# ΙΤΟ

# Challenges and Opportunities for Under Display Camera and NIR Sensors in Mobile Devices

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## **OTI** Develops Advanced Materials for the Electronics **Industry and is Backed by Leading Display Companies**

## **OTI Lumionics**

- UNIVERSITY OF TORONTO
- Founded in 2011 •
- HQ in Mississauga, Canada (Toronto) ٠
- 50+ FTEs (majority with PhD/MASc) ٠
- 25,000 sqft R&D facility and HQ ٠





# OTI

#### **OTI** Develops Advanced Materials



## **OTI** Has 25,000 Sq. Ft. Testing & Application Engineering Facility For Rapid Development of Complete Solutions





**Computational Design** 



**Synthesis** 



**Pilot Testing** 

### **Application Engineering**



## **OTI** Replaces Expensive Equipment and Toxic Chemicals for Patterning Thin Films with Nanoscale Driven Self-Assembly





### See our prior SID papers for different applications of CPM<sup>™</sup> in display production:

[1] Wang et al, SID 2019, p.853-856, [2] Wang et al, SID 2020, p.811-814, [3] Wang et al, SID 2021, p 285-288

1. Cathode Patterning Material (CPM™)

# **OTI** Has Developed Optimized Panel Designs Using CPM<sup>™</sup> Patterning To Enable Under Display Camera + NIR Sensors



	Cathode blocks the NIR signal			
_	Layer of Display	Effective NIR Transmission		
	Polarizer	~90%		
	Encapsulation	~90%		
	Cathode	~10%		
	Pixels	~90%		
	Backplane	~90%		
	Substrate	~90%		



### Application Protected by 150 Patents Granted and Pending

S	Product Design
ropertie	Device Structure
<b>Aaterial F</b>	Manufacturing Process
<	Composition of Matter

Mass Production Qualified

2023-05-24

OTI

## **OTI** Technology is Mass Production Qualified for Mobile Display Manufacturing by Multiple Leading Panel Makers





	2020 H1	2020 H2	2021	2022
Qualification Stage	Concept	R&D	Pilot	Mass Production
Equipment Size	-	Gen 1	Gen 4.5/H	Gen 6/H
Substrate Size	25 x 25 mm	200 x 200 mm	730 x 460 mm	1,500 x 925 mm
Substrate	Glass	OLED Glass	AMOLED Panel	AMOLED Module

# **Opportunity:** Device OEMs are Looking for New Features to Create New Demand as Smartphone Sales Have Peaked



#### YOU CAN ALWAYS LOWER PRICES! —

## Q4 2022 was a disaster for smartphone sales, sees the largest-ever drop

Phone sales plummeted 18 percent last quarter, 11 percent for the entire year.

1011 ANADEO 112012013, 4.00 FM



### BBC Sign in

### NEWS

### '5G makes my phone pretty worthless'

③ 2 December 2022 · ₱ Comments



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## Adoption of Digital IDs is Driving Demand for Biometric Authentication That is Fast, Secure, and Seamless to Use

## CNET

### You Can Put Your Driver's License on Your iPhone. Here's How

iPhone users in select states can use a digital ID in Apple Wallet to travel and get through TSA.



Dan Avery V Jan. 15, 2023 8:52 a.m. PT

5 min read 🔗





### Gen Z and millennials adoption of face biometrics reaches 75 percent — report

Nov 1, 2022, 5:05 pm EDT | <u>Alessandro Mascellino</u>

CATEGORIES Biometrics News | Facial Recognition | Trade Notes



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Face ID



## Rapid Advances in AI are Driving the Need for 3D Facial Recognition to Thwart Password Hacks and Deep Fakes

#### ZDINET

#### ⊕ Q

#### Home / Innovation / Artificial Intelligence

## How an AI tool could crack your passwords in seconds

More than half of the common passwords examined by online security experts can be cracked in less than a minute with help from AI.



Vritten by Lance Whitney, Contributor on April 10, 2023

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#### TECH / ARTIFICIAL INTELLIGENCE / SECURITY

Liveness tests used by banks to verify ID are 'extremely vulnerable' to deepfake attacks / Attackers can simply swap their face for another

By James Vincent May 18, 2022, 9:00 AM EDT <u>0 Comments / 0 New</u>







Here's how long it takes new BrutePrint attack to unlock 10 different smartphones

BrutePrint requires just \$15 of equipment and a little amount of time with a phone.

DAN GOODIN - 5/22/2023, 6:31 PM

Menu -



Researchers have devised a low-cost smartphone attack that cracks the authentication fingerprint used to unlock the screen and perform other sensitive actions on a range of Android devices in as little as 45 minutes.

Fingerprint unlock can now be easily hacked!

## Average Display Size for Mobile Phones Has Continued to Increase Year-over-Year, Driving Narrower Device Bezels





#### iPhone 15 Pro Front Glass Leak Reveals Ultra-Thin Bezels Around Display

Sunday March 5, 2023 8:00 am PST by Joe Rossignol

While the iPhone 15 lineup is still around six months away, front glass panels for the devices were allegedly leaked today in a pair of videos shared on Chinese websites <u>Bilibili</u> and <u>Douyin</u>. The videos were later posted to Twitter by ShrimpApplePro and Unknownz21.



iPhone 14 Pro front glass (left) vs. iPhone 15 Pro front glass (right) via Bilibili

## Challenge: Broad Adoption of Under Display Camera and NIR Sensors Still Requires Significant Performance Improvement









### **Areas for Improvement:**

- 1. Image Blur / Diffraction
- 2. Low Light Performance
- 3. AI Image Compensation
- 4. Pixel Lifetime / Burn-in
- 5. 3D Facial Recognition

ZTE Axon 30 5G Visionox 6.9", Rigid ZTE Nubia Z50 Ultra BOE 6.8", Flexible NEW

Samsung Galaxy Fold 3 SDC 7.6", Foldable Samsung Galaxy Fold 4 SDC 7.6", Foldable

Not much has changed in the product landscape since our previous report at SID 2022

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## Perfecting the User Experience of Under Display Camera and NIR Sensors Requires a Full System Level Solution





See <u>Vampora et al</u>, SID 2022, pg 117 – 120 for example of integrating ALS under display

# **Pixel and Aperture Design in the Transparent Region of the Display has Significant Impact on User Experience**

Axon 30



Multiple pixels driven with each TFT reduces effective resolution





Lower resolution makes the transparent region obvious

Fold 4

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Lower resolution makes the transparent region obvious

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# Low Transparency of the Display Panel Limits Under Display Camera Performance in Low Light Settings





Higher transparency is required using cathode pattering (e.g., CPM<sup>™</sup>), other improvements to the panel design, and using more sensitive camera sensors

# Under Display Cameras Require Al Image Processing to Correct for Degradation Caused by the Display Panel





Al image compensate requires considerable computational overhead (and energy)

New AI image processing software and/or hardware is required for delivering high quality real time compensation of under display camera photos

Overprocessing with AI is a real risk to avoid!



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THAT'S NO MOON, THAT'S AN AI-PROCESSED PHOTO OF THE MOON! — Moon-gate: Samsung fans are mad about AIprocessed photos of the moon

When you know how the end result should look, how much AI is too much? RON AMADEO - 3/16/2023, 1:44 PM



Enlarge / Samsung's Galaxy S23 ad, showing the moon photography mode

## **Current AI Algorithms for Enhancing Images from Under Display Cameras Still Require Improvement**



iPhone X







Nubia Z50



- Too much smoothing
- Unnatural skin tone

Fold 4





- Artificial skin texture
- Unnatural skin tone

## Higher Resolution in the Transparent Region of Under Display Camera Panels Can Suffer From Pixel Burn-in





## く返回 数码闲聊站 <sup>※</sup> 消极掰时空伴随者 ● 0001 :我就想问小米mix特么的能不能售后多个选择!前置烧屏换挖孔屏!给 我爹买了一部烧两次了! 23-2-9 20:54 来自黑龙江 ① □ □ □ □ 4

# Users complain they had to replace the screen because of under display camera region burn-in



Axon 30 after 100 hrs burn-in

## OTI Has Developed Optimized Panel Designs Using CPM™ Patterning To Increase Pixel Efficiency to Reduce Burn-in



	Blue		Red	
	CE	CIE y	CE	CIE x
Standard	100%	0.048	100%	0.684
OTI Design	100%	0.048	150 - 180%	0.682

OLED device data with 8.5 nm cathode + 30 nm patterned cathode with 10 nm CPM layer deposited on the blue pixel

See SID 2023 **25.2** Subpixel Optimization in AMOLED Displays by Self-assembled Patterning of a Secondary Cathode for further details

**OTI Design with Second Cathode** 

(cathode thickness optimized for each color)



# Under Display 3D Facial Recognition Using NIR Doesn't Function Without Patterning of the Cathode Layer



NIR signal from Face ID module is blocked by thin cathode metal layer





Without Patterning (Face ID signal blocked)

With CPM<sup>™</sup> Patterning (Face ID signal works)



Without Patterning (Face ID Fails)



(Face ID Works)

Transparent **OLED** panel

## C

Conclusion

## Challenge

 Perfecting the user experience of under display camera and sensors requires a full system level solution approach

## **Opportunity**

 Under display camera and sensors can increase the value of display panels and drive new consumer demand





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## **Thank You**