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Transient Thermal Characteristics of Packaged SiC SBDs and its Temperature Dependence

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Abstract

This paper characterizes transient thermal resistance of the packaged SiC SBD and its temperature dependence for high temperature applications. Thermal resistance of the packaged SiC SBD between a junction and a case increases with temperature. The partial thermal resistances and capacitances of the packaged SiC SBD were extracted and analyzed. Experimentally, it was found that the SiC device is a main factor of variation in the thermal characteristics of the packaged SiC SBD with temperature, and the thermal resistance of the SiC device increases from 0.179K/W to 0.427K/W in temperature range from 25°C to 275°C.

1. Introduction

One of the main advantages of the SiC devices compared to the Si devices is high temperature operation ability, and its operation even at 450°C is reported [1]. Temperature changes thermal properties of the package materials such as thermal conductivity and specific heat that affect the thermal resistance and thermal capacitance that determine heat dissipation performance of the device. Generally, in case of a metal and a semiconductor, temperature reduces thermal conductivity and increases specific heat [2]. This effect results in degradation of thermal performance of the packaged semiconductor. For high temperature operation of SiC device, it should be considered that the worsened heat dissipation performance with temperature. Therefore, in this research, we investigate transient thermal characteristics of the packaged SiC SBDs in temperature environment from 25°C to 275°C.

2. Experimental

For this study, a SiC SBD (600V/10A rating) manufactured by "Rohm" was used as DUT. The SiC SBD was attached on the Active Metal Brazed (AMB) Si_3N_4 substrate using Au88Ge12. The Al wire is used to connect between the cathode of the SiC SBD and the pattern copper, and the substrate was covered using a high temperature resin. The thermo-couple was attached on the back side copper using a solder to measure the temperature variation of the case.

The transient thermal resistance was measured through electrical switching method [3], using the experimental set-up shown in Fig. 1. First, relationship between temperature and forward voltage drop (V_F) of the SiC SBD was extracted for constant current of 5mA, and its result is shown in Fig. 2. In the transient thermal resistance measurement, an input power of 5W is supplied to the DUT with close of SW1 to heat-up (heating phase). In thermal steady state, SW1 opens, and the constant current of 5mA is supplied to the DUT to measure V_F with closing SW2 (cooling phase). The case temperature was measured with V_F measurement in the cooling phase, simultaneously. The transient thermal resistance of the packaged SiC SBD was measured in case temperature from 25°C to 275°C.

3. Results and discussion

The transient thermal resistance between junction and case (Z_{th}) is defined eq. 1.

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

Where, T_J(t) is the junction temperature, T_C(t) is the case temperature and P is the dissipated power in the device. From Fig. 2, the slope of -1.704mV/°C is obtained. Using the slope and measured V_F in the cooling phase, T_J was calculated. The measured thermal resistances of the packaged SiC SBD are shown in Fig. 3.

Figure 3 shows the thermal resistance of the packaged SiC SBDs between the junction and the case. It is found that the thermal resistance increases from 2.11K/W to 2.42K/W when the case temperature increases from 25°C to 275°C. To analyze the thermal characteristics of the each layer of the packaged SiC SBD, the measured transient thermal resistance shown in Fig. 4 was characterized using TRAIT method [4], and partial thermal resistances and capacitances of the 5 stacked layers from the junction to case were obtained. The extracted partial thermal resistances and capacitances are shown in Fig. 5. At temperature of 25°C, the partial thermal resistance of the SiC SBD, die attach layer (Au88Ge12), pattern copper, Si_3N_4 substrate and bottom copper are determined to be 0.179K/W, 1.167K/W, 0.231K/W, 0.431K/W, and 0.101K/W, respectively. All of the partial thermal resistances increase with temperature. The die attach layer has the largest portion of the total thermal resistance (about 45%). The thermal resistance of the SiC device has 9% of the total thermal resistance, and it is observed that the thermal resistance of the SiC device increase, largely, with temperature over the other layers. The thermal resistance of the SiC device increases with a slope of 0.001 against temperature, gradually, and finally, it has 0.427K/W at 275°C. At temperature of 25°C, the partial thermal capacitances of the SiC SBD, die attach layer (Au88Ge12), pattern copper, Si_3N_4 substrate and bottom copper are determined to be 0.0001Ws/K, 0.0010Ws/K, 0.0102Ws/K, 0.0039Ws/K and 0.4278Ws/K, respectively. All of the partial thermal capacitances of the packaged SiC SBD increase with temperature.

3. Conclusions

The transient thermal characteristic of the packaged SiC SBDs and its temperature dependence in range from 25°C to 275°C was investigated. The total thermal resistance of the packaged SiC SBD increased with temperature. The partial thermal resistances and capacitances of the packaged SiC SBD were extracted. It was found that the main factor of the thermal characteristics variation with temperature is the SiC SBD device.

References

[1] T. Funak, *et al.*, IEEE Trans. Power Electron **22** (2007) 1321.
[2] M, Rencz, *et al.*, IEEE Trans Compon. Packag Tech. **27** (2004) 124.
[3] JEDEC STANDARD, No. 24-3 (1990).
[3] P. E. Bagnoli, *et al.*, IEEE Trans. Power Electron **13** (1998) 1208.

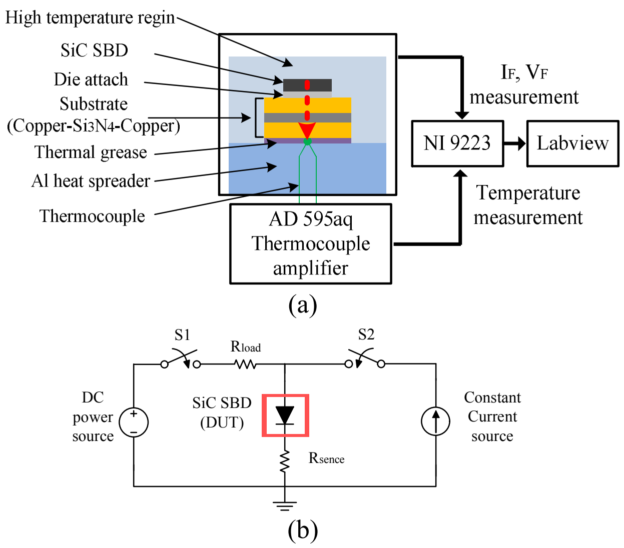

Fig. 1 Schematic diagram of experimental setup including schematic cross section of the packaged SiC SBDs (a) and the test circuit (b)

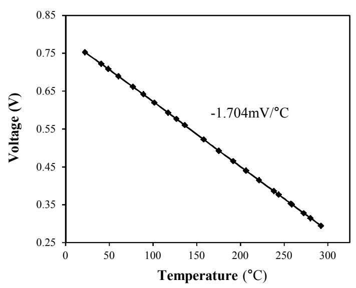

Fig. 2 Relationship curve between forward voltage and junction temperature of the SiC SBD at forward current of 5mA in temperature range from 25°C to 290°C.

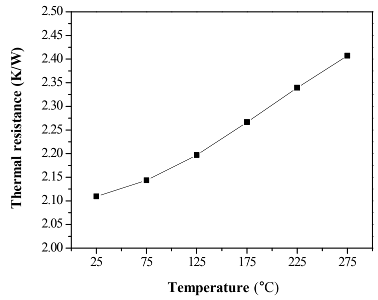

Fig. 3 Thermal resistance of the packaged SiC SBDs in temperature range from 25°C to 275°C.

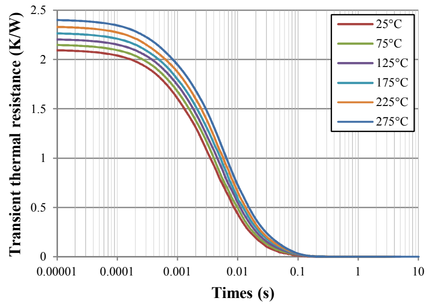

Fig. 4 Measured transient thermal resistance of the SiC SBDs in different case temperatures from 25°C to 275°C.

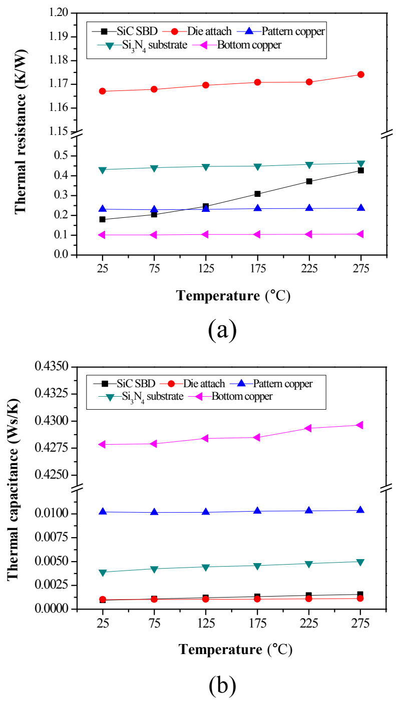

Fig. 5 Partial thermal resistances (a) and thermal capacitances (b) of the package SiC SBD as a function of the temperature.