SPD Change of HP LED Under Increased Temperature Stress

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Abstract **- High power light emitting diodes (HP LED) are energy efficient light sources that have been developing at great speed.**

Aging process was performed at increased pin temperatures, with approximate values of 80°C, 90°C and 100°C and constant current. The conditions in chambers are simultaneously monitored for approximately 5000 hours.

The change in HP LED's SPD was small and for the second test group was within the narrower wavelength interval than for the first. This interval corresponds to the phosphor emission region and indicates that important factor of white LED's SPD stability is the choice of type of phosphor used.

Keywords **- HP LED, SPD, accelerated life test, change in color.**

1. Introduction

In addition to high efficiency, on of the advantages of HP LED if compared to other light sources, is their longer life.[1] However, this characteristic depends on many factors: temperature, chip to air thermal resistance, type of phosphor and encapsulante, defects in semiconductor, contacts, etc. Investigation and better understanding of ambient temperature on the performance of LED is the key in further development of solid-state lighting. Understanding of temperature affected factors on HP LED and identification of faster and consistent method of estimation of life in certain applications is also necessary for determining procedures for reliability testing.

For light sources that have long life, such as HP LED, testing at nominal values is not an adequate approach. In that case, several years are needed to determine their life, and since this technology is developing at fast pace, in that time these devices would be surpassed, ergo the need for accelerated testing of HP LED as the way of investigating the degradation of their performance. The life and performance of HP LED is mostly affected by the temperature of its p-n junction.[2] The temperature of junction, the layer of semiconductor which emits light, is affected by ambient temperature.[3] Because of this, the experimental research focused on degradation of the tested LED with increased temperature stress with performance at temperature greater than nominal.

2. Method and Experimental Setup

The effect of temperature on GaN based HPLED is monitored on two groups of commercial samples. The degradation is accelerated by increased values of stress parameter, i.e. their performance is investigated at temperatures higher than their declared nominal values. The testing did not include increased voltage/current stress, because the studies show that this kind of stress also leads to the same mechanism of degradation, apropos, increase in the junction temperature[4].

The pin temperature was such that it does not cause mechanical deterioration of LED and was chosen after performing the estimation of the junction temperature. The pin temperature method was used for this estimation, which includes one-dimensional analysis of heat transfer.[5] The junction temperature was found using:

$$T_j = T_p + P \cdot R_{\theta_{j-p}}$$

where T_p , P i R_θ are pin temperature, power dissipated in junction and thermal resistance from junction to electrodes, respectively. The power is a product of voltage and current which are measured during the study, while R_θ is characterized by manufacturers in product specification. For the first group of tested LED, the thermal resistance is 4°C/W and maximum junction temperature is 125°C, as stated in its specification. For the second group of tested LED, the declared thermal resistance is 12°C/W and maximum junction temperature is 110°C. Calculated estimations of junction temperatures of both groups, as well as their corresponding used pin temperatures are shown in Table 1.

LED	#	t_{pin} (°C)	t_j (°C)
I group	1	80	104
	2	90	114
	3	100	124
II group	4	75	89,5
	5	85	99,5
	6	95	109,5

Tabela 1. Pin temperature and corresponding estimated junction temperatures for testing

The experimental setup consisted of specially designed individual chambers for each sample. This allowed for ambient temperature to stay constant during the testing and they also acted as light integrators. The conditions in chambers are simultaneously monitored for approximately 5000 hours. The SPD is measured using spectralradiometer. Other degradation parameters, such as voltage and current values, were also periodically measured.

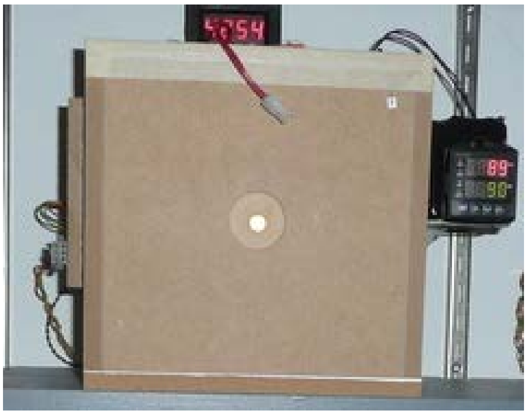

Figure 1. Test chambers

The test was performed at three temperatures in order to investigate if at different increased temperatures the behavior of LED follows the same pattern and by that give a reliable estimation of LED behavior at increased temperatures.

The tested samples included 3 "white" LEDs from each group. One group was connected to 3,4 V DC, while the other was supplied by 110 V AC. The dimensions of the tested LED are shown in Figure 1.

Each chamber is a box with a 23 cm side, with insides painted with a white coat with matt finish. Figure 2. shows the insides and all the elements of the chambers.

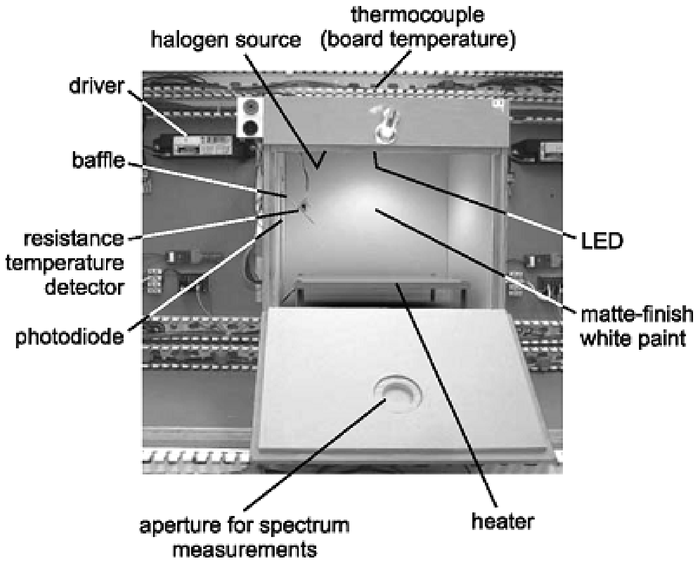

Figure 2. Placement of the elements inside the test chambers (as developed by the LRC)[6]

Since halogen light sources have SPD that negligibly change over time, each chamber included one for calibration purposes. That way, during life-testing, if SPD of LED is changed, by testing SPD of halogen source it can be checked if there has been any change in chamber color due to yellowing at high temperatures.

After the chambers were heated to the required increased temperatures, the devices were tested for approximately 5000 hours. During the first 1000 hours, every 100 hours trough the opening on the front of the chamber SPD of LED and halogen light source was measured by the spectroradiometer connected to the computer. In addition, using luxmeter the illumination was measured on the same opening, while voltage and current values were collected with multimeter connected to the designated output connectors. Thermocouples attached to the LED pin and inside of chamber were connected to the digital thermometers and gave temperature reading. After stabilization period, the reading interval was increased to approximately 300 hours.

3. Results and Discussion

Since the change in color of light is one of the possible problems that LED have with aging, using the collected data, potential change in SPD of the tested LED was investigated. The comparison of the initial and final SPD values of the tested LED is shown in Figure 3.

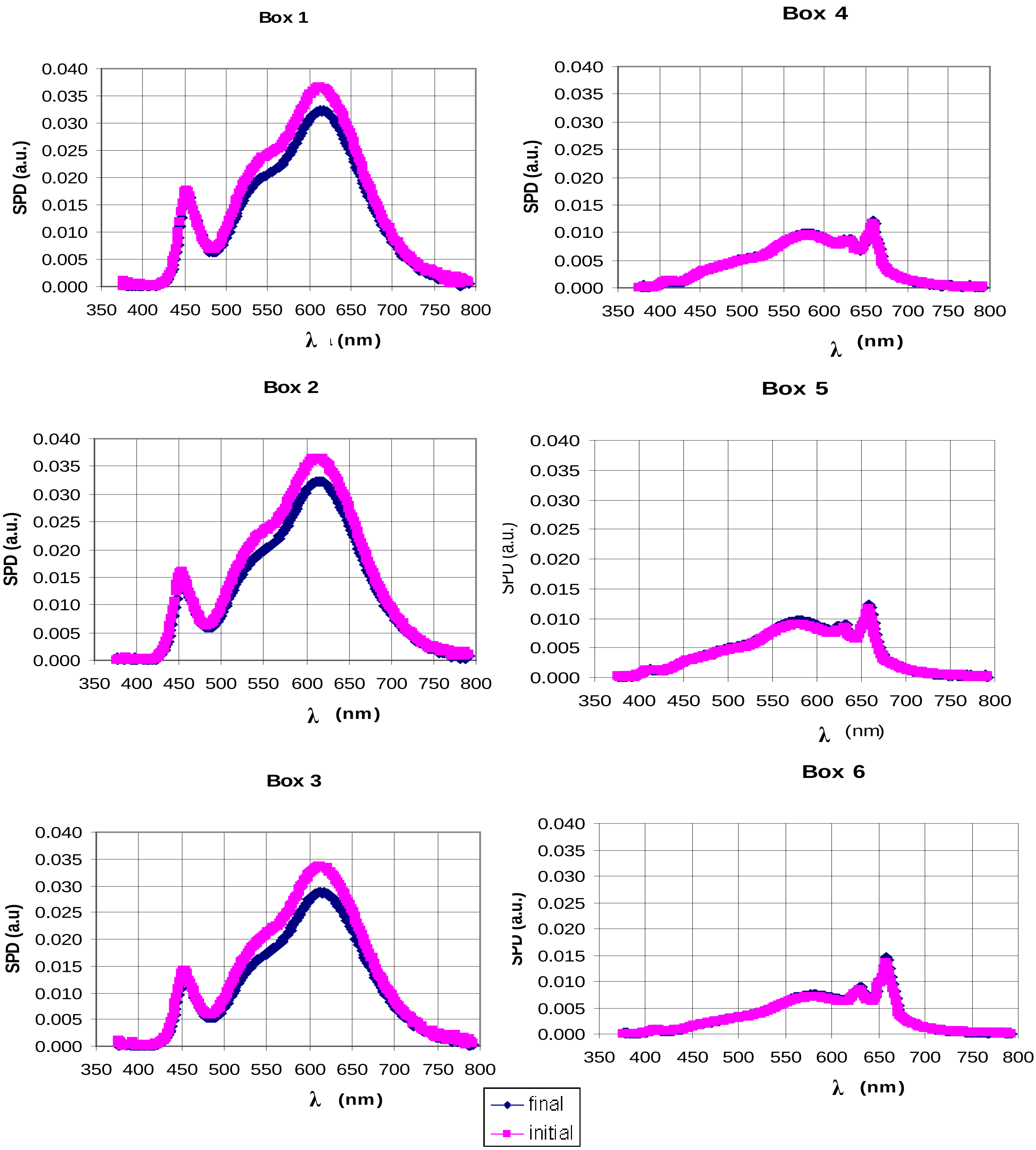

Figure 3. Initial and final SPD of the first (Box 1,2,3) and second group (Box 4,5,6) of LED

The graphs show small differences in the initial and final measured SPD. This change was not noted by the "naked eye" observation. From the peak placements of the SPD curves it is obvious that the tested LED groups used different types of phosphor for creation of white light. It is also evident that for the first group of LED the change in SPD is within the 500 to 700 nm interval, while for the second group this interval is narrower and goes between 550 to 670 nm. For wavelengths bellow and over these values, and which are in the region of semiconductor's emission, no changes were noted. This occurrence is in accordance with the observation that different types of phosphor were used in the tested groups. Since the noted change in SPD of tested LED is in the region of phosphor emission it is implied that the choice of phosphor affects the

The color of the inside walls of the chambers can affect the registered SPD of LED. This change can happen due the yellowing of paint when exposed to high ambient temperatures, as it was case in our study. For that reason, the test of possible change in color of chamber walls is performed. As already mentioned, the SPD of halogen light sources is negligible, so if change in halogen light source is noted it would be due to the change of color of chamber walls. As seen in Figure 4., the compared initial and final SPD values show a small change for all the halogen sources placed in test chamber.

change of SPD.

For the second group (graphs labeled Box 3 to 6) this change is more noticeable change. This indicates a possibility that the second group of tested LED has more heat management and that it dissipated more heat into the chamber causing the noted greater degradation of paint. This data analysis indicates that, since manufactures use different approaches to create white light, with different phosphors and different heat transfers mechanisms, more research work is needed it to better understand these parameters and develop a unified procedure for testing each commercially available product.

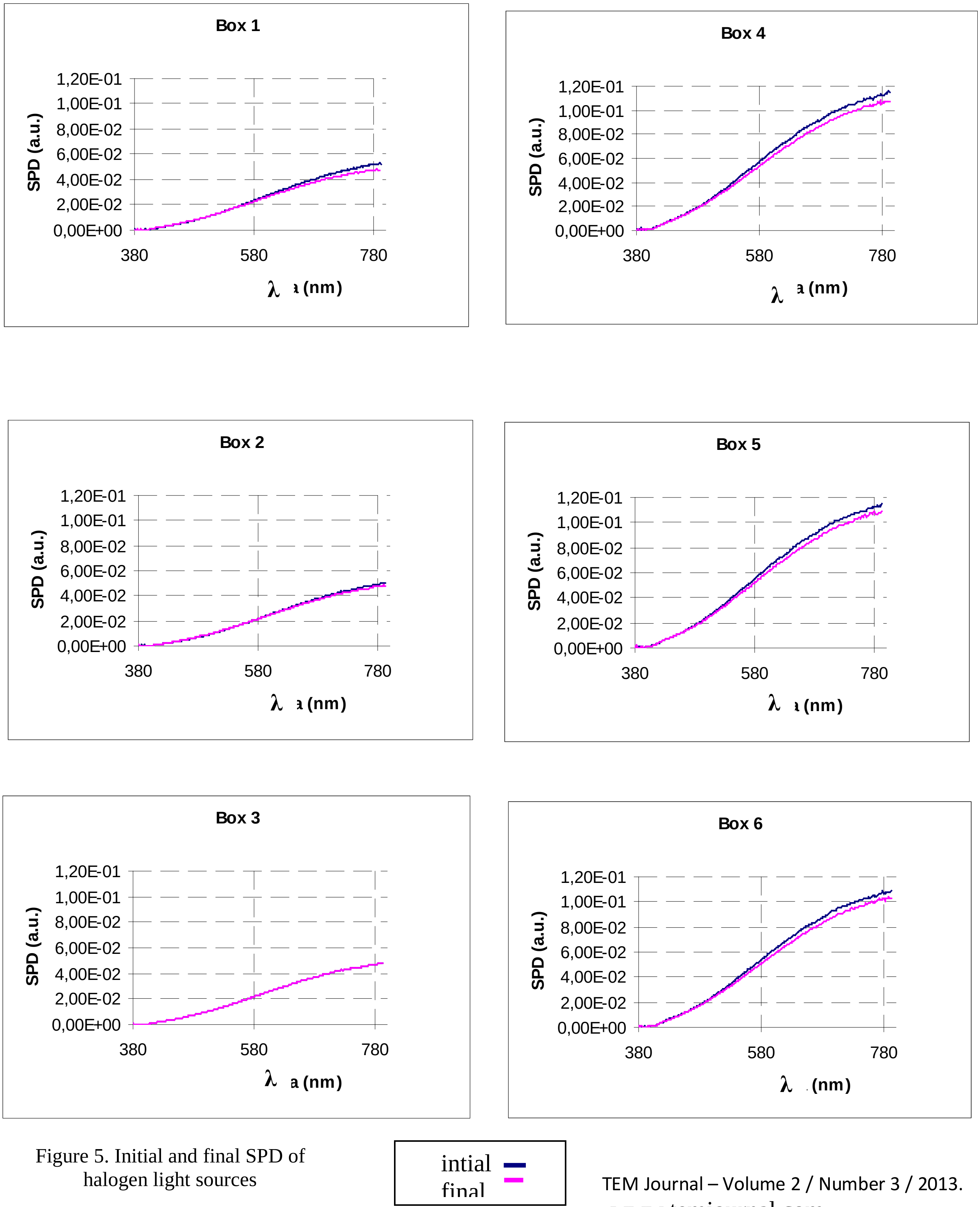

Figure 5. Initial and final SPD of halogen light sources

4. Conclusion

In the last few years of scientific research there is a race in placing more reliable commercial LED product in lighting applications. The performed test and analysis of obtained data enabled the better understanding of parameters relevant for degradation of LED performance. They also give insight in physical principals that affect operation and degradation of LED and other semiconductor based devices. This paper gives assumptions for testing standards which entail an individual approach in testing of reliability of white LED as a light source.

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