International Communications in Heat and Mass Transfer 38 (2011) 1206–1212

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Thermal investigations on LED vapor chamber-based plates ☆

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ARTICLE INFO

Available online 12 July 2011

Keywords:
LED
Vapor chamber
Illumination
Thermal performance

ABSTRACT

This study utilizes a thermal-performance experiment with the illumination-analysis method to discuss the thermal performance of three kinds of LED based plates comparing the experiments, theories, and simulation thermal resistances. The results show that the thermal performance of the LED vapor chamber-based plate is better than that of the LED copper-based plate with an input power above 5 W. And the experimental thermal resistance values of LED copper- and vapor chamber-based plate are 0.41 °C/W and 0.38 °C/W at 6 W respectively. And the illumination of 6 Watt LED vapor chamber-based plate is 5% larger than the 6 Watt LED aluminum-based plate. Thus, the LED vapor chamber-based plate has the best thermal performance above 5 W.

1. Introduction

Since the 20th century, luminescence technology has the highest merit among the technologies of artificial illumination lamps. Its continual development has resulted in many advantages, including energy savings, small packaging, light weight, anti-vibration and long lifetime [1]. Based on the two semiconductors of the IV chemical family elements Germanium (Ge) and Silicon (Si), the Solid-State Light Emitting Diode (SSLED) has attracted attention. LED employs the electrode contact along with voltage in order to enable the electronic jumping and the energy gap release of the light form, which is the illumination diode, composed of P-type and N-type semiconductors. Because of difference between energy gaps, if the light wave length belongs to the visible light scope, it is visible to the human eye. A typical single LED power package has a surface area of 1 mm^2 with a total heat power of 1 W. With high-luminance or high-power LED, the heat generation is above 1 W for a single LED die [2,3]. Nowadays, Thermal Management and Control (TM&C) is one of the major issues related to high-power LEDs. This is because depressing the luminous efficiency (Lm/W) and the lifetime of the P–N composition plane junction temperature (T_j) surpasses 60 °C [4]. The junction temperature immediately influences LED luminous efficiency and quality. Higher temperature reduces the luminous flux output and brightness, and also affects the wave length of photons, changing LED illumination color and lowering the lifetime [5]. Thus, in practical luminous systems, multiple high-power LEDs must be assembled using a system for heat dissipation of several Watts or more in order to carry out further applications. This kind of system yields high heat flux to dissipate through the heat transfer path of the base plate.

Single high-power LEDs usually have heat flux of above 100 W/cm^2. Fast dissipation of the quantity of heat flow from the LED based plate conduction to the exterior surroundings through the thermal module may increase the luminance and lifetime of LEDs [6–8]. This serious thermal concentration results in a hot-spot phenomenon. Currently, LED based plates may be divided into the following five kinds. 1. PCBs (Printed Circuit Board) are usually composed of fiber glass and an epoxy resin material (FR4), with thermal conductivity of about 0.36 W/mK and a thermal-expansion coefficient of about 15 ppm/K. The merit of this type of LED is that the technology is quite mature and the cost is low. The shortcoming is that the poor thermal performance resulting in low power (far less than 1 W). 2. MCPCBs (Metal Core Printed Circuit Board) are attached by a metal plate (Aluminum- or copper-thin plate) to increase thermal conductivity in the PCB. The merit of this type of LED is that the contact surface temperature of a MCPCB is far lower than that of a PCB. Its shortcoming is that it still has low thermal conductivity because of the dielectric material level. 3. IMSs (Insulated Metal Substrate) create a legal system (insulated level) by accumulating high polymer dielectric level etch copper foil electric circuits or printed circuits. This is done by the adhesive direct bonding on the aluminum- or copper-plate. Thus, there are no PCB/FR4 materials between them. The thermal conductivity of its dielectric level is about 1.6 W/mK. 4. CSs (Ceramic Substrate), no matter with MCPCBs or the IMSs by the metal plate (Al, Cu), take the heat conduction way. However, the metal plate itself has electric conduction. Therefore, the metal plate surface needs to be coated with a high polymer dielectric material level. This makes the LED based plate directly sinter thermally ceramic material, because the insulated material itself does not have the dielectric level. Moreover, its thermal conductivity is about 200 W/mK, the thermal-expansion coefficient is about 4 ppm/K and it has a good thermal performance. However, the shortcoming of this type of LED is its high cost with the

☆ Communicated by W.J. Minkowycz.

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doi:10.1016/j.icheatmasstransfer.2011.07.002