Holst Centre

Open Innovation by IMEC and TNO

Roll-to-Roll Processing for Solution Processed OLED Devices

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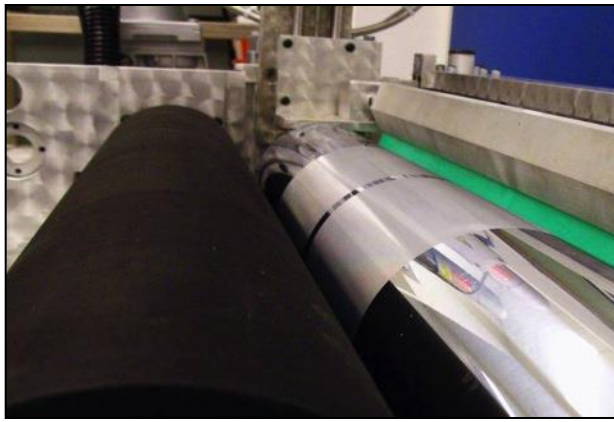
Vision on lighting

Now	2020
10,000 €/m²	100 €/m²
Rigid glass	Flexible substrates
40-60 % material loss	<5% material loss
Vacuum/litho processes	Direct printing processes
Rare materials	Mainstream materials
Glass encapsulation	Thin-film encapsulation

R2R Printing & Coating technology



Why?

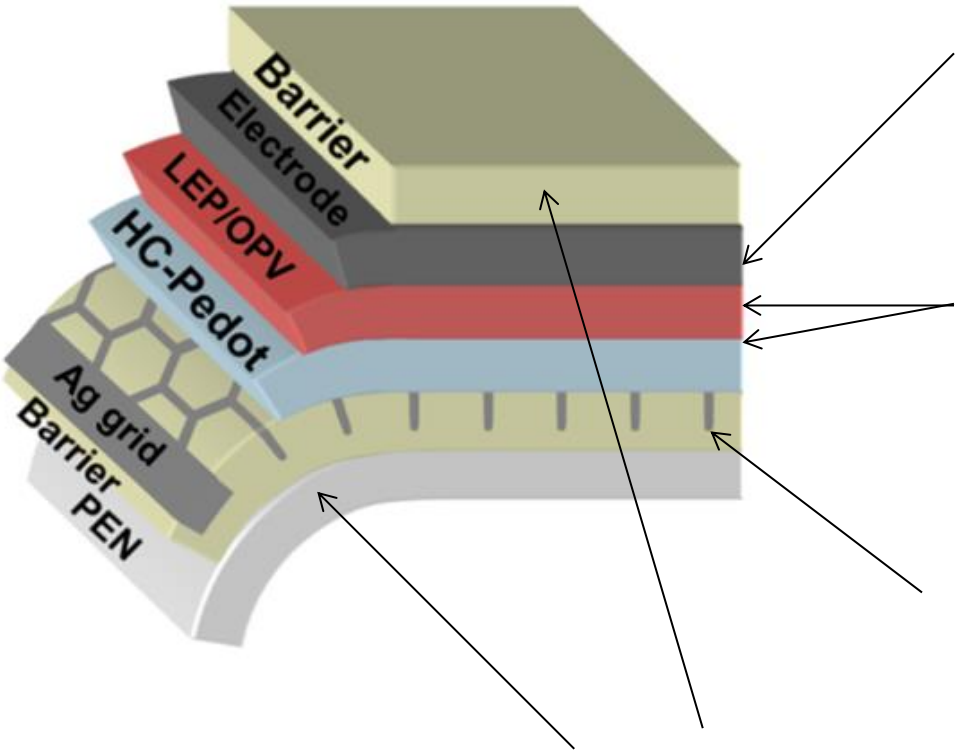
Printing/casting preferred over lithographic patterning

- easier for large scale processing
- fine features/patterning without complicated masks
- higher materials utilisation → lower cost

Topics:

- ✓ **S2S up scalable to R2R**
- ✓ **Multilayer coating**
- ✓ **Patterning & alignment**
- ✓ **Prevention of contamination – yield control**

Summary: Schematic of R2R solution processed OLED (ITO free)



3. Shunting cathode OLEDs by IJP

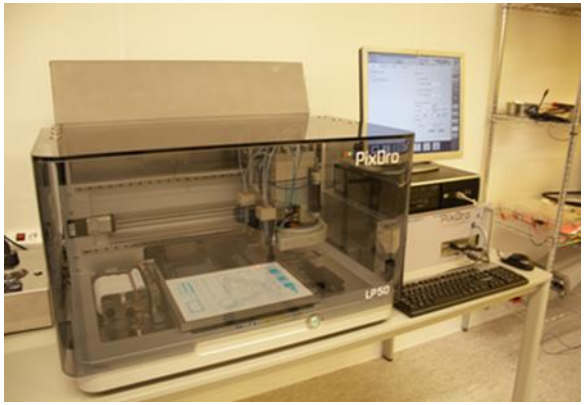
2. Large area coating

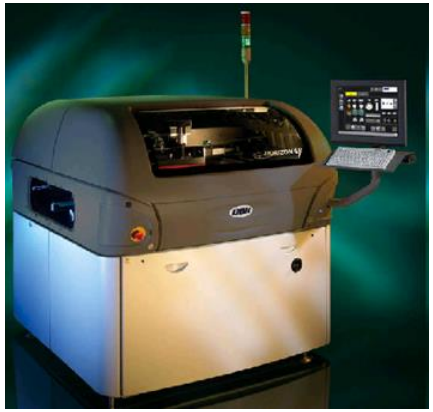
1. Printing and sintering of silver grids (anode)

4. R2R Barrier

1. Printing & Sintering

- **Printing silver: Ink jet – Screen printing**



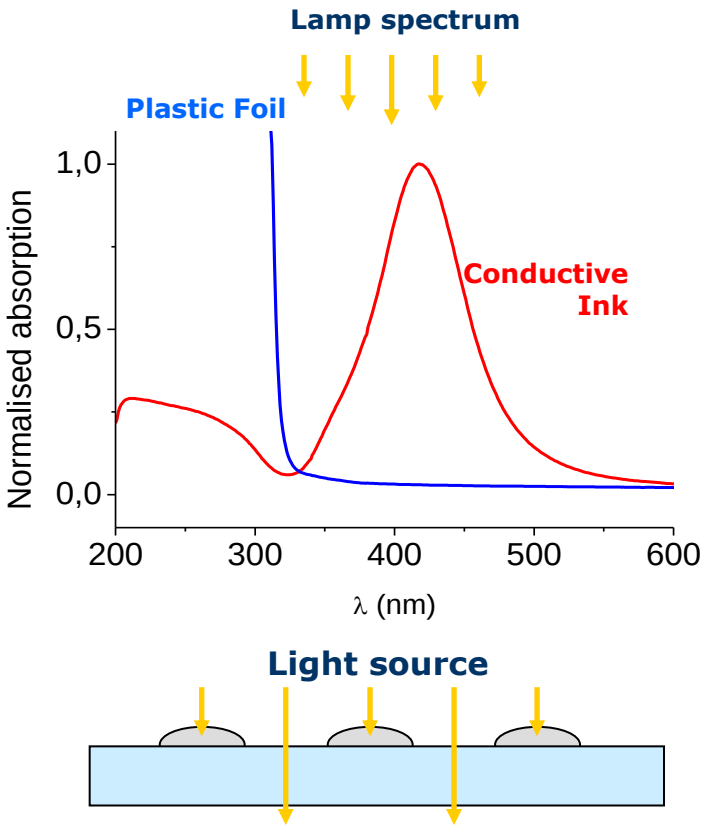


- **Baseline Process: Thermal Sintering in furnace at high temperatures (30 min./>150 °C)**
  - Limited to T_g of polymer foils
  - Slow and inefficient process
  - **In R2R line with 6 m/min a furnace of 60 m needed**

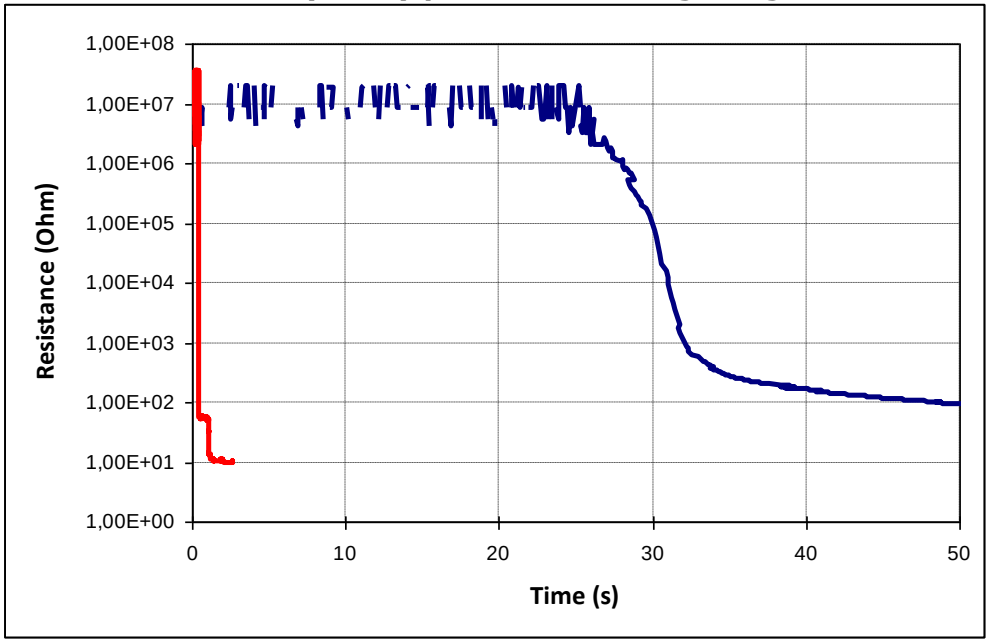
- **Photonic Flash Sintering**

Photonic sintering principle

- The principle of photonic sintering is the selective heating of the ink
- Lamps are chosen such that the light is mainly absorbed in the printed structures, not substrate



Result feasibility study photonic sintering of Ag-based inks

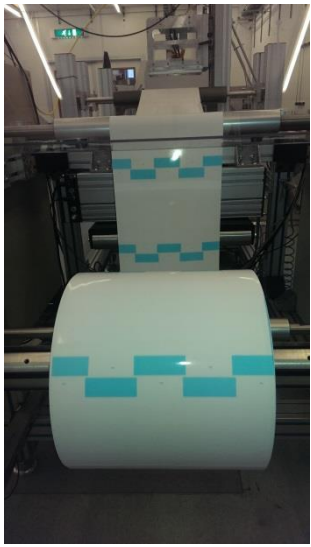


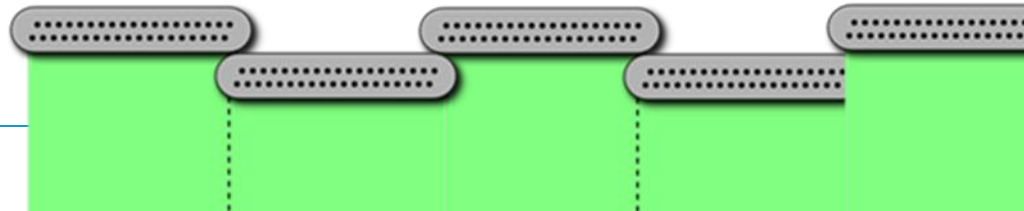
Achievements:

- Sintering time reduced from minutes to few seconds!

NOVACENTRIX

spgprints





Extended to 5 print heads

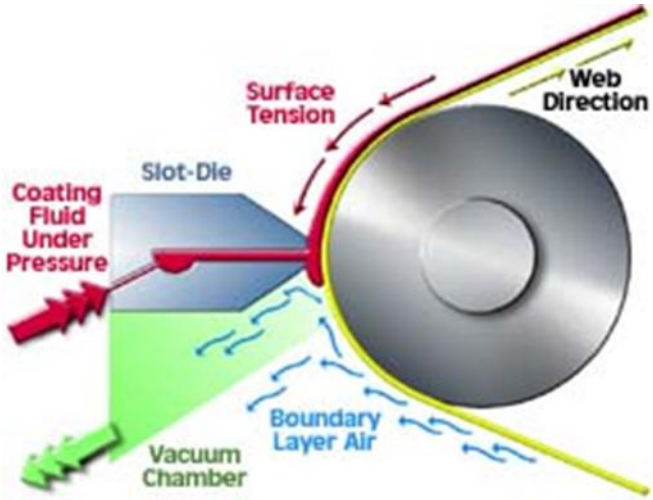
2. Large area coating (using solution processing)

Holst Centre's Approaches:

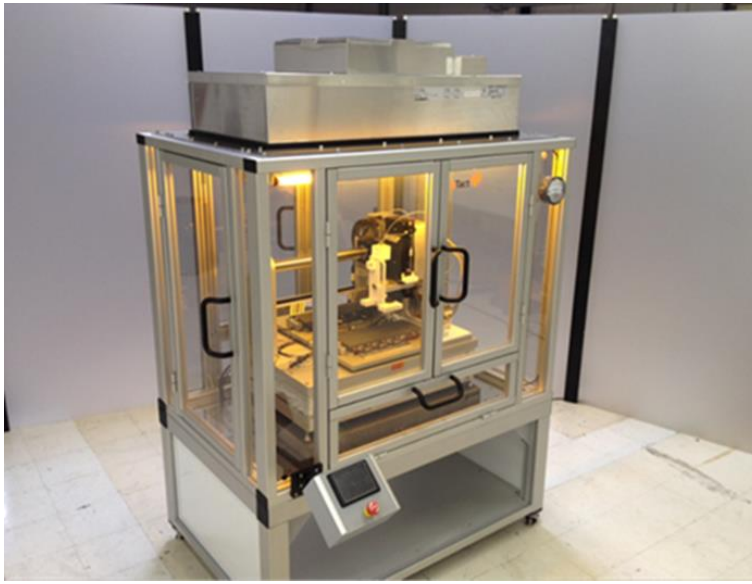
0) Spin coating: simple, no patterning

1) Ink-jet printing: non-contact, patterning is easy
- Homogeneity over large areas needs to be investigated

2) Slot-die coating: non-contact, large area blanket coating
*- **Pattering:** via laser ablation or selective wetting/dewetting or stripe coating and **intermittant coating***



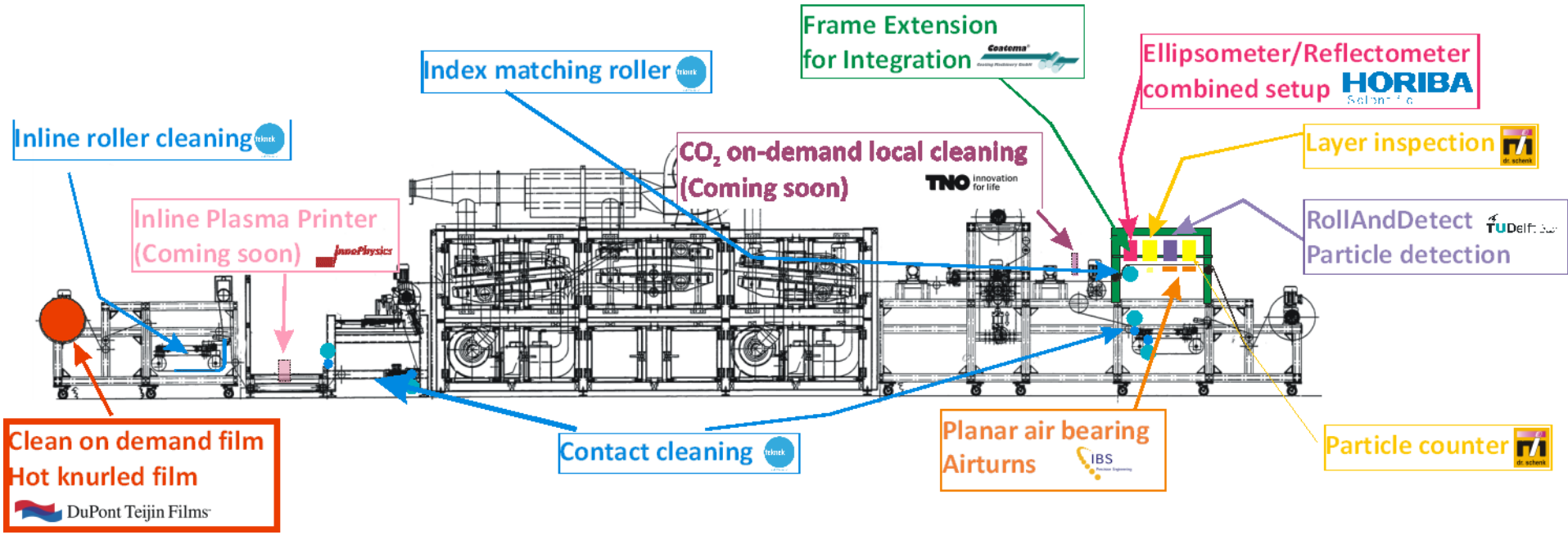
Slot die casting at Holst



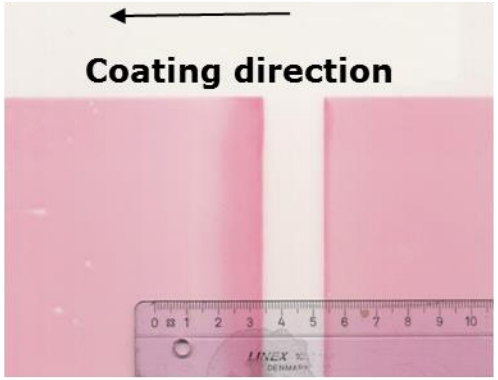
-Pattering !!!
-R2R atmosphere control
-Yield

Integration at Holst Centre

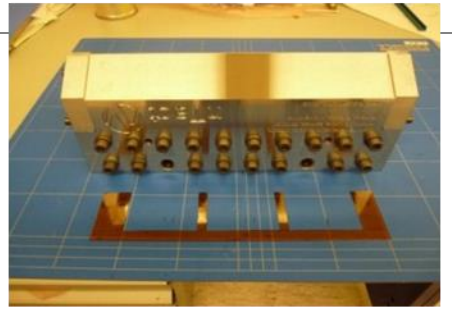
CLEAN4YIELD
DETECTION • CLEANING • PREVENTION • REPAIR

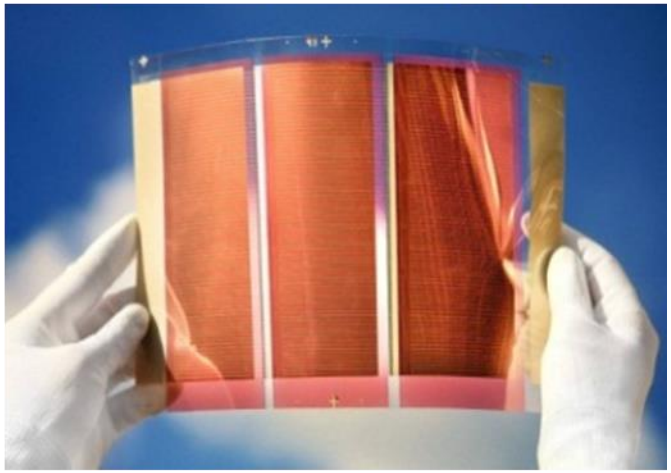


Patterning slot die

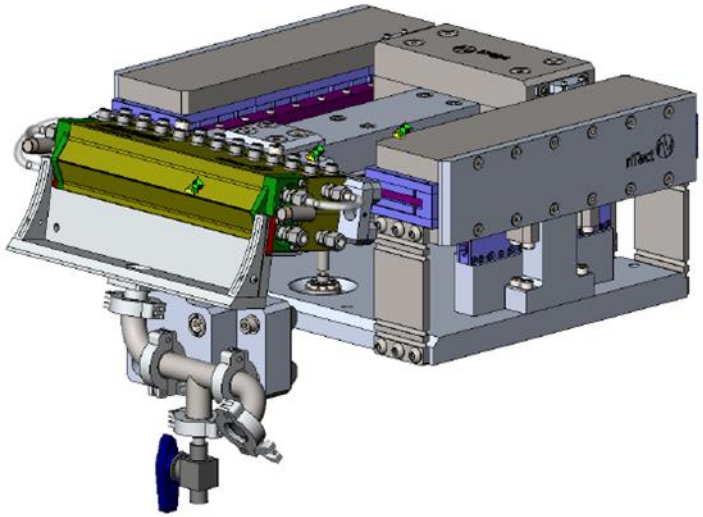


Stripe Coating





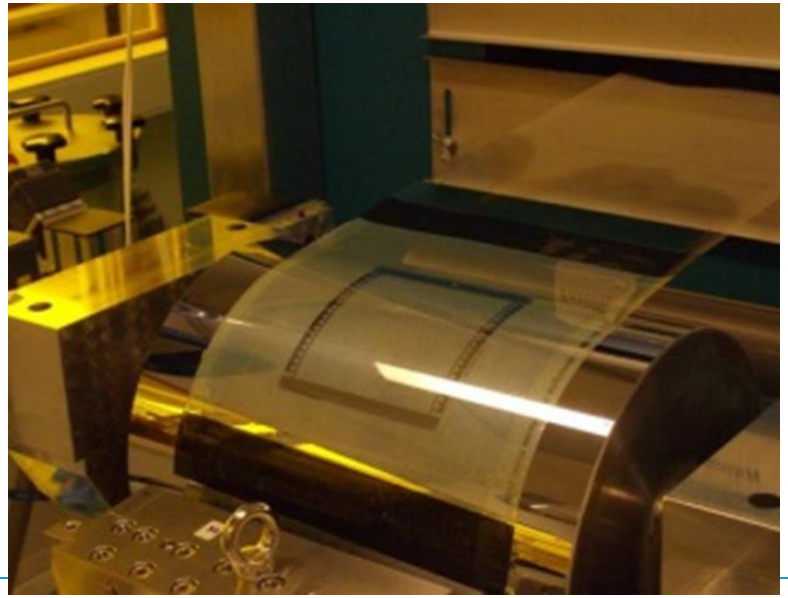
Intermittent coating with slot-die



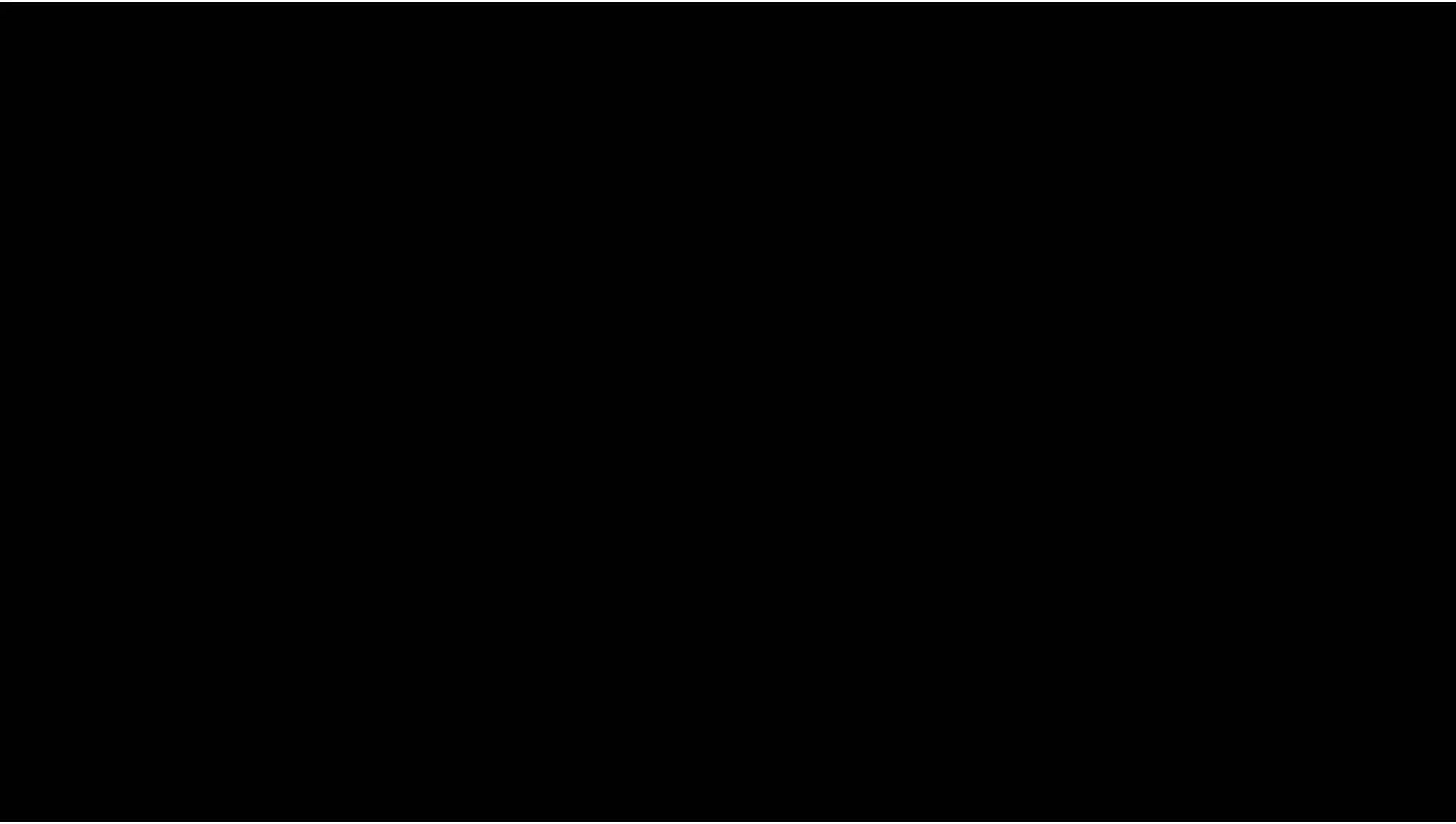
nTact
Adapting to Process

OLEDs: Large area slot die coated flexible demonstrators

- Slot-die coated layers of **100 - 30 nm** with thickness **variation only ± 2 nm**
- Sequential coating of up to **3 organic layers** on **plastic and metal foil** proven

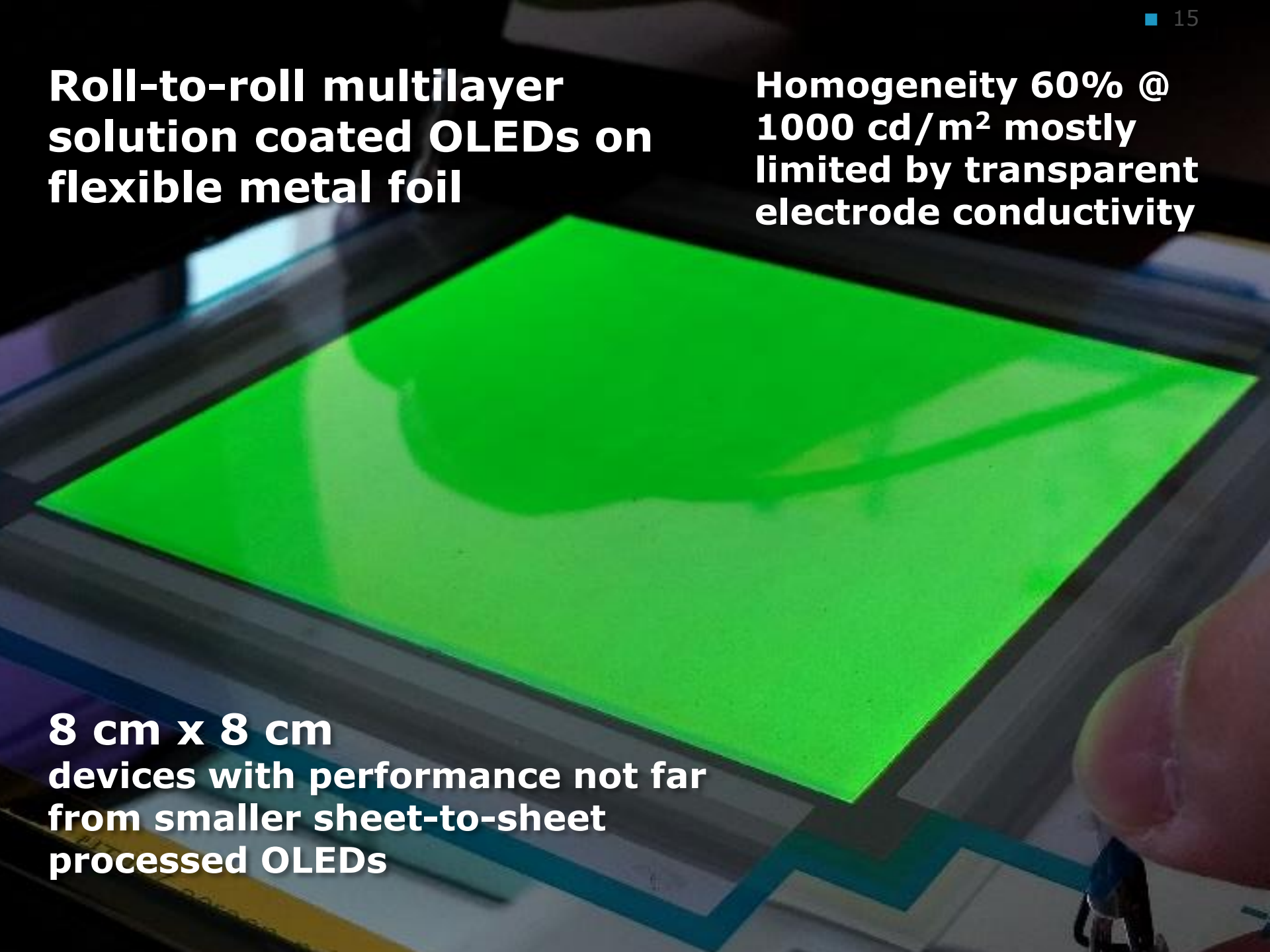


Roll-to-roll multilayer coating of OLEDs



Roll-to-roll multilayer solution coated OLEDs on flexible metal foil

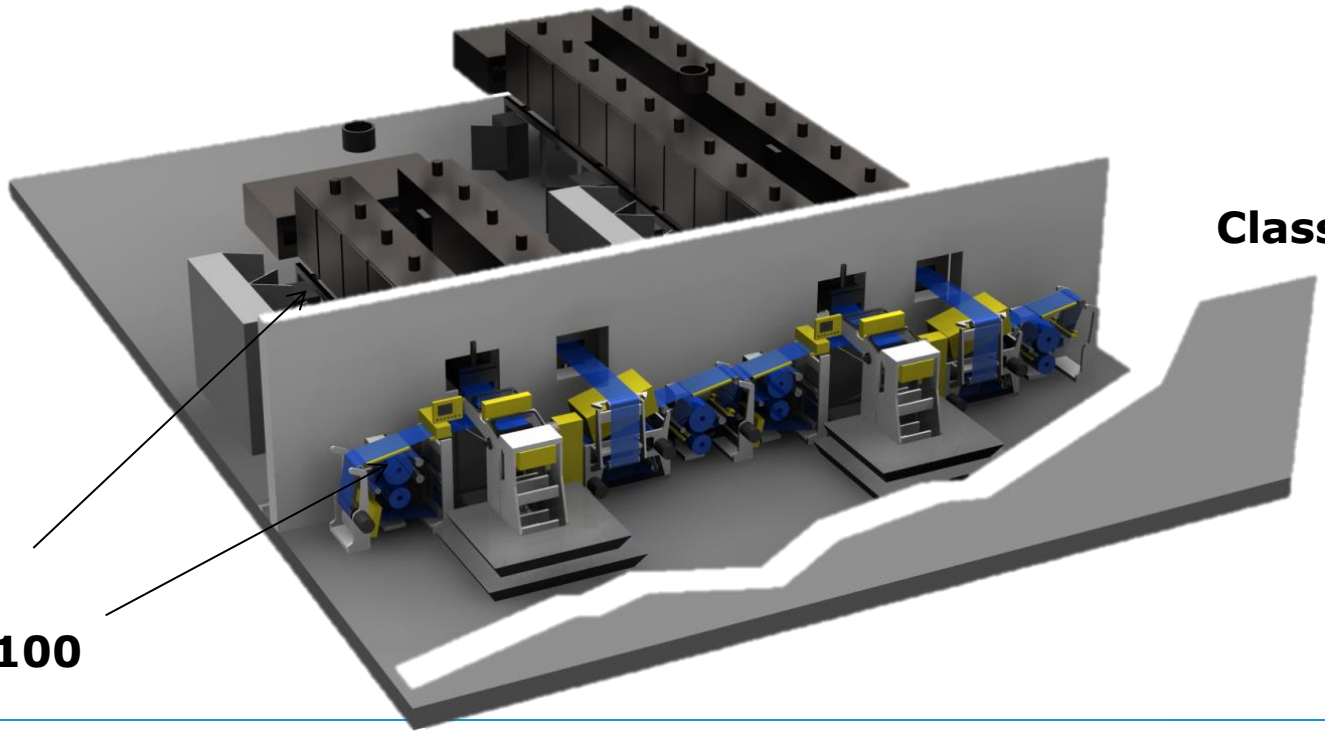
Homogeneity 60% @ 1000 cd/m² mostly limited by transparent electrode conductivity



8 cm x 8 cm
devices with performance not far from smaller sheet-to-sheet processed OLEDs

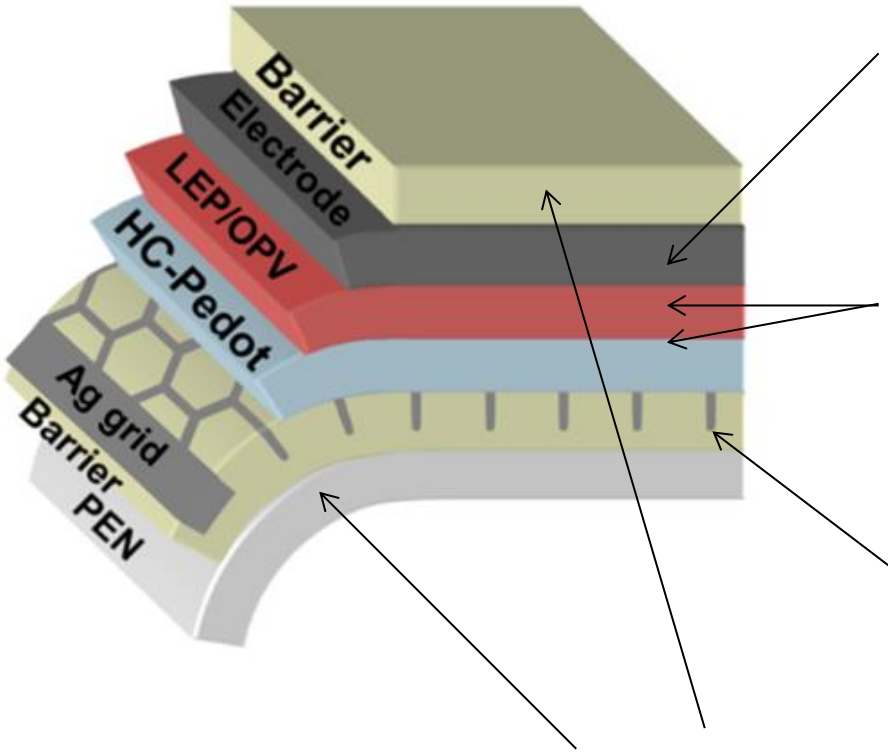
Holst Centre multicoat (2 x slot coating) pilot production line

- **Unique concept where web is never touched on topside essential for Oled production.**
- **Concept makes very efficient use of cleanroom space.**
- **Slot die coating in controlled atmosphere (all coating and drying in Nitrogen environment if needed).**
- **Closed furnace (class 10 + < 10 ppm O_2/H_2O)**



Multicoat R2R line

Summary: Schematic of R2R solution processed OLED (ITO free)



3. Shunting cathode OLEDs by IJP

2. Large area coating

1. Printing and sintering of silver grids (anode)

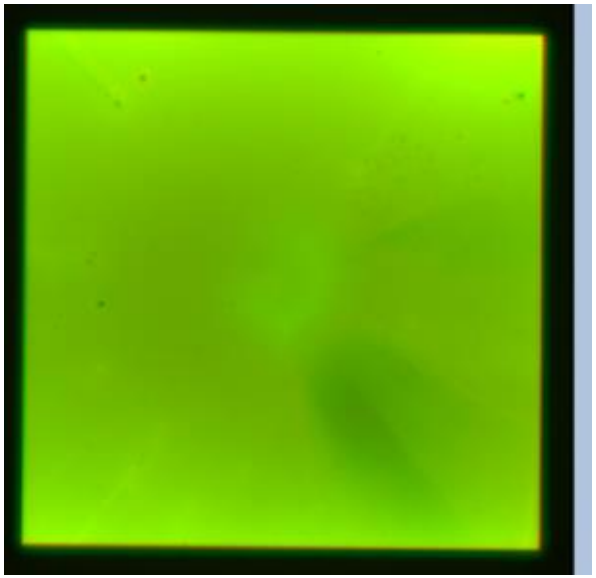
4. R2R Barrier

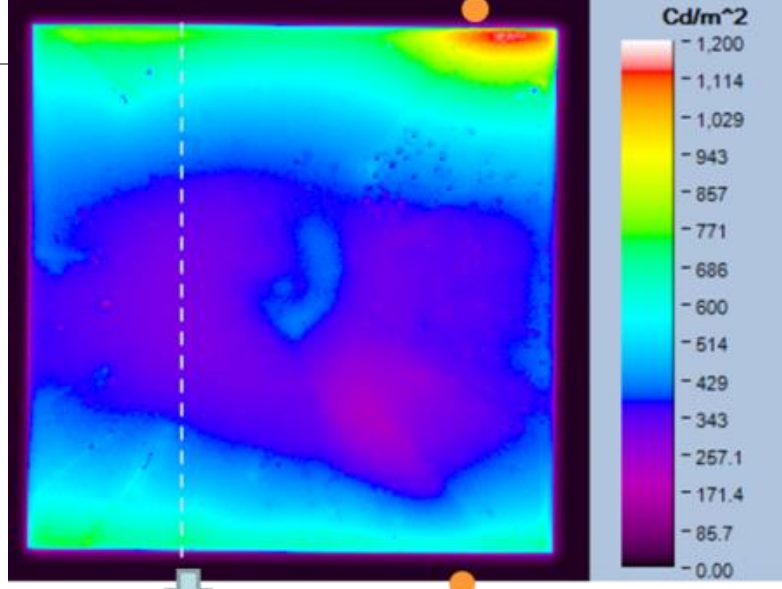
3. IJP grid to improve transparent electrode conductivity

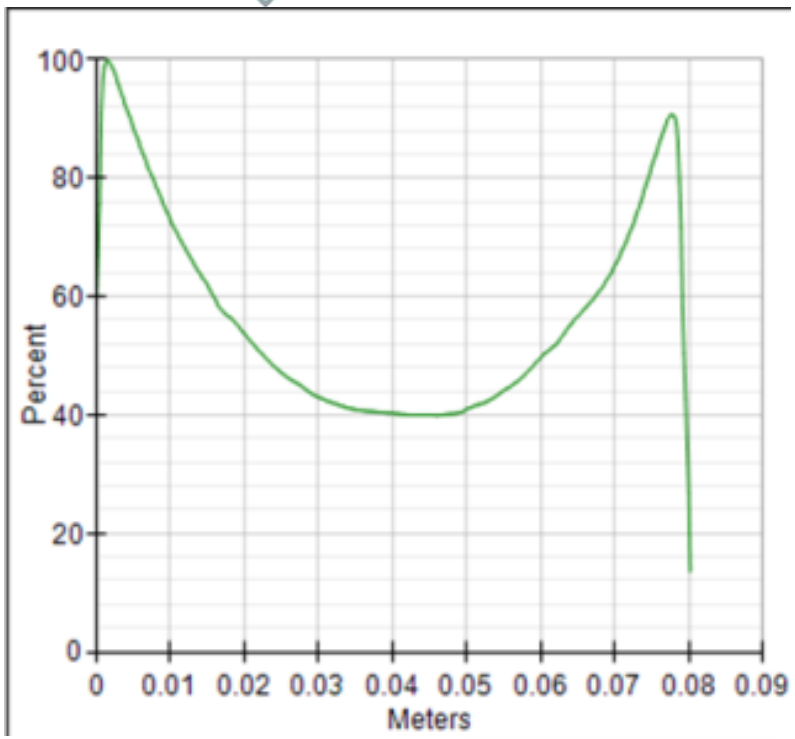
Device size 80 x 80 mm2

Without shunting lines:

Inhomogeneous due to limited conductivity of transparent cathode

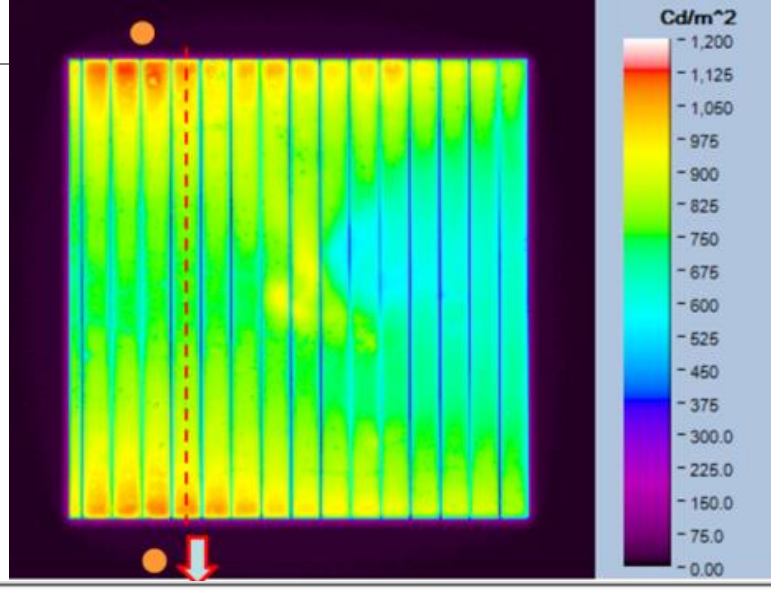


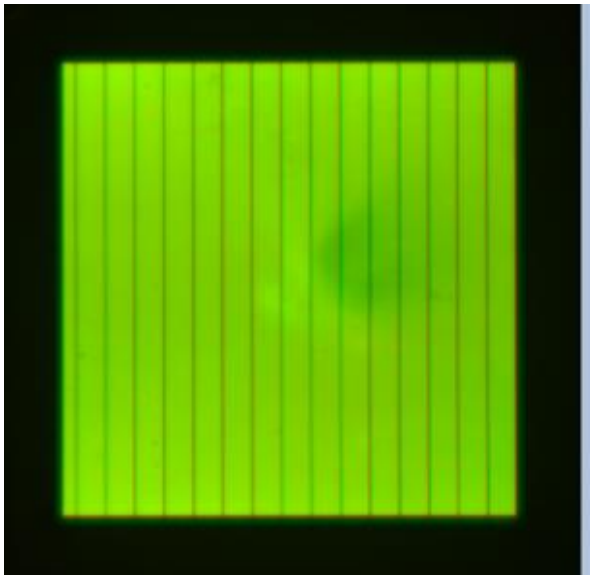


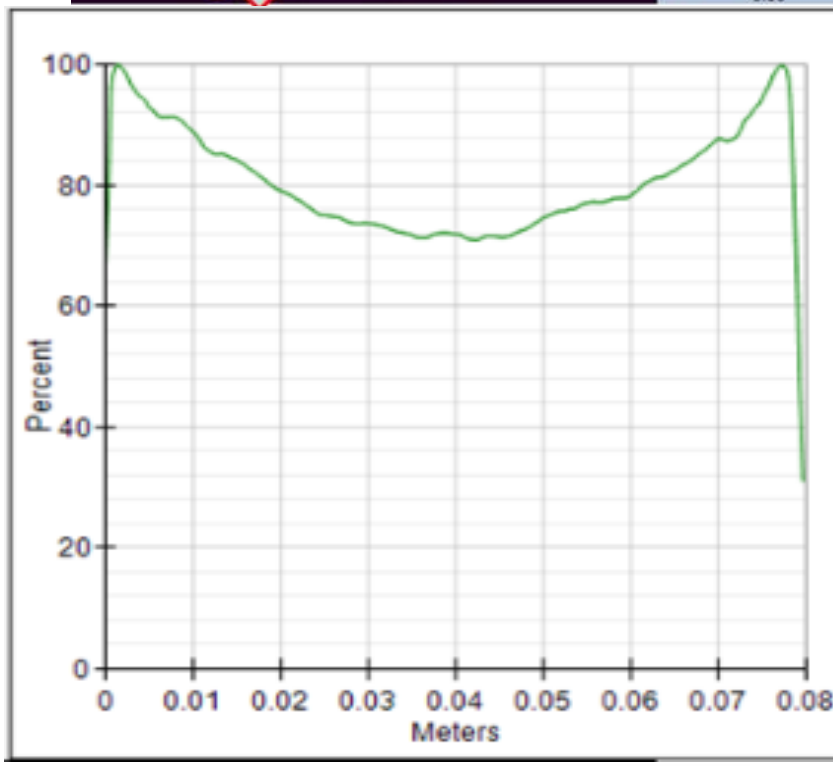


With ink jet printed shunting lines:

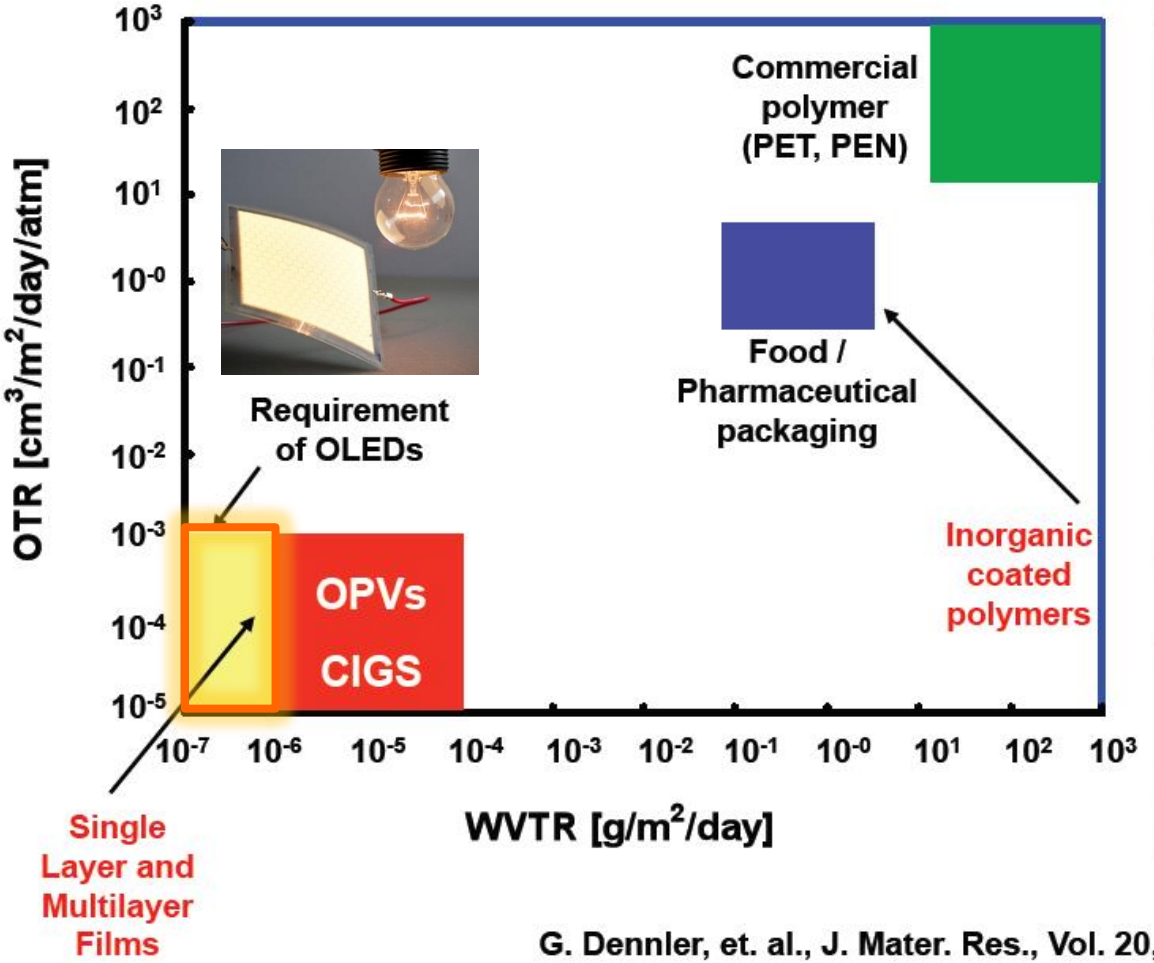
Less inhomogeneous due to shunt lines







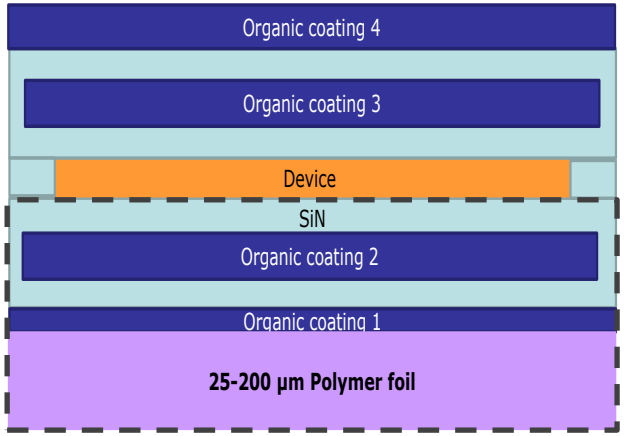
4. Barrier Requirements Organic Electronics



G. Dennler, et. al., J. Mater. Res., Vol. 20, No. 12, Dec 2005. Vol.20, 3224

S2S Thin Film Barrier Technology @ Holst Centre

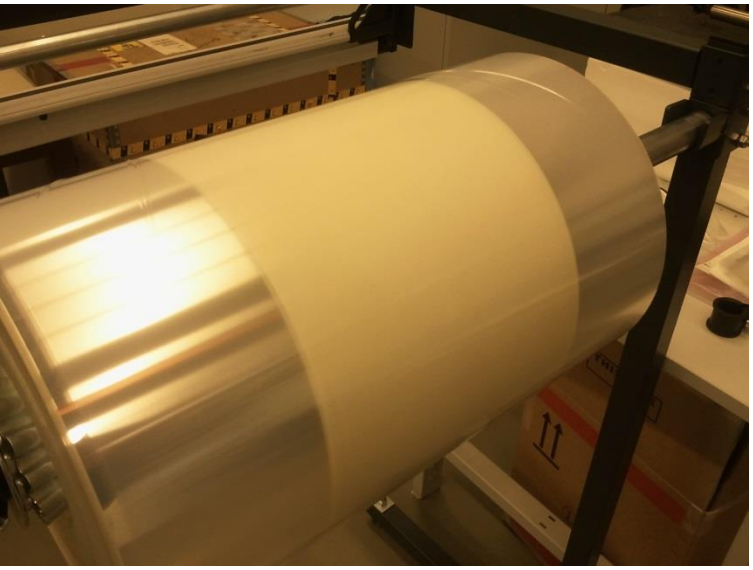
- **Holst Centre barrier fundamentals:**
  - Multilayer thin film barrier
    - PECVD SiN – organic coating – PECVD SiN
  - Inorganic layer (PECVD SiN)
    - real barrier with WVTR < 10^{-6} g/m^2/day
    - full coverage of cathode
  - Organic layer
    - decouple pinholes
  - Only 3 layers to keep costs low
  - Transparent:
    - suitable for top-emission or bottom-emission OLEDs



- **Validation done on real OLEDs against product spec:**
  - Black spot analysis in accelerated shelf lifetime test (60°C/90% RH)

4 R2R barrier film

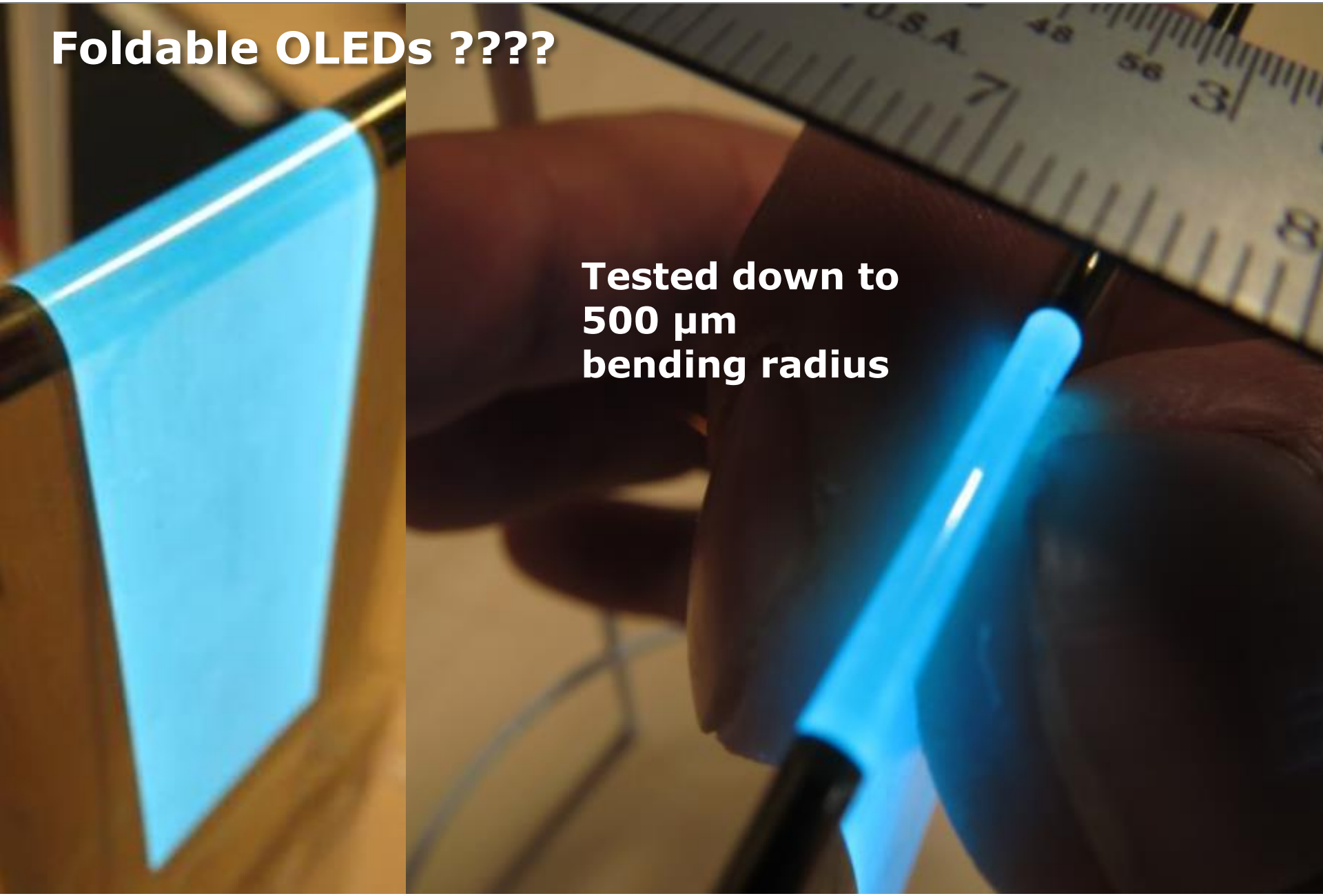
- **WVTR of the single SiN sampled over 350m length at 60°C and 90%RH for 20 days : Overall WVTR = (5±1)·10^{-5} g/m^{2}day**
- **450 m/day**
- **Full barrier stack R2R processed (OCP-SiN-OCP-SiN)**



ROLIC technologies

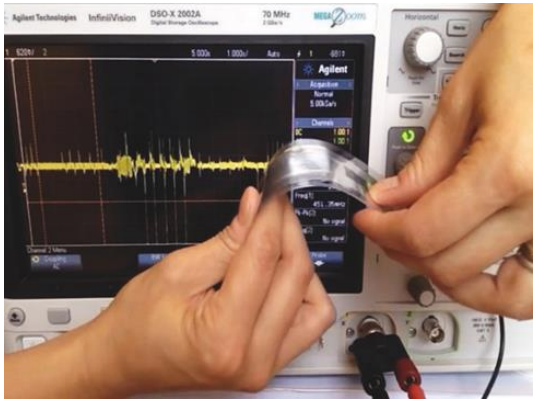
ROTH & RAU
CELL & COATING SYSTEMS

Foldable OLEDs ????



Integration

Light Touch Matters



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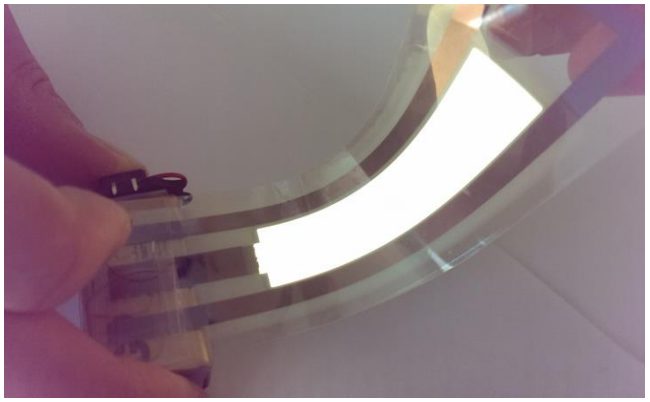

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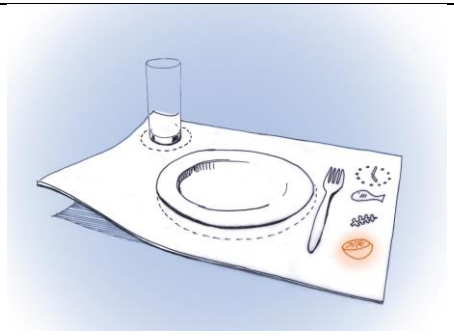			
Smart placemat to improve people's diet	Wristband for reminders and feedback	Force-sensitive grip for expressing anxiety	Intuitive interface for Emergency defibrilator

Conclusion

Lighting based on printing/ coating technologies

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no 281027 and 310311

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light.touch.matters
the product is the interface