The NEXT: 
OLEDs, the Next Light Source

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Overview

- Solid State Lighting
- OLED technology basics
- The OLLA project
- OLED Development status & issues
- Shaping the OLED industry
**Solid State Lighting**

= Direct conversion of energy into visible light

*Pure Controlled Efficient*

> The route towards more efficient lighting

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**Family of Solid State Lighting:**

- **LEDs:** Light Emitting Diodes (LED), point sources.
- **OLEDs:** Organic Light Emitting Diodes, area sources.
- **Lasers:** Ultra high brightness line sources.
Basic OLED technology

- Metal cathode
- Organic layer(s)
- Glass substrate
- ITO
- Light

Example of OLED stacking

- Total layer thickness: 100-200 nm
The OLLA project

**Organic emitting material types**

<table>
<thead>
<tr>
<th>Polymers</th>
<th>Small Molecules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Difficult to make</strong></td>
<td><strong>Easier to make</strong></td>
</tr>
<tr>
<td><strong>Easy to process</strong></td>
<td><strong>Difficult to process</strong></td>
</tr>
<tr>
<td>(solution processing)</td>
<td>(vacuum processing)</td>
</tr>
</tbody>
</table>

**OLED lighting: application advantages**

- Thin, flat, lightweight
- Large area diffuse source
- Pleasant, broad spectrum light
- Variable in color and form (any2D)
- Instant-on; fully dimmable
- Robust (no wires inside)
- Low voltage technology
- Green product (RoHS compliant, recyclable, no hazardous materials used)
- Long lifetime (>20,000 hours)
- No heat management support needed

Potentially cheap and very efficient
Optional: flexible, transparent
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Why OLED lighting?
And they look great!

Siemens

The Lighting challenge: white OLEDs

Already achieved OLED records
- >133 lm/W in green
- >10^6 cd/m^2
- > 50,000 h Very low luminance
- >10,000,000 h Very low luminance

Lighting market entry requirements
- 1.000 cd/m^2
- CRI > 80
- >10,000 h
- > 50 lm/W
- White

+ Reasonable price level
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High Brightness Organic Light Emitting Diodes for ICT & Lighting Applications

Project characteristics

EU funded integrated project
Programme: EU-FP6-IST priority
Duration: 45 months
October 2004 – June 2008
24 partners from 8 countries
Budget: 20 Mio Euro / 12 Mio funding

Central focus:
- OLEDs for Lighting Applications
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RUG - Groningen
HC Starck, Leverkusen
Merck Oled Materials Uni - Kassel
Sensient Tech - Wolfen
VTT - Oulu

Philips - Eindhoven
Philips, Aixtron - Aachen

U-Gent
IMEC
KU-Leuven

CNRS-IMN - Nantes

LCC - Toulouse

EPFL - Lausanne
CNR-ISOF - Bologna
NNL - Lecce

OLLA Consortium:
24 Partners:
- 10 Industries
- 7 Academia
- 7 Universities

SPIE INNOVATION SUMMIT

OLLA

Integrated Project:

• Horizontally integrated: SMO LED and PO LED in one project

• Vertically integrated: from molecules to applications.

• We are strongly interdisciplinary
Physicists, (electro) chemists, material scientists, industrial developers, optical designers, PhD students and even a manager!

Final target: OLLA light-tile

Brightness: 1000 cd/m²
Efficiency: 50 lm/W
Lifetime: 10,000h
Color Rendering Index: >70
Size: 30cm x 30cm
Color: White

> proves fit of OLEDs for Lighting Applications
The OLLA project

**OLLAR Final result OLLA project (June 2008):**

- 50.7 lm/W (color point 0.45/0.45) @ 1000 cd/m² and lifetime of over 10,000 hrs.

**OLLAR OLLA results: ITO-free OLED lighting devices**

A double emission green OLED on a polymer anode with an active area of 1.1 cm², using Clavios PH 500 from HC-Starck instead of Indium Tin Oxides (ITO).

Press release 2006
**OLLA result:** large sized white OLEDs

Large area OLEDs (150x150mm)

**OLLA results:** gravure printed OLEDs

Gravure printed PEDOT and emissive layer on glass (31cm²)
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Other results: dissemination

- Over 100 Scientific publications
- Contributions to all major OLED conferences
- Several patent filed
- Many public showcases, EU conferences
- 5 TV shows, many magazines, newspapers
- ..

OLLA Summer School Activity

We conducted 4 open summer schools, with 60-70 participants and 15 lecturers each, from all over the world.

Material online available,
next school: April 2009
OLL A

OLL A: N ot enough to beat existing light sources

<table>
<thead>
<tr>
<th>Technology</th>
<th>Power</th>
<th>Luminous Flux</th>
<th>Efficacy</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Bulb</td>
<td>100 W</td>
<td>1.360 lm</td>
<td>14 lm/W</td>
<td>1.000 h</td>
</tr>
<tr>
<td>Halogen lamp, Standard</td>
<td>50 W</td>
<td>910 lm</td>
<td>18 lm/W</td>
<td>2.000 h</td>
</tr>
<tr>
<td>White LED</td>
<td>3 W</td>
<td>&gt; 180 lm</td>
<td>&gt; 70 lm/W</td>
<td>70.000 h</td>
</tr>
<tr>
<td>Fluorescent lamp</td>
<td>35 W</td>
<td>3.300 lm</td>
<td>90 lm/W</td>
<td>16.000 h</td>
</tr>
<tr>
<td>Compact fluorescent lamp</td>
<td>11 W</td>
<td>630 lm</td>
<td>57 lm/W</td>
<td>12.000 h</td>
</tr>
</tbody>
</table>
Towards OLEDs for general illumination

**State-of-the-art in white OLED (as of June 2008)**

<table>
<thead>
<tr>
<th>Company/Institution</th>
<th>Year</th>
<th>Efficacy at 1.000 cd/m²</th>
<th>Lifetime at 1.000 cd/m²</th>
<th>Emitter type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novaled / Philips</td>
<td>2006</td>
<td>32 lm/W</td>
<td>20.000 h</td>
<td>P, P, F</td>
</tr>
<tr>
<td>Konica-Minolta</td>
<td>2006</td>
<td>64 lm/W</td>
<td>10.000 h</td>
<td>P, P, P</td>
</tr>
<tr>
<td>The OLLA-Project</td>
<td>2007</td>
<td>25 lm/W</td>
<td>5.000 h</td>
<td>P, P, F</td>
</tr>
<tr>
<td>Idemitsu Kosan</td>
<td>2007</td>
<td>17 lm/W at 10 mA/cm²</td>
<td>30.000 h</td>
<td>F, F, F</td>
</tr>
<tr>
<td>Osram</td>
<td>2008</td>
<td>46 lm/W</td>
<td>5.000 h</td>
<td>P, P, F</td>
</tr>
<tr>
<td>Novaled</td>
<td>2008</td>
<td>35 lm/W</td>
<td>100.000 h</td>
<td>P, P, F</td>
</tr>
<tr>
<td>The OLLA-Project Philips / Novaled</td>
<td>2008</td>
<td>51 lm/W (80 lm/W)*</td>
<td>&gt;10.000 h</td>
<td>P, P, F</td>
</tr>
<tr>
<td>UDC</td>
<td>2008</td>
<td>(102 lm/W)*</td>
<td>8.000 h</td>
<td>P, P, P</td>
</tr>
</tbody>
</table>

*: Measured with macro-extractor

Trend 30-60 lm/W in white in combination with good lifetime achieved
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**Further OLED Research steps:**

- **higher efficacy** 100 lm/W or more
- **Longer lifetime** > 10,000 h
- **Higher brightness levels** > 1,000 cd/m²
- **Larger area** OLEDs

And at the same time
- Lower **manufacturing cost**
- Improve **reliability**
- And set early **standardization** for the market

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**Means big innovation for OLEDs steps in:**

- Material research
- Device research
- Optical outcoupling enhancement
- Process development
- Equipment development
- Industrialization
- Standardization

**No party can do this all alone!**

Many interactions and cycle loops needed

> Cooperation essential to meet these challenges
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European solution: co-creation in projects

- OLLA: oled for general lighting
- Rolled/Fast2Light: flexible oleds
- Aeviom: electrical modeling
- O PAL: Large OLEDs
- CarO LED: automotive OLEDs
- Hobbit: Polymer oled
- HypO LED: O led on CMOS
- Comboled/Rollex: printed OLEDs on metal

- VTT / Comeddd / HolstCentre: Cooperation R&D centres
- Bi-lateral cooperation
- Sponsored University research
- Coordination networks (Opera)
- Coordination platforms (Photonics21)

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Partners:

14 partners from 6 countries
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The ‘100’ objectives:

- High energy efficiency: 100 lm/W
- Long operational lifetime: 100,000 hours
- Large area processing: 100x100 cm²
- Low-cost production: 100 €/m²

• System integration  
• Standardization  
• Application research

Start: Sept. 2008  
Philips coordinator  
14 partners  
6 countries  
www.oled100.eu

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The O LED proposition

- Novel bright light source with totally different form factor
  - Customizable Any2D
  - Transparent
  - Flexible
- Potentially very efficient
  - Environment
- Potentially very long lasting
  - Install once
- Potentially very cheap
  - No luminaire optics needed

Whole range of novel lighting applications

Philips
Sketch: OLED industry environment

- Global development race
- University & company research and mixed
- Complex interactions: parallel development of materials, processes and machines

But also:
- Large collection of IP already settled
- No player controls the whole v-chain
- More efficient other light sources
- Specialized personnel need
- No market / production yet (price & lack of experience)

A couple of technical challenges ahead

- How to raise efficiency performance
- How to extend lifetime of OLEDs
- How to lower the price of OLEDs
- How to produce square km of OLEDs
- How to enlarge OLED tiles efficiently
- How to make them on flexible substrates
- How to get the trapped light out of the substrates
- How to electrically drive the OLEDs
- How to beat existing light sources

working alone is not the best answer to all of these questions
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OLED Value chain: *still to be defined*

- Material Supplier
- OLED
- Wholesaler
- End customer

Glass Materials → O LED Deposition → Driver & Mounting → O LED luminaire

High price
No volume

No experience
No demand

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Lack of OLED experience among value chain

- Need to inform and educate value chain partners
  - Architects
  - Lighting Designers
  - Early customers
  - Material manufactures
  - Machine developers

- No standards yet applicable
  - Measurement standards
  - Device size standards
  - Connections and driving standards

Awareness vs. Experience
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Philips

Philips: first to offers OLED Technology Kit

Available via www.lumiblade.com

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My conclusions

- OLLA proved that **OLED is a true Lighting Technology** with many opportunities
- Still many technical challenges ahead and being worked on at various locations
- But the **market challenge** may be the biggest challenge for the next decade
- Good and **close cooperation** between material suppliers, machine manufacturers, OLED developers, end-consumers is essential to meet these challenges.
- Europe is using the **cooperation projects** to unlock the OLED lighting market
The OLLA project

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View our OLEDs at www.lumiblade.com