Unlocking the Transparent OLED Display Market with Novel Cathode Materials
Company Overview

OTI Lumionics

- Founded in 2011
- 35+ employees
- Headquarters in Toronto, Canada + Offices in Asia
- Backed by VC, Strategic Partners + Government

Technology

- Advanced materials and process that solve large scale industrial problems
- Enabled by a proprietary materials discovery platform based on computational design
- Commercial materials in qualification with leading OEMs, display makers and tool builders

Materials

- High conductivity cathode materials
- High performance cathode materials
- Fine-tuned electro-optical properties
New Market Opportunities for Transparent OLEDs
Enabling new product categories and applications for OLED displays

1. Large area transparent panel for advertising
2. Medium area transparent panel for AR + Auto
3. Mobile transparent panel for under display sensor
Market Demand for Transparent OLEDs
Major OEMs looking for solution with high transparency

Augmented Reality
Automotive
Smart Home
Smart Speaker

Leading consumer electronic brands seeking very high transparency OLED displays
Mobile Transparent Panel for Under Display Sensor

Enable IR, camera and other sensors behind active area of display panel

Under display sensor requires high transparency (including in the NIR) to function
Both architectures require a highly transparent + conductive cathode solution

Transparent Pixel

Transparent Window

Open Window

Open Window
Cathode Transparency is a Significant Barrier
Worse for NIR to do strong absorption in metal thin films

![Diagram of OLED structure]

<table>
<thead>
<tr>
<th>Optical Layers</th>
<th>Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>~90%</td>
</tr>
<tr>
<td>OCA</td>
<td>~100%</td>
</tr>
<tr>
<td>Organic</td>
<td>~100%</td>
</tr>
<tr>
<td>Cathode</td>
<td>20 – 80%</td>
</tr>
<tr>
<td>TFE</td>
<td>95-100%</td>
</tr>
</tbody>
</table>

Transmission = Window Size × Window Transmission

Cathode layer transmittance is limiting factor for transparent OLED
Cathode Conductivity is a Significant Barrier

Worse for transparent display due to transparency trade-off

Cathode layer sheet resistance is limiting factor for transparent OLED
ConducTorr™ Electrode Technology
Micron-size patterning of top electrode

Self assembly yields low resistance electrode with micron resolution
ConducTorr™ Patterning Process

Multiple MP compatible process methods

Shadow Mask Deposition

Light Exposure with Photomask

Direct Laser Writing (DLW)

Open-frame CEM Deposition

(Patterning Material)

Electrode Material)
ConducTorr™ Enables Fine Features
Multiple MP compatible process methods

High Resolution patterning demonstrated down to 6.5 µm features
ConducTorr™ Demonstrated in 5.2” Mobile AMOLED

5.2” AMOLED display fabricated using ConducTorr™ Electrode

- 5.2” diagonal AMOLED panel
- Vacuum process using existing AMOLED tools and mask set
- No ConducTorr™ related defects
- 120 ppi (37” @ 4K equivalent)
- 10 µm auxiliary electrode width
- 1 Ω/□ cathode sheet resistance

- 15 nm cathode + 600 nm ConducTorr™ Electrode
ConducTorr™ Demonstrated in 5.2” Mobile AMOLED

5.2” AMOLED display fabricated using ConducTorr™ Electrode

- 15 nm cathode + 600 nm ConducTorr™ Electrode

No negative impact on panel reflectivity with ConducTorr™ Electrode
ConducTorr™ Electrode for Transparent OLEDs

Transparent pixel vs transparent window

ConducTorr™ solution can be applied to both transparent OLED architectures
ConducTorr™ Demonstrated in 17” Transparent AMOLED

17” Transparent AMOLED display fabricated using ConducTorr™ Electrode
Improved See-through Image Quality with ConducTorr™
Eliminates image blurring of see-through image for transparent AMOLED

Without ConducTorr™

With ConducTorr™
Improved See-through Image Quality with ConducTorr™
Eliminates image blurring of see-through image for transparent AMOLED

Without ConducTorr™

With ConducTorr™

Transmitted Background
Internal TFT Reflection
Transmitted Background
CEM
TFT
Transmissive window
Observer
Transparent display
Scene behind panel

Image Blur
ConducTorr™ Demonstrated in 17” Transparent AMOLED
17” Transparent OLED display fabricated using ConducTorr™ Electrode

- > 65% Transparency at Panel Level
- < 1 Ω/□ Sheet Resistance (15% fill factor)
- Eliminates see-through image blue

Live demo of 17” panel at SID 2019:
60.5 17-inch Transparent AMOLED Display
With Self-Assembled Auxiliary Electrode
Email to schedule private demo at SID 2019
ConducTorr™ CEM as Cathode in Transparent OLED

Fabrication process using ConducTorr™ to pattern transparent window

OLED organic stack

ConducTorr™ CPM on the Open Window

ConducTorr™ CEM with open mask
ConducTorr™ CEM as Cathode in Transparent OLED

OLED device performance using ConducTorr™ CEM as cathode

Comparable voltage, efficiency, CIE and lifetime for ConducTorr™ CEM vs MgAg (1:9) cathode
ConducTorr™ CEM as Cathode in Transparent OLED

Transparent OLED panels fabricated using ConducTorr™ CEM as cathode
Benefits of ConducTorr™ for Transparent OLEDs

Mass production ready solution to enable transparent OLED displays

- High Aperture Transparency of 99% (including NIR)
- High Electrode Transparency of > 85% (15% fill factor)
- High Panel Transparency of > 65% demonstrated
- High Conductivity of $R_s < 1 \, \Omega/\square$ (15% fill factor)
- Eliminates See-Through Image Blur from TFT
- Materials Ready for Mass Production in 2019
Thank you