Thermal Optimization of High Power LED Arrays with a Fin Cooling System

Sun Ho Jang and Moo Whan Shin*
Department of Material Science and Engineering, Myong Ji University, 38-2 Nam-Dong, Yongin, Kyunggi, Korea 449-728.
mwshin@mju.ac.kr

Abstract- **In this paper, we describe an optimization process of thermal design for the Light Emitting Diode (LED) arrays. The thermal performance of the high power LED arrays was shown to significantly improve by the optimization process of cooling system attached with it. A fin cooling system was designed for the high power LED arrays with the input power of 60 W. The effects of design parameters such as air temperature and air velocity on the thermal performance of LED lamp were investigated.**

I. INTRODUCTION

High power LEDs keeps attracting researchers' interests due to their significant impacts on solid state lighting industry. Increase of the optical efficiency of white LEDs is making the possibility of LED application into general lighting into reality [1-3]. In particular, this report focuses on the thermal optimization of the high power LED arrays due to its significant impact on the life time of high power LED arrays. It is expected that the high power LED arrays for illumination lamp requires high power operation for high flux of light. The life time of the illumination lamp using the LED package is endangered without effective thermal design. However, there have not been any reports on the thermal optimization of cooling system for the high power LED lamp to the best knowledge of the present authors to date. In this report, we describe an optimization process of thermal design for the LED lamp which utilizes high power LED module and cooling system. This is a very important design consideration due to the very high driving power and relatively low efficiency of LEDs [4, 5]. The thermal performance and reliability of the high power LED lamp were studied as functions of the air velocity and the design of the heat sink using a Finite Volume Method (FVM).

II. SYSTEM DESIGN AND MODELING

The precise fluid field modeling and heat transfer analysis using a Computational Fluid Dynamics (CFD) solver were applied according to the practical working conditions for the LED lamp. Flotherm (V8.1, Mentor Graphics LTD) was used to evaluate the thermal performance of LED package [6]. The high power LED lamp was composed of LED, lens, main case, support rod, Metal Core Print Circuit Board (MCPCB), thermal pad, and heat sink. Original cooling system has the fin height of 7.5 mm and fin thickness of 1mm, base (MCPCB) length of 220 mm. The structure was preliminary given by the consideration of normal conditions and conventional lighting systems. In our simulation, the die attaching material was not considered and the heat was assumed to be dissipated directly from the active region of the chip to MCPCB, heat sink and then to ambient by convection. In our simulation, the ambient temperature of 25 ^{o}C and natural cooling conditions were used except when we investigate the thermal performance relationships with ambient temperature and air velocity. The thermal parameters of the high power LED lamp material were shown in Table I.

TABLE I
THERMAL PARAMETERS OF PACKAGING MATERIALS IN LED LAMP.

Materials	Thermal conductivity (W/mK)
LED chip	130
Al Case	201
Poly Methyl Methacrylate (PMMA) Lens	0.2
Al MCPCB	201
Thermal Pad	8

III. RESULTS AND DISCUSSION

There are other parameters that should be considered in the design of the cooling system [7], including fin design (thickness, height, and numbers) and MCPCB design (length, width, and thickness).

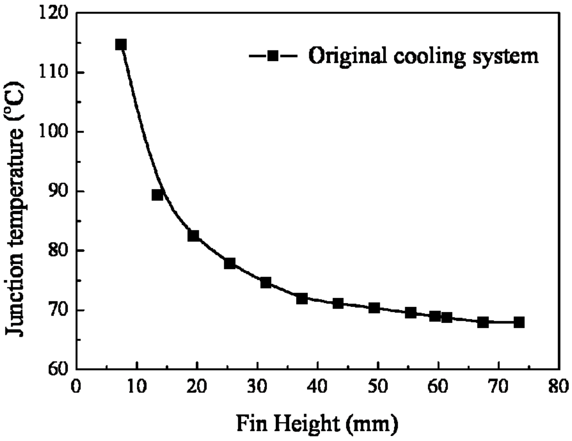

Fig. 1. Variation of junction temperatures as a function of fin height.

In this research, we investigated the effects of fin thickness, height, and MCPCB length on the thermal performance of high power LED lamp. It is well accepted that there is a trade-off between the thermally optimum solution and manufacturing and application constraints, for e.g. space limitations, weight

978-1-4244-7017-4/10/$26.00 ©2010 IEEE

restrictions and costs. In this research, we started with the parameters related with cooling fin. They are limited by space and weight of the LED lamp. The variation of simulated junction temperature with fin height is shown in Fig. 1. The junction temperature was decreased rapidly with the increase of fin height, and then reached saturation slowly. The junction temperature of LED lamp was decreased by 47 °C when the fin height was increased from 7.5 mm to 73.5 mm. These results confirmed the significant effect of fin height on thermal performance of high power LED lamp and provided an optimization data base. Considering the limited space of the LED lamp system, the fin height of 50 mm was selected as an optimized parameter.

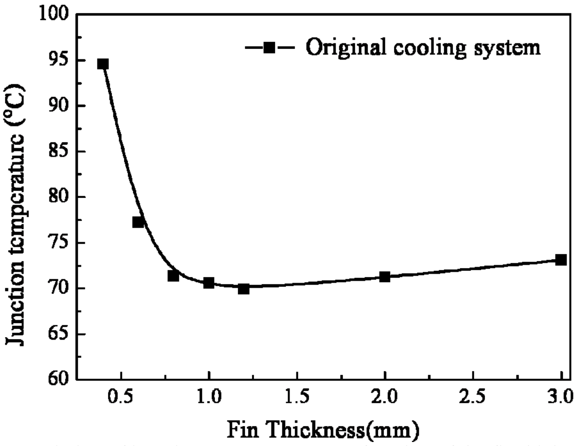

Fig. 2. Variation of junction temperatures as a function of the fin thickness.

The simulated junction temperature variation with the fin thickness was shown in Fig. 2. It can be seen that the minimum junction temperature was obtained when the fin thickness is equal to 1.2 mm in the fin thickness range of 0.1~3 mm and 1.2 mm was used for the thermal optimization process.

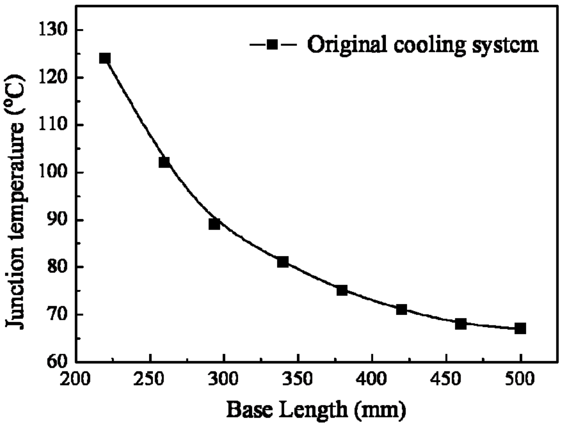

Fig. 3. Variation of junction temperatures as a function of base length.

Fig. 3 illustrates the junction temperature variation with base length. In the simulation, the MCPCB width was set to a fixed value (38 mm) due to space limitation caused by the system dimension. Thus, the surface area of the MCPCB was decided exclusively by the base length. As expected, the LED junction temperature was decreased with the base length. The junction temperature of high power LED lamp was decreased to about 60 °C when the fin height was increased from 220 mm to 500 mm and the length of 350 mm was considered as the optimized value considering the space limit of the system. The thermal performance of novel cooling system was simulated using the optimized fin thickness, height, and MCPCB length. Fig. 4 shows the thermal performance of LED lamp with original and optimized cooling systems. The junction temperature of high power LED lamp with the optimized features was decreased about 30 °C compared with the original design at 60 Watt operation. At natural cooling condition, the junction temperature with optimized cooling system was found to be much lower compared with the original cooling system.

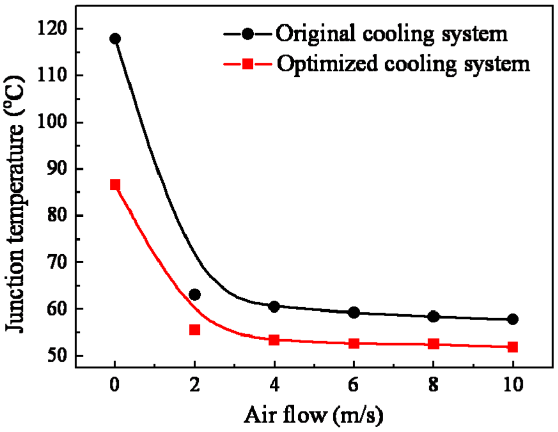

Fig. 4. Thermal performance of the LED lamp with original and optimized cooling system as a function of air flow.

IV. CONCLUSION

In this paper, thermal optimization process of high power LED lamp was demonstrated. The thermal performance of the LED module was shown to significantly improve by the optimization process. The simulation results showed that the introduction of fin and base parameter beneath the high power LED lamp could lead to a significant reduction of maximum junction temperature of the LED package.

ACKNOWLEDGMENT

This work was financially supported by the Korea Energy Management Corporation.

REFERENCES

[1] Ivan Moreno and Rumen I. Tzonchev, Proceeding of SPIE, Bellingham, WA., vol. 5529, no. 268, 2004.
[2] Lianqiao Yang, Jianzheng Hu, Sunho Jang, and Moo Whan Shin, Semicond. Sci. Technol., vol. 22, no. 705, 2007.
[3] Lan Kim and Moo Whan Shin, IEEE Trans. Component and Packaging Technology, vol. 30, no. 4, 2007.
[4] A.Miner and U.Ghoshal, Applied Physics Letters, vol. 85, no. 506, 2004.
[5] N. Narendran, Y. Gu, J. P. Freyssinier, H. Yu, and L. Deng, J. Crystal Growth, vol. 268, no. 449, 2004.
[6] Mentor Graphics Ltd., FloTherm TM 8.1 Instruction Manual 2009.
[7] Karimpourian, B. and Mahmoudi, J., Proceeding of the 6th EuroSimE Conference, pp. 406, 2005.