Reliability Growth and Assessment of Chip Scale Packaged Light-Emitting diodes with High Color Rendering Index

J. H. Lee[1*], B. Ma[1], S. –K. Jeon[2], S. H. Baek[2], and K. -H. Lee[1]

[1]Reliability Research Center, Korea Electronic Technology Institue (KETI), 25 Saenari-ro, Bundang-gu, Seongnam, South Korea
[2]Semicon Light, 49 Wongomae-ro 2beon-gil, Giheung-gu, Yongin, South Korea

[*]Corresponding author: leejuho@keti.re.kr

1. Introduction

Light-emitting diodes (LEDs) are have attracted a great deal of interest for the development of commercial displays/backlightings, mobile communications, and automotive lightings, due to their superior characteristics such as high efficiency, low power consumption, and long life [1, 2]. In the view point of LED manufacturing process, packaging is considered as an effective way to fulfil the electro-luminescence function and mass production of LEDs. In accordance with an industry requirements, LED packagings changed from injection molded packaging to chip-on-board packaging and chip scale packaging (CSP). Among the various packagings of LEDs, CSP LEDs show many advantages such as smaller size and lower processing cost. However, there are some reliability issues including heat dissipation to be solved to use as high power applications. In this study, we report on the reliability growth method and assessment of redesigned CSP LEDs with high color rendering index (CRI) for the high power applications. In addition, thermal characterization of the CSP LEDs conducted using dynamic thermal characterization method [3].

2. Experimental details

In order to enhance thermal characteristic and reliability of CSP LEDs with high CRI (> 95), we optimized current flow, ohimic contact, phosphor concentration, and metal printed circuit board (PCB). Thermal characteristics of CSP LEDs were measured by T3Ster using dynamic thermal characterization method [3]. Environmental test chmbers were used to assess reliability of CSP LEDs on temperature and humidity. We targeted operating current of CSP LEDs as 800 mA. For the high temperature (HT) operating test, we set atmospheric temrerature as 85 °C to make junction temperature as 150 °C.

3. Results and Discussion

Figures 1(a) and 1(b) show cross-sectional diagram and time-board temperature graph of CSP LED, respectively. As a result of structural optimization, current flow through flip chip enhanced and it leads to increasing heat dissipation via LED chips and metal PCB.

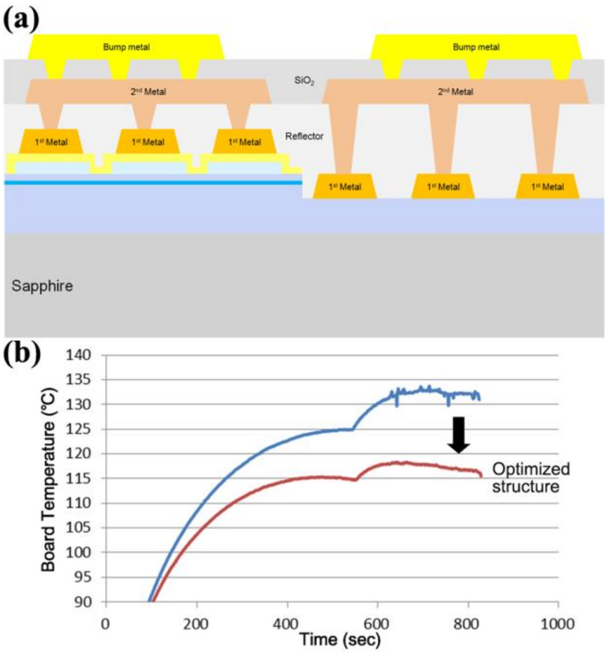

Fig.1 Cross-sectional diagram and (b) time-board temperature graph of CSP LEDs

By the structural optimization, tolerance to electric oversterss also enhanced. As showin in Figure 2, thermal resistance of metal PCB at board temeperature of 85 °C reduced from 17.8 K/W to 15 K/W by changing material of dielectric layer in the metal PCB. This observation means that thermal resistance and temperature change of CSP LEDs decrease with increasing thermal conductivity of dielectric layer. In order to increase the CRI of LED, phosphor concentration should be increased. However, as is well known, luminescence properties of phosphor are easily influenced by temperature [4]. Therefore, we investigated relation between phosphor concentration and retention rate of luminous flux under HT operating conditions. As shown in Figure 3, retention rate of luminus flux increases with increasing phosphor concentration under HT and high humidity operating condition. However, under the HT operting condition, retention rate of luminous flux decreases from certain phosphor concentration (i.e. above 160%). Therefore, to optimize the phosphor concentration, we fabricated two groups of CSP LEDs with different phosphor concentration. The CSP LED with relatively low phosphor concentraion (group A) shows better reliability and longer lifetime than that of the other group. The expected lifetime of group A is 5.7326×104 hours at confidence level of 0.9.

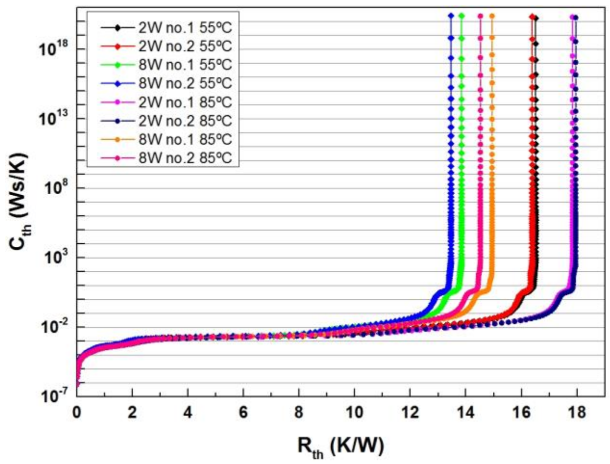

Fig.2 Thermal resistance-thermal capacitance graph of dielectric layers in metal PCB

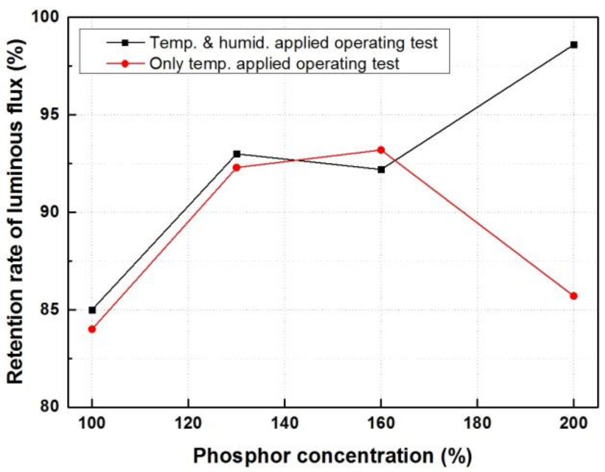

Fig.3 Retention rates of luminous flux under twi different operating conditions

4. Conclusions

We investigated thermal characteristics and reliability of CSP LEDs with high CRI (>95). By optimization of current flow, ohmic contact, phosphor concentration, and metal PCB, the thermal resistance of metal PCB reduced upto 15 K/W at board temperature of 85 °C. The phosphor shows trade-off relatonship between temperature and humidity, and exptected lifetime of CSP LED is 5.7326×104 hours.

Acknowledgment

This research was supported by the Korean government of Ministry of Trade, Industy and Energy (MOTIE) (grant no. N0002591).

References

[1] J. Fan, C. Yu, C. Qian, X. Fan, and G. Zhang, Thermal/luminescence characterization and degradation mechanism analysis on phosphor-converted white LED chip scale packages, *Microelectron. Reliab.* 74 (2017) 179.

[2] Z. Chen, Q. Zhang, K. Wang, X. Luo, and S. Liu, Reliability test and failure analysis of high power LED packages, *J. Semicond.* 32 (2011) 014007.

[3] B. Ma, C.W. Kim, K.H. Lee, W.-B. Suh, and K. Lee, Investigation on solder voids in flip-chip light-emitting diodes using thermal transient response, *THERMINIC* (2016)

[4]] Z.-Y. Liu, S. Liu, K. Wang, and X-B. Luo, Studies on optical consistency of white LEDs affected by phosphor thickness and concentration using optical simulation, *IEEE Trans. Compon. Packag. Technol.* 33 (2010) 680.