Application Note AN14
Reliability Data Sheet for Bridgelux LED Arrays

Introduction

The Bridgelux family of LED Array products delivers high performance, compact and cost-effective solid-state lighting solutions to serve the general lighting market. These products combine the higher efficiency, lifetime, and reliability benefits of LEDs with the light output levels of many conventional lighting sources.

The Bridgelux LED Arrays have been fully qualified to a rigorous set of reliability tests including extended endurance testing, environmental testing and mechanical testing. The qualification program is based on standard semiconductor qualification test methodologies defined by JEDEC. In addition Bridgelux conducts lumen maintenance testing in accordance with the industry standard requirements of IES document IES-LM-80-08

This application note provides a summary of the reliability data obtained during product qualification testing prior to the release of the Bridgelux LED Arrays to the market. The note also includes an overview of ongoing long-term lumen maintenance testing.

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Bridgelux LED Arrays – Designed For Reliability

Bridgelux LED Arrays are designed to ensure high reliability over a wide range of operating and environmental conditions. The construction of the LED Arrays includes an array of high power Bridgelux InGaN LED die bonded onto an aluminum substrate and encapsulated in a proprietary phosphor compound.

The design of the package has been optimized to achieve maximum reliability:

- The Bridgelux InGaN LED die used in the LED Array demonstrate exceptional stability with negligible degradation of output power observed after more than 12,000 hours of life-test at a junction temperature of 140˚C and operating currents in excess of 350mA per die.

- The Bridgelux LED Arrays demonstrate industry-leading thermal resistance values ranging from 1˚C/W to as low as 0.5˚C/W. The low thermal resistance ensures that the junction temperature of the LED die is maintained at a minimum level thereby maximizing reliability.

  The low thermal resistance of the Bridgelux LED Arrays is enabled through a LED die structure in which the thermal and electrical paths are separated. The base of the LED die is electrically isolated and therefore allows die to be bonded directly onto an aluminum substrate using a proprietary metal bond packaging technology, providing a thermal path of extremely low resistance.

- Redundant wire bonds ensure high reliability in harsh environmental conditions.

- Encapsulation and conversion materials of proven high reliability have been selected.

Overview Of LED Reliability

Bridgelux LED Arrays are inherently extremely reliable devices. The dominant degradation mechanism for all LED products is lumen depreciation, a very gradual decrease of light output over operating lifetime. This is characterized in the lumen maintenance statement on page 5 of this document.

LED arrays do not typically fail in a catastrophic manner in which the products fail to emit light under normal operating conditions. Bridgelux has conducted extensive product qualification testing to ensure that its LED Array products do not suffer from defects which may cause infant mortality. A comprehensive set of in-process and production monitors are in place to ensure product reliability.

Accelerated degradation or catastrophic failure of a LED Array may result from inappropriate handling or assembly procedures, the use of excessive drive currents or inadequate thermal management. Product reliability requires conformance to the specification limits published in the data sheet and adherence to the assembly, handling and system design recommendations published in the Application Notes.

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Qualification Testing Results

Bridgelux LED Arrays were subjected to an extensive set of qualification tests prior to product release. The test results are summarized in the table below.

Stress Test	Reference Specifications	Stress Conditions	Stress Duration	Failure Criteria	Results
High Temperature Operating Life (HTOL)	JESD22A-108	85˚C case temperature Rated I_F, constant current	1000 hours	Note 1,2,3,4,5	0 failures
Room Temperature Operating Life (RTOL)	JESD22A-108	55˚C case temperature Rated I_F, constant current	1000 hours	Note 1,2,3,4,5	0 failures
Low Temperature Operating Life (LTOL)	JESD22A-108	-40˚C case temperature Rated I_F, constant current	1000 hours	Note 1,2,3,4,5	0 failures
Temperature Humidity Operating Life (WHTOL)	JESD22A-101	85˚C case temperature 85% humidity Rated I_F, constant current	500 hours	Note 1,2,4,6	0 failures
High Temperature Storage Life (HTSL)	JESD22-A103	120˚C ambient Non operating	1000 hours	Note 1,2,3,4,5	0 failures
Low Temperature Storage Life (LTSL)	JESD22-A103	-40˚C ambient Non operating	1000 hours	Note 1,2,3,4,5	0 failures
Power Temperature Cycle (PTMCL)	JESD22-A105C	Case: T_{high} 85˚C, T_{low} -40˚C Dwell time 16 mins Transfer time 42 mins Rated IF, 4 mins off, 5 mins on	100 cycles	Note 1,2,3,4,5	0 failures
Temperature Cycling (TMCL)	JESD22-A104	Ambient: T_{high} 120˚C, T_{low} -40˚C Dwell time 15 mins Transfer time 5 mins Non operating	100 cycles	Note 1,2	0 failures
Mechanical Shock (MS)	JESD22-B104-A	1500g; 0.5ms; 5 shocks/axis		Note 1,2	0 failures
Mechanical Vibration (MV)	JESD22-B103-A	20 – 2—Hz; Random; 4 mins; 4 times/axis		Note 1,2	0 failures
ESD I (Human Body Model)	JESD22-114	8kV		Note 1,2	0 failures
ESD II (Machine Model)	JESD22-A115	400V		Note 1,2	0 failures
Solderability	JSTD-002	260˚C ± 5˚C; 10 secs ± 1 sec		Note 1,2	0 failures
Salt Atmosphere	JESD22-A107	5% salt solution ; 35˚C ± 3˚C pH = 6.0 – 7.5 at 35˚C Deposition rate 34g/m^2/24hours	48 hours	Note 7	0 failures

Notes:
1. No catastrophic failure
2. No parametric failure
3. Lumen maintenance > 70%
4. Change in V_F < 10%
5. Change in white color point, Δx, Δy < ±0.01
6. Lumen maintenance > 50%
7. No illegible marking

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Lumen Maintenance Projections For Bridgelux LED Arrays

Bridgelux projects that it's family of LED Array products will deliver, on average, greater than 70% lumen maintenance after 50,000 hours of operation at the rated forward test current. This performance assumes constant current operation with case temperature maintained at or below 70˚C.

These projections are based on a combination of package test data, semiconductor chip reliability data, a fundamental understanding of package related degradation mechanisms, and performance observed from products installed in the field using Bridgelux die technology. Observation of design limits is required in order to achieve this projected lumen maintenance.

Comparing Case Temperature vs. Junction Temperature For Lumen Maintenance Projections

The Bridgelux lumen maintenance projection is comparable with the best in the industry. Bridgelux chooses to make lumen maintenance projections relative to a case temperature of 70˚C, as this is a parameter that is easily measured and managed in a lighting system. Other manufacturers of LED packages publish projections relative to the junction temperature of the die. It is not possible to measure the junction temperature and therefore this must be calculated rather than measured. The junction temperature of the die is always higher than the case temperature. In comparing lumen maintenance projections, it is important to ensure that the comparison is made under the same conditions – Bridgelux recommends comparing lumen maintenance projections relative to a case temperature.

Figure 1 compares the construction of a Bridgelux LED Array with that of a typical single chip emitter package mounted onto a Metal Core Printed Circuit Board (MCPCB). Note that the Bridgelux LED Arrays have a significantly simplified thermal path in comparison to a light engine built using single chip emitter packages. As described previously, the die in the Bridgelux LED Arrays are bonded directly onto an aluminum substrate. For the single chip emitter package, the LED die is bonded onto the emitter package, and the package is then mounted onto a MCPCB substrate which is a required process step for building a lighting system using LED emitters. In this example, the case temperature (T_c) of the Bridgelux array should be compared with the temperature (T_c) at the MCPCB (substrate) for the single chip emitter.

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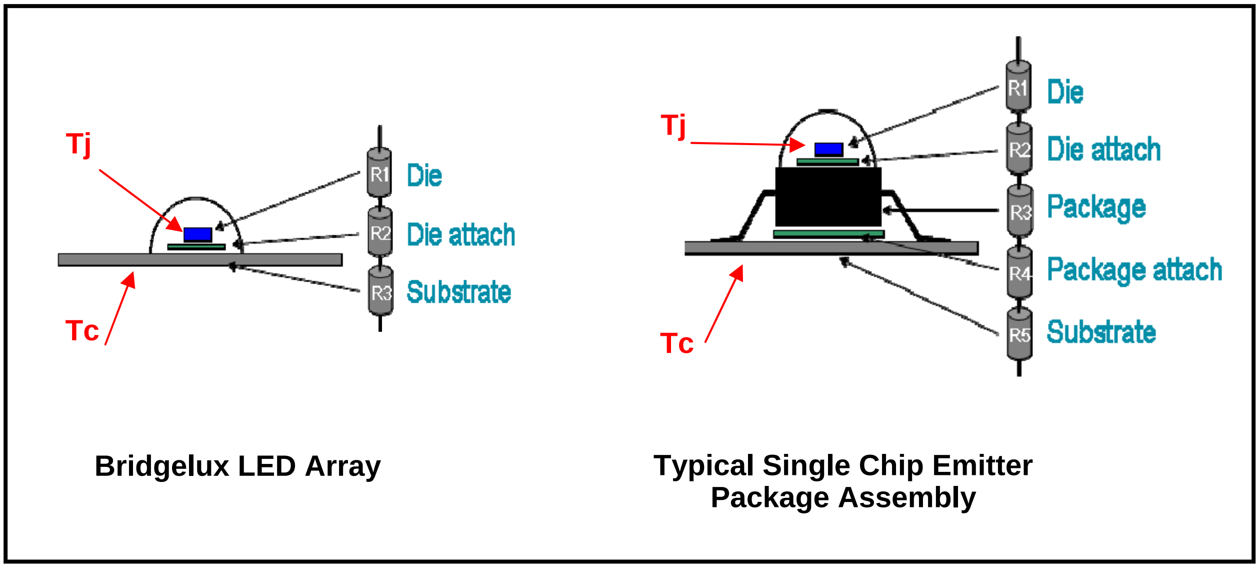

Fig 1: Comparison of thermal path for Bridgelux LED Array and a typical single chip emitter package

The junction temperature (T_j) is dependent on the case temperature (T_c), the electrical power dissipated (P) and the thermal resistance (R_{TH}) of the LED package and substrate or MCPCB mounting via the simple relationship:

$T_j = T_c + (P*R_{TH})$

For the typical single chip emitter
$T_j = T_c + P*(R1 + R2 + R3+ R4 + R5)$

and

R1 + R2 + R3 = thermal resistance of the emitter package
R4 + R5 = thermal resistance of the MCPCB and interface between emitter package and MCPCB

Although the MCPCB is a good conductor of heat, the incremental thermal resistance for the board and board interface is not trivial. Typical commercially available board solutions have thermal resistance in the range of 2˚C/W to 5˚C/W which is to be added to the thermal resistance of the emitter package to calculate the total thermal resistance of the lighting system. It is important to evaluate the complete system to accurately compare the performance of different LED products.

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About Bridgelux

Focused on bringing innovation to light, Bridgelux is a leading provider of high-power, cost-effective and energy-efficient light-emitting diode (LED) solutions. The company's proprietary epitaxy technology, innovative chip designs and leading-edge LED packaging technology have enabled the company to develop advanced solid-state lighting (SSL) products that offer superior quality, are lower in cost and environmentally friendly—all without compromising performance. In addition to LED chips, the company delivers a range of SSL light sources that customers can easily integrate into a variety of lighting applications that will open up new markets in solid-state lighting. Founded in 2002, Bridgelux is headquartered in Sunnyvale, California. For more information about the company, please visit www.bridgelux.com

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