



The Fortronic LED& Lighting Design Forum

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27th March 2012



Farnell

element14

Presentation for *The Fortronic LED& Lighting Design Forum*

Things you hear about LEDs ?

Basic Advantages of LED Light:

- ***Are very **energy efficient*****
- ***Are **directional** - No wasted light, any pattern possible***
- ***Have very **long lifetime*****
- ***Are inherently **rugged** - No filament to break***
- ***Start **instantly** - controllable : New lighting features, power savings***
- ***Are **environmentally** sound - no Hg, Pb, heavy metals***
- ***Love cold temperatures - **No cold starting** issues***

But

The performance will depends on the design of the Light fixture

The Fortronic LED& Lighting Design Forum

Lighting Class LED's for High Quality LED Lighting

Topics :

Introduction – an overview of Cree

Section 1 : Lighting Class LEDs

Section 2 : High Quality LED Lighting – How to achieve

Section 3 : Design and Handling considerations



Cree Overview

March 2012

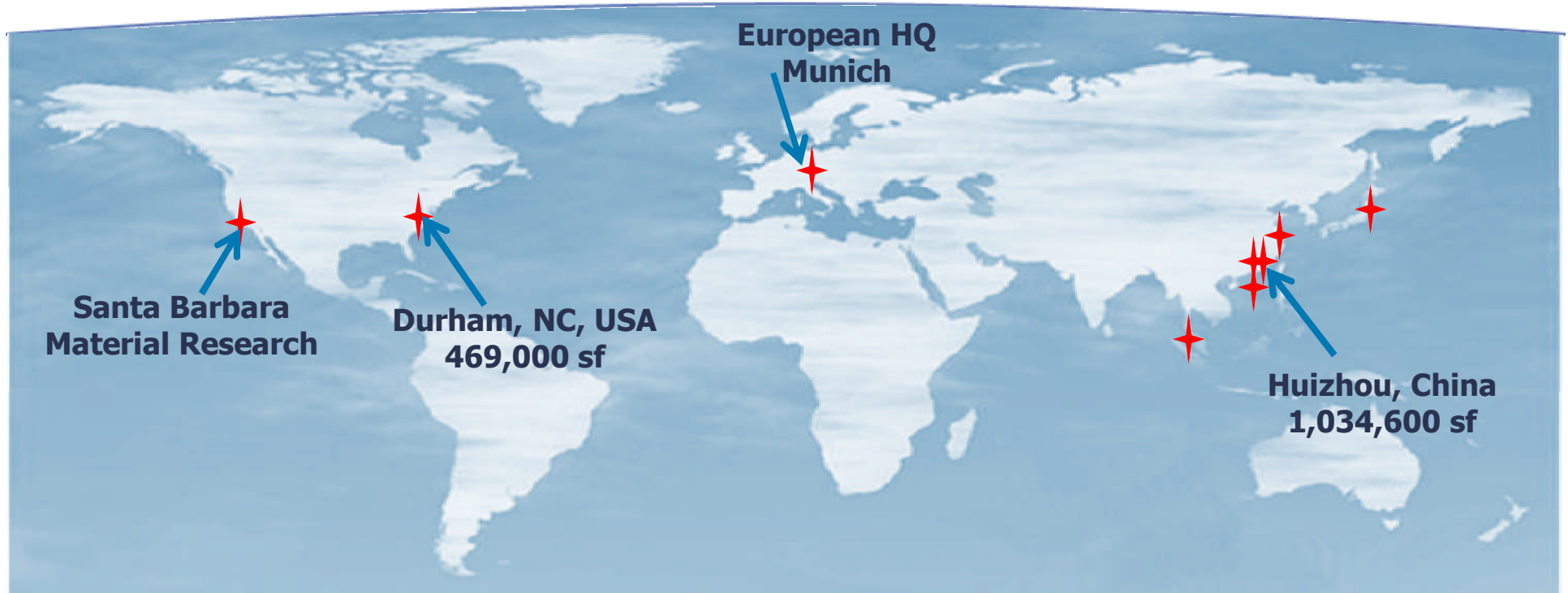


Cree's mission is to **lead the LED lighting revolution** to obsolete inefficient lighting

Cree will do **whatever it takes** to accelerate the adoption of LED light



Cree – A Global Company



- **US : Chip manufacturing**
- **China : Cree factories for high volume production**
 - **Manufacturing**
- **Regional Application and technology Centres**
- **Global and regional Distributors for local stock & service**

Value of the Cree Brand



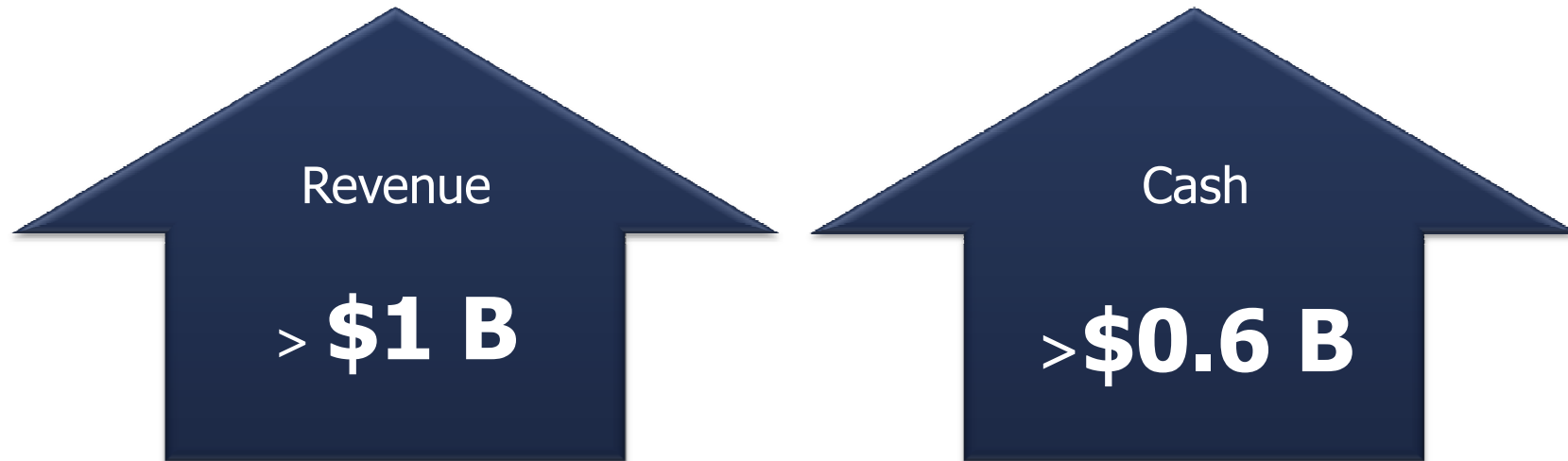
Nearly 9 out of 10 lighting buyers would be more likely to purchase products labeled "Cree LED inside"

– Perceived as **higher quality**

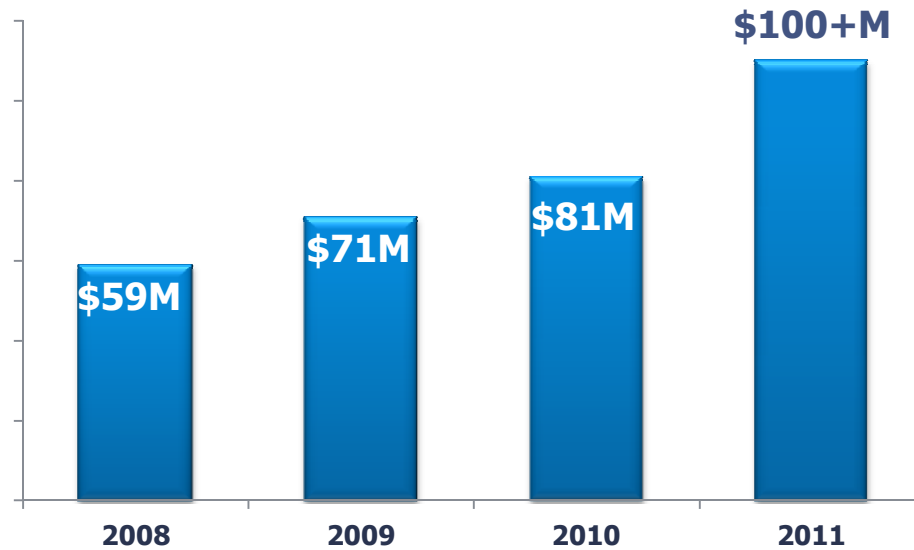
Cree recognized by IMS Research as the **market leader in LEDs for lighting** (Dec 2010)



Financial Strength & Sustainability



Investment in R&D – Driving Innovation



- **Advancements in lumens & lumens per Watt**
- **Larger wafers**
- **Reliability enhancements**
- **Optimized packages for lighting**



Proof of Technology Leadership



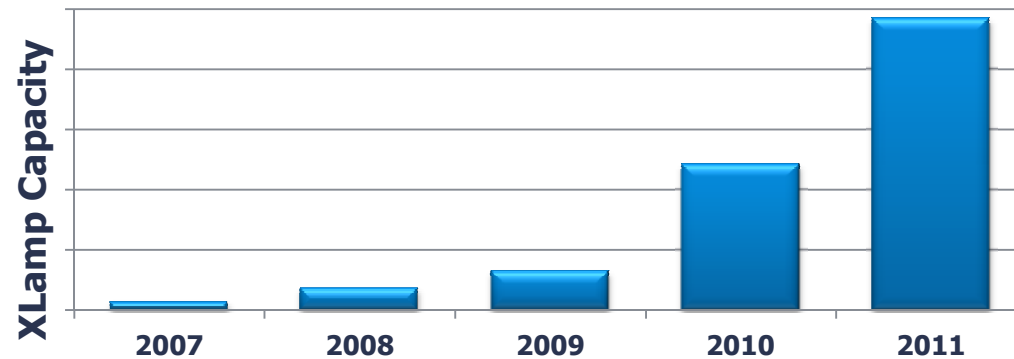
| | Issued Patents | Pending Applications |
|--------------|----------------|----------------------|
| U.S. | 546 | 599 |
| Non-U.S. | 1,005 | 1,543 |
| Total | 1,551 | 2,142 |

Note: All totals include exclusively licensed patents

- IP portfolio & scale large enough to provide indemnity that matters

Investment - high volume production & cost down

High volume production



- **\$475M invested into capacity expansion over 3 years**

Cost reductions

Larger Wafers - Creates Cost Reductions
Improvements in Flux / Efficacy – need less LEDs
Low cost manufacturing ; high volumes – lower unit cost

- **Year on Year savings passed on to customers**

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Lighting Class LED's for High Quality LED Lighting

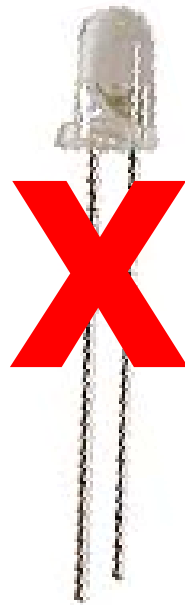
Topics :

Section 1 : Lighting Class LEDs

Section 2 : High Quality LED Lighting – How to achieve

Section 3 : Design and Handling considerations

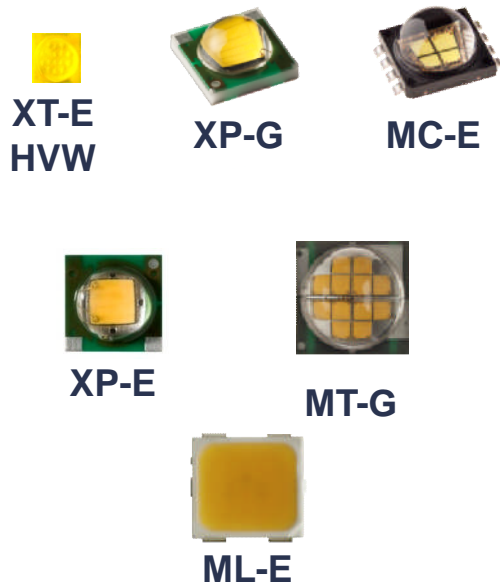
Lighting Class LED's - What are they ?





Lighting-Class LEDs are Not One Product

LAMPS



FIXTURES



XLamp LEDs and Modules Portfolio: Lighting

Discretes (Directional)



XR-E
XR-C



XP-G
XP-E
XP-C



XB-D



XT-E
WHT



XM-L

- Optical control – put more light where it is needed
- Design flexibility



Discretes (Non-Directional)



XM-L HVW



XT-E HVW



XP-E HEW



ML-E
ML-B



MX-6
MX-3

- Smooth look to emulate fluorescent in linear & panel lighting
- Uniform light & color over angle

Arrays (Directional)



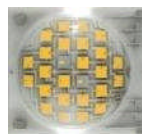
MC-E



XM-L EZW



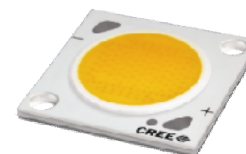
MT-G



MP-L

- High lumen density for optical control
- Excellent LED-to-LED color consistency

Arrays (Non-Directional)



CXA2011

- Easy assembly
- One component eliminates multiple shadows

Modules



LMH2



LMR2



LMR4



LMH6

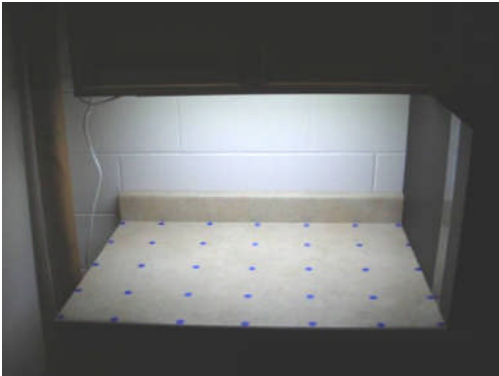
- Highest level of integration
- Speed time to market
- Excellent Color Consistency

What Can Go Wrong: Poor quality LEDs

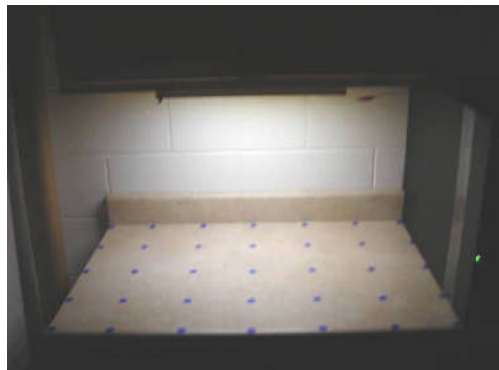
Time zero



*LED Puck
84.1% Drop*



*16.5" Linear
97.8% Drop*

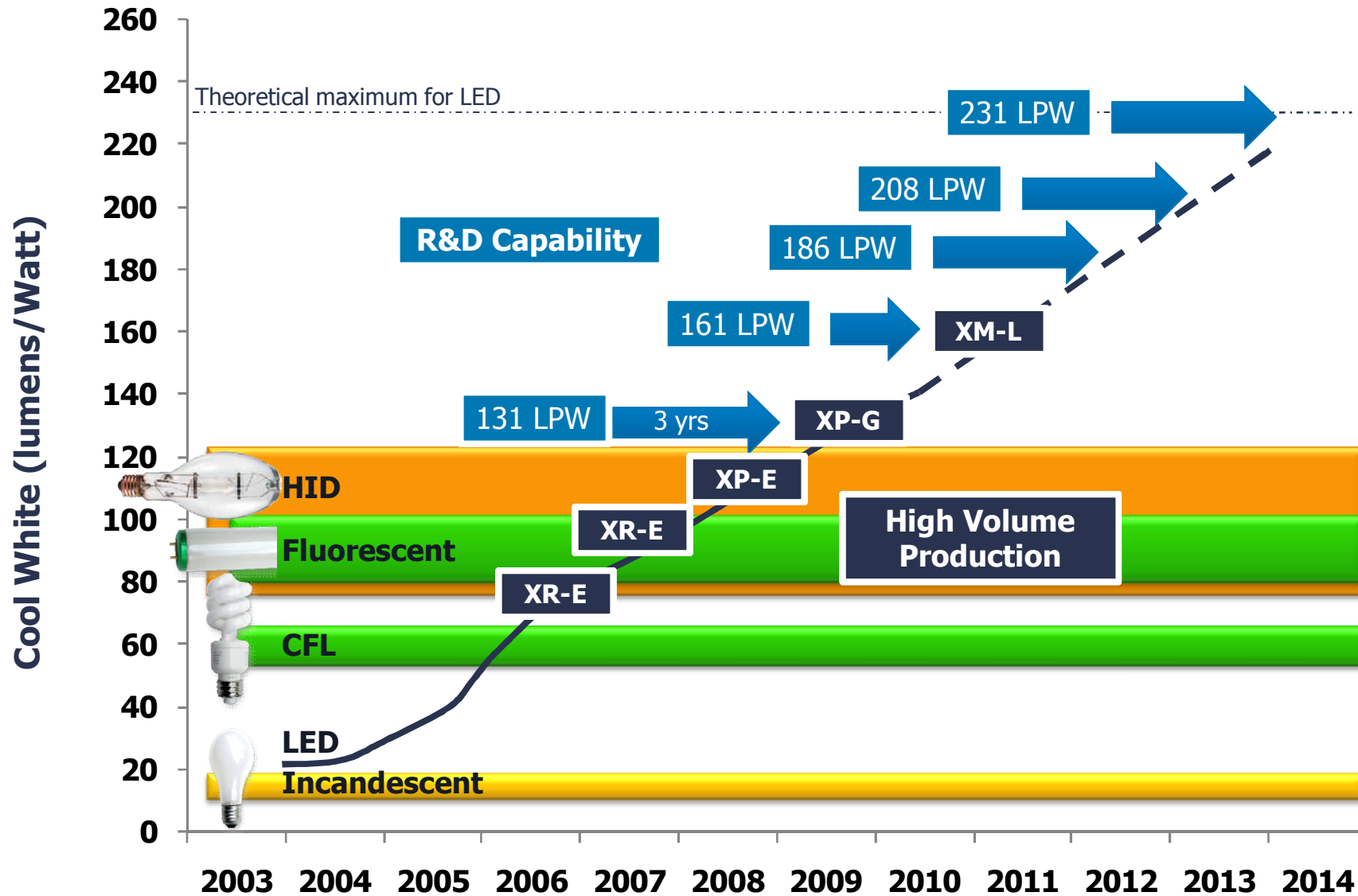


*22" Linear
96.9% Drop*

1000 hours



Lighting Class LED Efficacy Developments

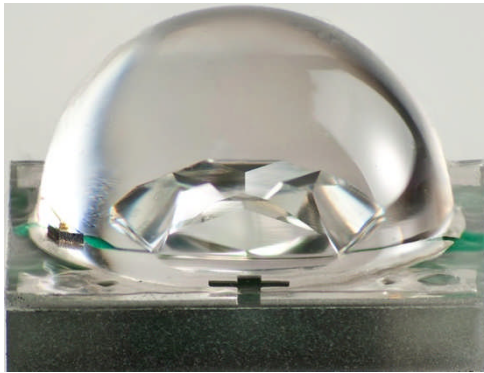


Cree Silicon Carbide Enables Next GEN Lighting Class LED

Best Performance

Compared to sapphire:

- Fewer dislocations → **More photons**
- Better index matching of GaN to substrate
→ **More light extraction**
- **Inherent 5-10% efficacy advantage**



Cree's newest SiC-based LED
(shown in Royal Blue for better
detail of the chip)

Best Reliability

- Fewer epi defects
→ **Fewer LED failures & less rework**

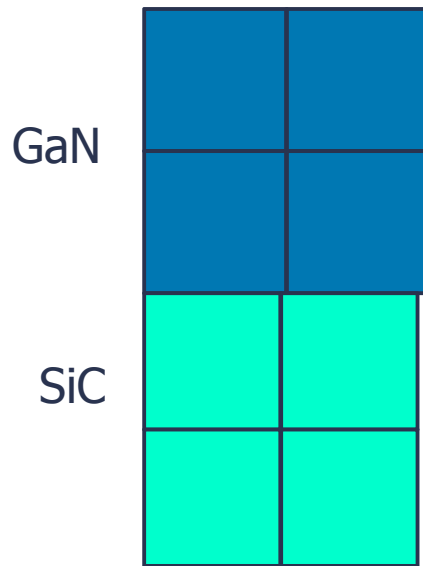
Security of Supply

- Only manufacturer of wafers AND chips
→ **Ability to scale production quickly**

SiC brings improvements optimized for lumens/\$

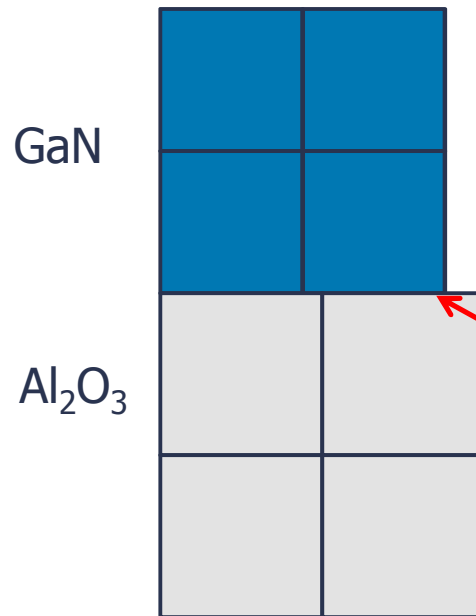
Silicon Carbide Creates More Efficient LEDs

Simple* 2D** Cartoon



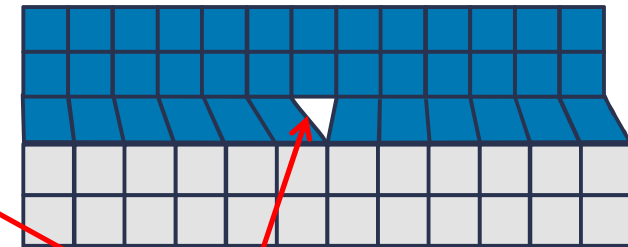
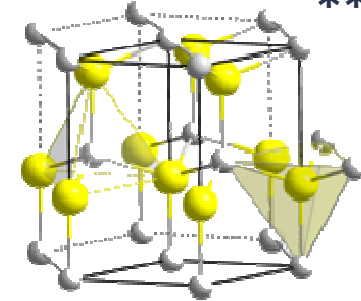
GaN on SiC

1: 0.967
(3.3% mismatch)



GaN on Sapphire

1: 1.148
(14.8% mismatch)



**Lattice mismatches
create areas where
the LED is less
efficient.**

SiC = 4.5x better lattice match to GaN

* Drawn to scale.

** SiC, GaN, and Al₂O₃ are actually 3D Hexagonal crystalline structures

Lighting Class LED's - Need for Quality

LED Chip

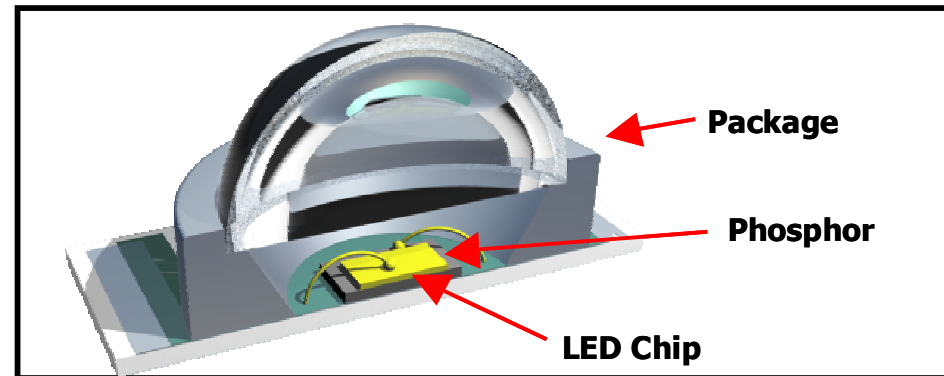
- Determines raw brightness and efficacy

Phosphor System

- Determines color point and color point stability

Package

- Protects the chip and phosphor
- Helps with light and heat extraction
- Primary in determining LED lifetime

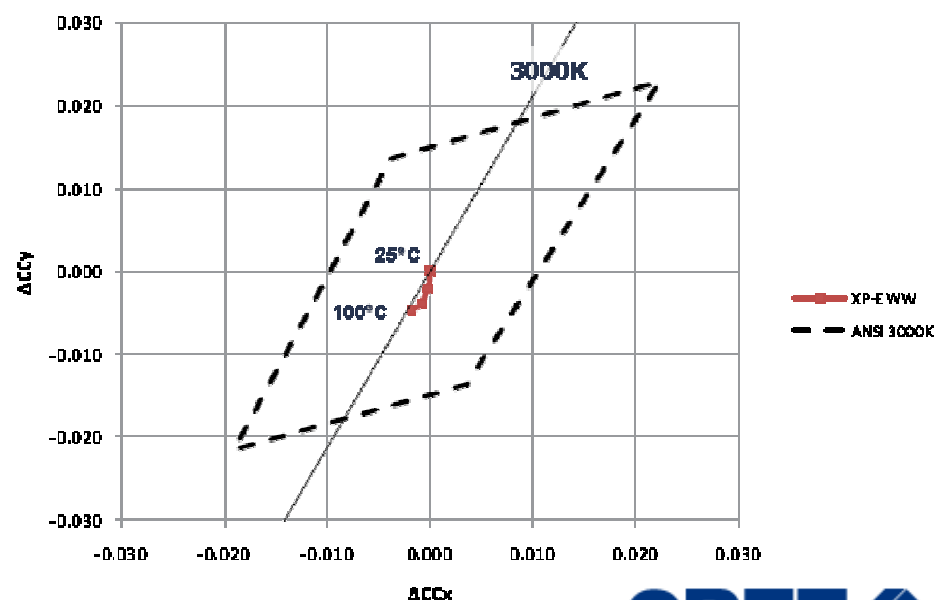
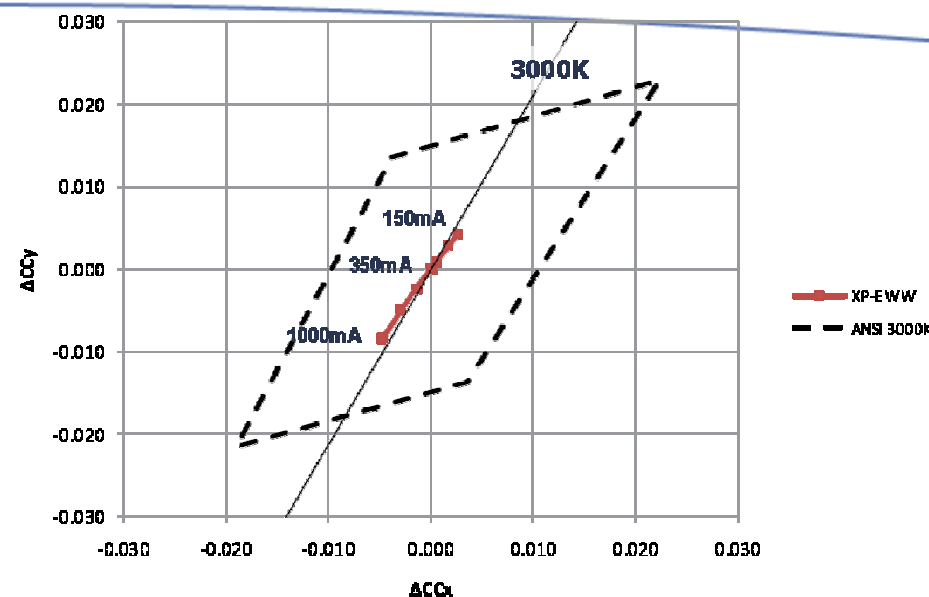


Lighting Class LED's

- **Colour stability**

Color Shift in Operation (XP-E, Correlation Document)

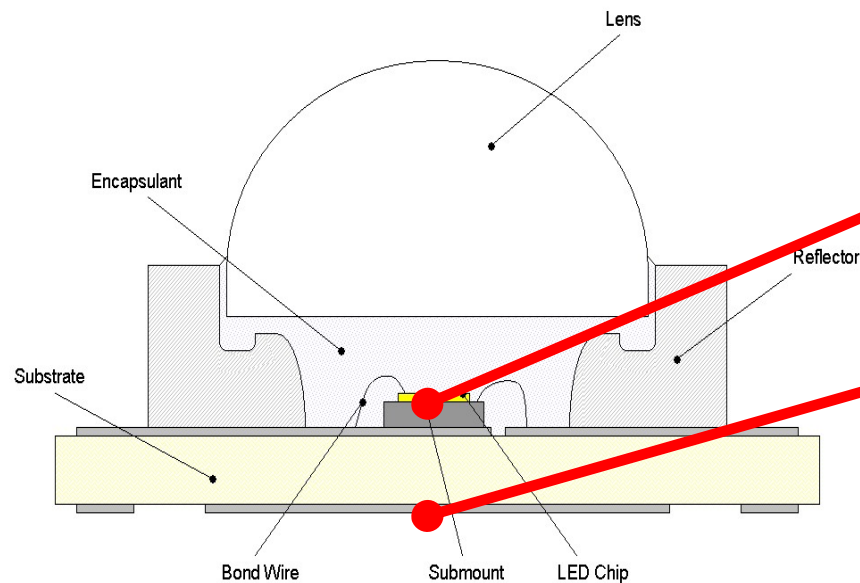
- Here the shifts are shown in X-Y space over the range of temperature and current
- These results are shown in detail in CLD AP81 rev 0, describing the correlation of measurements



Lighting Class LED's

- **Lumen Maintenance - Life Time
L70**

LED Lumen Maintenance Critical Parameters



1. T_{AIR}

Ambient Air Temperature

2. T_j

Junction Temperature

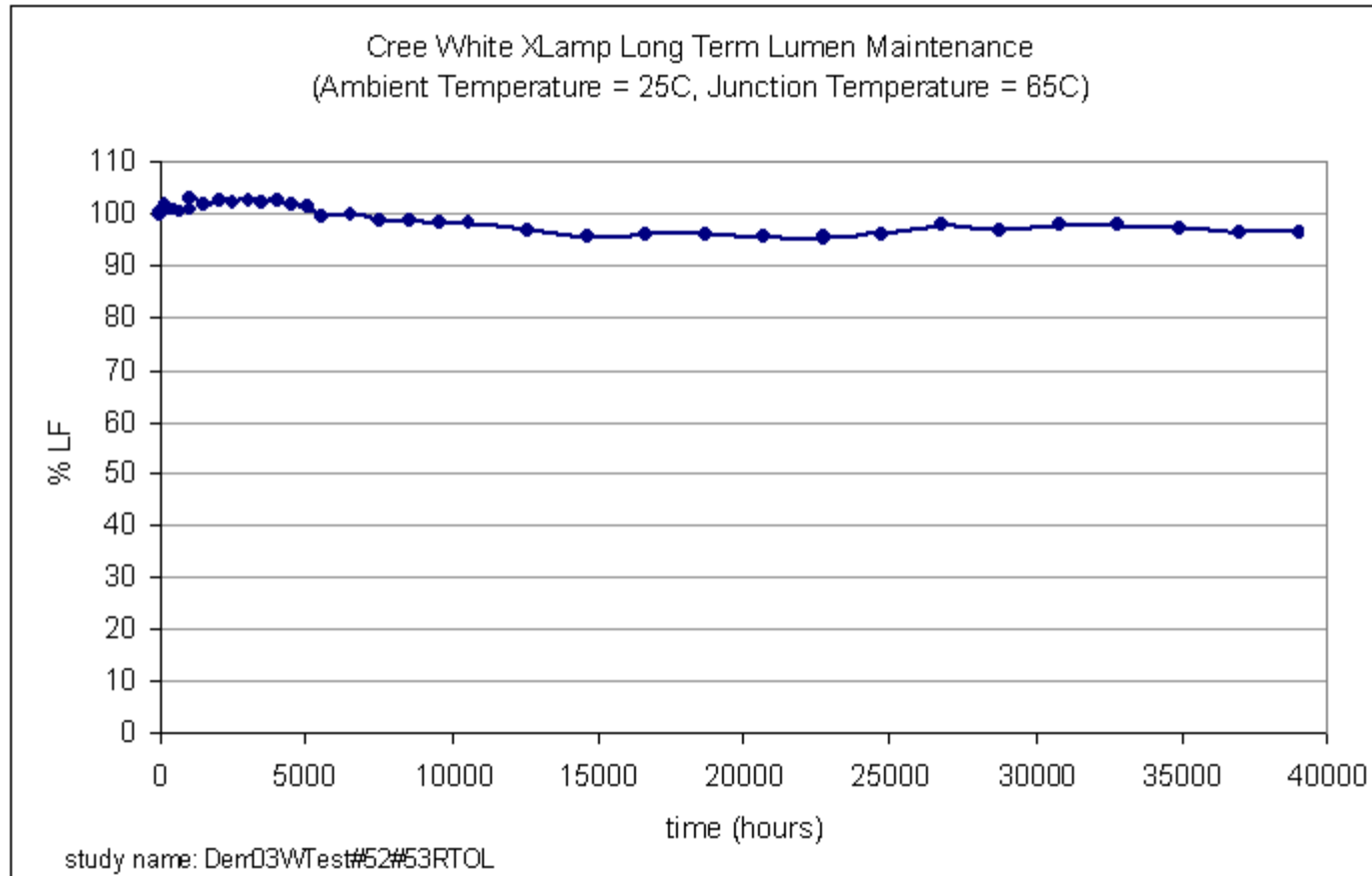
3. $T_{SP} / T_C / T_S$

Solder-Point Temperature /
Case Temperature

4. I_F

Forward Current /
Drive Current

40,000 Hour / 4.5 Year XLamp Long-Term Data



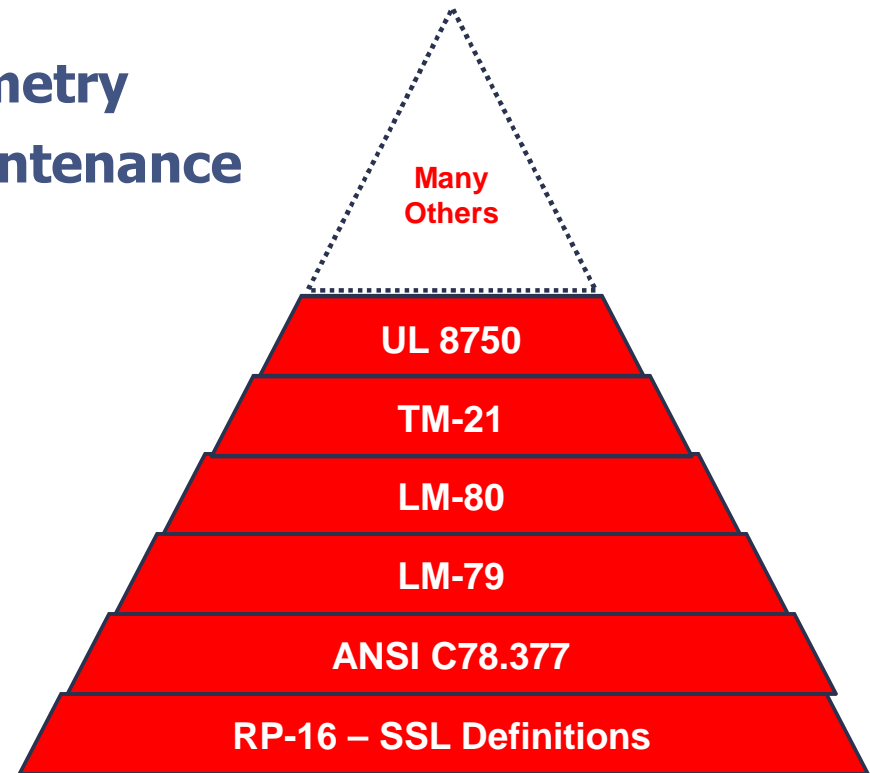
- **At lower ambient air temperature, LEDs hardly depreciate at all.**

Lighting Class LED's

- **Industry Standards**

SSL Standards (U.S.)

- 4 years ago: Major and reasonable objection to LED
- Today:
 - TM-21 - Projecting Long Term Lumen Maintenance of LED Light Sources
 - ANSI C78.377 – chromaticity
 - IES LM-79-2008 – SSL photometry
 - IES LM-80-2008 – Lumen Maintenance
 - UL 8750 – Safety
 - RP-16 – SSL Definitions
- Most of the major pieces are in place, many more on the way...
- Being practiced and referenced widely by industry and government programs



Lighting Class LED's

Lighting-Class Performance:

- **High efficacy ($>80\text{lm/w}$)**
- **Colour stability**
- **Lumen Maintenance**
- **Conform to industry standards**

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Lighting Class LED's for High Quality LED Lighting

Topics :

Section 1 : Lighting Class LEDs

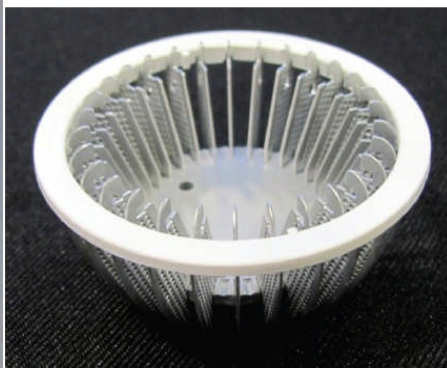
Section 2 : High Quality LED Lighting – How to achieve

Section 3 : Design and Handling considerations

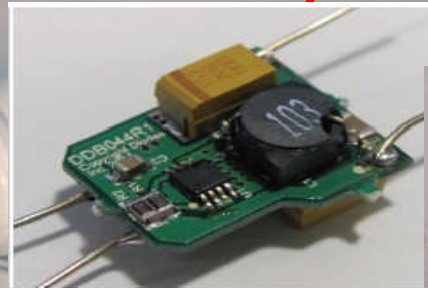
LED Lifetime Is Irrelevant

System Lifetime is What Creates Value

Heat Sink: Linchpin of the entire system. If this is poorly designed, all the other components can be compromised



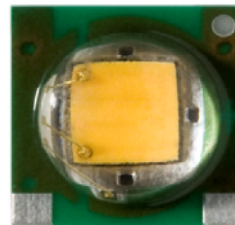
Driver: Currently the weakest point of the system, but the big companies are working on this



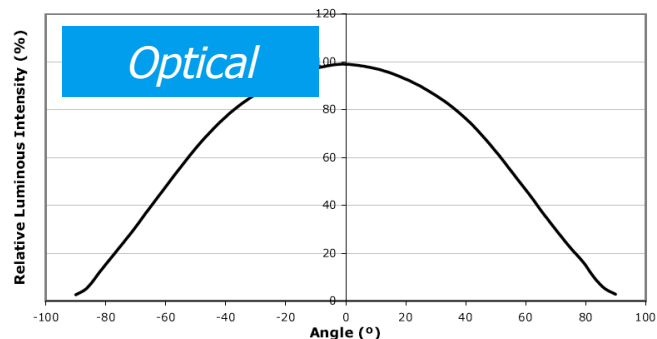
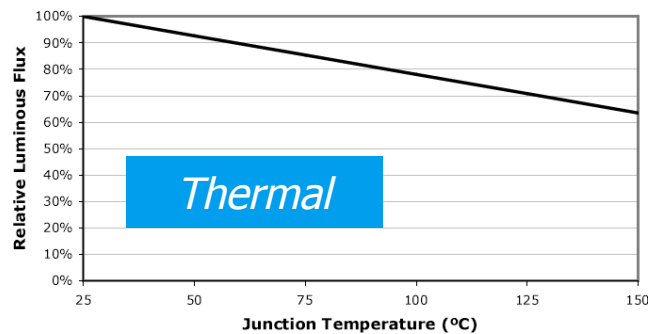
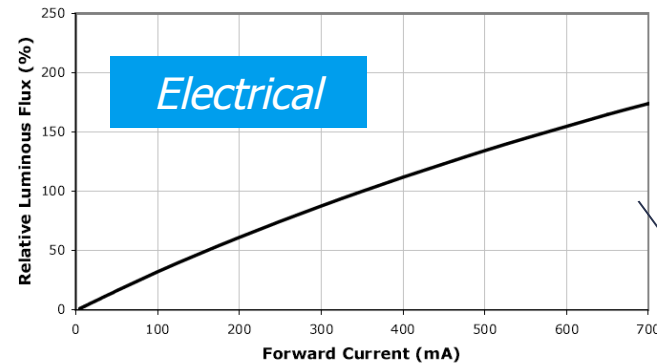
Optical Components: Can (rarely) yellow over time and lose light; system design choice



LED Lamps: Practically never fail; depreciate very slowly in a well-designed system



SSL Luminaire: Multi-Disciplinary Effort



- *Integrated systems approach required*
- *LED light is different than existing light technologies*
- *Not intuitive at first*

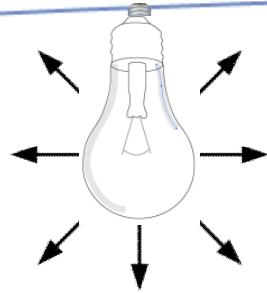
Delivered
lumens

Delivered
LPW

- *These graphs are on all LED data sheets; familiarization with them is essential to getting good results*

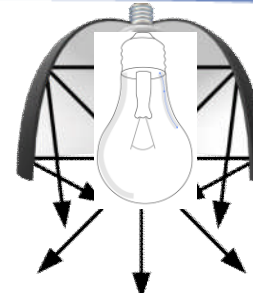
Fixture Efficacy

Incand



17 lm/W

X



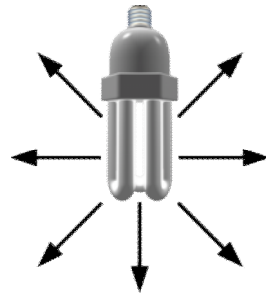
Coefficient of Utilization
58%

=

WARM WHITE

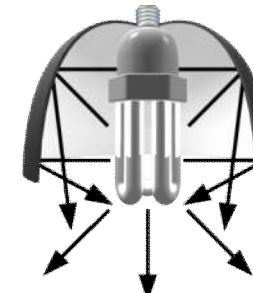
Fixture Efficacy
10 lm/W

CFL



60 lm/W

X

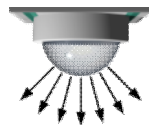


Coefficient of Utilization
58%

=

Fixture Efficacy
35 lm/W

XLamp



80 lm/W

X
X
X



Coefficient of Utilization 90%
Driver Efficiency 91%
Thermal Equilibrium 88%*

=



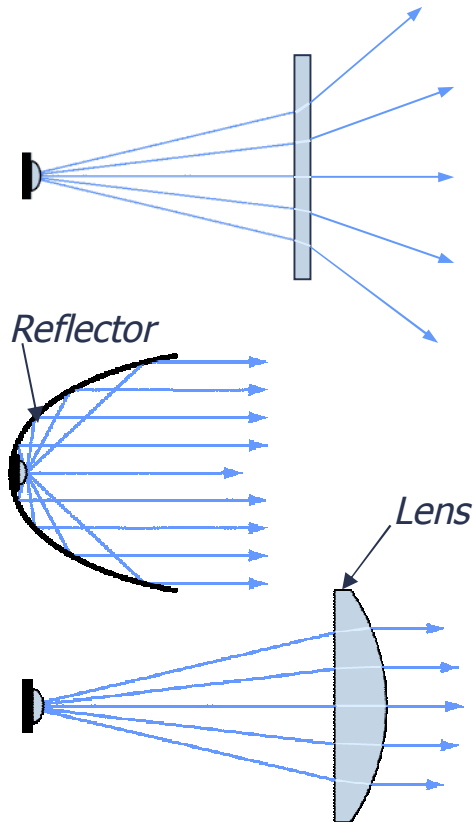
CA
Title 24

Fixture Efficacy
56 lm/W

* Including loss for thermal equilibrium @ Tj = 65° C

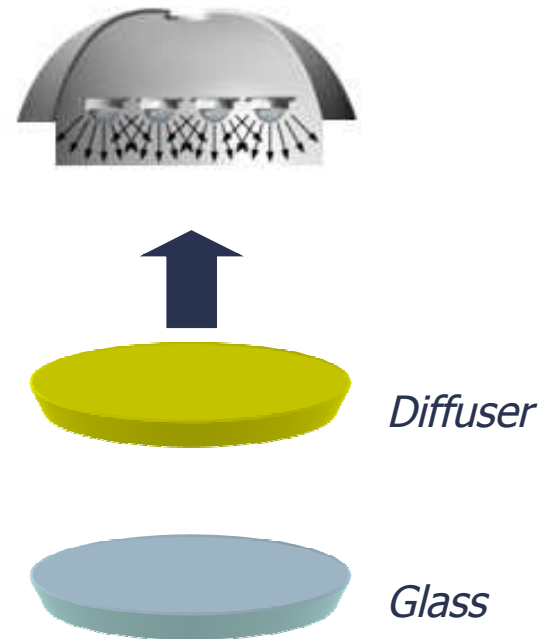
Typical Optical Losses

Secondary Optics



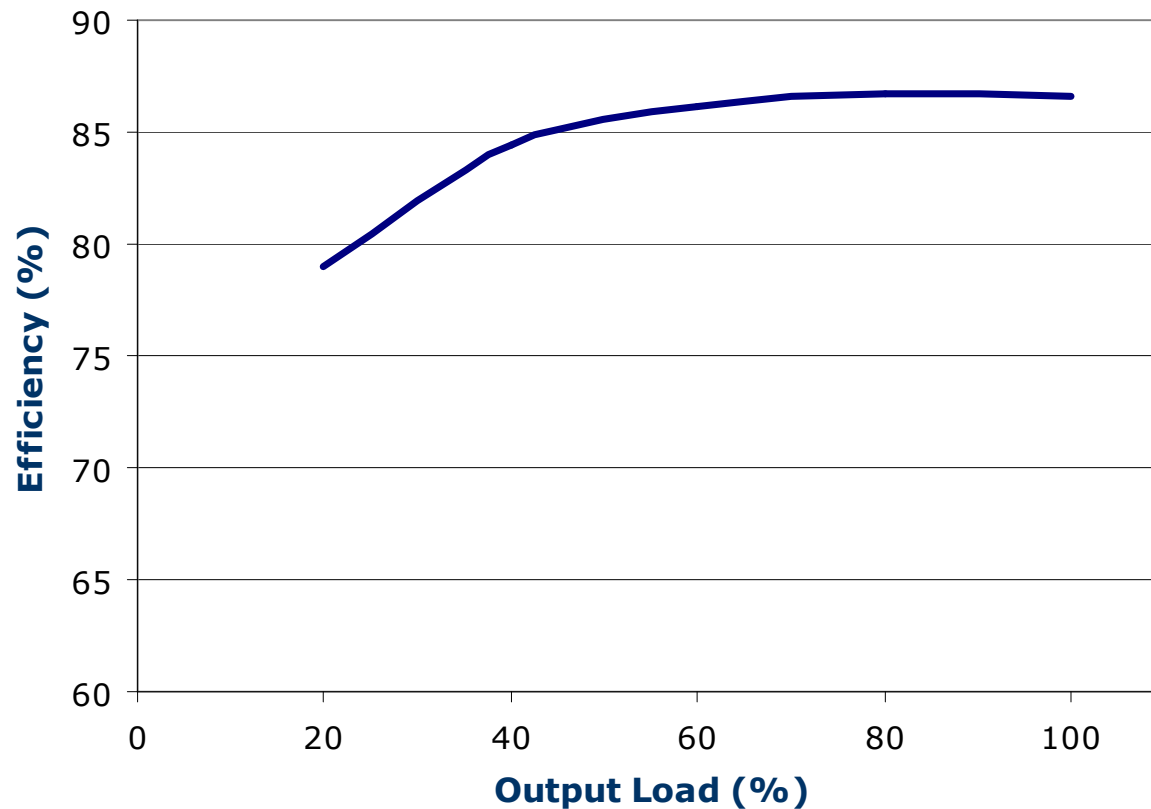
80%-90% Efficient

Diffuser/Glass



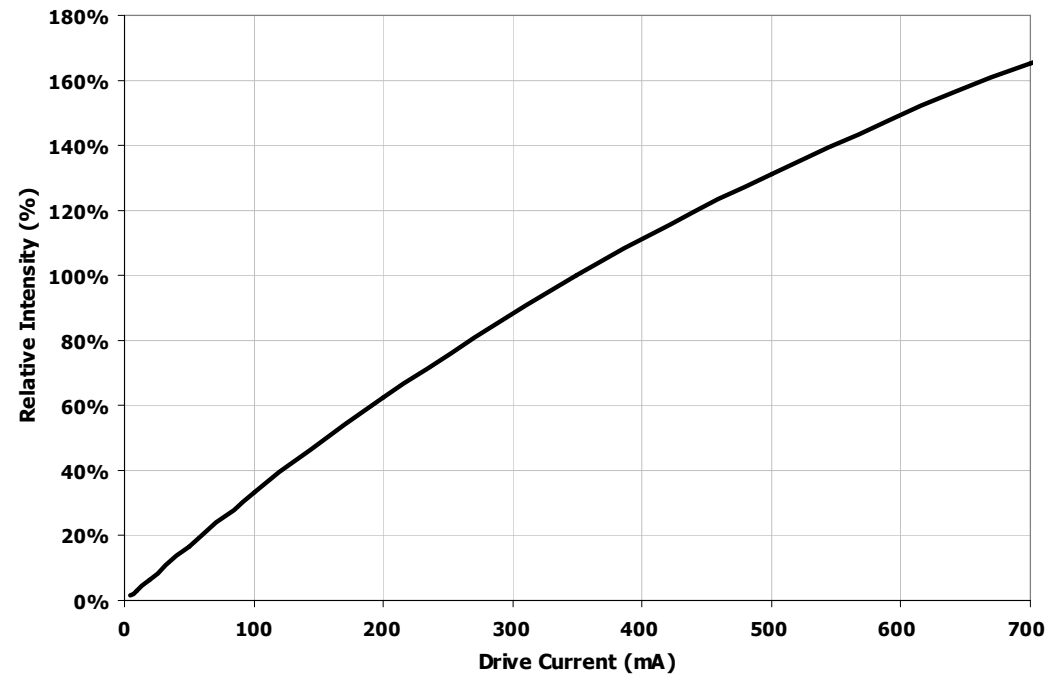
60%-90% Efficient

Typical Driver Losses

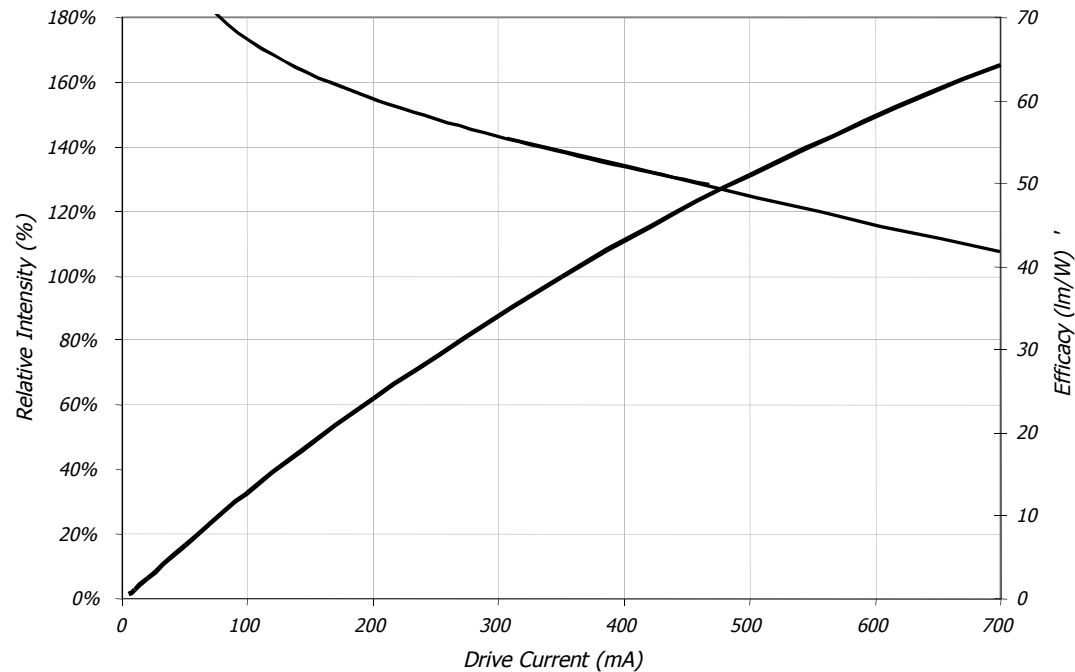


Generally, 80% - 85% is a good estimate – but some will claim MUCH higher

Iterative Process: More Power = More Light...



...But More Power = Lower Efficacy (Droop)



Many Opportunities For Optimization

| I_F (mA) | 700 | 500 | 300 |
|------------|-----|-----|------|
| LPW | 47 | 57 | 64 |
| # of LEDs | 18 | 22 | 34 |
| Cost | \$ | \$+ | \$\$ |

There is often an opportunity to trade-off drive current (I_F) and thermal design for both system LPW (efficacy) and overall system cost

High Quality LED Lighting

- To achieve a high quality LED lighting design

- Keys to success

- Lighting-class LEDs
- Thermal design
- Optical design
- Electronic design

- Integrated System!!

| | | <i>Luminaire Design</i> | |
|-----------------------|-------------|-------------------------|------------|
| | | <i>Good</i> | <i>Bad</i> |
| <i>Quality of LED</i> | <i>Good</i> | Excellent | BAD |
| | <i>Bad</i> | BAD | BAD |

Results



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Lighting Class LED's for High Quality LED Lighting

Topics :

Section 1 : Lighting Class LEDs

Section 2 : High Quality LED Lighting – How to achieve

Section 3 : Design and Handling considerations

Design and Handling considerations

- **Some examples of aspects that must be considered –**

Chemical compatibility

Thermal Design

Electrical over stress

Failure causes and modes due to bad handling

- Several times LEDs failed on the field before the expected life time
- Failures modes were graded by order of occurrence due to....



Chemicals



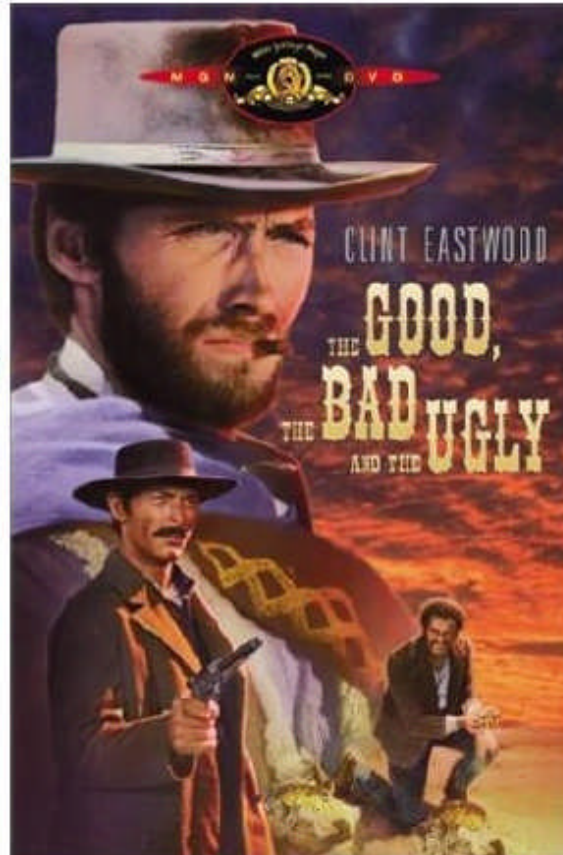
Electrical Over Stress EOS



Thermal

Chemical compatibility

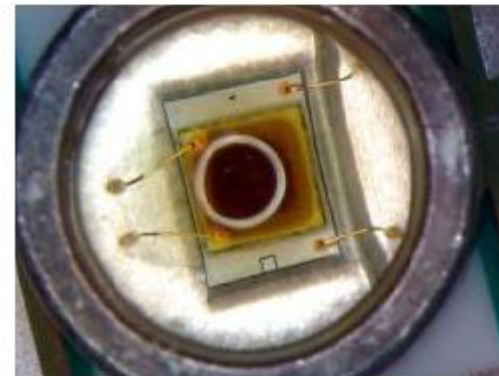
- There are good chemicals, and there are bad ones. Some are even ugly.
- Chemical incompatibility is generally more localized than “natural” silicone degradation.
- There are known molecules and families that are known to cause issues
- But there is nothing like testing!



Symptoms of material incompatibility

- The volatile hydrocarbons will cause the encapsulant to discolor (turn brown) and block light emitted from the LED
- Factors that affect discoloration:

- ✓ *Heat*
- ✓ *Photonic Energy*
- ✓ *Wavelength*



- The discoloration normally occurs at the top surface of the LED chip

ALL HIGH POWER LED LAMPS EXHIBIT THIS PHENOMENA

Material Compatibility

- Application note on cree.com
- Shows example compatible and incompatible material as well as test method to determine compatibility



XLAMP CHEMICAL COMPATIBILITY

Chemicals that can outgas aromatic hydrocarbons (e.g., toluene, benzene, xylene)

| |
|--|
| Methyl acetate or ethyl acetate (i.e., nail polish remover) |
| Cyanoacrylates (i.e., "Superglue") |
| Glycol ethers (including Radio Shack® Precision Electronics Cleaner - dipropylene glycol monomethyl ether) |
| Formaldehyde or butadiene (including Ashland PLIOBOND® adhesive) |
| Dymax 984-LVUF conformal coating |
| Loctite Sumo Glue |
| Gorilla Glue |
| Bleach |
| Bleach-containing cleaners, sprays |
| Loctite 384 adhesive |
| Loctite 7387 activator |
| Loctite 242 threadlocker |

Selected Chemicals

In testing, Cree has found the following chemicals to be safe to use with XLamp LEDs.

Selected chemicals safe for use with XLamp LEDs

| |
|---|
| Water |
| Isopropyl alcohol (IPA) |
| Arctic Silver & Arctic Alumina brand thermal grease |
| 3M Scotch-Weld epoxy adhesive DP-190 (polymeric diamante, kaolin) |

Selected Conformal Coatings

In testing, Cree has found the following conformal coatings to be safe to use with XLamp LEDs. Conformal coating should not be applied directly to or over the LED lens, as this may affect LED optical performance and reliability.

Selected conformal coatings

| |
|---|
| Dow Corning 3-1953 |
| Dow Corning 1-4105 |
| Dow Corning 1-2577 |
| Dymax 9-20557 |
| Humiseal 1H20AR1/S |
| Humiseal UV40 |
| Humiseal 1B51NS |
| Humiseal 1B73 |
| Humiseal 1C49LV |
| Shat-R-Shield |
| Specialty Coating Systems - Parylene |
| TechSpray Turbo-Coat Acrylic Conformal Coating (210B-P) |

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12



EOS – Electrical Over Stress

- **Electrical over stress happens every time the maximum driving current is exceeded**
- **High current peak can destroy immediately the LED**
- **Low current peak above the maximum driving current can create damages that accelerate the LED dead**
- **No immediate failure doesn't mean the LED is still totally undamaged**

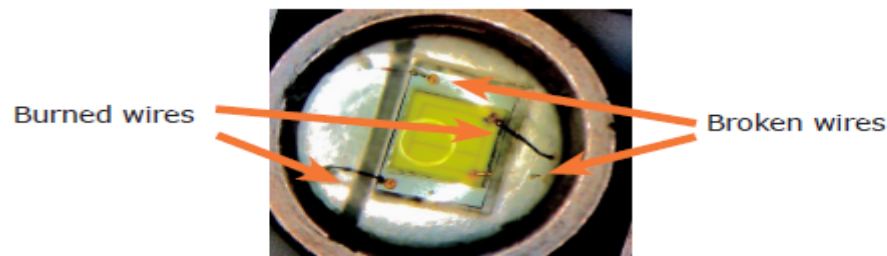


Figure 1

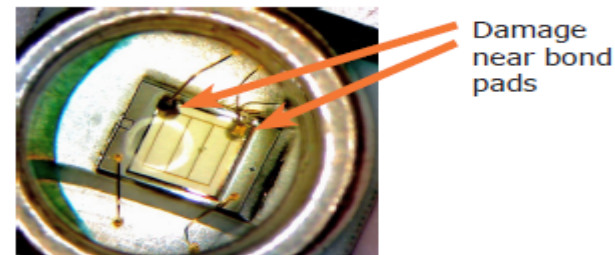
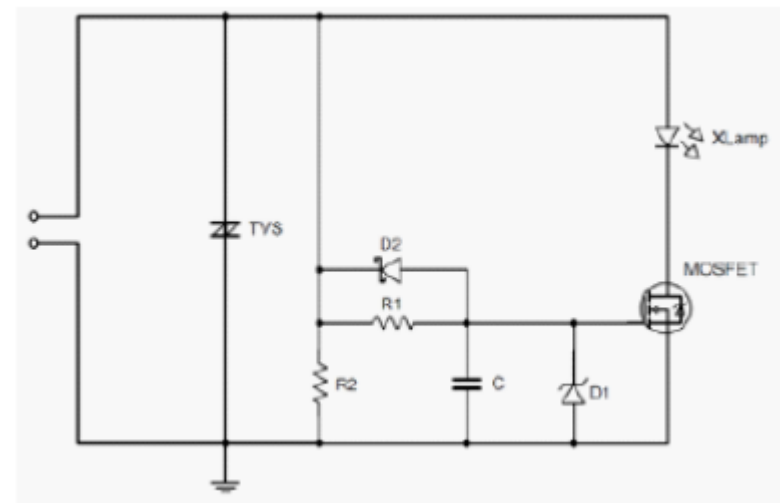
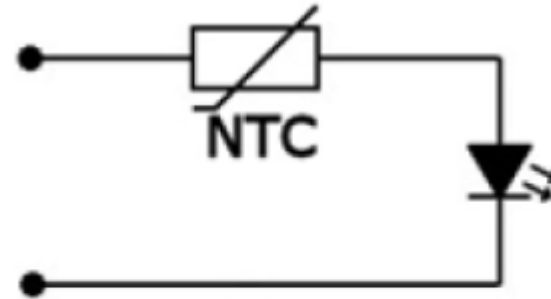


Figure 2

Prevention of Electrical Overstress

- Drivers should be developed or selected to minimize this effect
- Passive, or better active, in-rush current protection can also be used to reduce or eliminate this effect



Thermal

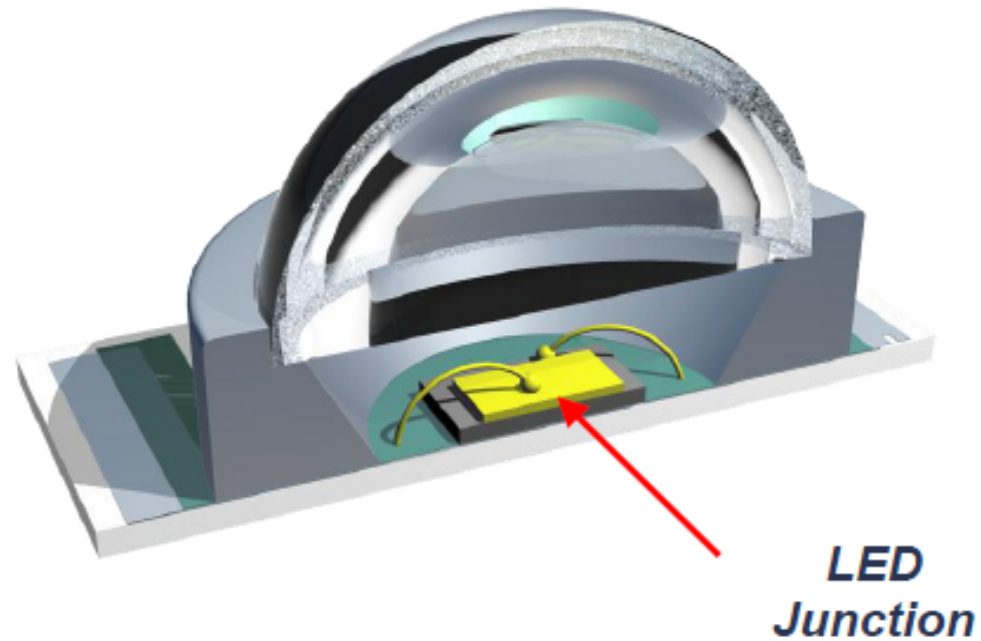


Good Design

Bad Design

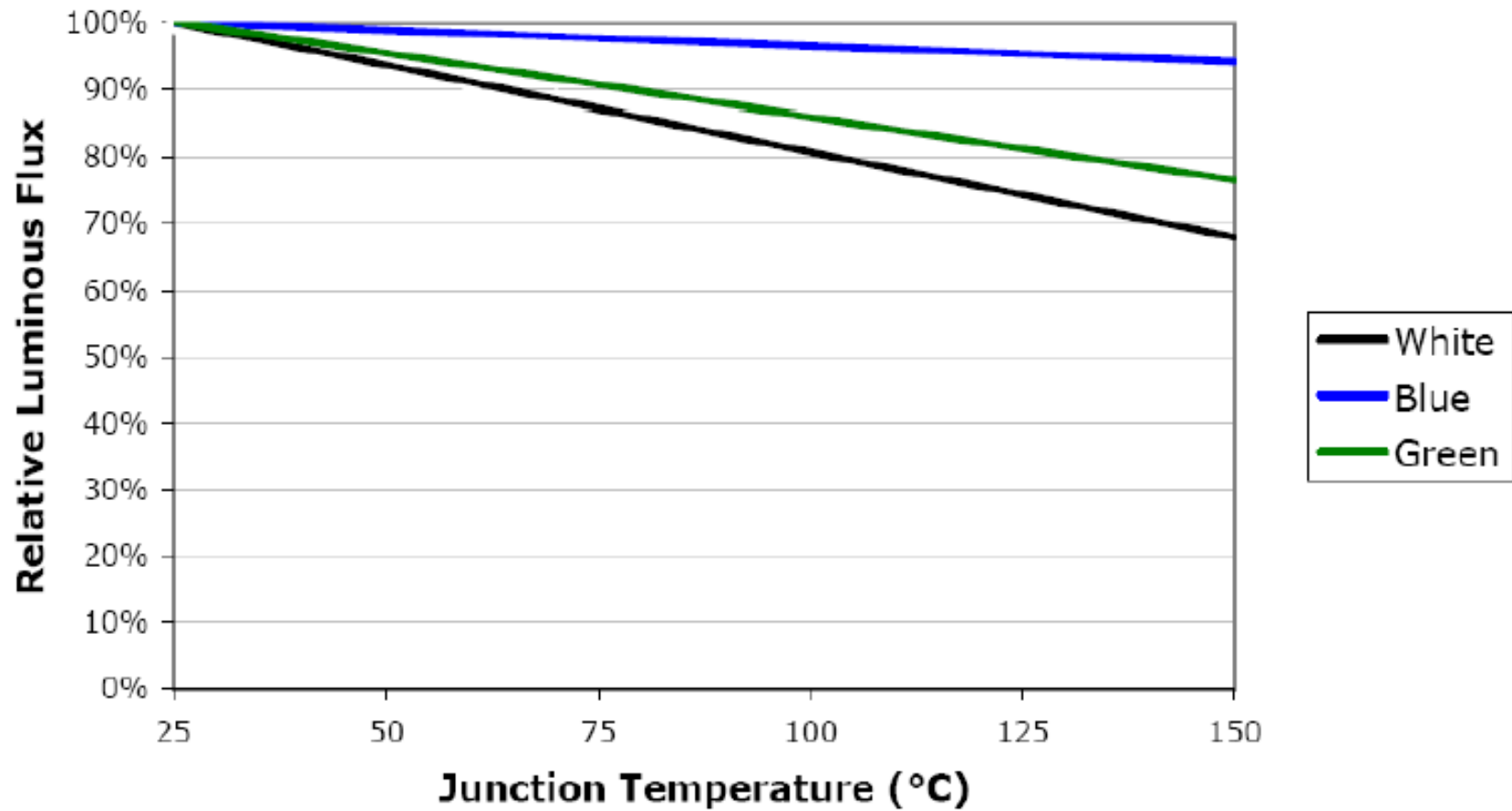


Where Is the LED Junction?

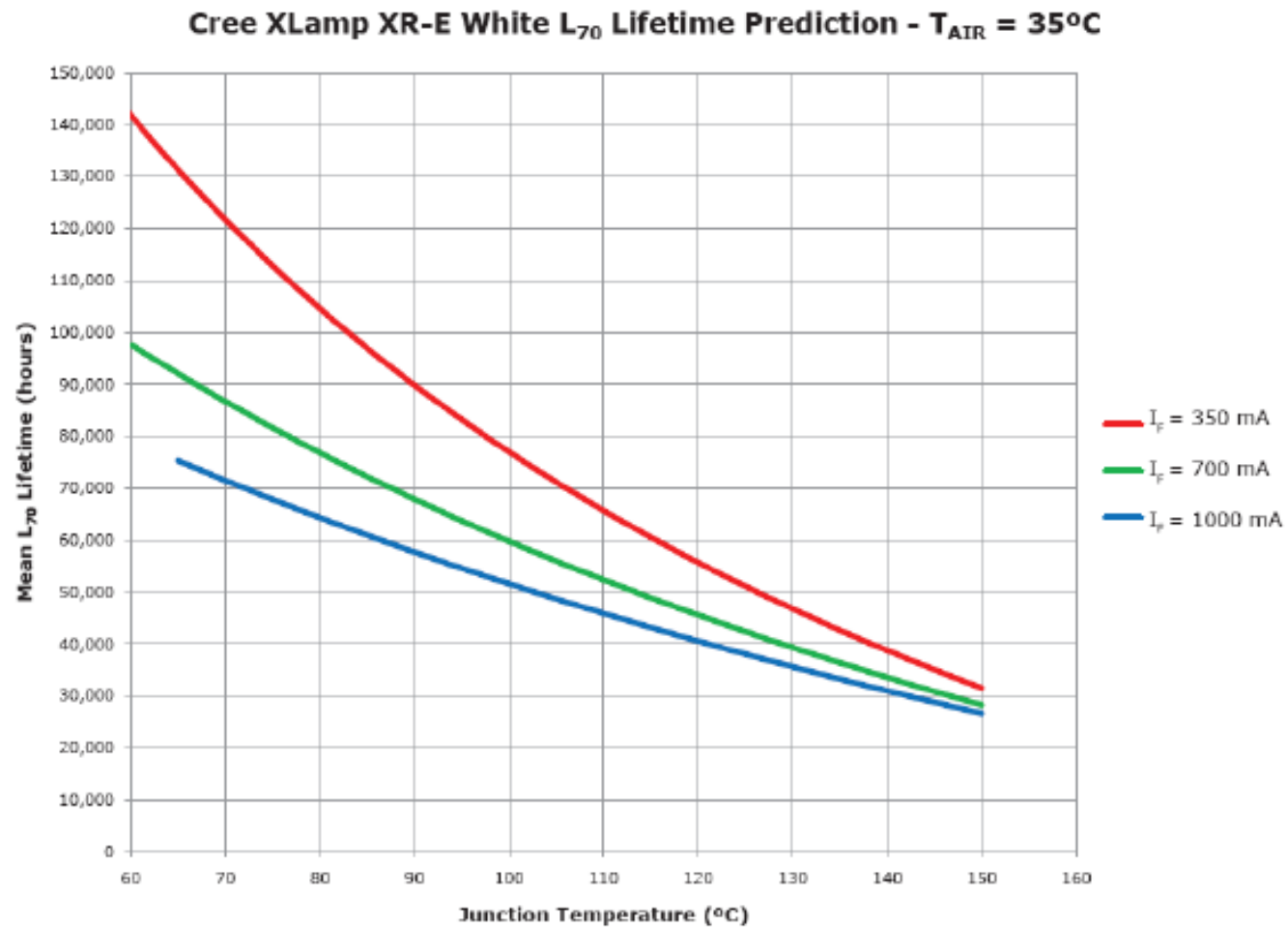


- *LED junction is located within the LED package*
- *LED junction temperature (T_j) cannot be measured directly*

Light output vs. Tj



Lifetime vs. Tj



Thermal issue origins

- **Thermal pad not soldered**
- **Thermal pad not properly soldered**
- **LED functional test with standard driving current but without heat sink**
- **Poor thermal system**

Thermal – some definitive design information

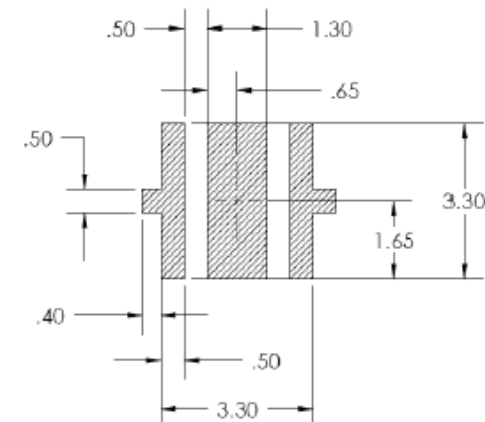
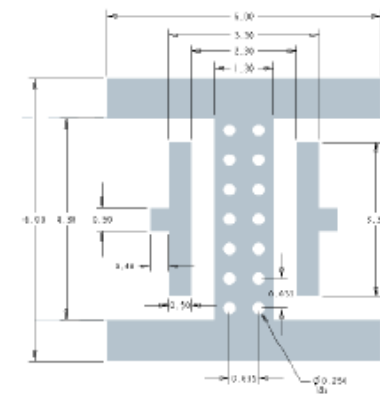
http://www.cree.com/products/pdf/XLamp_PCB_Thermal.pdf



Optimizing PCB Thermal Performance for Cree® XLamp® LEDs

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Examples of poor design

Driver & Thermal Problems



- *Color shift due to poor thermal design*

- **Driver/circuit board failure**



Not a Binning Problem (Poor LED Selection)

Time zero

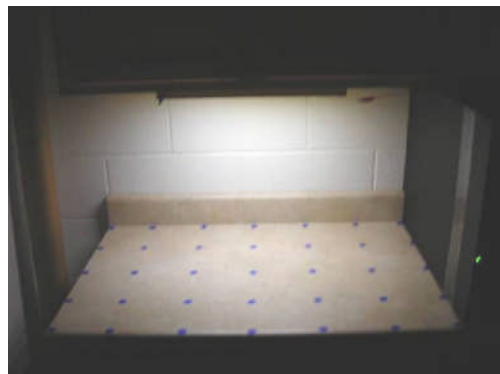
1000 hours



LED Puck
84.1% Drop



16.5" Linear
97.8% Drop



22" Linear
96.9% Drop



Summary: Quality Solid State Fixture Design

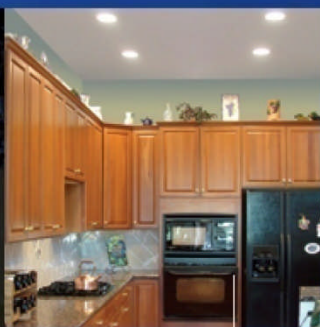
- Keys to success for High Quality SSL Fixtures :
 - Lighting-class LEDs
 - and good...
 - Thermal design
 - Optical design
 - Electronic design
 - **Handling**

| | | <i>Quality Luminaire Design</i> | |
|-----------------------|-------------|---------------------------------|------------|
| | | <i>Good</i> | <i>Bad</i> |
| <i>Quality of LED</i> | <i>Good</i> | Excellent | BAD |
| | <i>Bad</i> | BAD | BAD |

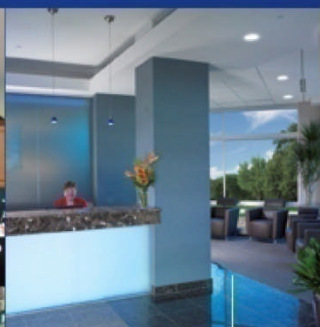
Results



PORTABLE



RESIDENTIAL



OFFICE



RETAIL



ARCHITECTURAL



OUTDOOR

LED lighting: Energy efficient & planet friendly.

Cree. Leading the LED lighting revolution.

Join Cree's LED lighting revolution. We invite you to see how our high-performance, high-efficiency LEDs are lighting up the world.

THANK YOU

CREE 