Emissive and Non-Emissive Displays

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Agenda

- Introduction
- Types of Displays
  - LCD
  - Plasma Displays
  - OLED
  - FED/SED
- Comparison
Emissive Displays

- The image is produced directly on the screen
- Phosphors convert electron beams or UV light into visible light
- E.g.: Plasma-, FE-, SE-Displays
Emissive Displays

- Cathode Ray Tube (CRT)
- Field emission display (FED)
- Surface-conduction Electron-emitter Display (SED)
- Vacuum Fluorescent Display (VFD)
- Electroluminescent Displays (ELD)
- Light-Emitting Diode Displays (LED)
- Plasma Display Panel (PDP)
- Electrochemical Display (ECD)
- Organic Light Emitting Diode (OLED)
Non-Emissive Displays

- Light is produced behind the screen and the image is formed by filtering this light

- E.g.: LC-Display (LCD)
Liquid Crystal Display

- Liquid Crystal Display = LCD

- TFT-LCD = Thin Film Transistor = AMLCD (active matrix)

- Liquid organic crystals
  - Known since 1888
  - First application in 1968
  - Cholesteryl benzoate

- Optical anisotropy
Working Principle LCD
Light Sources for LCDs

- CCFL = Cold Cathode Fluorescence Lamp
- White LED
- RGB LED
CCFL

- First CCFL was developed by Georges Claude in 1909
- Low pressure fluorescence lamp
- Edge lit backlight
- Emits white light
- Electrodes remain cold during operation
Working Principle CCFL

- Low pressure glass tube filled with Hg/Ar, Hg/Ne or Ne
  - 185, 254 nm and 74 nm

- Phosphors transform UV light into white light
  - BAM(BaMgAl$_{10}$O$_{17}$:Eu), LAP(LaPo$_4$:Ce,Tb), YOX(Y$_2$O$_3$:Eu)

- Color temperature: 2700 - 6500 K depending on mixture

- Activation: MeCO$_3$ $\rightarrow$ MeO + CO$_2$ (Me = Ca, Sr, Ba)

- Operation: W + 6 BaO $\rightarrow$ Ba$_3$WO$_6$ + 3 Ba
LEDs

- **White LED**
  - Blue LED with converter phosphor: YAG:Ce
  - Edge lit backlighting

- **RGB LED**
  - 3 LEDs per pixel
  - Full backlight

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Fig. 21.7. (a) Structure of white LED consisting of a GaInN blue LED chip and a phosphor encapsulating the die. (b) Wavelength-converting phosphorescence and blue luminescence (after Nakamura and Fasol, 1997).
**LCD**

**Pros:**
- Lightweight construction
- Thin panels
- Low energy consumption

**Cons:**
- Quality of image depends on viewing angle
- Low response times
PDP

- PDP = Plasma Display Panel
- „Production“ of light in every pixel
- Plasma as the „source of light“
- Large displays/TV sets possible
Working Principle PDP

- First displays in 1929
- Working pressure: 200-300 mbar
- Ne with 10-15% Xe
- Plasma emits UV-light
Mechanisms

\[ \text{Xe} + e^- \rightarrow \text{Xe}^{(3P_1)} + e^- \]
\[ \text{Xe}^{(3P_2)} + e^- \]
\[ \text{Xe}^{**} \]

\[ \text{Xe}^{**} \rightarrow \text{Xe}^{(3P_1)} + \text{hv (828nm)} \]
\[ \text{Xe}^{(3P_2)} + \text{hv (823nm)} \]

\[ \text{Xe}^{(3P_1)} \rightarrow \text{Xe} + \text{hv (147nm)} \]

\[ \text{Xe}^{(3P_1)} + \text{Xe} + \text{M} \rightarrow \text{Xe}_2^* + \text{M} \]

\[ \text{Xe}_2^* \rightarrow 2 \text{Xe} + \text{hv (150nm or 172nm)} \]
## Phosphors for PDPs

<table>
<thead>
<tr>
<th>Color</th>
<th>Chemical Composition</th>
</tr>
</thead>
</table>
| Blue  | \((Y,Gd)(V,P)O_4\)  \
BaMgAl\textsubscript{10}O\textsubscript{17}:Eu |
| Green | \(\text{Zn}_2\text{SiO}_4:\text{Mn}\)  \
BaMgAl\textsubscript{10}O\textsubscript{17}:Eu,Mn  \
BaAl\textsubscript{12}O\textsubscript{19}:Mn  \
\((Y,Gd)\text{BO}_3:\text{Tb}\) |
| Red   | \((Y,Gd)\text{BO}_3:\text{Eu}\)  \
\((Y,Gd)_2\text{O}_3:\text{Eu}\)  \
\((Y,Gd)(V,P)O_4:\text{Eu}\) |
Pros:
- Large displays
- Good color rendering
- Thin panels
- No dependence on viewing angle
- Brightness

Cons:
- High costs
- Power consumption
+ OLED

- OLED = organic light emitting diode
- Development started in 1980s and was lead by Kodak
- There are different OLEDs used for displays:
  - Passive-matrix OLED → less efficient → suited for small screens (2- to 3-inch)
  - Active-matrix OLED → very efficient using TFT
    → large displays, electronic signs
  - Transparent OLED → >70% transparency
    → Laptop, Head-up systems
OLED Structure

- Cathode
- Emissive Layer (Organic Molecules or Polymers)
- Conductive Layer (Organic Molecules or Polymers)
- Anode
- Substrate

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OLED

- **Pros:**
  - Thinner, lighter and more flexible than LED, LCD and Plasma
  - Brighter than LED because organic layer is a lot thinner than the corresponding emitting layer in the LED
  - Much less power due to unnecessary backlighting
  - Large fields of viewing

- **Cons:**
  - Lifetime (blue has only a lifetime of 14,000 hours)
  - Manufacturing is expensive
  - Air sensitive – Water can easily damage OLEDs
What is an FED?

**Cathode Ray Tube (CRT)**

Three hot cathodes produce electrons which are scanning in vacuum across a multicolor viewing screen to create an image.

**Field Emission Display**

Electrons from millions of tiny cathodes travel in vacuum to a multicolor viewing screen to create an image.
Concept of FED

- First concentrated efforts in 1991 by Candescent in cooperation with Sony; 2009 Sony gave up production due to a lack of capital but there are still some Japanese Companies working on it.

- Current between CNT’s and metal mesh producing the electrons and controlling them (large field electron source)

- Electrons reaching the phosphor layers and excite them

- Phosphors emit different colours

- Three sub-pixel add up to one pixel
Field Emission Display (FED)

Pros:
- More efficient than LCDs
- No backlighting system and extra active matrix like TFT \( \rightarrow \) very thin displays
- High image quality
- High response time

Cons:
- Production problems due to the high reliability (vacuum)
- Acceleration current not high enough to excite phosphors
- Contamination and damage in processing
SED

- SED = Surface-conduction Electron-emitter Display

- Emerging technology, Co-developed by Canon and Toshiba; 2010 Canon has halted further development

- Is based on the idea of Cathode Ray Tubes (CRT)
1. Electrons emitted in vacuum by tunneling due to potential difference (10 V) between the two electrodes

2. Electrons are accelerated by a high electric field towards the positively charged screen, which is coated with phosphors

3. The phosphors get excited by the electrons and emit visible light

This is one surface-conduction electron emitter (SCE). It represents one pixel.
How a SED-TV Works

- Millions of SCEs are arranged in a matrix and each one controls the red, green and blue aspect of one pixel of the picture.

- Parts which are not used to create pixels are black, resulting in a high contrast.

- Microfilters improve color accuracy and cut down on reflected light.
SED

Pros:
- Thin and lightweight
- High efficiency
- Excellent color and contrast potential
- Wide viewing angel
- Unlike CRTs, SEDs permanently display the entire image

Cons:
- Unknown life expectancy
- Potential for screen burn-in
- High manufacturing costs
## Overview Technical Data

<table>
<thead>
<tr>
<th></th>
<th>CRT</th>
<th>LCD</th>
<th>LCD LED</th>
<th>OLED</th>
<th>Plasma</th>
<th>FED/SED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contrast</strong></td>
<td>500:1</td>
<td>50,000:1</td>
<td>3,000,000:1</td>
<td>&gt; 1,000,000:1</td>
<td>2,000,000:1</td>
<td>20,000:1</td>
</tr>
<tr>
<td><strong>Brightness [cd/m²]</strong></td>
<td>300</td>
<td>500</td>
<td>300</td>
<td>600</td>
<td>1000</td>
<td>400</td>
</tr>
<tr>
<td><strong>Viewing angle [degree]</strong></td>
<td>180</td>
<td>170</td>
<td>170</td>
<td>&gt; 170</td>
<td>170</td>
<td>180</td>
</tr>
<tr>
<td><strong>Size [inches]</strong></td>
<td>&lt; 40</td>
<td>108</td>
<td>108</td>
<td>80</td>
<td>150</td>
<td>27</td>
</tr>
<tr>
<td><strong>Set depth [mm]</strong></td>
<td>400</td>
<td>20</td>
<td>2.6</td>
<td>0.05</td>
<td>7-18</td>
<td></td>
</tr>
<tr>
<td><strong>Response time [ms]</strong></td>
<td>5</td>
<td>10-25</td>
<td>10-25</td>
<td>0.01</td>
<td>&lt; 8</td>
<td>&lt; 2</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Very low</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>
New Display Technologies

- Quantum Dot Display (QDLED)
- Laser Phosphor Display (LPD)
- Organic Light Emitting Transistor (OLET)
- Nanocrystal Display
- Thick-film dielectric electroluminescent (TDEL)
- Inferometric Modulator Display (IMOD)