Single Layer Color Cholesteric Liquid Crystal Display

Frank Shiu
jwshiu@itri.org.tw
Tel: 886-35915562
Display Technology Center
Industrial Technology Research Institute
Taiwan, R.O.C.
Outline

• Applications
• Color Technologies of Ch-LCD
• Development Results of ITRI
• Future Planning
• Conclusions
Flexible Display is selected to meet the needs.
## How Flexible Display Meet the Needs?

### Approaches
- Plastic Substrate
- Rollable
- R2R Process
- Paperless/Bi-stable

### Needs
- Slim & Light
- Convenience
- Large area
- Ecology (Energy Saving)
Applications- Digital Signage

Restricted Color Signage

Printed Large Advertising Paper

Large Size Light Box

Curved Signage
“Display” Your Room ?? The Killer Application??
• Color Technologies of Ch-LCD
ChLCD Bistable Technique

Bi-stable:
- Low power consumption

Simple structure:
- w/o CF, optical film
- No backlight
- Light/Thin

Planar (stable)

Focal conic (stable)

Homeotropic
Stacked Layers Structure

Fujitsu, 2007

KDI, SID 2007

shared electrode design

2-layer

5 mil PET or rayon substrate

3-layer
Single-layer Structure

KSU, 2003 SID DIGEST

Photo-tuning+Encapsulation

Different UV doses

0J/cm²
130J/cm²
353J/cm²
684J/cm²

DTC/ITRI, 2006 IDW

Ink Jet Printing ChLC

- Surface treatment
- Printing: material, color
- Protection layer
- Suitable for R2R process

Copyright 2008 ITRI工業技術研究院
## Comparison of ChLCD Technologies

<table>
<thead>
<tr>
<th>Company</th>
<th>Kent Displays</th>
<th>Fujitsu</th>
<th>Eastman Kodak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tech.</td>
<td>Single Substrate Ch-LCD</td>
<td>Stacked color ChLCD</td>
<td>Single Substrate Ch-LCD</td>
</tr>
<tr>
<td></td>
<td>Encapsulated Ch-LCD by PIPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spec.</td>
<td>CR:45:1, R:37%</td>
<td>CR:40:1, R&gt;40%</td>
<td>CR:27:1</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>8 or 4096 colors</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>768x1024(XGA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A4/105ppi, A5/162ppi</td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>20x24pixels, 8dpi</td>
<td></td>
<td>R:27%</td>
</tr>
<tr>
<td>Description</td>
<td>Coatable multicolor stacks, single sub.</td>
<td>Encapsulated ChLC phase separation</td>
<td>Single-substrate self-assembled CH-PDLC via emulsion method</td>
</tr>
<tr>
<td></td>
<td>screen-printing(E1)</td>
<td>full color stacked ChLCD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Three layers ChLCD</td>
<td>FLEPIa A4 size 184.3x245.7mm2</td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>[Image]</td>
<td></td>
<td>[Image]</td>
</tr>
<tr>
<td>Reference</td>
<td>07 SID</td>
<td>2007</td>
<td>06 USDC</td>
</tr>
</tbody>
</table>
## Development Results of ITRI

<table>
<thead>
<tr>
<th>Company</th>
<th>ITRI</th>
<th>ITRI</th>
<th>ITRI</th>
<th>ITRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tech.</td>
<td>10.4” QVGA Monochrome PM Ch-LCD</td>
<td>4.1&quot; Color PM Ch-LCD</td>
<td>10.4&quot; Color Ch-LCD</td>
<td>Flexible 10.4” Ch-LCD</td>
</tr>
<tr>
<td>Spec.</td>
<td>CR&gt;10:1</td>
<td>QVGA CR&gt;10:1</td>
<td>QVGA (320xRGBx240)</td>
<td>QVGA (320xRGBx240)</td>
</tr>
<tr>
<td></td>
<td>R&gt;30%</td>
<td>R&gt;30%</td>
<td>512 color</td>
<td>512 color</td>
</tr>
<tr>
<td>Structure</td>
<td><img src="image" alt="Structure Diagram" /></td>
<td><img src="image" alt="Structure Diagram" /></td>
<td><img src="image" alt="Structure Diagram" /></td>
<td><img src="image" alt="Structure Diagram" /></td>
</tr>
<tr>
<td>Description</td>
<td>10.4” (320*240) monochrome Ch-LCD on PC substrates</td>
<td>Ink Jet Printing LC for single layer color Ch-LCD</td>
<td>Pixelized vacuum filling of the ChLC</td>
<td>Pixelized vacuum filling Flexible technology</td>
</tr>
<tr>
<td>Product</td>
<td><img src="image" alt="Product Image" /></td>
<td><img src="image" alt="Product Image" /></td>
<td><img src="image" alt="Product Image" /></td>
<td><img src="image" alt="Product Image" /></td>
</tr>
<tr>
<td>Reference</td>
<td>2006</td>
<td>06 IDW</td>
<td>07 ASID</td>
<td>07IDW</td>
</tr>
</tbody>
</table>
Specifications:
• Panel Size: 10.4”
• Substrate: glass (0.7mm)
• Display medium: Red/Green/Blue Cholesteric LC
• Resolution: QVGA (320×RGB×240)
• Bank: 10um (H), 20um (W), 190um (Pitch)

Features:
• Single Layer color Ch-LCD
• Cost effective process: Ink Jet Printing
• Material saving process
• Low power consumption
• Reflective type display (without backlight)
• Simple structure (without polarizer)
• Passive Matrix Driving display

Applications:
E-Book, E-Paper, Signage…
Pixelized Vacuum Filling Tech. (PVF)

**Structure design**


**Process flow**

1. Substrate
2. ITO deposition
3. Adhesive coating
4. Rolling assembly
5. Cutting
6. ChLC filling End seal
7. Bonding Driving

**PVF:**
- Batch Type Process
- Traditional Cell Process Flow
- Novel End Seal Method
Bank Structure and Fabrication

Photolithography process

Molding process

Plastic substrate

Sample size 10.4”

PMMA Bank

Ni Roller

Bank Structure

Design
Plane molding
Rolling molding
### Color Performance

<table>
<thead>
<tr>
<th></th>
<th>455 nm (B) $\Delta\lambda$= 49 nm</th>
<th>528 nm (G) $\Delta\lambda$= 53 nm</th>
<th>666 nm (R) $\Delta\lambda$= 61 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Host (5016+110)</strong></td>
<td>2.13464</td>
<td>2.38304</td>
<td>1.99535</td>
</tr>
<tr>
<td><strong>Dopant</strong></td>
<td>0.12820</td>
<td>0.12214</td>
<td>0.08229</td>
</tr>
<tr>
<td>*<em>(D/H+D)<em>100 (%)</em></em></td>
<td>5.6454</td>
<td>4.8755</td>
<td>3.9993</td>
</tr>
<tr>
<td><strong>CIE (x,y)</strong></td>
<td>(0.15964,0.11388)</td>
<td>(0.24898,0.63)</td>
<td>(0.62071,0.35705)</td>
</tr>
</tbody>
</table>

--- Merck

--- ITRI-ChLC

**NTSC % of ITRI (MCL)**

ChLC : 69.18%
Optical & Electrical Property of ChLCD

**Driving voltage**

Contrast:
- Red: 12
- Green: 16
- Blue: 13

Reflection:
- Red: 18%
- Green: 23%
- Blue: 8%

(EZ contrast)

**Reflective Spectrum**

(460, 544, 664 nm)
Process Issues & Solutions

Substrate (PC) deformation:

- Process modify
  - Deformation history
  - Structure design
  - ITO gap

Light leakage

No light leakage

---

Copyright 2008 ITRI
ChLCD Driving Voltage and Frequency

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Frequency (Hz)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 50V</td>
<td>0.5</td>
<td><img src="image1" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>200</td>
<td><img src="image5" alt="Image" /></td>
</tr>
<tr>
<td>50V</td>
<td>0.5</td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td><img src="image7" alt="Image" /></td>
</tr>
</tbody>
</table>

- Bipolar driving voltage better than uni-polar voltage
- Driving frequency ≥100 Hz can get better driving result
10.4” Single-layer Color ChLCD

Display on glass

Flexible display

- Size: 10.4”
- Driving: PM
- Reflection >8%
- Resolution: QVGA 320xRGBx240
- Gray scale: 8 gray levels
- Color: 3 bits color
- CR >10
- Bending< 30mm
10.4” Single-layer Color ChLCD
Future Planning
R2R Ch-LC Process Pilot Line

Monochrome

- Plastic Substrate
- ITO Laser Patterning
- Slot Die Coating LC
- Forming Protecting & Absorption Layer
- Forming Conducting Layer
- Cutting
- Product

Color R2R

- Plastic Substrate
- ITO Laser Patterning
- Coating & Molding (Bank Forming)
- Plasma Surface Treatment
- Ink Jet Printing LC(RGB)
- Forming Protecting & Absorption Layer
- Forming Conducting Layer
- Cutting
- Product
# Product Concept Roadmap

<table>
<thead>
<tr>
<th>Year</th>
<th>Small size Prototype</th>
<th>Digital Signage</th>
<th>Large size E-Banner</th>
<th>Advanced E-Banner</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>-3 bits colors</td>
<td></td>
<td>[High Brightness/color Tech.]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Size: 10.4”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-QVGA: 40ppi*RGB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[Single Layer Color Tech.]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **R2R Process Tech.**
- **Color R2R Pilot Line**
- **High Brightness/color Tech.**
- **Single Layer Color Tech.**
Integration in ITRI

DTC:
• Panel design/integration
• Large size driving system
• R2R Ink Jet Printing

MCL/EOL:
• LC material tech.
• IJP color display material
• High reflective LC
• Flexible bonding tech.

MSL/CMS/ITRI south:
• Defect inspection tech.
• R2R embossing tech.
• R2R process
Industrial Cooperation

Panel/System Makers:
1. Mass production analysis
2. Driving System
3. Product spec. / design

Material Suppliers:
1. Conducting materials
2. Dark layer/ Protection layer
3. Bank material
4. LC material

Equipment Suppliers:
1. Ink Jet Printing
2. Roll Coater

Integrated color R2R cooperation project:
1. Panel /System Makers
2. Material Suppliers
3. Equipment Suppliers

2008          2009          2010
Conclusions

- The single layer design simplifies the fabrication process.

- The 10.4” flexible, color, bi-stable display is realized by the PVF technique.
  - Resolution QVGA, CR>10, 3 bit color, voltage<60V, bending<30mm more than 10000 times

- Other topics on flexible bi-stable Ch-LC display
  - Brighter, Better Color, Lower driving voltage, Larger size, Higher resolution, R2R process.
Thank you for your attention!