

A photograph of a factory floor, likely a Philips Lighting production facility. The scene is filled with industrial equipment, including conveyor belts, metal frames, and various lighting fixtures. Some fixtures are illuminated, casting a warm glow. The ceiling is white with recessed lighting. The overall atmosphere is industrial and brightly lit.

Het voorspellen van de levensduur van LED verlichting met gebruik van omgevingstesten

En enkele voorbeelden van faal mechanismen

Boudewijn Jacobs

Philips Lighting

3 december 2015

innovation  you

PHILIPS

Toename in foutmodes



Light out due to:
1. Rain
2. No wood

Light out due to:
1. Rain
2. Wind
3. No candle

Light out due to:
1. Broken glass
2. Broken casing
3. EMS / ESD
4. Electrical short
5. Deterioration
6. Gas leakage
7. Mishandling

Light out due to:
1. Die Crack
2. Delamination
3. Software failures
4. ...
> 30 known FM's,
See next slide

Onze Reliability groep houdt zich o.a. bezig met:

1. Failure Mode and Mechanisms Investigation

- Color and lumen maintenance
- Catastrophic failures
- Accelerated testing
- Reliability of connected systems
- Development and deployment of release procedures
- Supporting businesses during development and service agreements



2. Reliability Lab ISO17025 compliance

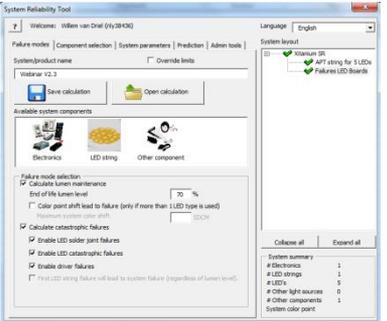
- Internal certification program
- Expanding in 2016 EMEA & NA
- 35 testing locations in scope

# Tickets	Internal Certification Level
< 60	Reliability lab under witness of Dev Q
60 - 80	Reliability lab under supervision of Dev Q
80 - 100	Recognized reliability lab
> 100	Expert reliability lab

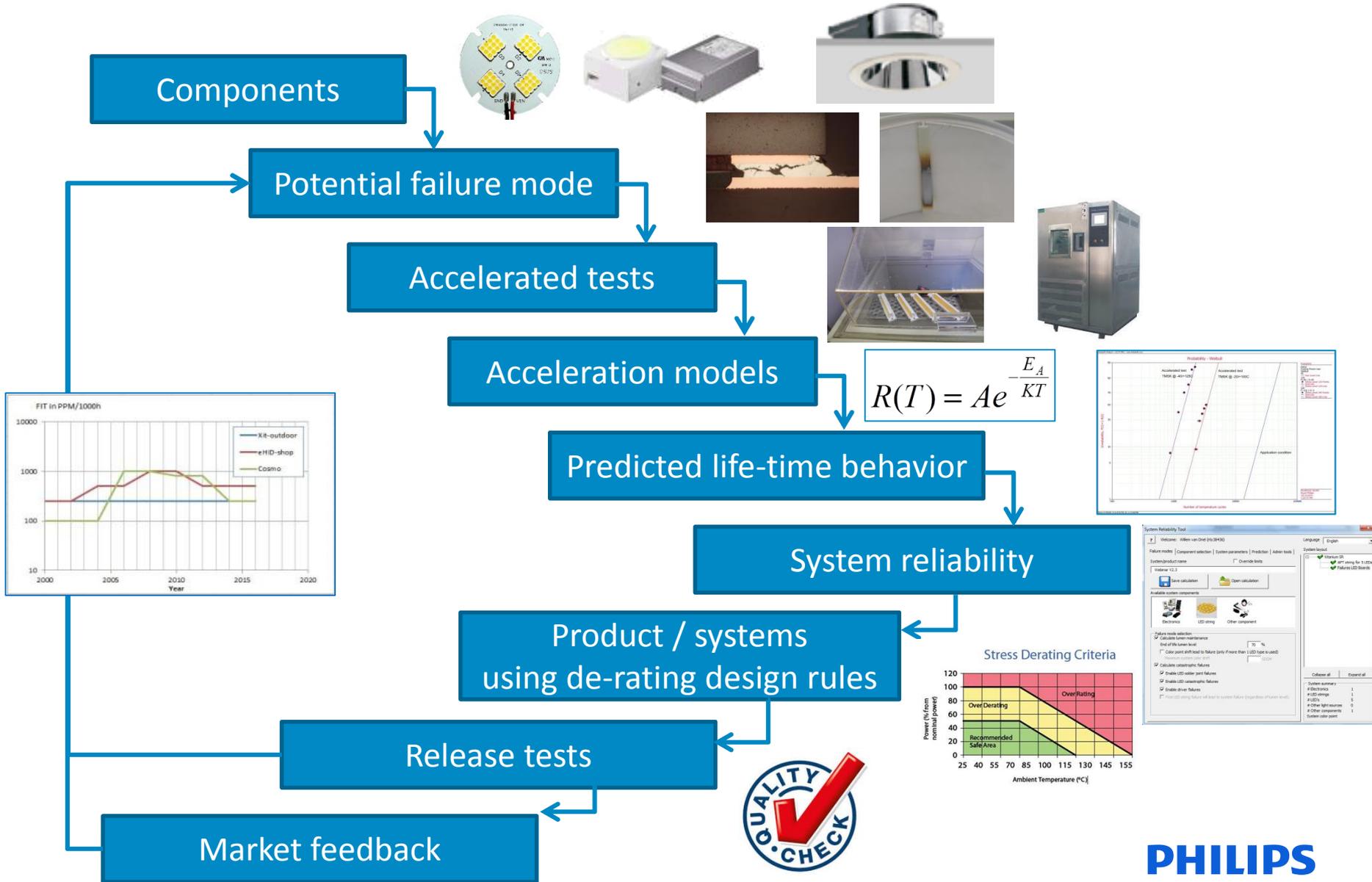


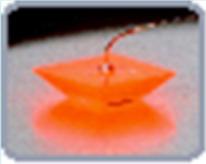
3. System Reliability Tool

- Single source for reliability calculations, >250 users
- Covering 90% of all our LED-based product developments
- Filled with up-to-date reliability models for all components, e.g. LEDs, drivers, controls, etc.

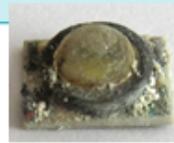
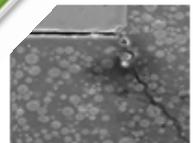


Our Reliability Approach



Level		Identified Failure Modes
0: Bare Die		<ul style="list-style-type: none"> •LED catastrophic failure •Lumen depreciation (several causes) <ul style="list-style-type: none"> •Degradation of active region / ohmic contact •Electro-migration causing dislocations •Diffusion of metal atoms to the active region •Current crowding (uneven current distribution) •Doping related failures
1: Packaged LED		<ul style="list-style-type: none"> •Yellowing of packaging materials (degradation/aging) •Electrostatic discharge (ESD) •Interconnect failure (solder or die-attach) •Cracks (f.e. vertical die crack) •Delamination (at any interface) •Wire bond failure
2: LED's on substrate		<ul style="list-style-type: none"> •Cracks (f.e. in the ceramic) •Solder fatigue •PCB metallization problem •Short (f.e. due to solder bridge)
3: LED module		<ul style="list-style-type: none"> •Casing cracks •Driver failures •Optic degradation (lens change) •ESD failures
4: Luminaire		<ul style="list-style-type: none"> •Fracture •Moisture ingress (condensing) •Component failure (burning) •Dust accumulation on the optics
5: Lighting system		<ul style="list-style-type: none"> •System integration issues •Electrical wiring issues •Installation / commissioning issues

Each failure mode has a certain failure level, which we need to understand, minimize or solve & understand using reliability lifetime tests and analytical / numerical models



Browser window showing the URL: <http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lifetime>. The browser interface includes a menu bar (File, Edit, Go to, Favorites, Help), a toolbar with navigation and printing icons, and a status bar at the bottom.

Page Thumbnails sidebar showing two document pages. Page 1 is selected and highlighted in blue. The thumbnails are small previews of the document content.

TM-21 will utilize LM-80 data collected at multiple operating temperatures. Because of their potentially long life and impracticality of complete testing, estimates of the life of LEDs will likely be based on the extrapolation of limited test data. It is, therefore, important at this technology's early stage to be conservative in design decisions based on expected useful life.

LED Lifetime Characteristics

How do the lifetime projections for today's white LEDs compare to traditional light sources?

Light Source	Range of Typical Rated Life (hours)* (varies by specific lamp type)	Estimated Useful Life (L ₇₀)
Incandescent	750-2,000	
Halogen incandescent	3,000-4,000	
Compact fluorescent (CFL)	8,000-10,000	
Metal halide	7,500-20,000	
Linear fluorescent	20,000-30,000	
High-Power White LED		35,000-50,000**

*Source: lamp manufacturer data.

**Depending on drive current, operating temperature, etc. some manufacturers are claiming useful life (L₇₀) values greater than 100,000 hours.

Electrical and thermal design of the LED system or fixture determine how long LEDs will last and how much light they will provide. Driving the LED at higher than rated current will increase relative light output but decrease useful life. Operating the LED at higher than design temperature will also decrease useful life significantly.

Most manufacturers of high-power white LEDs estimate a lifetime of around 30,000 hours

www.eere.energy.gov

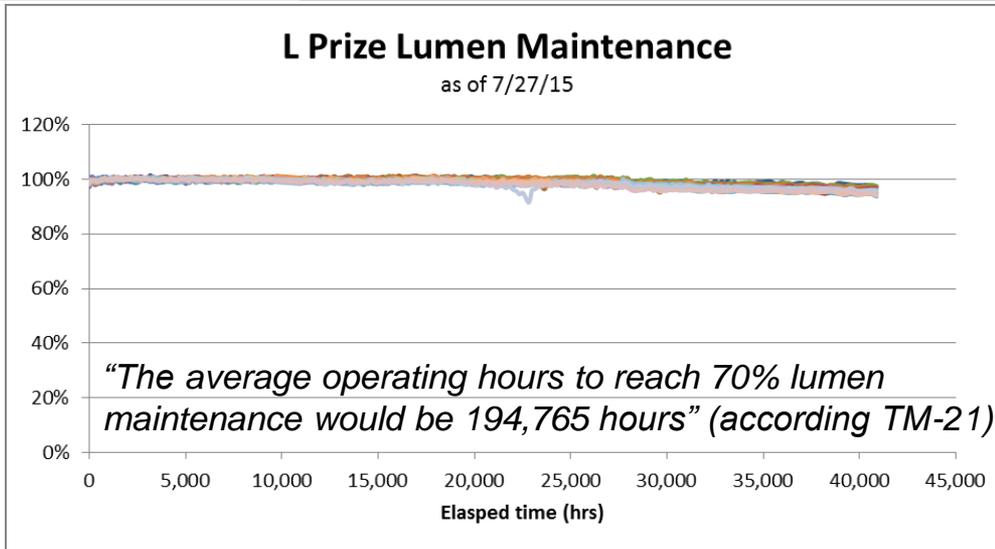
For Program Information on the Web:
www.ssl.energy.gov
DOE sponsors a comprehensive program of SSL research, development, and commercialization.

For Program Information:
Robert Lingard
Pacific Northwest National Laboratory
Phone: (503) 417-7542

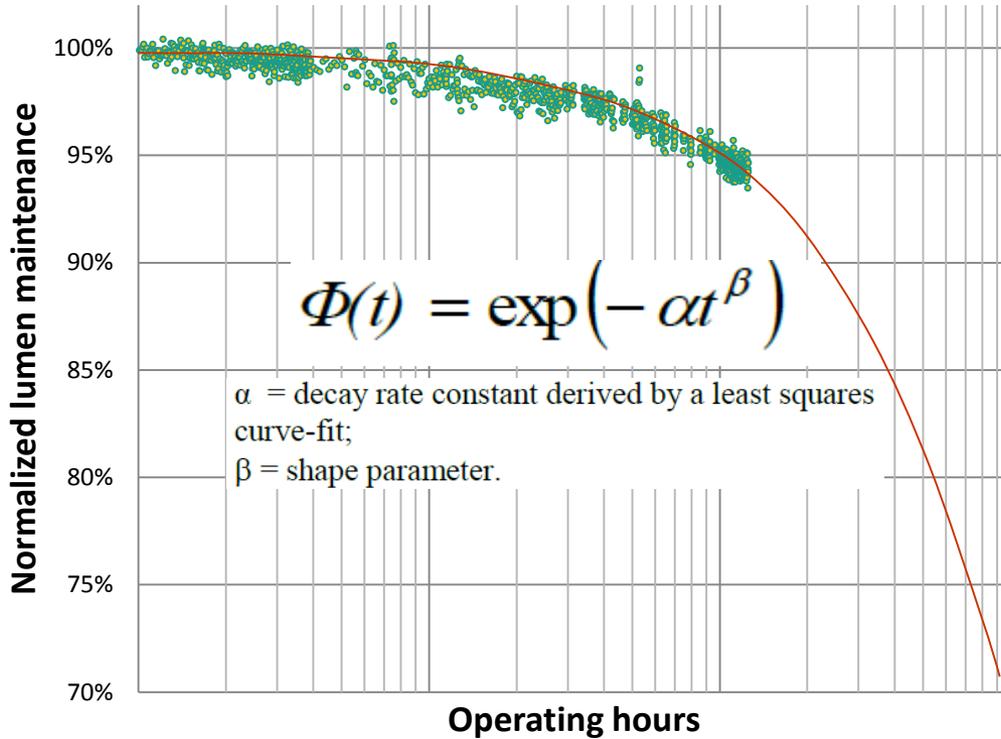
L•PRIZE®

Lumen Maintenance Testing of the Philips 60-Watt Replacement Lamp L Prize Entry

Updated July 2013



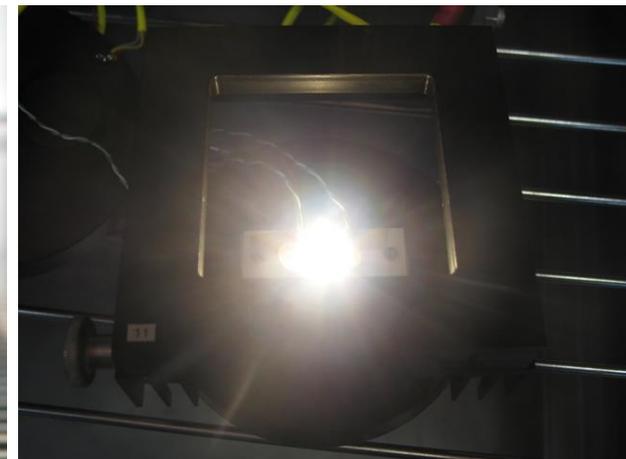
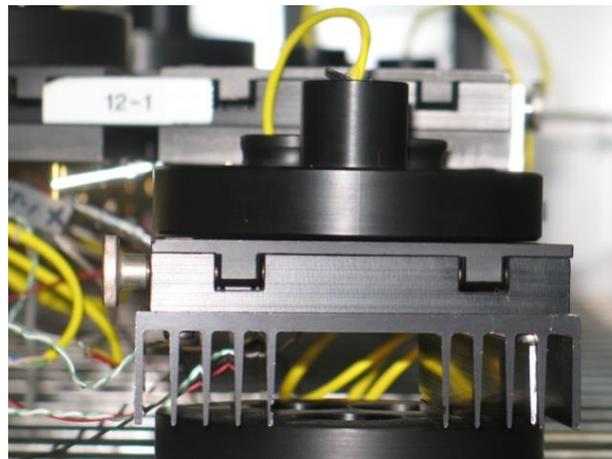
Stress testing result: “Philips L Prize Entry Analysis : Due to the lack of any design-intent failures on the Philips L Prize entry lamps, no meaningful failure analysis could be done.”



$$\alpha = A \exp\left(\frac{-E_a}{k_B T_s}\right) I^n$$

$$L_{70} = (-\ln(0.7) / \alpha)^{1/\beta}$$

Extrapolatie van 6 x test tijd is geoorloofd volgens TM-21 standaard.



Bij toepassing van 6 x versnelling betekent het nog steeds dat circa 9.000 uur getest moet worden om een levensduur van 50.000 uur aan te tonen

Lumen Maintenance Predictions for LED Packages using LM80 data

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Voorbeeld van toepassing van Power Cycling
Operating Damp Heat Test om acceleratie factor
tijdens levensduurtesten te verhogen

De acceleratie factor voor de afname van de lichtintensiteit wordt (vereenvoudigd) weergegeven door:

$$AF = \left[\frac{E_{stress\ application}}{E_{stress\ accelerated}} \right]^{-p} \cdot \left[\frac{L_{application}}{L_{accelerated}} \right]^{-r} \cdot \left[\frac{RH_{application}}{RH_{accelerated}} \right]^{-n} \cdot e^{\frac{E_a}{k} \left(\frac{1}{T_{application}} - \frac{1}{T_{accelerated}} \right)}$$

Where

E_{stress} = Electrical stress, such as driving current

p = electrical dependent parameter

L = Load, such as duty cycle

r = added stress depended parameter

RH = Relative Humidity (%)

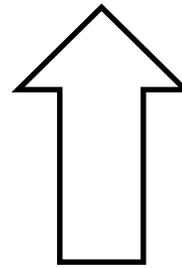
n = Humidity depended parameter

E_a = Activation energy (eV)

k = Boltzmann's constant

T = Temperature (K)

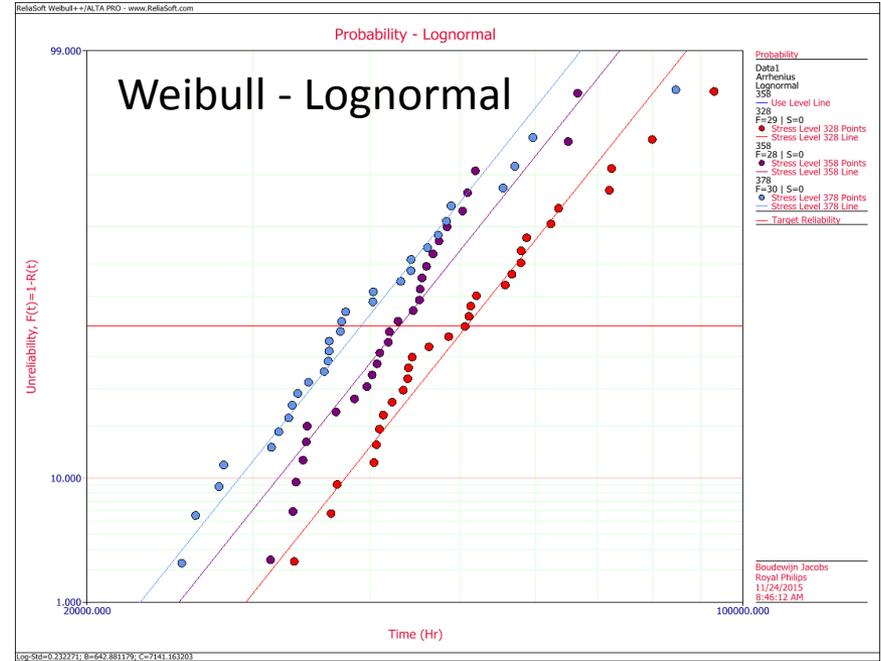
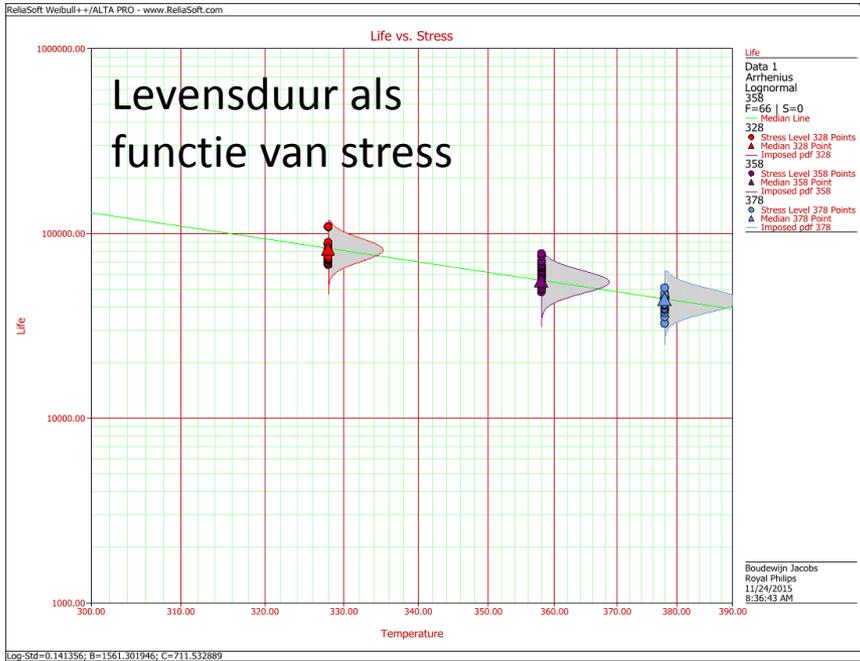
$$AF = \left[\frac{E_{stress\ application}}{E_{stress\ accelerated}} \right]^{-p} \cdot \left[\frac{L_{application}}{L_{accelerated}} \right]^{-r} \cdot \left[\frac{RH_{application}}{RH_{accelerated}} \right]^{-n} \cdot e^{\frac{E_a}{k} \left(\frac{1}{T_{application}} - \frac{1}{T_{accelerated}} \right)}$$



Adding moist in test environment accelerates lumen decay.



Test ID	Test	Condition	Testing time		
1	WHTOL	T _{amb} 60°C / 90 % R.H. 120 mA	6000 hrs		Model building
2	WHTOL	T _{amb} 85°C / 85 % R.H. 120 mA	6000 hrs		
3	WHTOL	T _{amb} 85°C / 45 % R.H. 120 mA	6000 hrs		
4	LM-80	T _s 55°C	6000 hrs		
5	LM-80	T _s 85°C	6000 hrs		
6	LM-80	T _s 105°C	6000 hrs		
A	HTOL	T _s 92°C and T _s 107°C on R20 Lamp	10000 hrs		Model verification
B	HTOL	T _s 95°C and T _s 105°C on Entry Bulb Lamp	10000 hrs		



(Extra) acceleration factor between WHTOL and HTOL

3.2
(Besparing van 6.000 uur om 50.000 hrs LT aan te tonen)

Activation energy for lumen decay (E_a)

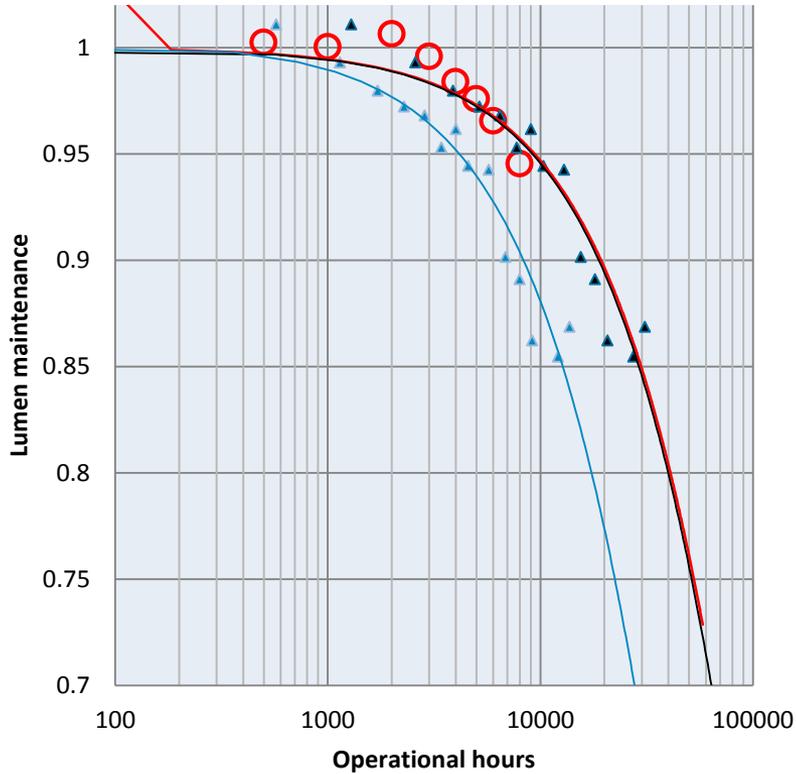
0.3 eV

Humidity dependent factor for lumen decay (n)

$n = 0.2 - 1.0$

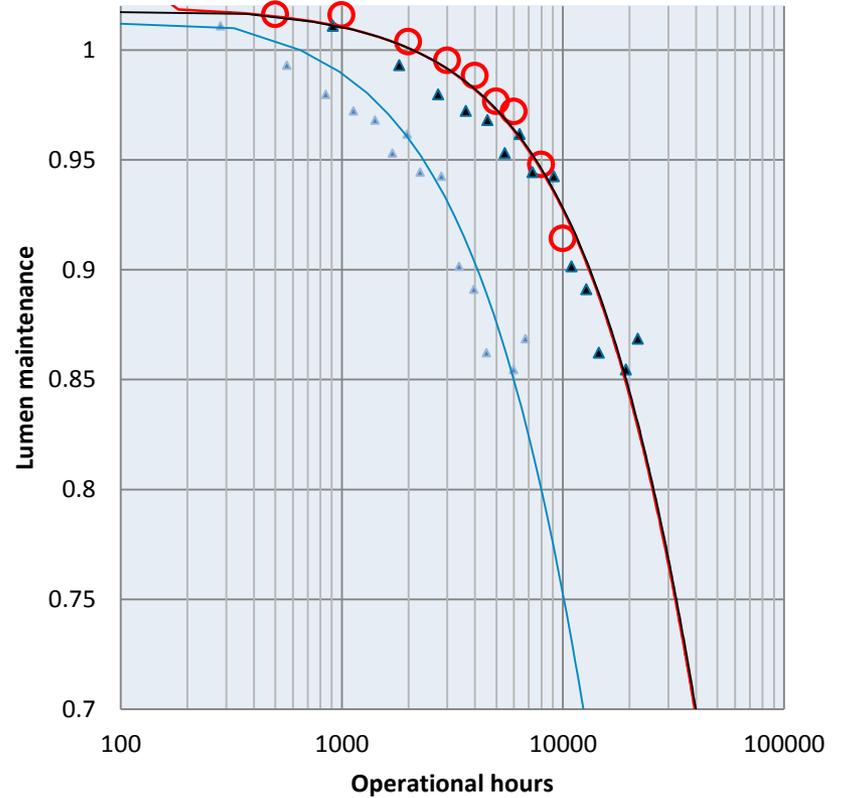
$$AF = \left[\frac{E_{stress\ application}}{E_{stress\ accelerated}} \right]^{-p} \cdot \left[\frac{L_{application}}{L_{accelerated}} \right]^{-r} \cdot \left[\frac{RH_{application}}{RH_{accelerated}} \right]^{-n} \cdot e^{\frac{E_a}{k} \left(\frac{1}{T_{application}} - \frac{1}{T_{accelerated}} \right)}$$

Lumen Maintenance
WHTOL LED -> R20 @ 25C Lamp Ts = 92C



- Actual lifetest data R20 @ 25C
- ▲ According new model
- ▲ According previous model

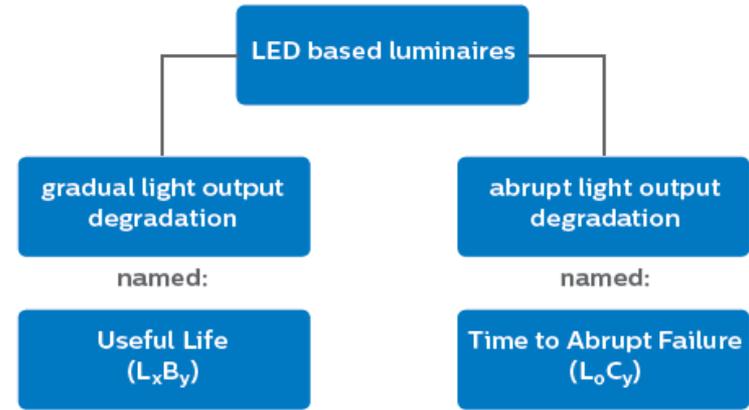
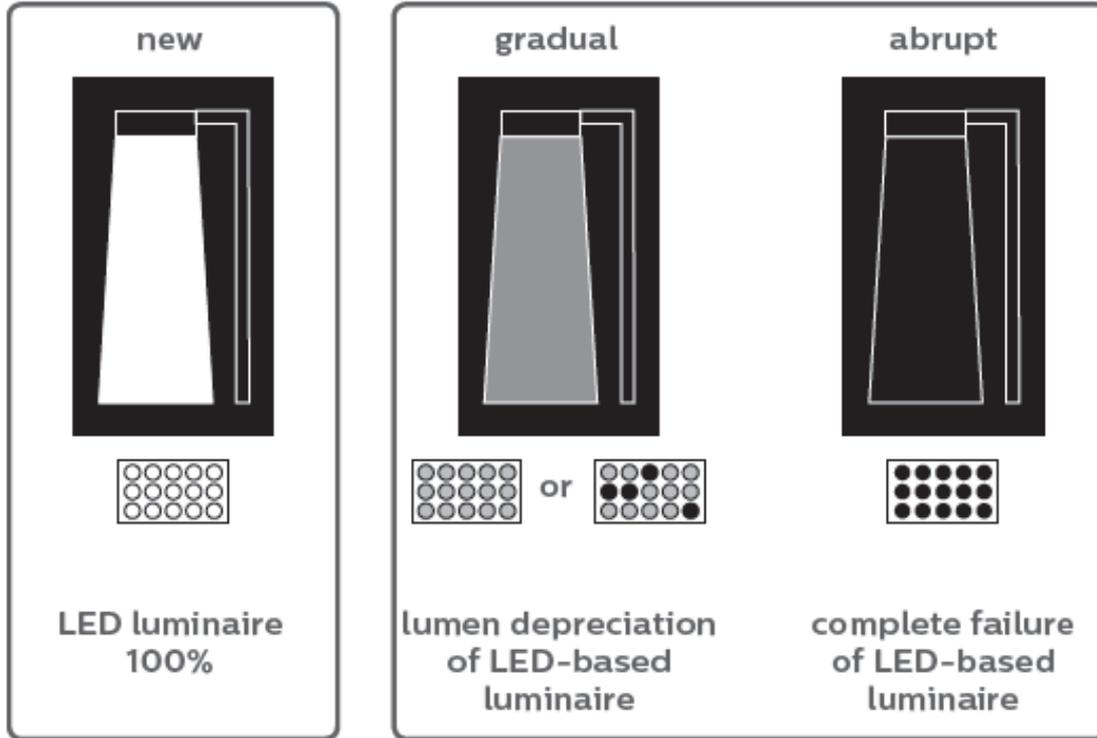
Predicted B50 Lumen Maintenance
WHTOL LED -> R20 @ 45C Lamp Ts = 107C

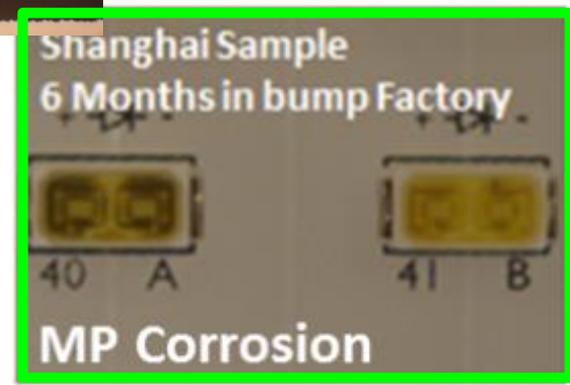
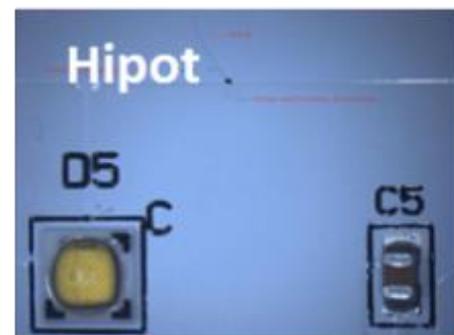
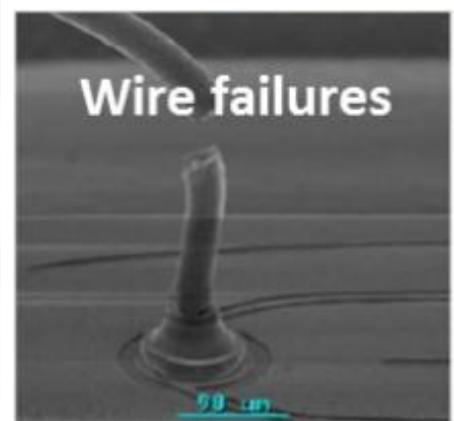
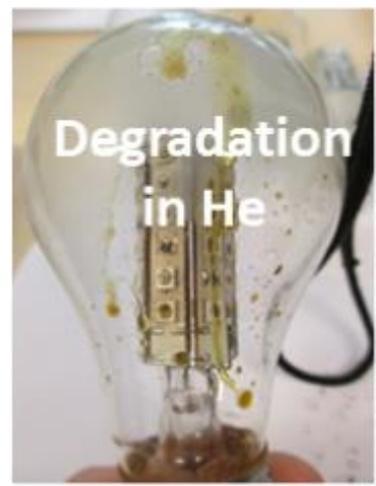
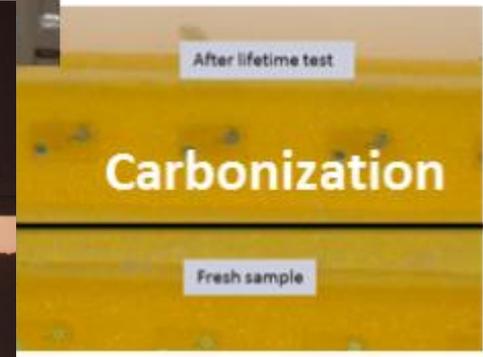
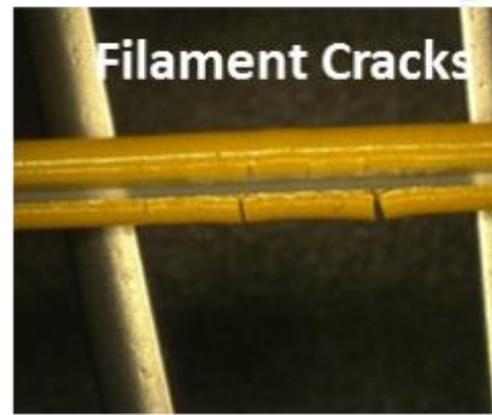


- Actual lifetest data R20 @ 45C
- ▲ According new model
- ▲ According previous model

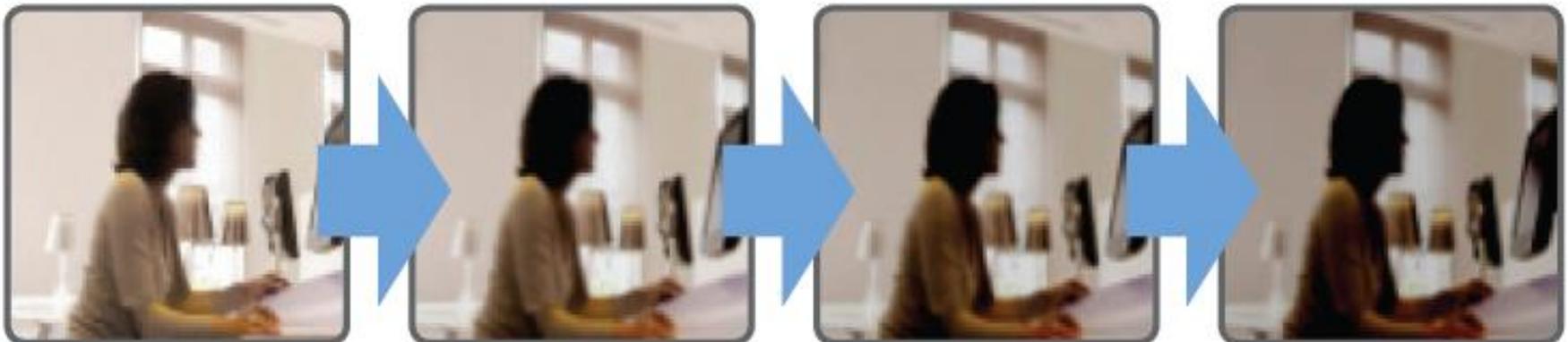
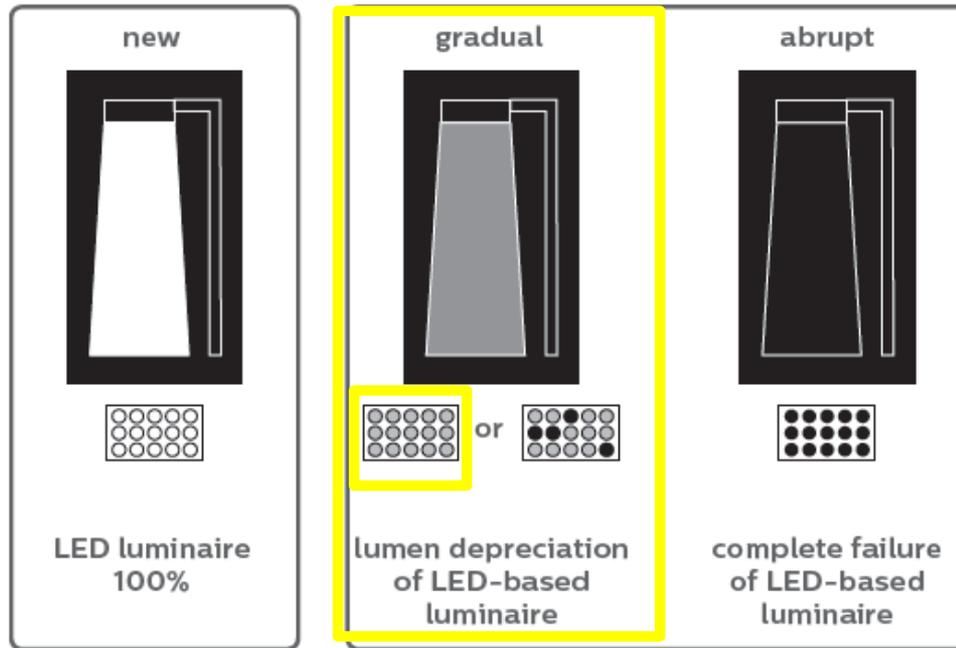


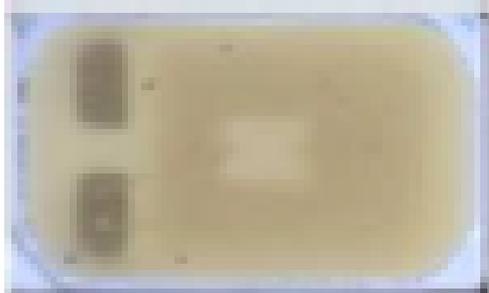
Voorbeelden van
faalmechanismen

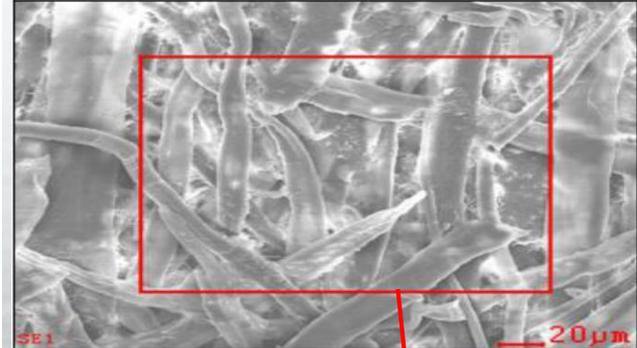
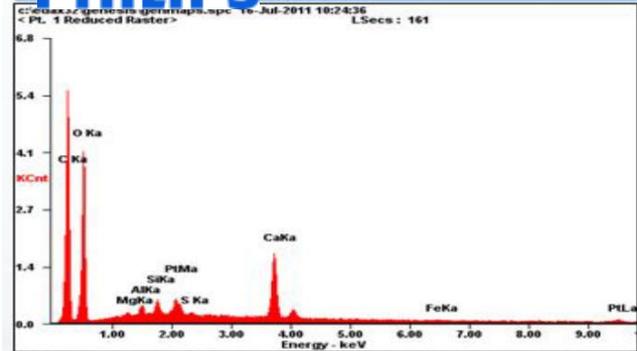
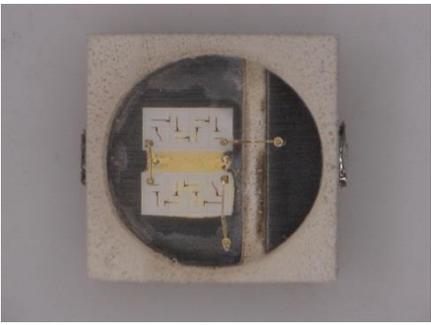
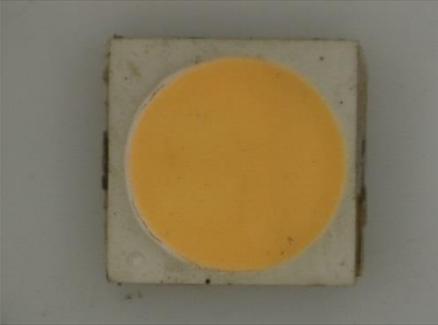




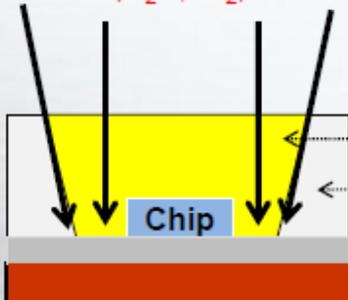
Corrosie van zilverspiegel in LP/MP LEDs is één van de belangrijkste oorzaken van een geleiderlijke maar versnelde vermindering van de lichtintensiteit







Diffusion of Corrosive Gas
(H_2S , Cl_2)

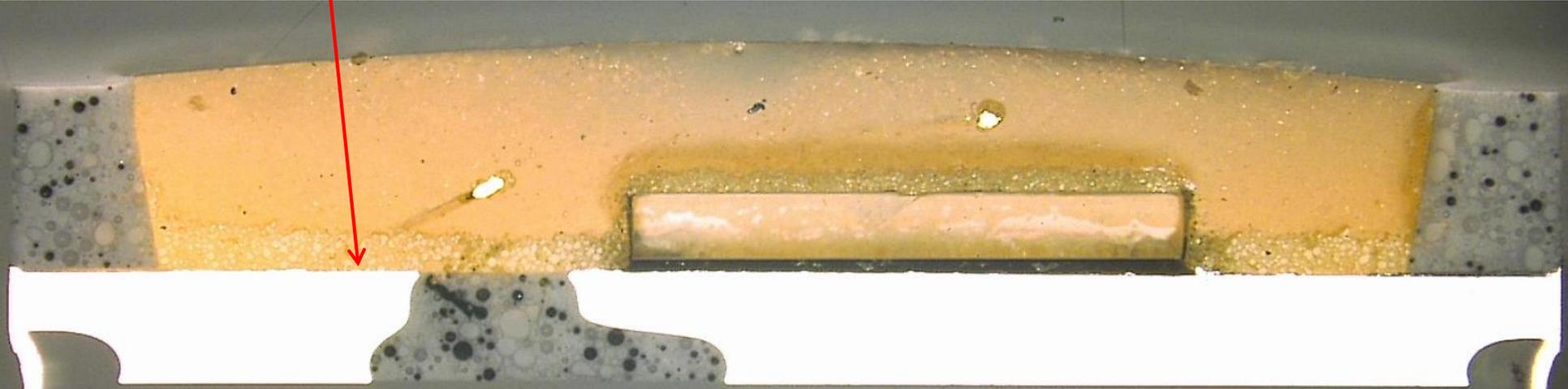


Silicon
Reflector

Ag plating layer
Lead Frame (Cu)

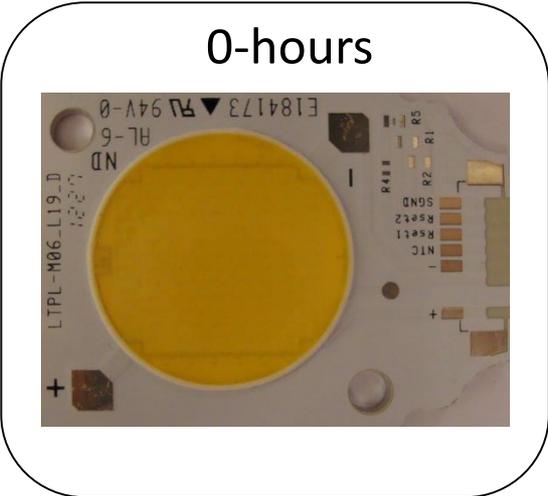
Result of Ag_2S , $AgCl$ creation

1. Luminance aging
2. Color Shift
3. Bonding strength is weakened between silicon and Ag Layer

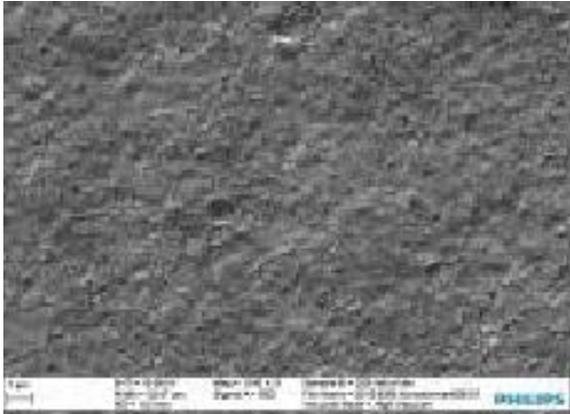
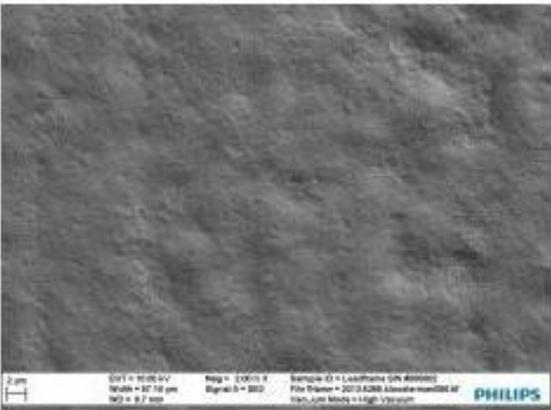
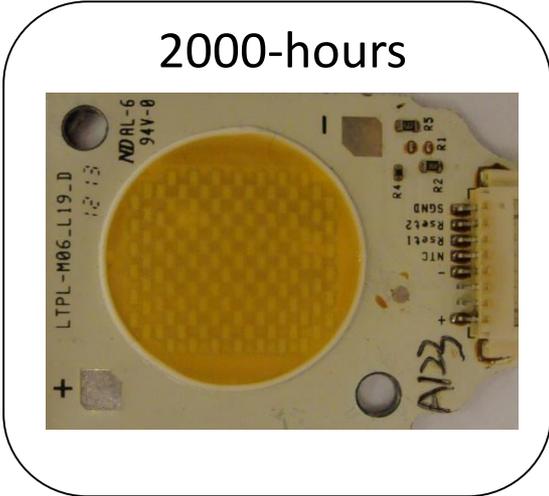


Corrosion Ag-mirror CoB

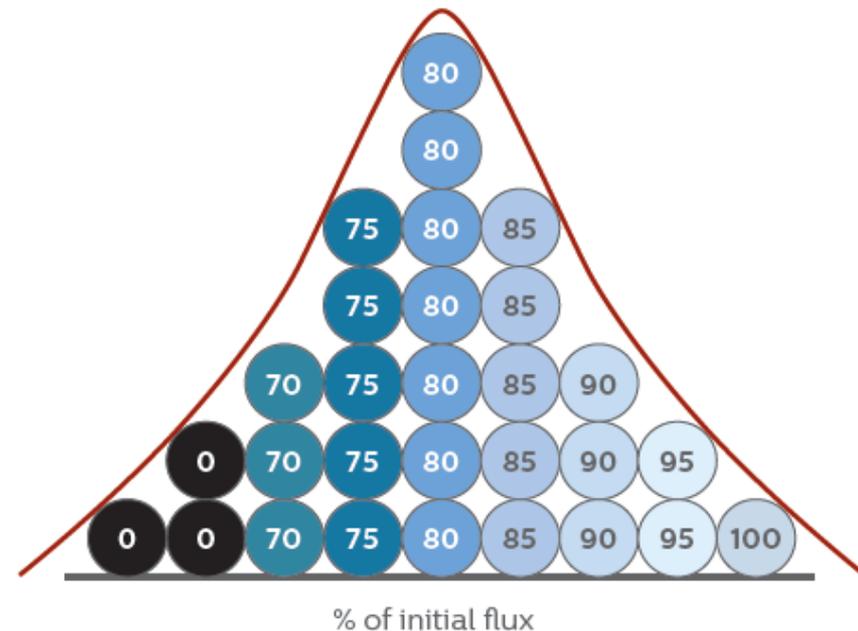
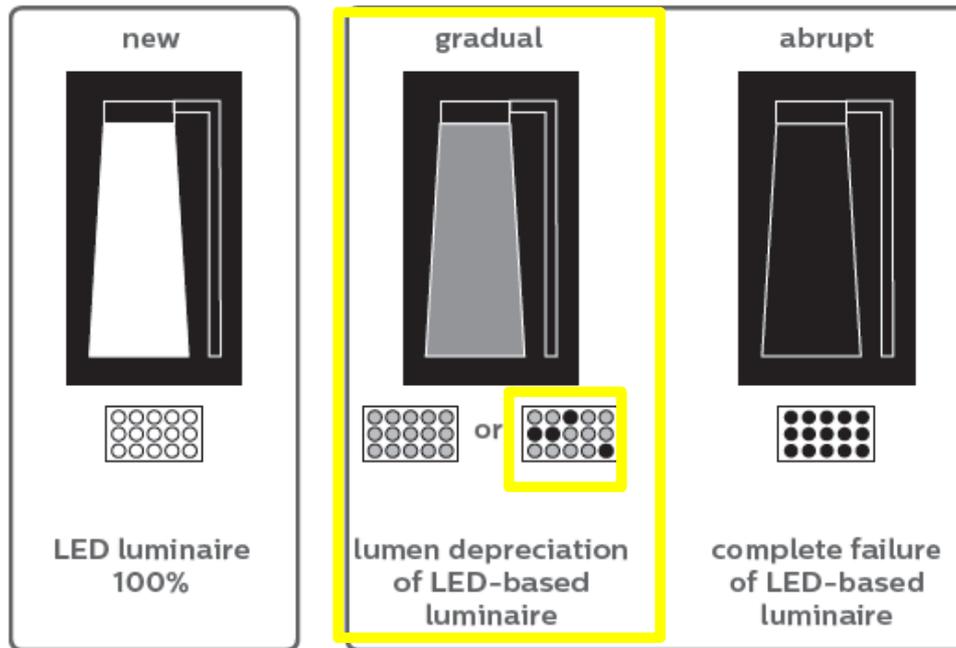
0-hours



2000-hours



Wirebond failure is één van de belangrijkste oorzaken bij een abrupte afname van de lichtintensiteit op LP/MP LED package niveau



“Wire bond fatigue in LED Packages: testing and modelling”

**The 2016 International Applied Reliability Symposium, Europe
April 4 – 7, 2016
Munich, Germany**

