



Materials Science and Technology

Fall Series 2021  
Coating and Printing  
4 Nov 2021



INSPIRE



CONNECT



DISCUSS



IGNITE

# Invisible Printed Sensors Based on ITO Nanoparticle Ink for Security Applications

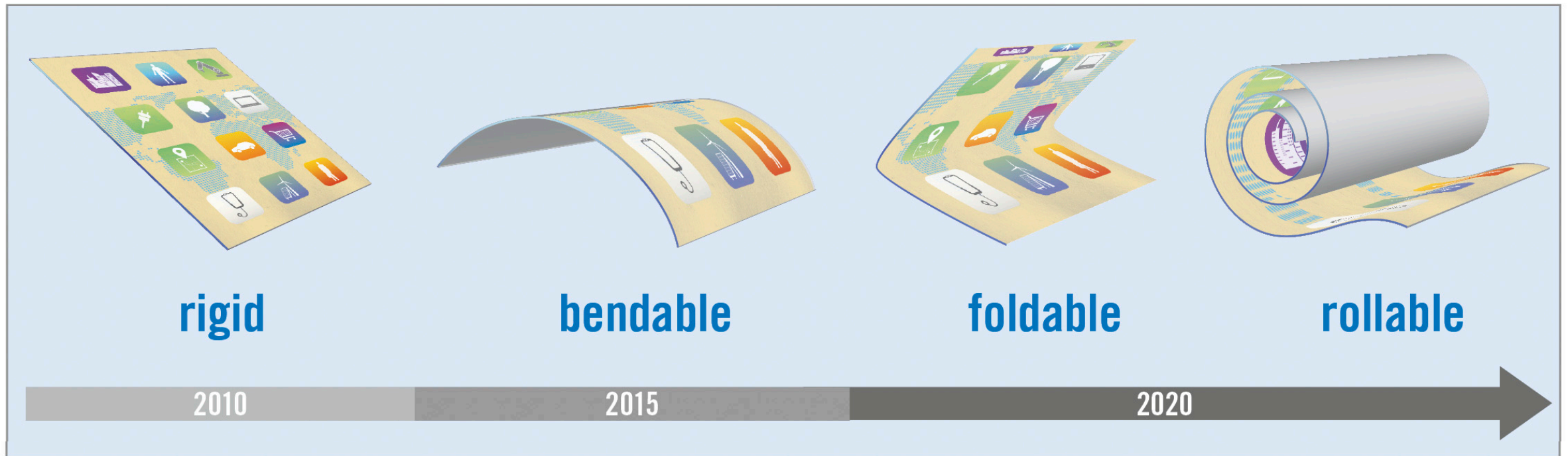
Evgeniia Gilshtein



IGNITE

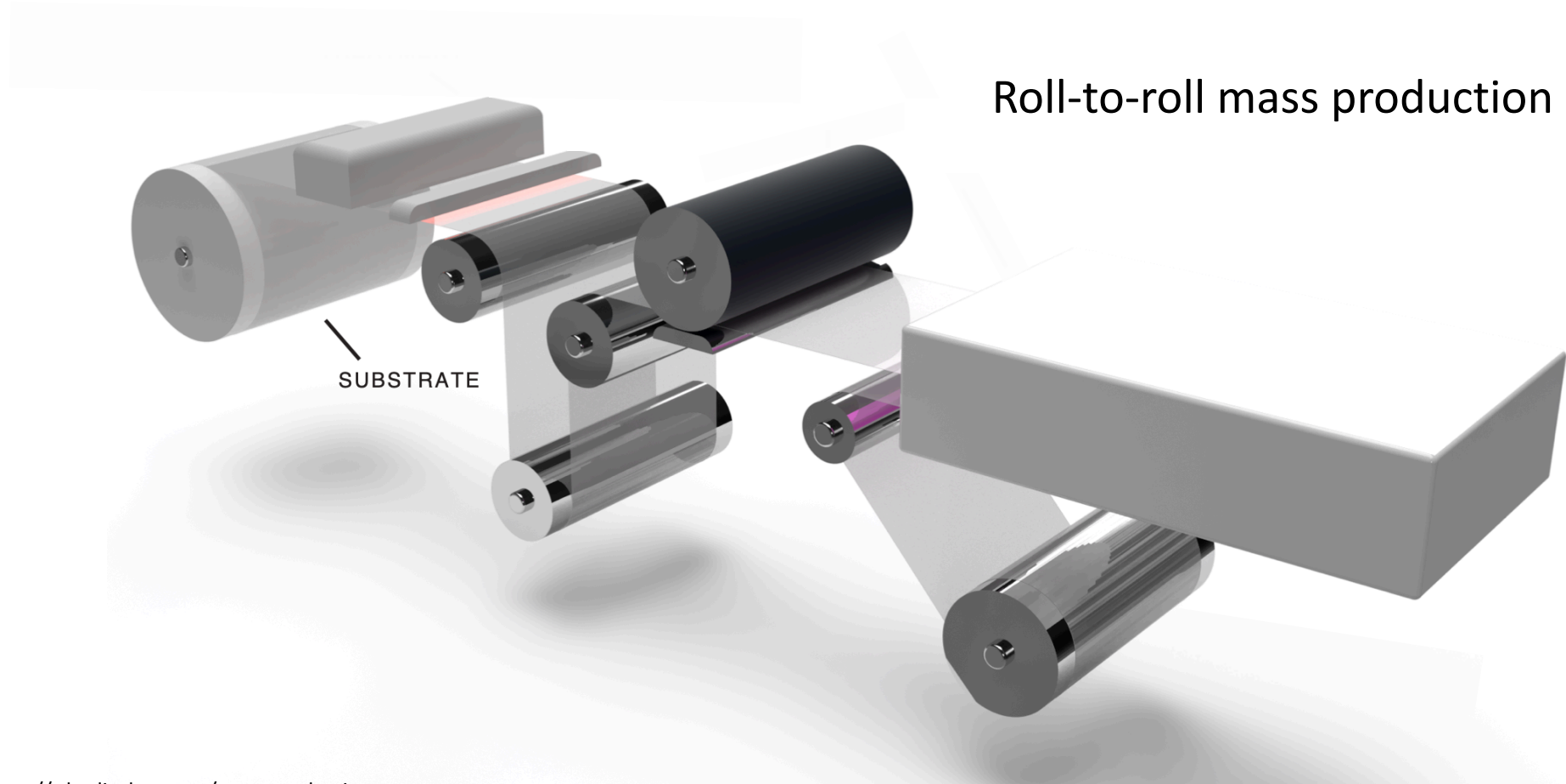


# Current trend in consumer electronics development - end-user prospective



Heraeus infographics

# Current trend in consumer electronics development - industry prospective



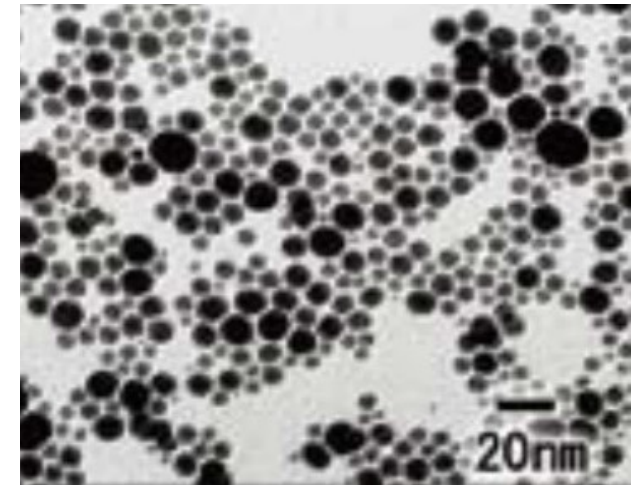
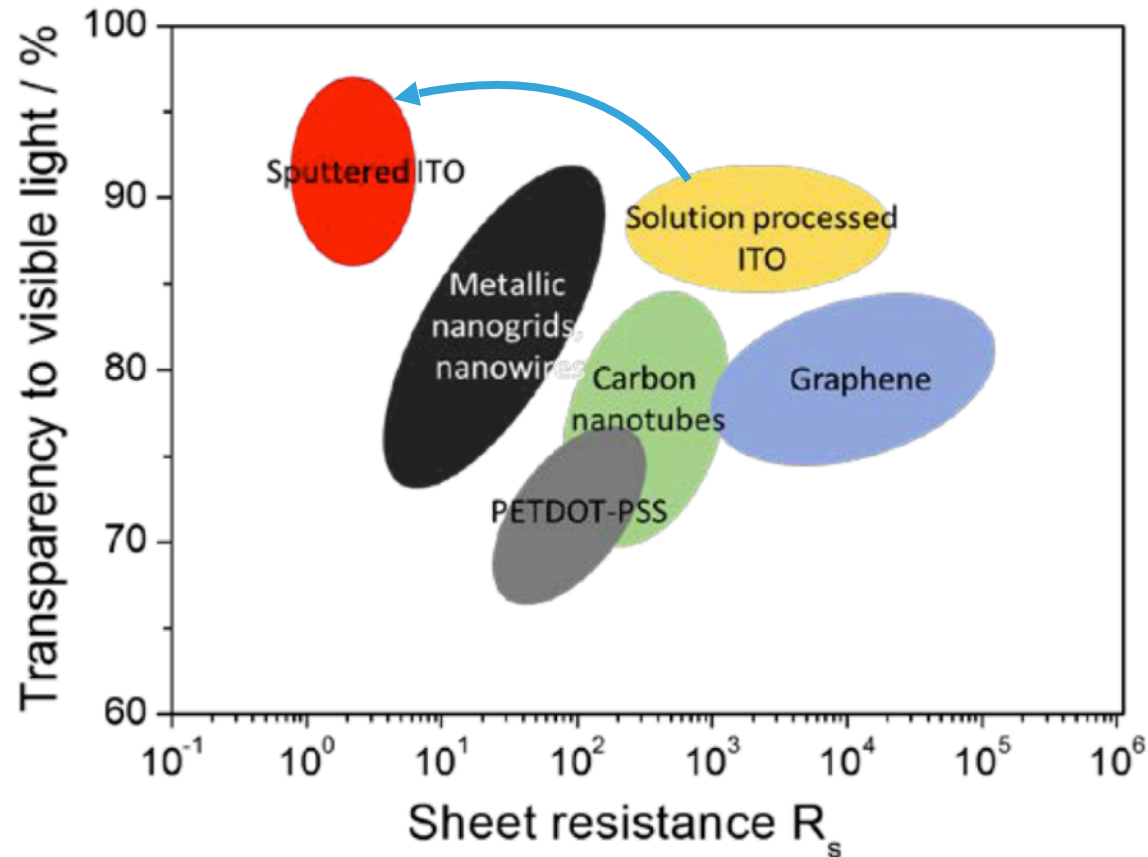
<https://rdotdisplays.com/mass-production>

# Motivation - conductive materials



<https://www.chemistryworld.com/podcasts/indium-tin-oxide-ito>

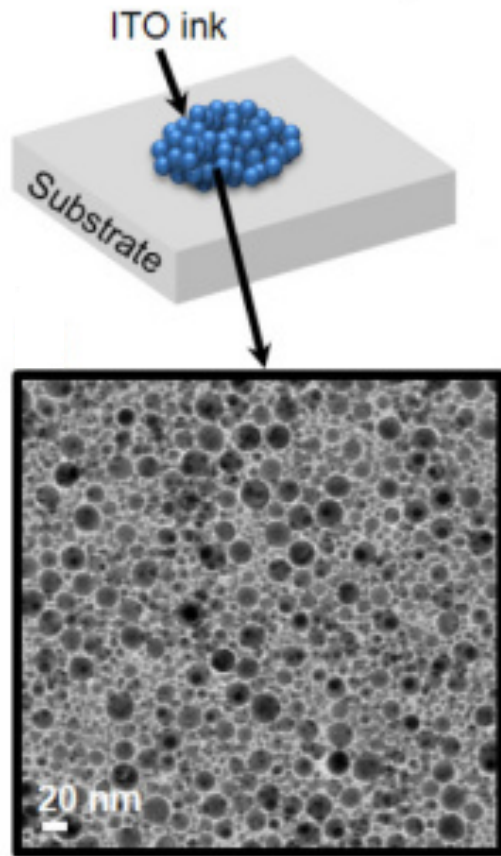
Sputtered ITO



Solution processed ITO

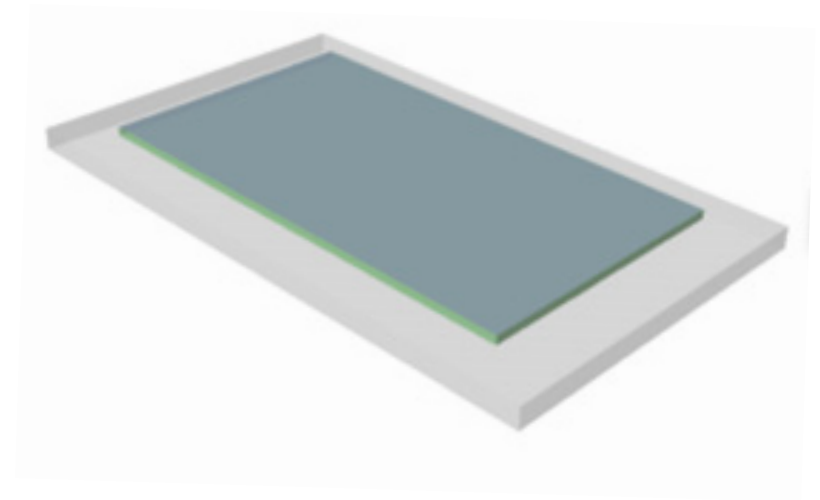


# Challenge 1



DOI: 10.1364/OE.19.021803

Solution-based  
vs  
Sputtered layer

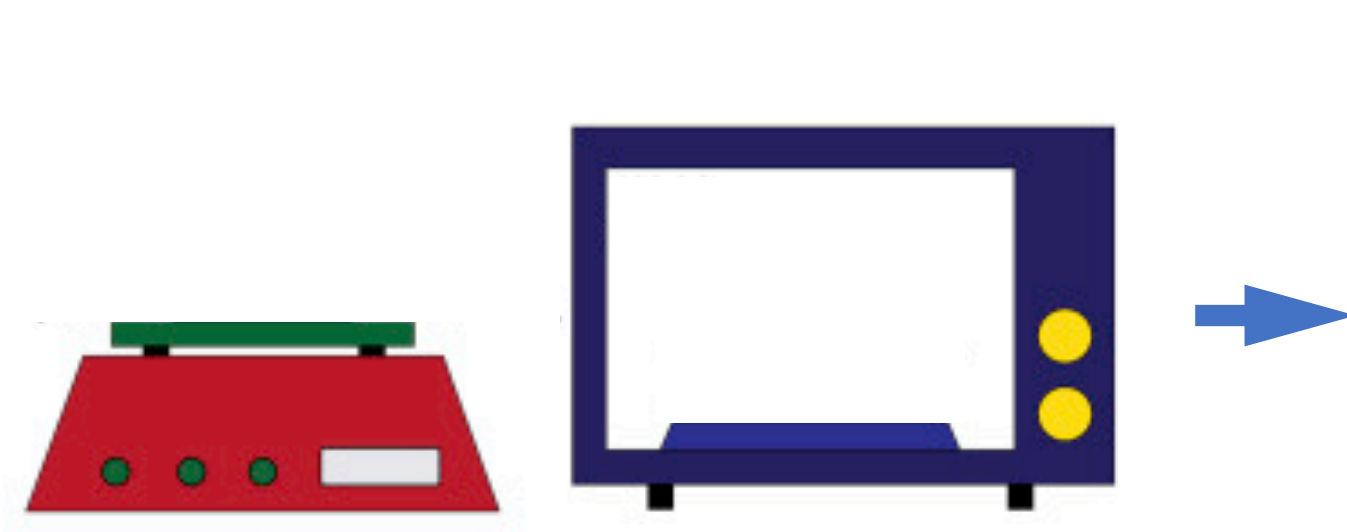


**SINTERING METHOD REQUIRED  $T < 250\text{ }^{\circ}\text{C}$**   
flexible sensitive to  $T^{\circ}\text{C}$  substrates

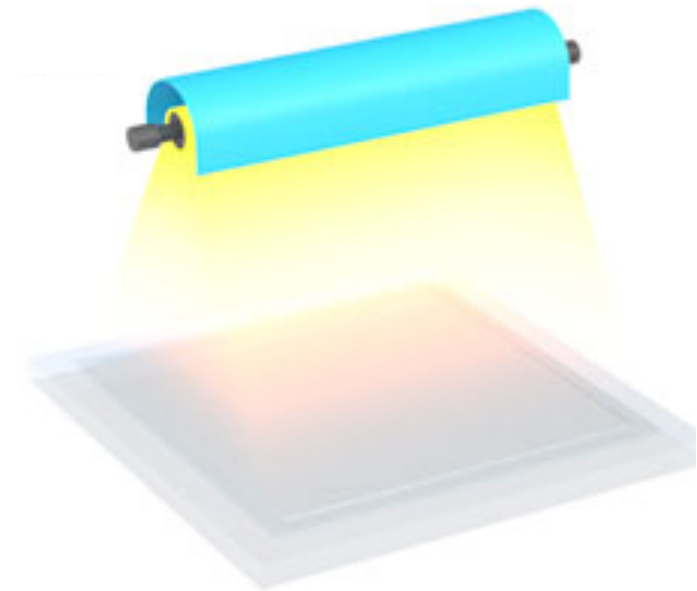
# Hypothesis - can we move:

from conventional heat treatment

to advanced light-irradiation treatment



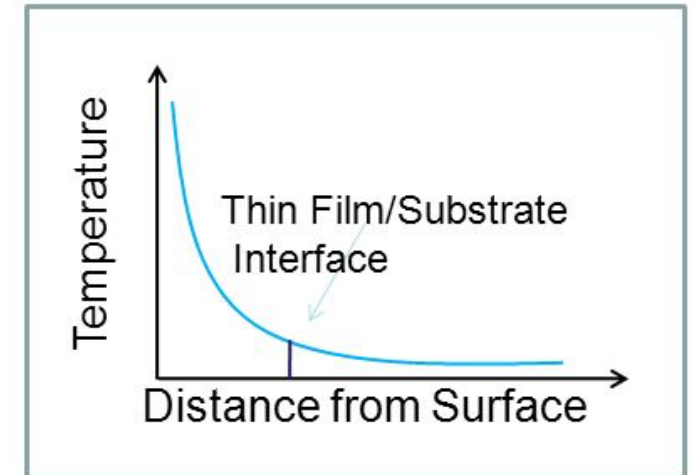
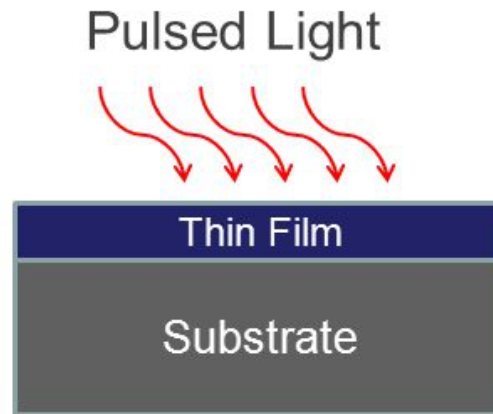
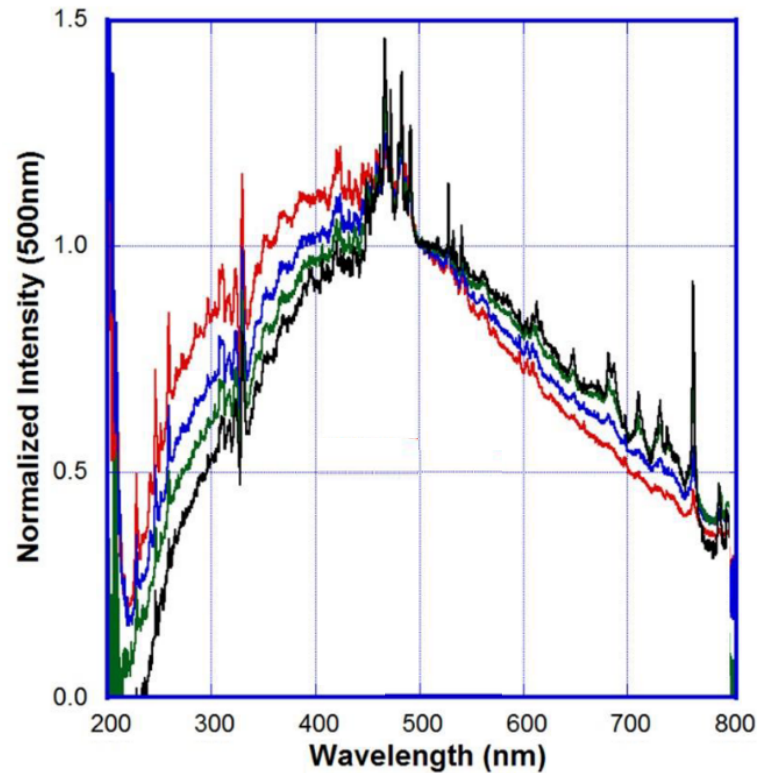
long times; heating from the bottom



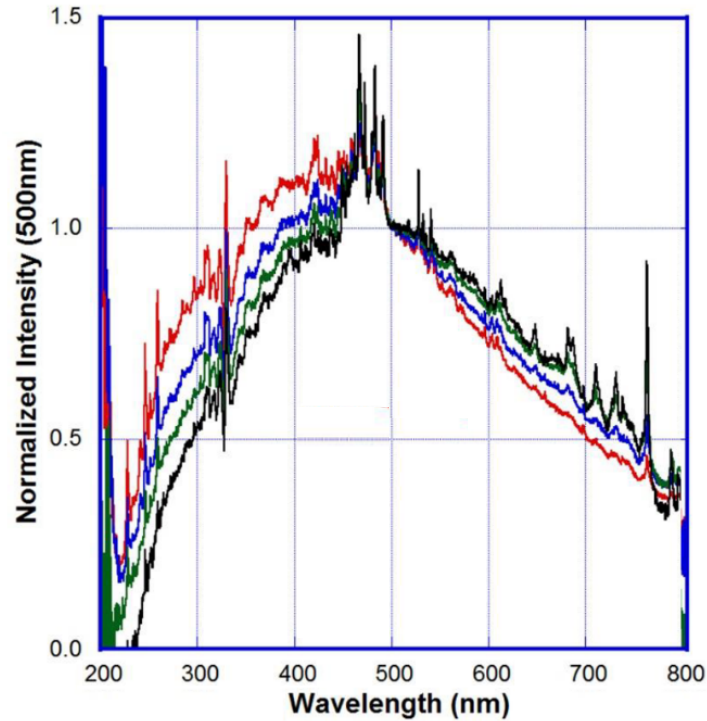
short times; heating from the top

# Methodology - FLA (flash lamp annealing)

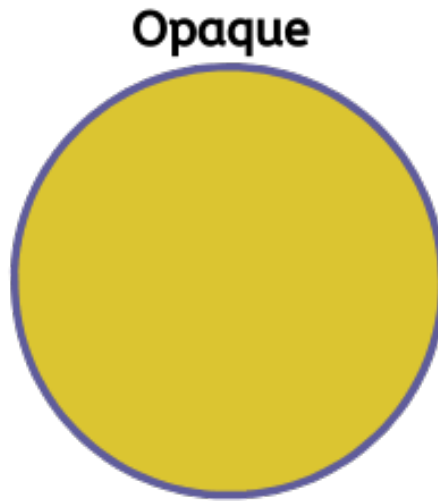
known as Photonic curing (PC), Intense pulsed light (IPL)



# Challenge 2



all energy absorbed

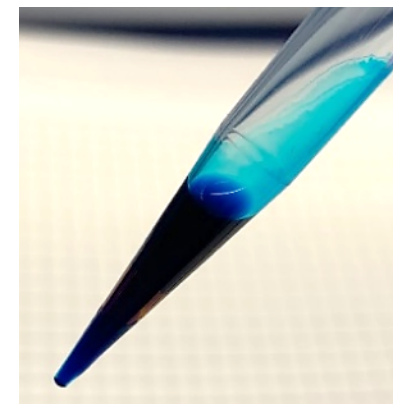
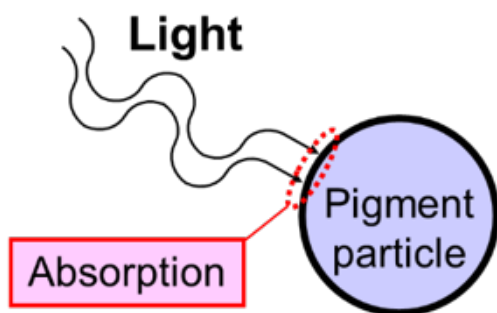
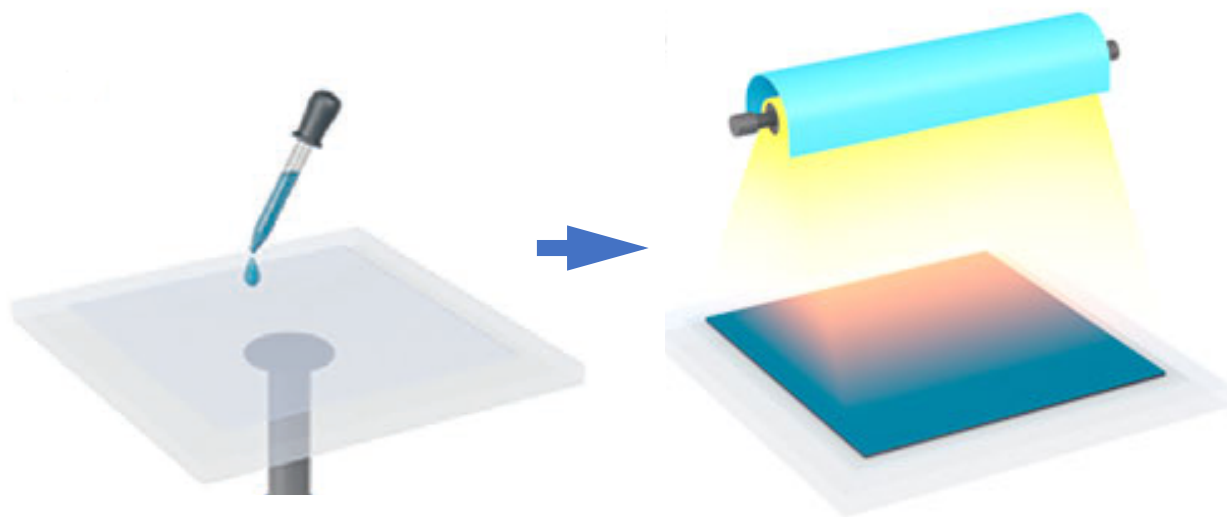


no energy absorbed

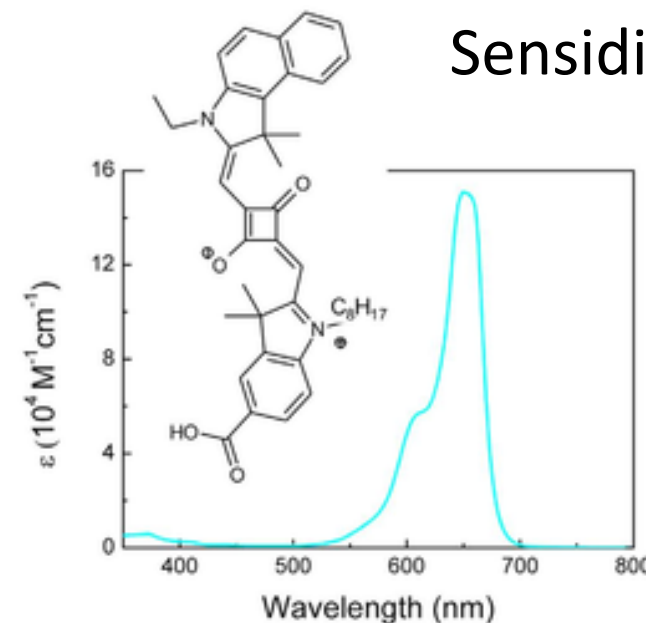


**TRANSPARENT FILM  
SHOULD ABSORB LIGHT  
from FLA**

# Approach - adding colored dye layer on top

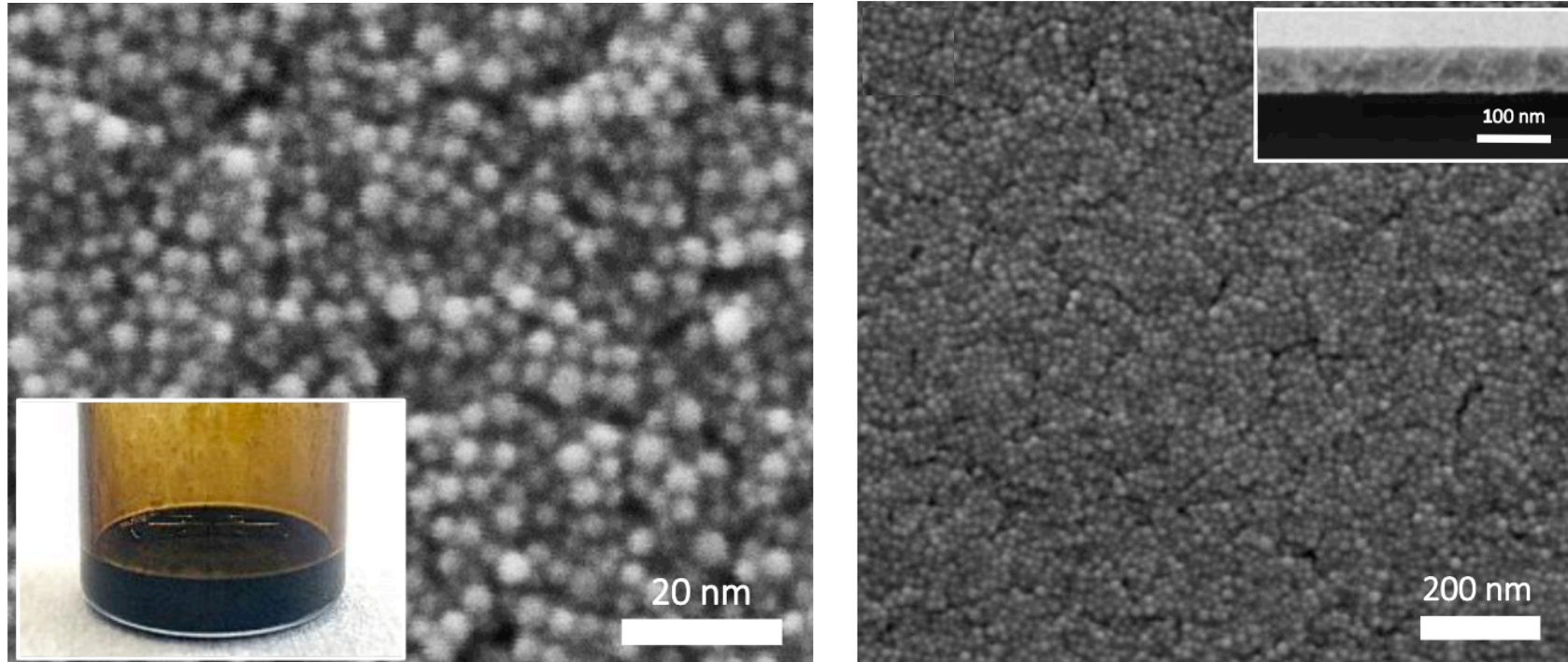


Sensitizer SQ2



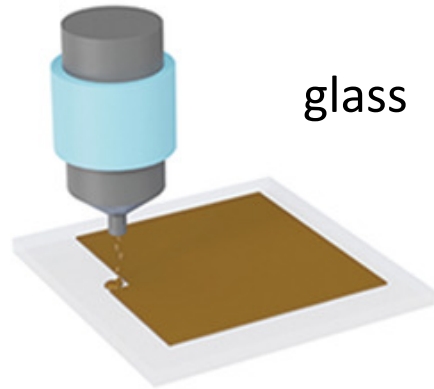


# Solution. Step 1 — ITO nano ink

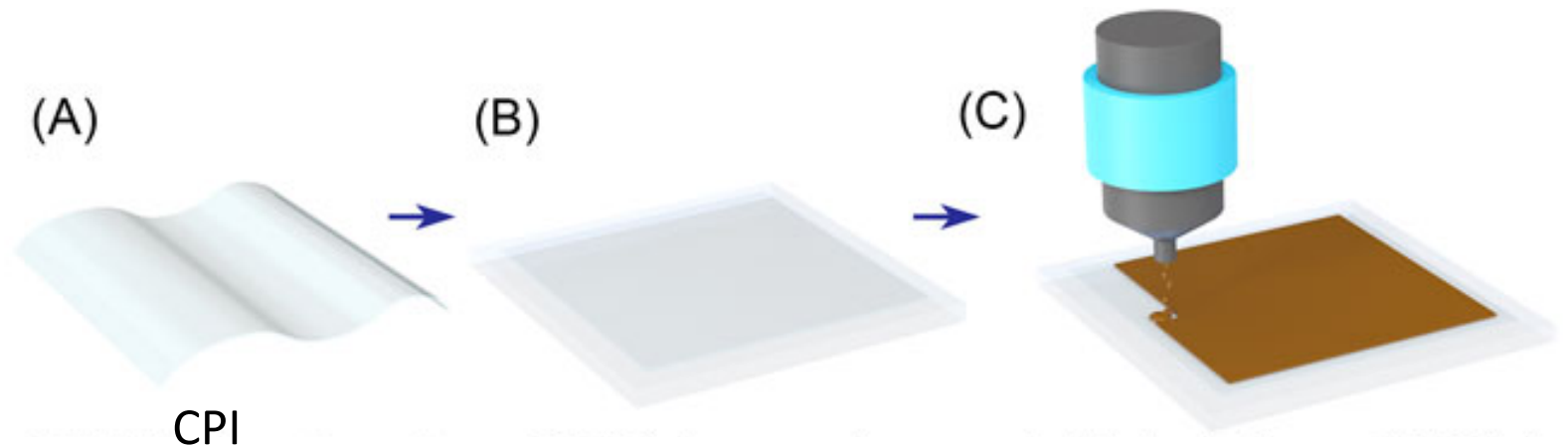
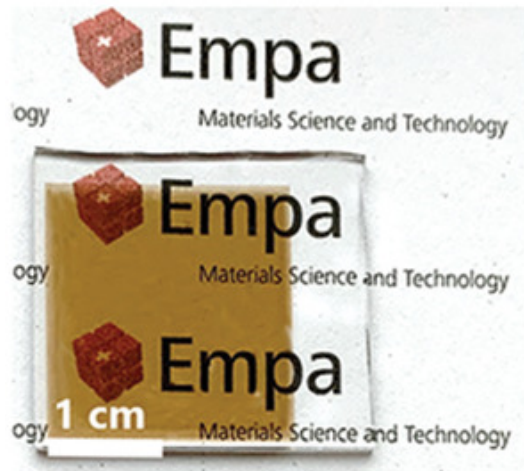


spin-coated ITO nano ink

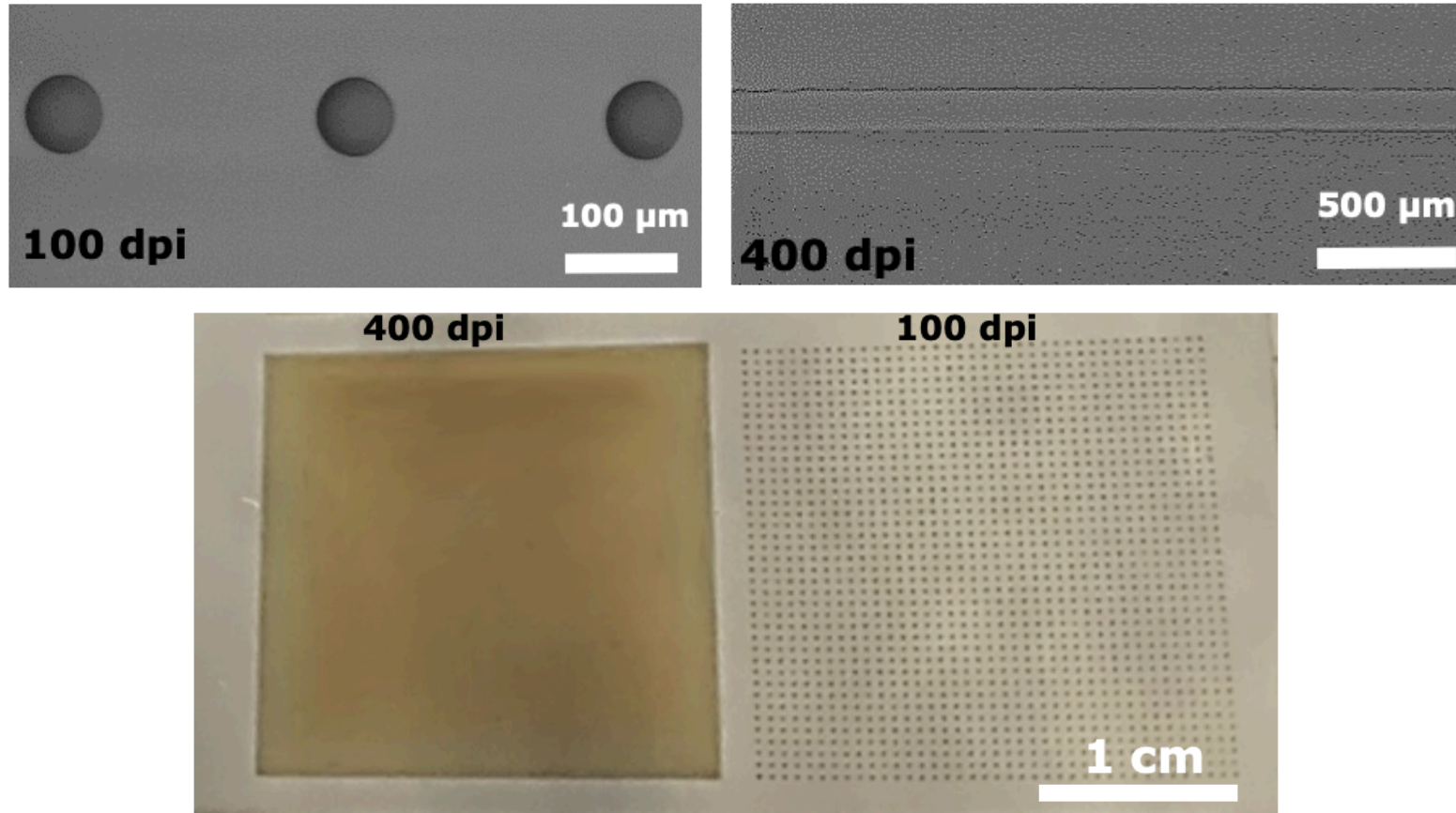
# Solution. Step 2 — substrate material



CPI - colorless polyimide (withstands 250 °C)



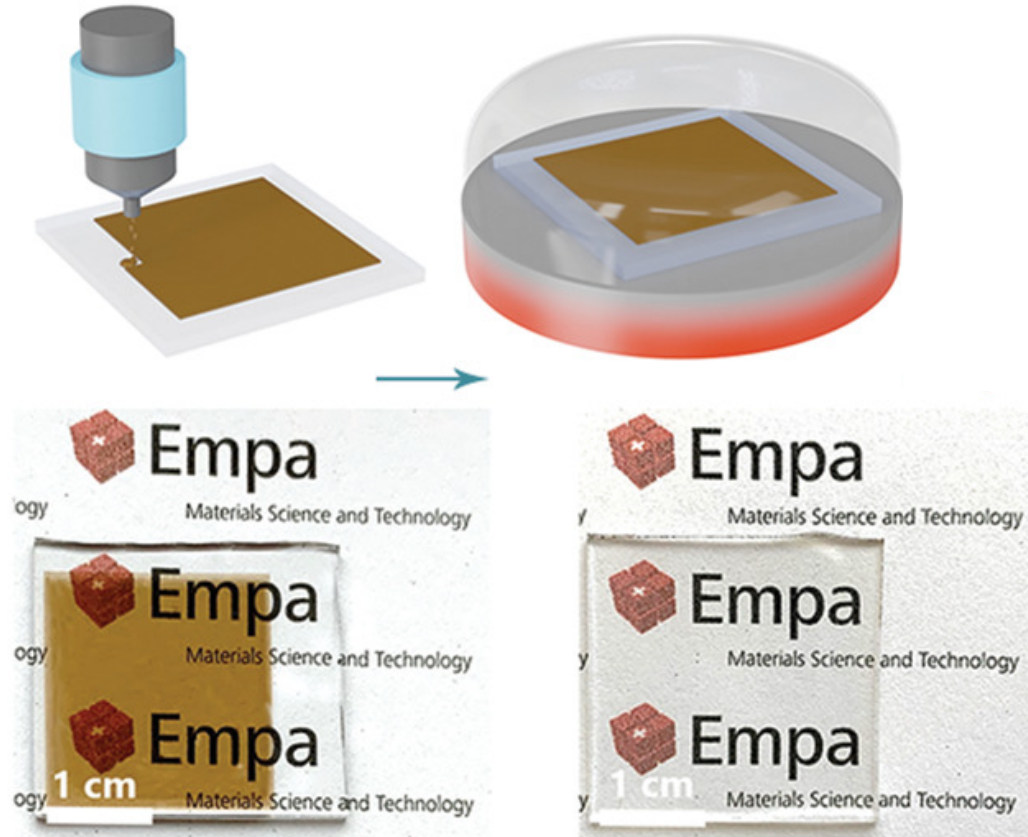
# Solution. Step 3 - inkjet printing



inkjet-printed ITO nano ink

# Solution. Step 4 - initial annealing

short vacuum annealing step



glass

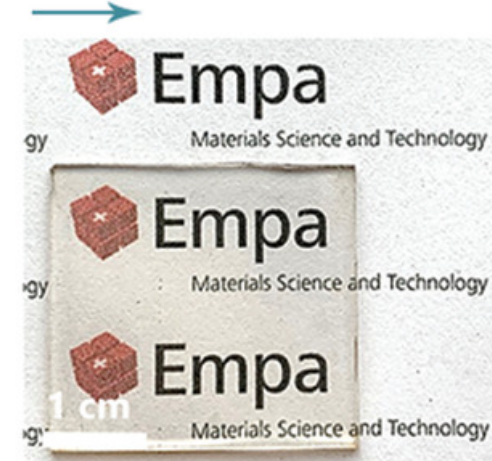
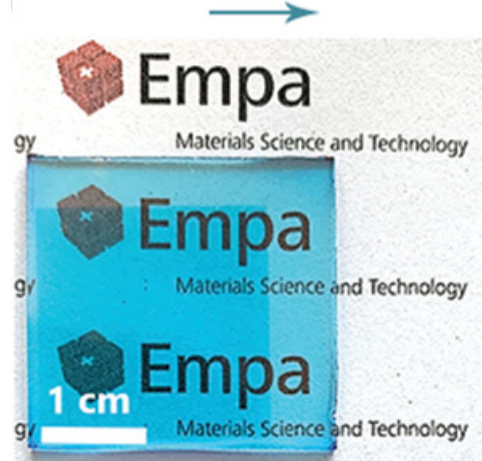
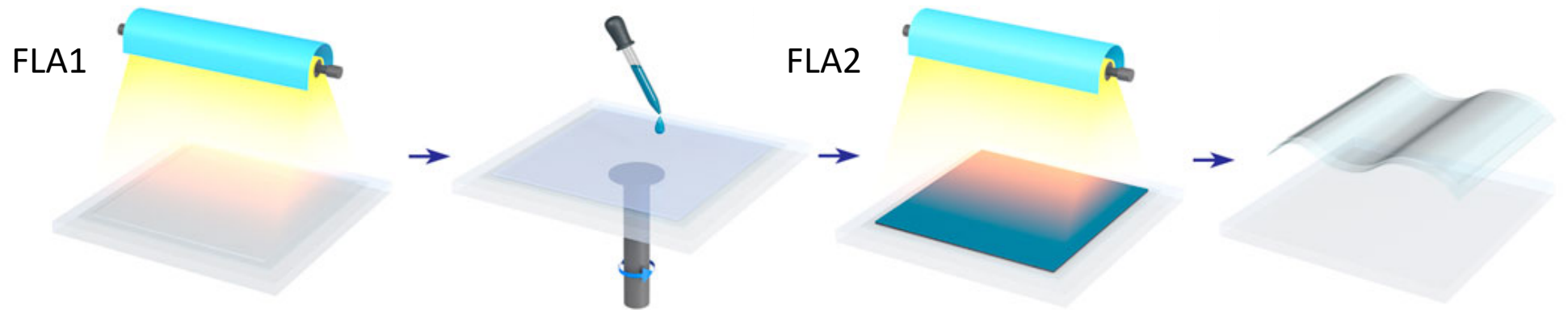
**Electrical properties needs to be further improved**



CPI



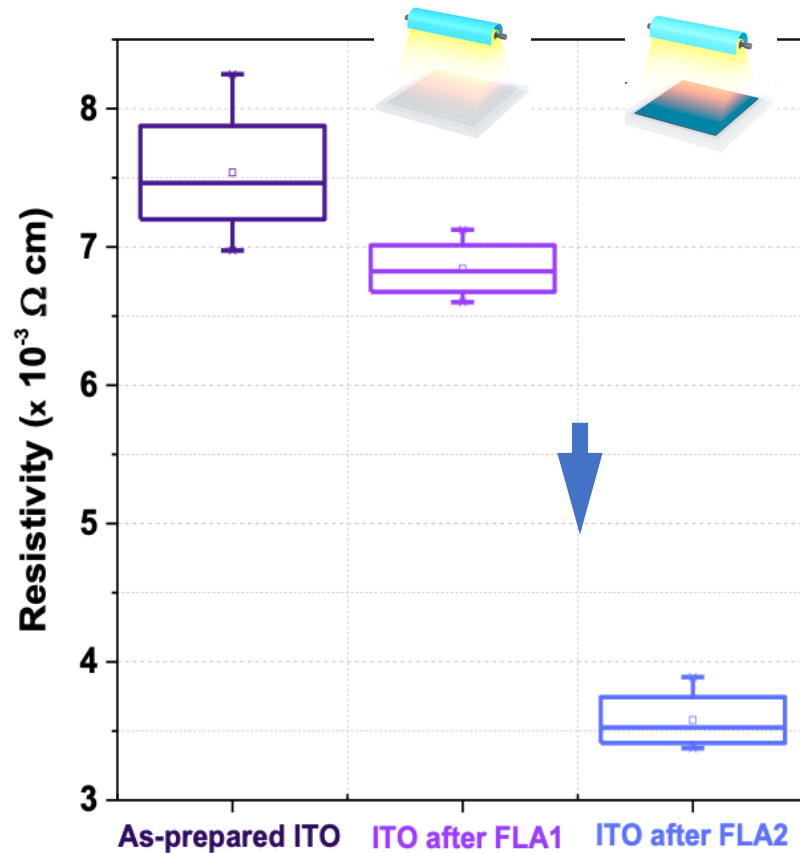
# Solution. Step 5 - FLA annealing



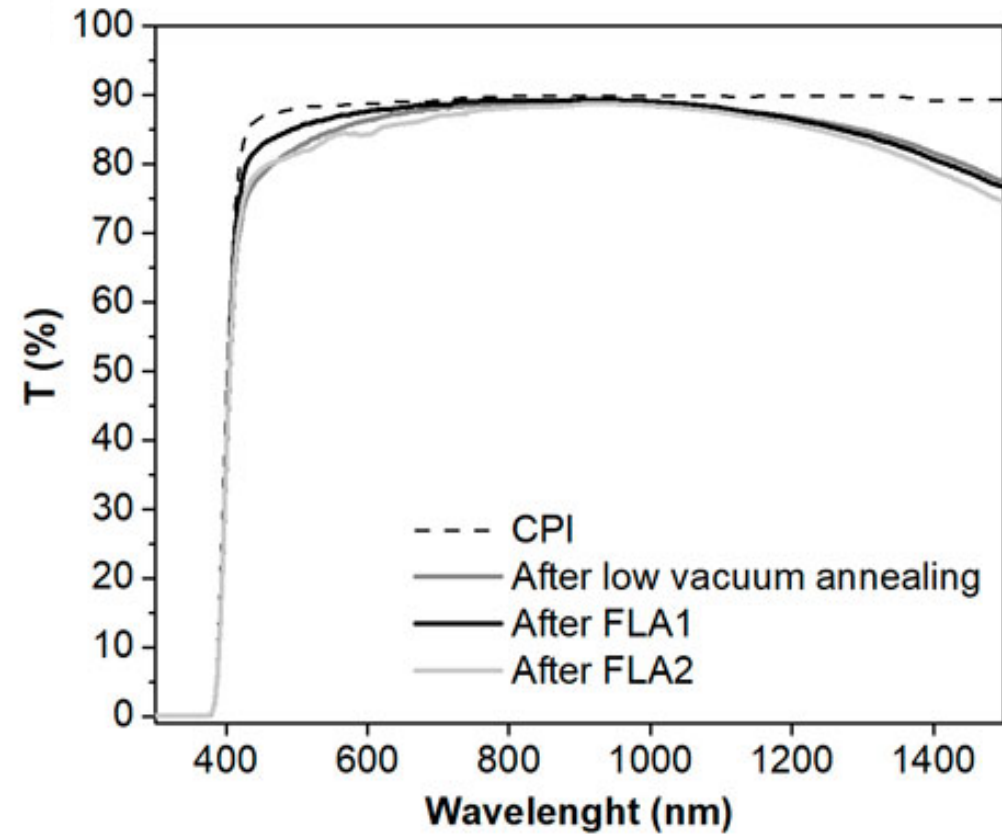
Final structure



# Scientific finding. Layers characterization

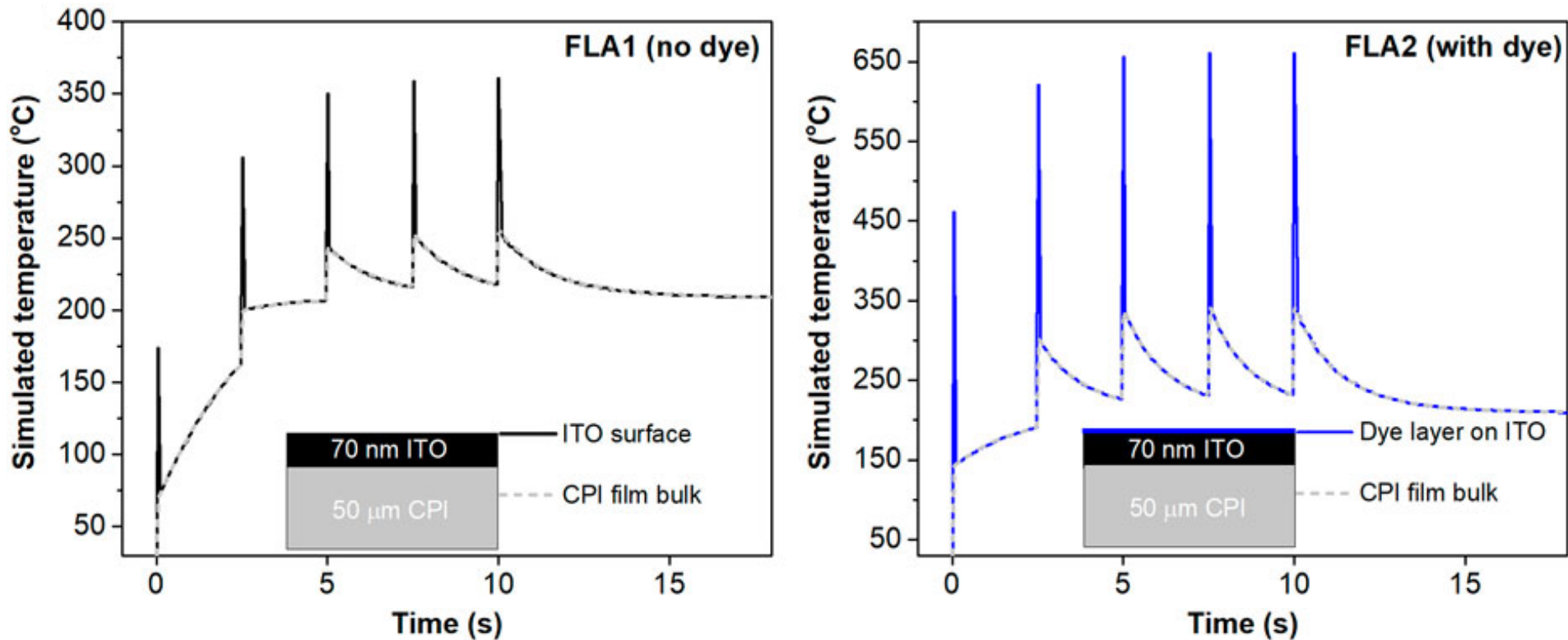


Improvement of conductivity



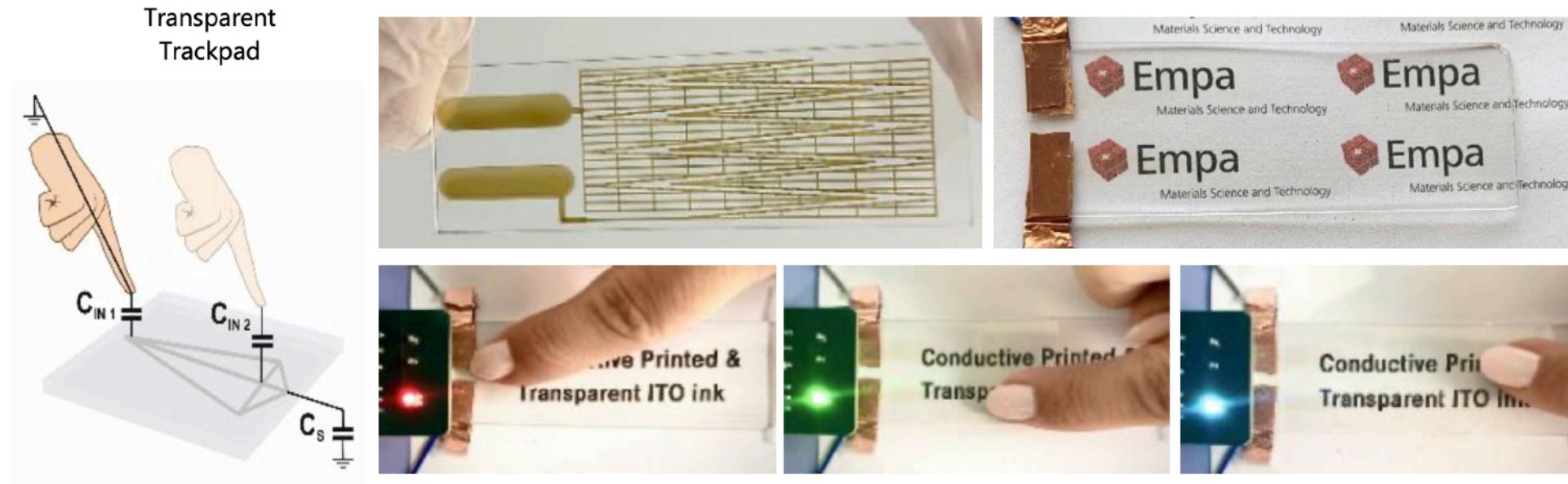
Unchanged transmittance

# Scientific finding. Modelling



Effective increase of  $T$  °C with dye

# Application - trackpad

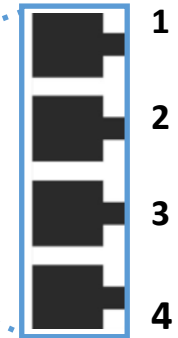


Where invisibility will be advantageous?

# Application - security system

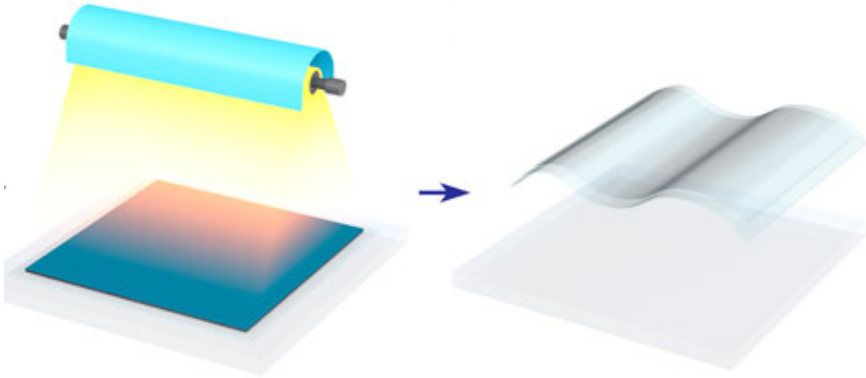


**NOT POSSIBLE TO DISTINGUISH  
POSITION OF THE BUTTONS!**

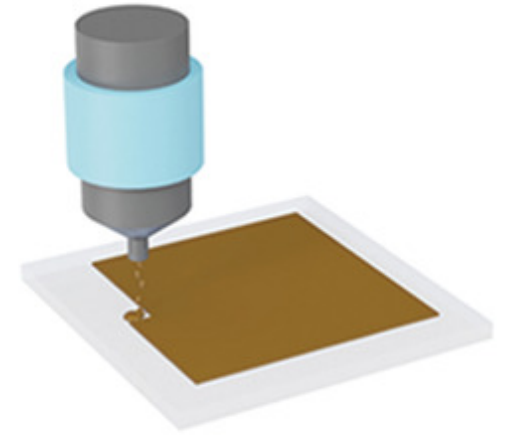


# Take home messages

Inkjet printing can be used to create Transparent Conductors



Colored organic dye effective for FLA light absorption



Transparent processed materials - “key” for security systems







Recent study

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Empa

Laboratory for Thin Films and Photovoltaics

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**Sami Bolat**