Flexible and OLED display latest technology trend

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Flexible Display
FLEXIBLE DISPLAY SHIPMENT TREND

Source: IHS Report 'Flexible Display Market Tracker'

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Recent Prototypes of flexible displays

- EDO Flexible 5.6” WQHD
- BOE Foldable 4.35” WVGA
- Tianma Bendable 5.5” FHD
- GVO Rollable 4.6” WVGA
- CPT Rollable 4.5” QVGA
- SDC Rollable 5.7” FHD
- LGD Rollable 18” HD
- AUO Rollable 5.0” HD
- Sharp Wrap-around 3.4” qHD
- JDI Curved 5.2” FHD
- Truly 5.2” 600x200 (flexible AMOLED)
- Royole (flexible AMOLED)

Source: IHS Report ‘Flexible Display Market Tracker’
KEY TECHNOLOGY – 1 : TO REDUCE THICKNESS

- Targeting to coat Polarizer

Source: IHS Report 'Flexible Display Market Tracker'
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## KEY TECHNOLOGY – 2 : FLEXIBLE TOUCH SENSOR

### Touch Sensor Development History for AMOLED

**Rigid OLED**
- **(a) On-cell TSP**
  - Cover window
  - OCA / OCR
  - Polarizer
  - TSP sensor
  - Encap glass
  - Sealing (frit or resin)
  - Emitting layer
  - Substrate glass
  - TSP sensor on encapsulation glass (Up side)
  - Total 8 layer

- **(b) Reverse On-cell TSP**
  - TSP sensor on encapsulation glass (Down side)
  - Total 8 layer

**Flexible OLED**
- **(c) TSP on plastic film**
  - TSP base film
  - OCA / OCR
  - Plastic substrate
  - TSP sensor on additional base film
  - Total 10 layer

- **(d) TSP on polarizer**
  - TSP sensor on polarizer
  - Total 8 layer

- **(e) Flexible On-Cell**
  - TSP sensor on Thin film encapsulation
  - Total 8 layer

### Flexible On-Cell Touch Sensor

- **(a) Varnishing Plastic Resin on Touch Sensor Pattern**
- **(b) Thermal Curing for making Plastic Resin as a film**
- **(c) Touch Sensor Pattern by Low tem. Process on Encapsulation of completed flexible OLED**

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Source: IHS Report ‘Flexible Display Market Tracker’
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KEY TECHNOLOGY – 3 : PANEL CUTTING & LIFT OFF

- a) Encapsulated panel substrate (PI substrate on the carrier glass)
- b) Laser Cutting (Ok for any shape such as circular)
- c) Laser Lift Off (Melting the sacrificing layer under PI)
- d) Cell Cleaning
- e) Visual Inspection
- f) Fab-out

Laser Process is important to manufacture with better quality

No need to edge cutting & grinding (which glass display should do)

Source: IHS Report 'Flexible Display Market Tracker'

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KEY TECHNOLOGY – 4 : Drive IC Bonding

Drive IC can be bonded directly on the PI Substrate. (No film needed)

Additional COP Film was used to optimize the repair process.

Issue Solved

Drive IC can be bonded directly on the PI Substrate. (No film needed)

Additional film was needed to wire DIC.

Drive IC can be bonded directly on the PI Substrate. (No film needed)

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Drive IC can be bonded directly on the PI Substrate. (No film needed)
KEY TECHNOLOGY – 5 : FLEXIBLE COVER LENS

Characteristics by folding type

<table>
<thead>
<tr>
<th>Type</th>
<th>C type</th>
<th>G type</th>
<th>S type</th>
<th>C+ Type</th>
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<td>C</td>
<td>G</td>
<td>S</td>
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<td>Display</td>
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<td>Outside</td>
<td>Inside</td>
<td>Inside &amp; Outside</td>
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<td>Application</td>
<td>Tablet</td>
<td>Smartphone</td>
<td>Tablet</td>
<td>Smartphone &amp; Smartphone</td>
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<td># of folding</td>
<td>1 time</td>
<td>1 time</td>
<td>2 time</td>
<td>2 time</td>
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<td>Thickness</td>
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<td>Difficulty</td>
<td>Low</td>
<td>High</td>
<td>Mid</td>
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</table>

Source: IHS

[ Thickness issue of foldable display ]

T = Thickness, R = Radius
Max = (2T + R) * 20 (mm)
Min = (2a + R) * 20 (mm)
Different of Max & Min = 2 * (T-a) * 20 (mm)

It should be thin as possible as it can.

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FLEXIBLE DISPLAY MARKET FORECAST

Source: IHS Report 'Flexible Display Market Tracker'

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FLEXIBLE AMOLED CAPACITY FORECAST

Source: IHS Report ‘Flexible Display Market Tracker’

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POLYIMIDE SUBSTRATE MARKET FORECAST

Source: IHS Report 'Flexible Display Market Tracker'

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Small & Medium AMOLED Display
Small & Medium AMOLED Issue 1 – APPLE’S DEMAND

<table>
<thead>
<tr>
<th>Brand</th>
<th>2013</th>
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<th>2016</th>
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<td><img src="image4" alt="Samsung 2016" /></td>
<td><img src="image5" alt="Samsung 2017" /></td>
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</tbody>
</table>

Various type of Curved Screen with flexible AMOLED

Repeating Simple Flat type Screen with LTPS LCD

Curve Screen would not be innovative or differentiated for Apple.

Source: IHS Report ‘Flexible Display Market Tracker’
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Small & Medium AMOLED Issue 2 – Fine Metal Mask

**Improvement of FMM**

**Thermally Stable**
Invar Alloy

**Light Weight**
Split Mask

**Narrow Pitch**
Dual Side Etching

**Thinner Structure**
Electro-forming, Fine Hybrid Mask

[ Source: IHS Report ‘OLED Technology Market Tracker’ ]
Recent Technologies of Manufacturing FMM

[ Electro-forming Mask (Plating Process) ]

- **SUS Substrate**
- **PR Patterning**
- **PR Etching**
- **Plating**
- **Releasing**

Specific Condition of Plating Solution:
- pH 1.5-3 of NiCl₂, FeCl₃,
- Current density: 20-100 mA/cm²,
- Temperature 45-55°C

Plating solution
- ITO (as a release layer)
- SUS plate
- Photo Resist
- Developing Reverse Mask Pattern
- Invar (Ni+Fe)

Over 20 μm Pitch
10-20 μm Slit

[ Fine Hybrid Mask (Plating Process + Polyimide Laminating) ]

Structure of Non-tension FHM:
1. Polyimide film patterned by Laser.
2. Ni mask by electroforming.
3. Support Metal

PI Hybrid Mask
- Mask Frame
- Spot Welding

Slit Pitch
- PI Film
- Invar

Source: IHS Report ‘OLED Technology Market Tracker’
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AMOLED FINE METAL MASK MARKET FORECAST

Source: IHS Report ‘OLED Technology Market Tracker’
Small & Medium AMOLED Issue 3 – RIGID CAPACITY

Source: IHS Report ‘OLED Technology Market Tracker’
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Impact of Small & Medium Rigid AMOLED Capacity

Advantages for

• AMOLED Frontiers
  > Huge Capacity (but limited)
  > Various Products (focusing high-end)
  > Less Depreciation (No additional Capa)
  > Less Cost (Yield improving)

• Followers
  > Supply for candidates customers
  > Sharing catch up (if capacity exists)
  > Follow up rigid AMOLED technology
  > Sourcing better material & source

Source: IHS Report ‘OLED Display Market Tracker’
Large sized AMOLED Display
Large sized AMOLED Issues 1 – Panel Price

[ Price Trend (2014 Q1~2016 Q4) ]

- 55" 3840 x 2160 AMOLED
- 55" 3840 x 2160 TFT LCD
- 55" 3840 x 2160 QD LCD

[ Price Forecast (2017 ~ 2020) ]

- 55" 3840 x 2160 TFT LCD
- 55" 3840 x 2160 AMOLED

Source: IHS Report ‘OLED Technology Market Tracker’

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Large sized AMOLED Issues 2 – Low supply efficiency

Glass cutting efficiency by generation & panel size

<table>
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<th>Gen 9.7 Full Cut</th>
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<td>2200x2500 mm</td>
<td>2500x2950 mm</td>
<td>2940x3370 mm</td>
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<tr>
<td>55”</td>
<td>6 (91%)</td>
<td>6 (91%)</td>
<td>8 (90%)</td>
<td>8 (67%)</td>
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<tr>
<td>65”</td>
<td>2 (42%)</td>
<td>3 (64%)</td>
<td>6 (95%)</td>
<td>8 (94%)</td>
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<tr>
<td>77”</td>
<td>2 (59%)</td>
<td>2 (59%)</td>
<td>3 (66%)</td>
<td>3 (49%)</td>
</tr>
</tbody>
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Source: IHS Report ‘OLED Technology Market Tracker’
Large sized AMOLED Issues 3 – Top Emission

Gen8 Bottom Emission Process (Pilot from 2013)

- Glass Substrate
- Color Filter on Array
- Oxide TFT
- White OLED
- Cathode
- Thin Film Encapsulation
- Metal Foil
- Polarizer

Gen8 Top Emission Process (Pilot from 2017)

- Glass Substrate
- Oxide TFT
- White OLED
- Transparent Cathode
- Color Filter on Glass
- Glass Encapsulation
- Reflection Film
- Polarizer

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Large sized AMOLED Issues 4 – Ink Jet Printing

Gen8 Hybrid Blue Common Layer Inkjet/Evaporation AMOLED (Pilot from 2018)

Gen8 Full Inkjet Printed AMOLED (Pilot from 2021)

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OLED TV Panel Capacity Forecast

Source: IHS Report 'OLED Technology Market Tracker'

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OLED TV Panel Market Forecast

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Summary
## AMOLED PANEL MAKERS STATUS SUMMARY

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</tbody>
</table>

MP : Mass Producing, Pilot : Pilot Producing
Ready : Ready to MP, - : R&D, X : Not considering

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Thank you!