VIPERLAB

FULLY CONNECTED **VI**RTUAL AND PHYSICAL
PEROVSKITE PHOTOVOLTAICS **LAB**

SPECIFIC, Swansea University
PV Manufacturing and Testing facilities

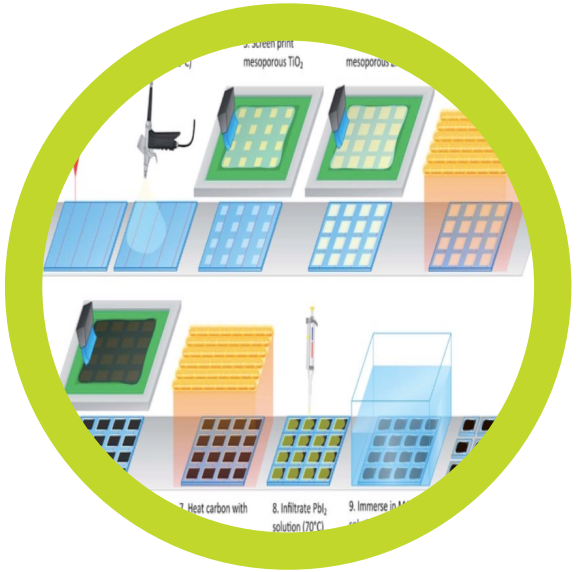
Dr David Beynon
13/11/2023

Swansea University
Prifysgol Abertawe
Materials Science and Engineering
Gwyddor Deunyddiau a Pheirianneg

specific®

SPECIFIC –Swansea University

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°101006715



Energy Materials Research (including scale-up)

Full-scale pilot manufacturing

Building "Buildings as Power Stations"

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Full-scale pilot manufacturing

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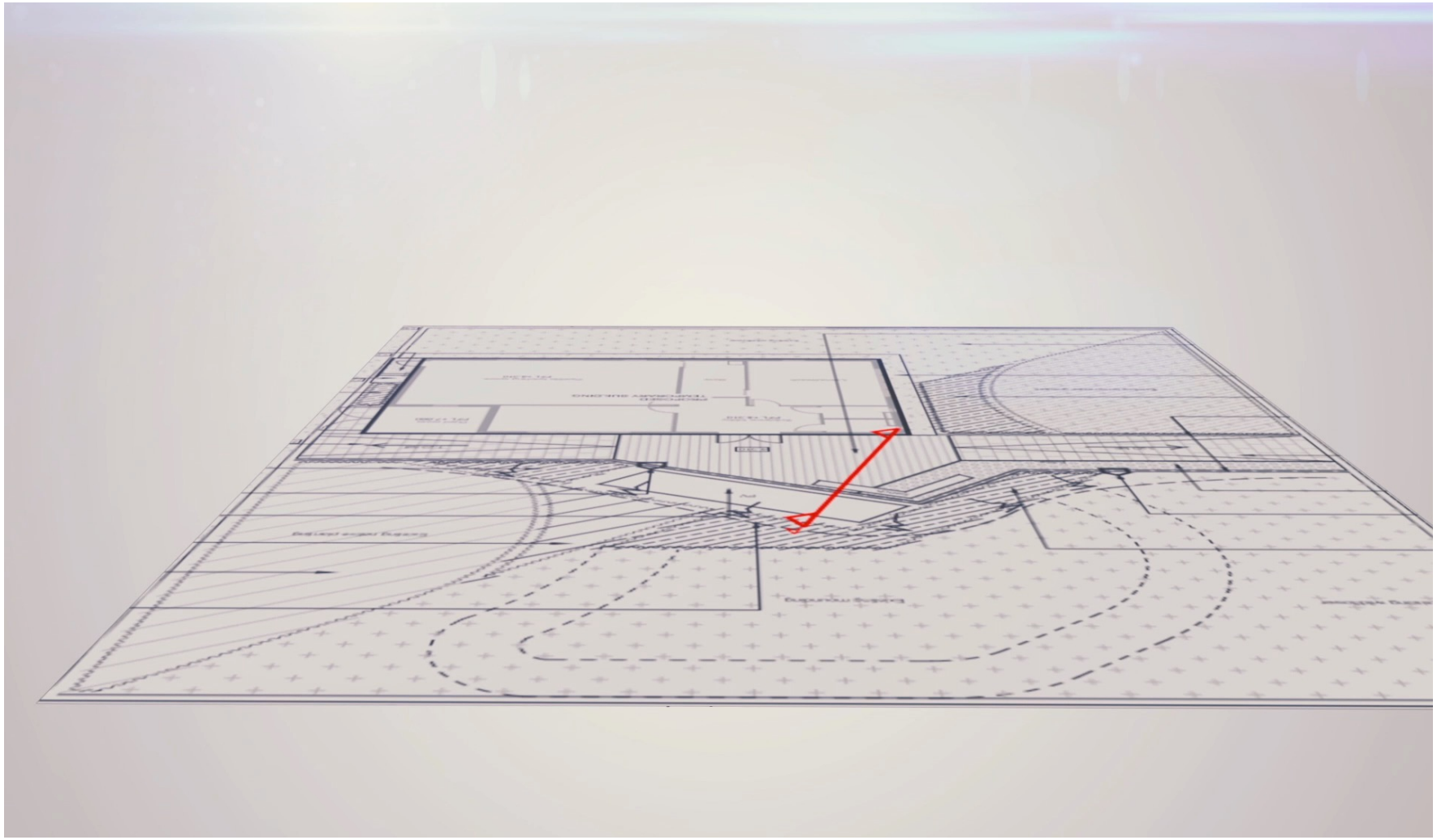
Buildings as Power Stations – concepts to reality



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Facilities

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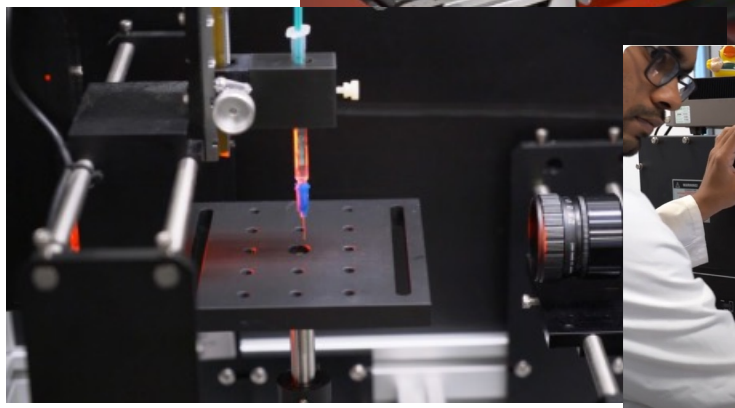
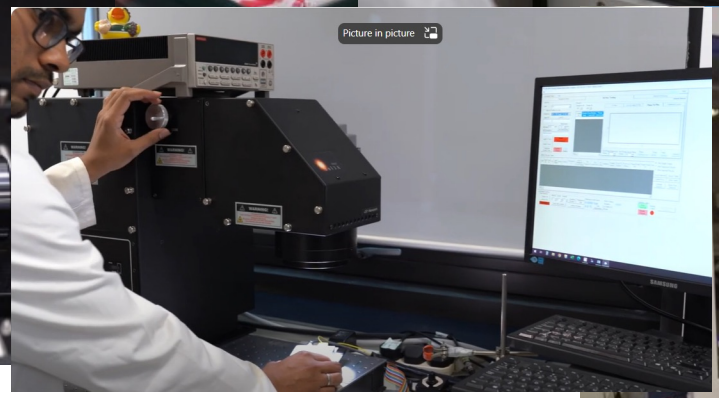
- Scale Up of Perovskite Photovoltaics
  - Sheet to Sheet
  - Screen Printed Mesoporous Carbon
  - Roll to Roll
    - Pilot Scale Facilities
- Ink formulation and analysis
  - Mills
  - Surface energy
  - Rheology
- Characterisation
  - Coating
  - Performance
    - Solar Simulators
    - Stability testing
- Outdoor testing
  - –





https://www.viperlab-kep.eu/infrastructure.asp?i=16

https://specific-ikc.uk/facilities/#bay-campus-laboratories-and-cleanroom

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Scaling up perovskite

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Sheet to Sheet

Glass

Roll to roll

Plastic or metal

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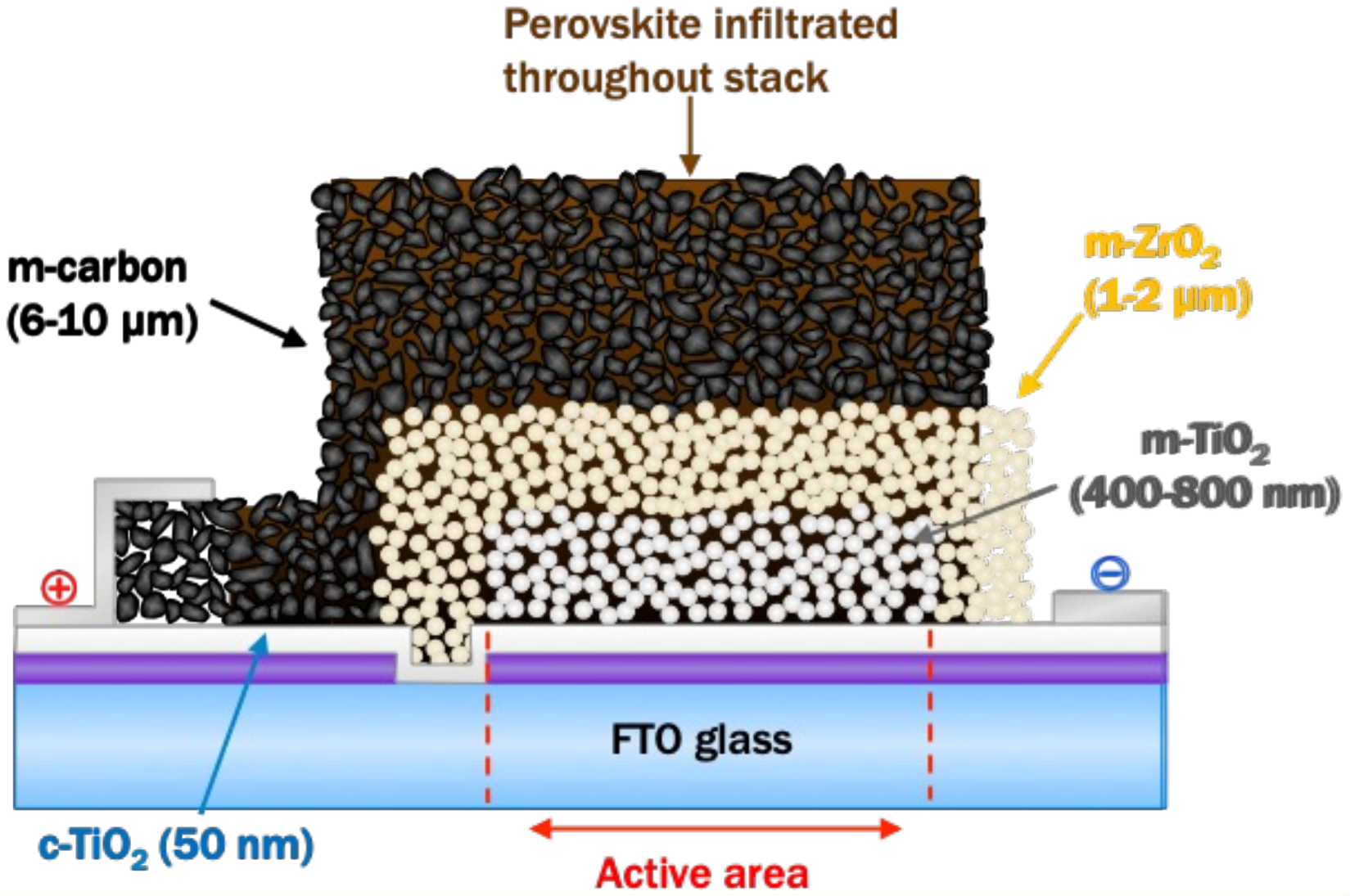
Mesoporous carbon cell (Sheet to Sheet Screen Printing)

- Multi – layer scaffold
  - Built on FTO-Glass
- Infiltrate perovskite into the scaffold



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C-PSC Fabrication Method

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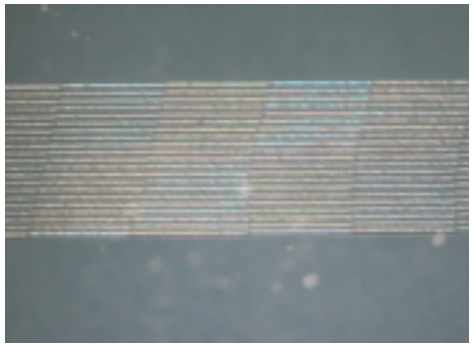
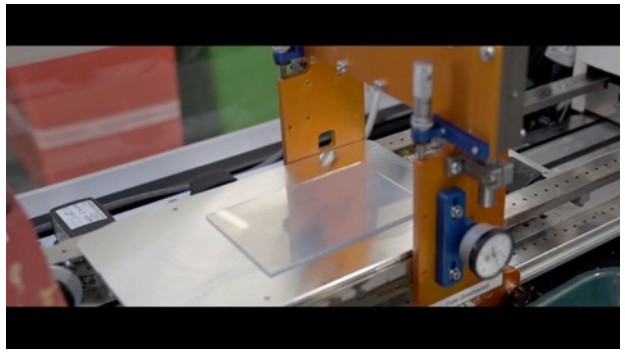
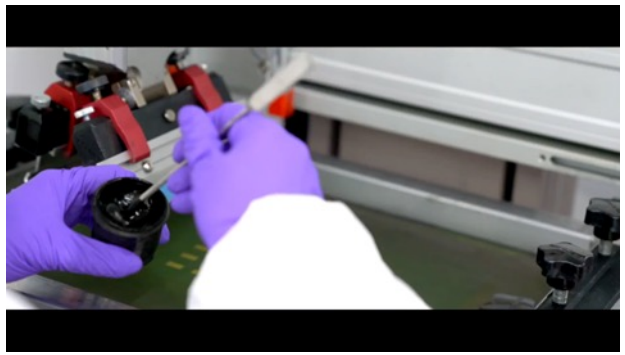


1. Laser patterning of FTO

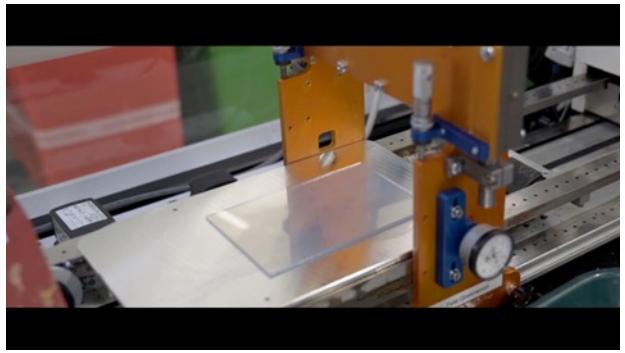
2. Apply TiO_2 and ZrO_2



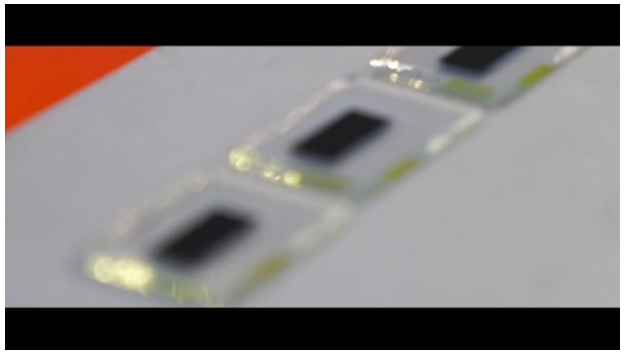
3. Heat layers (~500^{o}C for 30 mins)



4. Apply Carbon layer



5. Heat layers (~400^{o}C for 30 mins)



6. Manual infiltration of perovskite followed by heating

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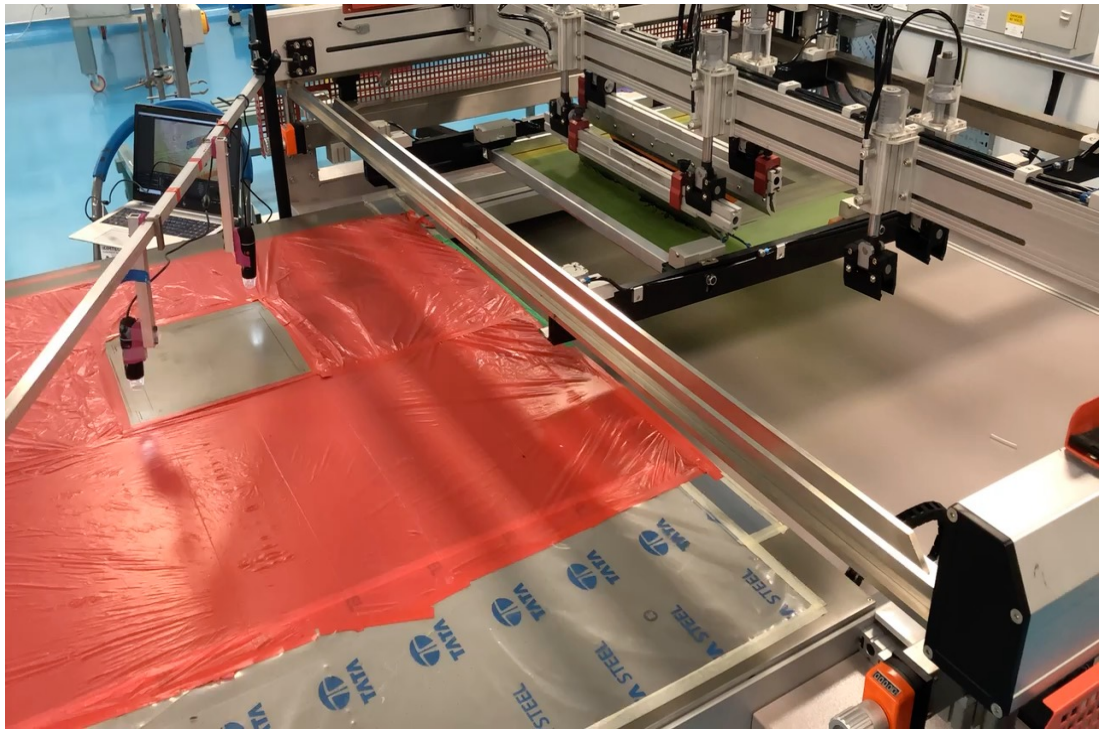
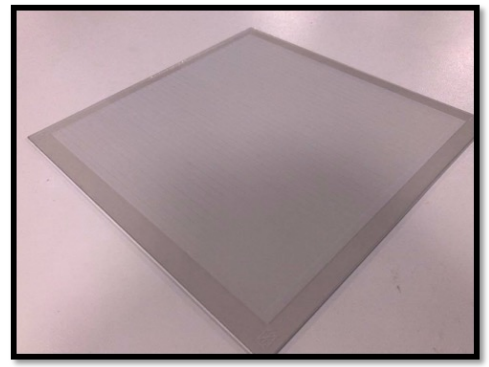
Module fabrication (517cm^2) - Screen printing

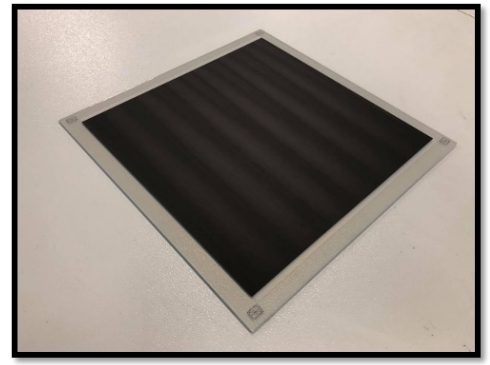


‘Continuous' batch processing

TiO + ZrO2



Carbo
n



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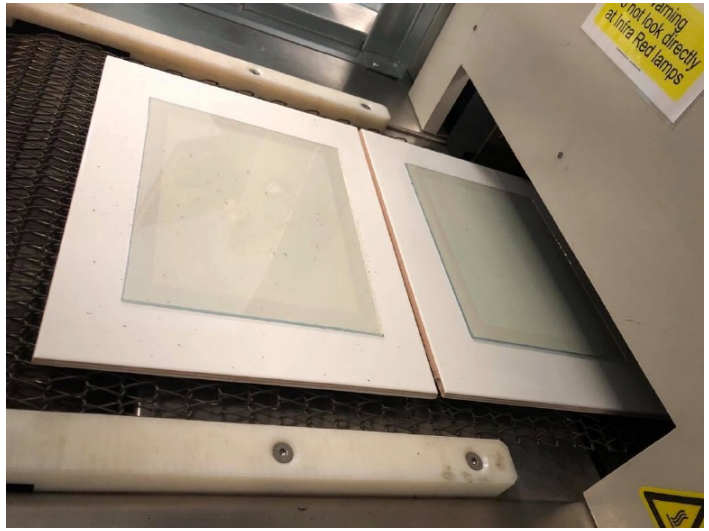
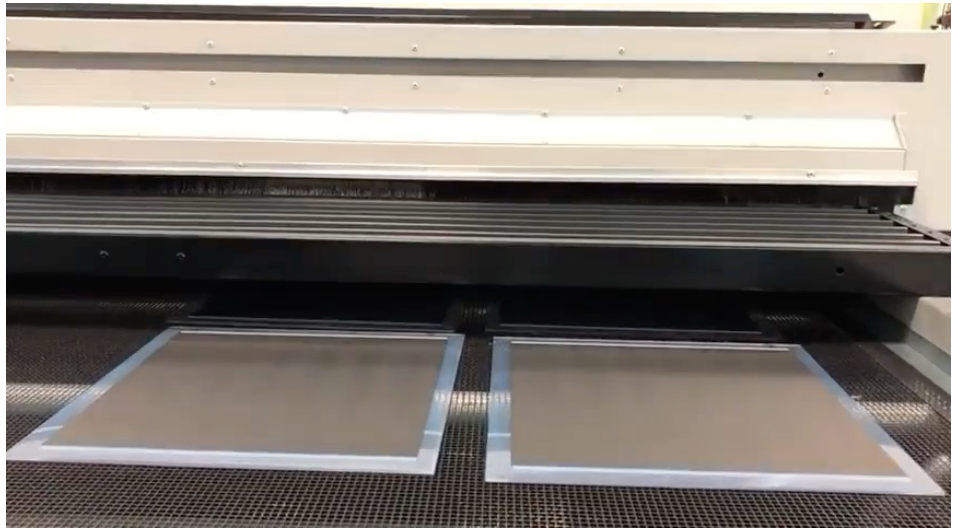
Module fabrication (517cm^2) - Heating





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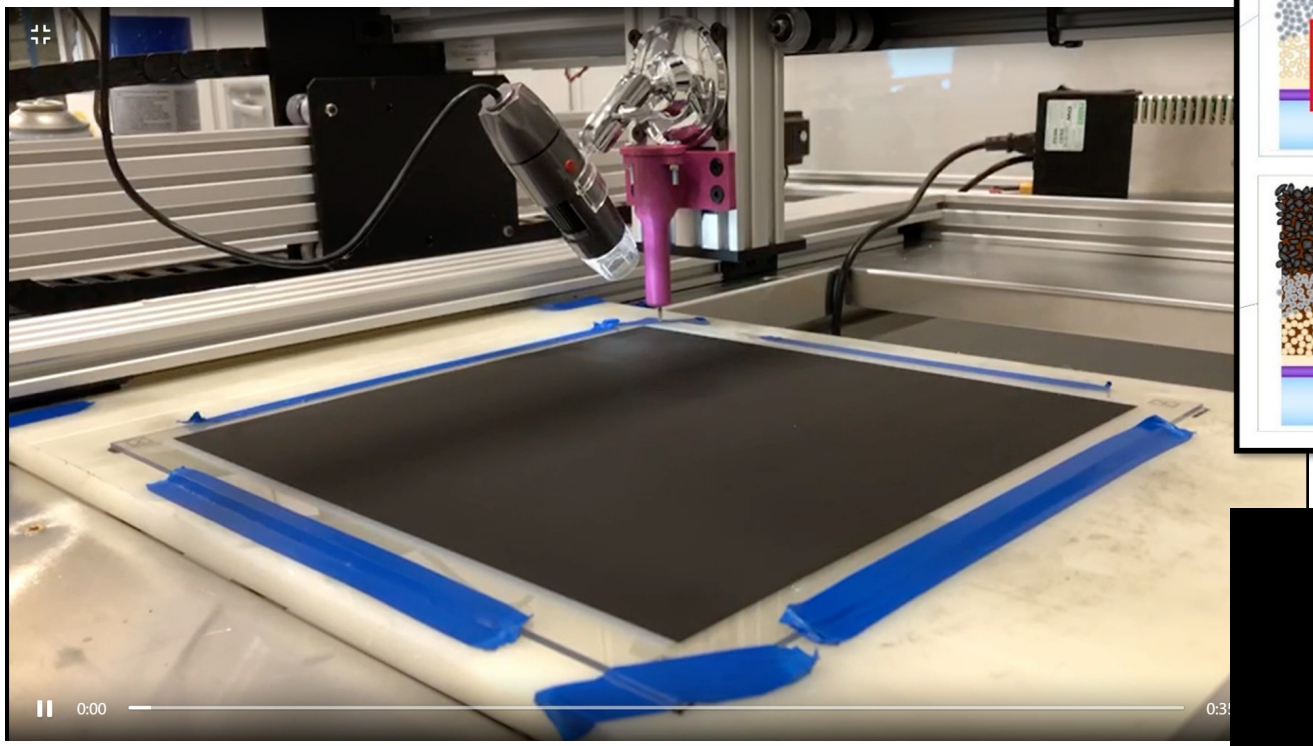
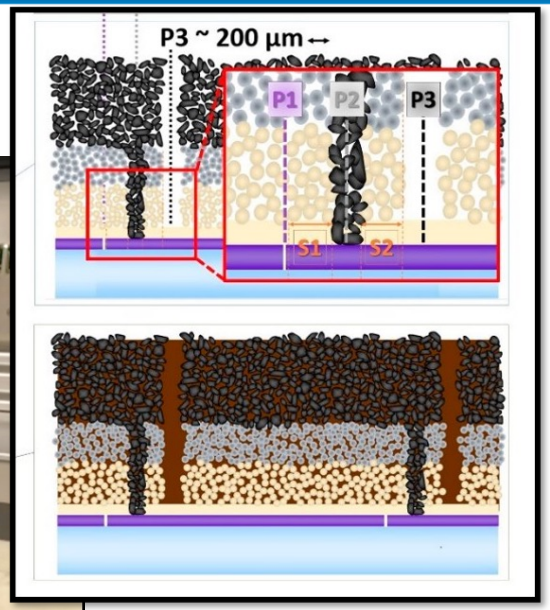
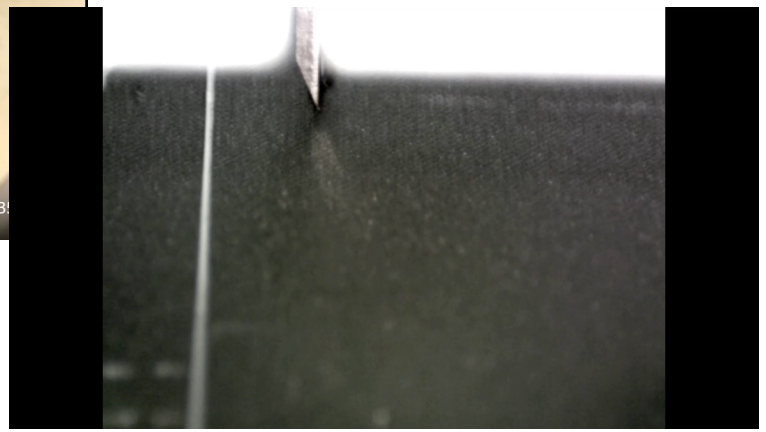
Module fabrication (517cm^2) - Interconnects







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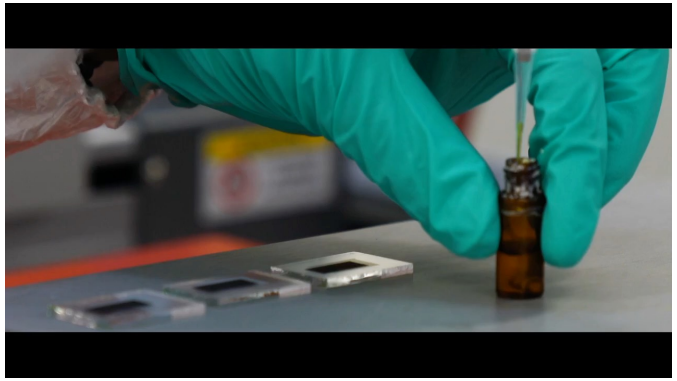
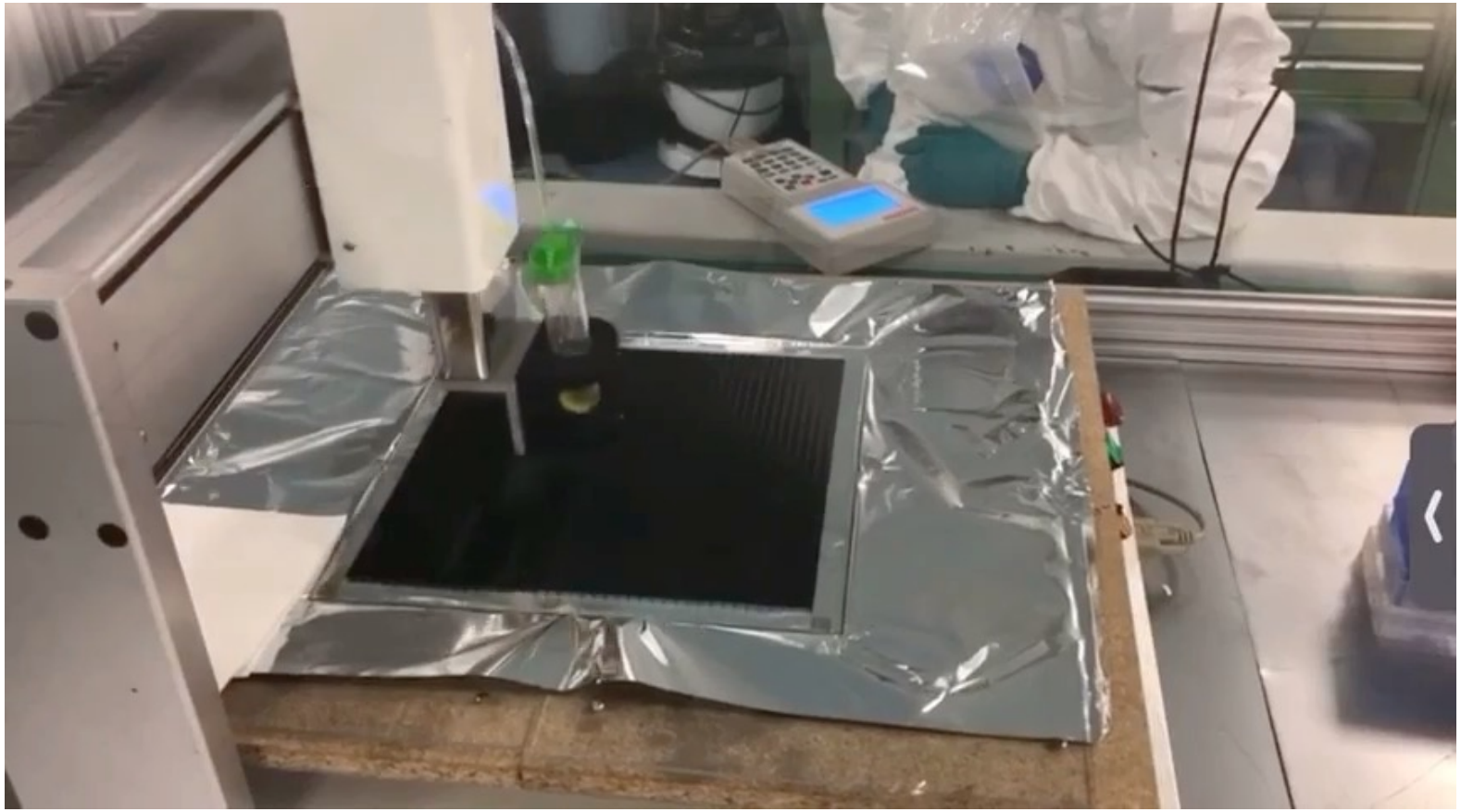
Module fabrication (517cm^2) – Infiltration



Lab-scale fabrication



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Complete modules

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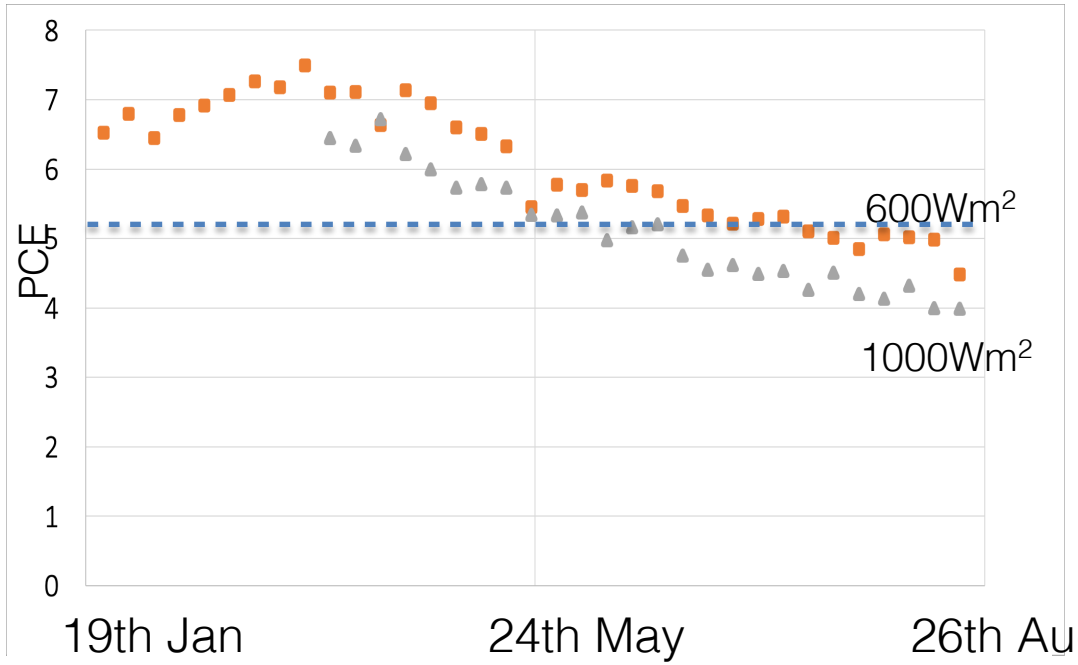

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Roll to Roll (Scale up path)

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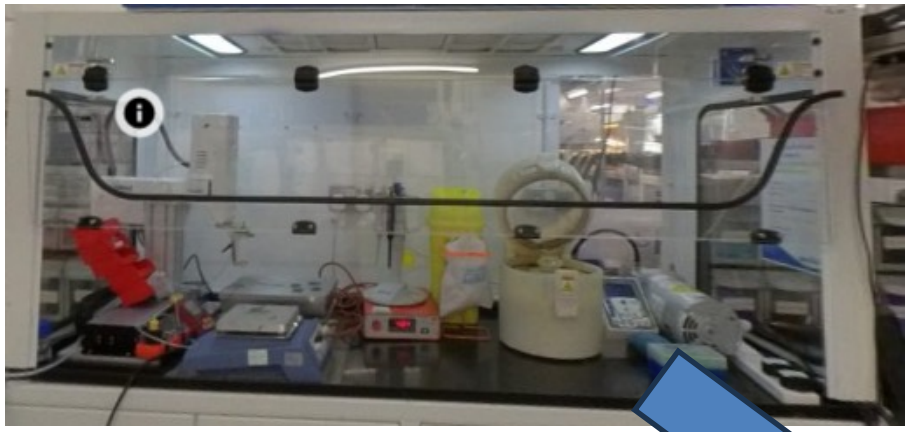

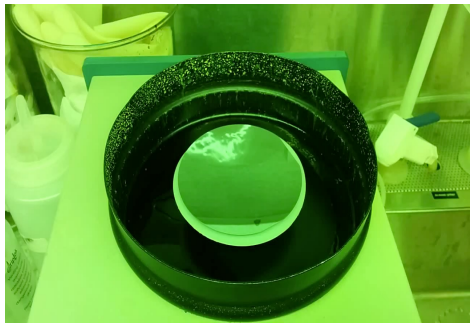

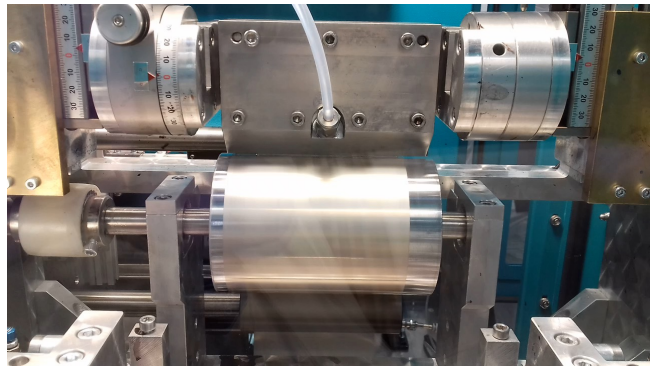

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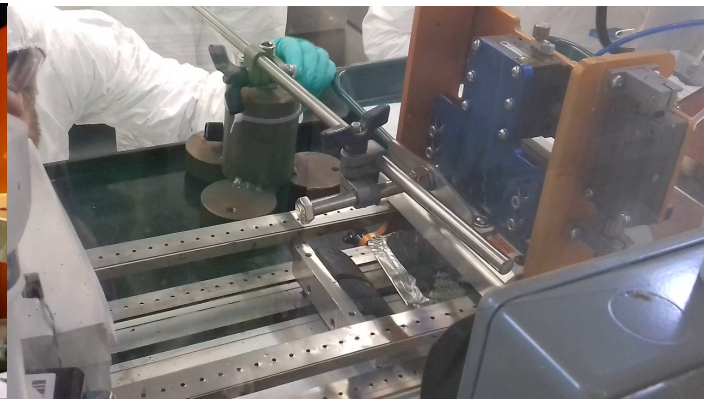
Sheet to Sheet Coating

- Three Slot Die Coaters
  - Ossila
  - Bench Top Coater
  - FOM flat bed slot die
- FOM Coater
  - Substrate carrier
    - Vacuum table
  - Integrated in-line oven
  - Roll-to-roll simulation
  - Air-Knife
  - Heating
    - Syringe and substrate
  - Multiple Heads
    - Inc R2R Heads



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Sheet to Sheet Coating

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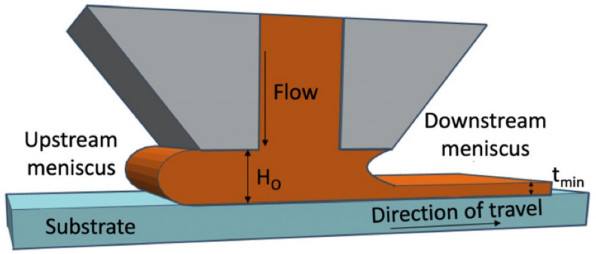
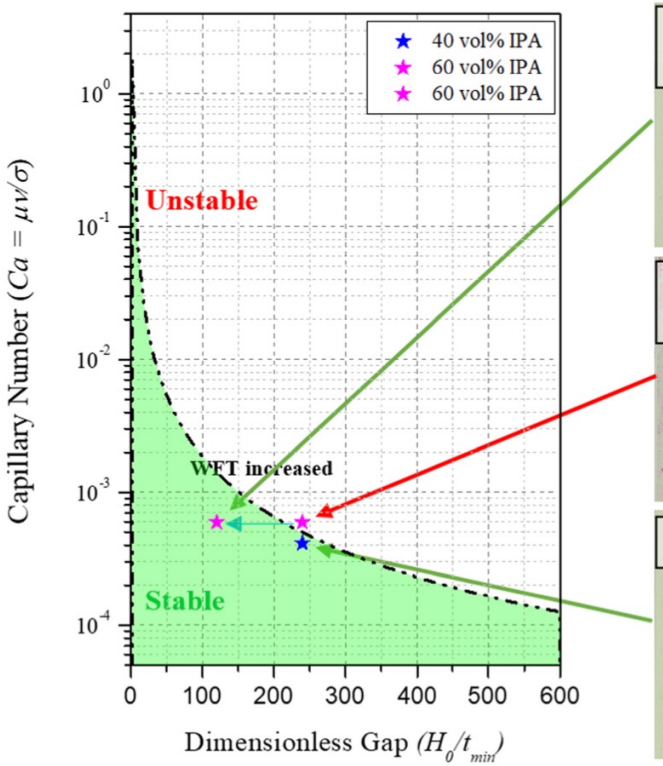
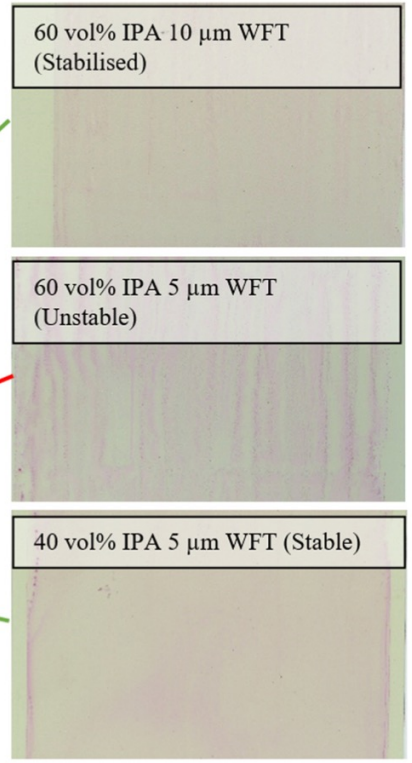
- Develop Coatings
  - Compatibility with process
- Examples
  - Viscocapillary modelling
    - Measure solution
      - Density
      - Viscosity
      - Surface tension
    - Determine stable coating
      - Modify solution and/or coating parameters
  - Thermogravimetric Analysis
    - Mass loss with temperature
    - Solvent blends
      - Optimise drying profile
      - Avoid drying defects







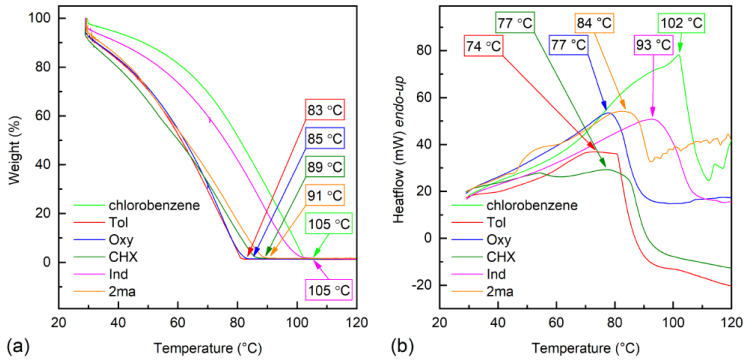


Fig. 6 Simultaneous Thermal Analysis of PCBM inks with various solvent blends at 10°C per minute. The labelled temperature on the gravimetric analysis is when the weight derivative with respect to time is equal to zero (a). The labelled temperature on the thermal analysis is the peak heatflow (b). Solvent system abbreviations are Tol = toluene, Oxy = O-xylene, CHX = cyclohexanone, Ind = Indan, 2ma = 2-methylanisole.

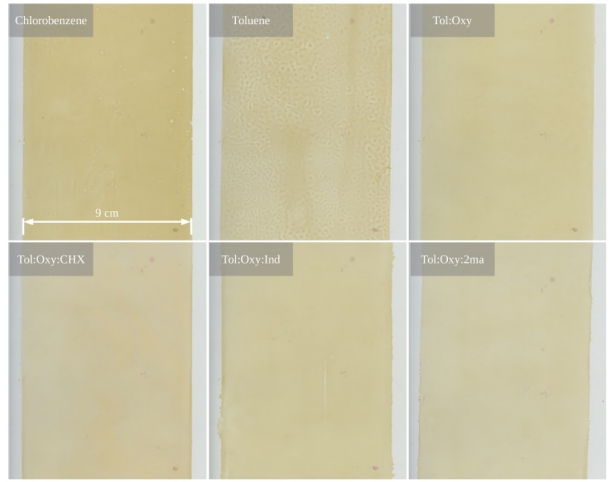


Figure S17: Images of PCBM dry films deposited by slot-die coating a 5µm wet film on bare PET substrate, using 10mgml^{-1} inks with solvent systems of either chlorobenzene, toluene, toluene:O-xylene (7:3v/v) (Tol:Oxy), toluene:O-xylene:cyclohexanone (6:3:1v/v) (Tol:Oxy:CHX), toluene:O-xylene:indan (6:3:1v/v) (Tol:Oxy:Ind), toluene:O-xylene:2-methylanisole (6:3:1v/v) (Tol:Oxy:2ma).

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Characterisation Tools

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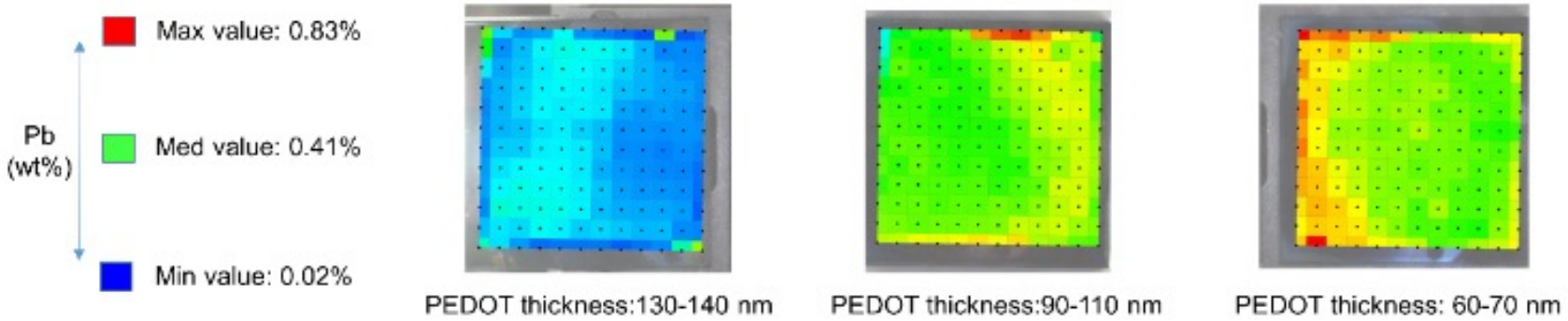
XPS

- Kratos Axis Supra
  - Dual monatomic Ar+ and Ar+ gas cluster source for depth profiling versatility.
  - Ultraviolet photoelectron spectroscopy (UPS) with He (I) or He (II)
  - CasaXPS analytical software site licence
- Surface Chemical Analysis
  - Quantitative chemical stoichiometry
    - 10nm surface depth



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More Characterisation Tools within SPECIFIC

- **Electrical:**
  JV Measurement
  MPPT Testing
  EQE
  CV

- **Optical Characterisation:**
  UV-Vis
  TRPL
  Photocurrent and PL Mapping

- **Imaging:**
  AFM
  SEM
  TEM

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R2R Processing

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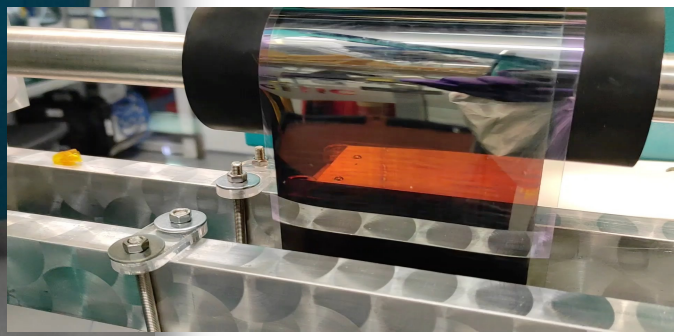
- Coatema Smartcoater
  - Multiple coating heads
    - Blade, gravure, dip
    - Slot Die
  - 100mm coating width
  - Web guide
  - Inline oven
  - 10m/min
    - 1m/min standard
- Full Perovskite Device
  - Rewind and rerun



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Closure

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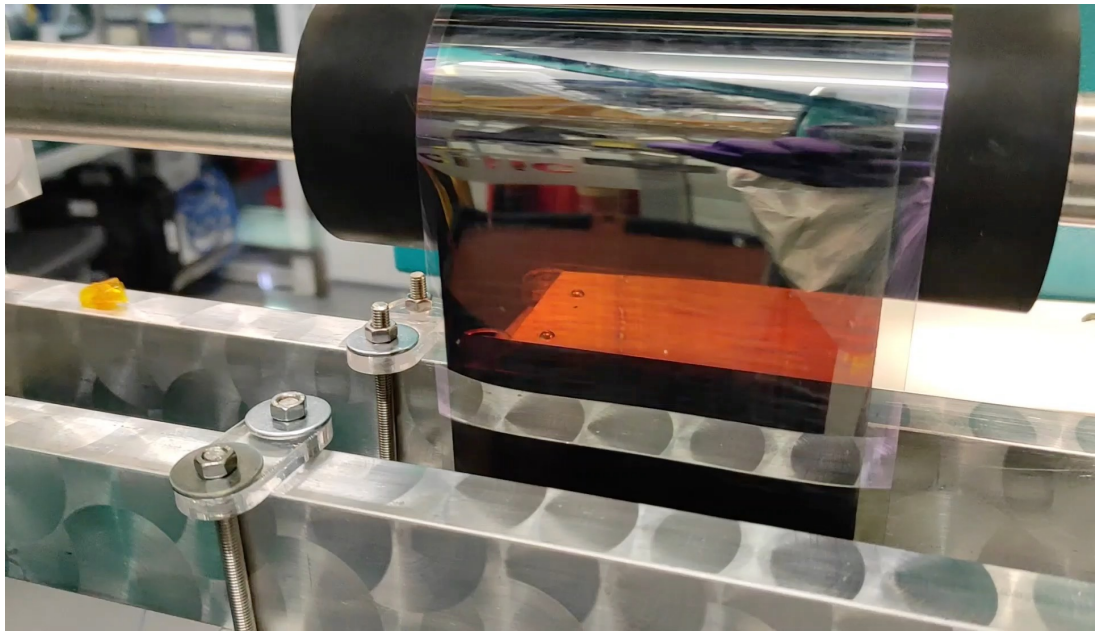
- SPECIFIC
  - Research group in Swansea University
- Scale up of Perovskite PV
  - From lab to pilot scale production
  - Mesoporous structure
    - Screen printing
  - Planar structure
    - Roll to roll coating
- Comprehensive characterisation
  - Range of advanced characterisation tools



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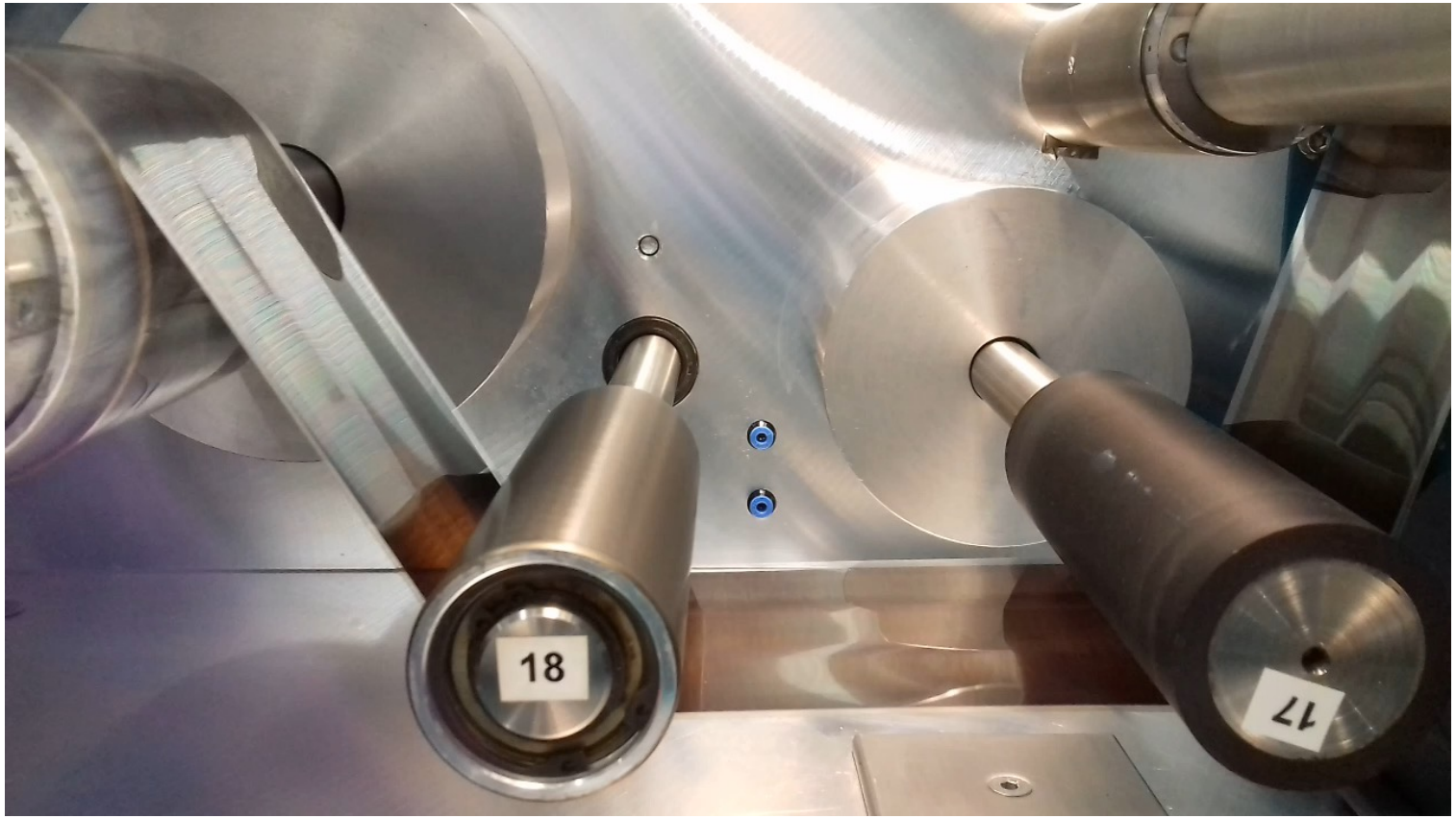
Thank You! - Questions?



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Swansea University
Prifysgol Abertawe
Materials Science and Engineering
Gwyddor Deunyddiau a Pheirianneg

Funded by:

Ariennir gan
Lywodraeth Cymru
Funded by
Welsh Government

UKRI Engineering and Physical Sciences Research Council

Strategic Industry Partners:

AkzoNobel

NSG GROUP

TATA STEEL

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