Electroluminescent Light Sources

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Overview on Electroluminescent Light Sources

• There are several kinds of electroluminescent light sources e.g. OLEDs, LEDs and so on
• There are all depending on the kind of applied field and the field strength
• This presentation will deal with high voltage AC inorganic EL light sources
History of powder based AC electroluminescence

• AC electroluminescence in ZnS was discovered by George Destriau in 1936
• In the 1950s a basic theoretical understanding of the effect gave this technology a first push
• In the 1990s the development of more durable phosphors gave the technology a second push
• It is still present in the market because it is the only mature technology for flat and flexible large area light sources
Structure of AC PEL lamps

- AC PEL lamps have a very simple internal structure.
- The particles in the emitting layer have a particle size of ca. 10-30 μm and are often ZnS particles (determines the film thickness).

Materials for Powder-Based AC-Electroluminescence, Michael Bredol and Hubert Schulze Dieckhoff, Materials 2010, 3, Fig 1
Mechanism of AC PEL

• An AC field is applied on the system with a frequency typically ranging from 50 – 1000 Hz and an operating voltage from well above 50 V

• Electrons and holes are separated at highest field strengths close to the surface and recombine radiatively on reversal of polarity

• Imperfections in the crystals are needed because otherwise too high field strengths would be needed for charge separation
The Phosphor

• All commercial phosphors are dominated by ZnS Phosphors (one typical example is ZnS:Cu,CL)

• Excitation of the phosphor happens via donor/acceptor mechanism

• Cu plays an important role for the excitation of the phosphor
  – The Cu concentration has to be so high that it exceeds the solubility in ZnS and Cu$_x$S is precipitated
Role of Cu in the excitation mechanism

Between CuₓS and ZnS heterojunctions are formed.

- The CuₓS Needles concentrate the applied field at the tips and include tunneling of holes and electrons into ZnS.

Source: Electroluminescent Displays, Yoshimasa A. Ono, P 12 Fig. 7
Examples

Source: Electroluminescent Displays, Yoshimasa A. Ono, P 12 Fig. 6

- Problems:
  - For the generation of white light different phosphors of to be mixed
  - The number of phosphors which can be used in ac powder based EL is limited because of the unique properties of ZnS as a host material
Production of a powder based ACEL device

- Front electrode is typically made of a polymer foil or glas sputtered with ITO
- All other parts are placed by simple screen printing techniques

→ Problems with the big particles sizes of the particle used
  - it is always necessary to find a good compromise of a good printability and a sufficient particle size
Applications

• AC powder EL Lamps are used for the illumination of night lights and exit/safety lights
History of thin film ac electroluminescence

• In 1968 Bell scientists started to work on thin film EL devices
• 1974 T. Inoguchi and his group report a stable and high brightness TFEL Display
• 1975 Sharp demonstrates a 320x240 display
• 1983 Sharp introduces first commercial TFEL display product
Structure of a thin film EL device

Figure 1: Schematic Diagram of Conventional TFEL Structure

Source: ELECTROLUMINESCENT DISPLAYS, CHRISTOPHER N. KING, Planar Systems, Inc. Fig.1
Excitation mechanism

• The exciation of the luminescent centers in the active layer happens via direkt impact of electrons
• The active centers in the layer (typically manganese relaxes via photon emission
• The electrons are accelerated by the applied electrical field
Requirements on the phosphor

- The band gap of the phosphor must be big enough to emit light without absorption
  - Semiconductor \((E_g > 3 \text{ eV})\) and Insulators
- The host lattice must be able to transport high energy electrons

- Up to date only II-VI materials such as ZnS and SrS have been commercially used
The used Phosphors

<table>
<thead>
<tr>
<th>Emission Color</th>
<th>Phosphor Material</th>
<th>CIE X</th>
<th>CIE Y</th>
<th>Luminance (nits @ 60Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>ZnS:Mn</td>
<td>0.50</td>
<td>0.50</td>
<td>400</td>
</tr>
<tr>
<td>Red</td>
<td>ZnS:Mn/Filtered</td>
<td>0.65</td>
<td>0.35</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>CaSSe:Eu</td>
<td>0.66</td>
<td>0.33</td>
<td>25</td>
</tr>
<tr>
<td>Green</td>
<td>ZnS:TbOF</td>
<td>0.30</td>
<td>0.60</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>ZnS:Mn/Filtered</td>
<td>0.47</td>
<td>0.53</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>SrS:Ce</td>
<td>0.28</td>
<td>0.53</td>
<td>110</td>
</tr>
<tr>
<td>Blue</td>
<td>SrS:Ce</td>
<td>0.19</td>
<td>0.36</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>SrGa$_2$S$_4$:Ce</td>
<td>0.15</td>
<td>0.10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>CaGa$_2$S$_4$:Ce</td>
<td>0.15</td>
<td>0.19</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>SrS:Cu</td>
<td>0.17</td>
<td>0.16</td>
<td>28</td>
</tr>
<tr>
<td>White</td>
<td>SrS:Ce/ZnS:Mn</td>
<td>0.46</td>
<td>0.50</td>
<td>470</td>
</tr>
<tr>
<td></td>
<td>SrS:Cu/ZnS:Mn</td>
<td>0.45</td>
<td>0.43</td>
<td>240</td>
</tr>
</tbody>
</table>

Source: ELECTROLUMINESCENT DISPLAYS, CHRISTOPHER N. KING, Planar Systems, Inc. Table II
Production of color TFEL displays

Another possibility for the production of a full color TFEL display is to use a red, a green and blue phosphor pattern.

One possibility is to use a white phosphor and a color filter.

Source: ELECTROLUMINESCENT DISPLAYS, CHRISTOPHER N. KING, Planar Systems, Inc. Fig. 10
Production of a TFACEL device

• Thin film EL devices are built via epitactic crystall growth on a substrate
  → it is possible to create very thin films with a thickness of 500 nm
Applications of TFEL

- In the 2000s TFEL became cheaper for consumers and are used for decorative clothing and thin film applications.
- EL technologies are not used as lamps because of the low lumes output and low efficiency compared to LEDs.
- The unique spatial aspects still (flat and flexible) saved EL devices a marked
Applications of TFEL

- **ICEBrite monochromatic displays**
  - ZnS(Mn) active layer emits yellow light which can be filtered into red / yellow / green colors. Blue has not been developed yet.

- **Multi-color monitors**
  - These use transparent semiconductors such as indium tin oxide (ITO) & fluorine doped oxide (FTO)

- **Transparent Displays**

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- **Grid**
  - 1983

- **HP**
  - 1985

- **Data General**
  - 1986

- **DEC**
  - 1989
References

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