Michael G. Helander, PhD
President & CEO

+1 (647) 479-4074 x103
michael.helander@otilumionics.com
www.otilumionics.com

Material Advances for Transparent OLEDs

OTI Lumionics

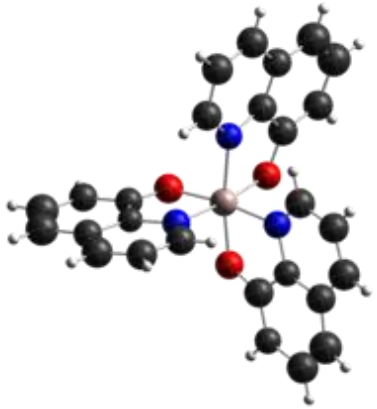
What we do

Advanced Materials by Design

Developing New Materials is Really Hard

One set of properties can map to many different potential structures

Structure



Materials Science
(well understood with theory)

Materials Discovery
(hard to predict; one-to-many)

Property

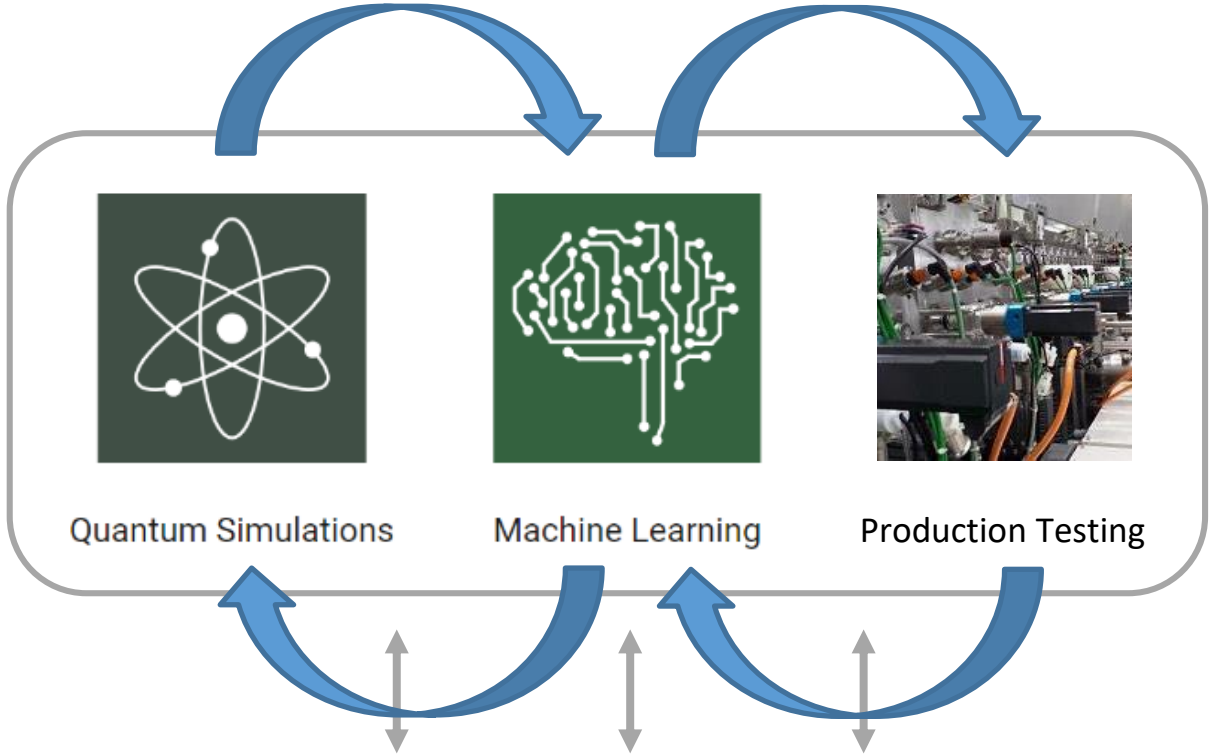
- Melting Point
- Light Absorption
- Crystal Structure
- Etc.

Integrated Materials Discovery Platform

Quantum simulation + AI/ML + production validation

Properties

- Vapor pressure
- Optical constants
- Electronic structure
- Film forming
- Crystallinity
- Etc.



Structure

CPU GPU QPU (Quantum Computer)

Production Testing of Candidate Materials

Real World testing closes the loop on software platform

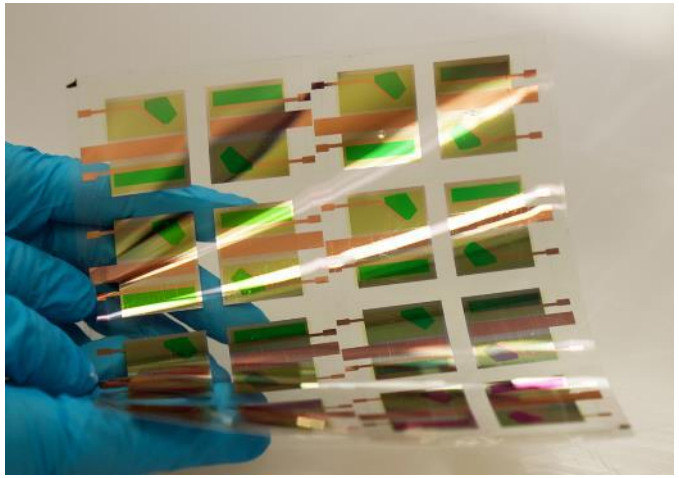
- 6,000 sqft facility in Toronto, Canada

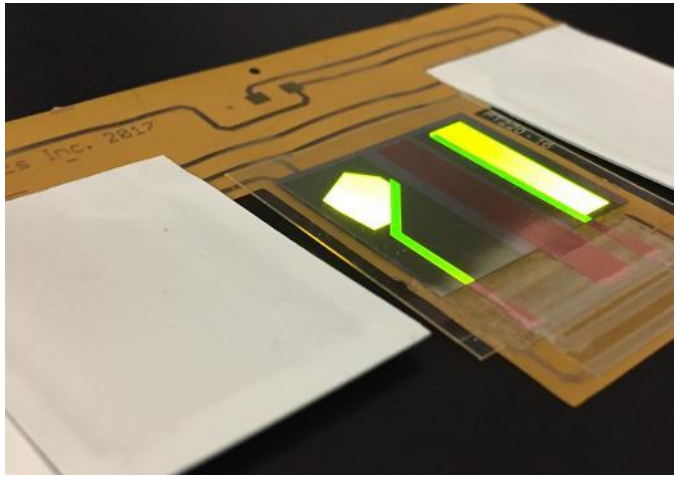
Facility supported by:

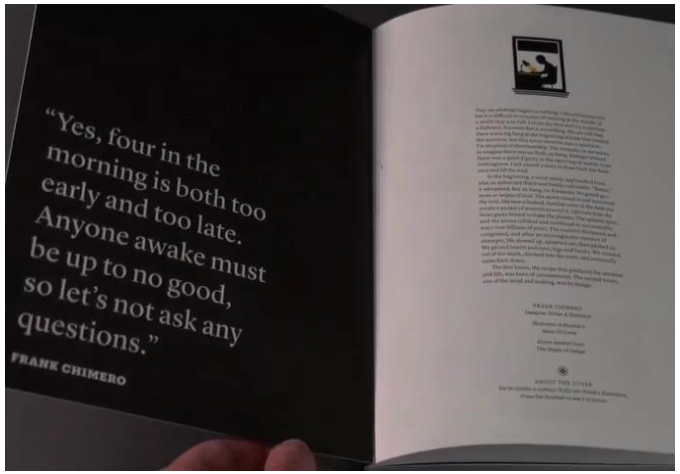
SUSTAINABLE DEVELOPMENT TECHNOLOGY CANADA

Example: Aerelight for Print™

Flexible OLED module for print + packaging







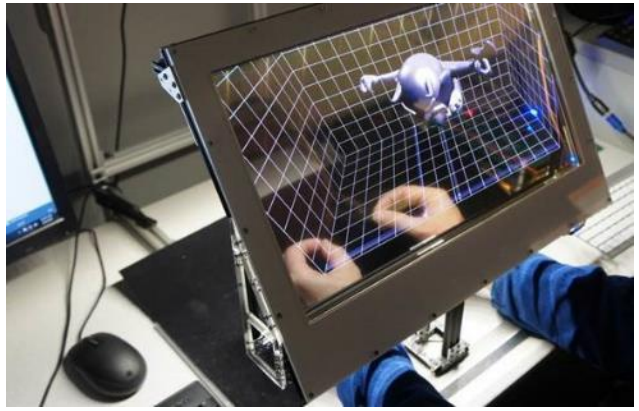
New Market Opportunities for Transparent OLEDs

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

Microsoft Google amazon HUAWEI

Leading consumer electronic brands seeking very high transparency OLED displays

Large Area Transparent Panel for Advertising

Transparent signage and windows display for retail

Global Transparent Digital Signage Market

Source: Technavio

Transparent OLED Signage production in 2019, but transparency is still poor (~45%)

Medium Area Transparent Panel for AR + Auto

Augmented reality display for automotive and knowledge worker

40+ nameplates adding HUD for the first time in history! (past 18 mo.)

1. 2019 Acura RDX (W-HUD)
2. 2018 Audi Q2 (W-HUD)
3. 2018 BMW X2 (W-HUD)
4. 2017 BMW X3 (W-HUD)
5. 2019 BMW Z4 (W-HUD)
6. 2018 Buick Regal GS (W-HUD)
7. 2019 Chevrolet Silverado (W-HUD)
8. 2019 Citroen Berlingo (C-HUD)
9. 2019 Ford Focus (C-HUD)
10. 2019 Ford Escape (C-HUD)
11. 2018 Genesis G70 (W-HUD)
12. 2019 GMC Sierra (W-HUD)
13. 2018 Honda Accord (W-HUD)
14. 2018 Honda CR-V (C-HUD)
15. 2018 Hyundai Kona (C-HUD)
16. 2019 Hyundai Veloster (C-HUD)
17. 2018 Hyundai Santa Fe (W-HUD)
18. 2018 Hyundai Grandeur (W-HUD)
19. 2018 Infiniti QX50 (W-HUD)
20. 2018 Jaguar E-Pace (W-HUD)
21. 2019 Jaguar I-Pace (W-HUD)
22. 2018 Kia Stinger (W-HUD)
23. 2017 Land Rover Discovery (W-HUD)
24. 2018 Mercedes A-Class (W-HUD)
25. 2018 Mercedes CLS-Class (W-HUD)
26. 2017 Mini Countryman (C-HUD)
27. 2018 Mitsubishi Eclipse Cross (C-HUD)
28. 2018 Range Rover Velar (W-HUD)
29. 2018 Singulato IS6 (W-HUD)
30. 2018 Subaru WRX (CWO HUD)
31. 2018 Subaru Levorg (CWO HUD)
32. 2018 Subaru Ascent (CWO HUD)
33. 2018 Toyota Camry (W-HUD)
34. 2018 Toyota Avalon (W-HUD)
35. 2020 Toyota Supra (W-HUD)
36. 2018 Volkswagen Arteon (C-HUD)
37. 2018 Volkswagen Tiguan (C-HUD)
38. 2018 Volkswagen Touareg (W-HUD)
39. 2018 Volvo XC40 (W-HUD)
40. 2019 Volvo V60 (W-HUD)
41. And likely others!

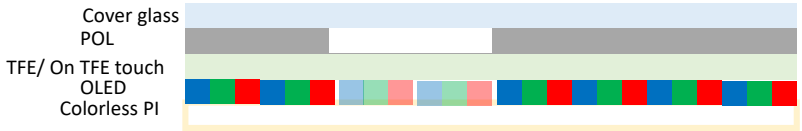
Source: IHS

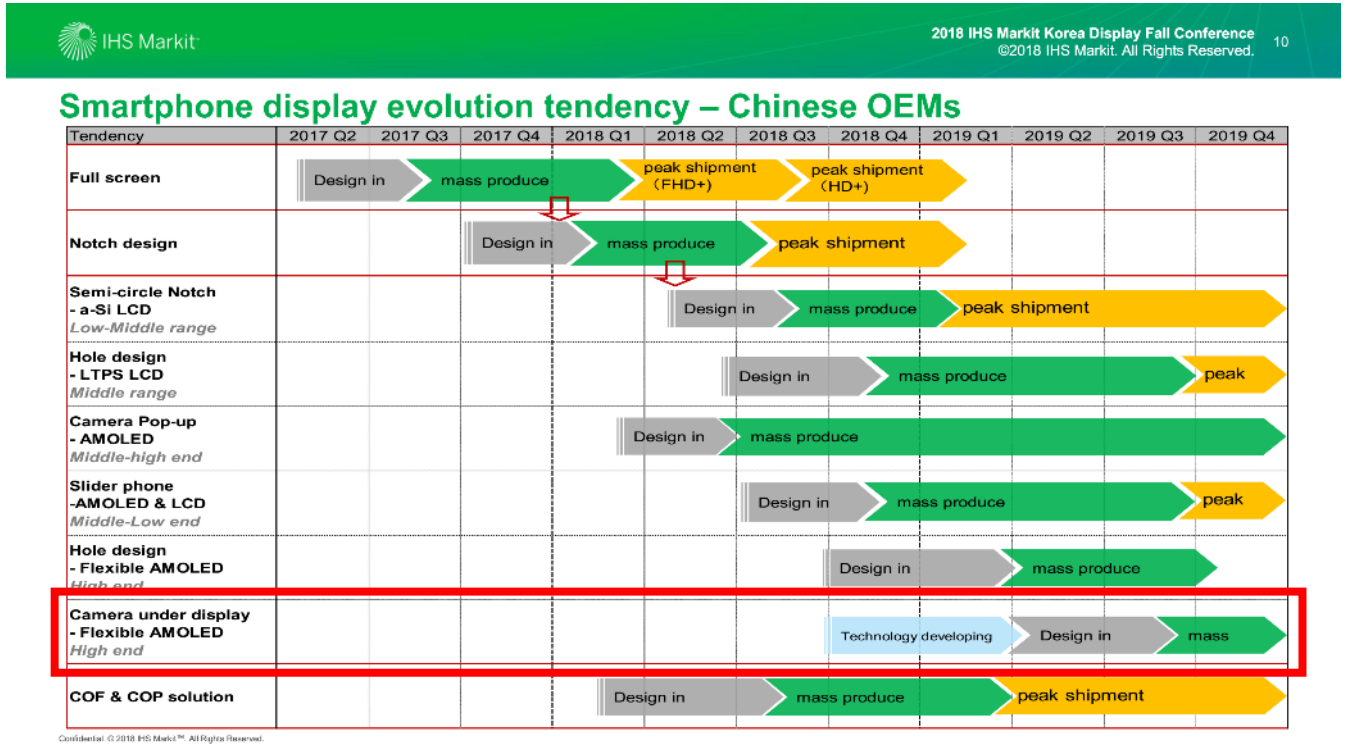
Automotive brands want transparent OLEDs for HUD, but transparency is too low (~45%)

Mobile Transparent Panel for Under Display Sensor

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

Transparent OLED +
Under Display Sensor



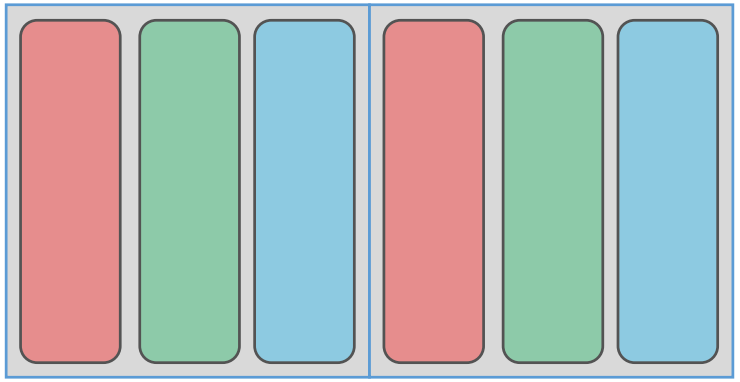


Under display sensor requires high transparency (including in the NIR) to function

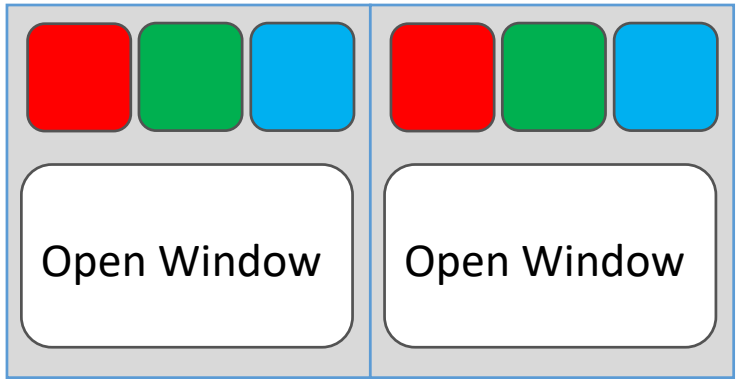
Transparent OLED Architectures

Transparent pixel vs transparent window

Transparent Pixel



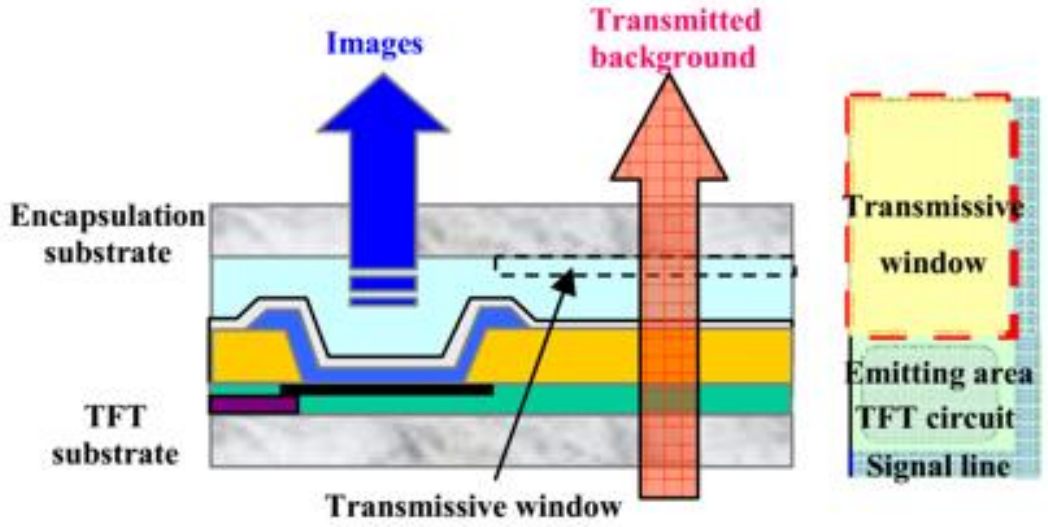
Transparent Window



Both architectures require a highly transparent + conductive cathode solution

Cathode Transparency is a Significant Barrier

Worse for NIR to do strong absorption in metal thin films



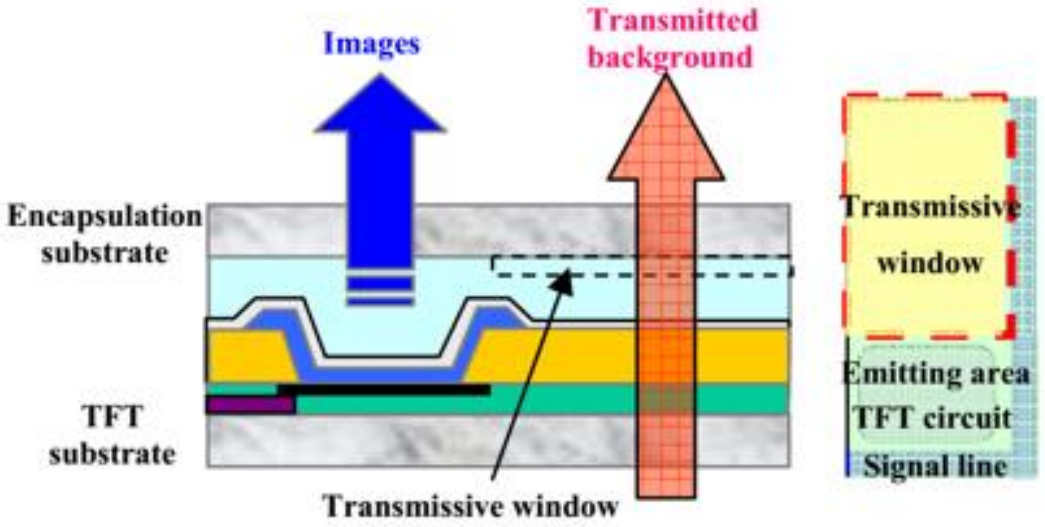
Optical Layers	Transmission
Glass	~90%
OCA	~100%
Organic	~100%
Cathode	20 – 80%
TFE	95-100%

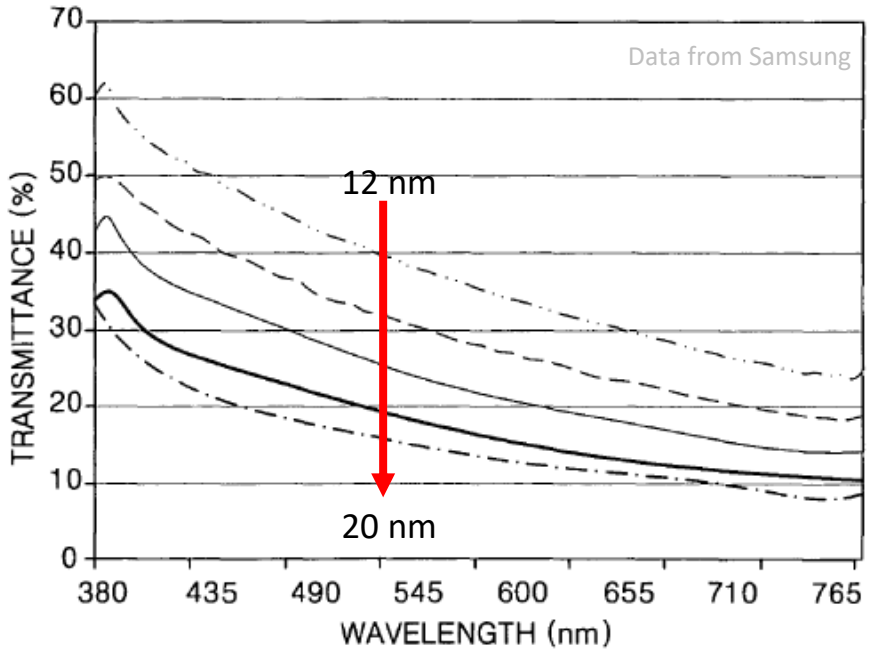
Transmission = Window Size × Window Transmission

Cathode layer transmittance is limiting factor for transparent OLED

Cathode Transparency is a Significant Barrier

Worse for NIR to do strong absorption in metal thin films



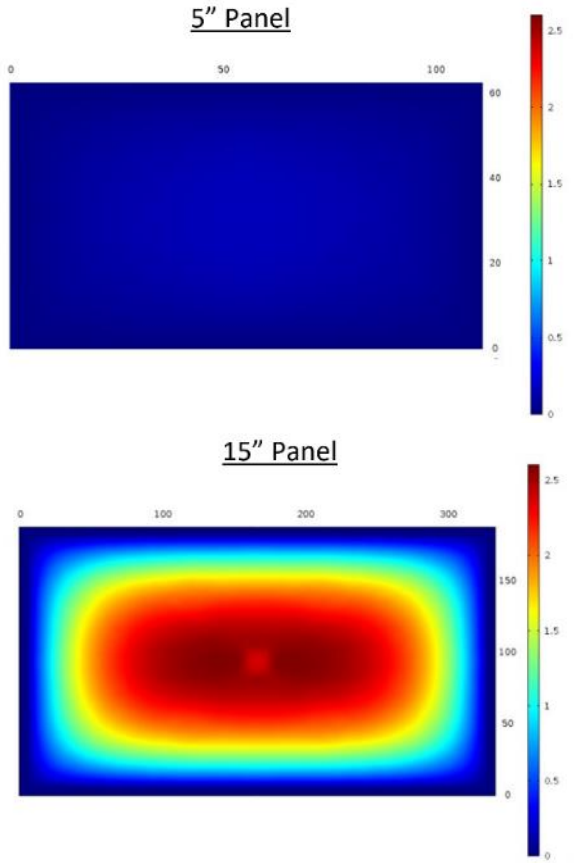


Transmission = Window Size × Window Transmission

Cathode layer transmittance is limiting factor for transparent OLED

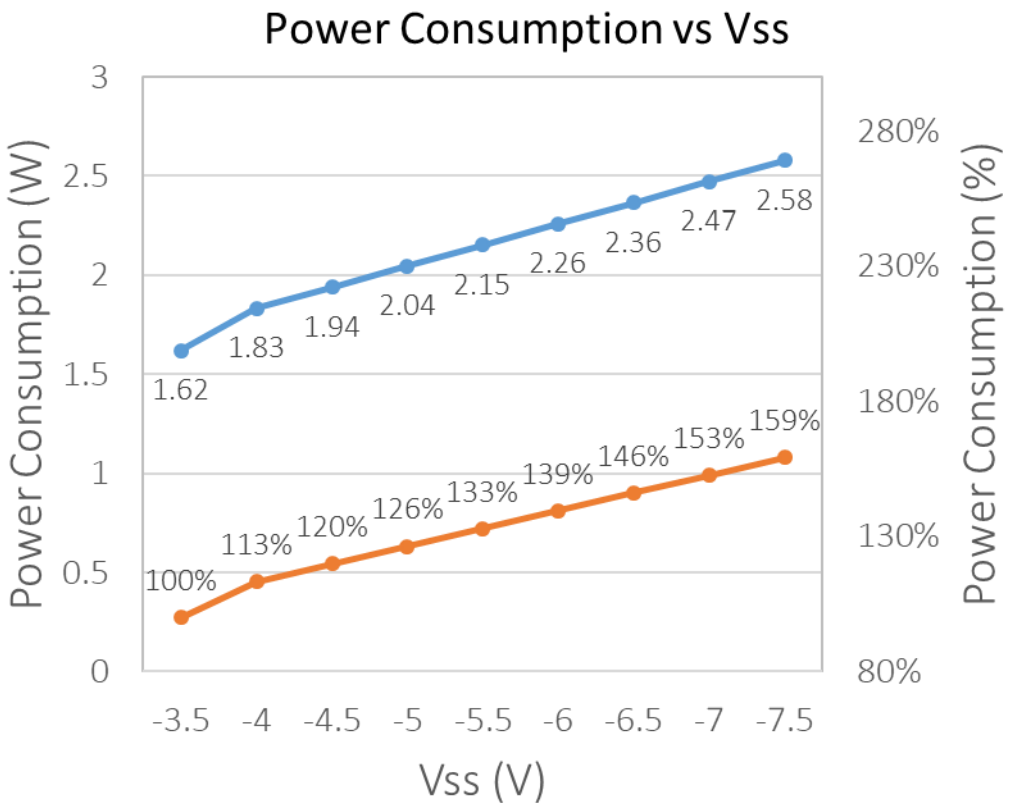
Cathode Conductivity is a Significant Barrier

Worse for transparent display due to transparency trade-off



0.5V

2.6V



Cathode layer sheet resistance is limiting factor for transparent OLED

ConducTorr™ Electrode Technology

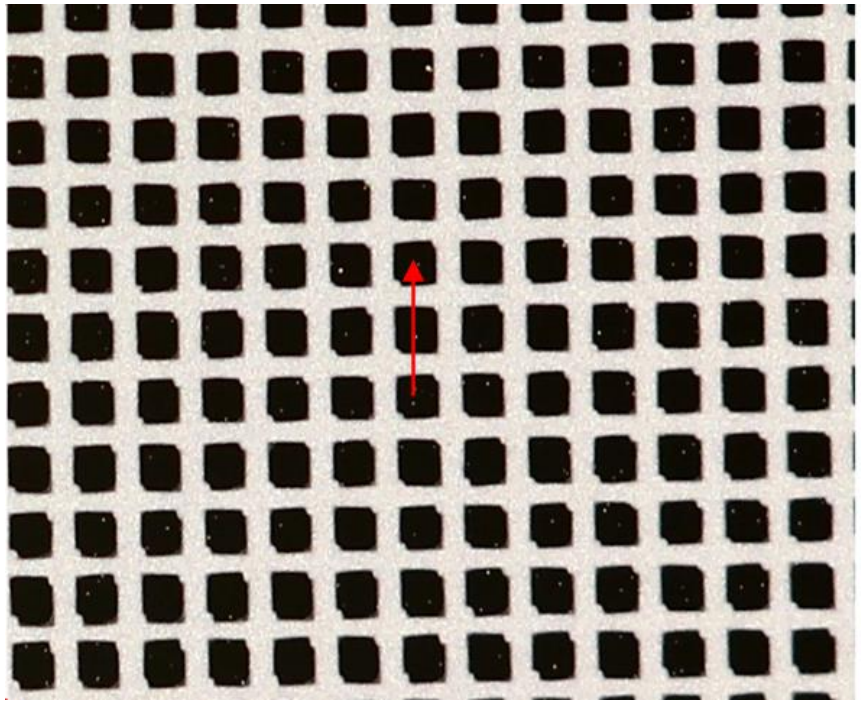
Micron-size patterning of top electrode

ConducTorr™ Patterning Material (CPM)

+

ConducTorr™ Electrode Material (CEM)

Patterning Process

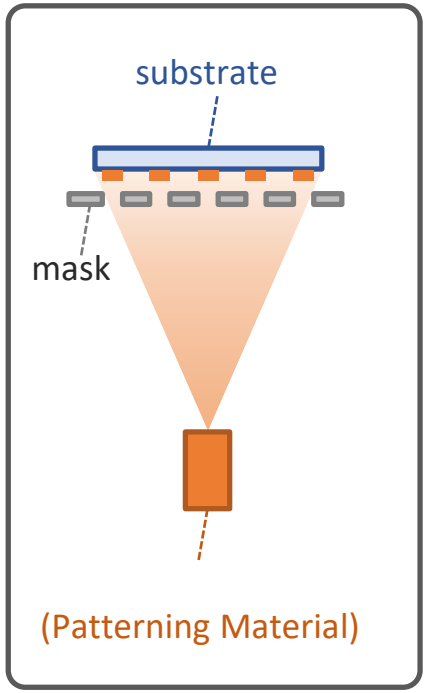


Self assembly yields low resistance electrode with micron resolution

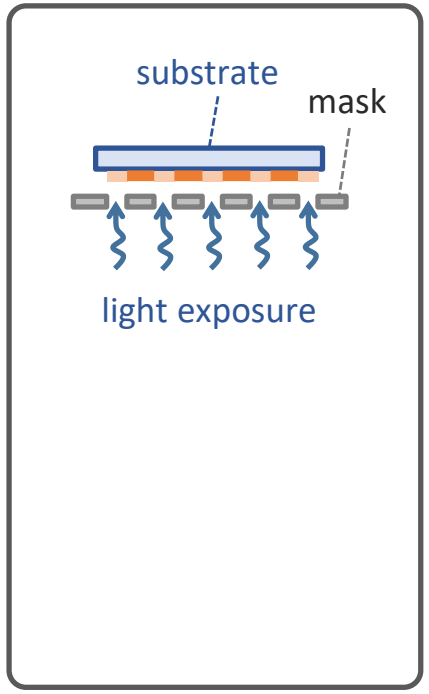
ConducTorr™ Patterning Process

Multiple MP compatible process methods

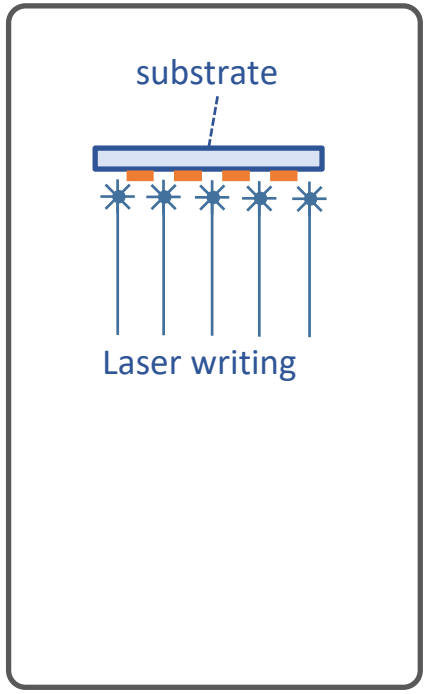
Shadow Mask Deposition



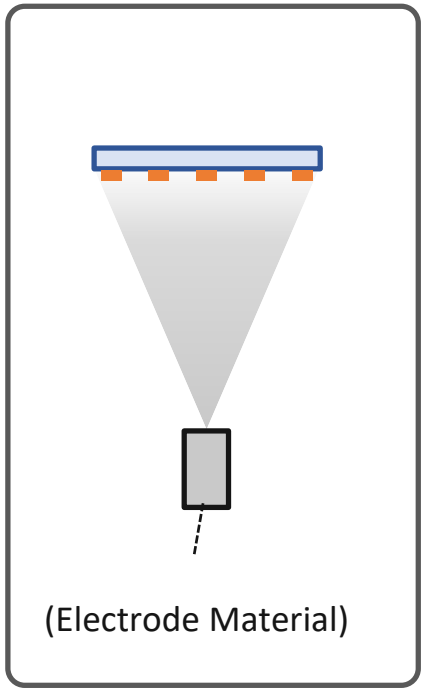
Light Exposure with Photomask



Direct Laser Writing (DLW)

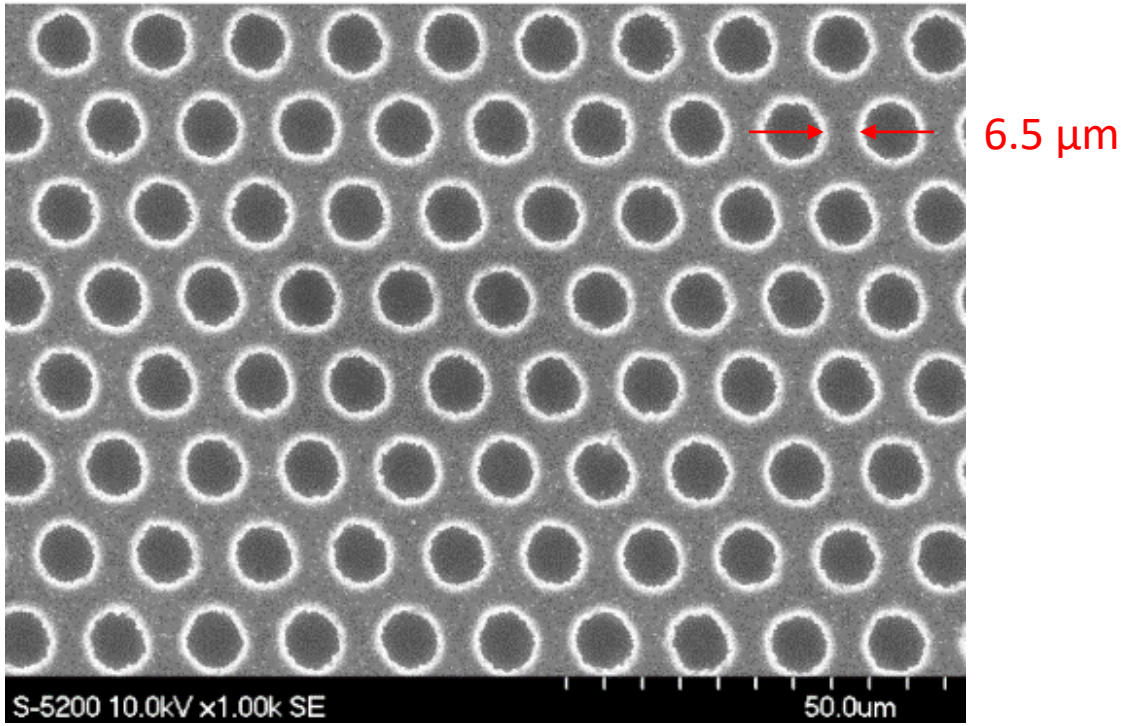


Open-frame CEM Deposition

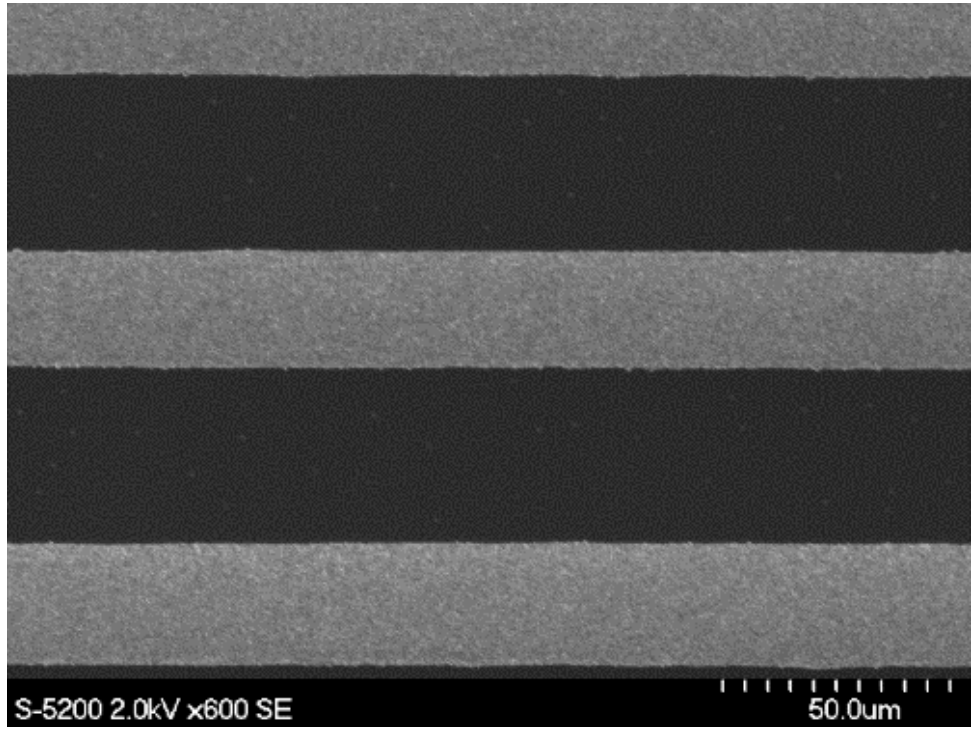


ConducTorr™ Enables Fine Features

Multiple MP compatible process methods



ConducTorr™ film with 6.5 µm circular mesh (mask patterning)

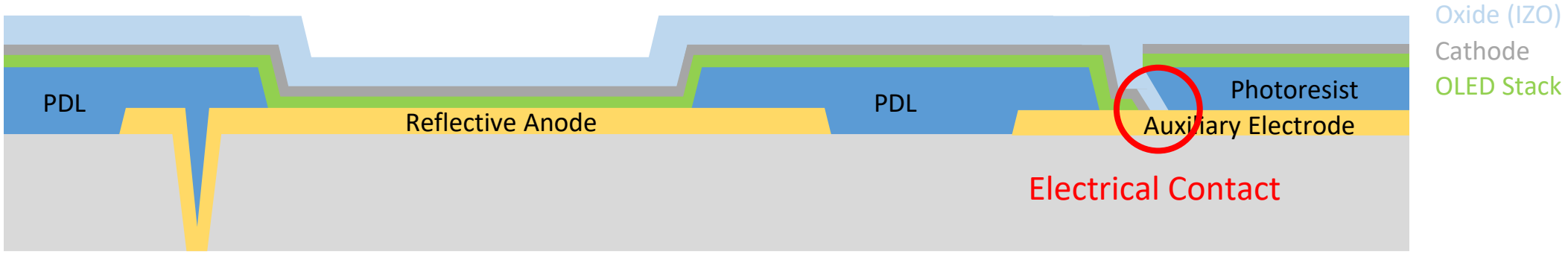


ConducTorr™ film with 25 µm lines (UV patterning)

High Resolution patterning demonstrated down to 6.5 µm features

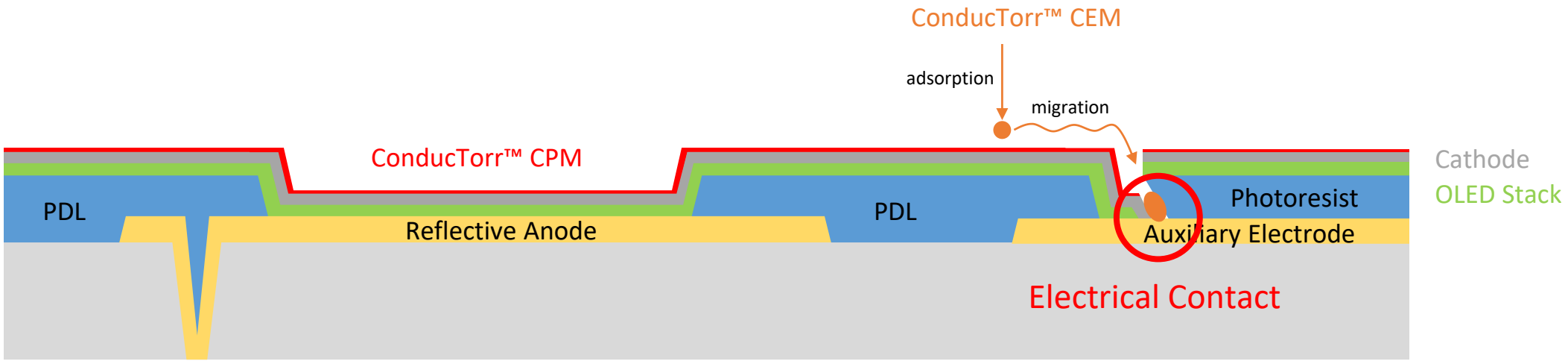
ConducTorr™ Mask-free Patterning

Connection to auxiliary electrode in backplane

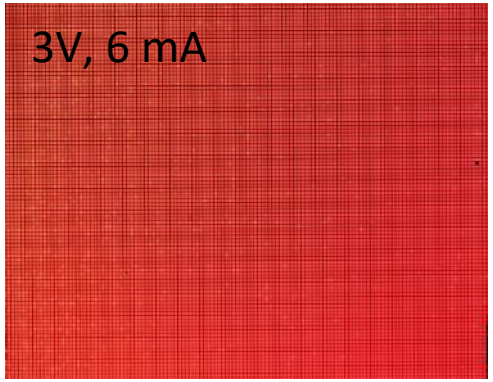


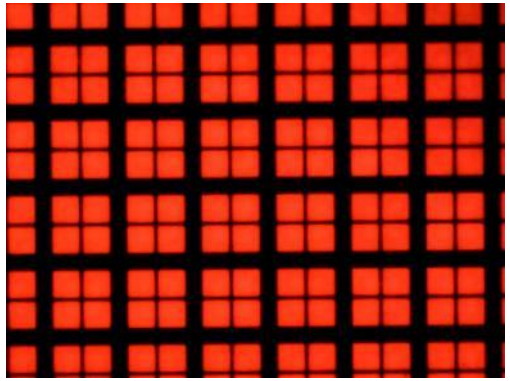
ConducTorr™ Mask-free Patterning

Connection to auxiliary electrode in backplane



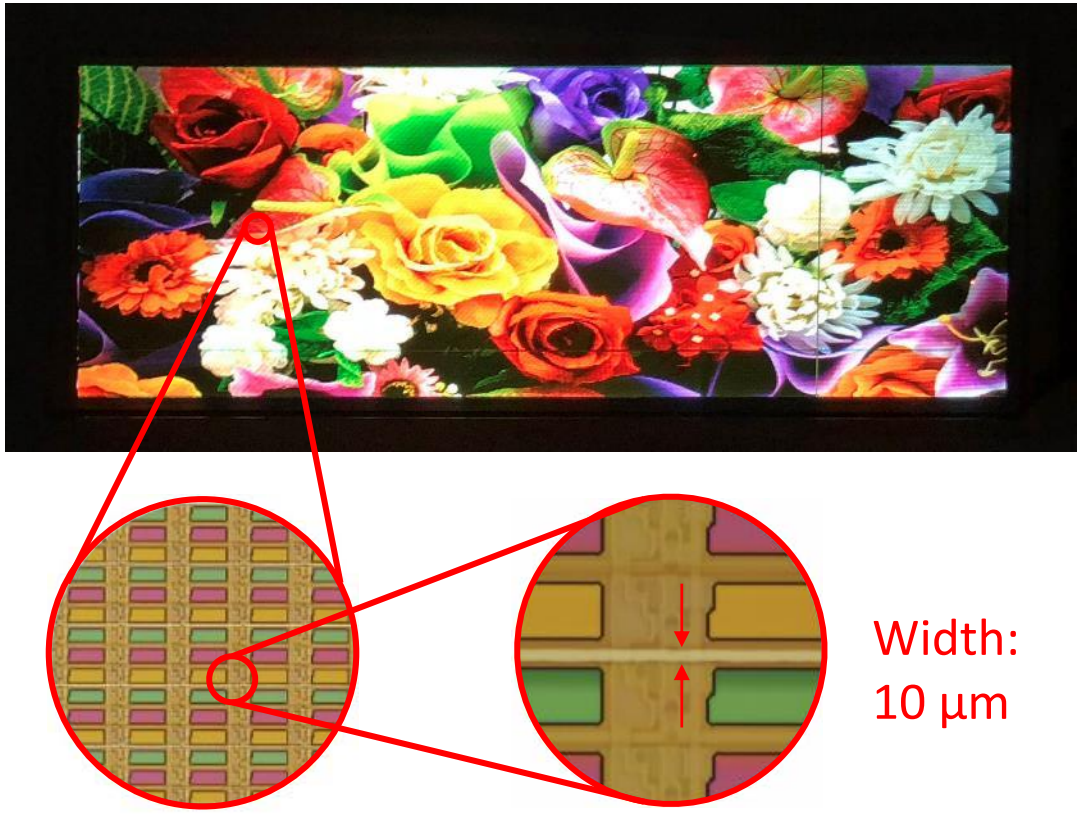
Top-emission PMOLED sample with ConducTorr™ Mask-free Patterning





ConducTorr™ Demonstrated in 5.2” Mobile AMOLED

5.2” AMOLED display fabricated using ConducTorr™ Electrode



- 15 nm cathode + 600 nm ConducTorr™ Electrode

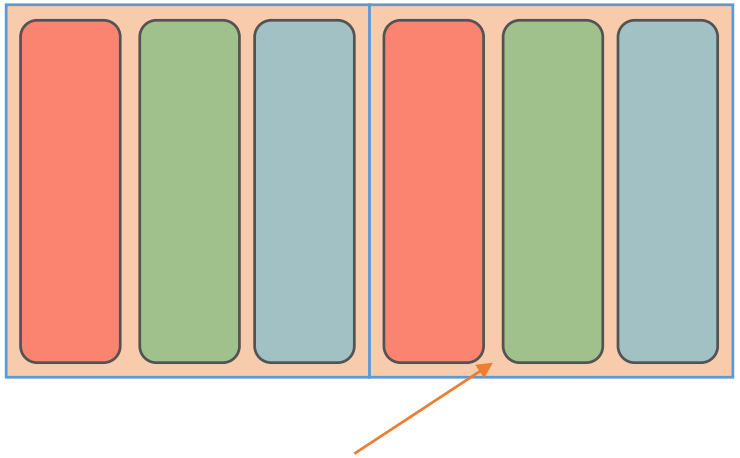
- 5.2” diagonal AMOLED panel
- Vacuum process using existing AMOLED tools and mask set
- No ConducTorr™ related defects
- 120 ppi (37” @ 4K equivalent)
- 10 µm auxiliary electrode width

Mass production ready ConducTorr™ materials now available in kg scale

ConducTorr™ Electrode for Transparent OLEDs

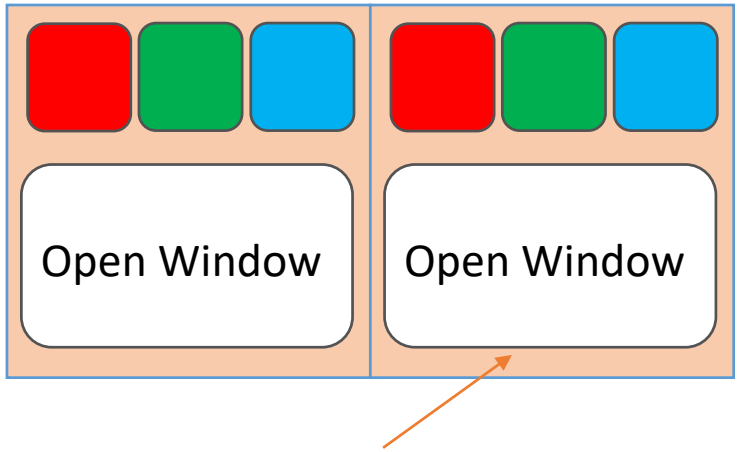
Transparent pixel vs transparent window

Transparent Pixel



CEM as Auxiliary Electrode

Transparent Window

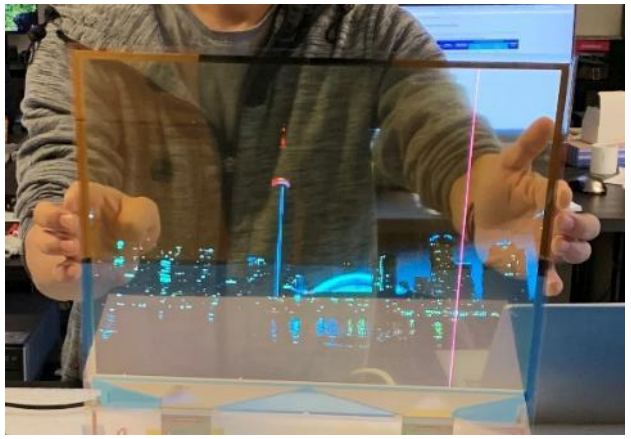


CEM as Patterned Cathode

ConducTorr™ solution can be applied to both transparent OLED architectures

ConducTorr™ Demonstrated in 17” Transparent AMOLED

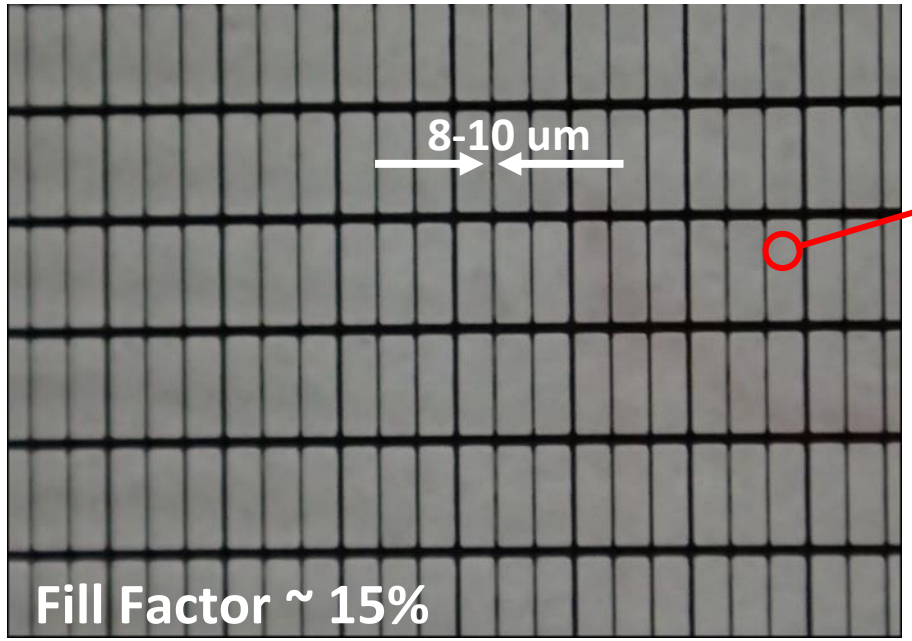
17” Transparent AMOLED display fabricated using ConducTorr™ Electrode

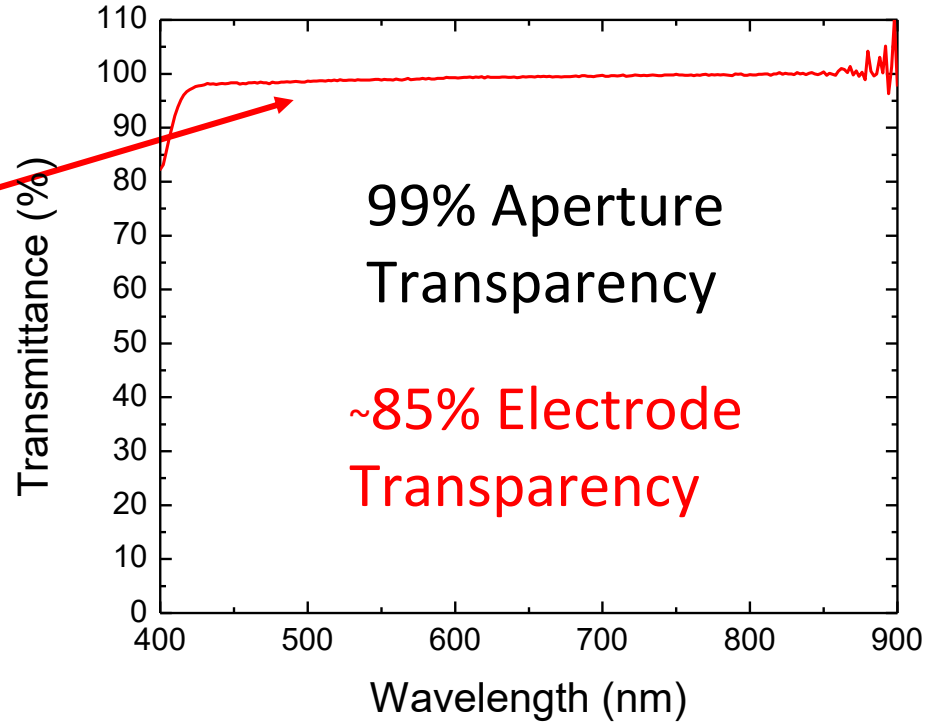


ConducTorr™ Demonstrated in 17” Transparent AMOLED

17” Transparent AMOLED display fabricated using ConducTorr™ Electrode

< 1 Ω/□ Sheet Resistance





ConducTorr™ solution enables lowest resistance and highest transparency

Improved See-through Image Quality with ConducTorr™

Eliminates image blurring of see-through image for transparent AMOLED

Without ConducTorr™

Image viewed through transparent panel

With ConducTorr™

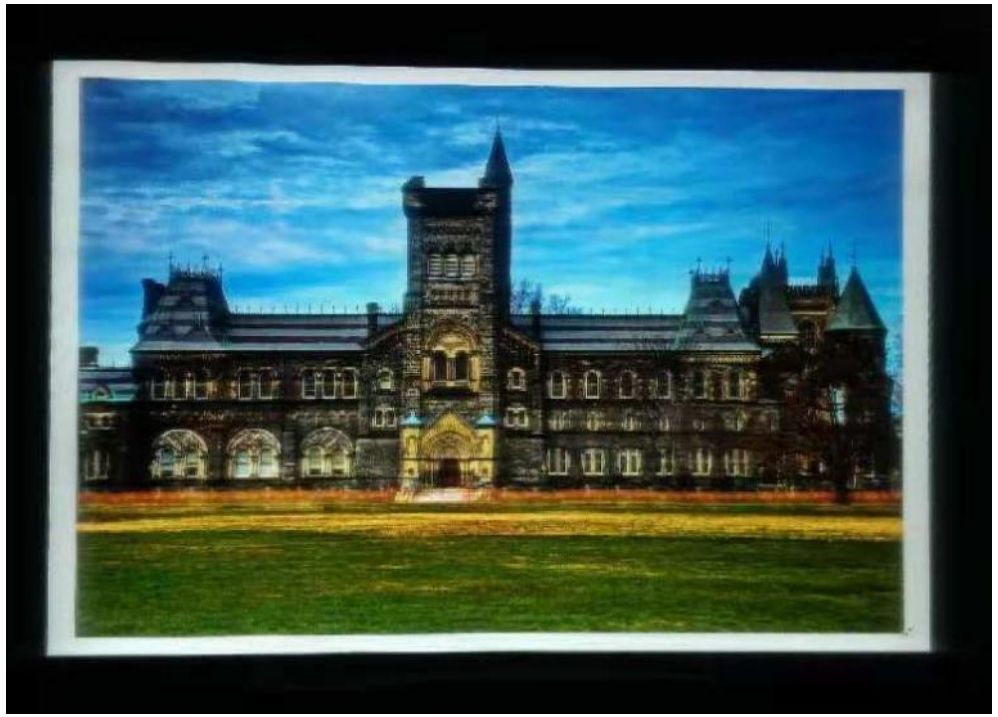
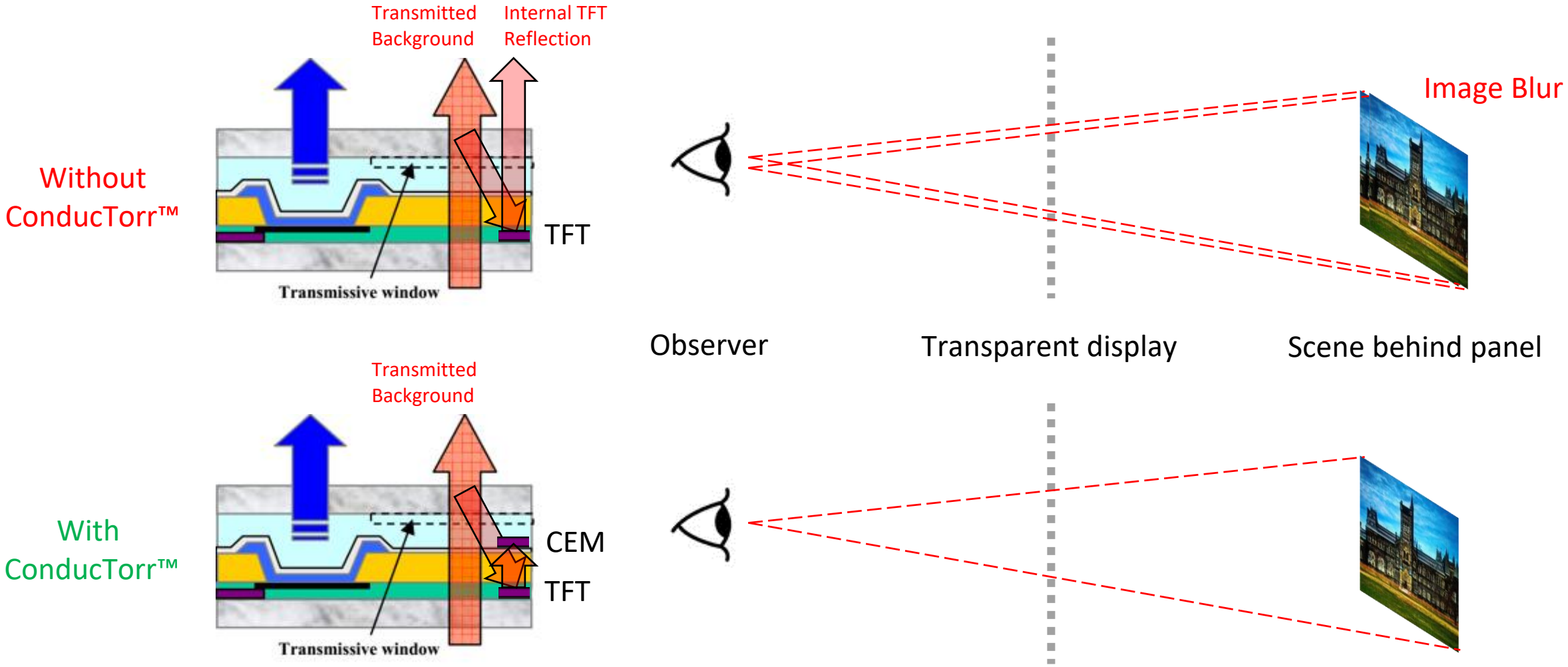


Image viewed through transparent panel

Improved See-through Image Quality with ConducTorr™

Eliminates image blurring of see-through image for transparent AMOLED



ConducTorr™ Demonstrated in 17” Transparent AMOLED

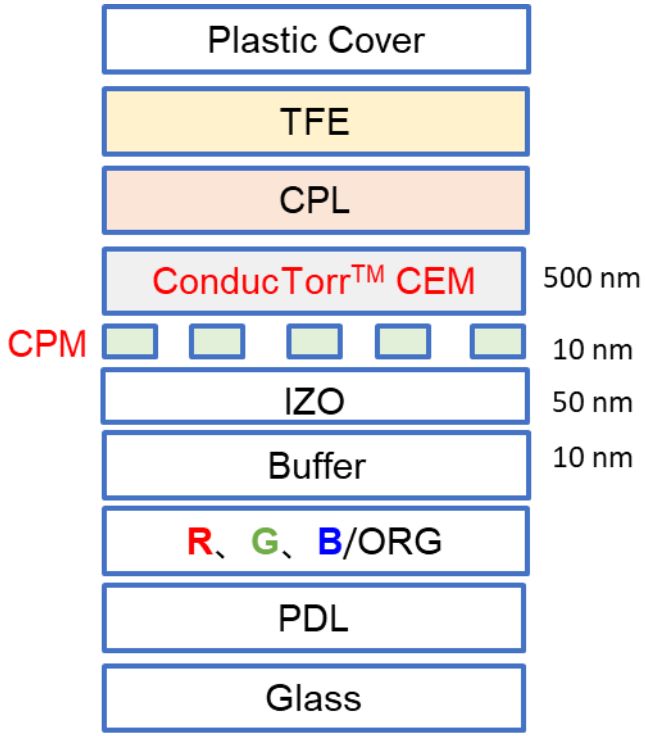
17” Transparent OLED display fabricated using ConducTorr™ Electrode

- > 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:

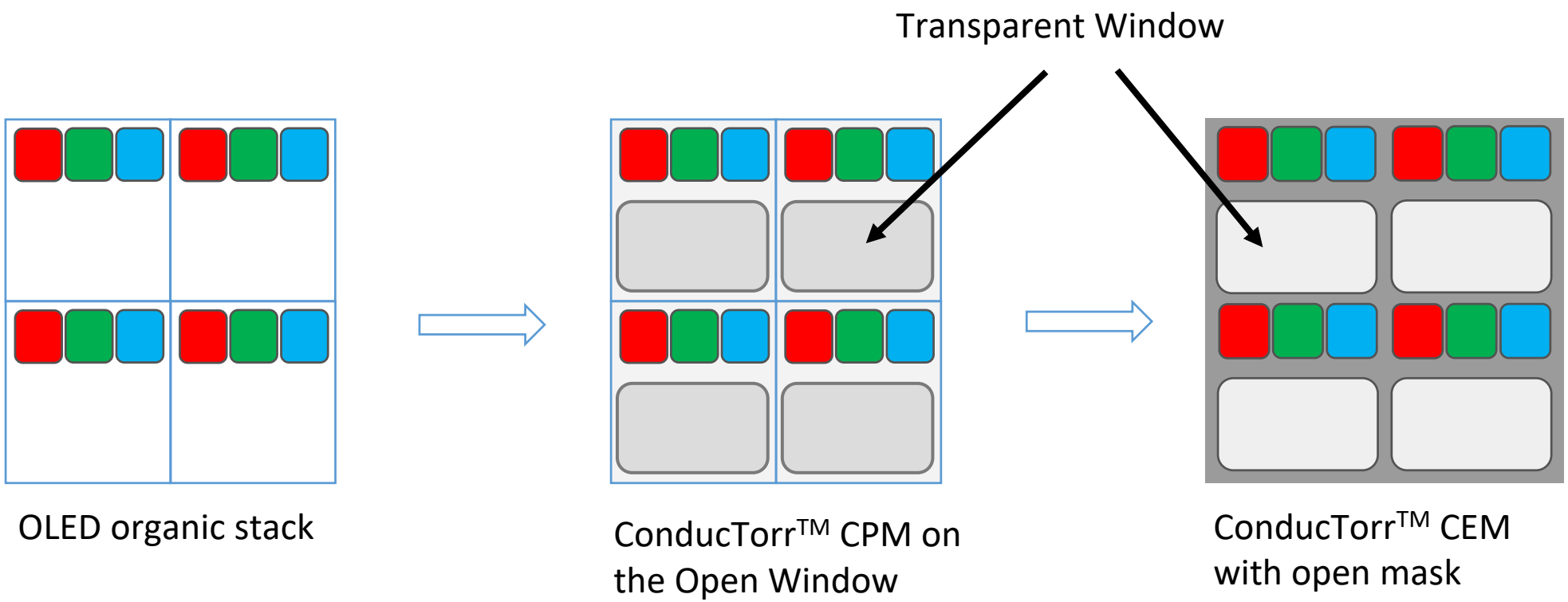
60.5 17-inch Transparent AMOLED Display
With Self-Assembled Auxiliary Electrode

Email to schedule private demo at SID 2019



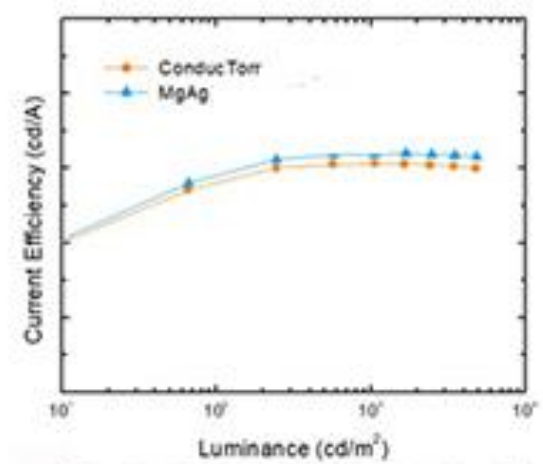
ConducTorr™ CEM as Cathode in Transparent OLED

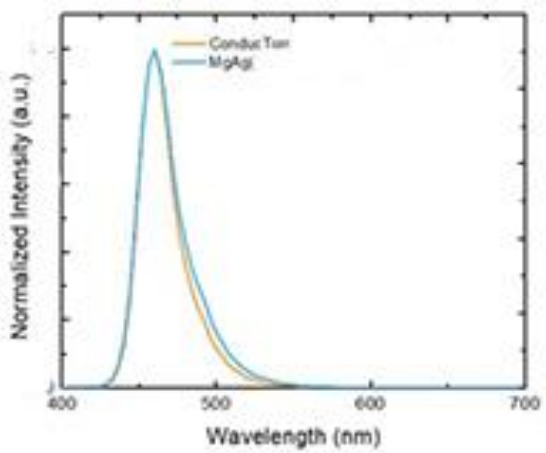
Fabrication process using ConducTorr™ to pattern transparent window

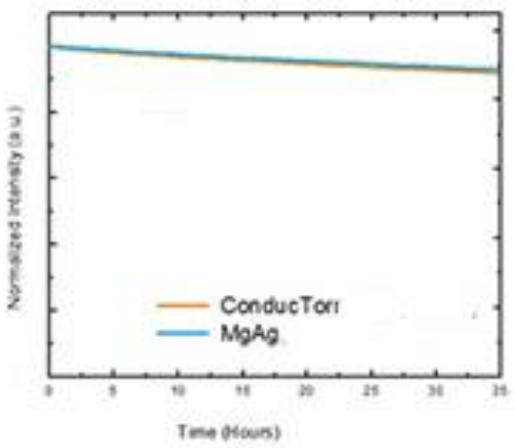


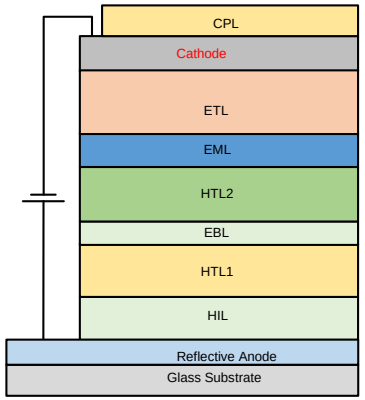
ConducTorr™ CEM as Cathode in Transparent OLED

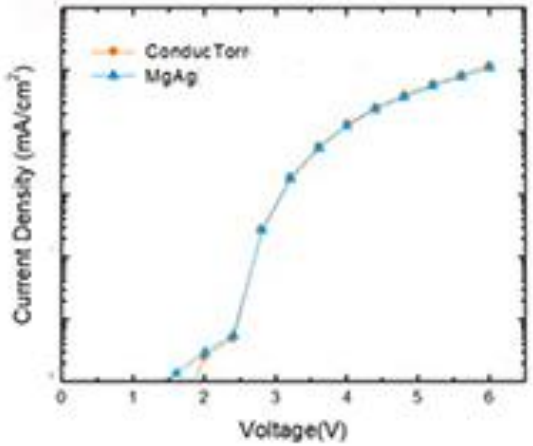
OLED device performance using ConducTorr™ CEM as cathode

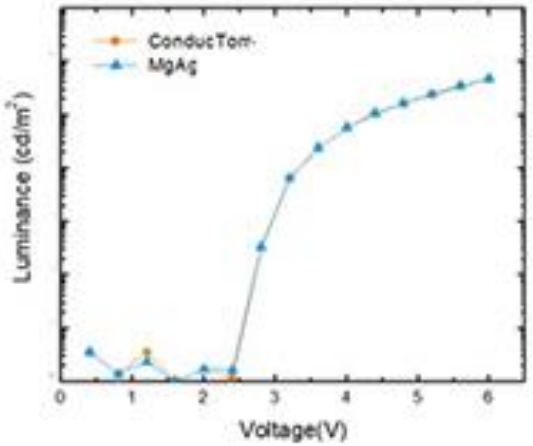












Comparable voltage, efficiency, CIE and lifetime for ConducTorr™ CEM vs MgAg cathode

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 Rs < 1 Ω/□ (15% fill factor)
- Eliminates See-Through Image Blur from TFT
- Materials Ready for Mass Production in 2019

Michael G. Helander, PhD
President & CEO

+1 (647) 704-5816
michael.helander@otilumionics.com
www.otilumionics.com

Thank you

OTI Lumionics