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Indirect thermographic temperature measurements of a diode die made on a silicon carbonide substrate

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Abstract

The paper deals with the issue of heat distribution in the case of the FFSH10120A diode. It is a diode made on a silicon carbonide substrate and placed in the TO-247-2LD case. The motivation for the undertaken research work were discussed. It presents the environment in which the simulation tests of heat distribution were performed and how the simulation parameters were selected. The obtained results were presented. On the basis of the presented differences between the temperature die and the temperatures of case parts, it is possible to select such a point on the case that the thermographic measured temperature of the case is closest to the temperature die.

1. Introduction

Semiconductor diodes made on a silicon carbonide (SiC) substrate, compared to diodes made on a silicon (Si) substrate, are characterized by lower heat release in the case. For this reason, their operation is more stable, also in the field of high currents and voltages. In addition, the diodes made on SiC substrate, compared to the analogous diodes made on Si substrate, may be subjected to greater electric loads. The diodes made on a SiC substrate are used in the construction of the switched-mode power supplies, in photovoltaic systems and in the automotive industry (electric cars). Therefore, they are a part of the devices on which safety and comfort depend [1].

As the current load on the semiconductor diode increases, the temperature inside the case increases. This dependence can also be observed in the case of diodes made on a SiC substrate. As the temperature of the diode die increases, its parameters change. As a consequence, the flow of currents and the distribution of voltage drops in the device of which the diode is a part may change. This, in turn, can lead to incorrect operation of the entire device. It should be added that a diode which die works at a higher temperature is more exposed to failure and its lifetime is shorter. For this reason it is important to know the temperature of the diode die.

Information about the temperature of the die of a semiconductor diode made on a SiC substrate is difficult to obtain. Due to the high value of the current that can be conducted through the diode, the use of the contact temperature sensor may be dangerous. Another solution is to use the thermography. This non-contact method is a safe method. Its use eliminates the possibility of electric shock. An additional advantage of using the thermography is the possibility of obtaining the temperature distribution on the diode surface.

Thermography, despite its significant advantages, has also disadvantages. In order to perform such thermographic temperature measurement, which is burdened with the possibly lowest error, it is necessary to know the value of the emissivity factor ε. Another problem that needs to be solved is the choice of the observation site on the semiconductor diode case. Depending on the choice of the observation site, the values of the differences between the die temperature and the temperature of the case will be different. For this reason, the research has been undertaken, the result of which is to indicate such a place on the case of the semiconductor diode made on the SiC substrate, so that the difference between the die temperature and the temperature of the case is as low as possible.

2. Methodology

The FFSH10120A (ON Semiconductor, Phoenix, Arizona, USA) diode placed in the TO-247-2LD case was selected for the research. This diode has, inter alia, a max junction temperature of 175 ℃, peak repetitive reverse voltage (VRRM) of 1200 V and continuous rectiofied current (IF) of 10 A for case temperature (TC) = 158 ℃.

In order to find out the internal dimensions of the diode case, the black epoxy layer of the case covering the die was removed. Then the internal dimensions of the case were measured with a Moticam 3+ microscope (Motic GmbH, Wetzlar, Germany). Before taking measurements, the microscope was calibrated with an ocular micrometer (Muhwa, Shanghai, China). The external dimensions of the TO-247-2LD case have been read from the catalog card of the FFSH10120A diode.

The location of the case with the smallest difference between the die temperature and temperature of the case was selected on the basis of simulation. Solidworks with module Simulation was selected to perform the simulation. The values of specific thermal conductivity λ were selected on the basis of the literature [2]. The value of the convection coefficient α_k was calculated using the dependence of fluid mechanics and criteria numbers on the basis of the literature dependencies, while the values of the emissivity coefficient ε were determined in the conducted research. These works consisted of gluing PT1000 sensors in the SMD 6203 case (Heraeus, Hanau, Germany). The emissivity coefficient was determined by comparing the temperature of the case surface made with a thermographic camera and with the PT1000. The value of ε was selected until the results of the contact and thermographic measurements were consistent. In addition, the results obtained from the PT1000 sensors were used to verify the simulation results. The parameters selected in the simulation are presented in Table 1.

Table 1. *Selected simulation parameters*

L.p	The part of the case	The convection coefficient α_k	The emissivity coefficient	The thermal resistance	The element dimensions	The thickness of the element
		[-]	[-]	[W/mk]	[mm^2]	[mm]
1	Epoxy	9.51-14.30	0.96-0.97	0.2	310.78	3.12
2	The back part of the case	9.39-14.03	0.26-0.58	400	192.79	1.7
3	Leads	9.39-14.03	0.26-0.58	400	47.66	0.71
4	Die	-	-	150	3.9	0.2
5	The glue between die and the case	-	-	0.9	3.9	0.1

3. Results

The simulation results for a junction power of 1.759 W are shown in Figure 1.

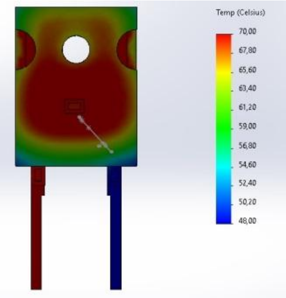

Fig. 1. *The temperature distribution on the FFSH10120A diode case obtained as a result of the simulation.*

The results of the simulation of temperature die and temperatures in the selected places of the case for the selected powers released at the junction are presented in Table 2.

Table 2. *The temperature values on the case of the FFSH10120A diode obtained as a result of the simulation.*

L.p	The power of die [W]	The temperature of die [^{o}C]	The temperature of the epoxy (above die)	The temperature of the back of the case (under die)	Temperature of the leads (next to the case - left leg / right leg)
1	0.509	44.24	39.85	42.80	42.46/30.30
2	1.080	65.32	55.31	63.82	60.70/39.33
3	1.759	87.88	72.41	85.18	82.41/48.36
4	2.528	111.31	89.48	105.32	103.34/56.94

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