Smartkem

Low Warpage Solution for MicroLED Displays

Outline

- About Smartkem Ltd
- The needs for MicroLED displays and their approaches
- An alternative to integrating frontplane and backplane
- Our offerings for display product structure

SmartKem Officers

Ian Jenks
Chairman and Chief Executive Officer

Ian was formerly the president of Uniphase Inc, Chairman of Oplink Communications Inc which he took public on the NASDAQ and spent seven years as a partner of Crescendo Ventures llp Ian has been a director of Techstep ASA, Paysafe plc., and Brady plc.

Barbra Keck
Chief Financial Officer

Barbra served as the Chief Financial Officer of Deverra Therapeutics, Inc., a developer of cell therapies. She held positions of increasing responsibility at Delcath Systems, Inc., an interventional oncology company, starting as Controller and ultimately becoming a senior vice president in March 2015 and chief financial officer in February 2017.

Dr. Beverley Brown
Chief Scientist

Beverley has worked in R&D at Imperial Chemical Industries Ltd. ("ICI"), Zeneca Group PLC and at the Avecia Group PLC. Beverley has worked in the field of organic semiconductor technology and in printable electronics for almost 20 years.

Dr. Simon Ogier
Chief Technology Officer

Simon has previously worked at Avecia, Merck, CPI and more NeuDrive Limited. He currently manages a team of 19 engineers and scientists using the equipment for SmartKem's process development and prototype fabrication. Simon has co-authored 30 journal articles and has been co-inventor on 16 patent families.

History of Smartkem

- Established 2009.
- In February 2021, SmartKem raised $24.6 million in gross proceeds through a private placement of common stock-only at $2.00 per share.
- To date, over $70 million has been invested in SmartKem.

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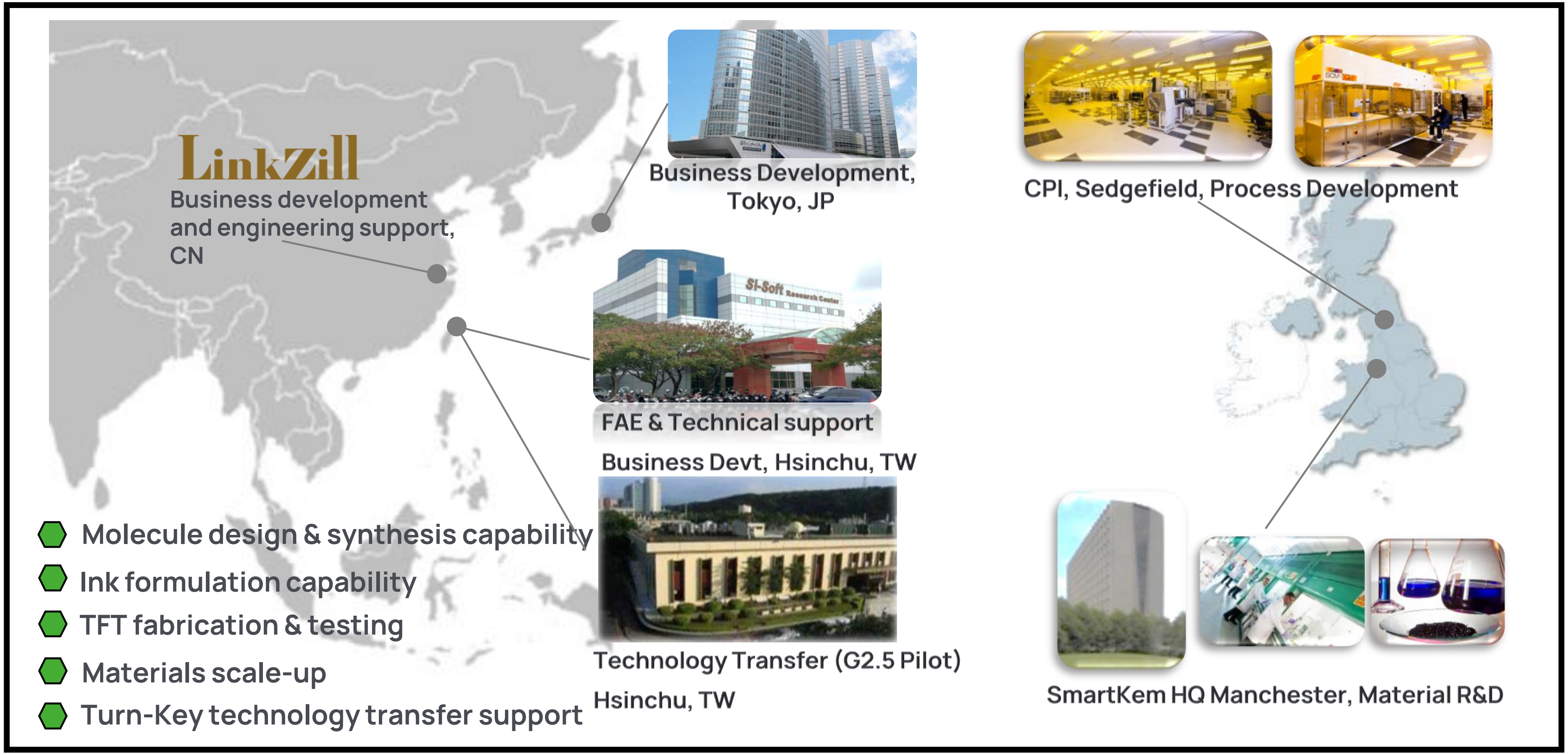
Facilities in UK and Asia



- Molecule design & synthesis capability
- Ink formulation capability
- TFT fabrication & testing
- Materials scale-up
- Turn-Key technology transfer support

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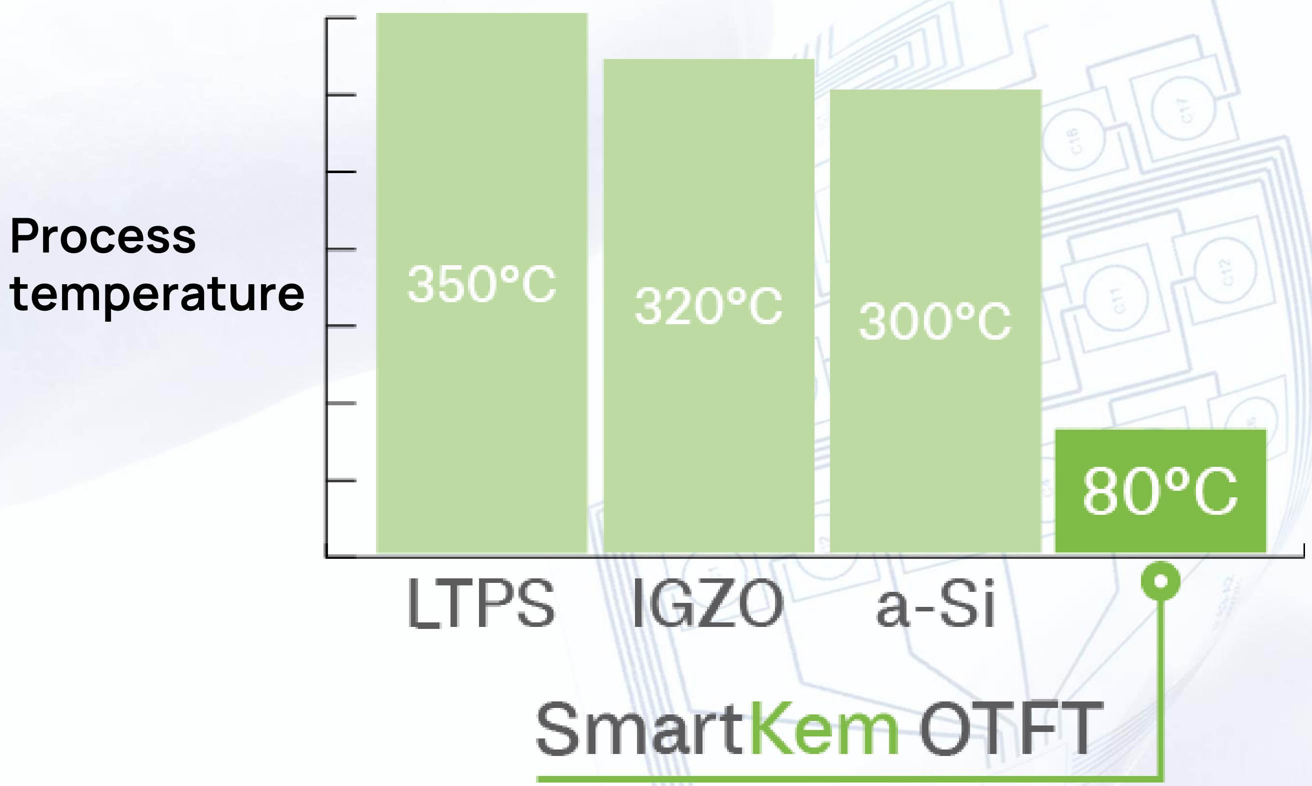
What is needed



Solution-coated (Printable) **frontplanes**, OLED and EQD

+

A manufacturing process compatible with amorphous silicon infrastructure with higher performance

+

Low temperature processing that enables **backplanes** that are solution-coated on low-cost substrates

Smartkem is offering a **Low-temperature** semiconductor platform

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MicroLED Backplane requirement: Low IR drop

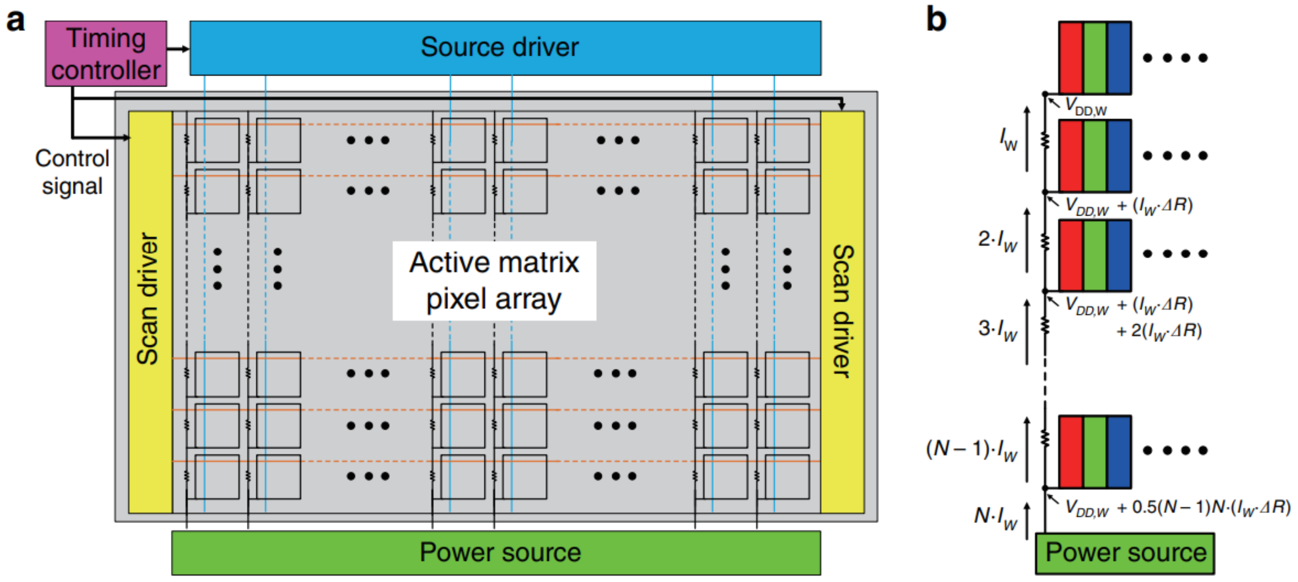

Fig. 4 Illustration of V_{DD} voltage drop. a System schematic of an AM panel. **b** Voltage drop on a V_{DD} line

Huang et al. Light: Science & Applications (2020) 9:105

In addressing panel performance while minimizing heating issues, adjusting the driving scheme through duty adjustment is a visible approach.

- Reducing IR drop necessitates increasing metal thickness, leading to the implementation of panel-level RDL (Redistribution Layer) processes.
- RDL processes require a thicker dielectric thickness (>10μm) compared to the conventional 1μm or 2μm dielectric (PFA) used in TFT-LCD

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Physical properties for Conventional Dielectric vs. Warpage

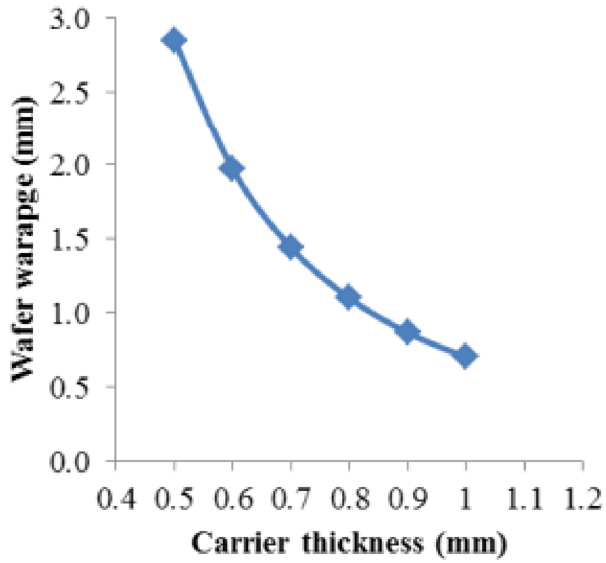
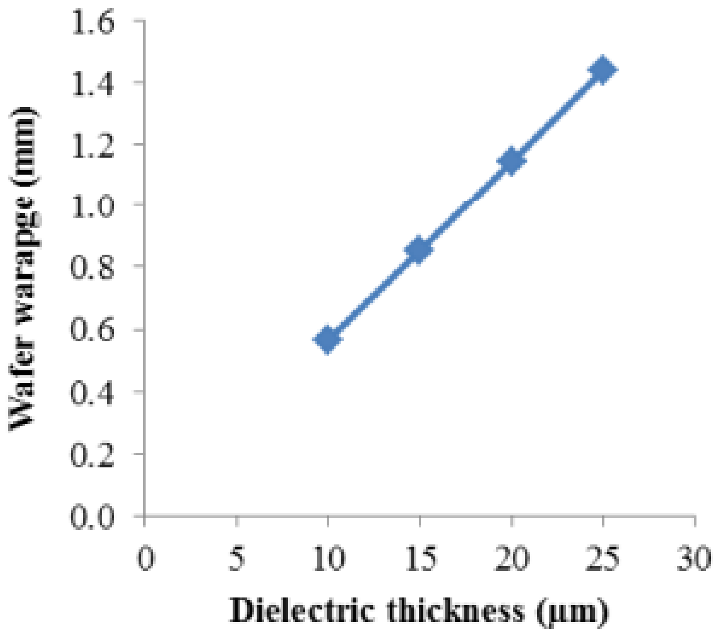


Fig. 11. Effect of glass carrier thickness on wafer warpage.



Article *in* IEEE Transactions on Components, Packaging, and Manufacturing Technology · December 2018
DOI: 10.1109/TCPMT.2018.2889308

Effect of PID (photo-dielectric material) on glass warpage :

When PID thickness ↑or carrier thickness ↓ › › Warpage ↑

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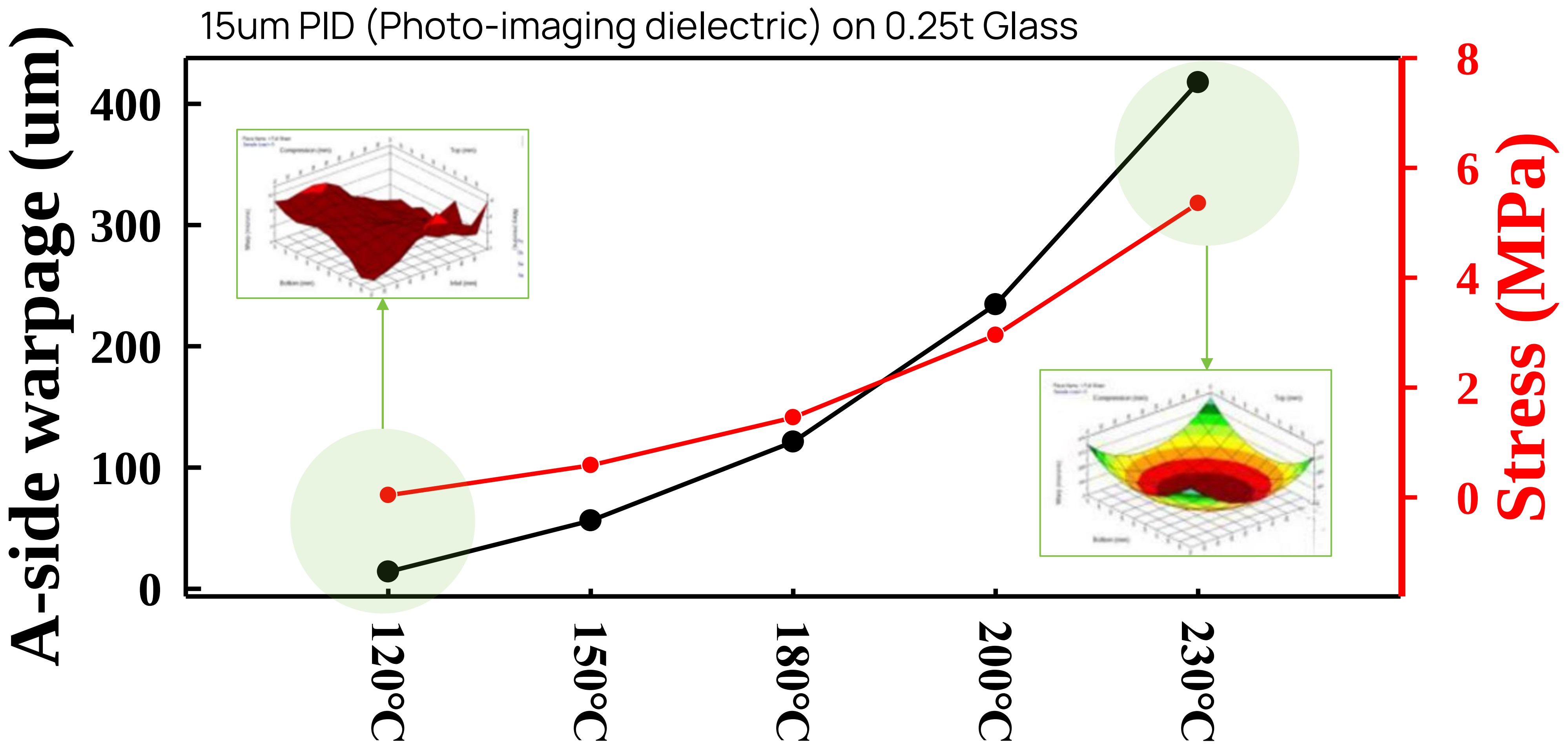
Temperature effect on Warpage



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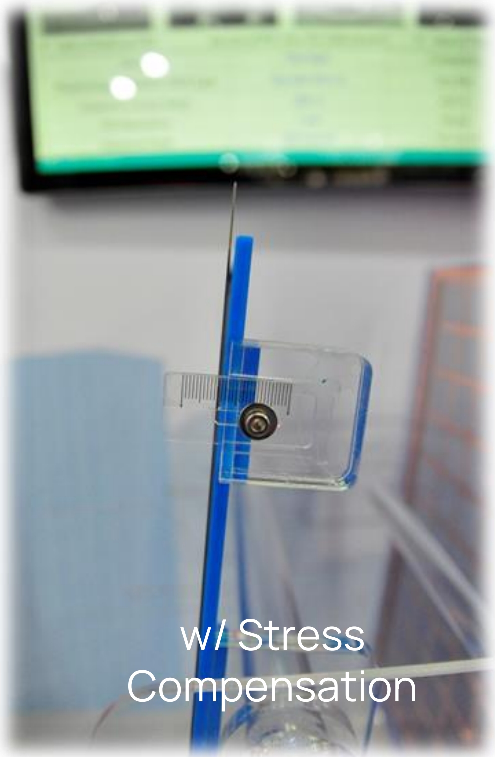
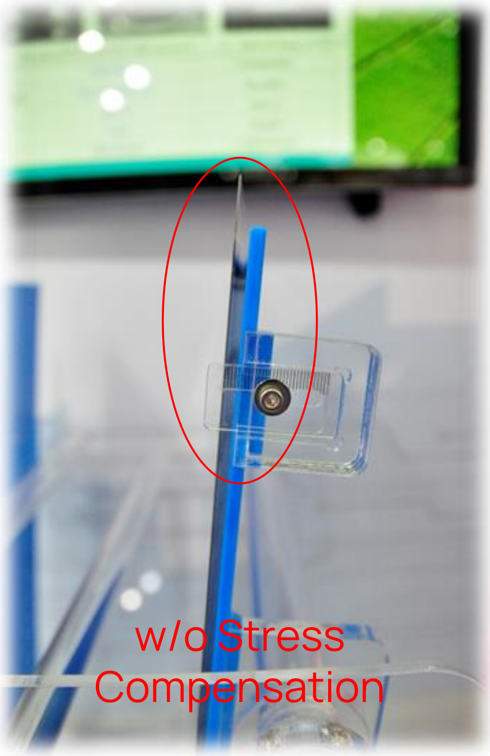
Low Warpage Solution via Low Cure (Low-Temperature)

TRUFLEX® Product SPEC: Cu sheet resistance < =0.002 (Ω/□)

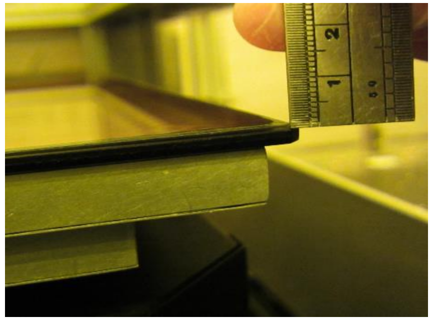


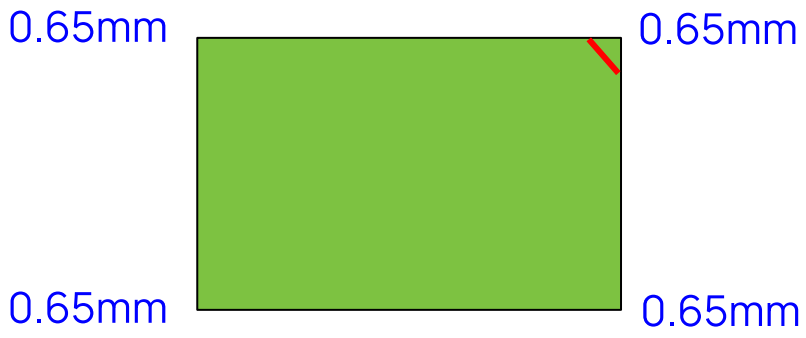
Low Warpage



High Warpage

Substrate dimension : 370mm x 470mm





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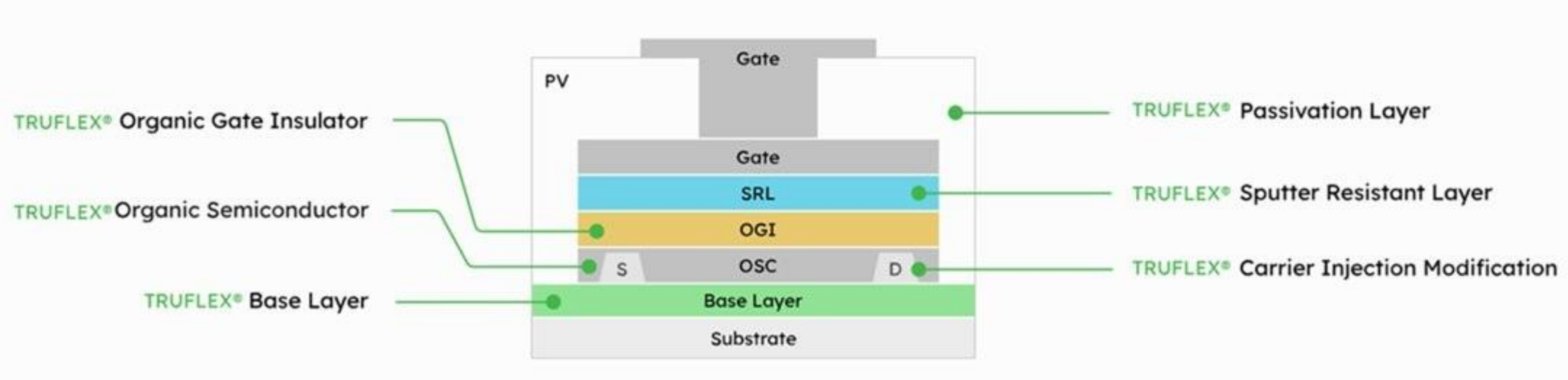
Smartkem's TRUFLEX® Materials



Ease of
Technology Transfer

Chemistry, process and stack owned

Solution processed
At 80°C

Formed on low-cost glass & plastic

Drop in technology
for **today's fab lines**

(and ready for next gen printing)

World leading electronic performance

Meets industry critical test standards

Outperforms market leader a-Si

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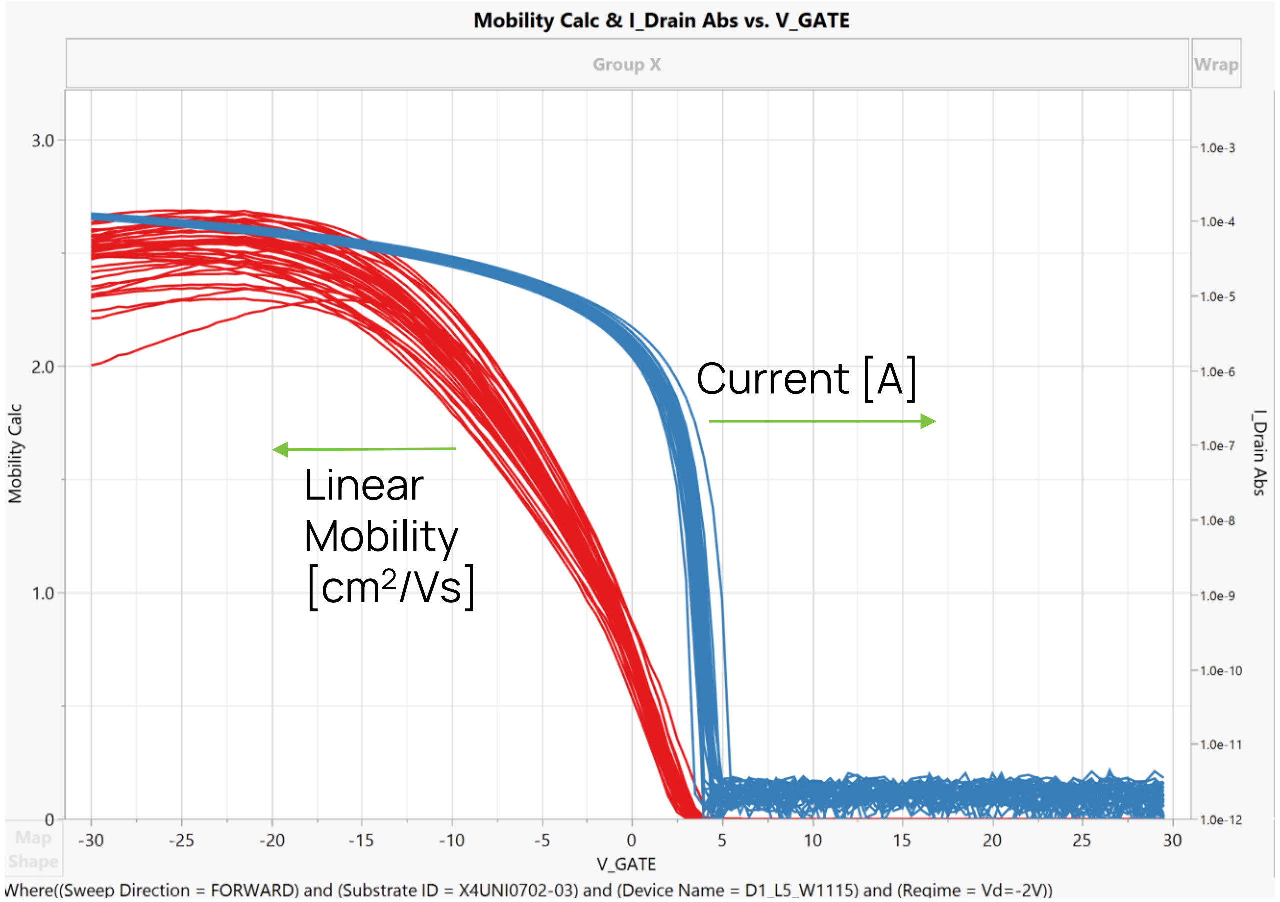
Mobility and current uniformity – overlaid on same graph

Mobility uniformity[1] = 4.1%
Max/Min[2] U%=8%

$$\mu = \frac{\partial I_{DS}}{\partial V_G}\frac{L}{WC_iV_{DS}}$$



(1) - one standard deviation
(2) - ((max-min)/(max+min))*100

Variability Summary for Mobility

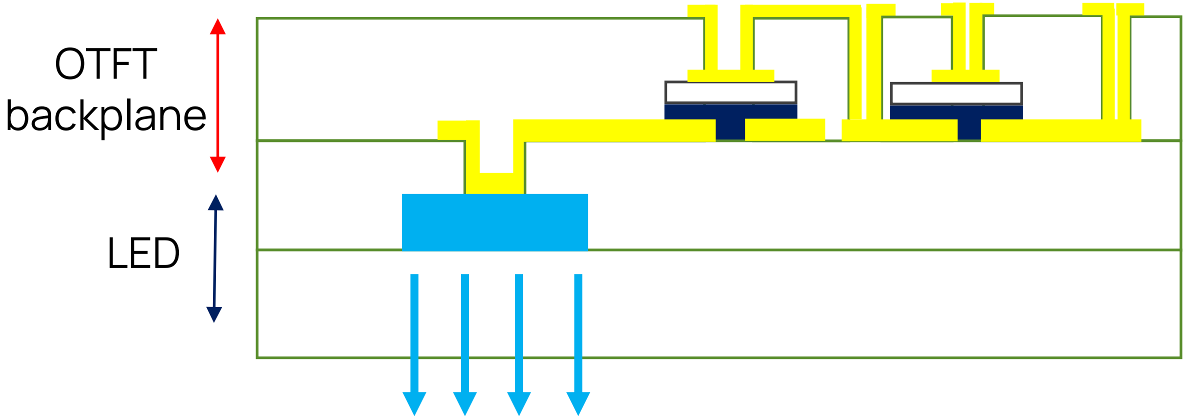
	Mean	Std Dev	CV	Lower 95%	Upper 95%	Minimum	Maximum	Range	Median	Observations
Mobility	2.5	0.1	4.1	2.5	2.6	2.3	2.7	0.4	2.5	41

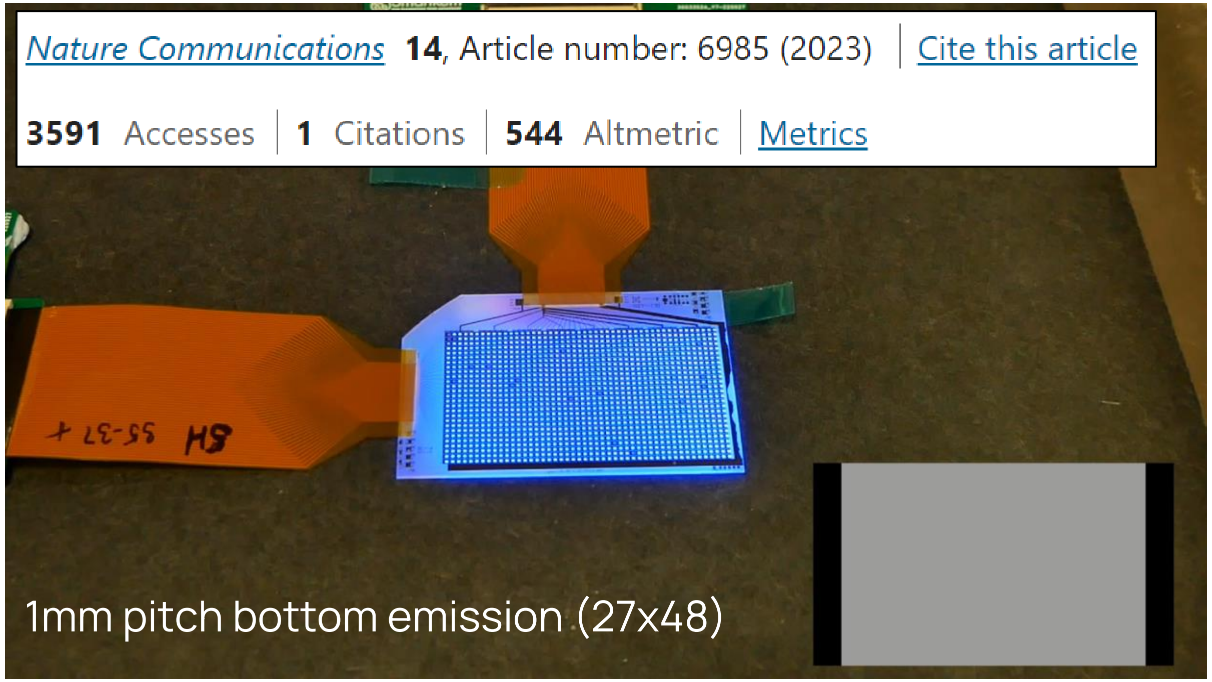
Variability Summary for Vto Forward

	Mean	Std Dev	CV	Lower 95%	Upper 95%	Minimum	Maximum	Range	Median	Observations
Vto Forward	4.6	0.4	8.5	4.5	4.7	4.0	5.5	1.5	4.5	41

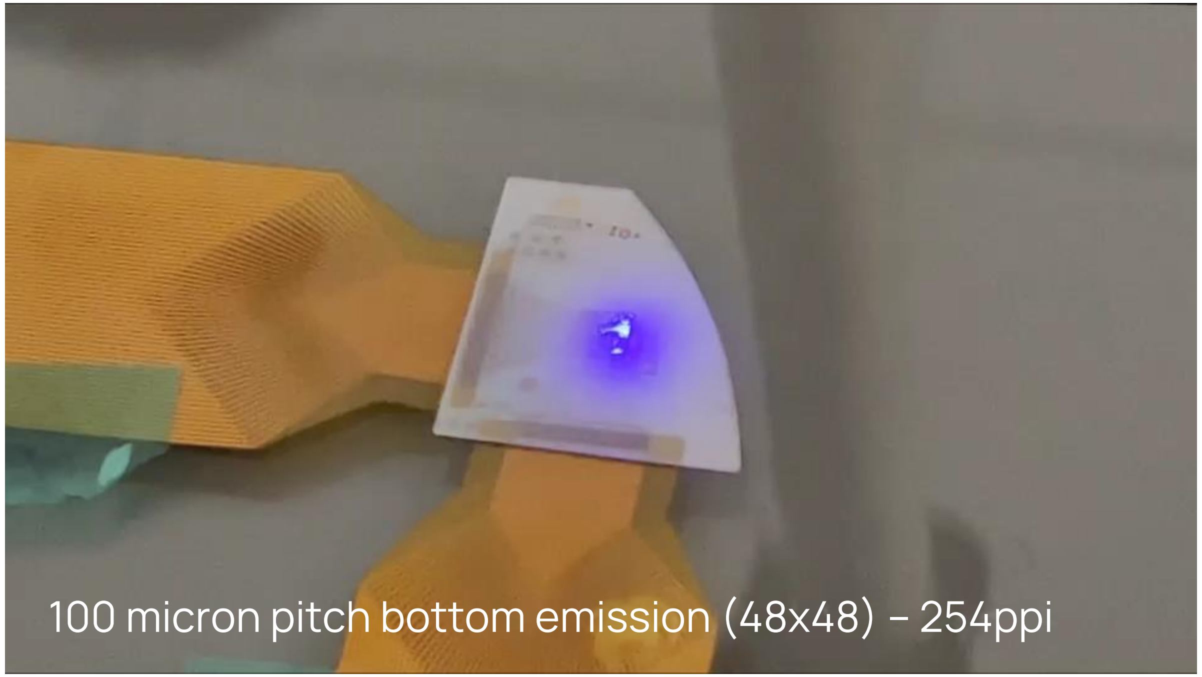
Monolithic MicroLED Via OTFTs

- Process can be scaled from 10ppi to >1000ppi with appropriate lithography tools





1mm pitch bottom emission (27x48)



100 micron pitch bottom emission (48x48) – 254ppi

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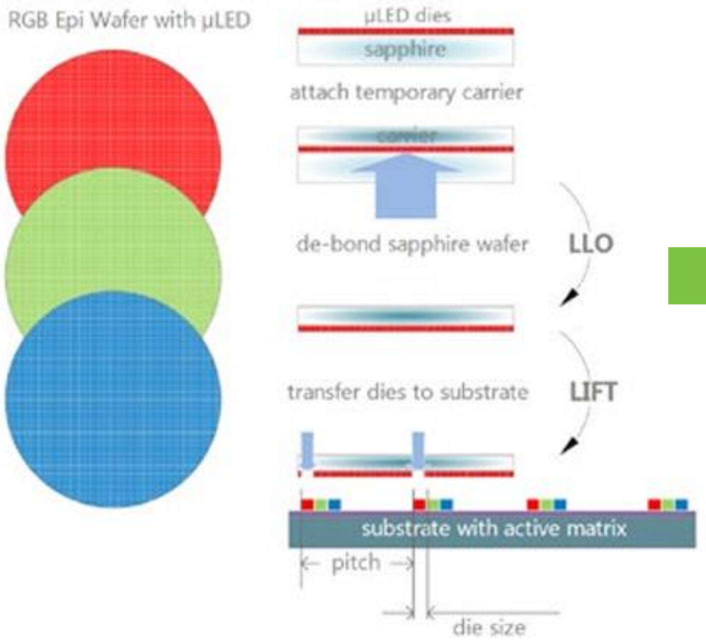
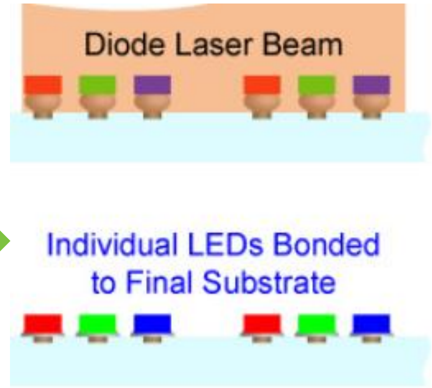
Mass Transfer Process for MicroLED Displays

LIFT (Laser induced forward transfer)



The MicroLED Association - White Papers

LAB (Laser Assisted Bonding / so called mass welding 巨量焊接)



Laser Assisted
Bonding (LAB)

Reference from COHERENT

Major Yield Loss steps , Required mass repair !

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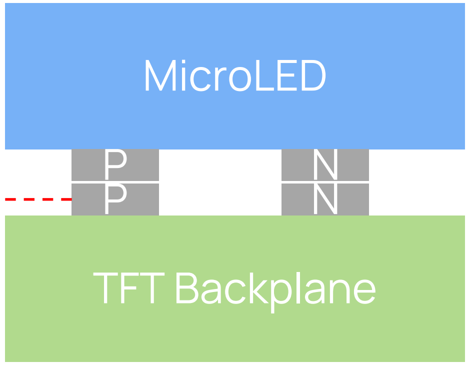
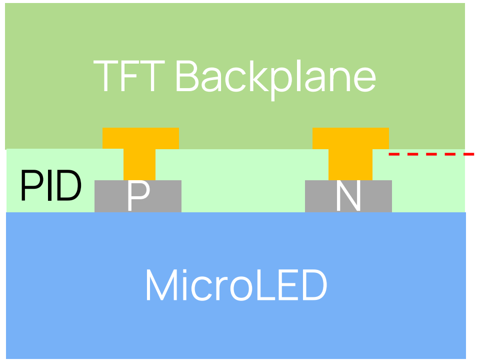
MicroLED via Chip First RDL Process

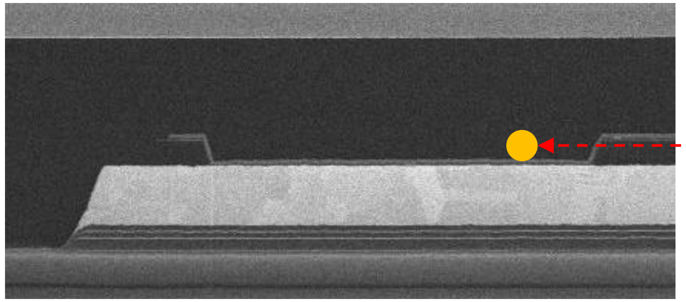
Conventional
LAB (Laser Assisted Bonding /巨量焊接)



Low melting point metal
Or
Thick Au
Or
Solder ..etc

Smartkem approach
RDL Process Via PID materials





Mo/Al/Mo
Or
Cu
or
Ti/Al/Ti

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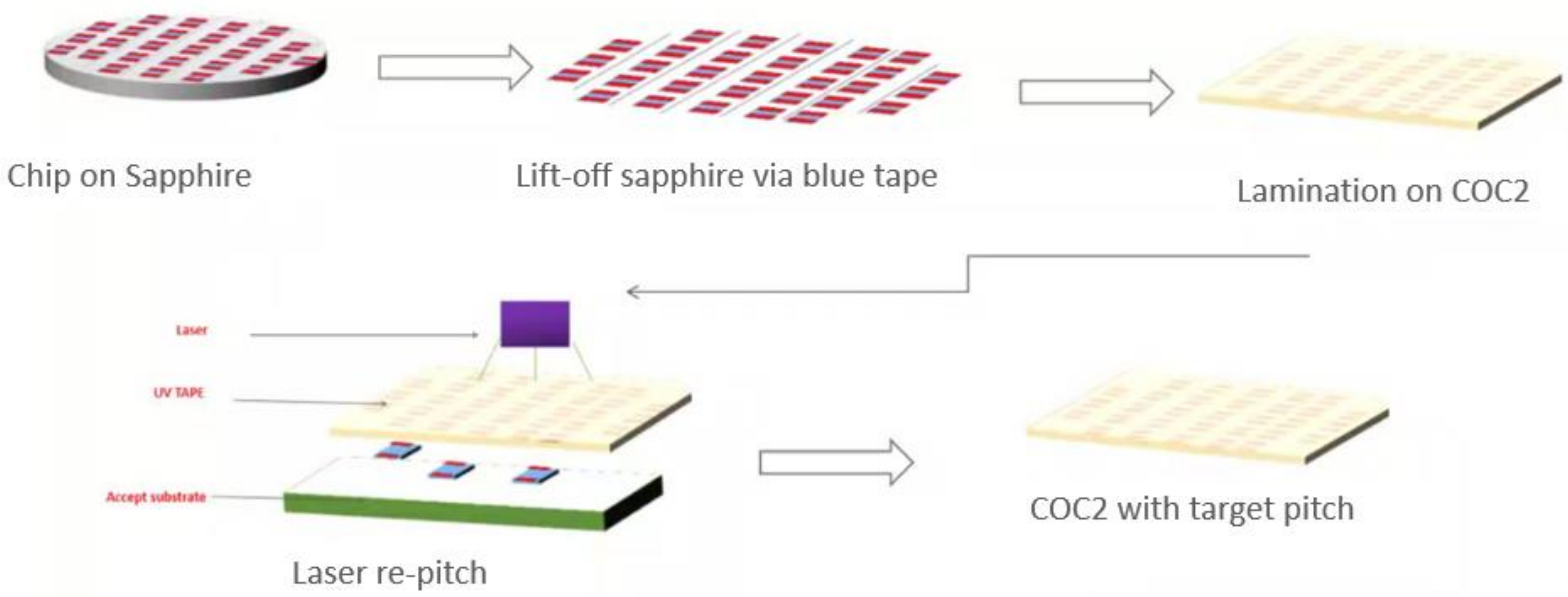
Overall MicroLED via RDL Process



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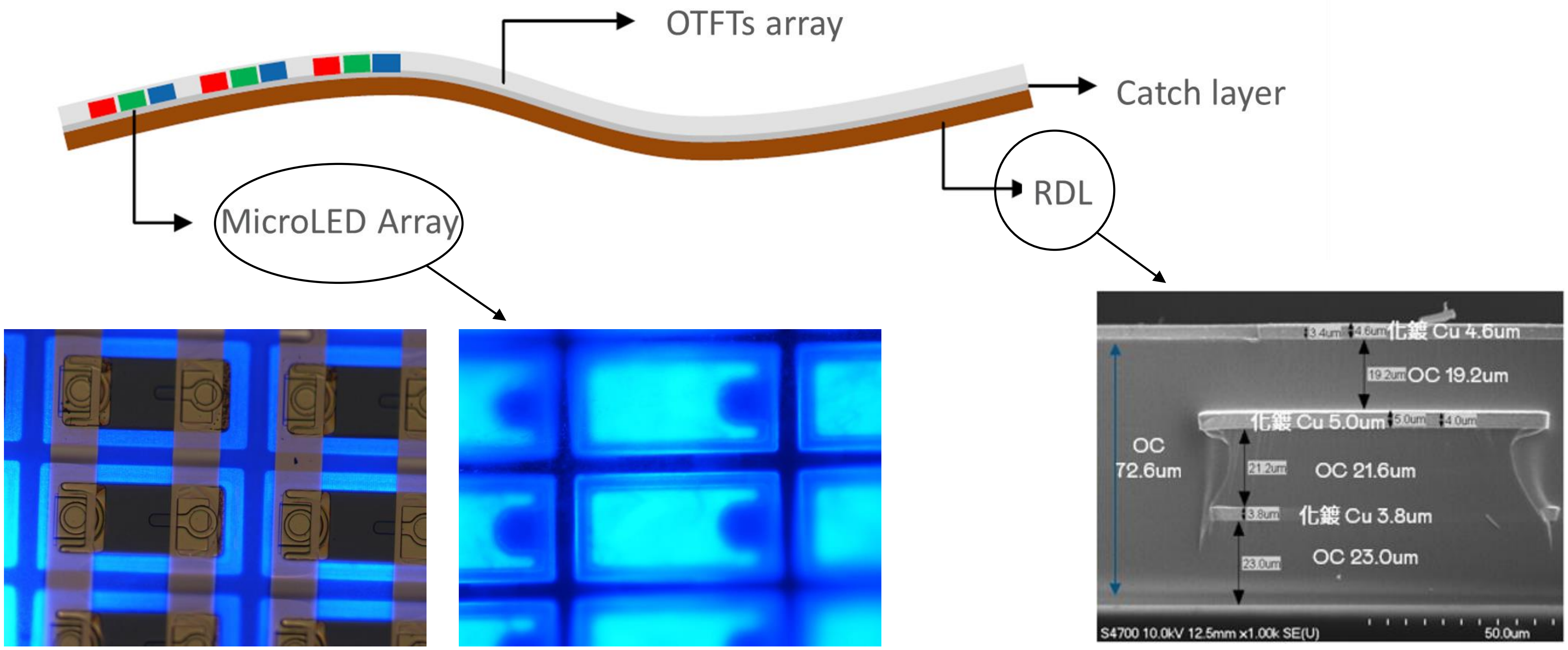
Smartkem MicroLED Displays



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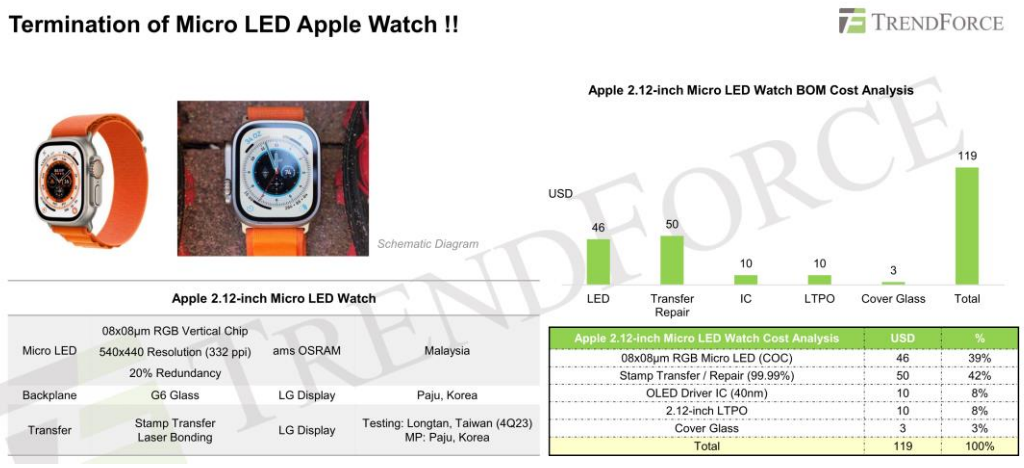
Our Offerings



Apple 2.12-inch Micro LED Watch Cost Analysis	USD	%
08x08μm RGB Micro LED (COC)	46	39%
Stamp Transfer / Repair (99.99%)	50	42%
OLED Driver IC (40nm)	10	8%
2.12-inch LTPO	10	8%
Cover Glass	3	3%
Total	119	100%

Via Smartkem Chip-first approach

- Cost of micro-LEDs will be about $10 for an 8x15 die size (maybe $7 for 8x8 dies) – based on $1000 cost of source wafer
- Remainder of COC cost will be the cost of die sorting, testing, pitch adjustment ($39) – assume same as for 8x8um Apple case
- Stamp transfer/Repair cost could be substantially reduced if the chip-first approach is used (no transfer and 1st time yield increase of 99.99% →99.999%) - <$5 repair cost
- OTFT backplane cost will be <50% of LTPO cost
- Total cost would therefore be $72 (vs $119) - %40 reduction
- Potential further reductions would come from greater efficiency in die sorting, testing and pitch adjustment
(maybe blue + QD-CC approach would be lower cost)

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An Introduction to the Monolithic OTFT-on-uLED Process

Exploiting SmartKem's Ultra-Low Process Temperature
to unlock novel methods of micro-LED backplane manufacturing

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Thank you

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