Experimental study on luminous intensity of white LEDs of different configurations

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Abstract. The relationship with input voltage to the light intensity at constant current supply of four (04) separate white LEDs containing different number (5, 9, 13 and 27 pcs) of SMD chips are investigated in this research. Voltage between 10 and 16 volts is applied to LED lights at constant current supply. The light intensity produced by the LEDs was measured. Light intensity was found linear related to the voltage. The phosphor coating over the chips are also observed by microscope and found that the light intensity has an important impact on phosphor coating. The light intensity found lower than the expected due to the non-uniformity of phosphor coating. Keywords: luminous intensity, light intensity, white LEDs.

1. Introduction

A light-emitting diode (LED) is a semiconductor that allows only one direction of current flow. It is a p-n junction diode (shown in Figure 1). There are extra electrons in the n type atoms and electron holes in the p type atom. The current moves the atoms to the junction. While the n-type atoms become close, they 'donate' their additional electrons to the p-type atoms. Negative charge on the n-side causes a current to flow from the (-) charged region to the (+) charged region, which is known as the 'forward bias'. As additional electrons of n-type material fall through the holes in the p-type material, they emit light energy (photons)\textsuperscript{[1][2][3]}. LEDs vary from traditional light sources, including neon, flickering and gas discharge lamps. LEDs light up very quickly. It is useful for battery driven or energy-saving devices and produces more light per Watt than incandescent watts\textsuperscript{[4]}. LED manufacturing industries are also in competition to supply quickly to meet up the demand.

Figure 1. A circuit diagram of semiconductor chip
But it is very important to maintain the quality of LEDs. By maintain the proper manufacturing process, we can deserve the best possible LEDs only. Usually a layer of phosphor is dispersed over chip surface. The layer of phosphor absorbs some blue light from a blue LED chip and emits yellow light, so that white light is produced as a mix of the yellow light and blue light [5]. The quality of white light is responsive to placement and uniformity of phosphor. It has been studied that phosphor can significantly improve the total light intensity and luminous capacity of white LED [6][7][8][9].

The phosphor is spread inside an epoxy adhesive that covers the LED die or chip of most consumer LED packages. Standard commercial white LEDs provide poor overall illumination intensity and light efficiency, which in general lighting applications must be enhanced significantly. Though the industry have specific luminous intensity target [10]. The purpose of this work is to verify the luminous intensity of several commercial white LEDs containing separate number of chips from the same manufacturer with respect to known values. Another objective of this work is to find out the reasons of unexpected luminous intensity.

2. Experimental procedure
The photographic view of the experimental set-up is shown in Figure 2. The SMD type four (04) white LEDs containing 5,9,13 and 27 pcs SMD chips respectively are prepared as test specimen for our experiment. The mentioned LEDs are noted as Specimen-A, B, C and D respectively. To maintain the constant current supply, a laboratory DC power supply unit is attached with this set-up. Well centred light holder is used with the integrated sphere of the spectrometer. The experimental set-up is calibrated by lighting a LED with a known luminous intensity. The light output of white LED can be increased by applying proper phosphor layer thickness and concentration. Yet higher thickness and concentration often contribute to warm light instead of white light. [11]. Keeping these facts in view the commonly used white LEDs from same manufacturer has been undertaken for the proper investigation.

![Figure 2. Experimental setup for measuring Luminas intensity](image)

When left on for a duration of one (01) minute, the light intensity of the LED decreases considerably. The LED are kept turn off at least five (05) minutes between measurements to
control this variation. The reading is taken for seven different voltages (10 to 16V) remaining the constant current. This cycle is repeated for every LEDs. The microscopic views of phosphor coating surface for each LED is observed by a digital microscope also.

3. Results and Discussion

Remaining the constant current supply, the luminous intensity (Lux) is measured for each LEDs. The voltage applied to the LEDs are 10 to 16V. Fig-3 shows the relative graph representing obtained Lux for each LED with voltage variation. The graph shows that Lux is linearly increased up to a voltage of 14 V. At 15 V, the data point lies below the linear fit but for Specimen-D, the maximum intensity obtained at 16V. This implies that the LED can be more effective just above the activation voltage, although further tests are required to confirm this.

![Figure 3. Lux vs input voltage relations curve for different LEDs](image)

The comparison between the maximum Lux as per specification and experimentally measured are noticeable (shown in Table-1). Interestingly, the experimental value becomes higher than the specification for Specimen-A. But all other Lux values are lower than specification. Specimen-B shows the nearest value of Lux as per known lux.

| Specimen | LED Type | Maximum Lux (as per specification) | Maximum Lux (actually measured) |
|----------|----------|------------------------------------|---------------------------------|
| A        | 5 pcs SMD | 1500                               | 1670                            |
| B        | 9 pcs SMD | 2700                               | 2580                            |
| C        | 13 pcs SMD| 2900                               | 2390                            |
| D        | 27 pcs SMD| 8100                               | 6800                            |

The light intensity depends on the LED Chip material, die attachment, wire bonding, junction temperature, phosphor coating, encapsulations quality etc. The variation might be occurred due to all of them. The manufacturer cannot produce all the products are in same batch, so the variation is normal in sense if it is not properly maintained the standard manufacturing process.
Figure 4 (a), (b), (c) and (d). LED Specimens with microscopic view of each chips coated with phosphor

The value of Lux should higher if the number of chips is higher. Figure-4 shows the microscopic view of phosphor coating surface over the chips of each LED. Based on this view, specimen A and B have a good concentration of phosphor, even the coating thickness is also acceptable as per visual observation. But for the Specimen-C, phosphor concentration is lighter than others, though D is better than C but lighter in concentration than A and B. As all the LEDs are collected from same manufacturer but due to variations in phosphor coating the values of Lux is not like estimated values. To investigate more details, the thermal and optical analysis is to be studied broadly.

4. Conclusion
Enhancing the light output of white LEDs is often desired and can be accomplished by increase of input voltage and current or concentration of phosphorus and thickness of layer. Although these methods increase the output, the White-LEDs also have reliability effects. All potential causes of such reduction or change in light intensity should be investigated in detail. Die attachment and wire bonding process also strongly affect the light output and electrical operating conditions for LEDs, and thus should be considered carefully in a product design. Commercial manufacturer should more conscious about the product quality with considering the market demand.

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6. References

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