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High Speed Real-time Temperature Monitoring System inside Power Devices Package Using Infrared Radiation

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Abstract

We proposed high speed real-time temperature monitoring system using infrared radiation in order to analyse thermal behaviour inside power device packages. This system was able to monitor thermal distribution in the package and confirmed thermal transition in this area with time resolution of 10 ms and special resolution of 15µm. Accuracy of the measured temperature of each material with different infrared emissivity in the package was ensured by calibration obtained experimentally.

1. Introduction

The complexity of the internal structure and the miniaturization of power devices are increased thermal density in the package. In order to ensure the reliability of power devises, therefore, it is necessary to analyze the thermal behavior in the packages and to consider proper thermal design. Experimental verification is also essential in addition to thermal simulation in the proper thermal design for power devices [1].

Temperature monitoring with infrared radiation is generally used by the way of non-contact method. However, it is difficult to monitor the accurate temperature distribution in the package because the emissivity is different by materials and it easily changes by irregularity in the surface or oxidation [2, 3, 4]. Although this problem is resolved by black spray paint, spatial resolution and time response to temperature transition is spoiled.

We propose a high speed temperature monitoring system to measure the thermal distribution in power device packages by using infrared radiation. Infrared radiance from each material inside the package was converted to accurate temperature by calibration curve obtained experimentally. This method did not spoil spatial and time resolution of measurement.

2. Infrared Measurement System

We used an infrared camera (FLIR SC7600) to measure the thermal distribution in this temperature measurement system (see Fig. 1). The frame rate of this camera is up to 3 kHz. In order to measure local area of a power semiconductor chip, slitting process was employed to exposed semiconductor chip inside the package (see Fig. 2). In addition, we use the optical slit to cut off radiation except the slitting bottom (see Fig. 3). We also simultaneously measure the temperature of each material in the package by a fiber-optical thermometer to obtain accurate temperature carburation curves.

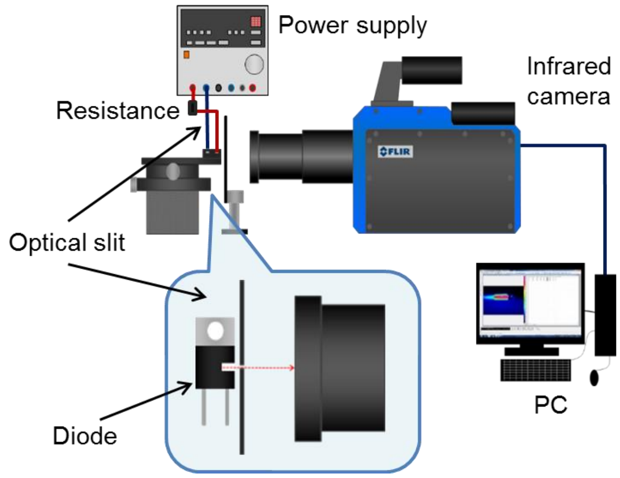

Fig.1 High speed real-time temperature monitoring system inside power device package

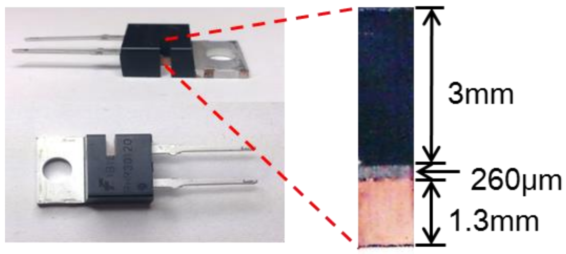

Fig.2 Slitting sample

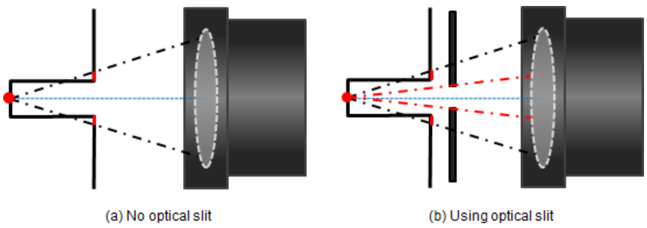

Fig.3 Effect of optical slit

3. Measurement results

A TO-220AC packaged power diode with maximum rating of repetitive reverse voltage of 1200 V was prepared for this demonstration. Radiation from 1 mm width chip region monitored through a 0.8 mm width optical slit was shown in Fig. 4. This system acquired these images with time resolution of 10ms and spatial resolution of 15µm.

The radiance of the infrared camera measured from each material inside the package was converted to temperature with relationship in Fig. 5. Although, the radiance indicated discontinuously at the interface between Si chip and Cu plate, the temperature distribution after calibration was kept continuously at each interface (Fig. 6).

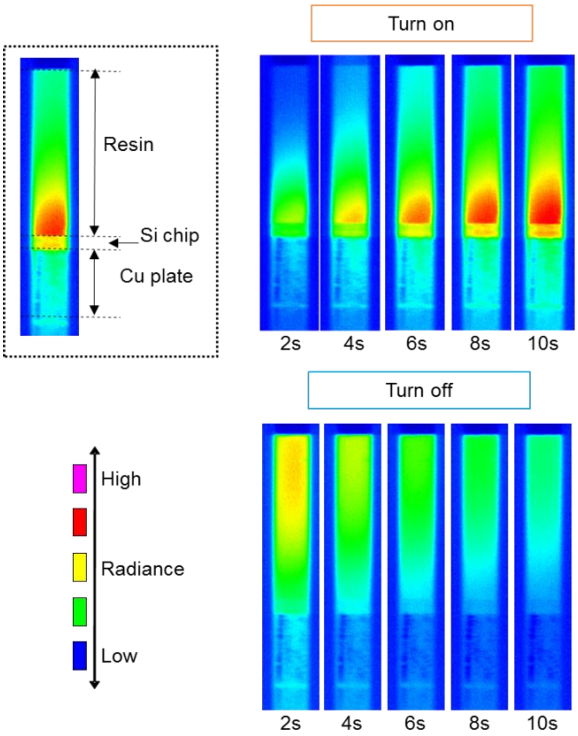

Fig. 4 Infrared radiation image

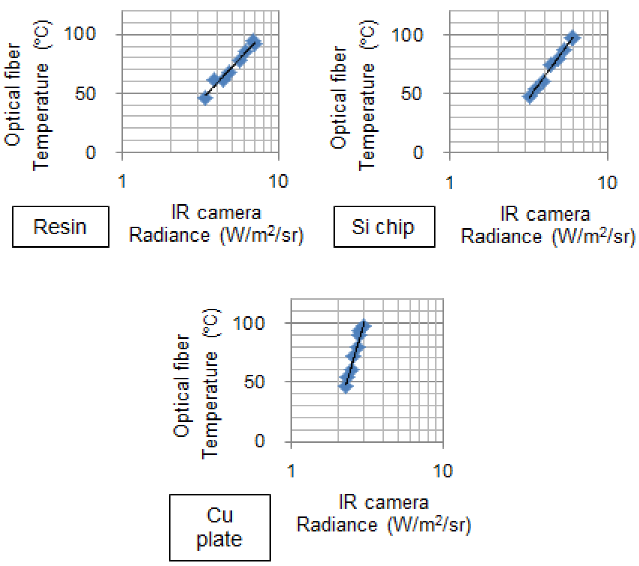

Fig.5 Calibration curve for each part of package

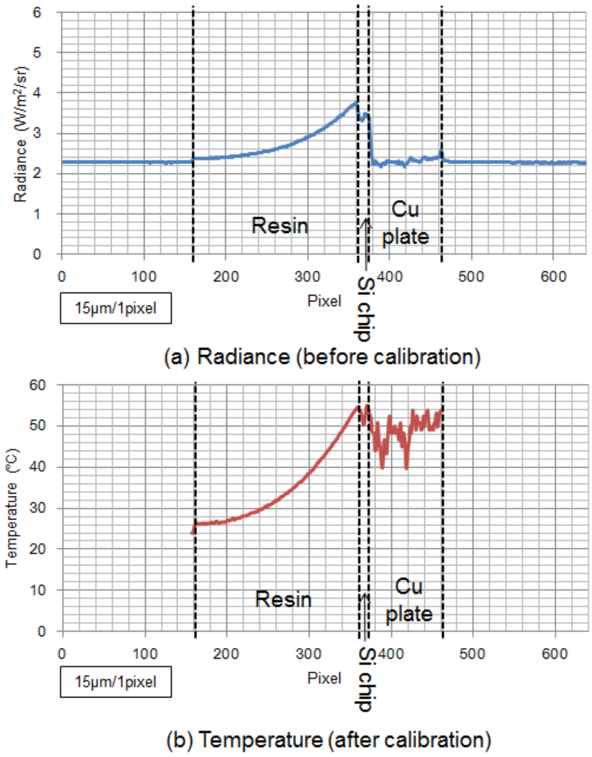

Fig. 6 Radiance distribution (a) and calibrated temperature distribution (b)

4. Conclusion

Our proposed temperature monitoring system was successively measure the thermal distribution in the package of power devices. Original calibration method solved difficulty of conversion from infrared radiation data to accurate temperature value without spatial and time resolution of the monitoring.

References

[1] M. Riccio et al. “Analysis of large area Trench-IGBT current distribution under UIS test with the aid of lock-in thermography” Microelectronics Reliability 2010; 50: pp.1725-1730

[2] A. Irace “Infrared Thermography application to functional and failure analysis of electron devices and circuits” Microelectronics Reliability 2012; 52: pp.2019-2023

[3] A. Irace et al. “Reliability enhancement with the aid of transient infrared thermal analysis of smart Power MOSFETs during short circuit operation” Microelectronics Reliability 2005; 45: pp.1706-1710

[4] Richard D. Hudson Jr. “Infrared system engineering” WILEY-INTERSCIENCE pp.20-66