Temperature Distribution Imaging inside Power Devices by Real-Time Simulation

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Abstract

We propose an imaging method of temperature distribution inside a power device in real-time. The imaging system was constructed by integrating a real-time monitoring and a real-time simulation. The surface temperatures of a device under test (DUT) is monitored by infrared cameras and a high speed temperature simulator calculates temperature distribution inside the DUT by using the surface temperatures as boundary conditions. Our system successively imaged inside temperature distribution of a TO packaged power diode under power cycling test with frame rate of 1 fps.

1. Introduction

The heat management of power devices is important issue from the point of view of reliability [1-5]. The temperature distribution in a device package is hardly obtain experimentally without modifying the package, therefore its evaluation is mainly carried out by numerical simulation. A precise thermal simulation usually takes long time, therefore it is not suitable to apply for a real-time evaluation under acceleration test.

In this paper, we propose an imaging method of temperature distribution inside a power device in real-time. The imaging system was constructed by integrating a real-time monitoring and a real-time simulation.

2. System configuration

The system is constructed by several infrared cameras and a high-speed temperature simulator (Fig. 1). The infrared cameras surrounding the DUT monitor the temperature whole of the DUT surfaces. The monitored temperature uses as a boundary condition of temperature simulation. The original temperature simulator calculates temperature distribution inside the DUT at high speed by solving a discretized three dimensional equations for non-steady state heat conduction. The monitoring and the simulation are carried out simultaneously and temperature distribution inside the DUT is imaging in real time.

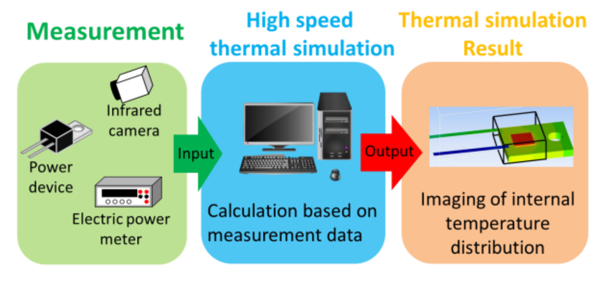

Fig. 1 Principle of temperature distribution imaging by teal-time simulation.

3. Confirmation of the imaging system

The accuracy of the original simulator was confirmed by comparing commercial simulator (ANSYS Icepak). When a same heat conduction model was calculated, the relative error in temperature was within 0.0006% and the simulation time of our simulator was almost one hundredth.

The principle of the method was verified with a metal block specimen (SUS304). The temperature at three different point in the specimen obtained by the proposed system and thermometers was shown in Fig. 2. The specimen was heated from one side by a heat gun. The result indicated same behavior and a difference between them was within 2 ^{o}C.

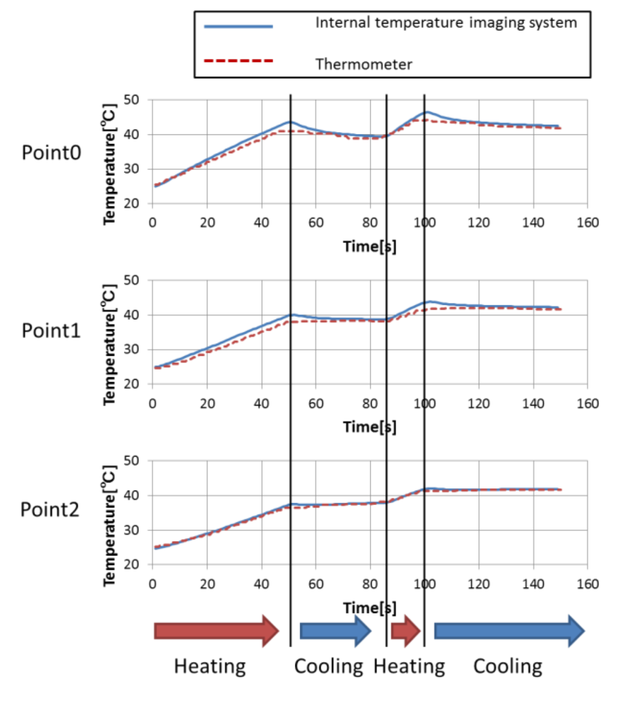

Fig. 2 Comparison between our system and thermometer.

4. Application to power device

The system was applied to power cycling test of a TO packaged power diode. DC current of 3 A was applied to the

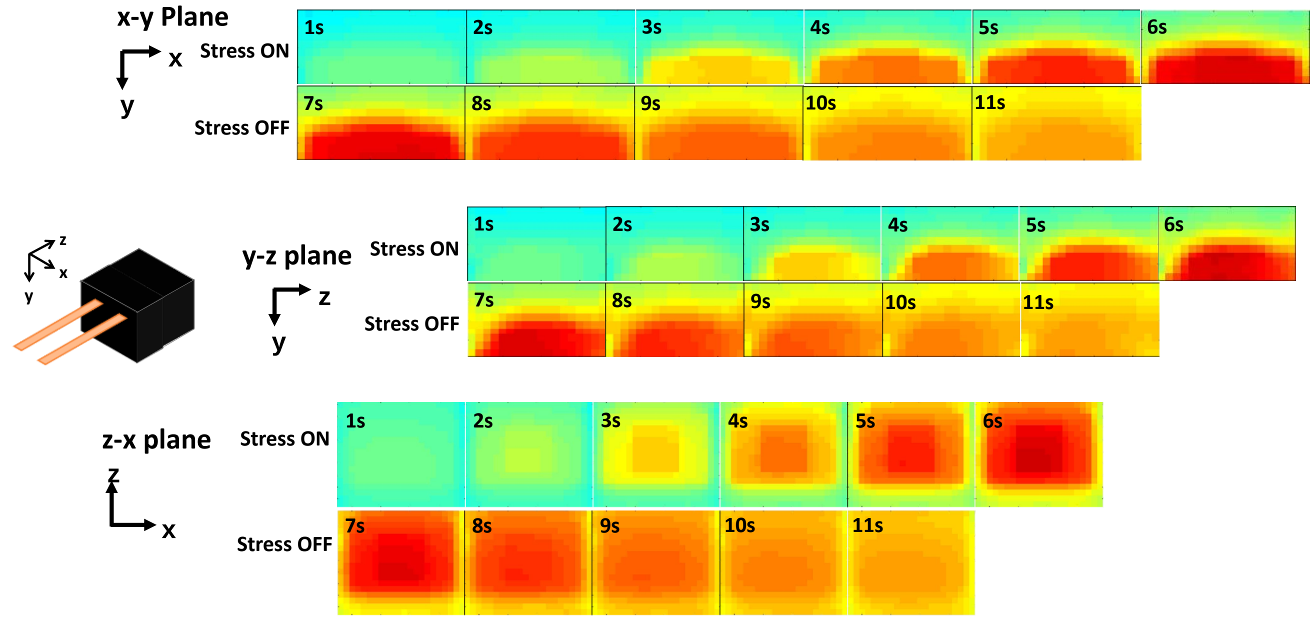

Fig. 3 Temperature distribution images inside power device under power cycling test.

device with 5 s turn-on and 5 s turn-off. Surface temperature was monitored by five infrared cameras surrounding the specimen device. The device was painted by black spray to uniform infrared emissivity. The simulation model of the device was formed by 4356 (22 × 11 × 18) meshes. The mesh size was 0.3 mm at the Si chip, 0.025 mm at solder layer and 0.5 mm at other materials. In the case of power cycling test, the self-heating of a semiconductor chip was heat source, therefore applied power was also monitored and input to the thermal simulation.

Fig. 3 shows the temperature distribution imaging result. The system was carried out in framerate of 1 fps. When the stress current was applied, the temperature at Si chip that is a heat source and at copper plate was high. When the stress current was turned off, the temperature distribution became uniform in the package because of natural convection cooling. Fig. 4 shows the Si chip temperature obtained by our system and the junction temperature estimated by forward voltage drop of pn-junction. Although the junction temperature is able to estimate only when the stress current is turned off, they showed good agreement with temperature difference within 2 °C.

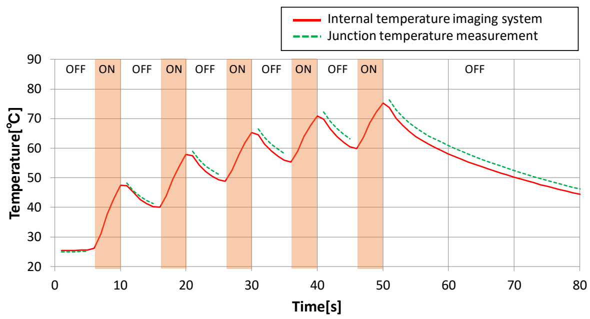

Fig. 4 Comparison between Si chip temperature and junction temperature.

5. Conclusions

We propose an imaging method of temperature distribution inside a power device in real-time. The principle of this method was confirmed experimentally. The system was applied to power cycling test with TO-packaged device. The system was able to image the temperature distribution inside the device with frame rate of 1 fps.

References

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