A New type 1.0 mm x 0.5mm Light Emitting Diode using AlInGaN cell structure and Its Display Module

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Abstract

The main goal of this work is to fabricate light emitting diode (LED) module and apply it to mobile handset. We first fabricated the blue-color LED based on the AlInGaN cell structure with size of 200 µm × 200 µm. Also we proposed a new 1.0 mm × 0.5 mm (1005size) packaging procedure for the LED cell. Thus the overall dimension of our LED cell was as small as 1.0 mm × 0.5 mm × 0.4 mm (W × L × T). As far as we knew it was the first time that this small LED cell dimension had been fabricated and operated.

1. Introduction

The light emitting diode (LED) is a basic element for many electronic devices and industrial applications such as liquid crystal display (LCD) TV's, mobile applications and light source of illumination devices [1]. Especially, the overall performances of mobile applications are highly dependent on the LED design. Many researchers have studied to fabricate the smaller LED because it has a simple structure and thereby can provide useful device for human life. Nowadays, most of personal mobile phones use the LED for LCD display backlight unit and numeric key lighting. The most widely used LED in such applications is a *1.6 mm × 0.8 mm (1608size) LED* [2].

Currently we attempted to develop a new light emitting diode with smaller size, *1.0 mm × 0.5 mm (1005size),* for display applications, which is the smallest size among commercially available LEDs. To implement the 1005size LED we fabricated the *200 µm × 200 µm AlInGaN* cell structure and proposed a new packaging procedure for it. In addition, we also designed a new control integrated circuits (IC) with MAXIM Dallas for mobile handset application.

2. Experimental

A New type *1.0 mm × 0.5 mm* size packaged LED technology is almost significant of dice cell structure stability and fabricated procedure in this work. We will describe of developed new type *1.0 mm × 0.5 mm* size LED and its using displayed mobile application method. Fig.1 shows we proposed *200 µm × 200 µm* cell structure using *AlInGaN*. This bare dies are quite small size structure. In addition, we applied a top surface emitter method for *AlInGaN* bare dies.

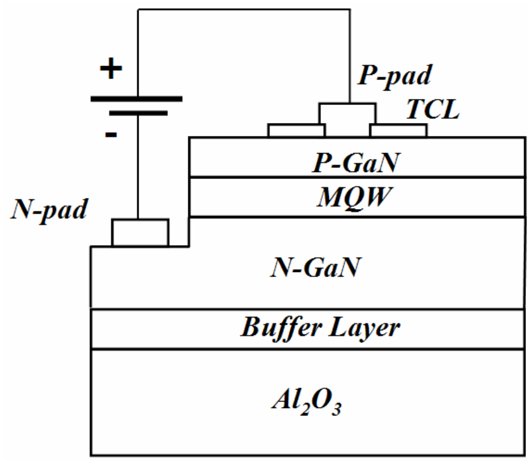


Fig. 1. Structure of blue-color LED by *200 µm × 200 µm* cell die

200 μm × *200 μm* cell dies are composed of Al_2O_3 substrate, buffer layer, *N-GaN* layer, Multi-Quantum Well layer and *P-GaN* layer. *N-GaN* is grown above the buffer layer on Al_2O_3 substrate. N-pad, negative bias, locates in *N-GaN* layer. On the other hand P-pad, positive bias, locates in above *P-GaN* TCL layer. MQW layer is placed in between *N-GaN* layer and *P-GaN* layer. Fig.2 shows that the new type *1.0 mm* × *0.5 mm* blue color-LED array module.

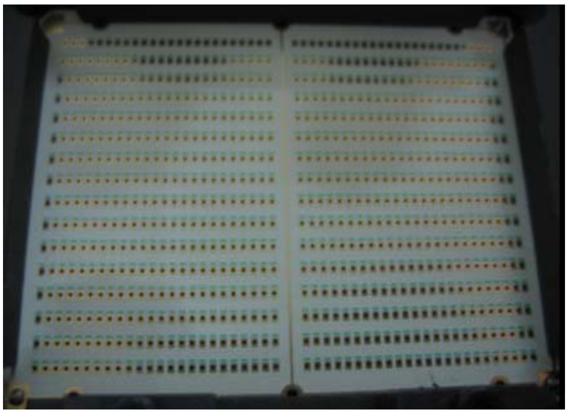


Fig. 2. Photograph of *1.0 mm* × *0.5 mm* blue color-LED array module

As shown in Fig.3, the cathode and anode are composed of a *Gu* material, It shown wire bonding process complete to silver filled and die attached process. We found a defect of inrushing solder cream into *200 μm* × *200 μm* dies at our first try. The reason was unconsidered surface mount condition and the amount of solder cream. Thus, we concentrated on those conditions. We tried several times of pilot samples and finally the problem was fixed by design-change of electrode pad.

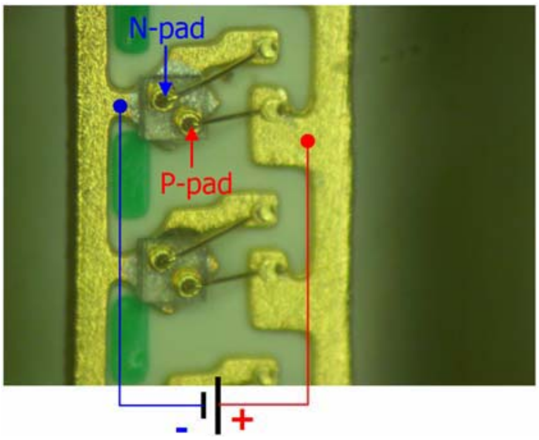


Fig. 3. Bare LED image of *1.0 mm* × *0.5 mm* blue-color LED array including *200 μm* × *200 μm* dies

Fig.4 shows the simple fabrication process. The overall chip size is *1.0 mm* × *0.5 mm* × *0.4 mm*. In this process, the LED size is the most significant, which has an important difference from the previous design *1.6 mm* × *0.8 mm* × *0.4 mm* LEDs. It has significant meaning in two points. Firstly, it can be easily applied to diverse industrial parts. Second, *1.0 mm* × *0.5 mm* white color-LED is possible. It can be with the same die and the same fabrication process. *1.0 mm* × *0.5 mm* white color-LED technology is available by changing the mold- material properties ratio. That is an enormous advantage in this work. Fig.4 shows the fabrication process. We have accomplished all process. Firstly, dispensing process carry out of die wire bonding on substrate and baking Fig.4 *(a)* to *(g)*. Secondly, encapsulating process is shown Fig.4 *(h)*. Initially we applied of *8524H* epoxy however it was found a defect between substrate and mold. Therefore, we changed to *8523* epoxy instead of *8524H* to improve mold adhesion. Thirdly, we have post curing process, applied temperature is *150 ℃±10 ℃*, baking time is *4hrs* and *Sn* pad plating Fig.4 *(i)* to *(k)*. Lastly, we have sawing process its need of removed burr problem. We adjust the sawing moving blade speed and moving blade current, blade rotate speed is *3,000rpm* at blade thickness *0.1mm* and moving current adjust *85mm/sec* to *90mm/sec*.

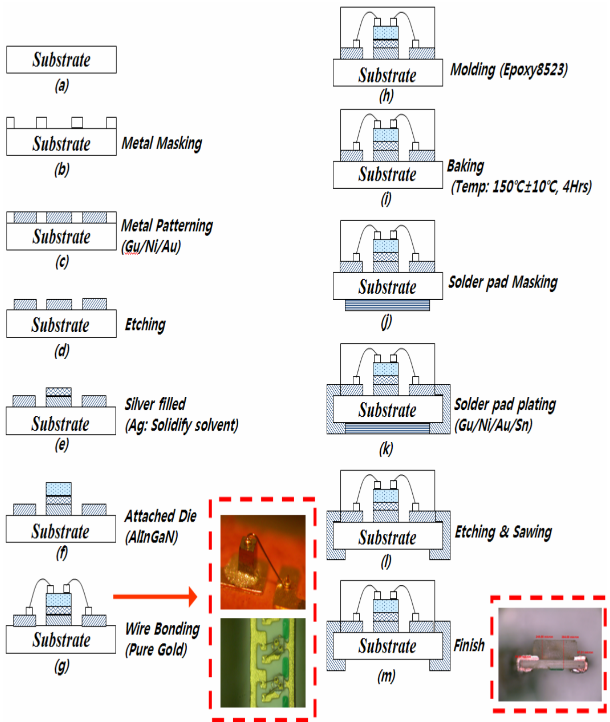


Fig. 4. Process of the experimental procedure for this work

3. Results and discussion

An experiment was performed to verify the feasibility of the proposed method. We proposed electrical forward voltage of *1.0 mm* × *0.5 mm* blue color-LED is *2.7V* at forward current *2mA*. The operating voltage range is *2.5V* to *3.0V* at *2mA*. The color Bin range is minimum *18mcd* to *28mcd* at *2mA*.

Fig. 5 shows an actual structure of *1.0 mm* × *0.5 mm* blue color-LED used *200 µm* × *200 µm* die cell.

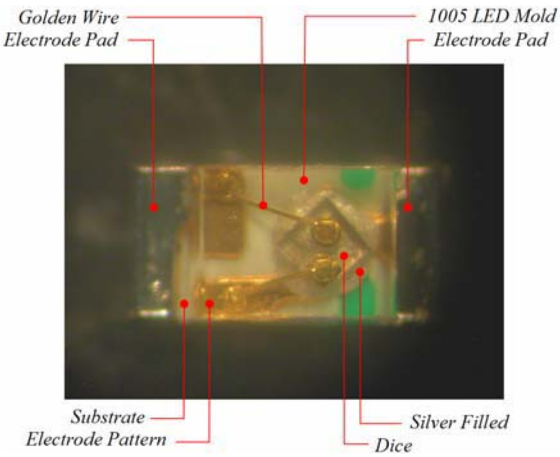


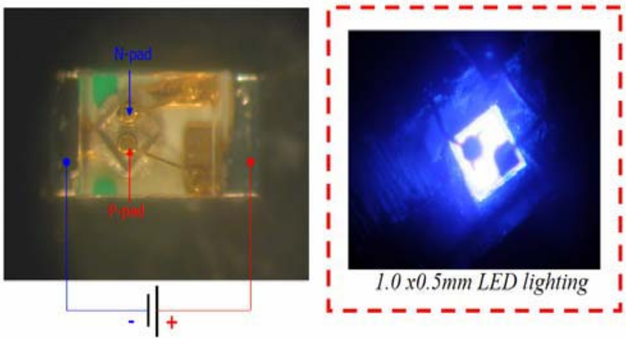
Fig. 5. An actual structure of *1.0 mm* × *0.5 mm* blue LED.

Table.1 shows the material description of each inner layer about the new type *1.0 mm* × *0.5 mm* size packaged LED. In addition to, with this technology it can be easily introduced *1.0 mm* × *0.5 mm* white color-LED. It can be used not only the same die but also the same fabrication process. In fact, the technology, adding YAG materials in mold section, is a general technology [3]. However, nobody tried to *1.0 mm* × *0.5 mm* chip type white color. It is a significant aspect.

Table1. Material description of each Inner layer section about *1.0 mm* × *0.5 mm* blue LED.

Section	*Raw Materials*
Substrate	*PCB*
Electrode Pad	*Gu/Ni/Au/Sn*
Electrode Pattern	*Gu/Ni/Au/*
Silver filled	*Ag/Solidify solvent*
Dice	*AlInGaN*
Wire	*Pure Gold*
Molding	*Epoxy8523*

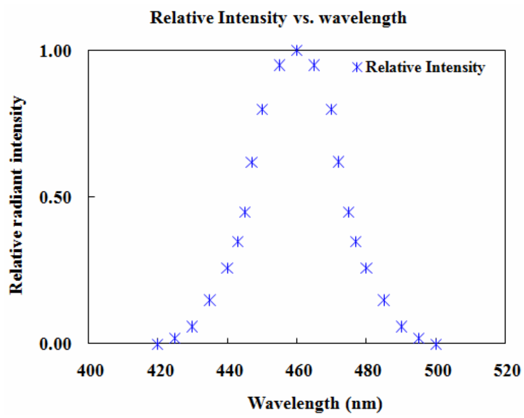
Fig. 6 shows a uniform emission from *1.0 mm* × *0.5 mm* size packaged LED nominal operated at *2.7V*.



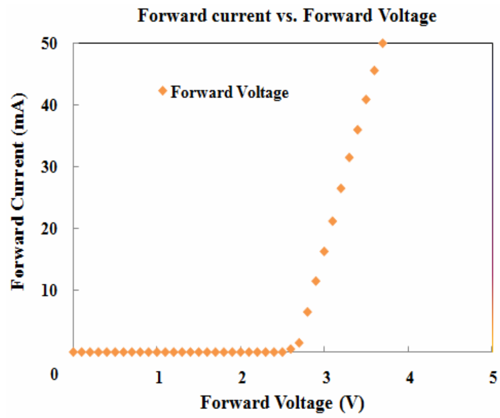
(a) 1005 LED polarities (b) 1005 blue LED emission

Fig. 6. *1.0 mm* × *0.5 mm* blue LED polarities (a) and Emission image (b).

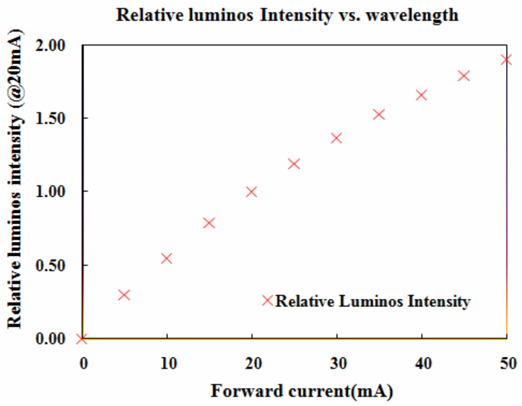
Fig. 7 shows the optical and electrical ratio characteristics at supplied voltage *3.0V*. Fig.7 (a) is characteristic of relative intensity versus wavelength. We proposed wavelength result of between *420nm* and *500nm*. Fig.7 (b) is a ratio of operating forward voltage versus forward current. Fig.7(c) shows luminous intensity versus wavelength.



(a) Relative intensity versus wavelength.



(b) Forward current versus Forward voltage.



(c) Luminous Intensity versus wavelength.

Fig. 7. Emission characteristics of *1.0 mm* × *0.5 mm* blue LED as a function of 3.0 applied voltage.

Fig.8 shows the photograph of 16-segment customized display module applied to mobile display. It consists of *80pcs* of *1.0 mm* × *0.5 mm* LEDs. We propose *5d*igits with *16*segments on the *FR-4* type printed circuit board.

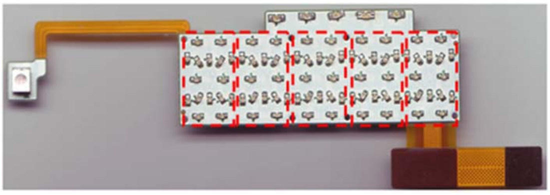


Fig. 8. An actual structure of 5 digits, 16 segments customized display module in mobile application.

The original interface control IC size was *12 mm* × *10 mm* and operating voltage was *4.5V*. However it can't be applied to mobile application. Therefore, we proposed *6 mm* × *6 mm* new packaged IC has *3.5V* nominal operating voltage with MAXIM Dallas [4]. Fig.9 shows real mounted photograph of *6 mm* × *6 mm 16*segments IC.

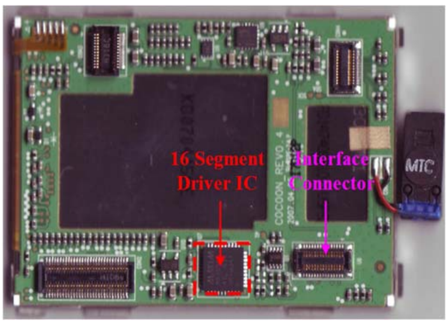


Fig. 9. Real mounted photograph of 16 segments control IC with I^2C controller and applications.

4. Conclusion

Fig.10 shows the realized display image used of *1.0 mm* × *0.5 mm* LEDs in mobile application. We suggested *1.0 mm* × *0.5 mm* LED display module showed a good performance in a dark environment and night. It has advantage of long visibility range. Moreover, it can be possible real-time displaying at incoming call, scrolling music title and alarm function. As a result, our suggested and developed *1.0 mm* × *0.5 mm* LED is successful task; we expect to meet it in more industrial applications and personal mobile applications.

Fig. 10. Incoming call scrolling text image at applied personal mobile handset.

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6. References

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