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Characterization of Temperature Dependence of Parasitic Diodes of SiC JFETs for Transient Thermal Resistance Measurement

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1. Introduction

JEDEC [1] defines a standard method to measure transient thermal resistance for designing a heat sink of power devices in a power electronics system. In JEDEC standard method, temperature sensitive parameters (TSPs) that electrical parameters of a semiconductor vary directly with junction temperature are used to estimate junction temperature. In high attention for silicon carbide (SiC) material due to its superior electrical and thermal characteristics to silicon (Si), SiC JFETs are developed. For the thermal impedance measurement of the SiC JFETs, the TSPs of the SiC JFETs should be defined and characterized. Several research results about the TSPs of the SiC JFET have been reported [2],[3]. The voltage drop across the forward biased diode is the most widely used as the TSP due to distinct temperature dependence in Si FETs. The SiC JFET has parasitic diodes that can be used for junction temperature measurement. Until now, there have been few research results that deal with characterization of parasitic diodes of the SiC JFET for the junction temperature measurement. In this paper, we characterize the parasitic diodes of the SiC JFET for junction temperature measurement to extract transient thermal resistance. Temperature dependence of the forward voltage drop of the parasitic diodes of the SiC JFET is measured and discussed. Finally, transient thermal resistance of the SiC JFET is measured with temperature dependence of the gate-source diode.

2. Experiments

A. SiC JFET structure

For this study, the SiC JFET manufactured by "SiCED" is used. The SiC JFET has normally on characteristic and 1200V/20A rating. The SiC JFET die is attached on AlN substrate. Fig. 1 shows cross section of the SiC JFET structure and device symbol with the parasitic diodes. The SiC JFET has three parasitic diodes, a gate-drain diode, a gate-source diode and a source-drain diode. The gate-drain and the gate-source diode has p-n junction with common p terminal. The source-drain body diode is activated with applying negative bias voltage between gate-source of the SiC JFET to block channel conduction.

B. Experimental System

Tektronix 371b curve tracer, which measures with 250us width current pulse is used for the I-V characteristic measurement. The packaged SiC JFET is attached on an aluminum heat spreader with pressure contact. The temperature of the SiC JFET is changed by a heat plate from room temperature to 150°C and the measurement is carried out in thermal steady state condition.

3. Results and discussion

Fig. 2 shows the I-V characteristics of the gate-drain (a) and the gate-source (b) diode of the SiC JFET from room temperature to 150 °C. From the I-V characteristics of the diodes with different temperature, temperature dependence of the forward voltage drop of diodes can be obtained. Fig. 3 shows the temperature dependence of the forward voltage drop of the gate-drain and the gate-source diode of the SiC JFET at the constant current of 5mA. The forward voltage drops of the both diodes show temperature dependence with a slope of -2.6mV/°C and good linearity. Because the gate-drain diode and the gate-source diode of the SiC JFET has p-n junction with common p terminal, the characteristics of both diodes are very similar because between source and drain is conducting. Fig. 4 (a) shows the I-V characteristics of the source-drain diode of the SiC JFET with different biased voltages between the gate-source to keep the channel in the OFF condition, and fig. 3 (b) shows the I-V characteristics of the source-drain diode with different temperature at applying the gate-emitter biased voltage of -24V. Because I-V characteristic of the source-drain diode shows irregular values with different temperature in the fig. 3 (b) so that it is difficult to extract the temperature dependence of the forward voltage drop of the source-drain body diode. From the results, the gate-drain or the gate-source diode of the SiC JFET can be applicable for the junction temperature measurement in the thermal impedance measurement. Finally, we have measured the transient thermal resistance of the SiC JFET as shown in fig. 5 with the temperature dependence of the forward voltage drop of the gate-source diode using the standard method that uses cooling curve.

3. Conclusions

This paper measured and discussed the temperature dependence of the forward voltage drop of the parasitic diodes of the SiC JFET to estimate the junction temperature for the transient thermal impedance characterization. The gate-drain diode and the gate-source diode of the SiC JFET have similar characteristics because both diodes have p-n junction with the common p terminal and there is conduc-

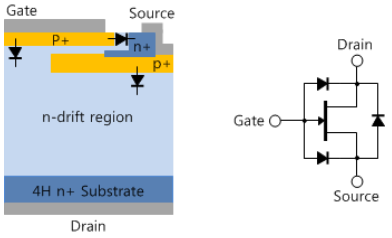
tion between the drain and the source as normally on character. From the results, the gate-drain or the gate-source diode of the SiC JFET can be applicable for the junction temperature measurement, but the source-drain diode of the SiC JFET can't be applicable due to irregular characteristic with different temperature. Finally, we measure the transient thermal resistance of the SiC JFET using temperature dependence of the gate-source diode.

References

[1] JEDEC STANDARD, No. 24-3 (1990).

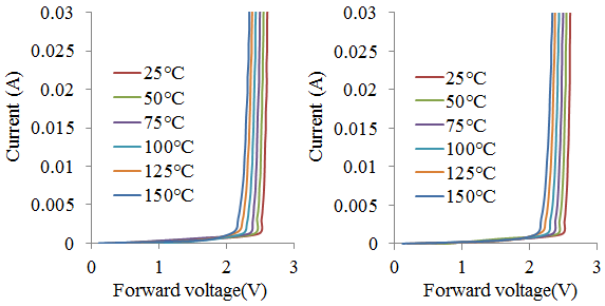
[2] M. Nowak, J. Rabkowski, R. Barlik, 2008 13th International Power Electronics and Motion Control Conference (2008) 84.

[3] T. B. Salah, S. Khachroumi and H Morel, Sensors (2010) 10, 388.



(a) Cross section (b) Device symbol

Fig. 1 The structure of the SiC JFET (a) and the device symbol (b)



(a) (b)

Fig. 2 The I-V characteristics of the gate-drain diode (a) and the gate-source diode (b) of the SiC JFET with different temperature

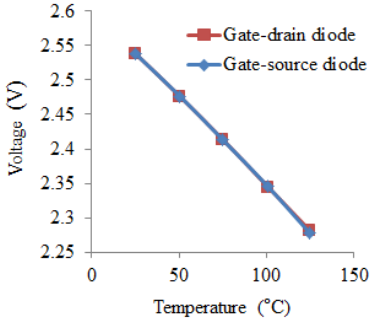
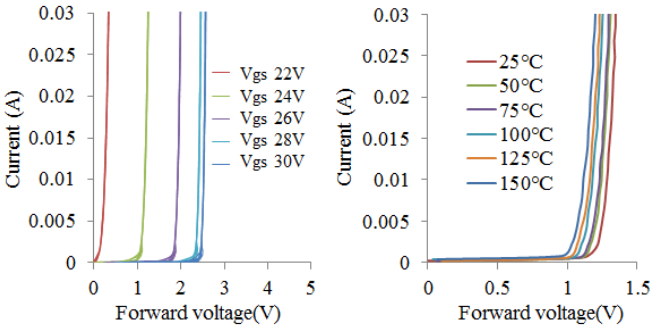


Fig. 3 The temperature dependence of the gate-drain and the gate-source diode of the SiC JFET at constant current of 5mA



(a) (b)

Fig. 4 The I-V characteristics of the source-drain diode of the SiC JFET (a) applying the different gate-emitter biased voltage (b) different temperature at applying the gate-emitter biased voltage of -24V

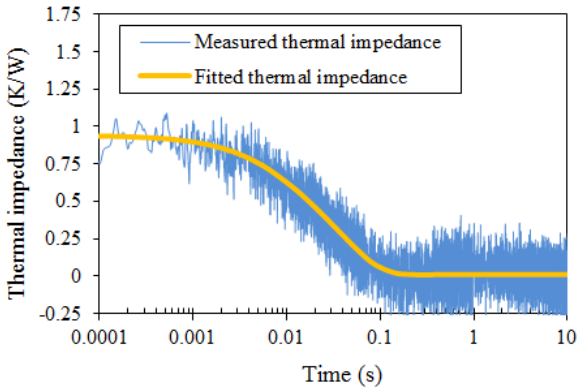


Fig. 5 The measured transient thermal resistance of the SiC JFET with the temperature dependence of the forward voltage drop of the gate-source diode