Commercialization of Micro LED

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Industrialization of Micro LED

- Micro LED’s Role in Evolution of Display
- Challenges of Micro LED’s Commercialization
- Micro LED’s Potential and Market Development
LED Display Applications- Backlight and Pixel Light (1/2)

**Application Segment**

- **LED as Pixel**
  - Public Display
    - Outdoor/Indoor
  - LED Display
    - Monocolour
    - RGB

- **LED as Backlight**
  - Consumer Display
    - Phone/Tablet/MNT/TV/Wearable/Projector/Auto
  - LCD Display with LED Backlight
    - Direct-Lit
    - Edge-Lit
LED Display Applications- Backlight and Pixel Light (2/2)

**TV**
- LED Type: White LED
- LED Size: 3 mm X 3 mm
- Pixel Control: Liquid Crystal
- Backplane: TFT Glass
- Brightness: 300~400 nits
- PPI: 40~100

**Signage**
- LED Type: RGB LED
- LED Size: 0.8 mm X 0.8 mm
- Pixel Control: LED
- Backplane: PCB
- Brightness: 500~1000 nits
- PPI: 10~20
LED Larger than Pixel-Backlight

55” 4K TV

Pixel Size

LED Size

- 200 μm
- 3,000 μm

- 200 μm
- 3,000 μm

Light

- Plane light source used as backlight
- Optical Design
  - Lens (D)
  - LGP (E)

Pixel Control

- LCD and polarizer realizes pixel gray scale and switch
- Pixel Control
  - Pixel→L/C
  - Sub-Pixel→C/F
Pixel Larger than LED-Micro LED

55” 4K TV

- 200 μm

LED Size

- 50 μm

Pixel Size

- 200 μm

Light

- Using point light sources as the emission layer
- The process is similar to the cell procedure in TFT process.

Pixel Control

- Direct pixel control with μLED, similar to OLED
- Pixel Control
  - Pixel → μLED
  - Sub-Pixel → μLED
Light Source and Pixel is the Core of Display (2/2)

Light

- CRT
  - Electron Gun + Deflection Electrode + Shadow Mask

- PDP
  - Address Electrode

- LCD
  - TFT + Liquid Crystal + Prism

- OLED
  - TFT

- QLED
  - Quantum Dot

- µLED
  - LED Chip (+QD)

Pixelization

- CRT
- PDP
- LCD
- OLED
- QLED
- µLED

Past

- CRT
- FPD

Future

- Self-emissive

CCFL + C/F
LED PKG (Blue Chip + Phosphor/QD) + C/F
Phosphor
LED Chip (+QD)
OLED (+C/F)
Quantum Dot
LEDinside
Combination of High Density Circuit and High Density Light Source

- Increase of viewing angle
- Increase of brightness/contrast

- Increase of color gamut
- Increase of brightness/contrast
- Lower power consumption
- Increase of free backplane space

LED Display

TFT LCD

LCOS

PPI

LOW

5-20

30-300

1K

HIGH

LED

PCB

L/C

TFT

CMOS

μLED Display

TFT/CMOS
Challenges of Micro LED’s Commercialization
Micro LED Requires Highly Supply Chain Integration
Varied Micro LED technology Development

- Micro LED
- Bonding
- BGA
- Nano Tube
- ACF
- Horizontal
- Vertical
- RGB chip
- Nano Phosphor
- Quantum Dot
- Pixelated Film
- Micro Inkjet
- Full-Color Method
- Wafer Bonding
- Thin-film Transfer
- Pick & Place
- Transfer
- Epitaxy
- Horizontal
- Vertical
Multifaceted Technical Barriers for Micro LED to Overcome

**LED Epitaxy**
- Uniformity
- Height
- Substrate Lift-off

**Transfer**
- Accuracy/Precision
- Temporary Substrate/Adhesive
- Mems/Nozzle

**Bonding**
- Bonding Force
- Electric Conductivity
- Heat-resistant

**Others**
- Optic (Crosstalk/Mura)
- Color Conversion
- Circuit/Driver
### Apple and Sony’s Micro LED Commercialization

<table>
<thead>
<tr>
<th>Company</th>
<th>Product</th>
<th>PPI</th>
<th>Sub-Pixel Qty.</th>
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</thead>
<tbody>
<tr>
<td>Sony</td>
<td>Crystal LED Display</td>
<td>40</td>
<td>6,220,800</td>
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<tr>
<td>Sony</td>
<td>CLEDIS™</td>
<td>15</td>
<td>345,600</td>
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<td>Apple</td>
<td>Apple Watch 38mm</td>
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<td>277,440</td>
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<tr>
<td></td>
<td>4K Display (3840 x 2160)</td>
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<td>24,883,200</td>
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</table>

#### Key Points:
- **Small Size**: PPI = 300~600; Pixel Volume = Reduce; Yield Rate = Improvement
- **Big Size**: PPI = 4K (3840 x 2160); Sub-Pixel Qty. = 24,883,200

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Reduce PPI + Reduce Pixel Volume = Yield Rate Improvement
Micro LED’s Potential and Future Market Development
Micro LED Potential Market Opportunity

- **Wearable**
- **HMD**
- **Automotive**
- **Signage**

**Panel Size**
- 2”
- 4”
- 12”
- 55”
- 100”

**Timeframes**
- **Short Term**
- **Mid Term**
- **Long Term**
- **Ultimate Goal**
Micro LED Triggers Supply Chain Reshuffle (1/2)

BL-LED → Chip → PKG → LB → BLU → LCM → Display

LED Maker
Panel Maker
Micro LED → Chip → Micro LED Module → Display
LED Maker
Panel Maker
Panel

Driver IC
Micro LED
Array
T-Con
Integrator
Micro LED Triggers Supply Chain Reshuffle (2/2)

Pro-longed manufacturing process

Smooth manufacturing process

LED Chip

Wire Bond

Die Bond

SMT

BL/LC Assembly

Mass Transfer

Display

OLED Material

Evaporation

Display
Market Value and Output of Display Related Applications

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<td>$4,952</td>
<td>$4,536</td>
<td>$4,357</td>
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<td>Public Display</td>
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<td>Automotive Display</td>
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Micro LED as Replacement in Existing Display Market

### Demand Side

<table>
<thead>
<tr>
<th>Technology Replaced by Micro LED</th>
<th>Total Revenue (M USD/Year)</th>
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<tbody>
<tr>
<td>Consumer Display</td>
<td></td>
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<tr>
<td>Back Light Unit</td>
<td>$30,000</td>
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<tr>
<td>Liquid Crystal</td>
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<td>Polarizer</td>
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<td>Color Filter</td>
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<td>Automotive Display</td>
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<tr>
<td>$5,000</td>
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<tr>
<td>Public Display</td>
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<tr>
<td>PLCC RGB LED</td>
<td>$2,000</td>
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### Supply Side

- Epi Yield%
- Transfer Yield%
- Equip. Depreciation
- Test/Repair

### Cost Barrier

-TFT-LCD
-OLED
-Micro LED
Will It Create Opportunities or Simply Replace Existing Technology?

Opportunity Creation

Replacement

Micro LED

- Super high PPI
- Super Power Saving
- High WCG
- High Brightness
- Long Life Time
- High Contrast Ratio
- Short Response Time

Flexible
Transparent
Multi-function
Micro LED and its Unlimited New Market Potential

- Smart Lighting
- HUD
- Projector
- AR/VR
Micro LED Technology is a Revolution and Paradigm Shift

Van der Waals Forces
Static Electricity

Mass Transfer

Free Space

Micro LED

Backplane

Micro transfer of things!

Micro LED
Touch

Backplane

Sensing
Display
Comm.

Omni-Display panel

Transfer and integration of micro-component

Photo Diode
Driver IC
IR

Celeprint
LuxVue
Thank you!

www.ledinside.com

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Research Director of LEDinside, TrendForce
RogerChu@TrendForce.com
- **Equipment**: Sapphire and Chip Market Report
- **Material**: Chinese LED Chip and Package Industry Report
- **Chip**: Gold / Gold+ Member Report: Backlight Lighting Automotive Display UV Infrared
- **Market**: Equipment Material Chip
- **Global LED Package Industry Data Base**: Niche Market
- **IT Product Backlight And Lighting Market**: UV LED
- **Automotive**: Silver+ Member: TV Mobile, Projector Automotive CID OLED QLED μLED 2018 Outlook
- **Silver Member**: Silver Member
- **Emerging Lighting**: SE Asia
- **Gold / Gold+ Member**: Street Light Panel Light Plant Growth Lighting Stage Light 2018 Outlook
- **Emerging Lighting**: EU / US JP / CN
- **Chinese LED Package Industry**: China LED Chip and Package Industry Report
- **Global LED Package Industry Data Base**: Global LED Package Industry Data Base
- **Niche Market**: UV LED
- **Global Lighting**: Silver+ Member
- **Emerging Lighting**: Silver Member
- **LEDforum 2016**
<table>
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<th>LEDinside</th>
<th>Content</th>
<th>Characteristics</th>
<th>Format</th>
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<td>Silver</td>
<td>Lighting Market Trend</td>
<td>Lighting Market Demand (Street Light / Panel Light / Plant Growth Light / Stage Light / 2018 Outlook), Market Scale, Product Specification and Price, Policy and Standards, Player Strategy</td>
<td>PDF</td>
<td>Quarterly / Annual</td>
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<td>LED Price Survey</td>
<td>2835, 5630, 3030, 7070, 1<del>3W LED, 1</del>5W LED, COB</td>
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<td>40W/60W Equiv. LED Lamp Price</td>
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<td>Demand</td>
<td>2015-2020 market demand in backlight, lighting, automotive, display, UV, infrared, SSL like and son on</td>
<td>1Q/3Q EXCEL</td>
<td>Quarterly Update / Annual Report</td>
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<td>Supply</td>
<td>Chip market revenue (external sales, total sales) WW new MOCVD chamber installation volume / WW accumulated MOCVD chamber installation / WW new and accumulated MOCVD by K465i Epi wafer market demand (total / by size)</td>
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<td>1Q/3Q: Excel 2Q/4Q: PDF</td>
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<td>Chip</td>
<td>Top 10 Chip vendors' MOCVD installation, wafer capacity, and revenue</td>
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<td>LED Industry Quarterly Update</td>
<td>Major Manufacturer's Movement EU / the US / Japan / Korea / Taiwan / China Financial, strategies, product technology and trend</td>
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Contact

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<thead>
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