PEROVSKITE PRINTING PHOTONICS

HZB Helmholtz Zentrum Berlin

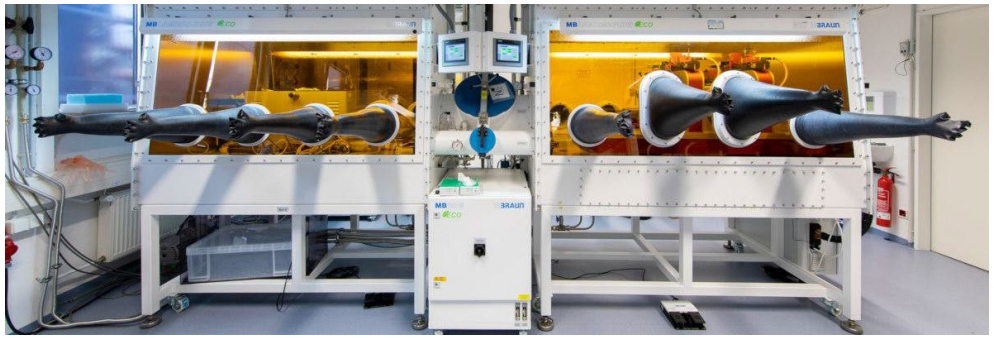
PVcomB

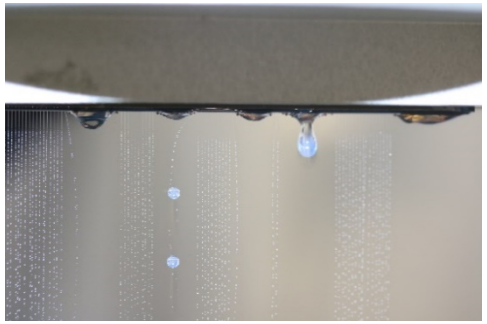
HySPRINT

EMIL

Break-out Session

Inkjet-printed applications - PV, LEDs and integrated Devices





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Inkjet-printed applications - PV, LEDs and integrated Devices

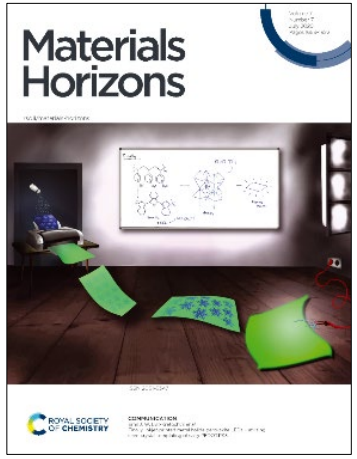
Inkjet-printing is a **reliable**, **versatile** and **cost-effective industrial production technology** in many areas from graphics to printed electronics.

We use Inkjet-printing technology as a

a) scalable deposition technique for hybrid and metal halide perovskite optoelectronic applications (PV, LED, FET,…).[1]

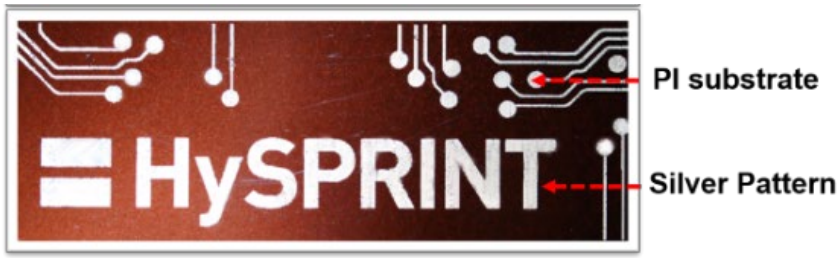
b) highly **accurate additive and subtractive process** such as metallization and module structuring.[2]

c) material screening platform, e.g. combinatorial inkjet-printing.[3]



First Inkjet-printed perovskite LED

[1] Hermerschmidt and Mathies *et al.* *Mater. Horiz.*, **2020**,7, 1773-1781



Particle-free silver ink

[2] Yang *et al. J. Mater. Chem. C*, ***2020***, *Advance Article*

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Combinatorial high-throughput printing

[3] Nässtrom *et al. J. Mater. Chem. A*, **2020**,8, 22626-22631

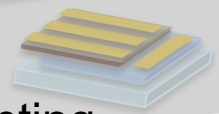
inkjet-printing perovskite solar cells at HZB

R&D

- Ink characterization
- Ink development
- Inkjet-printing process development
- New hybrid Materials
- Small area devices (<1cm²)

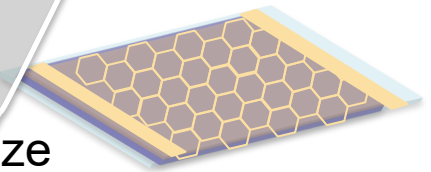
Prototyping

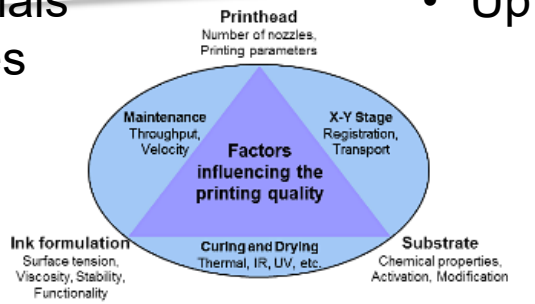
- Small and medium area devices (~cm²)
- Module development
- Ambient and inert printing
- Up to 17% PCE

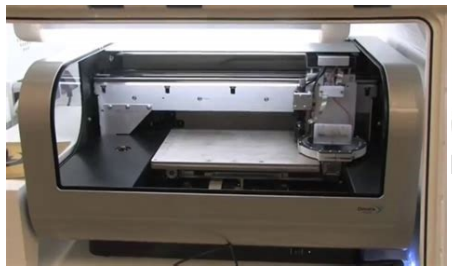


Industrial Printing

- Multi-head & combinatorial printing
- Up-scaling to full wafer size
- Controlled atmosphere







Fujifilm Dimatix

Fujifilm Dimatix

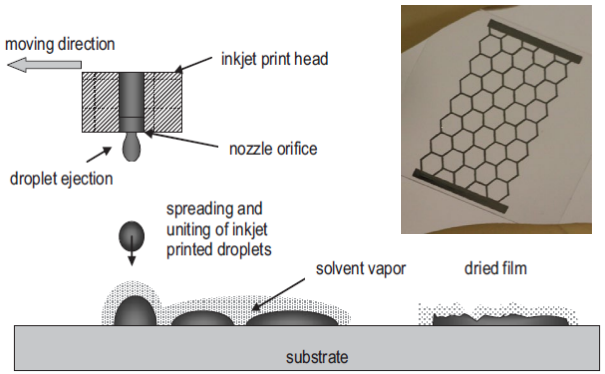
PixDro LP50

Konika Minolta

Spectra S-class

NotionSystems n.jet Lab

inkjet-printed transparent conductive electrodes (TCEs)



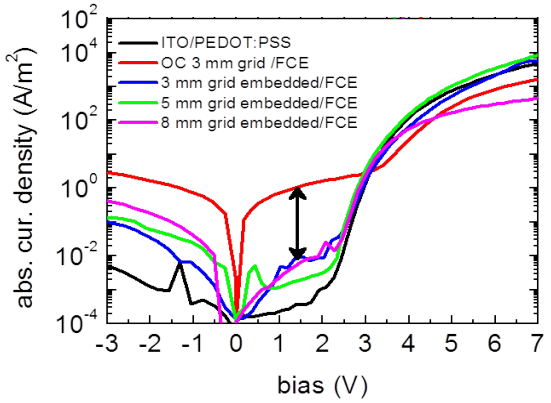
requirements:
- low cost, flexible, stable,
- low sheet resistance (< 5Ω/sq)

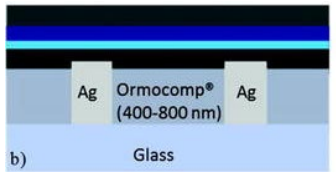
state of the art:
- indium tin oxide (ITO)
- aluminium-doped zinc oxide (AZO)

emerging alternatives:
- carbon nanotubes or graphene
- PEDOT:PSS
- Cu/Ag nanowires (NWs)
- particle-free inks

F. Hermerschmidt et al. Adv. Mater. Technol. 4, 1800474 (2019).

Ag



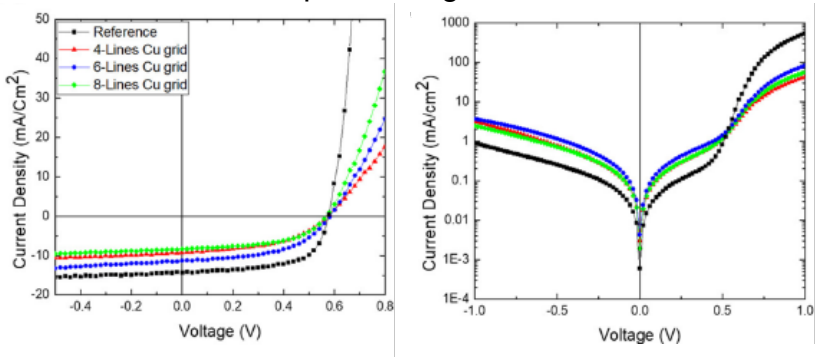


Ag-grid/PEDOT:PSS/HIL/LEP/Ca/Al
improved stability due to embedding
max. luminance 20000 cd/m²
max. efficacy 9.4 cd/A
reduced shunt current

S. Nau et al. Adv. Mater. 25 4420 (2013).
L. Kinner, et al. Appl. Phys. Lett. 110 101107 (2017).

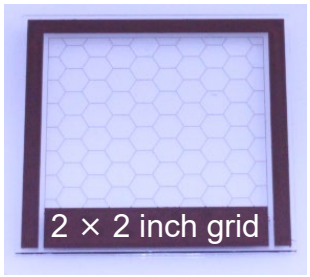
Cu

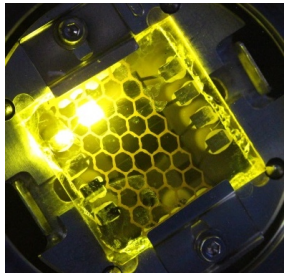
first example of Cu-grid based OPVs



OPVs	Voc (V)	Jsc (mA.cm-2)	FF (%)	PCE (%)
Reference	0.58	14.3	61.7	5.11
IJP Cu grid	0.58	11.26	51.7	3.38

first example of Cu-grid based OLEDs

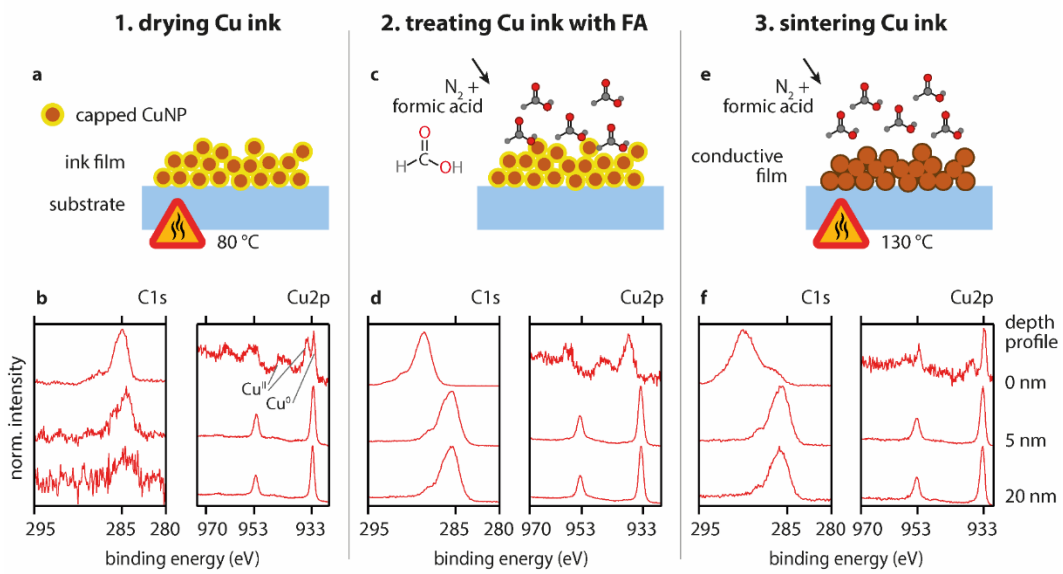




E. Georgiou et al. Solar RRL 2 1700192 (2018).
S. Pozov et al. Flex. Print. Electron. 4, 025004 (2019).

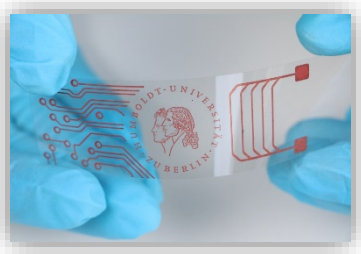
electronic circuits produced by inkjet printing Cu ink

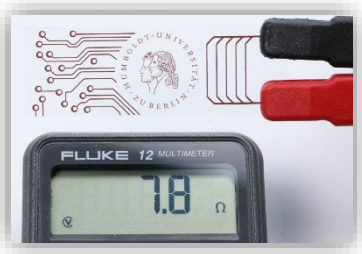
sintering at low temperature (<130 °C) using formic acid

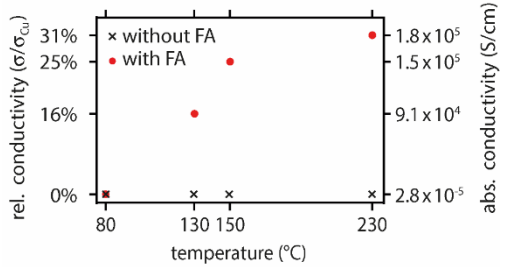


Adhesion test: 0 (ISO), 5B (ASTM) and high conductivity achieved at low T

No noticeable increase in resistivity after five days under ambient conditions







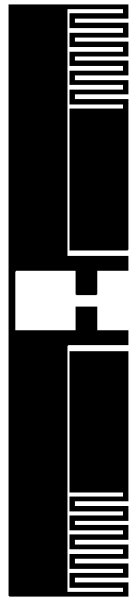
F. Hermerschmidt et al. Adv. Mat. Technol. 3, 1800146 (2018).

inkjet-printed UHF-RFID antenna

first prototypes printed on laboratory scale

upscaling to S2S test facility

upscaling to R2R processing



bitmap file

printed sample

© Fujifilm USA

laboratory printer DMP 2831

© Fujifilm USA

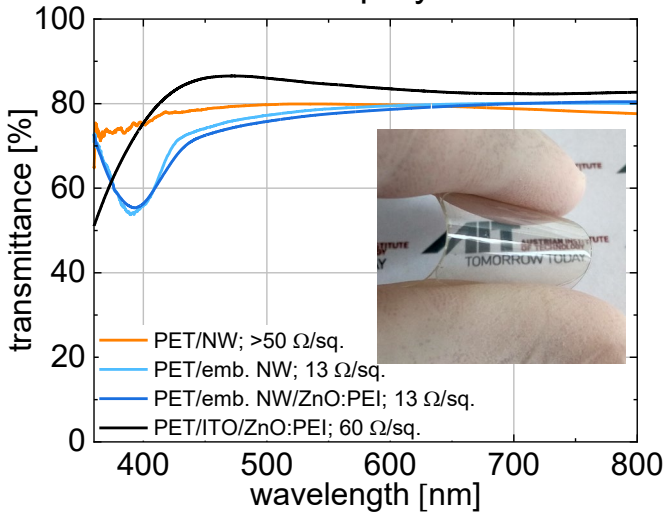
S2S test printer with industrial printhead

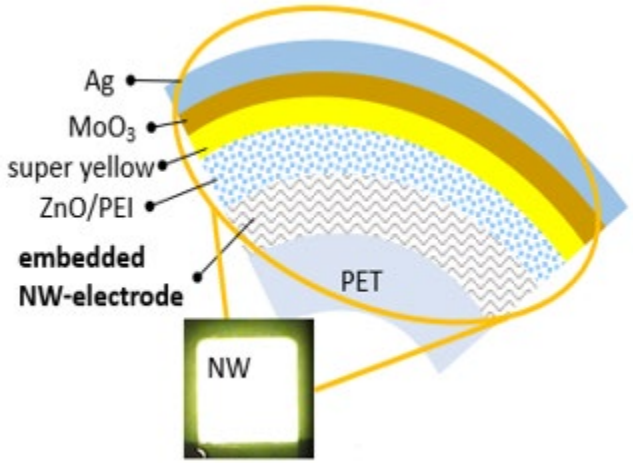
© 3D Micromac AG

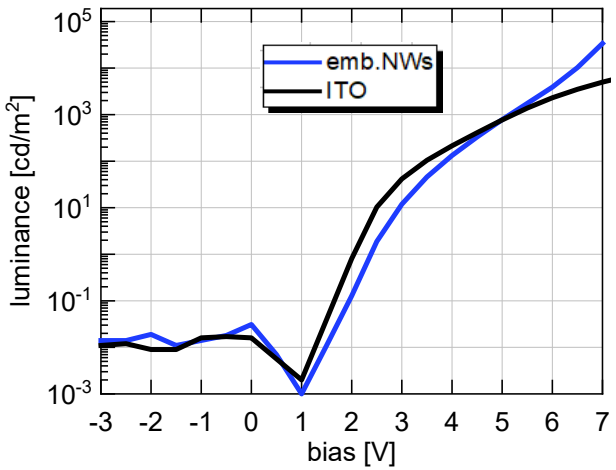
R2R industrial printing machine

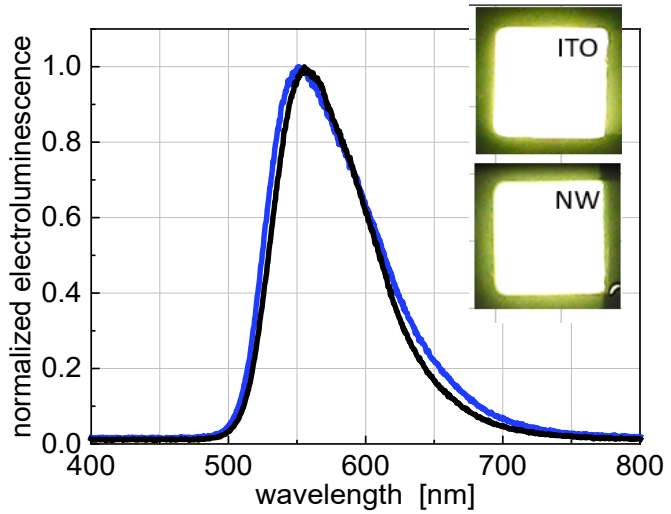
beyond inkjet printing: flexible electrode approaches for OLEDs

flexible spray-coated embedded Ag nanowire electrodes



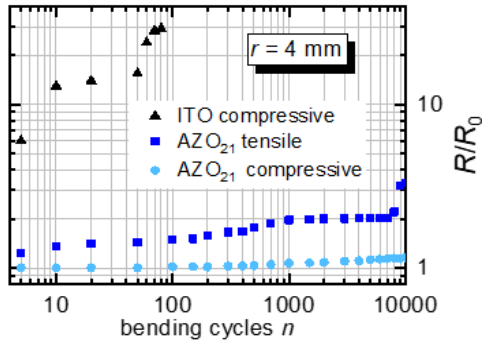


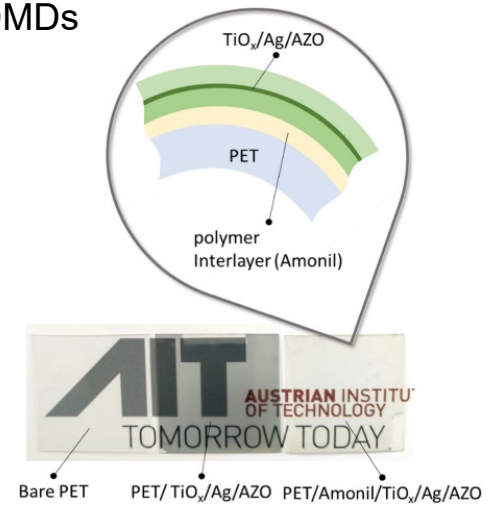


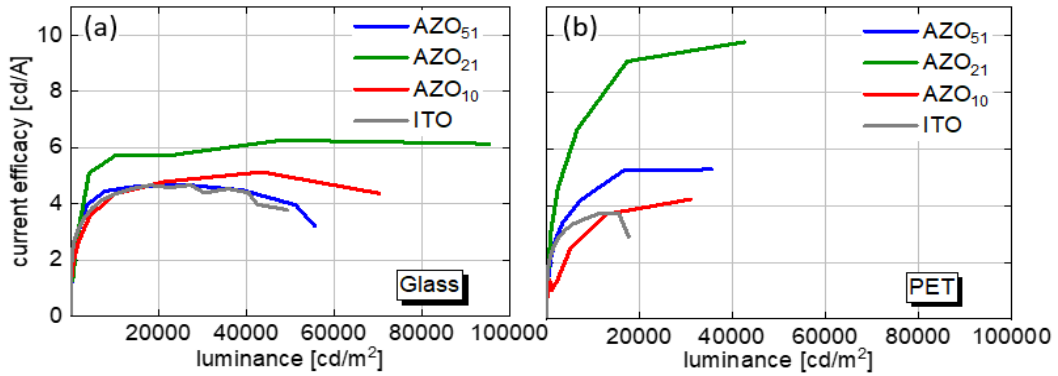


L. Kinner et al. Nanotechnol. 31, 365503 (2020).
L. Kinner et al. Phys. Status Solidi RRL 2000305 (2020).

transparent electrodes using DMDs (dielectric/metal/dielectric)







L. Kinner et al. Mater. and Design 168, 107663 (2019).
L. Kinner et al. in preparation.

Industry Day

PEROVSKITE PRINTING PHOTONICS

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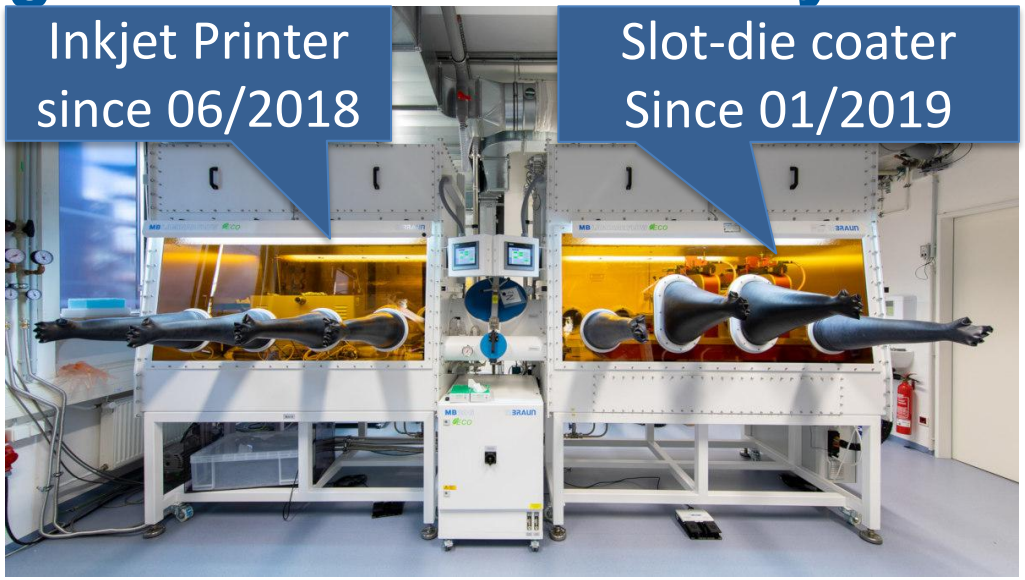
get in touch with the system / utilise equipment



CONTRACTUAL SCIENTIFIC RESEARCH

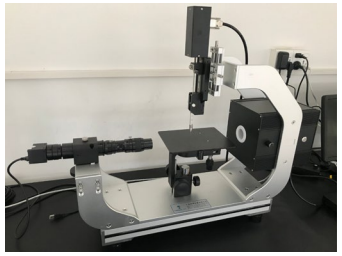
- Utilise tools and methods for next generation energy devices and printed electronics
- **Ink formulation** and optimization (viscosity, surface tension, contact angle and particle size)
- **Film characterization** (thickness, absorptivity, conductivity, morphology)
- **Functional device** coating and testing

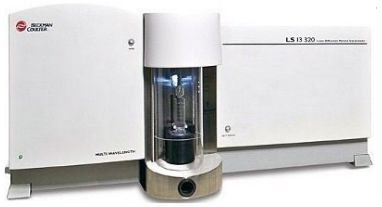
Inkjet-Printing or Slot-Die Coating WORKSHOPS

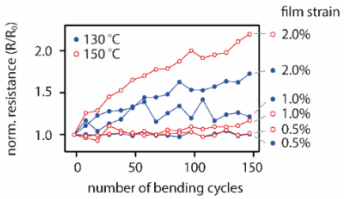
At HySPRINT Innovation Lab

- 2-day guided workshops
- Insights into scalable production of OPV, perovskites, OLED, batteries and more
- Supplementary lectures
- Q&A access to expert instructors
- Guided programs OR bring your own materials!

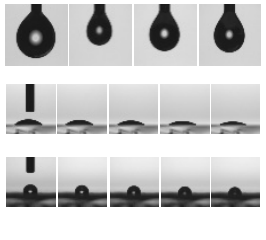

Viscosity

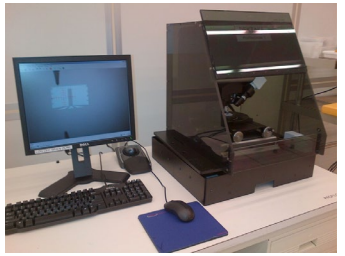

Surface energy


Particle size

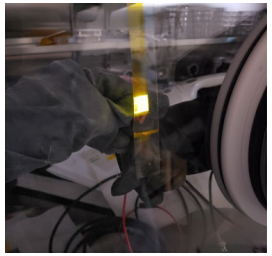


Bending/Adhesion


Wetting


Layer thickness


Absorbance


Device fabrication

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Florian Mathies

What are
YOU
looking for from HZB?

Felix Hermerschmidt