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An Experimental Study on the Life Time of Commercially Available White pcLED For Indian Standards

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Abstract: White phosphor converted LEDs (pcLEDs) are important device for solid state lighting applications. It is found that at a higher ambient temperature, as expected in tropical countries like India, life of LED shortens even with the prescribed rated current. So it is important to estimate the 'useful life' of such devices under specified ambient conditions. In the present paper, lumen depreciation characteristic of commercially available 5 mm white pcLED are experimentally studied at 45°C ambient temperature for two different forward currents, one at rated value and at a value lower than that. The results clearly show that for higher forward currents, the 'useful life' of such device is lowered. The degradation increases with the increasing value of drive current. It is also to be noted that the change that occurs in the LED is an irreversible permanent change. If the current is more, the depreciation is faster and vice versa. So in order to have a longer 'useful life', the forward current through the LED must be set at lower values at a particular ambient temperature suitable for tropical countries like India, for these LEDs.

Keywords: White pcLED, Junction Temperature, 'Useful Life'.

1. INTRODUCTION

There are different test procedures for determining the 'Useful Life' of white pcLED. The procedure recommended by Illuminating Engineering Society of North America (IESNA), which is based on the Alliance for solid state Illumination System and Technologies (ASSIST) recommendation, has become a general standard. But when we are using these pcLEDs in a tropical country like India, where temperature sometimes goes up to 45°C, the suggested life time for LEDs varies widely. So in this paper we would like to suggest that, with the change of temperature and application, i.e. whether the LEDs are being used in a system like a array of LEDs or not, if we want to keep the 'Useful Life' of pcLEDs stable, we have to make necessary modifications with the forward current.

2. FACTORS EFFECTING USEFUL LIFE

It is reported in [1] that there may be a wide variation (> 400% for 3.4 volts forward voltage) in the forward current of 5 mm white pcLED with same forward voltage for LEDs from two different manufacturers. Each LED is characterized by absolute maximum ratings for forward current which appears to be on an average 30 mA for most commercially available LEDs. However, this rating is specified at a particular value of ambient temperature. If the ambient temperature is raised, then the value of forward current needs to be de-rated appropriately for reliable operation of the device. It is evident that the forward current should be limited to 20 mA for use up to 50°C. This temperature is chosen with reference to the maximum ambient temperature of tropical countries like India. In order to have a reliable operation of white pcLED, it is therefore necessary to maintain suitable constant current through the device rather than a constant voltage as per [1] and hence a suitable constant current drive circuit should be used.

Heat dissipation from LED and hence its junction temperature is a very important parameter so far as the useful life of LED based system is concerned [2] – [4]. Three things affect the junction temperature of an LED: drive current, thermal path, and ambient temperature. In general, the higher the drive current, the greater the heat generated at the system. Heat must be moved away from the system in order to maintain expected light output, life, and color. The amount of heat that should be removed depends upon the ambient temperature and the design of the thermal path from the system to the surroundings.

System manufacturers generally quote the same life value for their lighting systems that the LED manufacturers estimate for a single LED. The life of a Led system can be much different compared to the life of an individual LED tested under standard conditions as the system packaging, ambient temperature and junction temperature can affect system life. Different types of LED packages would have different degradation mechanisms [2]. The primary reason for light output degradation in white pcLEDs is due to yellowing of the epoxy encapsulate [5]–[7]. In general, LEDs do not fail catastrophically, but instead their light output slowly decreases over their operating period. Presently some manufacturers use a 50% light output level as their criterion for LED life. Although 50% light loss might be acceptable for noncommercial applications using monochromatic LEDs, it might not be acceptable for general lighting applications. It is also reported in [8] that, for a 5 mm white pcLED, the degradation rate is very rapid. The second reason is the degradation of the semiconductor due to the thermal effects. With heat, these defects grow and cause light loss over time [2], [5], [8], [9], [10]. There are complicated interactions between current density, radiative recombination, non-radiative recombination localized at structural defects; such as dislocation and point defects, photon interactions and ambient temperature which cause degradation of the white LED. All light sources convert electrical power to visible radiant energy and heat in different proportions. From [11], we find that a considerable portion (~75% to 85%) of the energy is converted to heat and the rest (~15% to 25%) is converted to light in a white pcLED. This generated must be efficiently conducted from the LED chip to the circuit board and heat sinks, housings, etc. There may be short term and long term effects of excess heat as illustrated in the Table 1.

Table 1
Short and Long Term Effects of Heat

	Effects
Short-term effects	Color shift (reversible)
	Reduced light output
Long-term effects	Accelerated lumen depreciation
	Shortened useful life

In [11], it has been shown that when the difference of junction temperature is 11°C between two LEDs, the useful life decreases from 37,000 hours to 16,000 hours which is a 57% reduction. So, thermal management along with a proper knowledge about the operating environment are important aspects of LED based lighting system design. To operate an LED array with longer useful life, therefore, requires superior heat sinks to dissipate heat and keep junction temperature lower as well as design an effective drive circuit which gives proper light output but also keeps the junction temperature below the maximum limits.

LED life of general lighting, revolve around the concept of 'useful life' that was first proposed by Narendran et al. in 2001 [7], [12]. The term describes the period in which a light sources provides an acceptable light level for a given application, and in addition does not have a noticeable color shift. The guidelines specify two levels of lumen maintenance for different types of LED lighting applications. The group has proposed lumen maintenance of 70%, corresponding to a 30% reduction in initial light output, as the end of useful life for general lighting [13]. For decorative lighting applications where light level is not critical, the group recommends a drop of 50% as the end of life. The 70% cut-off was based on research showing that most people will accept up to a 30% reduction in light level.

3. EXPERIMENTAL SETUP AND RESULTS

The IESNA suggested procedure involves operating the LED component or system at rated current and voltage at a particular ambient temperature for 1,000 hours as a 'seasoning period' [15], [16], which is necessary because the light output actually increases in many cases during the first 1,000 hours of operation, for most LEDs. Then the LED is operated for another 5,000 hours. The radiant output of the device is measured at 1,000 hours of operation; this is normalized to 100%. Measurements taken between 1,000 and 6,000 hours are compared to the initial (1,000 hours) level. If the 70% and 50% levels have not been reached during the 6,000 hours, the data are used to extrapolate those points and predict the 'useful life' [15]. In Fig. 1, 'A' is a light and heat insulated chamber (with air flow arrangement) containing 8 numbers of 5mm white pcLED and matched photo detectors. 'B' is Constant current source to drive the LEDs.

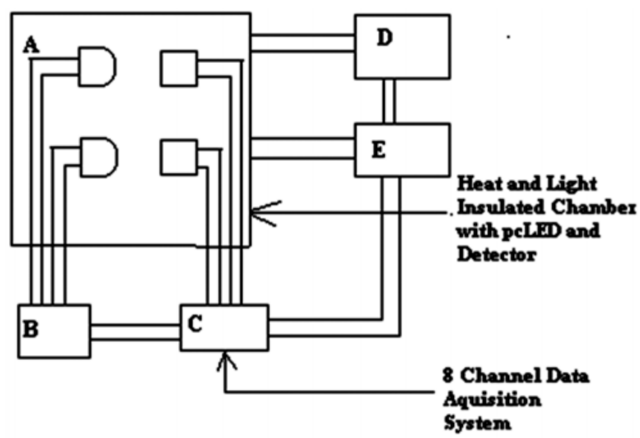

Fig. 1: Experimental Setup to Measure Lifetime of White pcLED

'C' is a 8-channel data acquisition system (IES, Model no. 3003 DI-16)to detect the output of the photodiodes. 'D' is the Uninterrupted Power supply (UPS). 'E' is a temperature controller cum indicator for maintaining the temperature inside the chamber within specified limits set in the experiment. Initially, two groups of white pcLEDs (each group having 4 LEDs) are driven by constant currents of 17 ma and 20 ma respectively. The ambient temperature is maintained at 45 (+/– 1)°C with the help of the temperature controller. The data acquisition system takes the data for all eight LEDs separately. For first 1000 hours, the LEDs are allow to settle as per recommendation of IESNA. The light output at the end of 1000 hours is noted, averaged and consider as 100% [15]. The data is now taken after every 500 hours intervals and it is averaged and normalized with respect to the data at the end of 1000 hours. The values of the currents are chosen as per [1] without crossing the maximum limits. The data is then plotted in a graph with the forward current through the LED as the parameter.

The graph shown in Fig. 2, clearly indicates that the lumen depreciation characteristics in depends on the forward current, and degrades linearly with respect to time, for commercially available 5 mm white pcLED at an ambient temperature of 45 ± 1°C. The degradation increases with the increasing value of drive current. It is also to be noted that the change that occurs in the LED is an irreversible permanent change. If the current is more, the depreciation is faster and vice-versa.

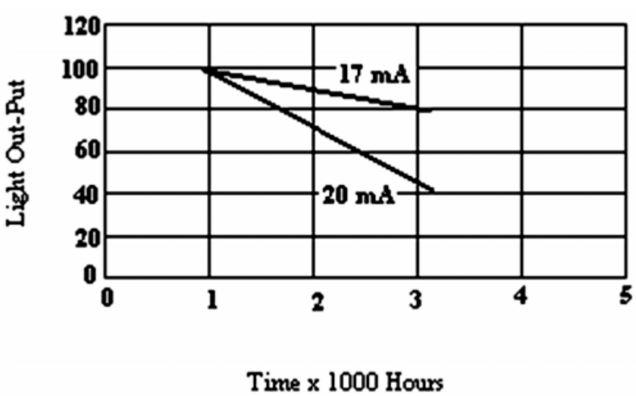

Fig. 2: Lumen Depreciation Characteristics of White pcLED for 17 mA and 20 mA Forward Current (at 45°C Ambient Temperature)

As per recommendation of IESNA [15], these curves may be extrapolated to touch the 70% (and 50%) levels which will predict their ‘Useful Life’. From Fig. 1 it is clear that for 20 mA forward current, the ‘Useful Life’ is reached before 6000 hours. For 17 mA forward current the graph has been extrapolated to touch the 70% mark to estimate its ‘Useful Life’. So from the results we can show that in order to have a longer ‘Useful Life’ the forward current through the LED must be set at a lower value at particular ambient temperature suitable for countries like India.

4. CONCLUSION AND FUTURE WORK

From the experimental studies made in this paper, it can be inferred that these commercially available white pcLEDs are not very much suitable for lighting applications in tropical countries Like India. The methodology and results of this study may be used for similar devices for selection of the proper devices with higher ‘useful life’ for solid state lighting applications. The lighting industry needs LED manufacturers to provide data that is compatible with current design practice. However, this only answers a part of the challenge. LED vendors should also be in a position to provide more detailed information about product lifetimes under various operating conditions. This data allows lighting designers to deliver the best combination of purchase price, lighting performance, and cost of ownership for the life of the product. So while operating in a tropical country like India, if we want to achieve a higher Useful Life for LEDs, the above mentioned approach can be followed.

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