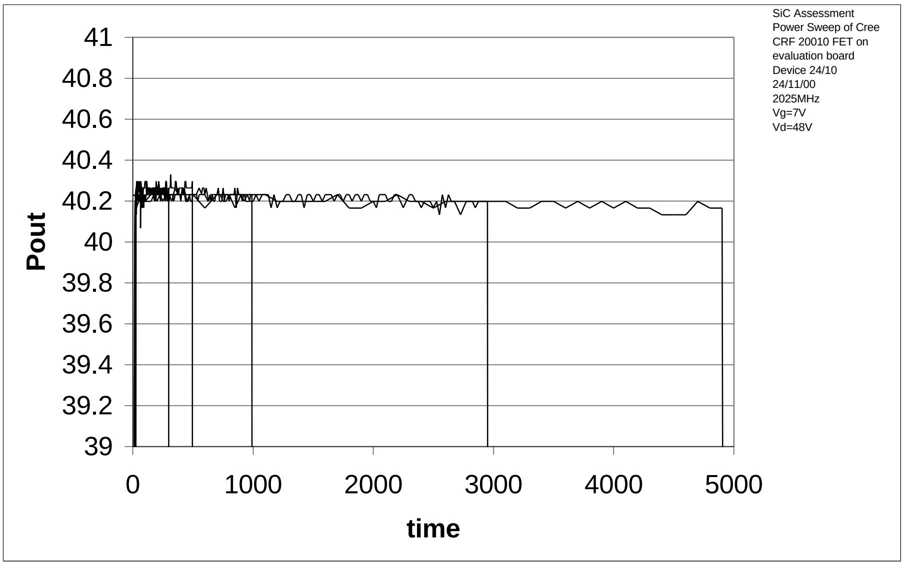

Figure 2: Output power (dBm) vs time (μs)

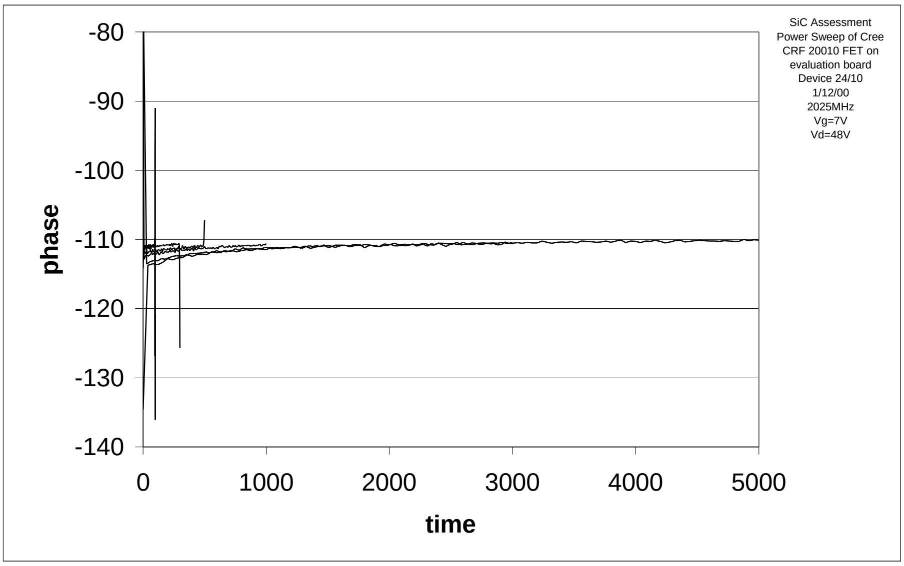

Figure 3: Phase (°) vs time (μs)