Modeling and simulation of LED optical component to enhance light extraction efficiency

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Abstract- A simulated model consists of chip-on-board (COB) packaged light emitting diode (LED) array with silicon resin based optical component was built. The principle of the simulation was to investigate the roles of optical component feature play in light extraction efficiency (LEE) by adjusting shape and size of the component to obtain maximum optical output power. Since cylinder resin based optical component is commonly seen in COB packaged LED product, such geometry was chosen and optimized in the simulation. In addition, micro lens array was applied to further improve the performance and it has been found that such design is an effective approach to improve LEE of LED.

I. INTRODUCTION

The past few years have seen remarkable progress in the GaN material system, chip fabrication and packaging. GaN-based LED is becoming a promising candidate in many applications including illumination applications and full color display [1]. In contrast with incandescent and fluorescent lights, LED has numerous advantages such as environment friendliness, low power consumption, high efficiency, small size, long lifetime, and reliability[2]. Though great success has been achieved in the performance of the device, there are still critical issues and challenges needed to be overcome to improve the performance of the device [3][4]. This makes it desirable to increase the internal quantum efficiency (IQE) and LEE [3-6]. As far as LEE is concerned, one of the main drawbacks of LED technology is that the greatest part of light generated in the device is not able to escape [7]. Generally speaking, refractive indices of semiconductor layers of LEDs are relatively higher than that of LED encapsulate, such as epoxy and silicone resins. In this case, light generated from the active layers are trapped and prohibited from extraction due to total internal reflection at the interface between the device and ambient [8]. As a result, the out-coupling efficiency of the LED is insufficient and enhancement is desired. To reduce the problem of light trapped in the high index semiconductor and to enhance the light extraction, numerous works[6][8][9]have been done to optimize LED package for higher performance. One of the approaches is to optimize optical components of LED package.

II. SIMULATION WORK

In this work, a simplified but reasonable LED model was built by utilizing the software named TracePro. Simulation based optimization of LED optical component was then developed to enhance LEE of the light source. As illustrated in Fig.1, a 3×3 LED array was packaged onto a square substrate with dimension of 2cm. In addition, the upper surface of the packaging substrate was set as perfect mirror in our simulation. In other words, light loss at the reflective substrate is zero. The parameters of each LED die used in the model are the following: each LED in the array has a dimension of 1×1mm, with 1mm space between each die.

Fig.1 Top view illustration of our LED package model (a) with and (b) without micro lens array.
Therefore, the dimension of the LED array is 5×5mm. For the convenience of comparison and calculation, the optical output power of each LED in the array was assumed to be 1W. The package material for making optical component in the simulation was silicon resin with a refractive index of 1.4935, which is a fixed constant in the software for simulation. Encapsulated lens in the model was set to be cylinder, meaning the light source has a flat top surface. Such design is commonly seen in COB packaged LED light source. The principle of the simulation was to investigate the roles that geometry of the optical component plays in LEE of the light source. Therefore, thickness and radius of the silicon resin based encapsulated lens were adjusted to find the maximum total optical output power of the LED array. Since each LED die in the array has an output power of 1W as mentioned previously, the ideal case is that the maximum output power of the array is 9W. Hence, an optimized design would give an output power as close to 9W as possible. First of all, silicon based lens with thickness of 0.5mm and a range of radius was applied onto the LED array to determine the optimal lens radius. As shown in Fig.2a, the highest optical power is 7.53W and the radius is 9mm at this case. Secondly, the lens with radius of 9mm was chosen to determine the optimal lens thickness, which is 0.5mm, as illustrated in Fig. 2b. Thirdly, concave and convex micro lens array with different spacing was applied onto the cylinder lens respectively to further improve LEE of the light source. As a result, the highest obtained power was 8.32W thanks to the application of micro lens array.

III. CONCLUSION

In summary, a simplified model was built to study the influence of optical component geometry on the performance of a LED array. The output power of the array with different optical component and micro lens array was measured and compared respectively. The micro lens array further improves the optical output power by over 10%. Therefore, it can be concluded that optical component with appropriate geometry is an effective approach to enhance optical performance of LED light source.

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References


