New applications of flexible displays

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Principal Engineer at Plastic Logic UK, Cambridge.
Plastic Electronics Technology

- Uses plastic instead of traditional silicon semiconductors and glass
- Enables a revolutionary design and form-factor

Flexible, thin, large, lightweight and shatterproof
Company History

Display Development

- 10+ transistors
- 100+ transistors
- 1.2 M transistors
- Colour EPD
- 2.8 M transistors

Research, Process Development & Manufacturing

- Cambridge University
  Research in organic electronics
- 2000: Cambridge Technology Center translating research into products
- 2008: Dresden Display Factory
  First plastic electronics factory in the world
Cambridge R&D Prototype Line (14”)

- Proof of concepts
- Highly configurable process
- New designs in < 1 month
- 1” Chips to A4 displays
- R&D Engineers
Dresden Gen. 3.5 Factory

- Backplane Manufacturing
- Qualified volume process
- Production equipment
- Fully Automated Handling
- Process, Equipment, Integration Engineers
- Thousands of displays/week

Proprietary to Plastic Logic
The Manufacturing Challenge

It is one thing to show a single display at a tradeshow…

...quite another to develop a high yield manufacturing process
Plastic Logic’s Manufacturing Process

- Key differences in manufacturing organic and flexible electronics:
  - Utilize solution processing to fabricate OTFTs
  - Process is designed to use lower temperatures which permits the use of lower cost flexible substrates
  - Harness direct-write fabrication techniques to improve overlay tolerances and feature registration

- Have developed unique process know-how and IP:
  - Handling plastic sheets through assembly processes
  - Large area deposition technologies of organic and inorganic materials
  - Cleaning and conditioning of the layers to improve device performance

- Passed through the “Industrialisation” phase
  - Reproducibility
  - Homogeneity

Proprietary to Plastic Logic
Processing challenges in development phase

Optimising process conditions is a critical part of industrialisation process

Monitoring data from coating process in the first year (2009)

Monitoring data from same process one year later
## Qualification tests for OTFTs and Display Modules

<table>
<thead>
<tr>
<th>Name</th>
<th>Test</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermo cycling</td>
<td>TST</td>
<td>Mechanical robustness &amp; CTE mismatch</td>
</tr>
<tr>
<td>High Temperature Storage</td>
<td>HTS</td>
<td>Storage of transport conditions</td>
</tr>
<tr>
<td>Advance Humidity Storage</td>
<td>AHS</td>
<td>Stability against moisture ingress</td>
</tr>
<tr>
<td>Low Temperature Storage</td>
<td>LTS</td>
<td>Storage of transport conditions</td>
</tr>
<tr>
<td>Real World Usage</td>
<td>RWU</td>
<td>Display use in non-accelerated mode</td>
</tr>
<tr>
<td>Advance Humidity Operation</td>
<td>AHO</td>
<td>Accelerated operation at high humidity</td>
</tr>
<tr>
<td>Low Temperature Operation</td>
<td>LTO</td>
<td>Accelerated operation at low temperature</td>
</tr>
<tr>
<td>Ambient Operation</td>
<td>AO</td>
<td>Accelerated operation at ambient conditions</td>
</tr>
<tr>
<td>Solar storage</td>
<td>SOR</td>
<td>Solar robustness</td>
</tr>
<tr>
<td>Altitude test</td>
<td>ALT</td>
<td>Pressure sensitivity</td>
</tr>
</tbody>
</table>

9 Proprietary to Plastic Logic
Technology Position Today

- Developed the lightest and most durable backplane display technology available today
- Qualified the processes in our volume production facility
- Have developed a strong portfolio of IP and know-how
  - 110 patent families and applications
- Capable of producing hundreds of billions of uniform and reliable plastic transistors on display backplanes each year
- 1-2 year lead over the competition for flexible backplane technology
PL Flexible Displays: Now available

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display size</td>
<td>up to 10.7”</td>
</tr>
<tr>
<td>Backplane Grey Levels</td>
<td>up to 16</td>
</tr>
<tr>
<td>Pixel density</td>
<td>up to 225ppi</td>
</tr>
<tr>
<td>Contrast Ratio</td>
<td>18:1</td>
</tr>
<tr>
<td>Thickness</td>
<td>down to 400µm</td>
</tr>
<tr>
<td>Colour</td>
<td>Also available</td>
</tr>
</tbody>
</table>

- Paper-like finish available
- Excellent readability
- Bi-stable EP media supports long battery life
- Colour versions ideal for office applications like charts and graphs

Photograph of a PL flexible display: 10.7” diagonal, 1280 x 960 pixels, sixteen grey-levels.
Colour display development
Colour Display - Architecture

- Colour Filter array (CFA)
- E Ink electrophoretic frontplane (FP) media
- Low distortion plastic logic backplane

- Colour Filter patterned by multiple approaches (wet printing, sheet-to-sheet alignment).
- During CFA pattern formation, the backplane pixel electrodes are not visible (obscured by FP media layer).

- Backplane:
  - 1280 x 960 pixels (monochrome) == 640 x 480 Colour
  - 150PPI (monochrome) == 75PPI Colour
  - Active Area: 217.6mm x 163.2mm

Proprietary to Plastic Logic
Plastic Logic have presented a process for coping with the issue of overlay distortion for multi-layered stacks made of plastics.*

The new process resets distortion at the top pixel electrode layer with no loss in pixel performance.

This means pre-patterned layers can be placed on top (eg Colour Filters)

*This topic was presented at SID2012 conference in Boston, by Dr Paul Cain
Colour Displays – Spatially Separated CFA

- RGBW colour filter array patterned directly on top of FP media surface
- Overlay accuracy of 10µm achieved across the active area
- Four variants of different colour density investigated
- Process has been qualified in our production facility**

**This topic was presented at ISEP2012 conference in Yokohama, by J.Watts**
Colour Display – Gamut options

- 4 colour densities tested (A,B,C,D)
- Gamut (\(\Delta E^3\)):
  - Type A: 5000
  - Type B: 4000
  - Type C: 3400
  - Type D: 3000

Acknowledgement: A. Bouchard, E Ink

Photograph of a PL flexible colour display: 10.7” diagonal, 1280 x 960 pixels.
What’s coming next?
Flexible plastic displays can easily be cut and bonded closely together to form larger displays.

Photograph showing two 10.7” displays bonded together to form a single 15.4” display.
Plastic Logic is flexible display OEM and can offer B&W or Colour displays in a variety of sizes and resolutions.

Plastic Logic is a global leader in fabricating OTFTs on plastics and has industrialised its process to fabricate backplanes containing millions of transistors. Plastic Logic can enable others to do this via our licensing arrangements.

Plastic Logic is constantly searching for partners wishing to create new markets and opportunities for our display technology.

Please visit our YouTube channel to view the video footage which was shown during this presentation and to discover our latest technology demonstrations: www.youtube.com/user/plasticlogic
Thank you.

Please come and visit our stand to see our technology in action.

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