High Resolution ESJET Printing for Solution Processing of Active Matrix OLEDs

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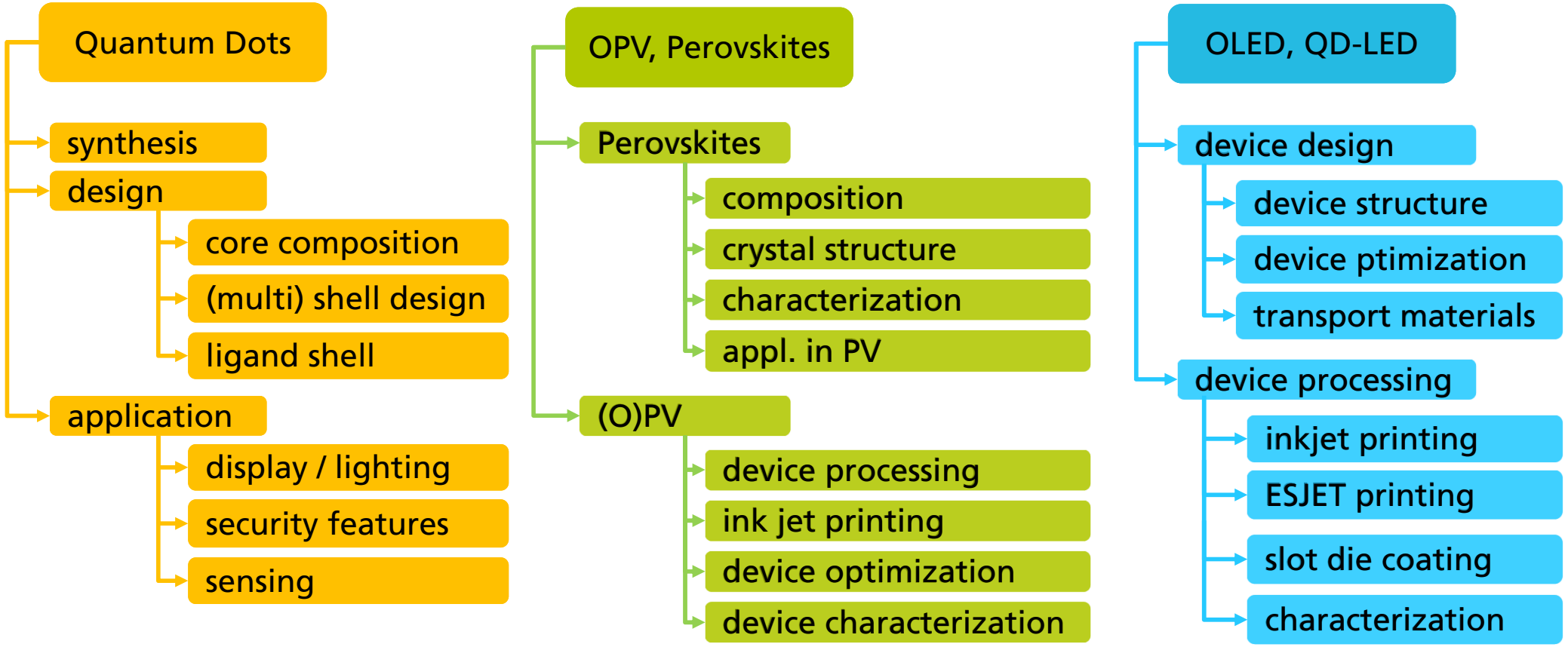
Outline

- **Introduction**
- **ESJET Setup**
- **Printing with ESJET**
- **First results**
- **Outlook**

Fraunhofer IAP

- First Polymer OLED (1994)
- Organic Electronic (1999)
- Passive Matrix OLEDs (2001)
- OLED Printing (2006)
- QD Synthesis und QD-LED (2009)
- Pilot Line (2012)

Topics @ Fraunhofer IAP - Functional Material and Devices



Why do we need another drop on demand printing method?

Inkjet printing successfully implemented also for OLED processing

Limitations:

- resolution ~ 10 – 20 µm
- Viscosity range < 30 cp

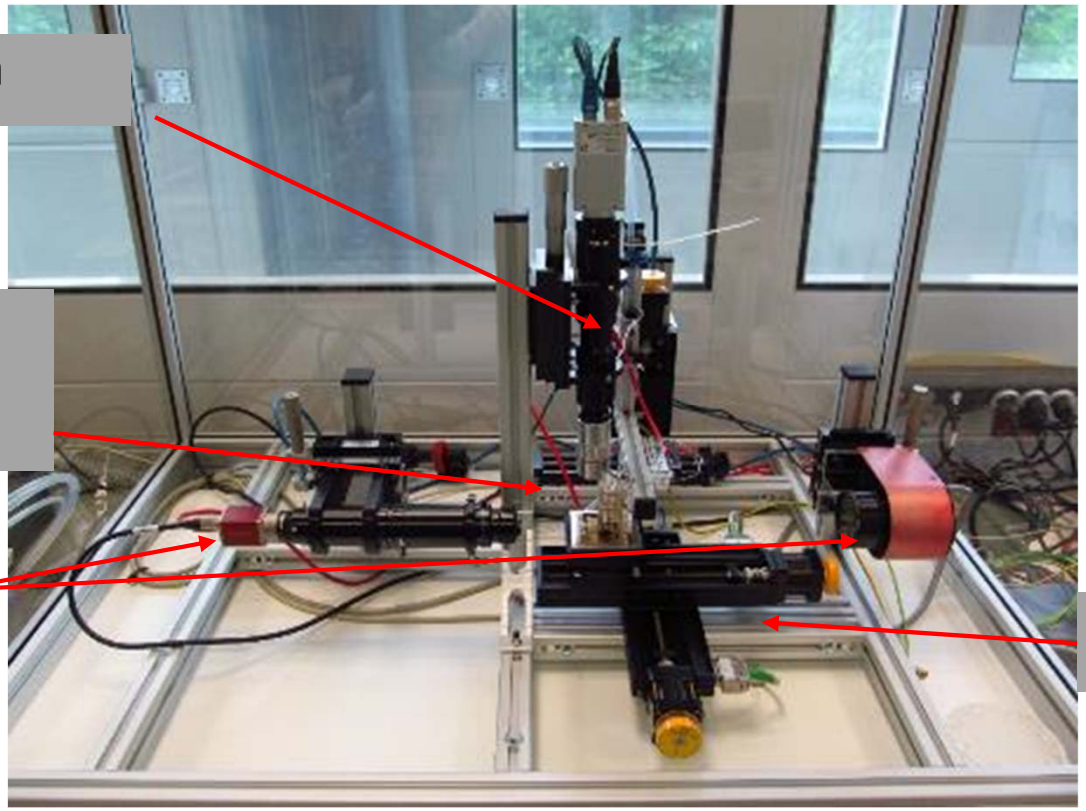
ESJET printing increases the range of

- Feature sizes: < 10 µm
- Viscosity range up to 10^5 cp

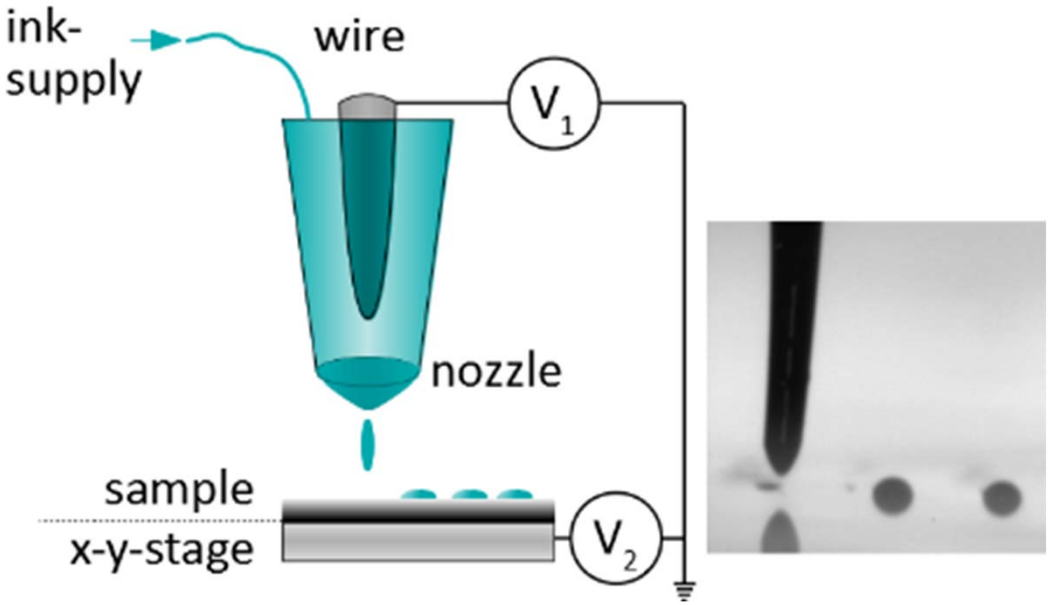
Inkjet printed OLED

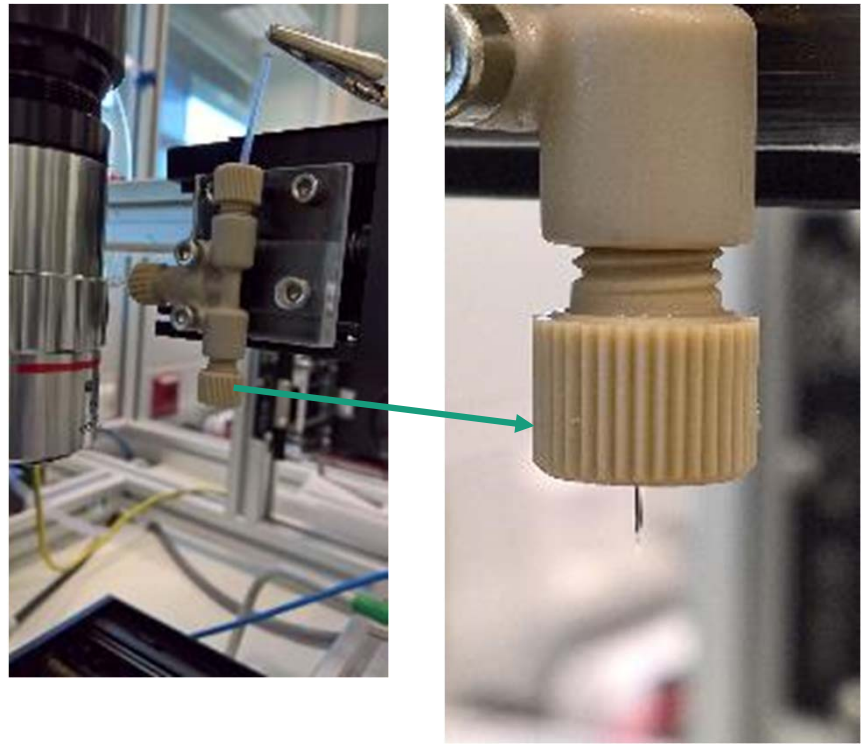
New Printing technology for High Resolution - ESJET

ESJET Printer @ IAP



ESJET-PRINTING – PRINCIPLE AND SETUP

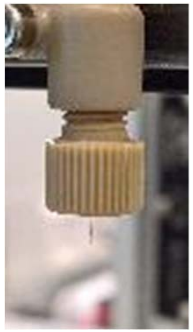


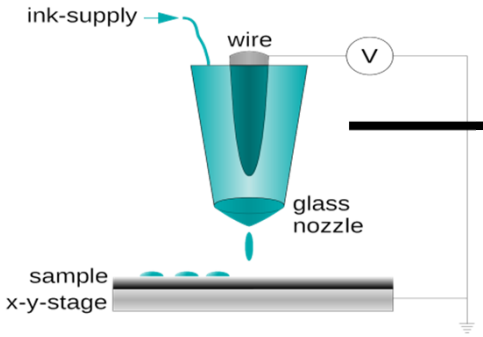


→ Drop on demand printing through application of high electric fields

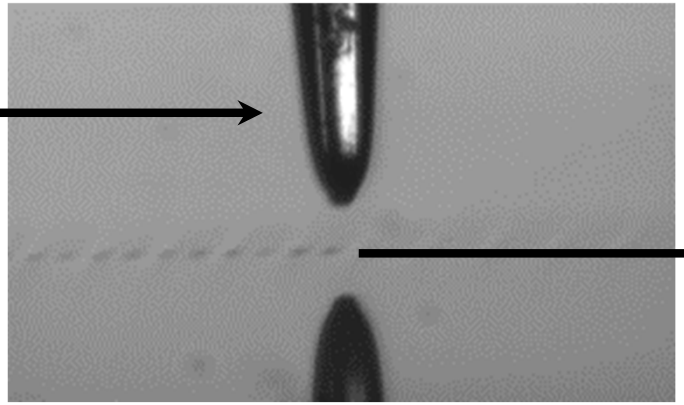
HIGH-RESOLUTION ELECTRO-STATIC JET (ESJET) PRINTING

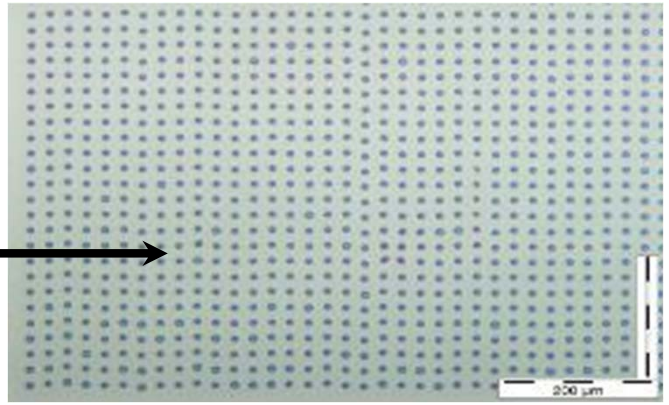
Printing Mode of ESJET

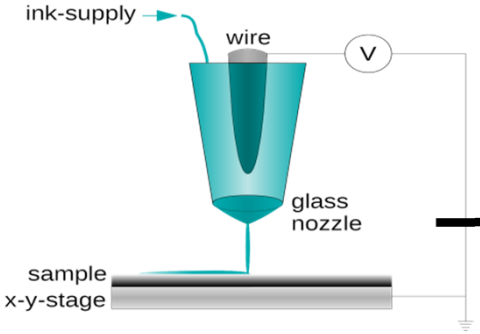




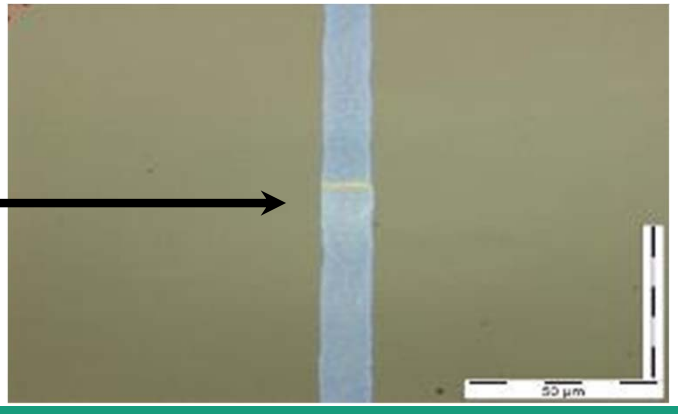
Mode: drop-on-demand







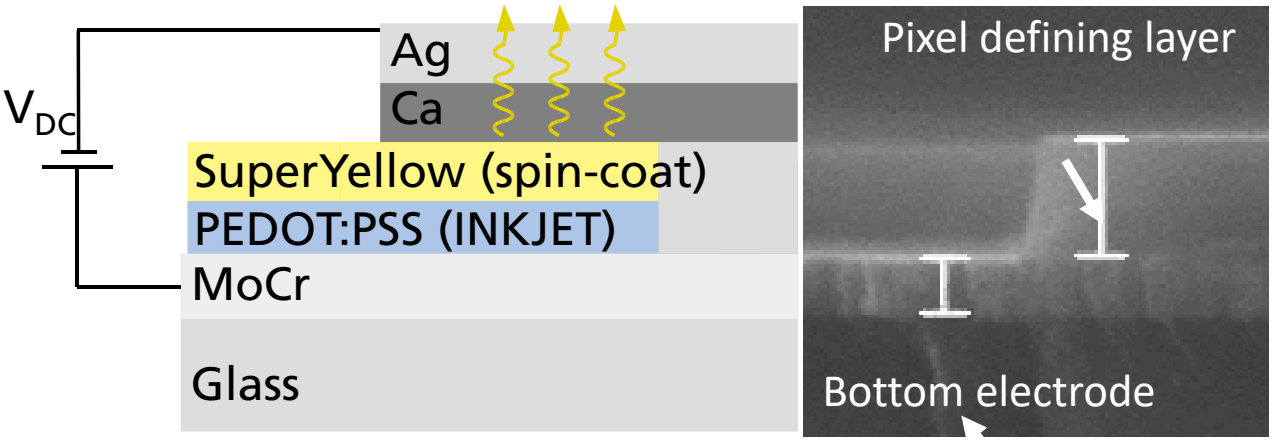
Mode: cone-jet



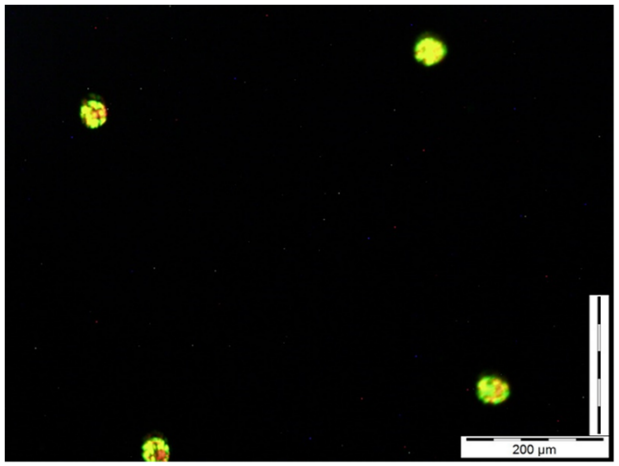
Hi-RESPONSE Fraunhofer IAP

Materials testing for single-droplet/single-pixel OLEDs

INKJET-printed OLED



OLED stack structure



OLED from single droplets of PEDOT:PSS

Single-droplet OLED with large pitch → higher resolution demonstrator for ESJET

High-Resolution Drop-on-Demand Printing

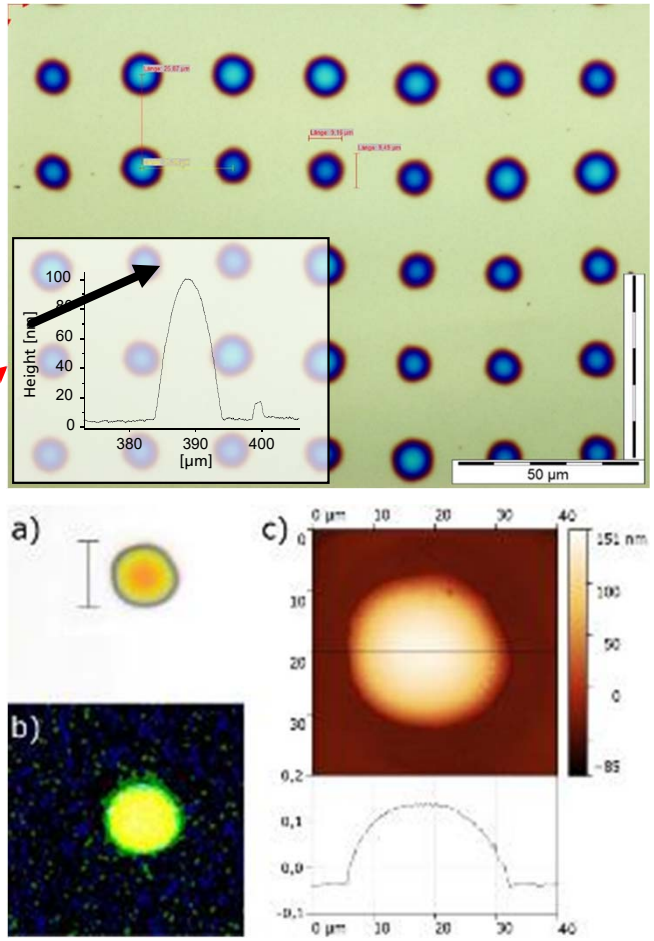
Highest Resolution so far:

PEDOT:PSS → 3.5 µm (non-conducting)
PEDOT:PSS → 7 µm (conducting)

Superyellow → 10 µm

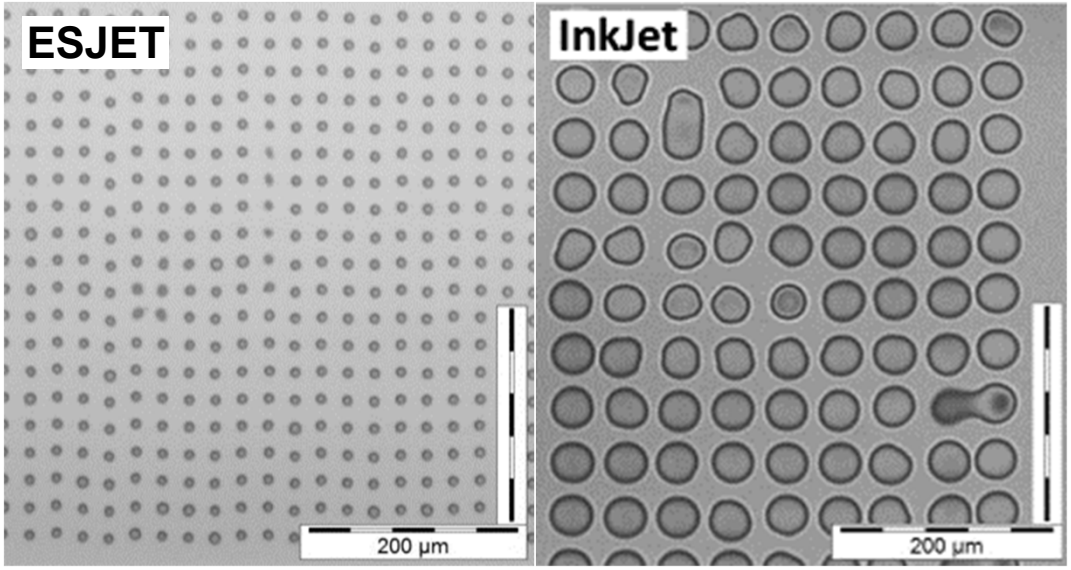
Reliable Printing:

PEDOT:PSS → 10 µm
Superyellow → 20 µm



Comparison: Inkjet versus ESJET

Printing on MoCr substrates with 50 µm spacing

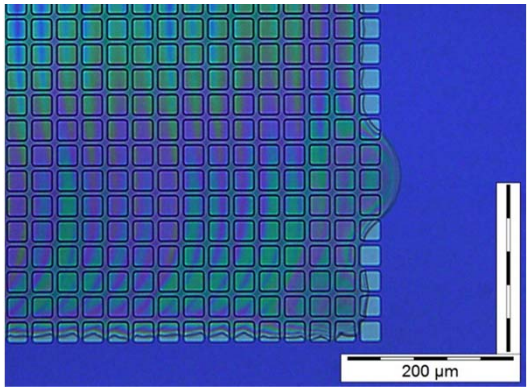


Drop volume ≤ 0.5 pl for ESJET versus 4 pl for Inkjet

Fabrication and characterisation of pixel test structures

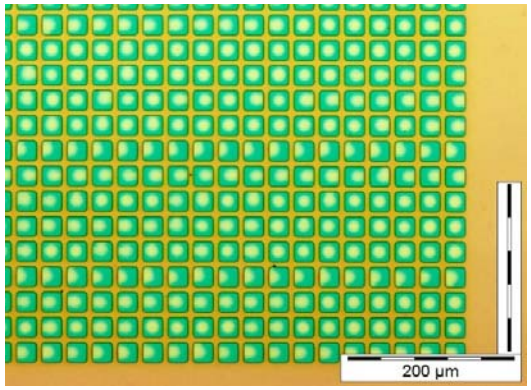
INKJET vs. ESJET print of PEDOT:PSS

INKJET, 20 µm (850 dpi)



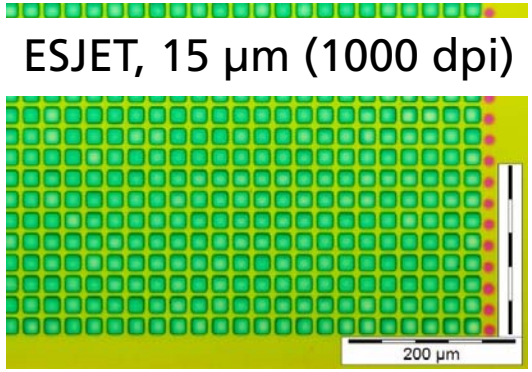
Drops too large and merge

ESJET, 20 µm (850 dpi)

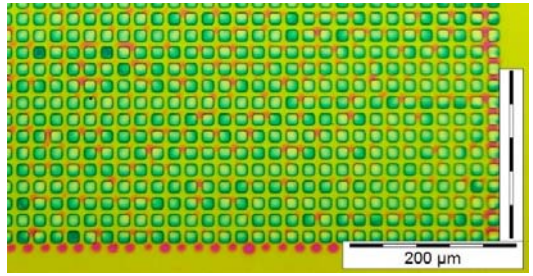


Drops much smaller

ESJET, 15 µm (1000 dpi)



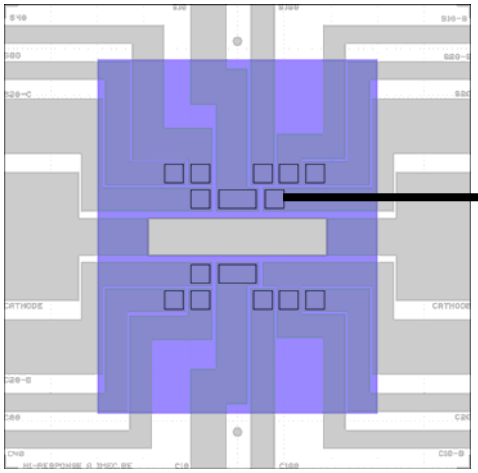
ESJET, 10 µm (1250 dpi)

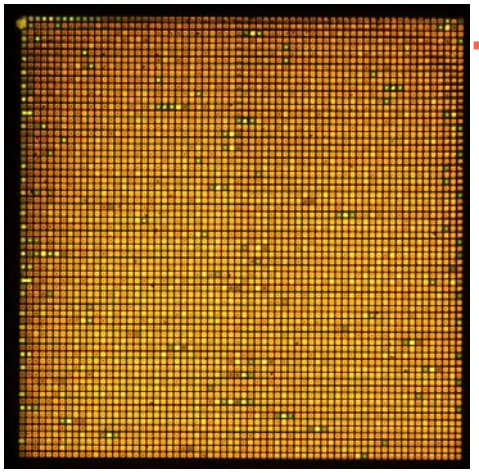


INKJET: 20 µm too small, ESJET: 10 µm possible
(on the edge of IAP pilot-line aiming precision)

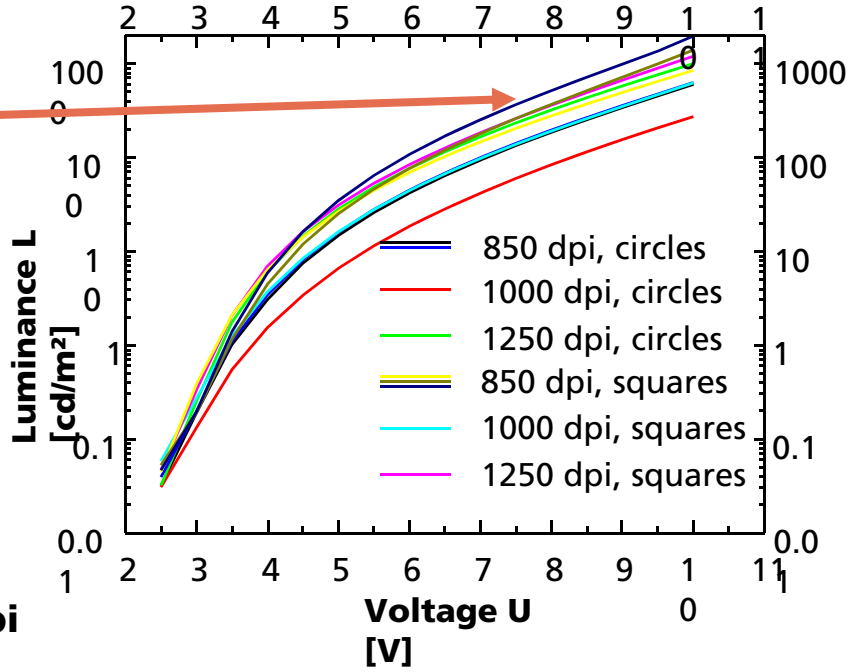
Fabrication and characterisation of pixel test structures

ESJET printed OLED structures, >500 ppi





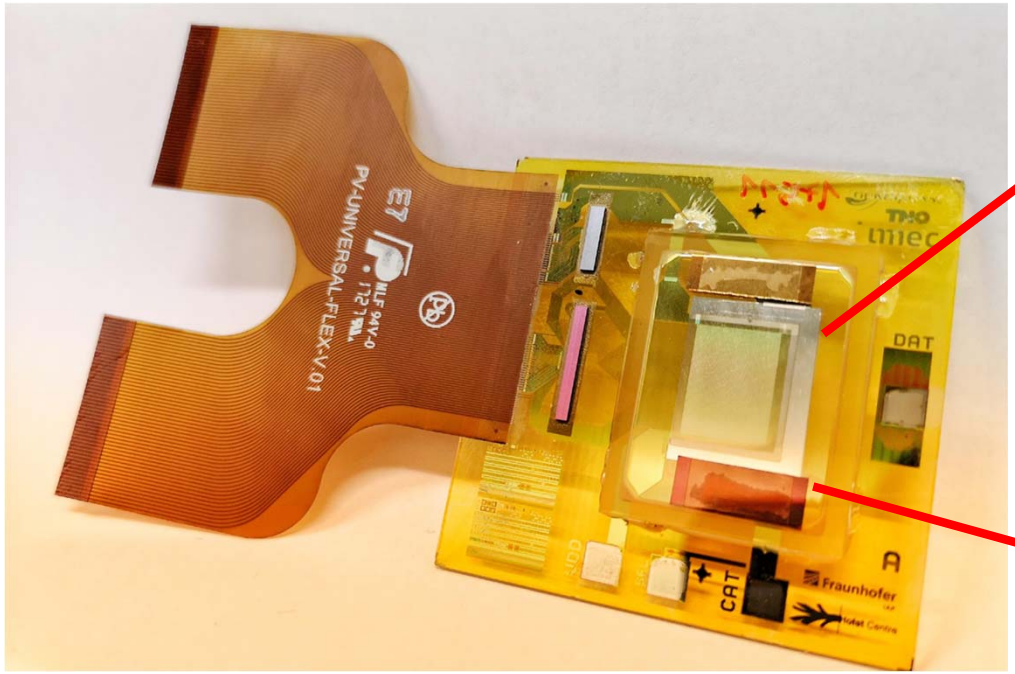
20 x 20 µm squares on 2x2 mm
4225 pixels, 30 µm pitch, **850 dpi**



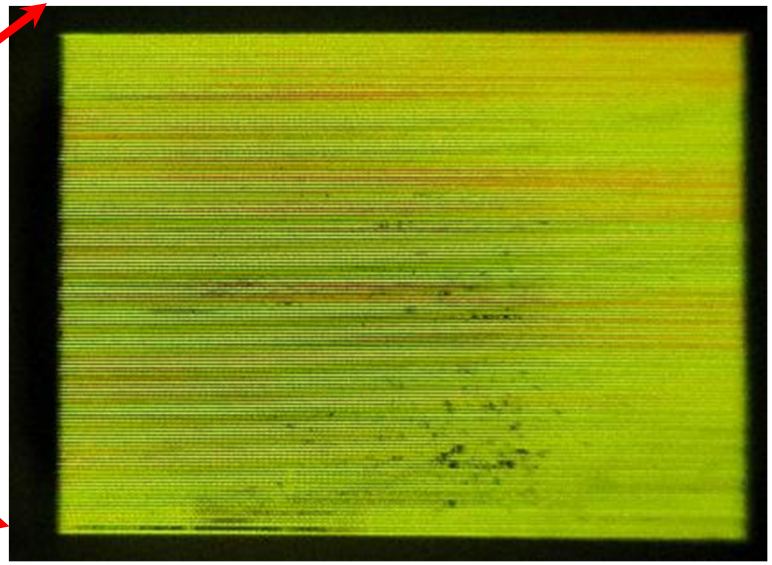
Reliable printing of PEDOT:PSS (thousands of pixels) with resolution >500 ppi achieved

Active Matrix OLED Display Design and Realisation

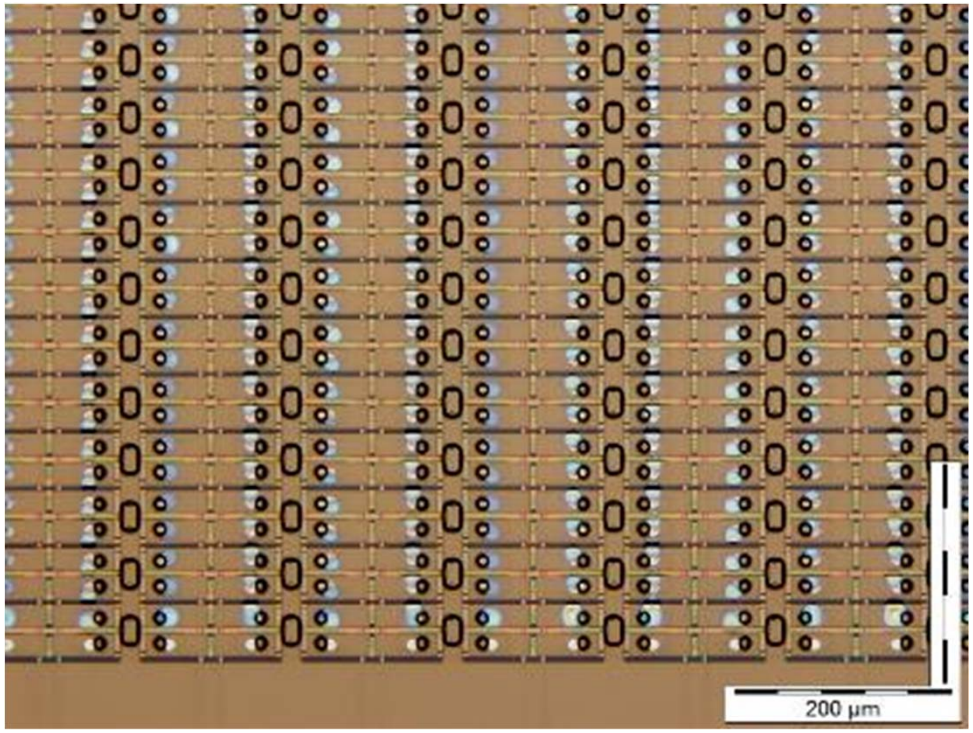
ESJET-printed AMOLED DISPLAY

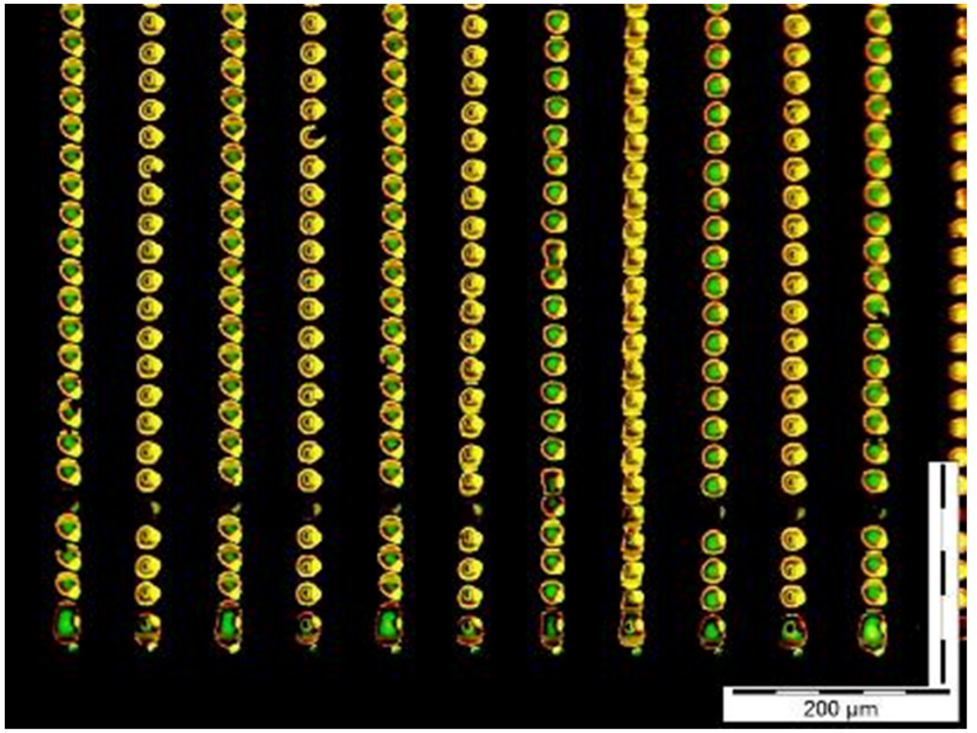


OLED with ESJET printed PEDOT:PSS
→ 62976 PIXELS printed successfully



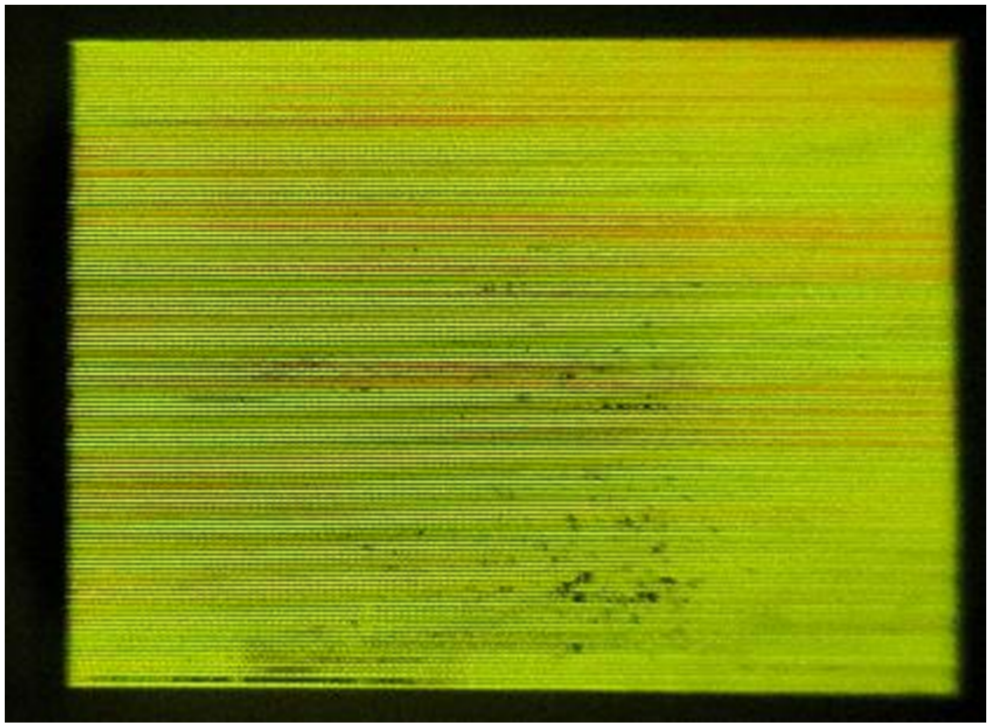
ESJET printing of PEDOT:PSS on AM backplane





OLED with ESJET printed pedot:pss

- QQVGA: 300 ppi (128 x (3x164)
- Substrate: 5.3 x 5.3 cm
- Active Area: 0.5'' (9 mm x 12.8 mm)
- → 62976 pixels to print (20 Hz)
- Printed with 1 nozzle (15 µm diameter)
- Printing time: 104 minutes



Images on ESJET printed OLED display

Summary

- Design and fabrication of 300ppi backplane for R-G-B AMOLED display are demonstrated
  - ESJET high voltages during printing do not interfere with backplanes electronic circuitry, e.g. no Electrostatic Discharge (ESD) damage
- Portable demonstration setup for ESJET printed AMOLED display is designed and realized
- ESJET Feasibility for OLED Printing
  - Achievable Resolution < 5 µm with ink viscosities 10 – 100 times higher than for inkjet
  - Achievable layer thickness sufficient for OLED stack device with one print step
  - Challenges
    - implementation of multi nozzle system for higher efficiency
    - Print RGB with multi nozzle system
  - Drawback
    - Printing frequency need to be improved for implementation into production process: currently ~10 Hz need to be increased to 1 to 10 kHz

Thank you for your attention!

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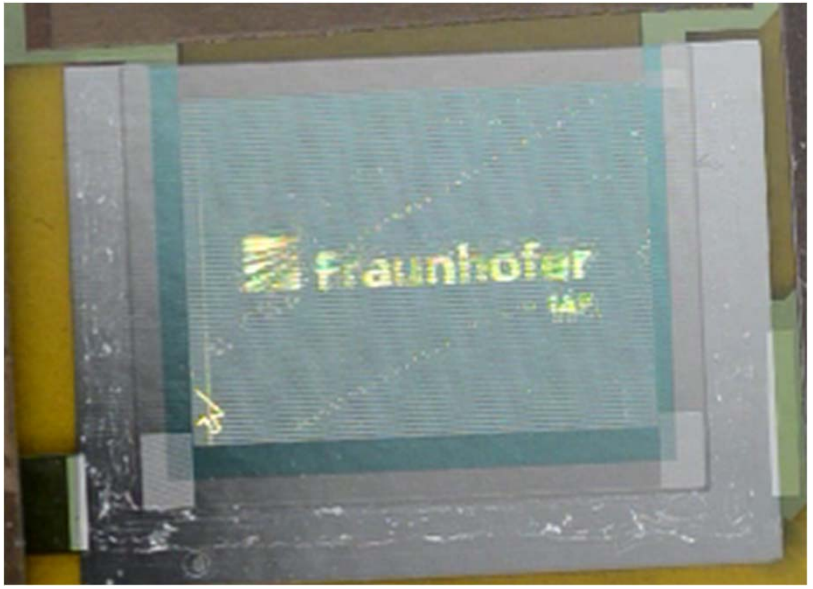

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