DIRECT PRINTING OF (ORGANIC) LIGHT EMITTING DEVICES ON TEXTILE

Inge Verboven

universiteit hasselt | imec
imo-imomec

OUTLINE

- Introduction
- Smart textiles
- Approaches for light emission
- OLED
  - Light emitting mechanism
  - Advantages and disadvantages
  - Structures
  - Techniques
  - Results
  - Challenges

INTRODUCTION

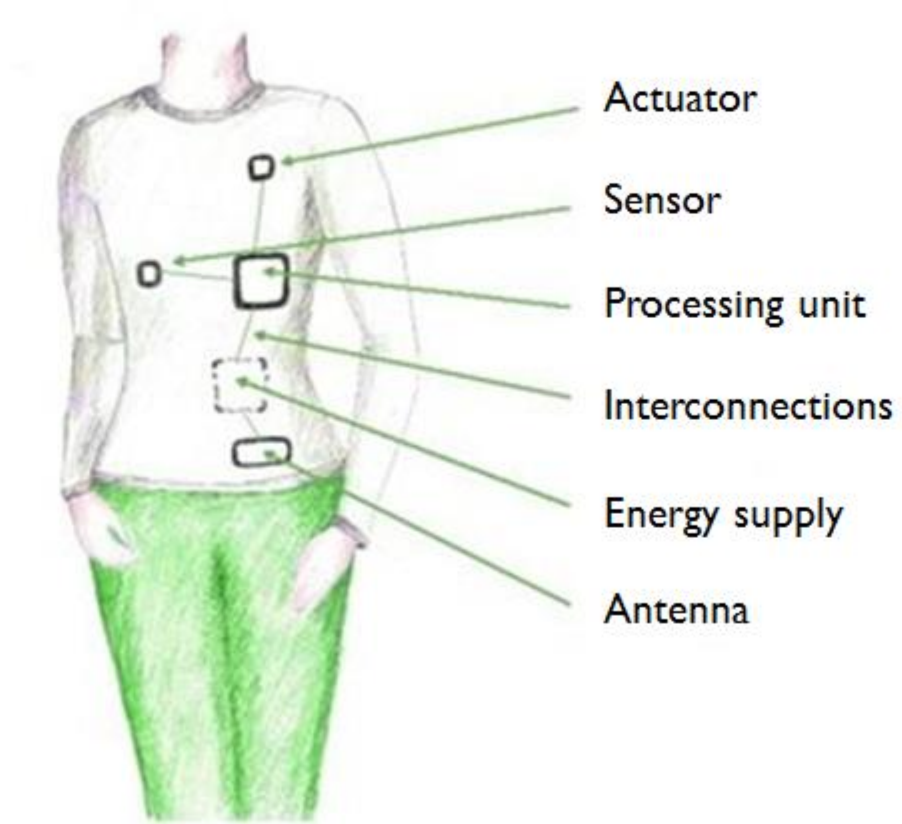
Institute for Materials Research (IMO)

Engineering Materials & APplications (EMAP)

- **Functional Materials Engineering (FME)**
- **Biomedical device engineering**
- **Energy systems engineering**

SMART TEXTILES

= textiles with enhanced functionality
= **Smart textile system**

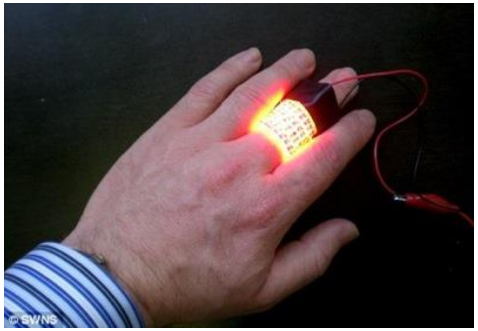
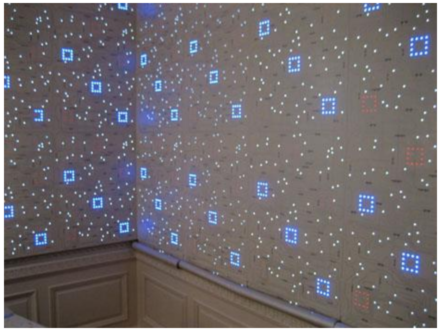


http://www.ugent.be/ea/textiles/en/research/research-themes/smart-textiles

SMART TEXTILES

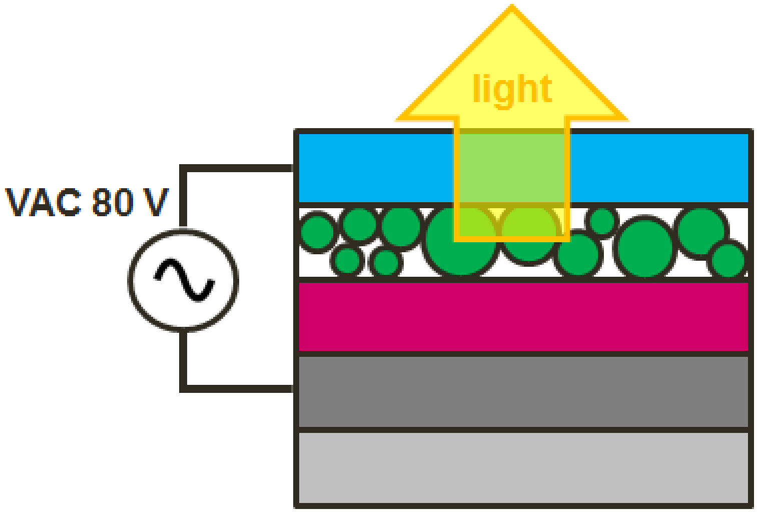
Integration of light-emitting properties in textiles

- Protective or safety clothing
- Fashionable clothing
- Indoor and outdoor applications
- Healthcare applications

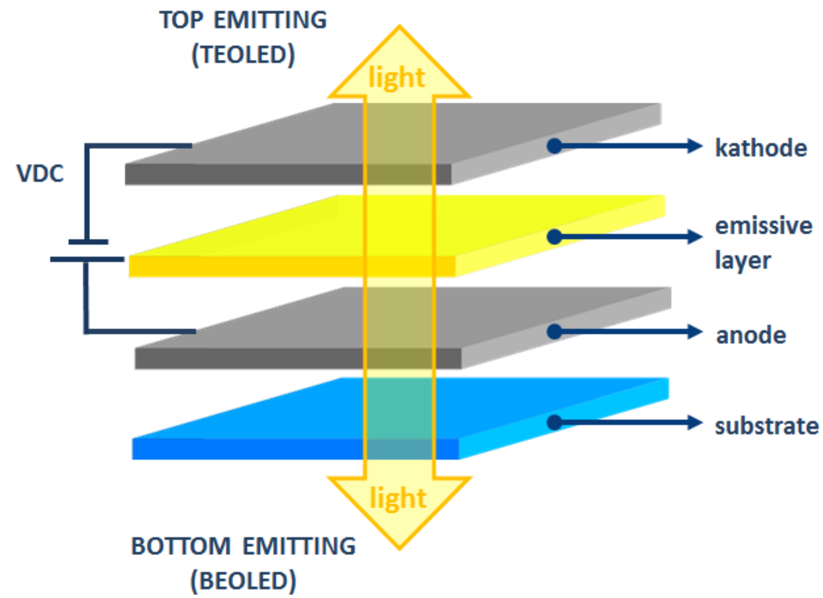

APPROACHES FOR LIGHT EMISSION

EL devices



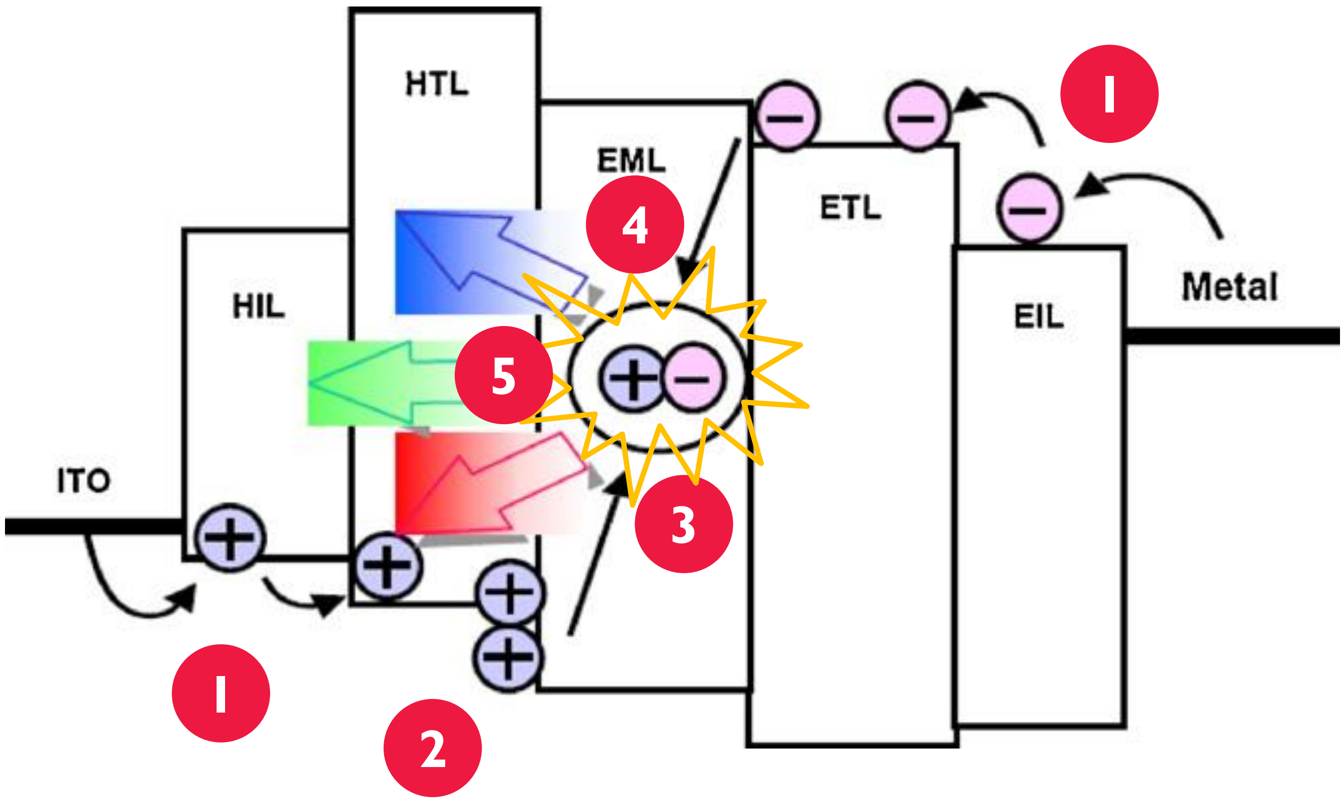
Indoor and outdoor applications

OLEDs



Wearable applications

OLED: LIGHT EMITTING MECHANISM



1) **Charge injection**
2) **Charge migration**
3) **Recombination**
4) **Exciton formation**
5) **Relaxation / light emission**

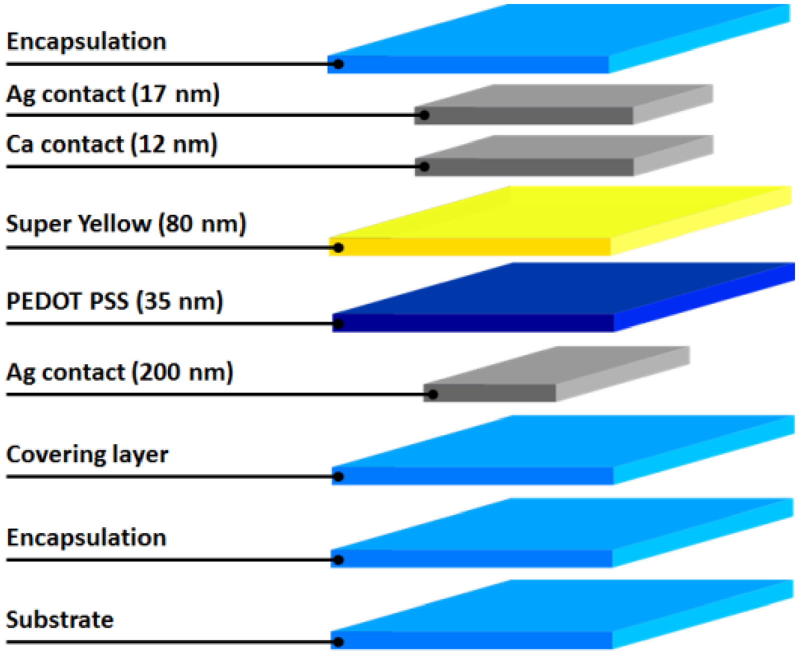
http://Thejo Kalyani, N., & Dhoble, S. J. (2012). Organic light emitting diodes: Energy saving lighting technology—A review. *Renewable and Sustainable Energy Reviews*, *16*(5), 2696–2723. doi:10.1016/j.rser.2012.02.021

OLED: ADVANTAGES AND DISADVANTAGES

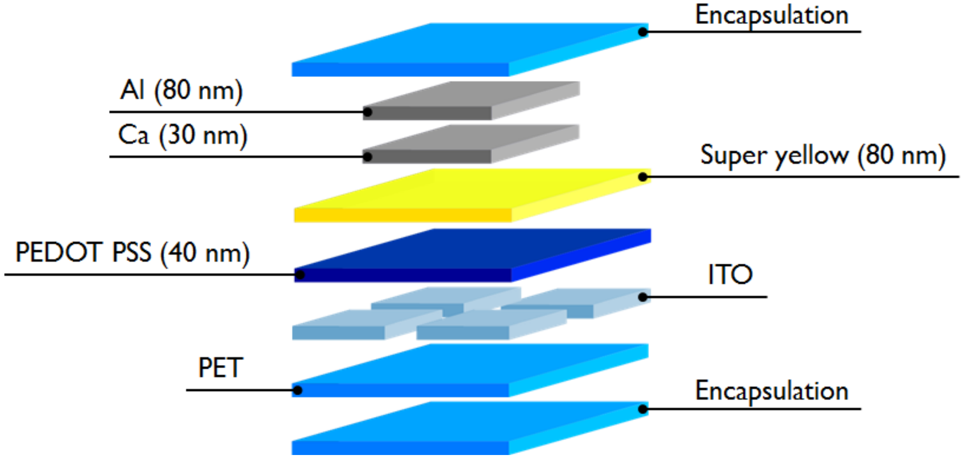
+	−
Thin layers	Encapsulation necessary (to avoid exposure to water vapor and oxygen)
Flexible substrates	Low lifetime
High brightness	Harmful solvents (toluene, chlorobenzene, …)
Low power supply (3-5 V)	Expensive production techniques (vacuum deposition, ..)
Low energy consumption	
Good efficacy	
Large fields of view	

OLED: STRUCTURE TEOLED

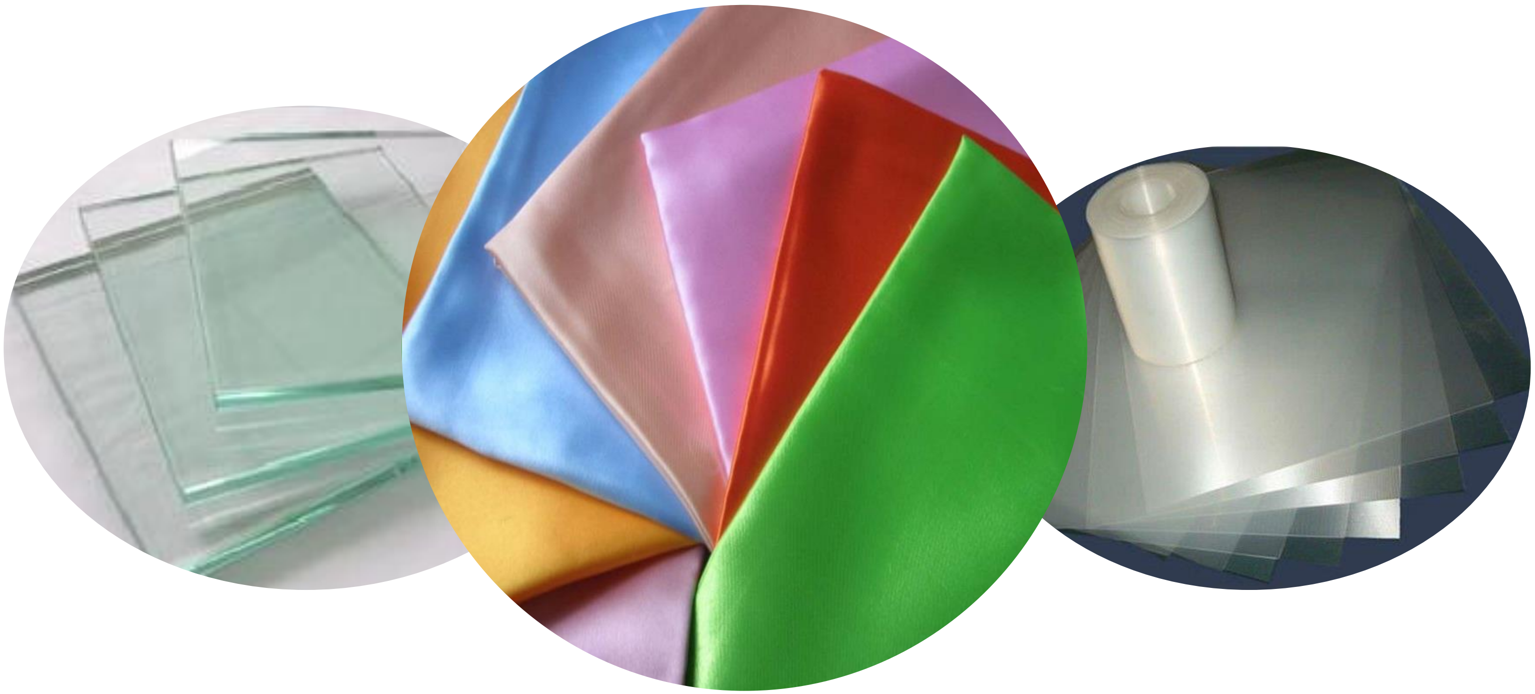
BEOLED on PET

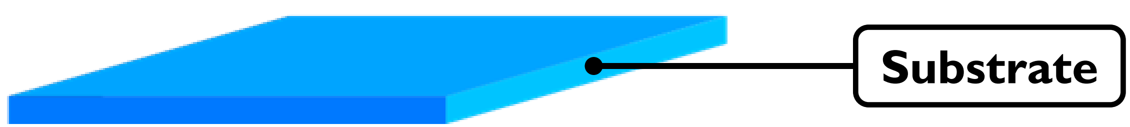


TEOLED on textile

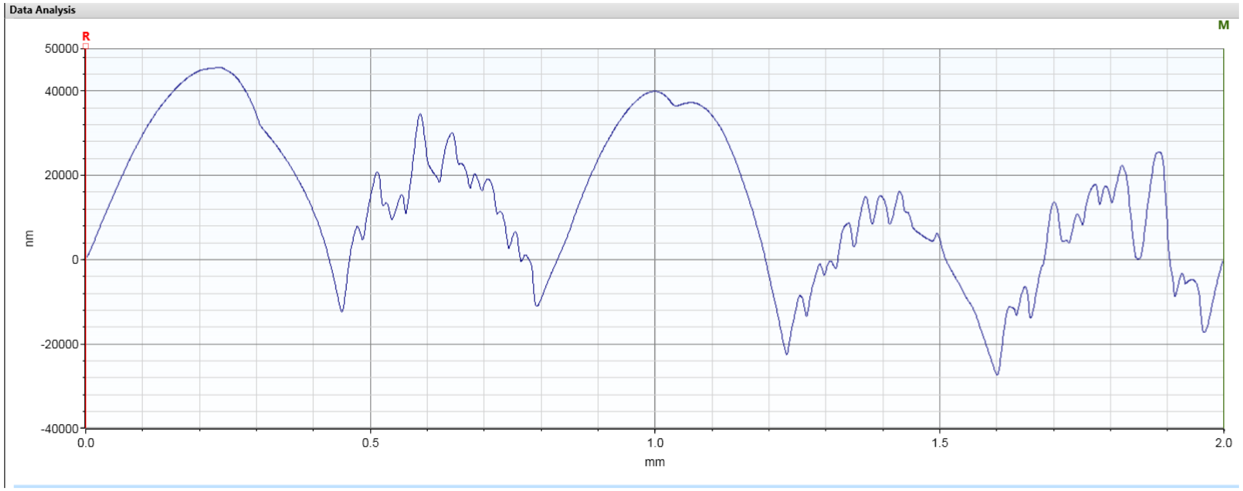


OLED: TECHNIQUES

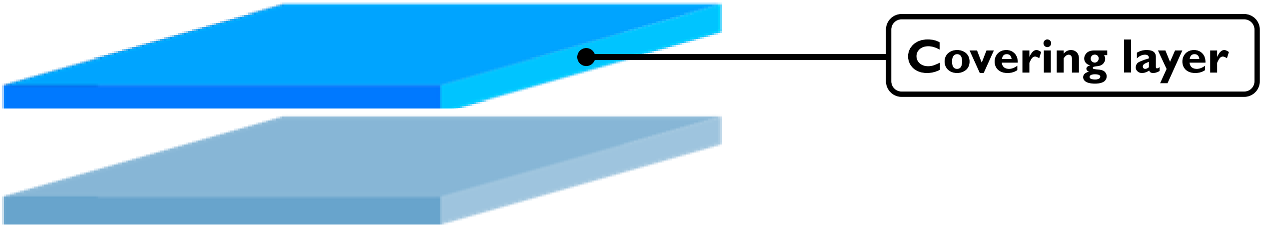




OLED:TECHNIQUES



Dektak surface profile measurement on polyester

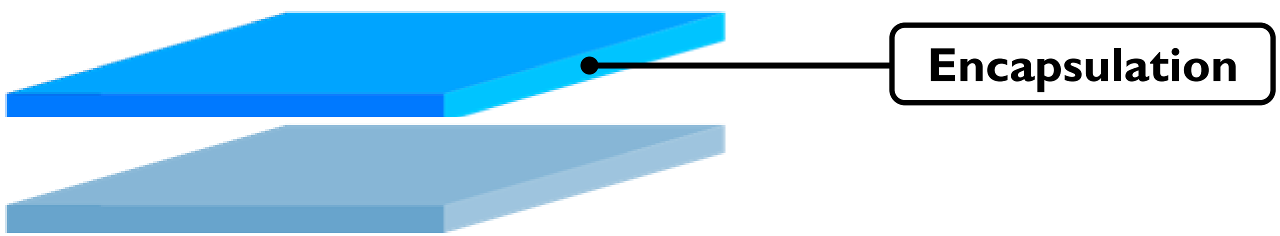


universiteit hasselt | imec

imo-imomec

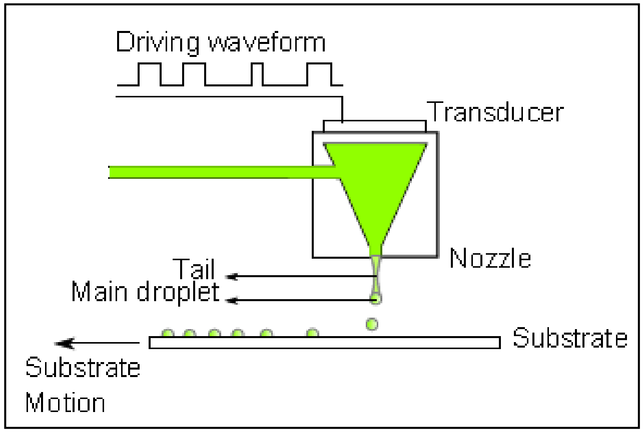
OLED: TECHNIQUES

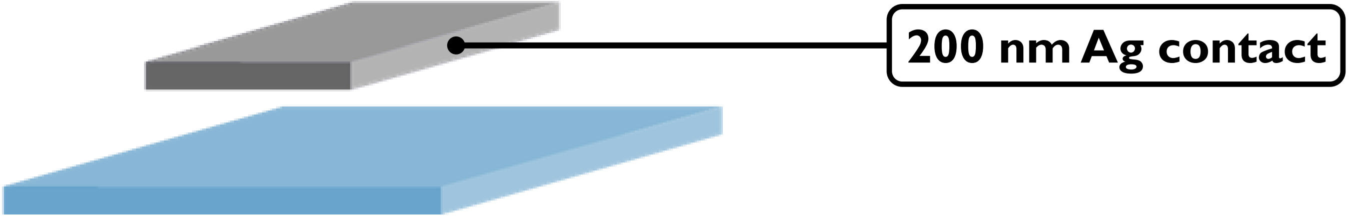
Plasma techniques



OLED:TECHNIQUES

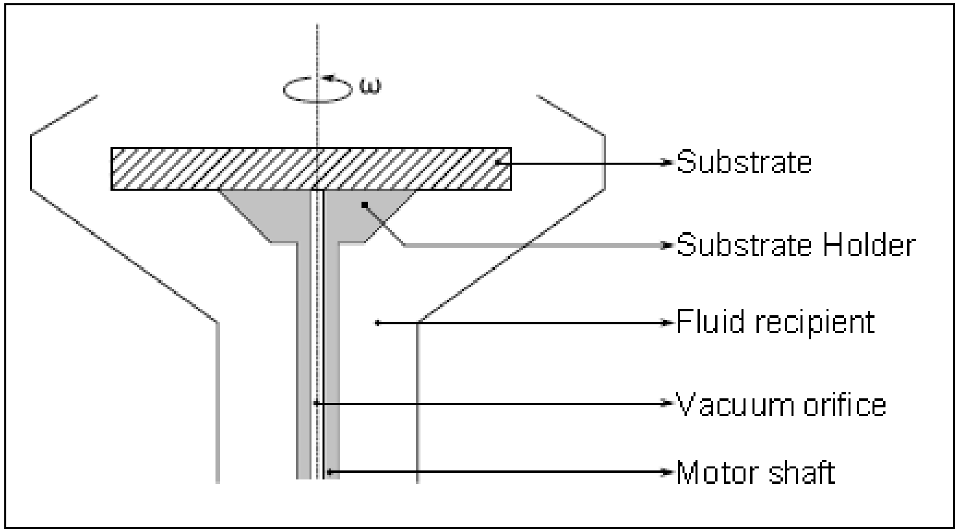
Inkjet printing





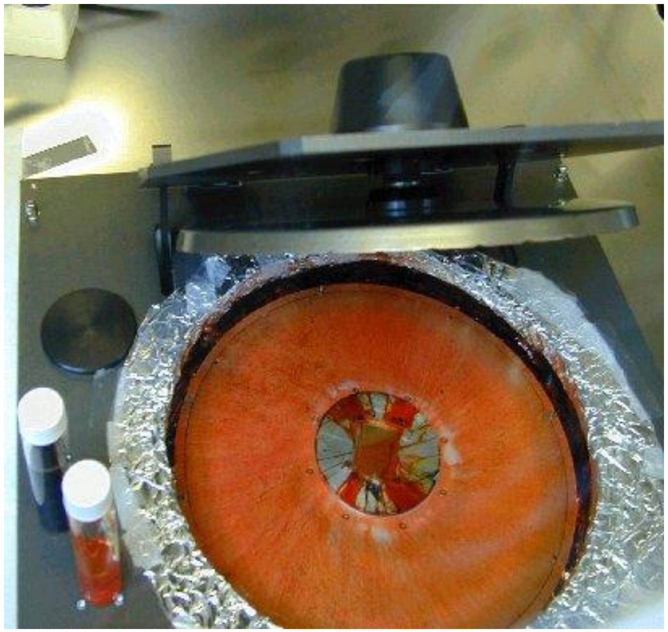
OLED:TECHNIQUES

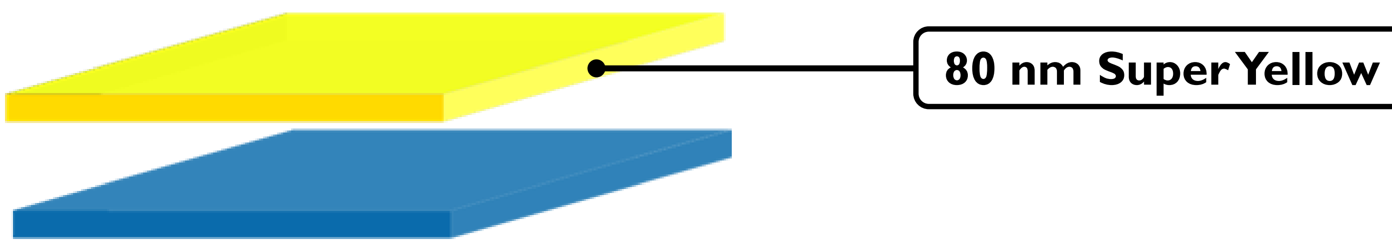
Spin coating



OLED: TECHNIQUES

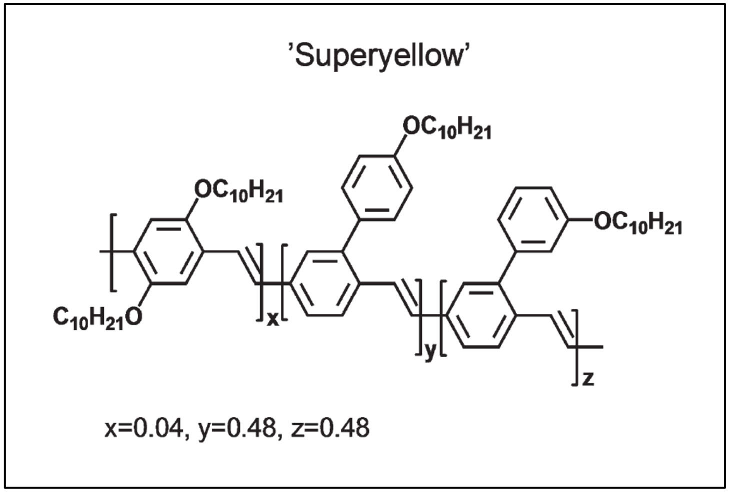
Spin coating and ultrasonic spray coating





OLED: TECHNIQUES

Super Yellow PDY-132

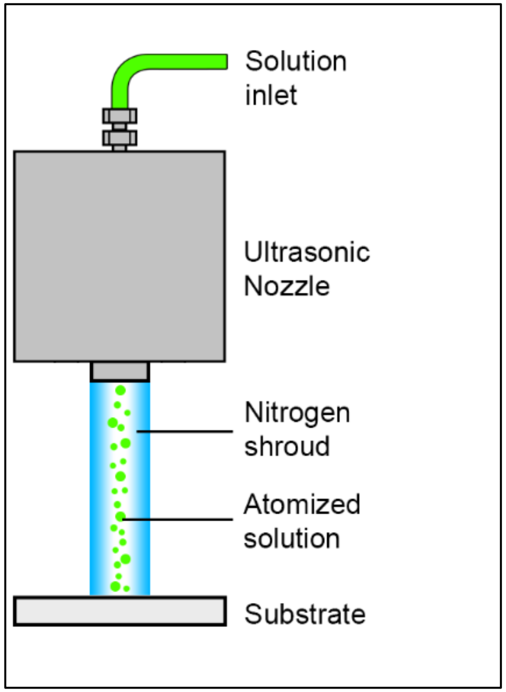


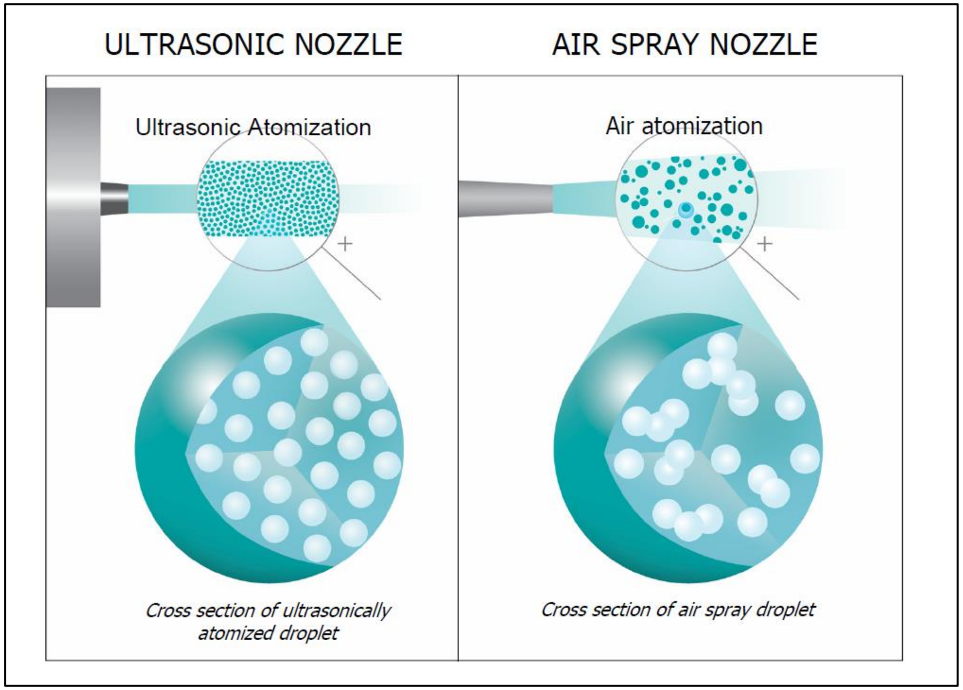
Parameter	Technique	Value	Unit	Ref.
Maj. Carrier Mobility	Time Of Flight (TOF)	10^{-7} – 10^{-6}	cm^2/Vs	[2]
External Quantum Efficiency (EQE)	n/a	5.3	%	[2]
Dielectric Constant ε_r	Impedance Spectroscopy	3.1	unit less	[3]
HOMO	n/a	4.8/5.2/5.4	eV	[4]/[5]/[6]
LUMO	n/a	2.4/2.7/3.0	eV	[4]/[5]/[6]

[1] M. Al-Sa'di, et. al., "Electrical and optical simulations of a polymer-based phosphorescent organic light-emitting diode with high efficiency," *J. Polym. Sci. Part B Polym. Phys.*, vol. 50, no. 22, pp. 1567–1576, Nov. **2012**.
[2] S. Gambino, et. al., "Comparison of hole mobility in thick and thin films of a conjugated polymer," *Org. Electron.*, vol. 11, no. 3, pp. 467–471, Mar. **2010**.
[3] A. Munar, et. al., "Shedding Light on the Operation of Polymer Light-Emitting Electrochemical Cells Using Impedance Spectroscopy," *Adv. Funct. Mater.*, vol. 22, no. 7, pp. 1511–1517, Apr. **2012**.
[4] E. B. Namdas, et. al., "Organic light emitting complementary inverters," *Appl. Phys. Lett.*, vol. 96, no. 4, p. 043304, **2010**.
[5] H. J. Bolink, et. al., "Efficient Polymer Light-Emitting Diode Using Air-Stable Metal Oxides as Electrodes," *Adv. Mater.*, vol. 21, no. 1, pp. 79–82, Jan. **2009**.
[6] W. Syu, et. al., "Efficient multilayer red fluorescent polymer light-emitting diodes by host and guest blend system," *Synth. Met.*, vol. 160, no. 9–10, pp. 871–875, **2010**.

OLED:TECHNIQUES

Ultrasonic spray coating

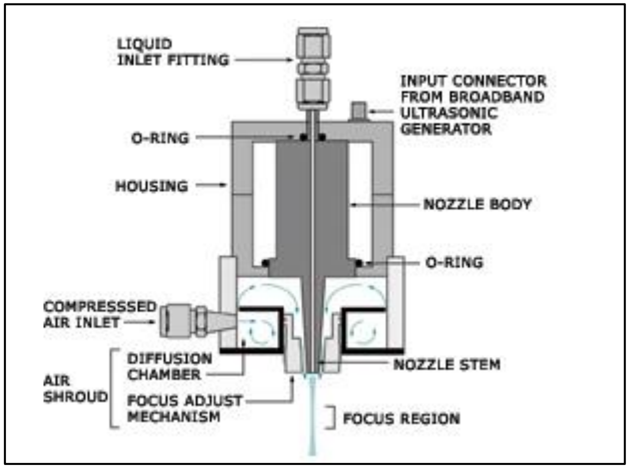


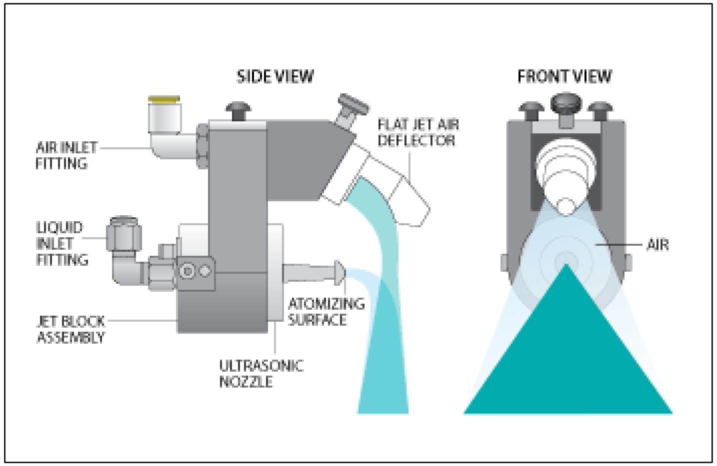


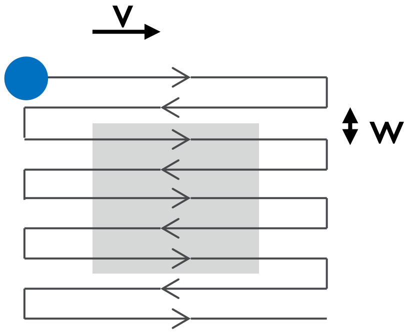
universiteit hasselt | imec
imo-imomec

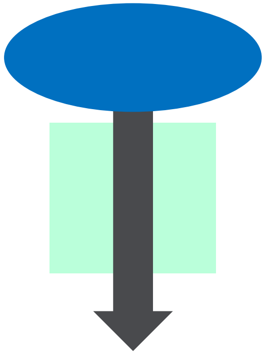
OLED:TECHNIQUES

Ultrasonic spray coating





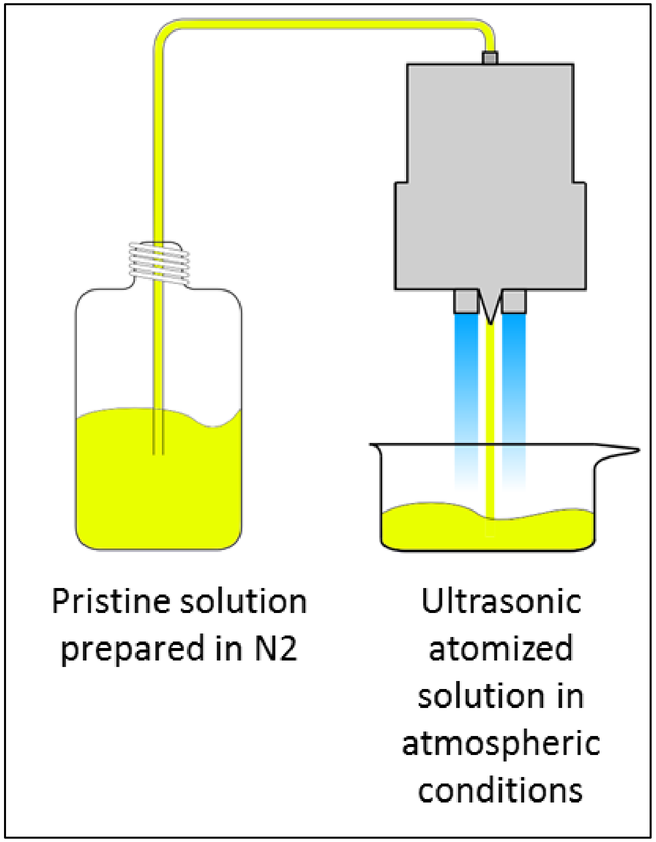




imo-imomec

OLED:TECHNIQUES

Ultrasonic spray coating of SY



Effect of ultra sonication on polymer chain

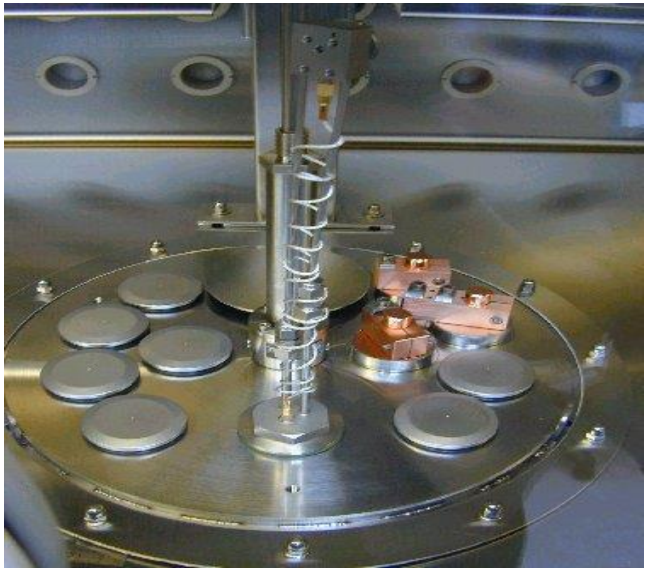
side-chain scission?
backbone cleavage?

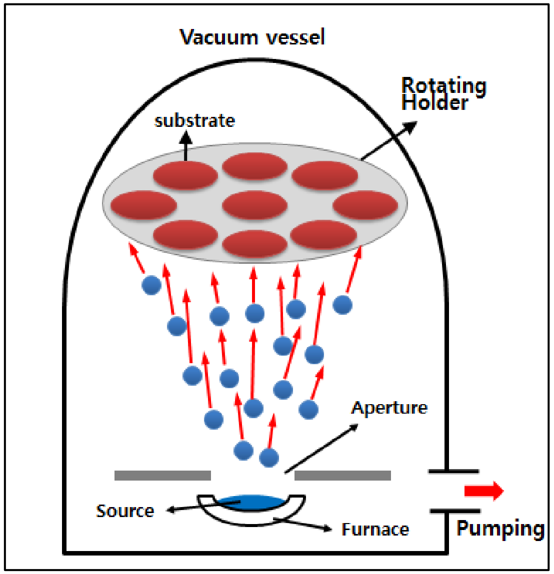
No changes to side-chain or backbone

Gilissen, K., Stryckers, J., Verstappen, P., Drijkoningen, J., Heintges, G. H. L., Lutsen, L., … Deferme, W. (2015). Ultrasonic spray coating as deposition technique for the light-emitting layer in polymer LEDs. *Organic Electronics*, *20*(February), 31–35. doi:10.1016/j.orgel.2015.01.015

OLED:TECHNIQUES

Thermal evaporation





12 nm Ca/ 17 nm Al contact

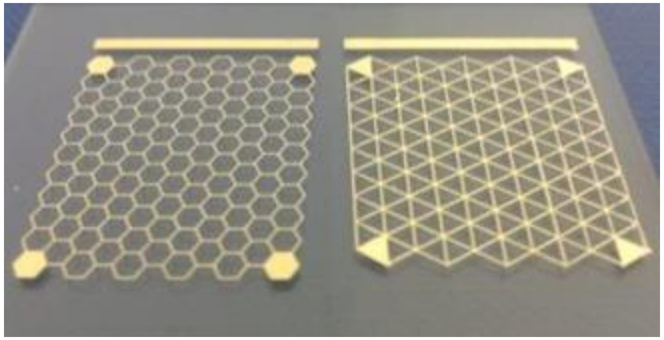
OLED:TECHNIQUES

Optimal transparent top contact

Au layers

- Thermal evaporation
- **Layer thickness 1-15 nm**
- Sheet resistance 3,2-123,7 Ω/□
- Transparency 25-70 %

Ag grids

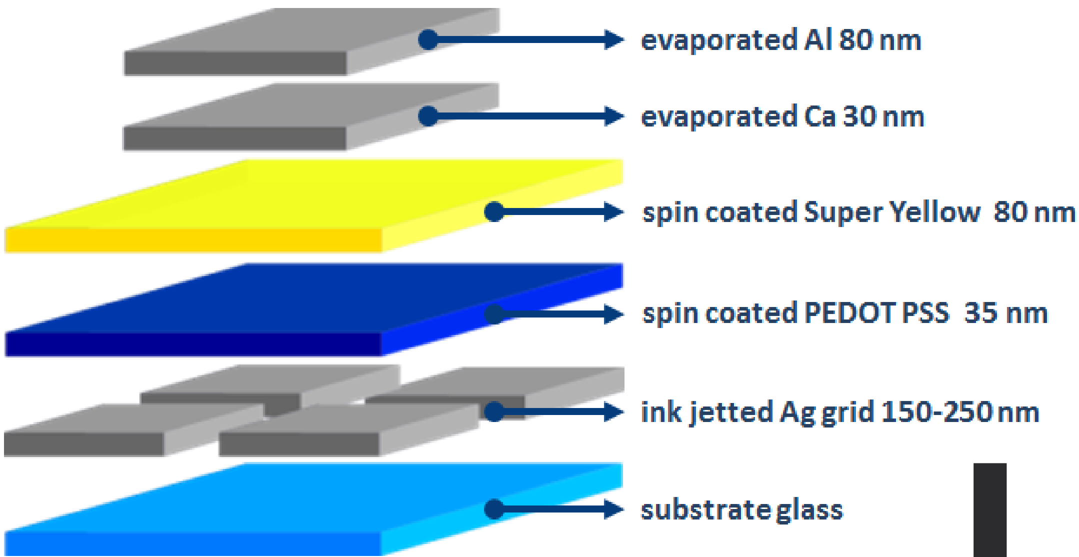


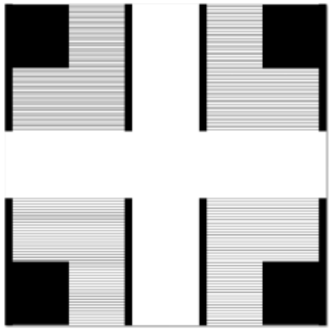
- **Ink jet printing**
- Layer thickness 150-250 nm
- **Sheet resistance 0,82-2,7 Ω/□**
- **Transparency 70-90 %**

OLED:TECHNIQUES

Optimal transparent top contact

Testing of a BEOLED with Ag grid

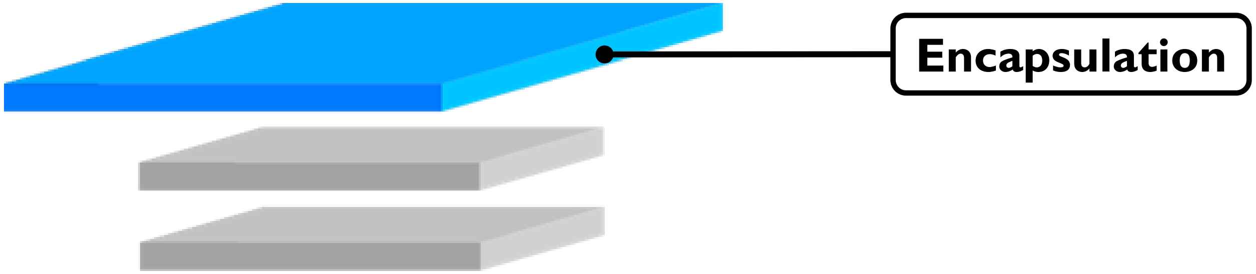




Sintered at 200 °C
Problem with TEOLED!
Sintering damages other layers!

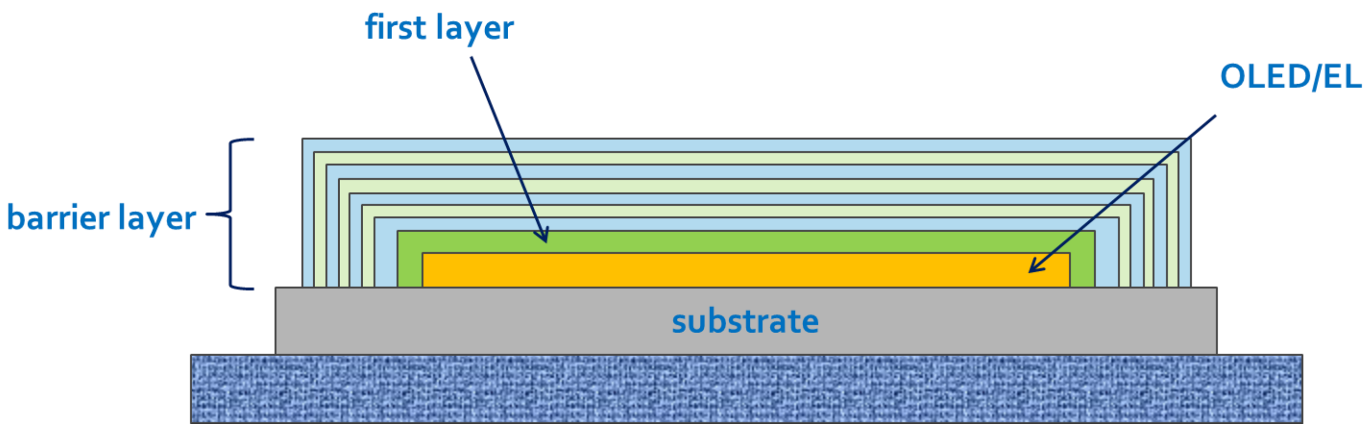
OLED:TECHNIQUES

Plasma techniques



OLED:TECHNIQUES

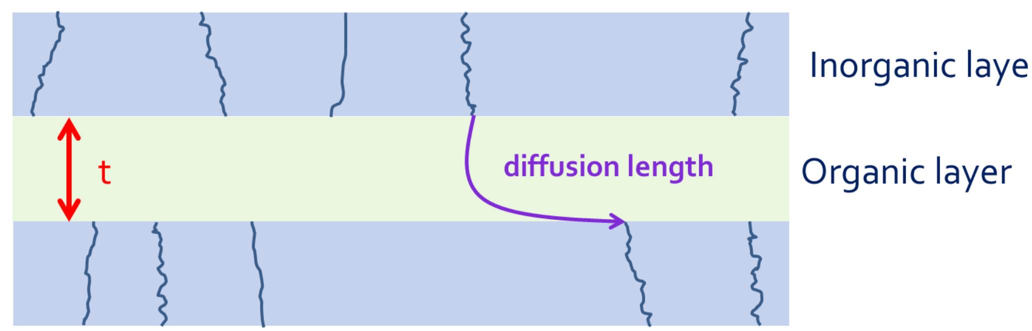
Plasma techniques



Alternation of organic and inorganic layers

Diffusion length is greatly increased

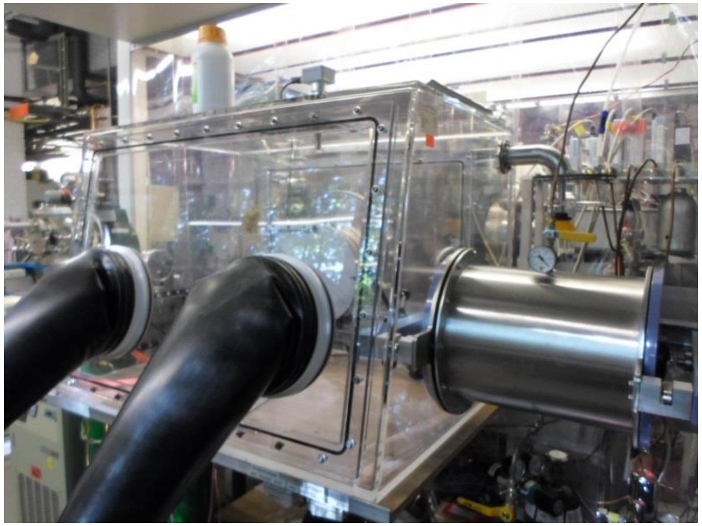
Good barrier properties



OLED:TECHNIQUES

Plasma techniques

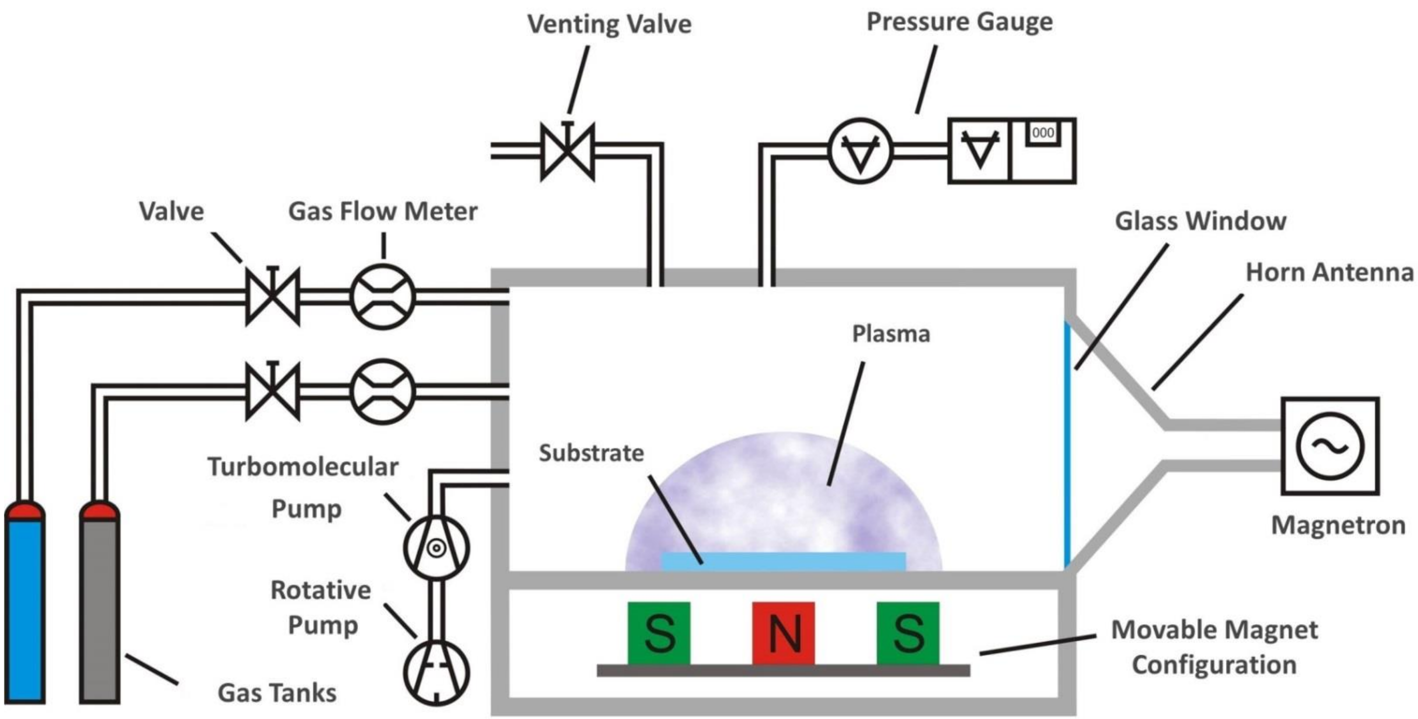
ECR plasma reactor

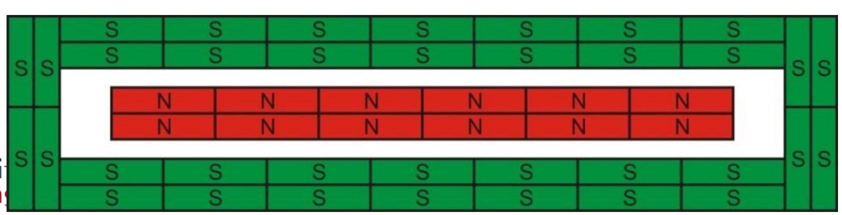


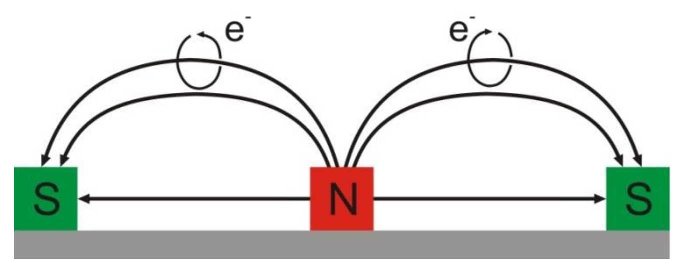
Glovebox

OLED:TECHNIQUES

Plasma techniques

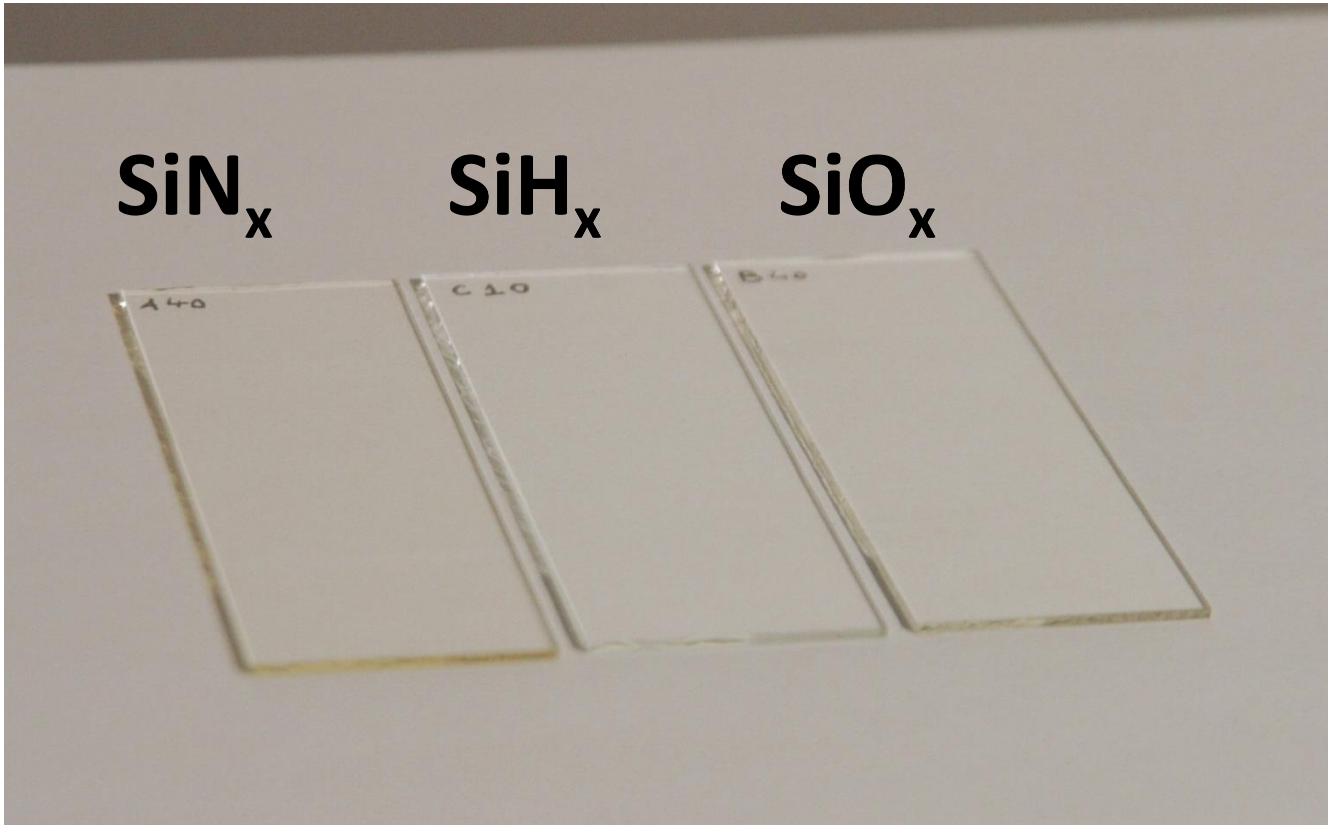






OLED:TECHNIQUES

Plasma techniques



OLED: TECHNIQUES

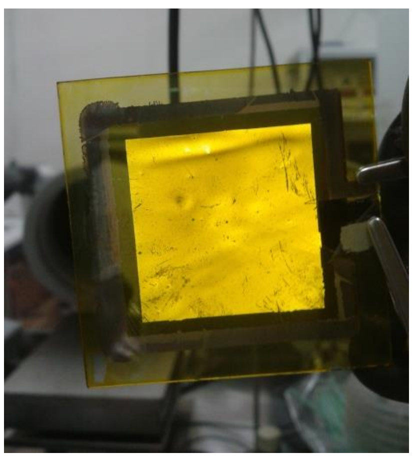
Plasma techniques

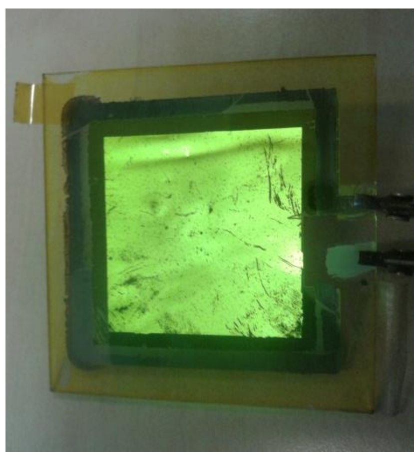
Challenges

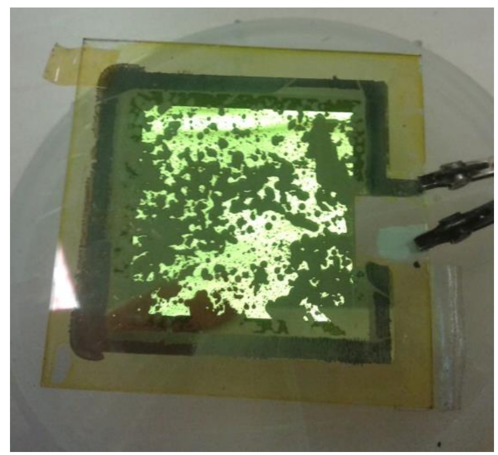
! Transportation of the OLEDs to Stuttgart!

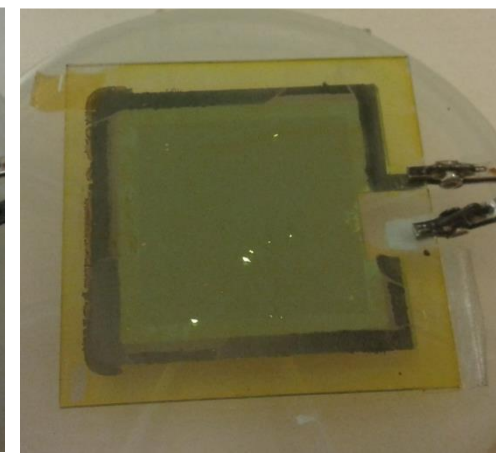
! O_2 level too high (5000 ppm inside glovebox)!

! Effectiveness encapsulation !



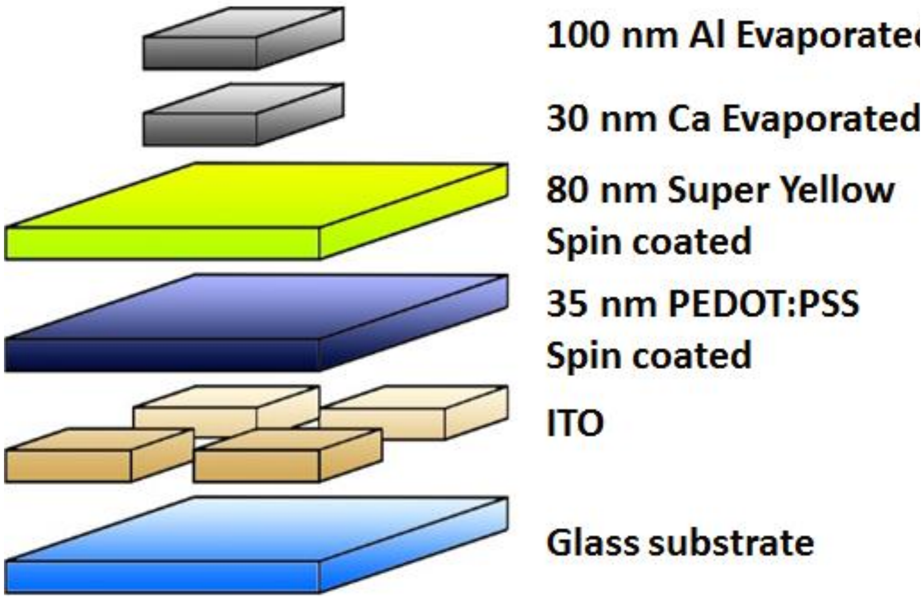


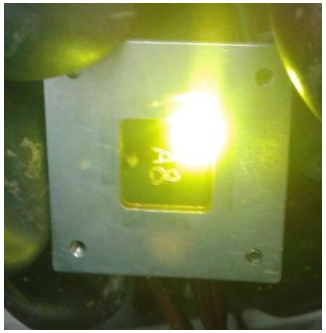


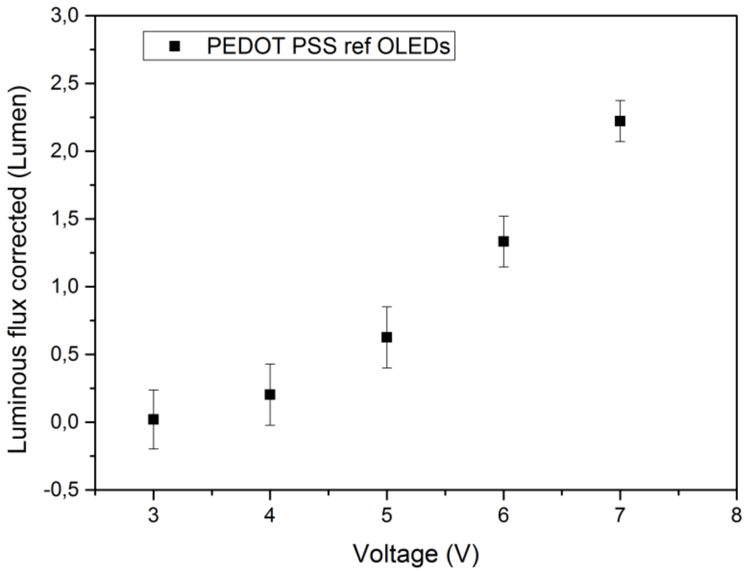


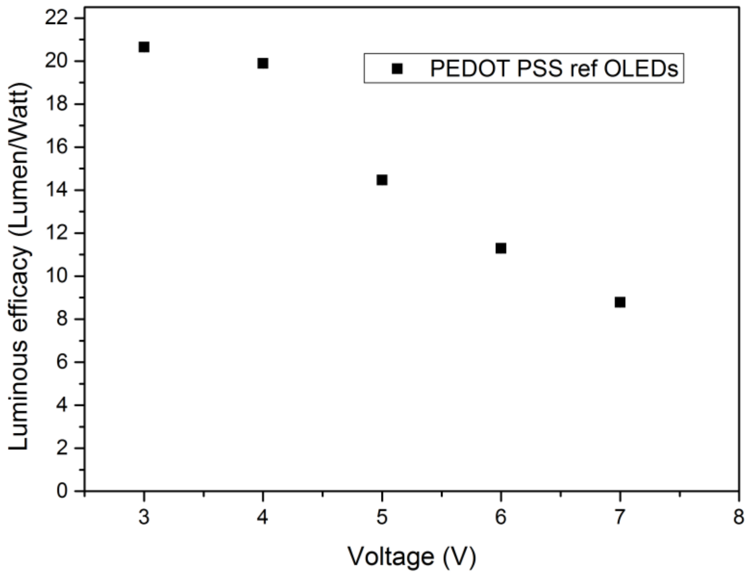
OLED:TECHNIQUES

Measurements



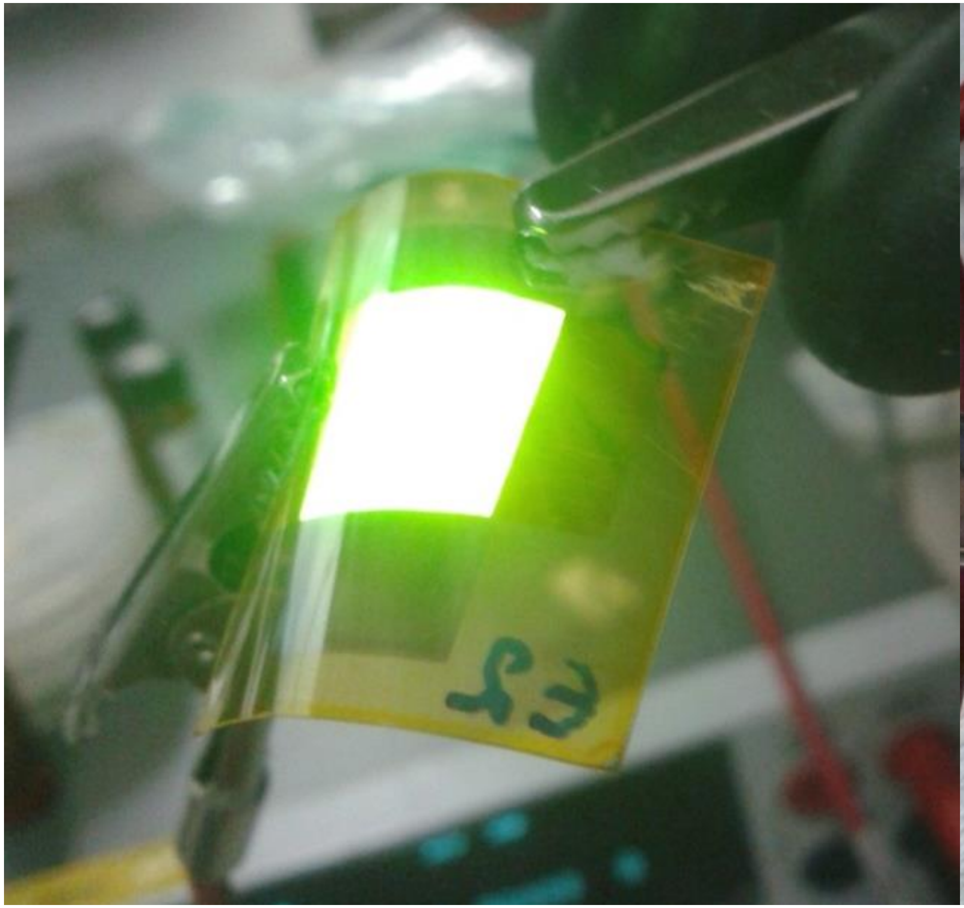
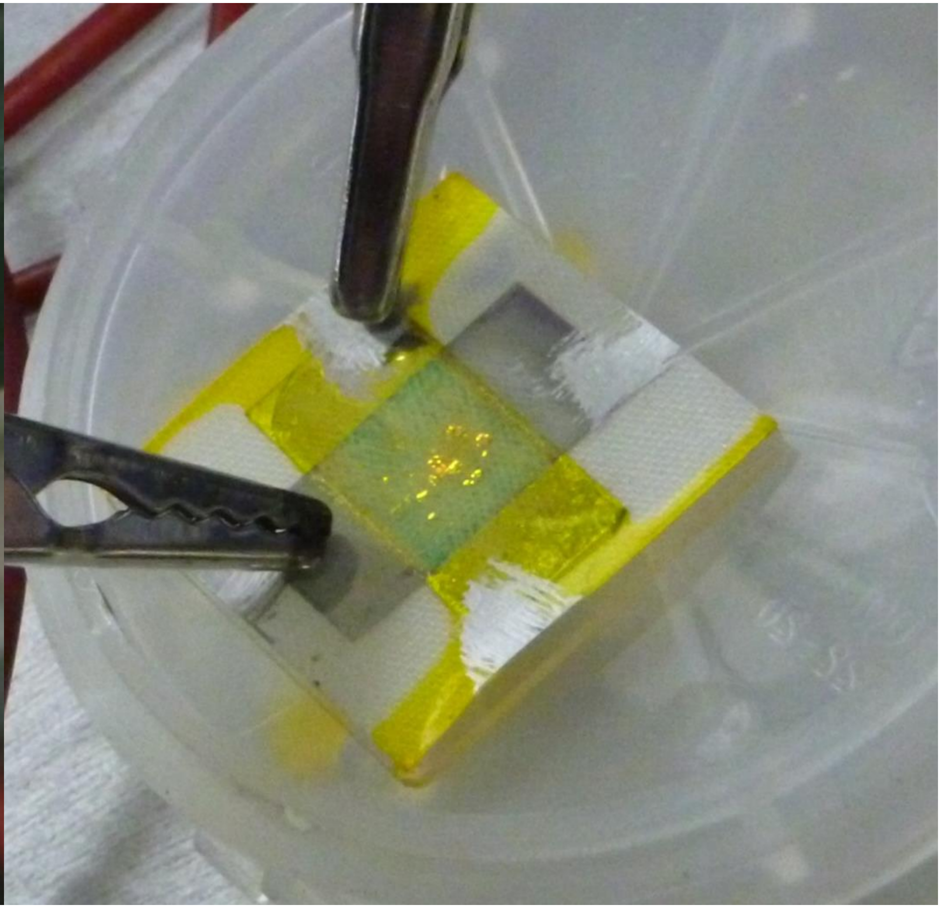






universiteit hasselt | imec
imo-imomec

OLED: RESULTS

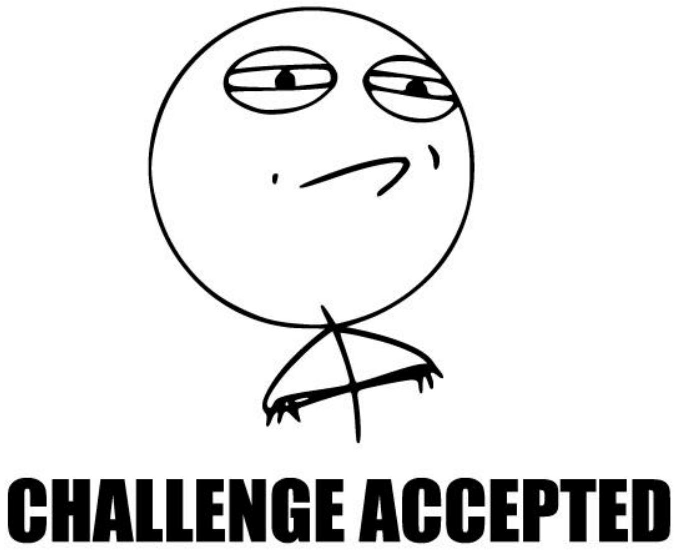



OLED: CHALLENGES

Transparent top contact: metal grids or thin metal layers

Covering layer on textile substrates

Encapsulation of OLED




A PHOTON CHECKS INTO A HOTEL AND IS ASKED IF HE NEEDS ANY HELP WITH HIS LUGGAGE.
"NO, I'M TRAVELLING LIGHT."