Testing of OLED Devices in Elevated Ambient Conditions

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Traditional LED Devices

- Due to low failure rates, the “Hammer Test” was developed as a highly accelerated stress test for LED-luminaires. Testing regiment was aggressive and consisted of high temperature bakes, temperature shock, and temperature-humidity testing.

- General finding was that LED failures were rare and driver electronics were often the limiting factor.

Other Testing on Traditional LED Devices

- CALiPER Testing on lumen and chromaticity maintenance for PAR38 and 60 W equivalent lamps. *(see DOE website)*
  - Continuous run @ 45°C ambient
  - Parts from ~2011 - 2013 timeframe

- At 45°C ambient, there has been findings of lumen depreciation and chromaticity shifts in some parts as early as 4,800 hr.

- Elevated temperature life test in Energy Star requires testing at 45°C ambient testing.

Mineral Lumen Depreciation in most LED PAR38 lamps.
Testing on OLEDs

- Analogous test results are not publicly known for OLEDs, but OLEDs can benefit from the lesson learned of traditional LEDs.

- Commonly used “accelerated testing” is room temperature operation at different currents.

- General perception is that OLEDs are less robust than conventional inorganic LEDs and will fail sooner.
  - Initial “benchmark” testing does not have to be as strenuous

- There have also been some reports of degradation in the off state during storage.

From: [http://ssl.energy.gov](http://ssl.energy.gov)
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<th><strong>FULL OLED LUMINAIRE TEST</strong></th>
<th><strong>OLED Panel TEST</strong></th>
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<td>- Commercial 5-Panel luminaires using manufacturer’s supplied driver (7.2 W, 150 mA).</td>
<td>- Operate new commercial OLED panels in more stressful environments.</td>
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| - Test protocol – elevated ambient of 45°C ambient with power applied. |  - 45°C bake at 200 mA  
  - 75°C bake at 150 mA  
  - 75°C and 75% ambient, 150 mA |
|   - *Operational Life Test.* | - All tests are operational life test. |
| - 250 hour test increments. | - Full photometry after each 250 hr test increment. Measurements at room temperature. |
| - Full photometry after each test. Measurements @ room temp. | |
| - Goniophotometry on different samples at PNNL. | |

Tests are just starting. More results to come.
OLED Panel Characteristics

- Hybrid triple stack with fluorescent blue emitters and phosphorescent green & red.
- Initial Flux: 88 Lumens
- Size: 100 x 100 mm²
- Current: 150 mA per panel
- Luminous Efficacy: 69 LPW
- CCT: 2976 K
- CRI: 88.1
- R9: 27.1
- 5 100x100 mm² panels electrically connected in parallel
- Initial Flux: 402 Lumens
- Current: 150 mA per panel
- Luminous Efficacy of System: 55 LPW
- CCT: 2995 K
- CRI: 87.4
- R9: 26.3
- TM-30 $R_f$: 86
- TM-30 $R_g$: 96
- Assuming exponential behavior, decay rate constant is $2.47 \times 10^{-5}$. **NOTE:** This is not TM-20 calculation.
- About 2x highest LM-80 values at 55°C for conventional LEDs.
- After 1000 hr. in 45°C elevated ambient, $\Delta u'v' = 0.0014$ (one step)
- Chromaticity shift caused by a drop of green and red emissions.
Conclusions

- OLED technologies can benefit from the lessons learned with inorganic LED lighting.

- Stress testing on a OLED luminaire product and OLED panels has just begun and results are limited. Relatively mild temperatures (e.g., 45°C) have been used to date. Findings are instructive, but no definitive conclusions can be drawn yet.

- Measured commercial OLED luminaire and individual panels had excellent chromaticity properties with high color fidelity ($R_f$) and color gamut ($R_g$) indices.

- Observed color shift is in the blue direction due to reduction of green and red-orange emissions. Blue emissions stayed relatively constant.

- Luminous efficacy at the luminaire level is ~55 LPW and decay rate constant ($\alpha$) is > 2.4x10^{-5} in limited measurements in 45°C ambient.
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