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A Simple Thermal Impedance Measurement of SiC JFETs with Constant Current Operation

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1. Introduction

Thermal impedance is an important parameter of a power device to estimate a junction temperature. For thermal impedance measurement, switched or pulsed methods [1]-[3] and an integrated sensing diode method [4] have been proposed. These methods require complex equipment for switched or pulsed measurement or a specific device that has an integrated sensing diode.

In this paper, we propose a simple method that can easily measure the thermal impedance of the power device with constant current operation. This method uses temperature dependency of I-V characteristic of the power device for the junction temperature measurement and a simple circuit to supply constant current.

2. Measurement Method

A. Thermal Impedance Expression

The thermal impedance between the power device and a package $Z_{th}(t)$ is expressed by eq. (1)

$$Z_{th}(t) = \frac{T_J(t) - T_C(t)}{P_D(t)} \qquad (1)$$

where $T_J(t)$ and $T_C(t)$ are a junction temperature and a case temperature of the power device, respectively, and $P_D(t)$ is dissipated power in the power device.

In the proposed method, the T_C is measured using a thermocouple simultaneously with the supplying power P_D that is calculated from measured terminal current and voltage across terminals. $T_J(t)$ is estimated from a electro thermal characteristic of the power device that is given in the following subsection.

B. Modeling of electro thermal characteristic of the power device

The thermal impedance of SiC JFET is characterized and modeled in this paper. I_D-V_{DS} characteristic of FETs depends on gate-source voltage V_{GS} and also is affected by the T_J. Drain-source voltage V_{DS} can be expressed as a function of drain current I_D, the T_J and the V_{GS} as eq. (2).

$$V_{DS} = f_1(I_D, T_J, V_{GS}) \qquad (2)$$

If the I_D and the V_{GS} are fixed at specific values, then the V_{DS} can be expressed as a function of the T_J. The relation between the V_{DS} and the T_J is adversely expressed as a function of the V_{DS} for the T_J as eq. (3).

$$T_J = f_2(V_{DS}) \qquad (3)$$

From this relation, the junction temperature of the power device can be estimated from the V_{DS} for fixed the I_D and V_{GS} operation. Consequently, the thermal impedance of the power device can be evaluated through the measurement of the T_C and the V_{DS} with supplying the constant drain current and the gate-voltage V_{GS} to the power device.

3. Thermal Impedance Measurement

For the experimental validation of the proposed method, a SiC JFET manufactured by "SiCED" is used as a DUT. The SiC JFET has normally on characteristics and is fabricated on a proto-type package in laboratory environment.

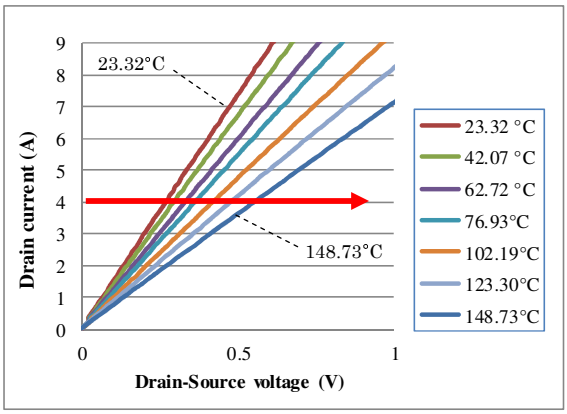

Fig.1 I_D-V_{DS} characteristic of the SiC JFET (V_{GS}=0V)

Figure 1 shows measured I_D-V_{DS} characteristic of the SiC JFET for the V_{GS} of 0V with different temperature from room temperature to about 150°C. The I-V characteristic is measured with Tektronix 371B curve tracer and the ambient temperature is controlled in a heat chamber. The rated current of the SiC JFET is 20A, and the I_D under 10A is in the linear region. It can be found that the slope of I_D-V_{DS} characteristic change with temperature stemming

from on- resistance change. From the Figure 1, the equation of the thermal sensitive parameter is obtained for ID of 4A as followings.

$$T_J = -613.42V_{DS}{}^2 + 933.03V_{DS} - 181.26 \quad (4)$$

Figure 2 shows the circuit diagram of an electrical circuit for the thermal impedance measurement. The case temperature of the DUT is measured by a thermocouple attached to the case with pressure contact. The DUT is also fixed with pressure contact on an air cooled heat sink that has a hole for the thermocouple connection to the case of the DUT. To supply the constant current, a current regulator and a power supply (Agilent U8002A) is used. The current regulator consists of a SiC JFET and a 2.5 Ω resistor.

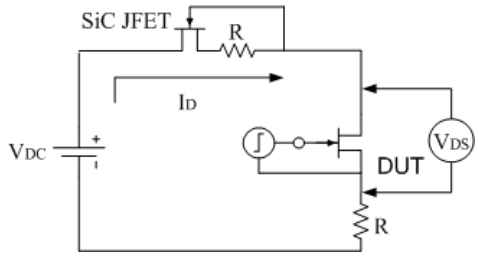

Fig.2 Electrical circuit diagram of the thermal impedance measurement system

The drain current ID is measured using a shunt resistor (0.01Ω) and data for the thermal impedance the ID, the VDS and the TC are monitored and saved using Labview 2010 and a NI 9215.

In order to validate the proposed method, the thermal impedance measurement was carried out with the conventional method that uses the cooling curve for the measurement [5] where forward voltage drop VF of gate-drain diode of the SiC JFET is used as the temperature sensitive parameter.

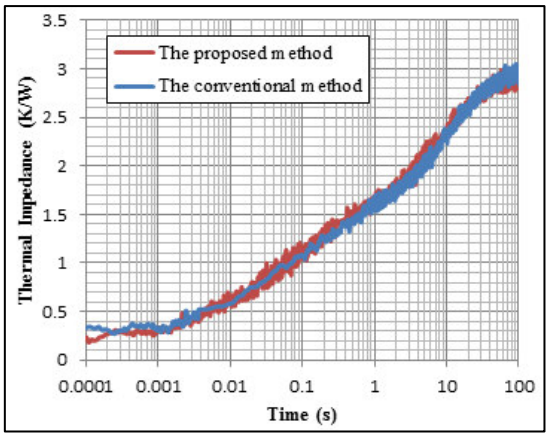

Fig.3 The measured thermal impedance curves with the conventional and the new measurement method

Figure 3 shows the extracted transient thermal impedance curves with the proposed and the conventional method. Both thermal impedance curves gives close agreement and finally reaches to 2.8K/W.

4. Conclusions

The simple method has been developed to measure the thermal impedance of the power device under the constant current operation. This method is applied to the SiC JFET. The thermal impedance curve measured by the proposed method is in good agreement with the result of the conventional method [5]. This method can be used for the other power devices.

References

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