Thermal Characteristics: Gap of LED Devices and LED's Lighting Application

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Abstract

The efficacy and its degradation of light emitting diode(LED) are related to its PN junction's temperature(Tj). Currently efficacy in certain temperature and thermo-resistant are defined for the depending. However, the definitions are quite inconvenient for lighting application. The paper focuses on the issue and presents a method to evaluate the thermal characteristics of LED efficay.

1. Introduction

Recently LED is very hot in the filed of lighting due to its advantages, of which potential high efficacy is greatly attracting, especially when the global is more and more facing shortage of energy. Theoretically luminous efficacy of radiation is more than 300lm/W for white LED spectrum[1], this value exists when its external quantum efficiency is 100%. Currently efficacy of commercial high power LEDs ha s approached 90lm/W, and that of laboratory samples has reached 132lm/W[2]. Optimistically the efficacy is increasing rapidly, this makes LED a bright future in general lighting application.

There are many requirements for a light source to be used for general lighting. Light degradation is another one besides efficacy. It is especially important for LED since it depends on PN's Tj substantially, and the temperature increases inevitably when it works. Furthermore, the increase of Tj causes the luminous efficacy decrease. Therefore, we must design luminaire reasonably to keep Tj in low value. On the other hand, the thermal characteristics to evaluate the relationship of LED's efficacy and Tj is also very essensial for LED application in general lighting. There are several definitions to express thermal characteristics concerned to luminous parameters, but they are not convenient for lighting application. The paper analyzes the problem and suggests a new definition.

2. Experiment on thermal characteristics of LEDs

Actually, three specifications relate to Tj of LED: efficacy, luminous flux and peak wavelength. We would like to investigate the case of efficacy. we tested samples from different manufacturers in 350mA with same size heat radiator and recorded the temperature, forward voltage, and the luminous flux.

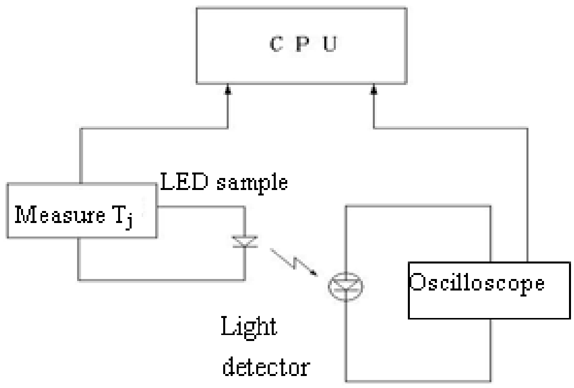

Fig.1 Set-up for thermal experiment

setup is shown in figure 1. Figure 2 is typical curve of forward voltage and luminous flux versus time after LED is burnt. We note that the data are stable after

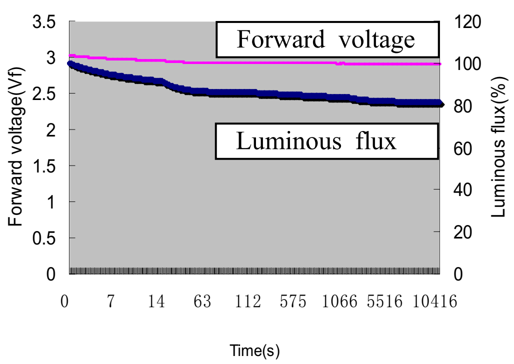

Fig. 1 Forward voltage and luminous flux versus time

LED is burnt for about 3 hours, the degradation of forward voltage and luminous flux are 3% and 20% respectively, it means the efficacy of LED decreases 17%. The degradation of luminous flux is far bigger than forward voltage (thus power), thus we may think approximately the degradation of luminous flux is the degradation of efficacy.

Six samples from different manufacturers were tested in same size heat radiator and 350mA stable current for about 3 hours at ambient temperature of 25℃, light degradation and increment of T_j were recorded

Tab.1 Light degradation and Increment of T_j

sample	light degradation(%)	Increment of T_j (℃)
1	89.94	50.8
2	90.34	60.5
3	90.76	54.8
4	83.23	63.8
5	95.86	42.4
6	85.56	46.3

3. Discussion on existing nomenclatures on thermal characteristics of LEDs

There are some nomenclatures to define thermal characteristics of LED products.

(1) Efficacy in pulse current

Efficacy in pulse current is used often. The luminous flux depends on Tj, which increases after LED is burnt. Therefore, to avoid the effect of temperature change, a very short, often less than 1ms, pulse current is used to burn a LED, the temperature increasing during the short time can be neglected, luminous flux during burning is measured to calculate its efficacy. This definition is easy for measuring on production line, but is problematic for lighting application. We may assume that luminous flux measured in pulse current is approximately equal to the data measured at very beginning by the method introduced above in item 2, but we care about the dataafter it turn on enough long time when LED is used for lighting application, these two data are different in ratio of light degradation. If the ratios are same for all products, then efficacy in pulse current is not perfect but useful for lighting design. Unfortunately, the ratios are quite different, range from 80% to 96% on our experiment. This shows that efficacy in pulse current is not good definition for LED when it is used for lighting application.

(2)Efficacy@T_j

Efficacy of LED is dependent on Tj, therefore, we must specify Tj when we talk about efficacy, this seems absolutely correct. However, from table 1, we note that at nearly same condition (there is a little different on power) the increments of Tj are different for each sample. This means, when we compare efficacy of LED, especially those from different manufacturers, we must assure they operate in same Tj and thus different condition (heat radiator mainly), this is unfair. Furthermore, we must change heat radiator (and thus luminaire) design when we want to replace LED in a luminaire with a new type, this is also not good.

(3)Thermal resistant

Considering the efficacy is depending on Tj, as addition to the nomenclature of Efficacy@Tj, thermal resistant is defined. It is true that Efficacy@ Tj plus thermal resistant is enough to express LED's luminous characteristics (the paper does not discuss the light degradation concerned to lifetime). However, Tj and thermal resistant is internal parameter and are not easy to be measured. This is not convenient for luminaire design.

4. Suggestion on nomenclature on thermal characteristics of LEDs

Basing on discussion above, we would like to suggest a nomenclature on LED's efficacy: at a ambient temperature, 25℃ often, LED sample is attached to a standard heat radiator with very low thermal resistant between them, driven by rated DC current, and measure its luminous flux after it lights on enough long time.

A problem exists in the definition: what is the standards heat radiator? We think it should be proportional to the power, since generally same power luminaire has same size in heat radiator.

5. References

(1 line spacing)

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