OLED Transfer Standards

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NEWRAD 2011, Maui, 09/20/2011

Germanys national metrology institute
2 Organic LEDs or Organic EL (Electroluminescence)

Thin: ≤ 3 mm  Large-area: ≤ 33 x 33 cm²  Colorful or white

Off-state behaviour can be: mirrorlike, milky or transparent

Source: Fraunhofer IPMS, Osram and Philips
3 Properties of OLEDs

- Diffuse, non-glaring illumination
- Good colour rendering properties
  - many emitters available (differ in efficiency and lifetime)
  - daylight spectrum feasible
- Flexible (under development, no commercial products)
- Transparent (under development, no commercial products)
- Potentially, any shape
- Efficient
- Dimmable
- Instant-on
- Low voltage device
- Color-tunable
- Environmentally friendly

Source: Philips
Device setup small molecule OLED

- Glass substrate
- ITO (+), anode
- Metal cathode
- Organic layer(s)
- Light
- Al-contact (-), cathode
- Electron transport layer
- Hole blocking layer
- Emitting layer(s)
- Electron blocking layer
- Hole transport layer
- ITO (+), anode

Layer thickness: 100-200 nm

Source: Philips
Luminance distribution of a large area OLED

$L > 97\% L_0 \rightarrow \text{white}$

$L > 95\% L_0 \rightarrow \text{yellow}$

$L > 93\% L_0 \rightarrow \text{red}$

$L > 90\% L_0 \rightarrow \text{green}$

$L > 80\% L_0 \rightarrow \text{blue}$
Nonuniformity is caused by a too low ITO conductivity
- Including metal bus bars for better current distribution
In a conventional OLED only 20% of the generated light leaves the device due to refractive index mismatch!

- Phots in air (~20%)
- Photons trapped in glass (~30%)
- Photons trapped in organics (~50%)

- Index-matched substrate
- Outcoupling structures

Source: Philips
8 Circular OLED
9 Rectangular OLED
10 Chromaticity shift of the light of an OLED

chromaticity diagram

- Red: OLED type a
- Green: OLED type b
- Cyan: OLED type c
- Blue: OLED type d
- Yellow: OLED type e

Color temperature:
- 3000 K
- 4000 K
- 5000 K
11 Spatial luminous intensity distributions

inclination angle / °

relative luminous intensity / a.u.

-90° -80° -70° -60° -50° -40° -30° -20° -10° 0° 10° 20° 30° 40° 50° 60° 70° 80° 90°

: Lambertian Emitter
: OLED type a
: OLED type b
: OLED type c
: OLED type d
: OLED type e
Geometrical alignment

After 10 minutes operating time

After 3 seconds operating time

$L > 97\% \rightarrow \text{white}$

$L > 95\% \rightarrow \text{yellow}$

$L > 93\% \rightarrow \text{red}$

$L > 90\% \rightarrow \text{green}$

$L > 80\% \rightarrow \text{blue}$
13 OLED Transfer Standard
14 Current/Voltage – Luminance correlation

\[ L_{\text{OLED}} = L'_{\text{OLED}} \cdot \left( \frac{J_{\text{OLED}}}{J_{0,\text{OLED}}} \right)^{-0.0025} \cdot \left( \frac{U_{\text{OLED}}}{U_{0,\text{OLED}}} \right)^{-2.55} \]
15 Current/Voltage – chromaticity correlation
Flux measurements in an integrating sphere

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (d)</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Reflectance (\rho)</td>
<td>0.95</td>
</tr>
<tr>
<td>Throughput (\tau)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[
\tau = \frac{\rho}{\pi \cdot d^2 \cdot (1 - \rho)}
\]
17 Warm-up behaviour of the OLED transfer standard
Relative luminous flux of the OLED standard

Repetition Measurement

$(\Phi_i/\Phi_0) - 1$ vs. Repetition Measurement
Relative luminous flux of an OLED w/o T-control

Operating-time: 47 min
Off-time: 30 min

Repeat number

\( \frac{\Phi_i}{\Phi_0} - 1 \) vs. Repeat number

Graph showing the relative luminous flux over time.
20 Luminance changes for two geometrical alignments

OLED without temperature control  

OLED with temperature control
Light sources of different technologies vary in their photometric properties. For calibration of measurement equipment it is always desirable to use transfer standards which have very similar properties as the light sources which shall be characterised with the equipment.

Thus, the presented OLED transfer standard is based on a commercially available OLED.

Most important to increase the reproducibility of photometric values is the stabilization of the OLED stack temperature. Due to the direct correlation between the stack temperature and the driving voltage it is possible to use the voltage as the monitoring quantity for temperature control.
Thank you for your attention.

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ACKNOWLEDGMENT
The work leading to these results has received funding from the European Community's Seventh Framework Programme under grant agreement n° FP7-224122 (OLED100.eu)