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Study on Reliability and Lifetime Prediction of High Power LEDs

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Abstract

With the rapid development of semiconductor lighting technology, the LED will gradually replace the traditional lighting to be the lighting market-led. However, the reliability life of LED products is the key to restrict its development. For further study on the reliability in this paper, the stress accelerated test was adapt to explore the reliability of LED, meanwhile, the failure of failure devices in the test was analyzed, and to study the correlation between the contact thermal resistance change of the LED device structure and the light fades. The finite element software was applied to simulate the work load impact on LED, and the corresponding changes in the internal structure was analyzed as well, then the establishment of the internal structure of the strain and thermal resistance were built. Ultimately, a method which is significant to short the cycle of the LED life prediction was proposed based on the ANSYS simulation.

Keywords*: high power LED, life Prediction, reliability, equivalent thermal resistance*

1. Introduction

In recent years, LED lighting has become much more attractive with many advantages such as long lifetime, lower energy consumption, compactness, etc [1]. And it will replace the traditional lighting in some time. However, most of LED products have a poor photoelectric performance and descent in a short [2], so the reliability issue of high power LED is the key problem to LEDs lighting. At present, most research is focus on how to study the reliability while some evidences point out that the reliability research mainly includes two aspects, one is the failure mechanism study and another is the lifetime prediction. Conventionally, lifetime prediction and related reliability issue analysis of LED are proposed by accelerated aging tests [3-5]. However, this method will take much time and the accuracy is boundedness. Recently, many papers refer to the reliability, and the most important factor of affecting reliability is the structure thermal management problem of high power LEDs. So the reliability of LED product is depends on the cooling channels with reasonable design and the materials with high heat conduction performance in LED packaging structure.

In this paper, in order to make much breakthrough on reliability research and get a better lifetime prediction method, the accelerated aging testing and thermal management of packaging structure were undertaken for reliability study of high power LED.

2. Experiment

2.1. Samples

Commercial 1 watt white LEDs have been used in this testing, and these components from one batch which were manufactured by a small company in China. The luminous efficiency output is about 70-80 Lm, forward voltage and forward current is 3.3 V and 350 mA, respectively. Working ambient temperature Ta=25℃. The LED components structure model and LED sample shows in Figure 1.

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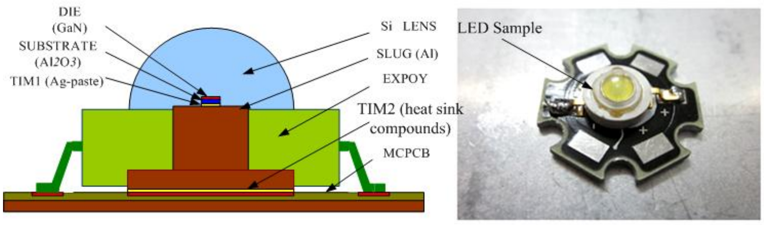


Figure1. LED Components Structure Model and Sample

2.2. Tests

In this paper, the test of LED reliability study include: accelerated aging test, the light output power measurement and the thermal resistance measurement. The focus of the study is mainly based on stress accelerated aging test to study the impact of different stress conditions on the LED light output power, and to analyze the variation of the thermal resistance of its internal structure after aging.

The reliability accelerated life equipment of SENSING company was adapt in this accelerated aging test, to make aging test to the same number of LED products under different temperature and current stress, the test is divided into batches:

In the first batch, select 5 LED samples to make accelerated aging, set the operating current I_f=350mA for the rated current and ambient temperature T_a=50$^\circ C$, the test load time is 300h.

In the second batch, select 15 LED samples, and divided into the A/B/C group to make accelerated aging, set A group the operating current I_f=700mA and ambient temperature T_a=40$^\circ C$, B group the operating current I_f=900mA and ambient temperature T_a=50$^\circ C$,C group the operating current I_f=1200mA and ambient temperature T_a=60$^\circ C$, respectively. The test load time is 300h.

The third batch is based on the second batch, replace A5 as the new No. 1, B2as the new No. 2, and C4, C5 was replaced by No. 3 and No. 4, the same operating current with the second batch, the ambient temperature is 50°C, 60°C, 50°C, respectively. The test load time is still 300h.

2.3. Results

After three batches of aging test, the LED luminous flux and structure of the thermal resistance was measured and test data was shown in Table 1.During the measurement, A5 will be replaced by No.1 after 300 hours, and go on to make aging text; C4 has been attenuation failure in the first 300h, and replace by No.3 in the post 300h; B2、C5 and No.4 have been broken, B2 and No.4 was burned in post 300h, replace B2 by No.2 go on to text for next 300 hours; In addition, the first batch of ② have been attenuation failure in 300h loading, the failure is mainly caused due to the surface of the phosphor and the aging of the plastic material.

3. Reliability Analysis

3.1. Failure Analysis

The failure form of accelerated aging test trials LED devices are mainly degradation of the material parameters, and open-circuit failure [6]. Figure 2(a) shown for the C11 sample silicon lens aging turns yellow, resulting in lower luminous flux; Figure 2(b) for the B2 sample of breakdown due to over-current chip causing chip cracking; Figure 2(c) lead fuse C5 sample due to large current temperature is too high.

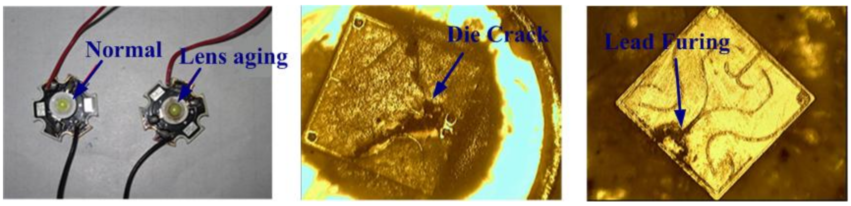
3.2. Thermal Resistance Analysis

Measurement study of the thermal resistance of the LED device found that there are varying degrees increased after LED internal structure of the thermal resistance aging. Figure 3 shows the differential structure of the curve before and after the thermal resistance of the B4-

like acceleration, in the aging process, the LED device internal between thermal resistance chips to MCPCB board was greater impacted. We can see that after 300h accelerating, thermal resistance changed to 0.5364K/W, thermal resistance gained to 0.2661K/W after another 300h [7].

Table1. Experiment Data Statistics

Ⅱ、Ⅲtesting	Φ_{t0} (lm)	R_{th} (k/w)	Φ_{t1} (lm)	P_t/P_0 (%)	ΔR_{th} (k/w)	Φ_{t2} (lm)	P_t/P_0 (%)	ΔR_{th} (k/w)
Code	**Original**		**1st 300h**			**2nd 300h**		
A1	76.54	5.87	67.66	88.40	0.4274	67.16	87.74	0.8297
A2	75.7	5.52	67.62	89.33	0.5323	60.31	79.67	0.8361
A3	67.72	6.61	65.59	96.86	0.2878	66.05	97.53	0.8117
A4	73.82	6.27	64.14	86.89	0.5362	59.17	80.15	1.055
A5	75.56	7.64	70.98	93.94	0.4628	/	/	/
B1	78.06	17.87	68.09	87.23	0.2041	63.33	81.13	0.628
B2	68.67	11.34	59.1	86.06	/	/	/	/
B3	68.73	8.94	54.82	79.76	0.8655	49.71	72.33	1.113
B4	74.99	5.89	70	93.35	0.5364	69.53	92.72	0.8025
B5	72.79	8.01	64.42	88.50	0.225	62.09	85.30	0.4919
C1	69.92	14.78	55.08	78.78	0.504	8.1	11.58	/
C2	71.84	6.31	58.29	81.14	0.7199	56.06	78.03	0.8975
C3	71.52	5.79	57.58	80.51	0.2542	46.93	65.62	0.6663
C4	76.28	7.43	48.87	64.07	0.9561	/	/	/
C5	76.31	8.33	/	/	/	/	/	/
N0.1	66.07	5.57	/	/	/	65.85	99.67	0.1877
N0.2	72.07	6.31	/	/	/	61.94	85.94	0.4428
N0.3	75.82	8.31	/	/	/	57.48	75.81	0.7838
N0.4	71.35	6.34	/	/	/	/	/	/
Code	**Original**			**300h**		**Illustrate**		
①	72.37	5.37	70.05	96.79	0.2457	Ⅰ **testing**: Ambient temperature is 50℃, Working current I_f =350mA。		
②	71.06	6.21	30.48	42.89	0.1328			
③	69.24	5.68	67.89	98.05	0.1907			
④	73.26	5.94	69.01	94.20	0.2431			
⑤	74.08	6.43	65.04	87.80	0.2392			



a) Lens aging b) Die crack c) Lead furing

Figure 2. Failure Model

In addition, we can see the Table 1 LED light failure and analysis of the thermal resistance of the changes that the thermal resistance change and the aging of the LED chip and the flux decay law are closely linked. Figure 4 is a direct relationship between luminous flux and thermal resistance, when the structure of the LED thermal resistance of increase 0.1877K while luminous flux attenuation is 99.67%; but when the structure of the thermal resistance increase 1.113KW flux decay is 72.33%, almost causing the LED luminous flux attenuation to the failure of the standard. Therefore, degradation of the LED chip to the relevant contact, LED internal structure of the thermal resistance increase with the increase of structure thermal resistance eventually led to an important reason for failure by the luminous flux attenuation.

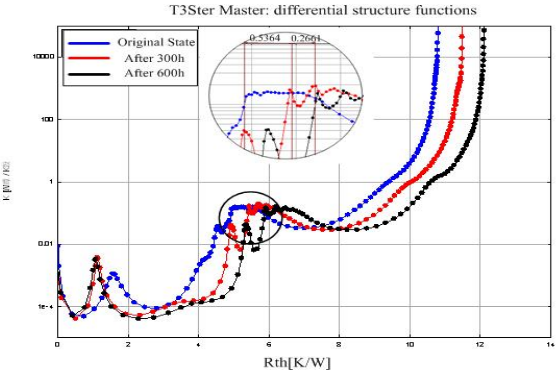


Figure 3. Thermal Resistance Properties before-after Aging

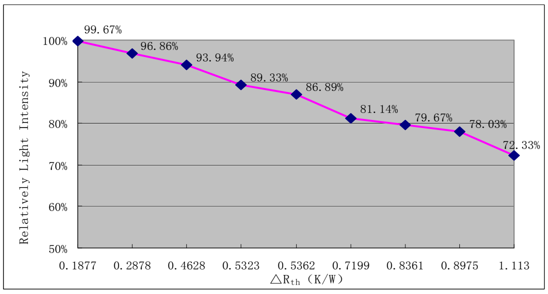


Figure 4. The Relationship between Luminous Flux to Thermal Resistance

3.3. Lifetime Estimate

We can predict the life under normal conditions of use by using the measured thermal resistance of the LED structure of the total thermal resistance data, and different temperature conditions the degree of aging through the use of the Arrhenius model [8-9].

$$P_t = P_0 \exp(-\beta t) \tag{1}$$

$$T_j = T_a + I_F V_F \cdot R_{th} \tag{2}$$

$$\beta = \beta_0 I_F \exp\left(-E_a / kT_j\right) \tag{3}$$

$$L_{(c,i)} = t_i \frac{\ln 0.7}{\ln P_{(t,i)} / P_{(0,i)}} \tag{4}$$

$$\tau = \exp\left[-\frac{E_a}{k}\left(\frac{1}{T_{(j,i)}} - \frac{1}{T_{(j,0)}}\right)\right] \tag{5}$$

$$L_c = \tau \times L_{(c,i)} \tag{6}$$

Which, by Equation (1) a junction temperature degradation coefficient can be calculated; (2) the chip junction temperature can be calculated; (3) can be calculated activation energy of the ambient temperature; (4) can access to the accelerated aging under the conditions of life; (5) yields the acceleration coefficient; Finally, (6) to calculate the life of the LED devices under normal operating conditions.

Take test conditions accelerated aging 350mA/50°C 300h for example, the average luminous flux attenuation is 94.21% and calculate aging time to failure 1793h, the structure of the total thermal resistance of 16.72k/w, and measured under the conditions of the forward voltage3.3V, by calculating the rectifiable batch of LED devices (350 mA/25°C) in its normal state working life of approximately 4000 hours.

4. Simulation Analysis

4.1. Simulation

Quarters of the finite element model of the high-power LED was shown in Figure 5. Aiming at the LED working process of alternating load in the thermal cycle test, the finite element method is taken for simulation [10]. Set the thermal cycling load temperature range of -40°C to 125°C. From room temperature 25°C to take the temperature cycle. Heating and cooling temperature is 10℃/min. When the high temperature is 125°C and low temperature is -40°C, then insulating 10 minutes. A loop may take a total of 53 minutes and cyclic loading five times, was shown in Figure 6.

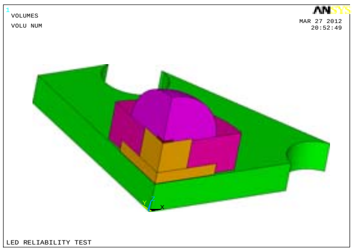


Figure 5. Quarters of the Finite Element Model

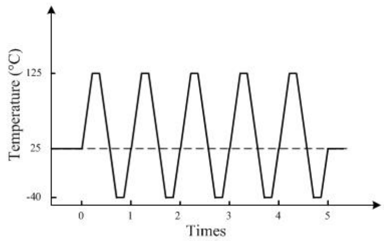
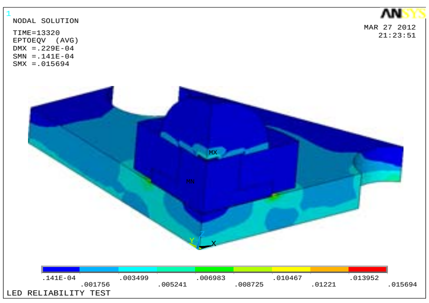


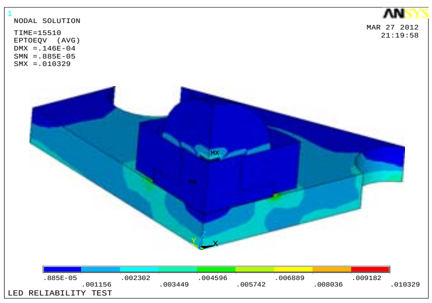
Figure 6. Temperature Profile

4.2. Results Analysis

Cyclic temperature load is applied, due to thermal expansion mismatch between the package structure and materials of the LED devices, and therefore larger thermal stress accumulated plastic strain within the package structure. During the imposed temperature cyclic loading process, the LED chip and the link layer will also have periodic stress and strain response [11]. Figure 7 shows, the maximum strain in the chip, substrate and die attach.



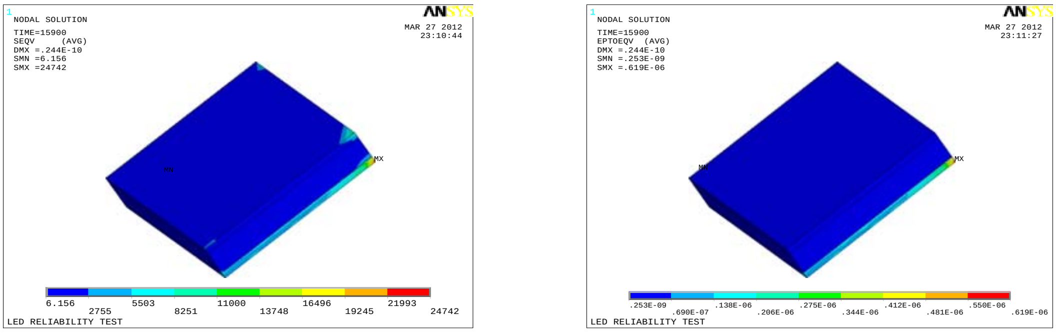
a) Conversion temperature -40°C to 125°C



b) Conversion temperature 125°C to -40°C

Finger 7. LED Equivalent Strain Contours of Temperature Cycling Test

After the end of the fifth temperature cycle was shown in Figure 8. When the temperature is 25°C, the LED chip and the die attach at the stress and strain contours. We can see from the figure, the LED devices within the structure still exists stress and strain after the end of the temperature cycle , and with the increasing times of loading temperature cycling, the stress and strain are increased its final stable at room temperature, the analysis of the reasons as: due to temperature stress and strain changes in the temperature cycle that leading to its internal residual thermal stress, and undercover deformation after elastic strain, and therefore leading to this phenomenon. Through the study found that this phenomenon has a certain value for the study of LED aging, equivalent strain generated will result in a hierarchical structure, thermal resistance increases and defects.



c) Stress at the temperature of 25 °C d) Strain at the temperature of 25 °C

Figure 8. Contours of the Fifth Temperature Cycle Stress and Strain of the Chip and the Die Attach

Due to the larger strain of the LED structure, layer, die attach layer and TIM layer ,that cause the much more obvious changes for the total thermal resistance of LED, the statistics about the strain of each layer in the Table 2.

Table 2. Equivalent Strain of the LED Structure

Cycles	Die		Substrate		Die Attach		TIM	
	Min	Max	Min	Max	Min	Max	Min	Max
1	$5.04\ e^{-11}$	$1.19\ e^{-8}$	$8.61\ e^{-11}$	$2.53\ e^{-9}$	$1.17\ e^{-11}$	$1.24\ e^{-7}$	$4.47\ e^{-11}$	$1.21\ e^{-7}$
2	$1.01\ e^{-10}$	$2.19\ e^{-8}$	$1.72\ e^{-10}$	$5.07\ e^{-9}$	$2.53\ e^{-10}$	$2.48\ e^{-7}$	$8.94\ e^{-11}$	$2.43\ e^{-7}$
3	$1.51\ e^{-10}$	$3.29\ e^{-8}$	$2.58\ e^{-10}$	$7.06\ e^{-9}$	$3.53\ e^{-10}$	$3.71\ e^{-7}$	$1.34\ e^{-10}$	$3.64\ e^{-7}$
4	$2.02\ e^{-10}$	$4.39\ e^{-8}$	$3.44\ e^{-10}$	$1.01\ e^{-8}$	$4.71\ e^{-10}$	$4.95\ e^{-7}$	$1.79\ e^{-10}$	$4.85\ e^{-7}$
5	$2.53\ e^{-10}$	$5.49\ e^{-8}$	$4.30\ e^{-10}$	$1.27\ e^{-8}$	$5.89\ e^{-10}$	$6.19\ e^{-7}$	$2.24\ e^{-10}$	$6.06\ e^{-7}$
$\Delta\overline{\varepsilon}$	$5.05\ e^{-11}$	$1.1\ e^{-8}$	$8.6\ e^{-11}$	$2.54\ e^{-9}$	$1.18\ e^{-11}$	$1.24\ e^{-7}$	$4.48\ e^{-11}$	$1.21\ e^{-7}$

5. Simulation of Lifetime Prediction

5.1. Strains and Thermal Resistance

When LED devices heating, due to the various parts of different materials have different CTE, resulting in the deformation for the structure, the volume size, and then giving rise to strain. Structure after the strain increase in size, irregular, thus creating a layered between layers of the LED or produce defects such as air gap, and therefore leading to the cooling channels extend, effecting the thermal efficiency. In order to calculate the size of the strain and the cooling effect after straining, make equivalent treatment for irregular strain, applying the form of equivalent strain to estimate the extension of the cooling channels to achieve the cooling effect which after the calculated deformation. The equivalent strain was shown in Figure 9.

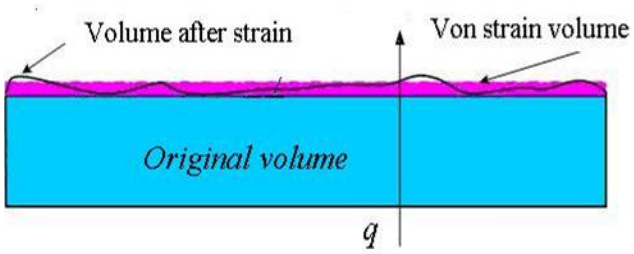


Figure 9. Equivalent Strain Diagram

For the channel of heat dissipation is the thermal resistance, the extension of the cooling channels will also lead to the increase of thermal resistance, which is demonstrated as Equation (7).

$$R_{th} = \frac{\delta + \Delta\varepsilon}{\lambda A} \quad (7)$$

$\Delta\varepsilon$ is equivalent strain; R_{th} is thermal resistance。Therefore, the thermal resistance increment:

$$\Delta R_{th} = \frac{\Delta\varepsilon}{\lambda A} \quad (8)$$

5.2. Thermal Resistance and Failure

According to LED structure model material thermal conductivity and basic dimensions, the thermal resistance calculation obtaining the layers were shown in Table 3.

Table 3. Layers of Basic Dimensions and Thermal Resistance

Designation		R(mm) L(mm)	R(mm) W(mm)	H (mm)	λ (W/m·K)	R_{th} (K/ W)
Die		1	1	0.02	350	0.154
Substrate		1	1	0.08	41.9	1.91
Die attach		1	1	0.02	8	2.5
Slug	small	1.5		1.6	237	1.05
	big	3		0.6		
TIM		3		0.02	0.8	0.88
MCPCB		10		1.5	170	0.028

The total thermal resistance is:

$$R_{th.\text{Total}} = R_{th.\text{Die}} + R_{th.\text{Substate}} + R_{th\cdot\text{Die attach}} + R_{th.\text{Slug}} + R_{th.\text{TIM}} + R_{th.\text{MCPCB}} = 6.522 \quad K/W$$

Figure 4 shows the optical attenuation and thermal resistance increment have a linear relationship, it can be established a straight line equation through the corresponding data about the LED relative luminous flux and variable thermal resistance, and make the least squares fitting for the set of data.

Assuming the linear relationship that:

$$y = a + bx \tag{9}$$

Which setting up thermal resistance increments is y ; relatively light flux is x .

Based on the least squares fitting theory [10], gotten the result x_i , y_i from the table data, then calculate x_i^2 and $x_i y_i$, formed into Table.4 in the end.

$$30a + 25.6724b = 16.9764$$
$$25.6724a + 22.21396b = 14.0721$$

Solve the equation, obtained a 、 b

$$a = 2.16, \quad b = -1.86$$

The resulting linear equations is:

$$y = 2.16 - 1.86x \tag{10}$$

Table 4. Least Square Method Data

/	x_i	y_i	x_i^2	$x_i y_i$
All data from Table.1			~	~
∑	2567.24%	16.9764	2221.396%	14.0721

Therefore, we can see that the relative luminous flux to decay to 70% when the LED structure of the thermal resistance will increase 0.858K/W; when the relative luminous flux attenuation to 50%, the LED thermal resistance will increase to 1.23K/W.

5.3. Lifetime Prediction by Simulation

1. Lifetime and cycles

The calculation shows that the life of the batch of LED devices at around 4000 hours. As applying the temperature cyclic loading mode in the simulation process, from low to high temperature cycle time of 53 minutes, so that it can be drawn the relative expectancy life from the LED in the normal working hours and in the process of temperature cycling:

$$n = \frac{T_{life \cdot time}}{t_{cycle}} = \frac{4000}{53/60} \approx 4500$$

Which, the life of the temperature in the loop simulation is n ; cycle time is t_{cycle} .

2. Layers of the total strain and the thermal resistance calculation

Due to LED layers strain showed a linear increase in the temperature cycling process, using its incremental average, as shown in Table 2. After the LED temperature cyclic loading 4500 times, the working life of the LED has turned out, obtaining strain variables of layers are:

$$\Delta\varepsilon_{Total} = \Delta\bar{\varepsilon} \times n \tag{11}$$

Which, LED internal layers of the total variable is $\Delta\varepsilon_{Total}$, and the strain is divided into the total maximum strain and minimum strain of the total points. By calculating the total strain, according to Equation (8) to calculate the total thermal resistance of the increment:

$$\Delta R^{\varepsilon}_{th.Total} = \frac{\Delta\varepsilon_{Total}}{\lambda A} \quad (12)$$

Which, thermal resistance of the total strain increment of LED internal layers is $\Delta R^{\varepsilon}_{th.Total}$, the maximum and minimum values of thermal resistance increment can be obtained in accordance with the maximum strain and minimum strain.

Table 5. Layers of the Total Strain and Total Thermal Resistance

Designation	Die		Substrate		Die Attach		TIM	
	Min	Max	Min	Max	Min	Max	Min	Max
$\Delta\overline{\varepsilon}$	5.05 e^{-11}	1.1 e^{-8}	8.6 e^{-11}	2.54 e^{-9}	1.18 e^{-11}	1.24 e^{-7}	4.48 e^{-11}	1.21 e^{-7}
$\Delta\varepsilon_{Total}$	2.27 e^{-7}	4.95 e^{-5}	3.87 e^{-7}	1.143 e^{-5}	5.31 e^{-8}	5.58 e^{-4}	2.02 e^{-7}	5.45 e^{-4}
$\Delta R^{\varepsilon}_{th.Total}$	6.5 e^{-4}	0.14	9.24 e^{-3}	0.27	6.64 e^{-3}	69.75	8.93 e^{-3}	24.1

As the high thickness and high thermal conductivity in the Slug layer and MCPCB layer, the strain variable during thermal cycling is relatively small, thermal resistance increment is not obvious, so that can be negligible. Therefore, the statistical calculation of the strain thermal resistance variable only consider the corresponding variables about the chip, substrate, die attach and TIM layer.

3. Strain relationship on thermal resistance

In larger or smaller strain areas of the LED structure, making the LED thermal conductivity of the channel extension, that come a emergence of layers, leading to the air gap, etc. The air gap will reduce the material cooling capacity, so that the thermal resistance increases. Therefore, aiming at the lower LED cooling capacity by thermal stress and strain, are regarded as the thermal resistance increases of LED internal structure, and the increment of the thermal resistance in internal structure is not determined by the maximum or minimum strain thermal resistance, its depends on an intermediary value. Therefore, in the calculation of the thermal resistance of LED structure can be expressed by equivalent thermal resistance increment ΔR_{th}^{*}, its expression is:

$$\Delta R_{th}^{*} = \Delta R^{\varepsilon}_{th.Total} \cdot \tau \quad (13)$$

Which, the equivalent to the total variable of thermal resistance of LED internal layers is ΔR_{th}^{*}, it is equal to the actual measured thermal resistance increment; τ is the equivalent scale factor minimum strain of the increased thermal resistance and the actual measured total thermal resistance and have relation to the thermal performance and minimum s train of the LED's internal thermal resistance.

Calculated by the formula (10) shows that to determine the LED the failure when the LED light attenuation to 70%, its structure thermal resistance of the total incremental $\Delta R_{th.Total} = \Delta R_{th.Total}^{*} = 0.858 K/W$, so:

$$\Delta R_{th.Total}^{*} = \Delta R^{\varepsilon}_{th.Total} \cdot \tau = \left(\Delta R^{\varepsilon}_{th.Die} + \Delta R^{\varepsilon}_{th.substrate} + \Delta R^{\varepsilon}_{th.Die\ attach} + \Delta R^{\varepsilon}_{th.Slug} + \Delta R^{\varepsilon}_{th.TIM} + \Delta R^{\varepsilon}_{th.MCPCB}\right) \cdot \tau \quad (14)$$

Which, $\Delta R^{\varepsilon}_{thSlug}$ and $\Delta R^{\varepsilon}_{thMCPCB}$ can be negligible, according to the thermal resistance of the minimum strain increments:

$$\Delta R_{th.Total}^{*} = \Delta R_{th.Total}^{\varepsilon} \cdot \tau = \left(\Delta R_{th.Die}^{\varepsilon}{}_{\min} + \Delta R_{th.Substrate}^{\varepsilon}{}_{\min} + \Delta R_{thDie\ \ attach}^{\varepsilon}{}_{\min} + \Delta R_{th\ \ TIM}^{\varepsilon}{}_{\min} \right) \cdot \tau$$
$$= \left(6.5e^{-4} + 9.24e^{-3} + 6.64e^{-3} + 8.93e^{-3} \right) \cdot \tau$$
$$= 0.858 \quad K/W$$

By calculating, the last available $\tau = 33.7$, and τ is the coefficient for the equivalent ratio in the minimum strain.

4. Failure determination

According to the formula (14), the equivalent thermal resistance increment of LED internal layers can be computable:

$$\Delta R_{th.Die}^{*} = \Delta R_{th.Die}^{\varepsilon}{}_{\min} \cdot \tau = 6.5e^{-4} \times 33.7 = 0.022 K/W$$
$$\Delta R_{th.Substrate}^{*} = \Delta R_{th.Substrate}^{\varepsilon}{}_{\min} \cdot \tau = 9.24e^{-3} \times 33.7 = 0.311 K/W$$
$$\Delta R_{th\ \ Die\ \ attach}^{*} = \Delta R_{thDie\ \ attach}^{\varepsilon}{}_{\min} \cdot \tau = 6.64e^{-3} \times 33.7 = 0.224 K/W$$
$$\Delta R_{thTIM}^{*} = \Delta R_{th.TIM}^{\varepsilon}{}_{\min} \cdot \tau = 8.93e^{-3} \times 33.7 = 0.301 K/W$$

The calculated incremental layers of equivalent thermal resistance shows that after the attenuation of the LED aging, the internal structure of the thermal resistance layers increased and compare to the original LED internal thermal resistance, thermal resistance increased to $\Upsilon\%$.

$$\Upsilon\% = \frac{\Delta R_{th.Total}^{*}}{R_{th.Total}} = \frac{0.858}{5.444} = 15.76\%$$

Therefore, when the LED internal structure of the thermal resistance increased by 15.76% compared its original total thermal resistance, to determine it is failure by its optical attenuator to 70%.

For more packaging structure of LED, because the structure does not exist TIM layer, taking into account the strain and thermal resistance of the greatest impact is the chip, substrate and die attach layer, it may be assumed that the thermal resistance increases to the three-layer thermal resistance $P\%$ can be determined to be invalid, the expression:

$$P\% = \frac{\Delta R_{th.Die}^{*} + \Delta R_{th.Substrate}^{*} + \Delta R_{th.Die\ \ attach}^{*}}{R_{th.Die} + \Delta R_{th.Substrate} + \Delta R_{th.Die\ \ attach}} = \frac{0.022 + 0.311 + 0.224}{0.154 + 1.91 + 2.5} = 12.2\%$$

In short, we can obtain the minimum strain scale factor by calculating; when the LED de vice structure is traditional with chip, substrate, Die attach and TIM layer, thermal resistance incr ease that part of the original P, can be judged for the failure; but when the LED is the new struct ure also with the chip, substrate and Die attach layer, the thermal resistance increases to the thr ee-layer $P\% = 12.2\%$, thermal resistance can be judged to be invalid.

6. Conclusion

In this paper, a reliability analysis of high power LED based on stress accelerated testing and life prediction by the simulation method with the test results were proposed. Main conclusions of this work are the following:

1) With the Accelerated test of LED under the stress conditions of different temperature current, coming to the conclusion: the higher temperature and current stress, the faster aging.

2) According to the failure mechanism analysis, the main failure model is the following: a phosphor or silicone lens aging leads to the luminous flux rapidly reduced; another case for the current high-temperature leads to cracking or Lead furring.

3) By measuring the thermal resistance of the LED structure analysis showed that the linear relationship between the internal structure of the thermal resistance change and the attenuation of luminous flux. Luminous flux decays sooner, the LED internal thermal resistance change greater.

4) Applying the way of thermal cycle to simulate LED load impact, when the return to room temperature the structure of its internal layers with varying degrees of strain, and then building the simultaneous contact between equivalent strain and the thermal resistance, the simulation budget method of LED life will be gained.

5) Finally, by the combination between experimental data and the results of simulation, obtain the result when the thermal resistance of the LED chip, the substrate and die attach increased by 12.2%, we can consider the LED failed, and the number of simulation cycle is a LED life.

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