Failure-Analysis Method of Soldering Interfaces in Light-Emitting Diode Packages Based on Time-Domain Transient Thermal Response

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Abstract – New soldering-interface failure-analysis method based on the transient thermal of the LED packages are proposed. This method is based on a physical property that the change of the junction temperature, which is monitored by voltage, represents the change of thermal gradient in the LED packages. Fast time-domain algorithm for failure-sensitivity enhancement was developed. And the feasibility of this algorithm was verified using a two-point measurement method during a thermal shock test.

1. Background and motivation

Light-emitting diodes (LED) have been widely deployed in many applications such as a mobile, a display and general lightings. However, the oversupply of them the competition among the LED suppliers require loser cost (i.e., smaller size chips and packages) and an integrity of chip fabrication and package-assembly process. Especially, two soldering processes of the LED packages, die bonding and the package bonding, have been critical to meet reliability requirements.

Electrical properties and X-ray inspection have been widely used to analyse these soldering failures. However, due to several drawbacks such as a low failure-detection sensitivity and an inefficient resolution, many research groups have developed new method based on transient thermal analysis [1-4]. They have utilized the facts that the operation voltage is inverse proportional to junction temperature and the change of junction temperature includes the thermal-gradient information through a thermal path of the LED packages.

Recently, we also proposed a two-point measurement method for the fast screening of die-bonding failures in the LED packages [5]. Our method followed the same physical principle of the previous groups [1-5] but focused on the speed of thermal dissipation to meet the requirements of fast and simple failure analysis systems.

Here, we propose a novel algorithm for the improvement of the failure-detection sensitivity in soldering interfaces. And in order to verify its feasibility, we applied the results of this algorithm to the 2-point measurement method while we carried out a thermal shock reliability test.

2. Method and results

2.1. Conventional analysis methods

In order to generate soldering cracks at the package bonding of the LED packages, we carried out a 1,000 run-thermal-shock-test with a condition of -40/125 ℃ temperature change. Static operation voltage, as shown in Fig.1, was not changed with respective to the thermal shock test run. However, the thermal resistance, shown in Fig. 2 (b) and obtained by a conventional structure-function analysis, changed considerably at the same condition. This results means that two soldering interfaces of a die bonding and a package bonding are not bottle necks of an electric path in the LED packages and the static electrical measurement is not effective to monitor these failures. On the other hand, these soldering interfaces are critical points of thermal path in the LED packages. Although the thermal resistance and thermal time constant, as shown in Fig. 2, are very effective to analyse the soldering failures, we need a special measurement system and time-consuming structural-function analyses.

2.2. New algorithm for soldering-crack sensitivity enhancement

New failure-analysis algorithm for monitoring the soldering cracks is proposed. This is carried out on a time domain instead of the structure function analysis or domain transfer. Fig. 3 (a) shows the measured transient voltages, v (n, t), in time domain. Here, “n” means the runs of the thermal shock test. Fig. 3 (b) shows the normalized transient voltages, v (n, t) – v (0, t), at the same time region. The speed of thermal dissipation in the LED packages is expressed as a transient response of the junction temperature, which is measured by the voltage change. Therefore the differential value of the normalized transient voltage, d[v (n, t) – v (0, t)]/dt), defined as a sensitivity function here, can be used as an fast indicator of soldering crack as shown in Fig. 3 (c). While the operation voltage as shown in Fig. 1 shows no sensitivity of soldering crack, the sensitivity function, measured by same voltage and shown in Fig. 3 (c), shows considerable change with respective to the crack growth. This sensitivity function can be used to obtain the specific time, involved in soldering-crack interfaces. Time constant analysis, as plotted in Fig. 2 (b), shows a good agreement with the result of the sensitivity function.

2.3. Two-point measurement method

The sensitivity function was used to set two specific measurement points of the two-point measurement method. Fig. 4 shows the voltage difference at two specific points (0.01s and 1s), v (2) – v (1), with respective to the runs of a thermal shock test. The voltage difference at the other specific points (0.1ms, 0.1s), used for the die-bonding crack or void in the same LED packages [5], was compared in Fig. 4. One can easily tell the package crack from the die-bonding problem.

3. Summary

A simple and fast time-domain algorithm is proposed for the soldering-failure monitoring and demonstrated its feasibility by the two-point measurement during a thermal shock test. This method can be applied other fields such as power electrical devices, integrated circuits, and prognosis-health monitoring.

Acknowledgements

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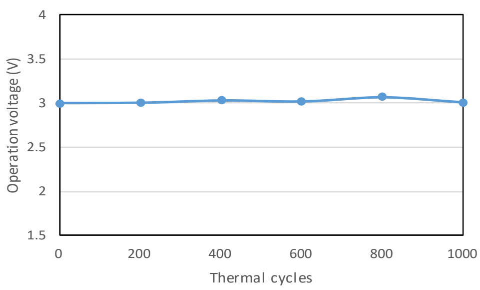
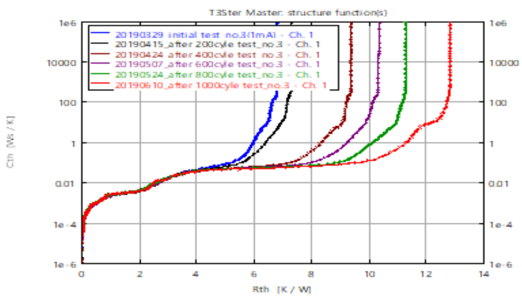
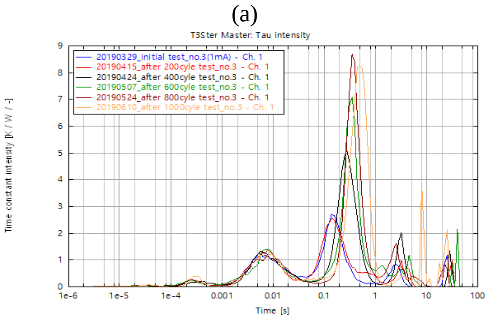


Fig. 1. Static operation voltage of a LED package during thermal shock test.

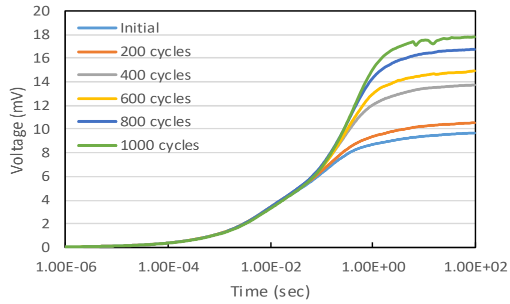


(a)

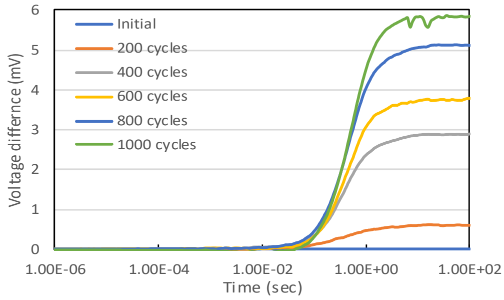


(b)

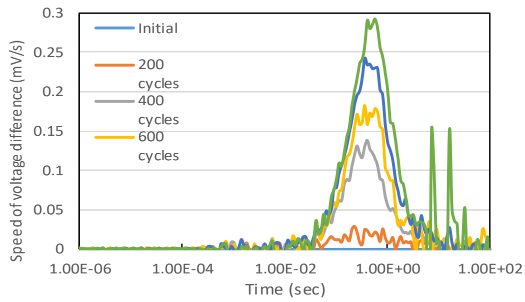
Fig.2. Structure function analysis of a LED package: (a) thermal capacitance–thermal resistance relationship (b) and thermal time constant.



(a)



(b)



(c)

Fig.3 Transient voltage (a), normalized transient voltage (b), and sensitivity function (c) of a LED package.

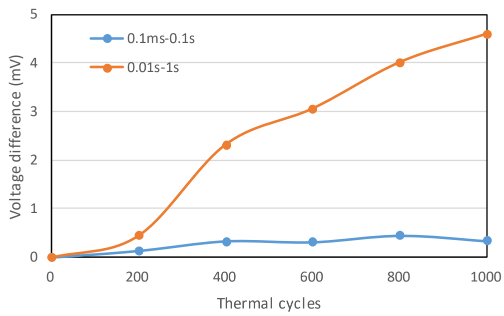


Fig.4. Voltage difference based on 2-point measurement of a LED package with respective to thermal shock test.