Field Emission Displays (FEDs)

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SS12
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History

- Field emission was discovered and studied independently from 1880s to 1930s
- Fowler-Nordheim-equation was developed 1928
- Application developments ongoing from 1930s
- 1991 first attempts to develop FEDs were made
- 2005 Sony started a joint venture with Tex Gate (Field Emission Technologies Inc.)
Field emission

Basics

- Fowler-Nordheim-Tunneling
- Field emission from a solid surface into vacuum
- Electrons are emitted from an emission tip, by applying electrical current
- Necessary current depends on the Aspect ratio
  - Preferably a long narrow tip with a small curvature radius
Field emission

Applications

- Microscopy
  - SEM, TEM, FIM
- Electron beam lithography
- Field emission lighting
- Field emission displays
Field emission display

Properties

- Self emitting display
- Direct electron beam
- Low voltage device
- Emission tips are called “Spind-tips” when consisting out of metals
Field emission display

Assembly

- Triode assembly
- Emission tips were firstly made out of W or Si (Spind –Tips)
- Attempts to use CNT are current
Field emission displays

CNT-FE

- Good properties:
  - low operating voltage
  - good emission stability
  - long operating life
  - high current density by equal electron distribution

- USA & Japan are heavily investigating

- Possible applications: lithography, SEM, TEM, lighting, X-Ray-source, microwave generator

- Problems are the proccessibility and the costs
Cathode

CNT-FED

- Aspect ratio
- Chemically and thermally “inert”
- Good response time
- Energy efficient
## Comparison

### Spindt-Tips vs. CNT

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Spindt-FED</th>
<th>CNT-FED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>Vanishing on the long term</td>
<td>Better in comparison</td>
</tr>
<tr>
<td>Emission density</td>
<td>$10^4$-$10^5$</td>
<td>$10^6$-$10^7$</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>“higher”</td>
<td>$1 \text{ V/µm}$</td>
</tr>
<tr>
<td>Processing</td>
<td>CVD or anisotropic etching</td>
<td>SWCNT - screen printing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MWCNT - CVD</td>
</tr>
</tbody>
</table>

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Phosphor

Requirements

- Fast decay times
- Phase pure
- Thermally stable & low degradation
- Superior stability against electron bombardment
- Low voltage phosphors
- Oxides are preferred against sulphides
Phosphor

Degradation

- Penetration depth depends on the voltage
- High surface excitation
  - Leads to a fewer number of excited luminescent centres
  - Appearance of defects increase on the long term
# Phosphor

## Examples

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SrTiO$_3$:Pr</td>
<td>0.4</td>
<td>0.670</td>
<td>0.329</td>
<td>red</td>
</tr>
<tr>
<td>Y$_2$O$_2$S:Eu</td>
<td>0.57</td>
<td>0.616</td>
<td>0.368</td>
<td>red</td>
</tr>
<tr>
<td>Y$_3$(Al,Ga)$<em>5$O$</em>{12}$:Tb</td>
<td>0.7</td>
<td>0.354</td>
<td>0.553</td>
<td>green</td>
</tr>
<tr>
<td>Y$_2$SiO$_5$:Tb</td>
<td>1.1</td>
<td>0.333</td>
<td>0.582</td>
<td>green</td>
</tr>
<tr>
<td>ZnGa$_2$O$_4$</td>
<td>0.15</td>
<td>0.175</td>
<td>0.186</td>
<td>blue</td>
</tr>
<tr>
<td>ZnS:Ag,Cl</td>
<td>0.75</td>
<td>0.145</td>
<td>0.081</td>
<td>blue</td>
</tr>
</tbody>
</table>
Advances

Four colour system

- Usage of NaCaPO$_4$:Mn$^{2+}$ a yellow phosphor

- RGB concept is extended to RGBY
  - Surrounding of a larger colour space
  - Displaying of more natural colours
  - Higher information density (pixel/ area)
Advances

**NaCaPO$_4$:Mn$^{2+}$**

- Fabricated via Pechini sol-gel method
- Ground state [Ar]3d$^5$ $\rightarrow$ 6S
- Origin of the colour is the $^4T_1 \rightarrow ^6A_1$ transition
Comparison

## OLED (PLED), CNT-FED & LCD (Pros)

<table>
<thead>
<tr>
<th>OLED (PLED)</th>
<th>CNT-FED</th>
<th>LCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>self emitting</td>
<td>self emitting</td>
<td>backlight</td>
</tr>
<tr>
<td>big viewing angle</td>
<td>big viewing angle</td>
<td>energy efficient</td>
</tr>
<tr>
<td>good processibility</td>
<td>energy efficient</td>
<td>good processibility</td>
</tr>
<tr>
<td>good response time</td>
<td>good response time</td>
<td></td>
</tr>
<tr>
<td>good colour rendering</td>
<td>good colour rendering</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>good contrast</td>
</tr>
</tbody>
</table>
Comparison

OLED (PLED), CNT-FED & LCD (Cons)

<table>
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<tr>
<th>OLED (PLED)</th>
<th>CNT-FED</th>
<th>LCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>limited operating time</td>
<td>cathode coating</td>
<td>limited viewing angle</td>
</tr>
<tr>
<td>organic comp. vulnerable towards O₂ and H₂</td>
<td>mass production</td>
<td>moderate response time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>moderate contrast</td>
</tr>
<tr>
<td></td>
<td></td>
<td>limited colour rendering</td>
</tr>
</tbody>
</table>
Conclusions

- FED brings along a variety of advantages
- Processibility seems to be a hard task
- Low voltage phosphors are a prerequisite
- Big competing techniques
Future aspects

- 2009 Inventions into Field Emission Technology Inc were cut down
- OLED, Plasma, PLED.... are maybe a too big competitor
- Four colour technology seems to be promising
References

- http://static.guim.co.uk/sys-images/Guardian/Pix/pictures/2008/05/20/nanotube.article.jpg
- http://kennano.com