LED Package Reliability
(Color Point Stability)

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CIE 1931 Color Space

ANSI C78.377
Color Bins Shown
CIE 1931 Color Space
CIE 1931 Color Space
CIE 1931 Color Space
Observed Color Shift with LEDs

Green Shift

Yellow Shift

Blue Shift
The white material in the package cavity reflects much of the light emitted from the LED chips.

The overall chromaticity (color) of the LED is a combination of all of the light emitted directly from the chips through the phosphor and that which is reflected internally in the package.

Short distance through phosphor = cooler color temperature

Long distance through phosphor = warmer color temperature
Color Shift with Plastic Packages

Short distance through phosphor = cooler color temperature

Long distance through phosphor = warmer color temperature
Color Shift with Plastic Packages

These photons will continue to be emitted from the package.

These photons will not be reflected off the package walls.

Over time the materials in these packages will discolor.
Color Shift with Plastic Packages

An overall blue shift and lumen depreciation results

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These photons will not be reflected off the package walls.

Over time the materials in these packages will discolor.
LM-80 Test – PPA Plastic Packages

LED lumen maintenance

Luminous flux (%)

0 840 1848 4536 7560 10584 13608 16632
Test hours

LED color stability

\[ \Delta u'v' \]

0.024 0.021 0.018 0.015 0.012 0.009 0.006 0.003 0.000

0 840 1848 4536 7560 10584 13608 16632
Test hours

Tsp = 85ºC

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LM-80 Test – PPA Plastic Packages

LED lumen maintenance

Luminous flux (%)

70

L70

Test hours

0 840 1848 4536 7560 10584 13608 16632

LED color stability

Δu'v'

0.000 0.003 0.006 0.009 0.012 0.015 0.018 0.021 0.024

Test hours

0 840 1848 4536 7560 10584 13608 16632

Tsp = 85°C
LEDs placed un-powered in reliability test chamber.
Storage Test – EMC Packages
LM-80 Test – EMC Packages
Storage Test – Ceramic Packages
Blue Color Shift with Plastic Packages
Phosphor Chip Coated LED

Silicone Lens
Phosphor
LED Chip
Wire Bond
Cathode
Anode
Substrate
A. Normal LED appearance – Phosphor layer is uniform across the LED Chip surface as LM-80 testing starts.

B. Delamination of the phosphor from the surface of the chip begins.

C. Severe delamination and cracking of the phosphor layer.
Phosphor Chip Coated LED

At high temperatures cracking and delamination of the phosphor can occur at the chips surface. The light scattering increase in the angle at which the emitted light travels through the phosphor. The path of the blue photons through the phosphor is increased causing a shift towards the warm end of the spectrum.
High temperature LM-80 testing has been used to accelerate the color shift in high power LEDs.
Yellow Color Shift
Can models be developed to project color shift over time?

\[
\begin{align*}
\text{y} = 8.3273E-07x - 2.2291E-03 \\
R^2 = 9.9238E-01
\end{align*}
\]
Color Shift during WHTOL testing

60/90 WHTOL Testing

Tsp = 60°C
Tair = 60°C
90% RH
1 hour on
1 hour off
Green Color Shift

Red Phosphor degrades causing a shift of the color point.
Summary

• Color shift can happen with LEDs.

• There are many applications where it is not critical.

• There are many applications color point stability is important.

• Materials used in LED package construction will result in different color point stability characteristics.

• There is no method currently available to project color shift.