OLED Technology and Product Development in RiTdisplay

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II. The Application of OLED

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I. The Technologies & Challenge of OLED
OLED and LCD Comparison

**OLED Display**
- Glass
- Electrode
- Seal
- ITO
- Glass
- Organic Layer
- Polarizer

**LCD Display**
- Glass
- Protection
- ITO
- Seal
- ITO
- Glass
- Alignment Layer
- Spacer
- Polarizer
- Back Light
- Liquid Crystal
- Color Filter
Performances Comparison

- Thickness (Thin) (With B/L)
- Low power (w)
- Brightness (candelas/m²)
- Low weight (gm)
- Operation Temp. (Wide)
- Angle of View (180°)
- Resolution (Fine)
- Response time (Fast)

LCD
OLED

Leading the New Vision
Manufacturing Process of OLED

- Anode Patterning
- Evaporation (SM-OLED)
- Spin Coating (PLED) (Inkjet Printing)
- Cathode Deposition
- Module Assembly
- Encapsulation
OLED MANUFACTURING ISSUES

- Organic material supply in a production scale
- High throughput equipment
  - Evaporation: OLED
  - Spin coater or ink-jet printer: PLED
  - Encapsulation
- Failure analysis or defect engineering knowledge
- Lab to pilot to production scale experience
- Driver ICs specific and/or integrated for OLED applications

<table>
<thead>
<tr>
<th>STN-LCD</th>
<th>TFT-LCD</th>
<th>LTPSi-LCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive OLED</td>
<td></td>
<td>Active OLED</td>
</tr>
</tbody>
</table>
Evolution of OLED

- **Material**: SM-OLED → PLED
- **Material**: Fluorescence → Phosphorescence
- **Color**: Mono → Area Color → Full Color
- **Substrate**: Glass → Plastics → Film
- **Driving**: Passive → Active
- **Encapsulation**: Metal Can → Glass → Film
- **Life Time**: 2K hours → 10K hours → 20K \(\uparrow\)
Demands from Customers

- Hand-held, small & easily portable
- Fully integrated
- Compatible to existing system
- High resolution & 3D display
- Long lifetime
- Low power consumption
- Low cost
Technical Challenges of OLED

- Power Consumption
- Sunlight Readability
- Image Residue
- Lifetime
- Color matching
- Thickness
- Resolution
- Mass Production
# Challenges for Different Applications

<table>
<thead>
<tr>
<th>Applications</th>
<th>Challenges</th>
<th>Solutions</th>
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</thead>
<tbody>
<tr>
<td>Mobile Phone</td>
<td>Power Consumption</td>
<td>Efficiency, Device structure, Material, New Encapsulation Tech.</td>
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<tr>
<td></td>
<td>Lifetime</td>
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<td></td>
<td>Thickness</td>
<td></td>
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<tr>
<td>PDA</td>
<td>High Resolution</td>
<td>LTPSi Tech., Shadow Mask Tech., New Color Patterning Tech.</td>
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<tr>
<td></td>
<td>Power Consumption</td>
<td></td>
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<tr>
<td></td>
<td>Lifetime</td>
<td>Efficiency, Device structure, Material</td>
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<td></td>
<td>Thickness</td>
<td>New Encapsulation process</td>
</tr>
<tr>
<td>Monitor</td>
<td>Lifetime</td>
<td>Efficiency and Cost of Device and Material, Large Glass Size, LTPSi Tech., S-Mask Tech., No. of Mask, High Throughput Color Patterning,..</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td></td>
</tr>
</tbody>
</table>
Thickness : Encapsulation

- **Purposes**
  1. Prevent damage
  2. Absorb and isolate humidity and oxygen

- **Key issues**
  1. Capability of absorbent
  2. Mechanism of absorption
  3. Minimize the humidity and oxygen penetrates
  4. Hardness
Resolution : Shadow Mask

- **Purposes**
  - Organic sub-pixel
  - Cathode window patterning.

- **Key issues**
  1. Alignment accuracy
  2. Pixel-to-pixel non-uniformity (shadowing effect)
  3. Thermal expansion of large-size metal mask (position shift)
  4. Resolution limitation
Mass Production: Deposition

**Purposes**
1. High throughput and low material consumption
2. Large substrate operation

**Key issues**
1. Vacuum and temperature control
2. Alignment accuracy
3. No. of layers
4. Maintenance of the machine
New Process/Technology

- Evaporation/Deposition -
  Linear Source: Applied Film (vertical)
  ULVAC/Kodak (horizontal)
  OVPD (Organic Vapor Phase Deposition): Aixtron
  Inkjet Printing: CDT/Litrex; MicroFab
  Laser Induced Thermal Image: 3M

- Encapsulation –
  Film Encapsulation: Vitex, otb
Dream Display

System Integrated and Flexible Pen Type Display
Only OLED Can Make Display Like This

Source: UDC
II. The Application of OLED
## Display Applications

<table>
<thead>
<tr>
<th>Product</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Main Display Size</th>
<th>Sub-display size</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV (CRT)</td>
<td>150M</td>
<td>US$600</td>
<td>17 ~ 60&quot;</td>
<td>—</td>
<td>large</td>
</tr>
<tr>
<td>Desktop PC</td>
<td>100 M</td>
<td>US$1,000</td>
<td>13 ~ 20&quot;</td>
<td>—</td>
<td>Medium</td>
</tr>
<tr>
<td>Notebook</td>
<td>30 M</td>
<td>US$1,500</td>
<td>12 ~ 15&quot;</td>
<td>—</td>
<td>Medium</td>
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<tr>
<td>Refrigerator</td>
<td>200M</td>
<td>US$600</td>
<td>—</td>
<td>—</td>
<td>Medium</td>
</tr>
<tr>
<td>PDA</td>
<td>15 M</td>
<td>US$300</td>
<td>3 ~ 5&quot;</td>
<td>—</td>
<td>Small</td>
</tr>
<tr>
<td>Mobile Phone</td>
<td>400 M</td>
<td>US$200</td>
<td>1 ~ 2&quot;</td>
<td>0.5 ~ 1&quot;</td>
<td>Small</td>
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</tbody>
</table>

Source: TRI, 2002/5
OLED Share of World Mobile Phone

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>DisplaySearch</td>
<td>NITTO</td>
<td>DisplaySearch</td>
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<tr>
<td>MSTN</td>
<td>368,023</td>
<td>475,000</td>
<td>380,186</td>
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<td>CSTN</td>
<td>27,067</td>
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<td>26,203</td>
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<tr>
<td>AMLCD</td>
<td>40,600</td>
<td>26,830</td>
<td>65,270</td>
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<tr>
<td>OLED</td>
<td>2,400</td>
<td>70</td>
<td>24,000</td>
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<tr>
<td>TOTAL</td>
<td>438,090</td>
<td>583,900</td>
<td>495,659</td>
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</tbody>
</table>

Zeon PDF Driver Trial
www.zeon.com.tw
## Taiwan’s M/Pone Market Share Forecast

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2002f</th>
<th>2003f</th>
<th>2004f</th>
<th>2005f</th>
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<tbody>
<tr>
<td><strong>World Wide</strong></td>
<td>362,780</td>
<td>380,400</td>
<td>390,000</td>
<td>410,000</td>
<td>423,000</td>
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<tr>
<td><strong>Taiwan</strong></td>
<td>11,920</td>
<td>28,500</td>
<td>50,000</td>
<td>73,000</td>
<td>120,000</td>
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Source: TPCA, Digitimes

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2001 ~ 2005 OLED Market Forecast

Average

<table>
<thead>
<tr>
<th>Year</th>
<th>DisplaySearch</th>
<th>World Sales</th>
<th>Stanford Resources</th>
<th>野村總合研究所</th>
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<tbody>
<tr>
<td>2001</td>
<td>45</td>
<td>78</td>
<td>90</td>
<td>154</td>
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<tr>
<td>2002</td>
<td>155</td>
<td>141</td>
<td>190</td>
<td>313</td>
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<tr>
<td>2003</td>
<td>815</td>
<td>370</td>
<td>380</td>
<td>451</td>
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<td>2004</td>
<td>1783</td>
<td>655</td>
<td>600</td>
<td>804</td>
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<tr>
<td>2005</td>
<td>3105</td>
<td>1060</td>
<td>870</td>
<td>1484</td>
</tr>
</tbody>
</table>

Sources: Stanford Resources / DisplaySearch / 野村總合研究所

Leading the New Vision
2007 OLED Market Breakdown

Total OLED Market: USD 1.6 billion

CAGR: 60%

Sources: Stanford Resources / PIDA
Technology Category
III. Who are Working on the Technology
Licensee of OLED

Kodak – SM-OLED

Japan: Pioneer, Sanyo, Rohm, Denso
Nippon Seiki, TDK, Optrex

Europe: Opsys

Korea: Samsung NEC

Taiwan: Ritek(RiTdisplay), TECO

U.S.: eMagin, Lite Array

CDT – Polymer LED or LEP

Philips, Seiko Epson, Delta, DuPont
Existing O/PLED Products

Quantity \( \geq \) 10K

- Game-RiTdisplay
- Phone-T Pioneer Sub-display
- Car-Audio T Pioneer
- Car-Audio TDK
- Phone-RiTdisplay Sub-display
- Phone-T Pioneer Main-display
- Shaver-Philips PLED
- Phone-SNMD P/M Color

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World OLED Development
(Active Matrix)

Kodak

SONY

Samsung

Toshiba-Matsushita
World OLED Development

(Passive matrix)
World PLED Development

DuPont

Toshiba

Seiko Epson

DuPont

Toshiba

Philips
Worldwide Production Schedule

1999
- Q1: Samsung/NEC 370x400 20K/M PM-OLED
- Q3: TDK 400x400 15K/M OLED
- Q4: Pioneer 300x420 10K/M OLED

2000
- Q1: Sanyo/Kodak 300x400 AM-OLED
- Q3: RiTdisplay 370x470 50K/M PM-OLED
- Q4: Samsung/NEC 370x400 20K/M PM-OLED

2001
- Q1: TDK OLED
- Q2: Siemens 400x400 10K/M PLED
- Q3: Philips 300x300 30K/M PLED
- Q4: LG 200x200 16K/M OLED

2002
- Q1: Philips 300x300 30K/M PLED
- Q2: LG 200x200 16K/M OLED
- Q3: Philips 300x300 30K/M PLED
- Q4: Siemens 400x400 10K/M PLED

2003
- Q1: Toshiba/Matsushida 600x720 AM-OLED
- Q2: Delta PLED

Full color:
- Samsung/NEC 370x400 20K/M PM-OLED
- Sanyo/Kodak 300x400 AM-OLED
- RiTdisplay 370x470 50K/M PM-OLED
- Philips 200x200 3K/M PM-PLED
- Sony 600x720 AM-PLED

Mono/Area:
- Pioneer 300x420 10K/M OLED
- RiTdisplay 400x400 15K/M OLED
- TDK OLED
- Siemens 400x400 10K/M PLED
- Philips 300x300 30K/M PLED
- LG 200x200 16K/M OLED
- RiTdisplay 370x470 30K/M PLED

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RiTdisplay Background

- RiTdisplay was founded in Mar. 2000
- Capital: US$ 177 Million
- Major Shareholder: RiTEK, Intel, DuPont, GE, ViewSonic, DF...etc.
- ISO 9001 Certificated in Apr. 2001
- ERP was on line in Sept. 2001
- Shipment of memorial mobile phone display for 2002 FIFA World Cup in May 2002

VISION: To be the world leading OLED display maker and Provide the best information interface to consumers

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Leading the New Vision

Capacity

- **Phase I**
  - Substrate: 400x400mm
  - For OLED mono: 15K/month

- **New FAB**
  - Constructed from Aug. 2000
  - Completed on Nov. 2001
  - Clean Room Space: 7,000 m²/floor (total 6 floors)
  - Substrate: 370x470mm
  - For OLED Full color: 50K/month
  - For PLED mono/area: 30K/month
  - Future Capacity: 160 ~ 200 K/month

*OLED Mass Production Line*
*PLED Mass Production Line*
Technology Sources

Material & Device
- Tech. of material analyses
- Technology of chemistry & material structure design

Panel Manufacturing
- Photolithography
- Glass cleaning & maintenance
- Etching
- Photo resist application

Thin Film Manufacturing
- Layer structure design
- Deposition techniques
  - Vacuum evaporation
  - Thermal evaporation
  - Spin coating
  - Metal evaporation
- Encapsulation

IC & Product Application
- Driver IC technology
- IC structure design
- LTPS driving technology
- Mobile phone application
- Lighting application

Developed by RiTEK & RiTdisplay (Owned 35 patents)
Developed by RiTEK & RiTdisplay (Owned 18 patents)
Developed by RiTdisplay (owned 19 patents)

OLED IP licensed from Kodak (50 patents)
Alliance with DuPont in PLED (30 patents)
(owned 18 patents)

ITO Glass Substrate
- Technology of glass cleaning, polishing & testing
- Thin film process of ITO, SiO2

OLED Display Technology
90 patents

Leading the New Vision
Lead-time for Customer Design

(IC Available)

- Spec. evaluation and quotation: 3 ~ 5 Days
- Counter drawing offering: 5 ~ 7 Days
- Sample offering: 45 Days ~ 60 Days
- Mass production (after approved): 30 Days ~ 60 Days
Conclusion

- OLED is the technology that Taiwan can compete with others
- More to join this business can make technology faster and cost lower
- Many Key Technology need to solve to make large OLED display
- Small size OLED manufacturing become mature that may easier to penetrate market and get revenue
- To develop the technology before mass production is a must
- Mass production is not easy now but the progress is very quick