10. OLEDs and PLEDs

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Some milestones

- **1953** Observation of the electroluminescence of acridine orange
- **1960ties** Studies of anthracene crystals
- **1987** Luminescent complexes: Al-8 hydroxychinolinate
- **1990** Luminescent polymers: poly(p-phenylenvinyliden)
- **2009** Universal Display Corp. 102 lm/W
  - Novaled/TU Dresden 90 lm/W
  - Konica 64 lm/W
  - Kodak 56 lm/W
- **2012** Samsung: 55 inch OLED TV

*Lit.: M. Dreußen, H. Bässler, Chemie in unserer Zeit 31 (1997) 76*
10.2 Electroluminescent Molecules

**Anthracene**

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[Al(8-hydroxyquinolinate)_3]
```

**Polyphenyl vinylidene**

**Eu-complexes**
10.3 Structure of OLEDs and PLEDs

Layer preparation by
- Vapor deposition (sublimation) of the organic components and metals
- Spin-coating from solutions
10.4 Working Principle of OLEDs

Schematic construction

Hole conductor

Electron conductor

Emitter (organic phosphors)
10.4 Working Principle of OLEDs

Charge transport

Exponentially determined singlet fraction for Alq$_3$ based OLEDs = 22 ± 3%
10.4 Physical Principle of an OLED

Strong spin-orbit-coupling mixes singlet and triplet MLCT states, $M = \text{Ir, Pt, Os, Re, etc.}$

$\text{MLCT} = \text{metal to ligand charge transfer, } \text{LC} = \text{ligand centered}$
**10.5 Luminescence of Metal Complexes**

**Energy level diagram of Eu\(^{3+}\)-complexes**

Absorption (ligand)
- \(1\pi-\pi \rightarrow 1\pi-\pi^*\)
- \(1\pi-\pi^* \rightarrow 3\pi-\pi^*\)

Ligand-metal energy transfer
- \(3\pi-\pi \rightarrow 5D_1, 5D_0\ (Eu^{3+})\)

Emission (metal)
- \(5D_0\ (Eu^{3+}) \rightarrow 7F_J\ (Eu^{3+})\)
- \(5D_1\) and \(5D_2\) levels are quenched due to electron-phonon coupling (multi-phonon-relaxation)
Advantages of Ir$^{3+}$ complexes
• Strong spin-orbit coupling

Emission spectrum of Ir$^{3+}$ complexes
• MLCT and $3\pi-\pi^*$ transitions
• Position of the HOMO and thus the emission bands can be determined by the ligands and controlled by substitutents on the ligands
10.6 Iridium Complexes

[(4,6-F$_2$-ppy)$_2$Ir(L)] - Photoluminescence and color points

- (ppy)$_2$Ir(acac)
- (F$_2$-ppy)$_2$Ir(acac)
- (F$_2$-ppy)$_2$Ir(pic)

Incoherent Light Sources
Prof. Dr. T. Jüstel
Chapter OLEDs and PLEDs
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### 10.7 White OLEDs - Options

#### Emitter | Colour | Efficiency | Lifetime
--- | --- | --- | ---
Fluorescent | R | + | ++
 | G | + | ++
 | B | + | +
Phosphorescent | R | ++ | +
 | G | ++ | +
 | B | + | 0

#### Expected external quantum efficiency without light outcoupling measures

<table>
<thead>
<tr>
<th>Source: Philips Lighting Aachen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full fluorescent RGB</strong></td>
</tr>
<tr>
<td><strong>Full phosphorescent RGB</strong></td>
</tr>
<tr>
<td><strong>Hybrid:</strong> B fluorescent</td>
</tr>
<tr>
<td>R+G phosphorescent</td>
</tr>
</tbody>
</table>

### Diagram with CIE 1931 Chromaticity Diagram

| Al | n-EIL | ETL | Matrix:Blue | Matrix:Green | Matrix:Red | HTL | p-HIL | ITO | Substrate |
10.7 White OLEDs - Light Out-coupling

External radiation: about 20 - 30% only

Glass substrate
Organic layers
Emitter molecule
Guided modes
Cathode (mirror)

Source: Philips Lighting Aachen
10.8 Polymer LEDs - Construction

Poly(dialkoxy-p-phenylenevinylene) “PPV”

Source: Philips Lighting Aachen
10.9 Operation of a Polymer LED

1: Injection

2: Intrachain transport

3: Interchain transport

4: Recombination

Glass

ITO

PPV

Ca

Glass

ITO

PPV

Ca

Glass

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10.10 Polymer LED Spectra

Emission spectra of some polymers

Source: Philips Lighting Aachen
10.11 Development of the Lifetime of PLEDs

Degradation due to $O_2$ and $H_2O \Rightarrow$ Encapsulation is necessary

Data for 20 cd/m² brightness
Flexible displays without backlight

- Shaver displays
- Digital cameras
- Warning signs
- OLED TVs/monitors
- Light tiles
- Smart phones

Philips Lumiblade