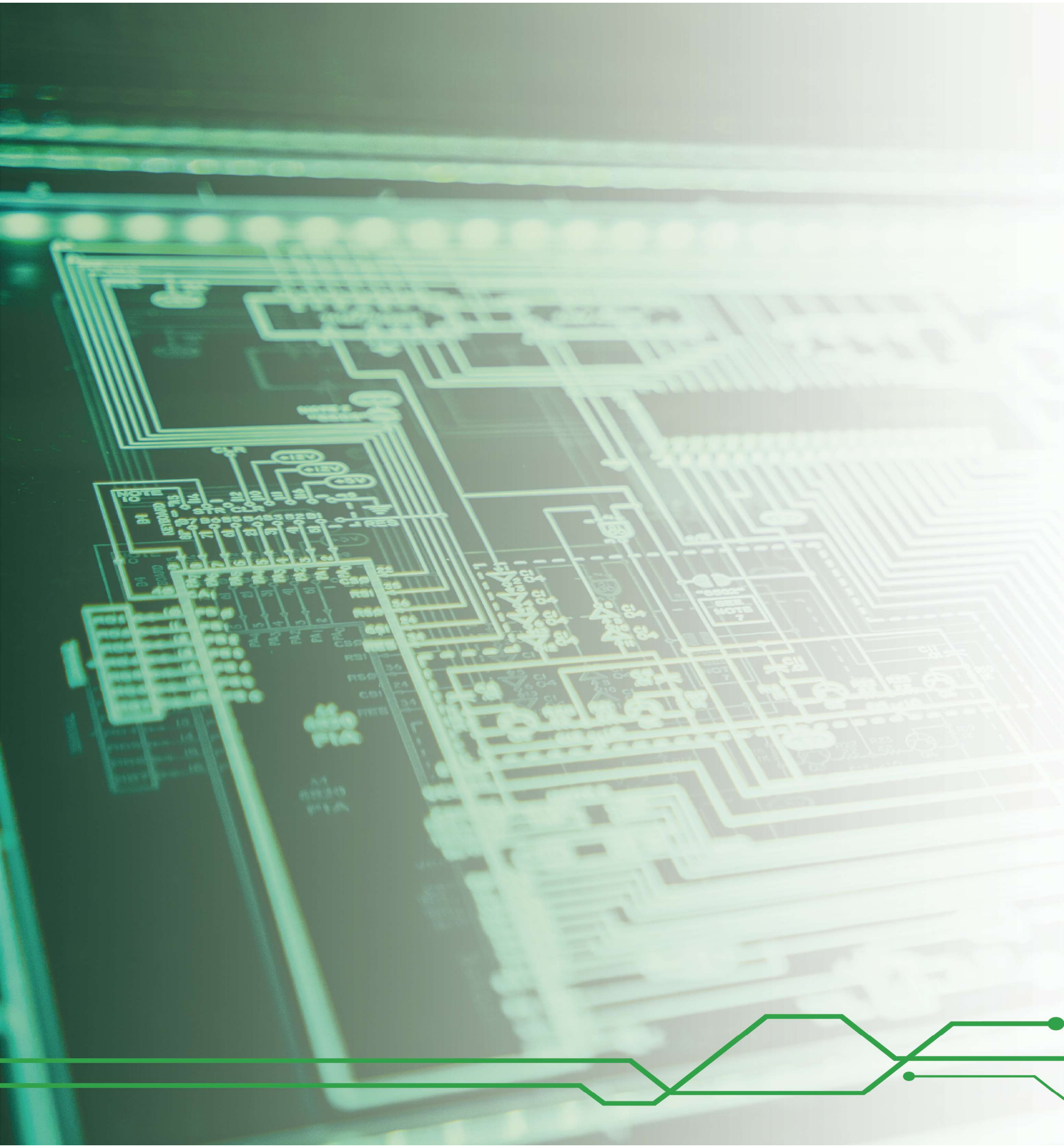

EMERGE scope includes:

To be the first integrated, distributed research infrastructure as a wider European research platform supporting comprehensive user projects for multi-and-trans-disciplinary research on sustainable printed electronics extending from **material synthesis, functional inks formulation and printing process optimization to characterization, device's processing and integration, modelling and simulation**

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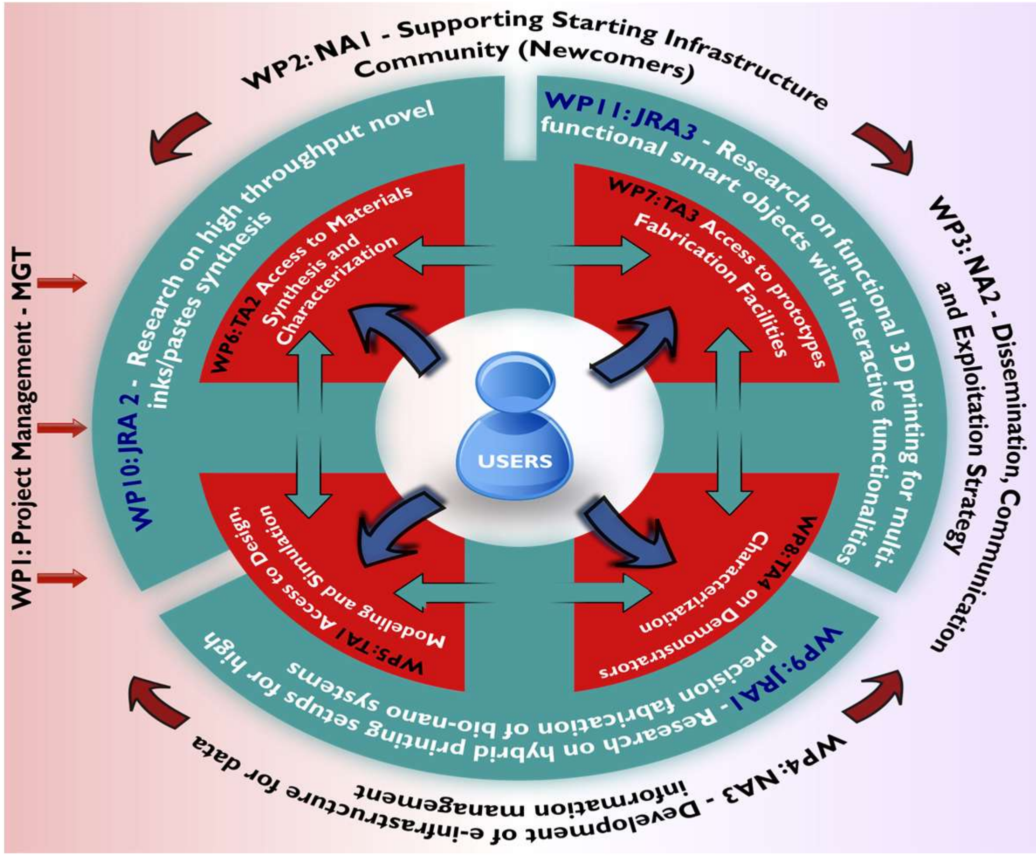
Emerging Printed Electronics Research Infrastructure

The EMERGE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement № 101008701

EMERGE at a glance- Structure



- ***3 Network Activities, NA (outer circle)***
- ***4 Trans-national access, TA (inner circle)***
- ***3 Joint Research Activities, JRA***

Accesses offered to RTO, Universities, SME and Industry

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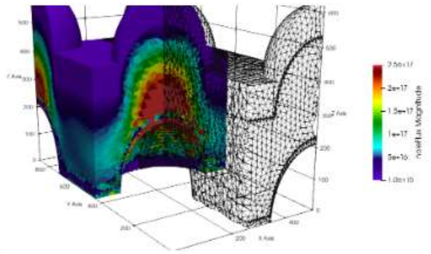
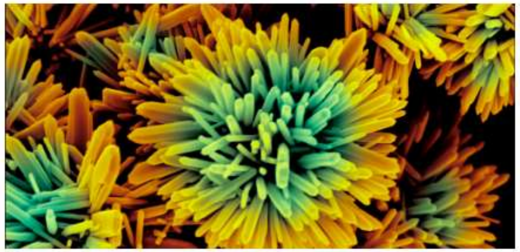
EMERGE: Transnational Access Activities (TA)

Users can apply to projects in any (or multiple) of the 4 TA:



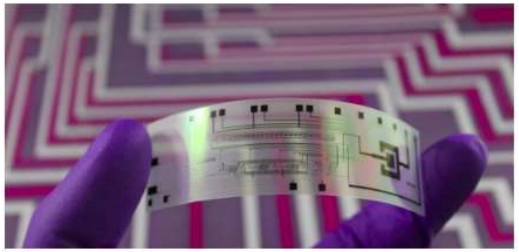
TA1 - Theory: Modelling, simulation, and design of materials, devices and systems

- Device design and architecture
- Modelling and simulation



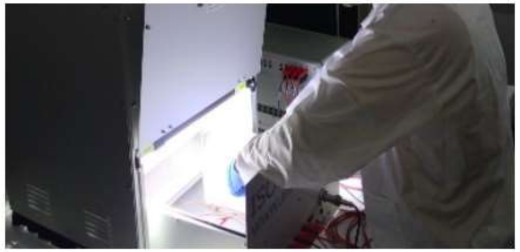
TA2 - Material synthesis and ink formulation

- Chemical techniques
- Physical techniques
- Materials characterization



TA3 - Prototype fabrication

- Device preparation
- Functional 2D&3D printing
- Industrial printing
- Nanoimprint and laser patterning
- Vacuum assisted deposition



TA4 - Characterization of prototypes and demonstrators

- Device metrology and characterization
- Validation and standardization

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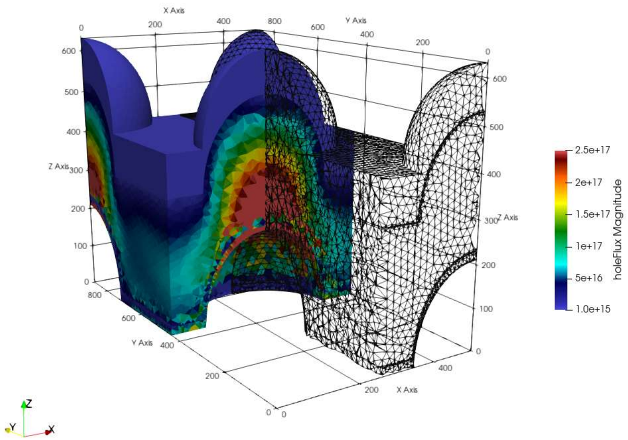
TA1. Access to design, modelling and simulation



20/10/2022

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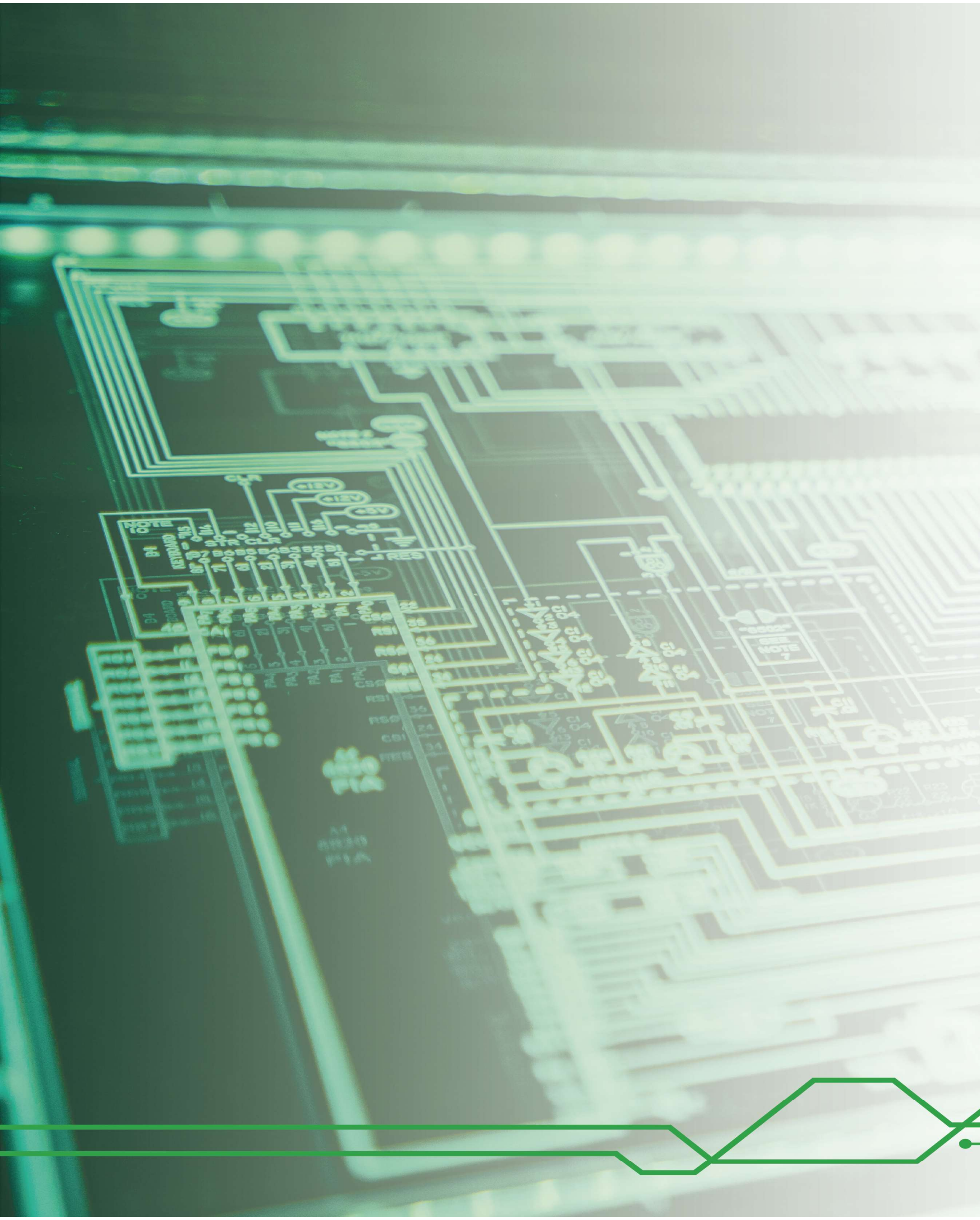

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TA1. Theory: Modelling, simulation, and design of materials, devices and systems

Addressing projects oriented to high-resolution multiscale process simulations, machine learning artificial intelligence based approaches, giving insight and guidelines for novel material growth, functional design, and fabrication.

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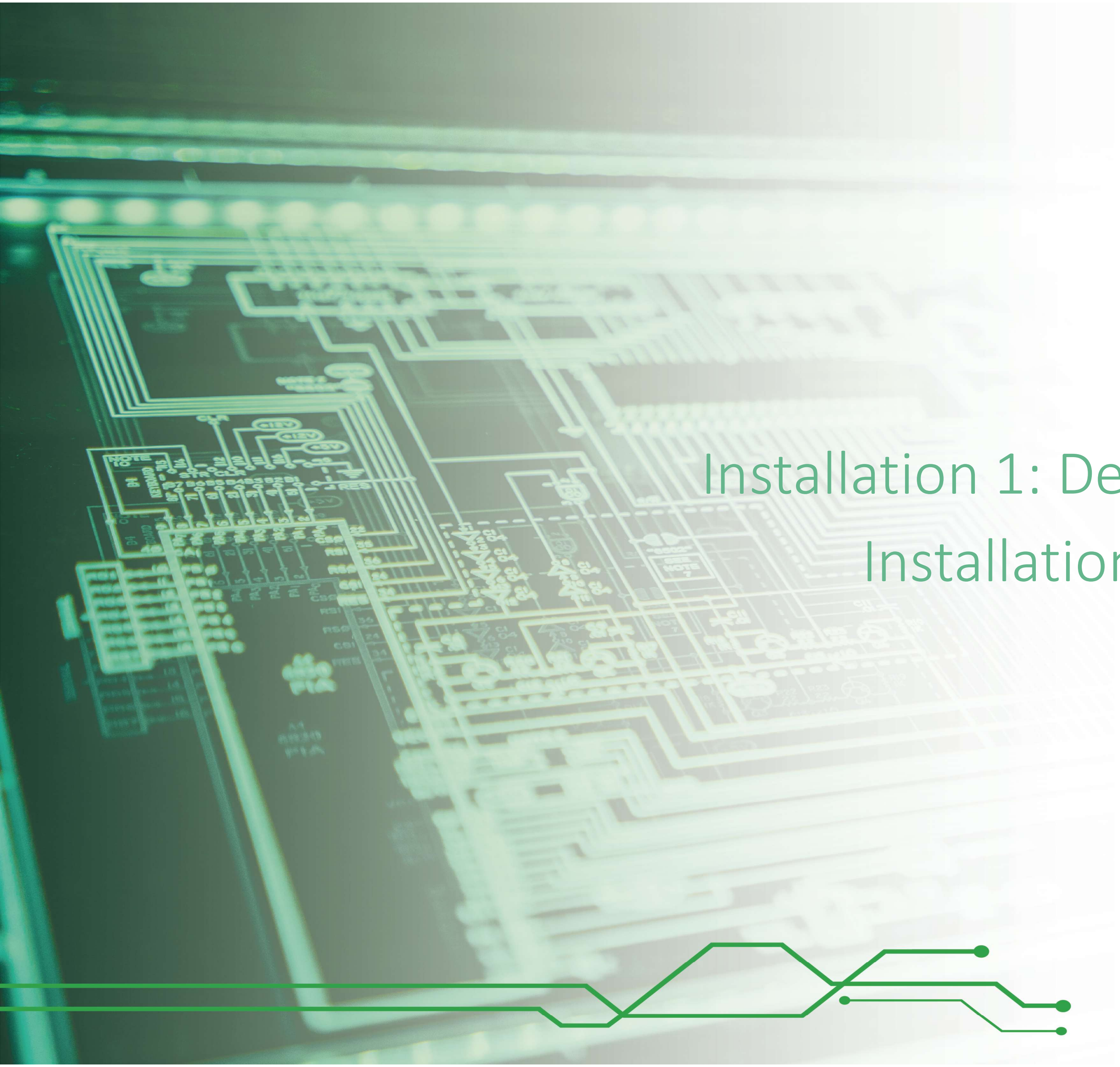

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Installation 1: Design and device architectures
Installation 2: Modelling and simulation

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TA1 : Participants

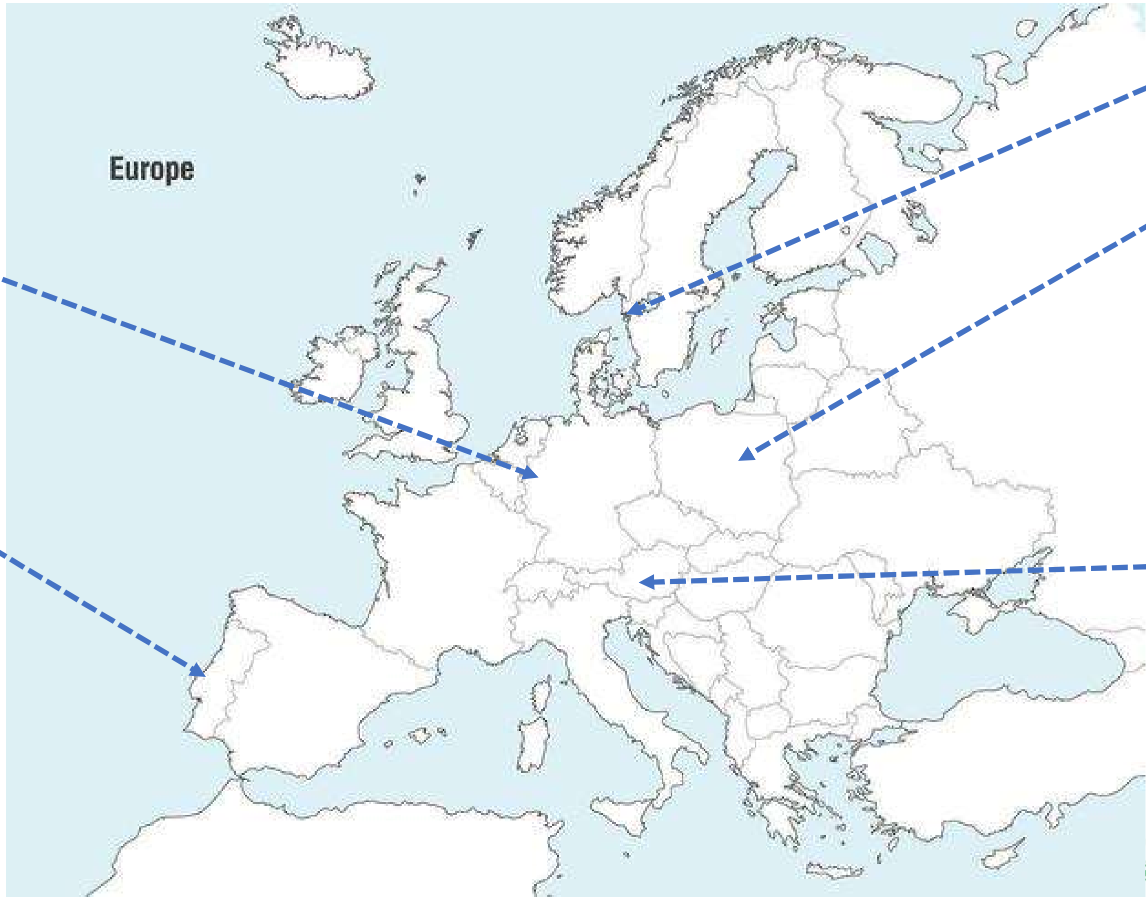
5 frontier European research institute share their knowledge and infrastructure

Phase field/lattice Boltzmann simulation of film formation, printing and coating processes

HI ERN Helmholtz Institute Erlangen-Nürnberg

UNINOVA

TCAD simulations from material design to complete systems/circuit architecture



RI. SE

simulation and design of ion-based devices and systems

CEZAMAT

modelling in engineering software for the design of structures and sensors, patterns

JOANNEUM RESEARCH

ray tracing, sub-wavelength and multiscale optical modelling and design for light management structures

EMERGE Emerging Printed Electronics Research Infrastructure

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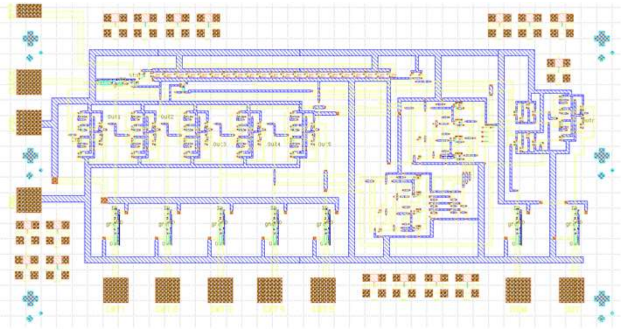
TA1 : Objectives

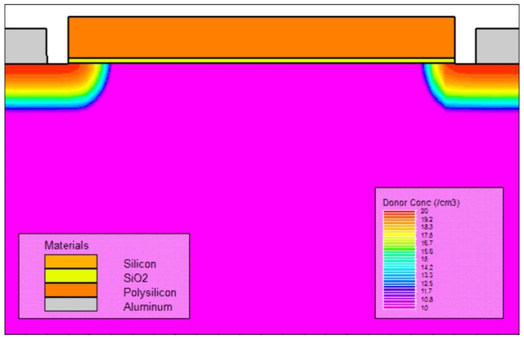
Challenge: tailor the microstructures of thin films and devices, which influence the electronic, optical, and mechanical properties

- process-structure relationships: modelling of printing, drying and post-processing
- structure-property relationships
- all the way up: from the material to the device



EMERGE partners provide access & support:

- Competences on computational tools and engineering software
- In-house simulation software and HPC facilities on a per project base
- Extend development of existing tools based on the user's needs (based on JRAs)



Support modalities:

- Users requesting computational support: Simulations performed by the staff of the infrastructure (remote access)
- Experienced users: Training and assistance provided by the staff of the infrastructure (remote, but users encouraged to visit the institute for training).

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TA1.1 : Device design and architectures

Digital tools for designing devices: CAD tools for frame design (printing), EDA for IC design (Europractice, access to multiple PDKs), PCBs

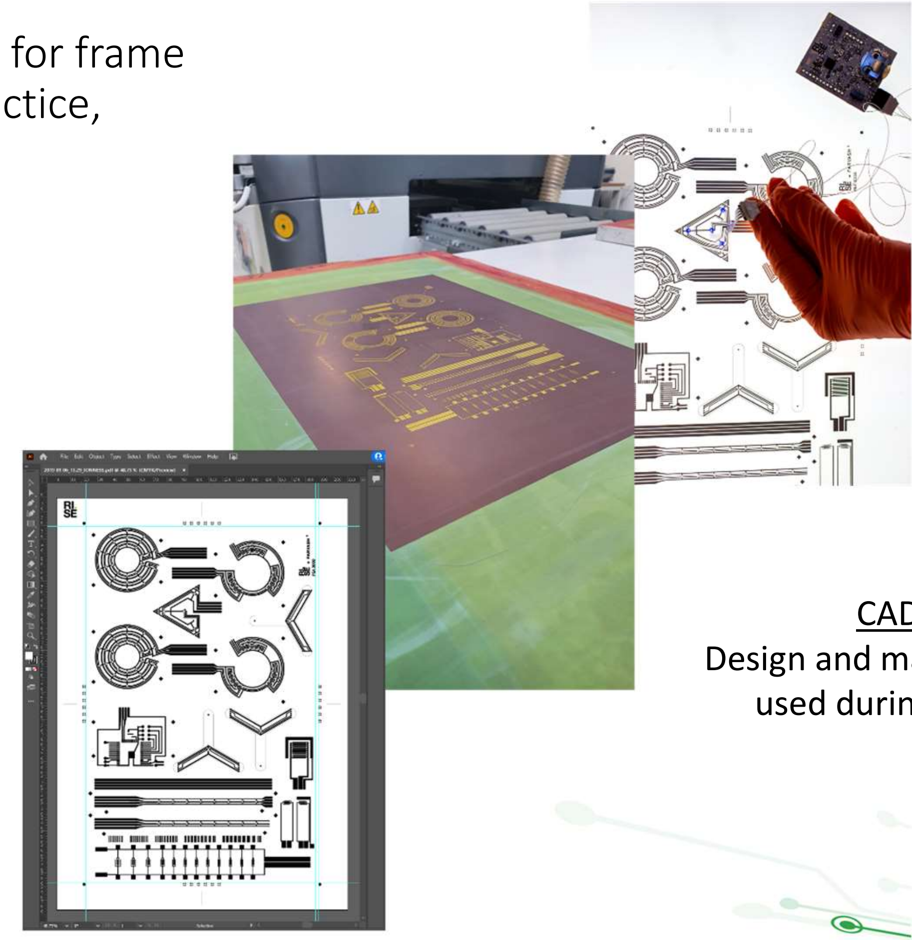
ALTIUM DESIGNER

Mentor® A Siemens Business

SYNOPSYS®

cādence®

RI. SE



<u>CAD example:</u>
Design and manufacture of frames used during screen printing

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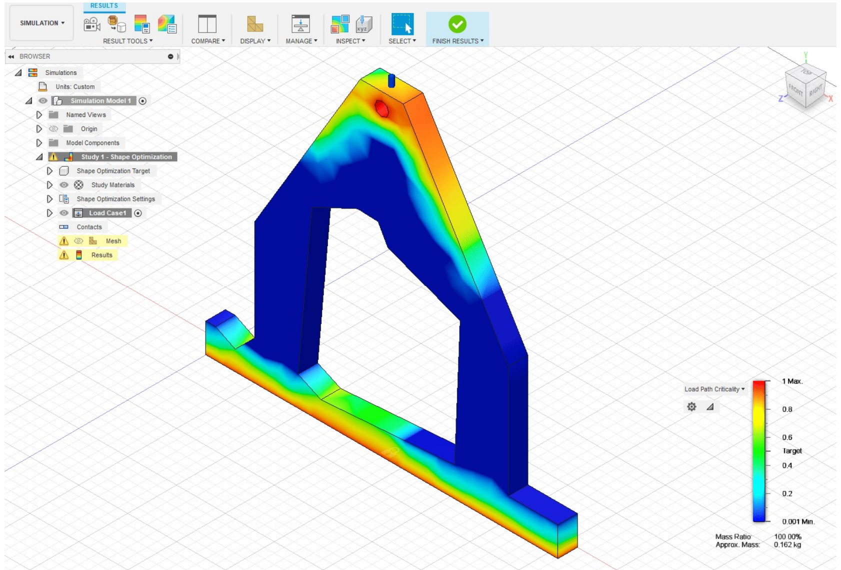
TA1.1 : Device design and architectures

Autodesk Fusion 360: cloud-based 3D modeling, CAD, CAM, CAE, and PCB software platform for product design and manufacturing.

Autodesk CFD: computational fluid dynamics simulation software to intelligently predict how liquids and gases will perform.



<u>Simulation example:</u>
Critical thermomechanical loading in a 3D shape

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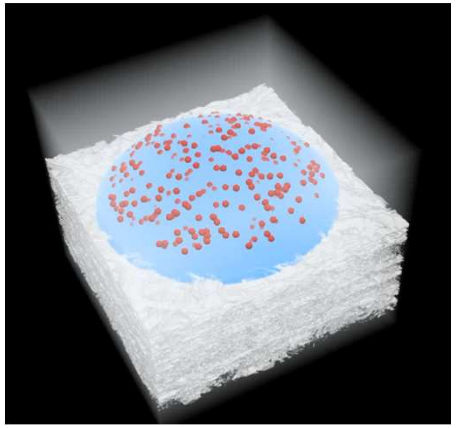
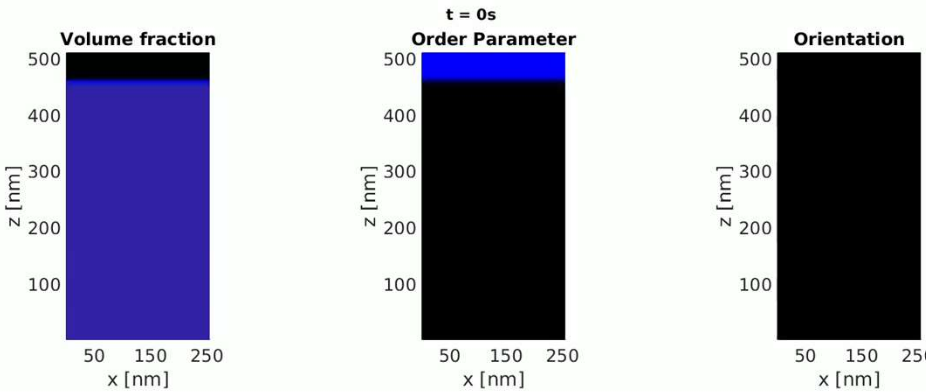
TA1.2 : Modelling and simulation

PFSim-Prost: parallel phase-field code for the simulation of multicomponent and multiphase mixtures undergoing thermodynamic phase transformations. Investigation of morphology formation of thin films upon drying, solvent vapor annealing, thermal annealing as well as stability during device usage



Process simulation example:
Drying of a particle-filled droplet on a porous substrate



Process simulation example:
Morphology formation of an organic photovoltaic layer (bulk heterojunction) upon drying

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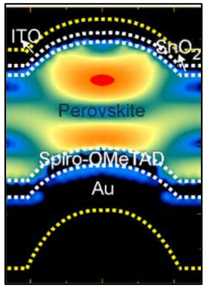
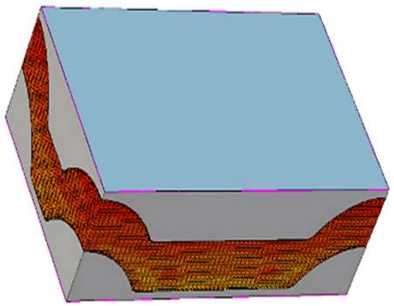
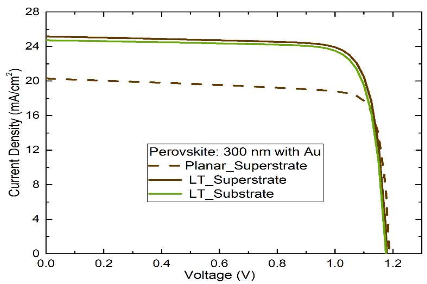
TA1.2 : Modelling and simulation

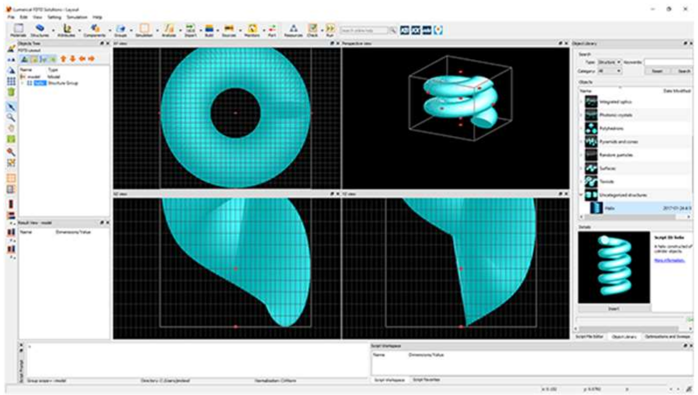
LUMERICAL/FTDT Solutions: numerical analysis technique used for modelling computational electrodynamics

G(x,y,z) from **LUMERICAL FDTD** (.mat file) → ***FEM drif-diffusion solver: Lumerical CHARGE*** → **Transport simulations**









<u>Device simulation example:</u>

Optoelectronic simulation and optimization of thin-film solar cells enhanced with photonic structuring for light trapping

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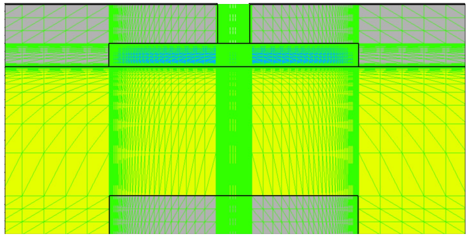
TA1.2 : Modelling and simulation

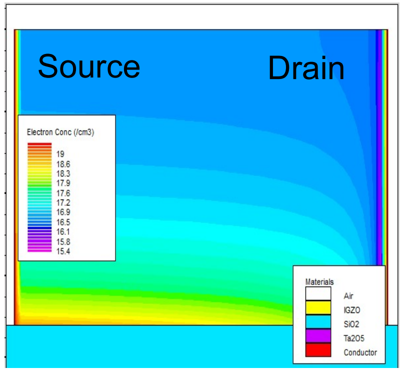
SILVACO TCAD: physical-based simulation providing predictability and insight into the physical-mechanisms of device operation.



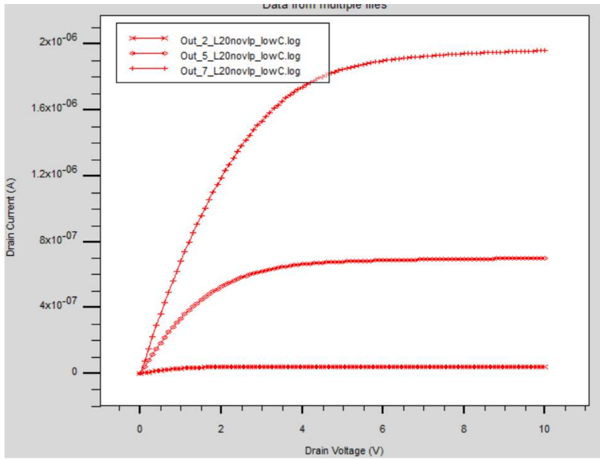
Finite element method

(schematic of TFT structure)

Carrier concentration



Prediction of IV characteristics

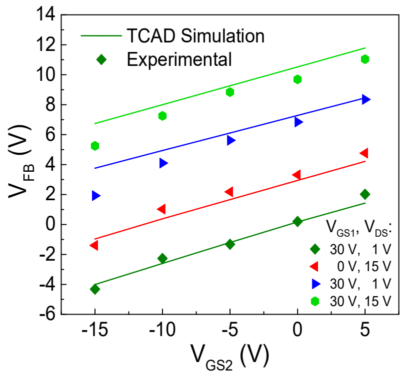


Semiconductor physics:

Poisson: $div(\varepsilon\nabla\psi) = -\rho$

Continuity: $\frac{\partial n}{\partial t} = \frac{1}{q} div\overrightarrow{J_n} + G_n - R_n \Leftrightarrow \begin{cases} n \\ p \\ \psi \end{cases}$

Drift-diffusion: $\overrightarrow{J_n} = q\mu_n\overrightarrow{E_n} + qD_n\nabla n$



Validation with fabricated devices

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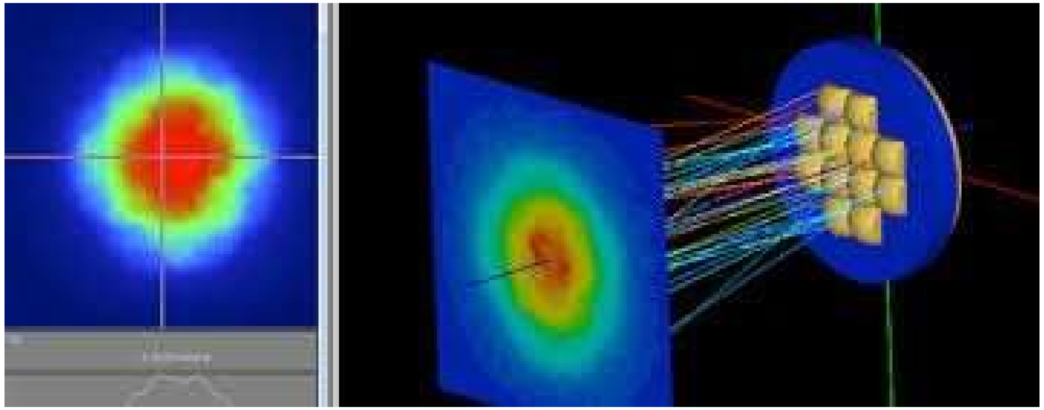
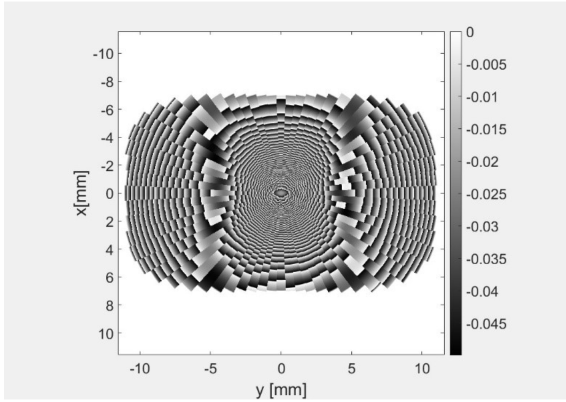
TA1.2 : Modelling and simulation

Breault Research/ASAP: commercial raytracing software for simulating the behaviour of optical components or entire optical systems, based on geometrical optical equations



Optical simulation example:

Calculation of the far-field irradiance distribution of a 3D entire optical system



Optical simulation example:

Calculation of light intensity distribution for a thin free-form micro-optical element, from self-developed calculation algorithms

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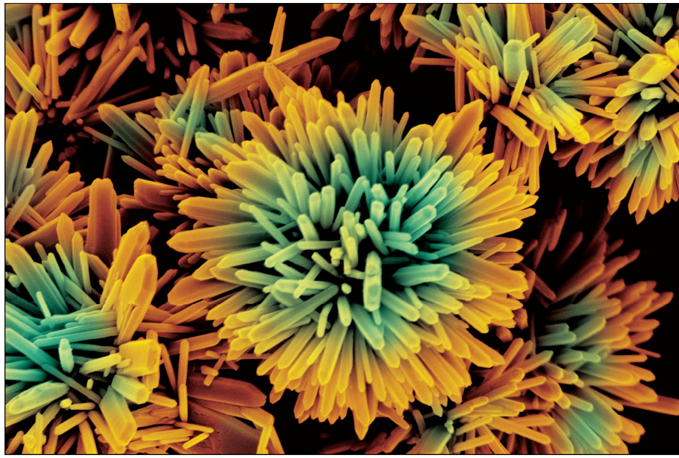
TA2. Material Synthesis & Ink Formulations



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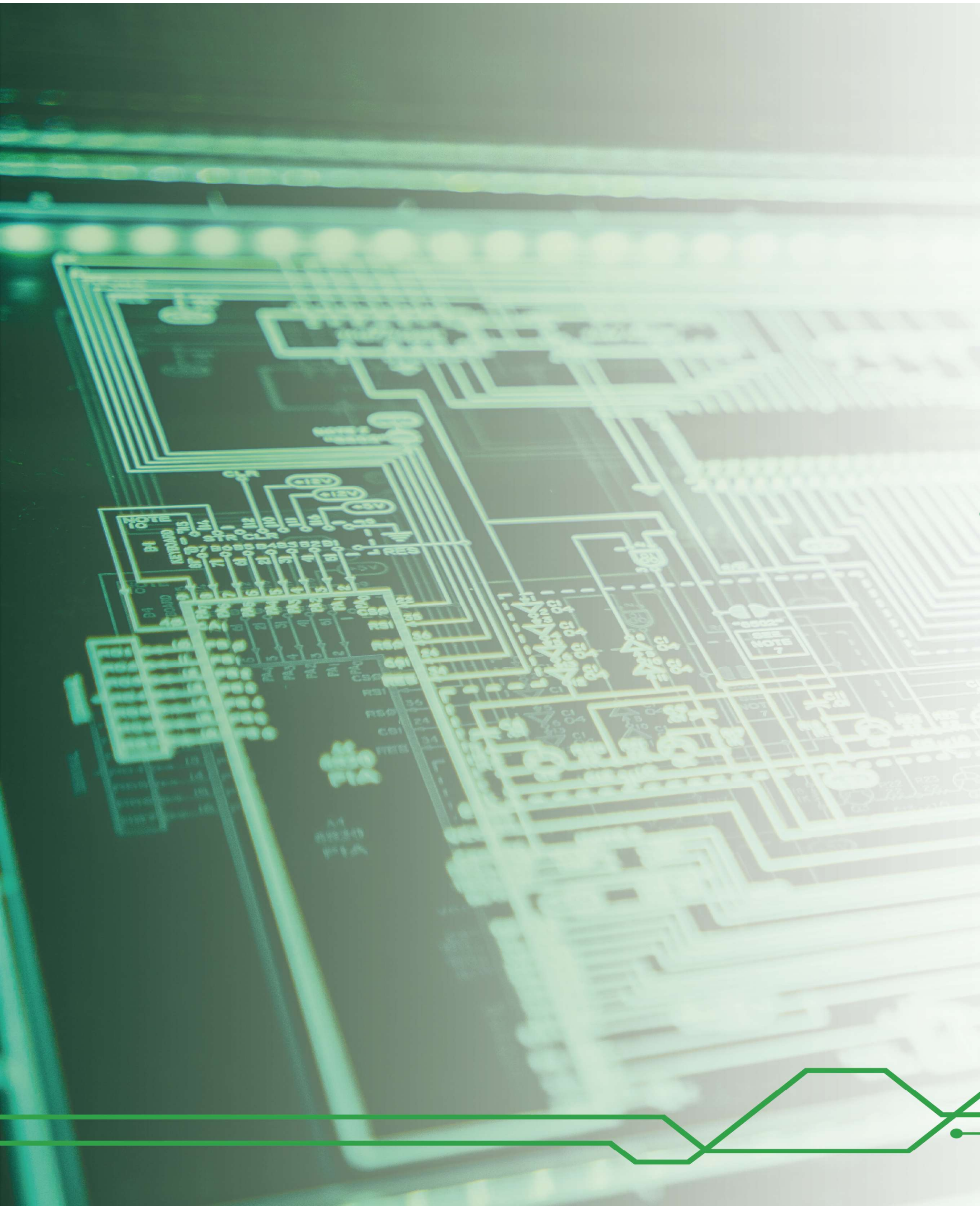

TA2. Material Synthesis & Ink Formulations

"We provide a European wide infrastructure to research projects for **Novel nanomaterial preparations, inks/pastes formulations and fabrication** and their **characterization**"

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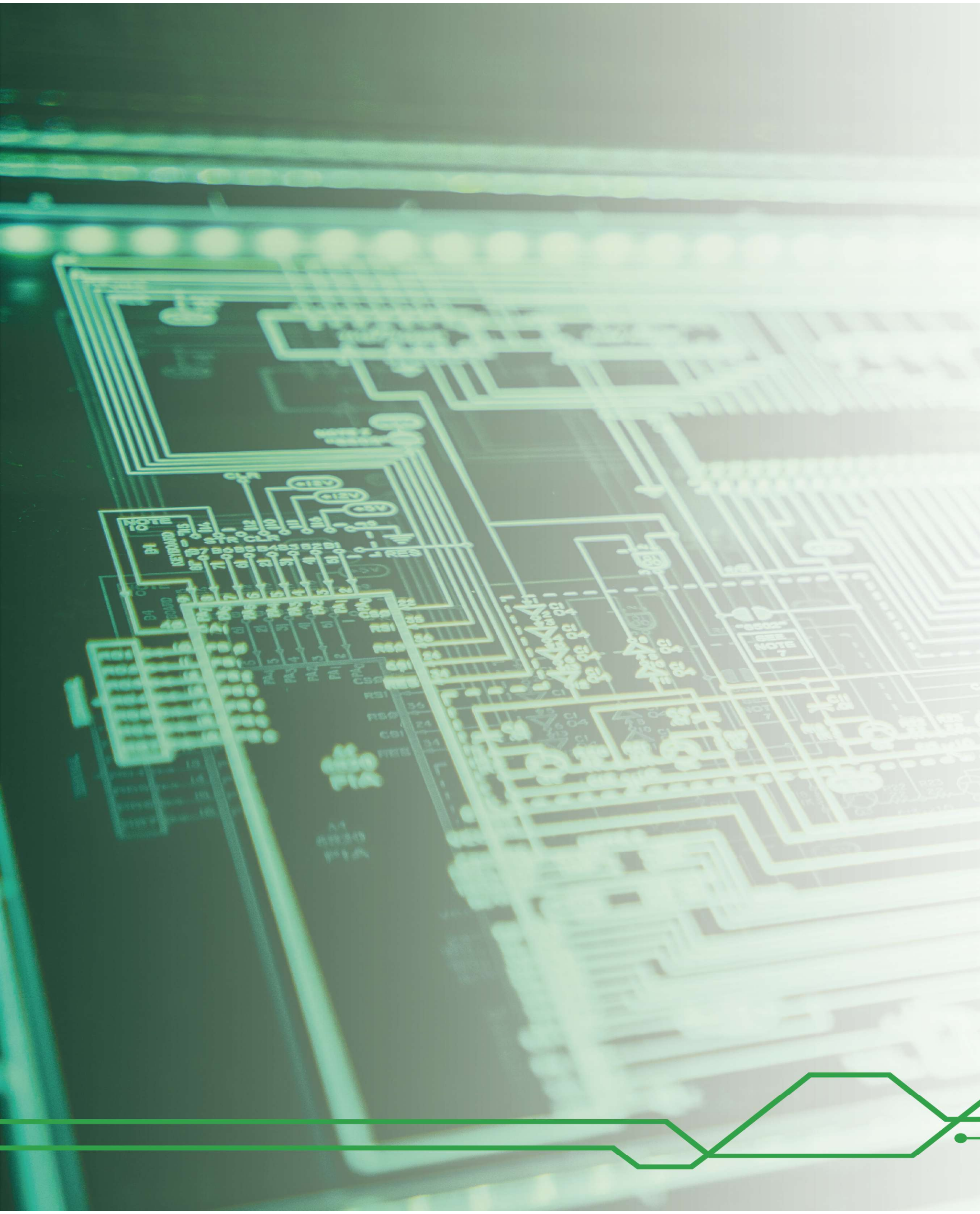

Installation 3: Physical techniques
Installation 4: Chemical techniques
Installation 5: Material characterization

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TA2: Installations

- Provision of access to infrastructures of above partners (65 projects, for 48 months)
- Preparation of materials in suitable ink form for printing (organic, inorganic, or functional foams)
- Materials characterization

1- Physical formulation methods:
Ball milling, Triple roll milling, Physical processing, Ultrasonication, etc.

2- Chemical formulation methods:
Liquid phase exfoliation, Chemical exfoliation, Electrochemical exfoliation, Ultrasonication surfactant assisted exfoliation, Synthesis of conducting MOF, COF and 2D polymers, etc.

3- Characterization techniques:
SEM, TEM, XRD, XPS, NMR, AFM, GC, MALDI-ToF, HPLC, IR, UV-vis, fluorescence, Raman spectroscopy, etc.

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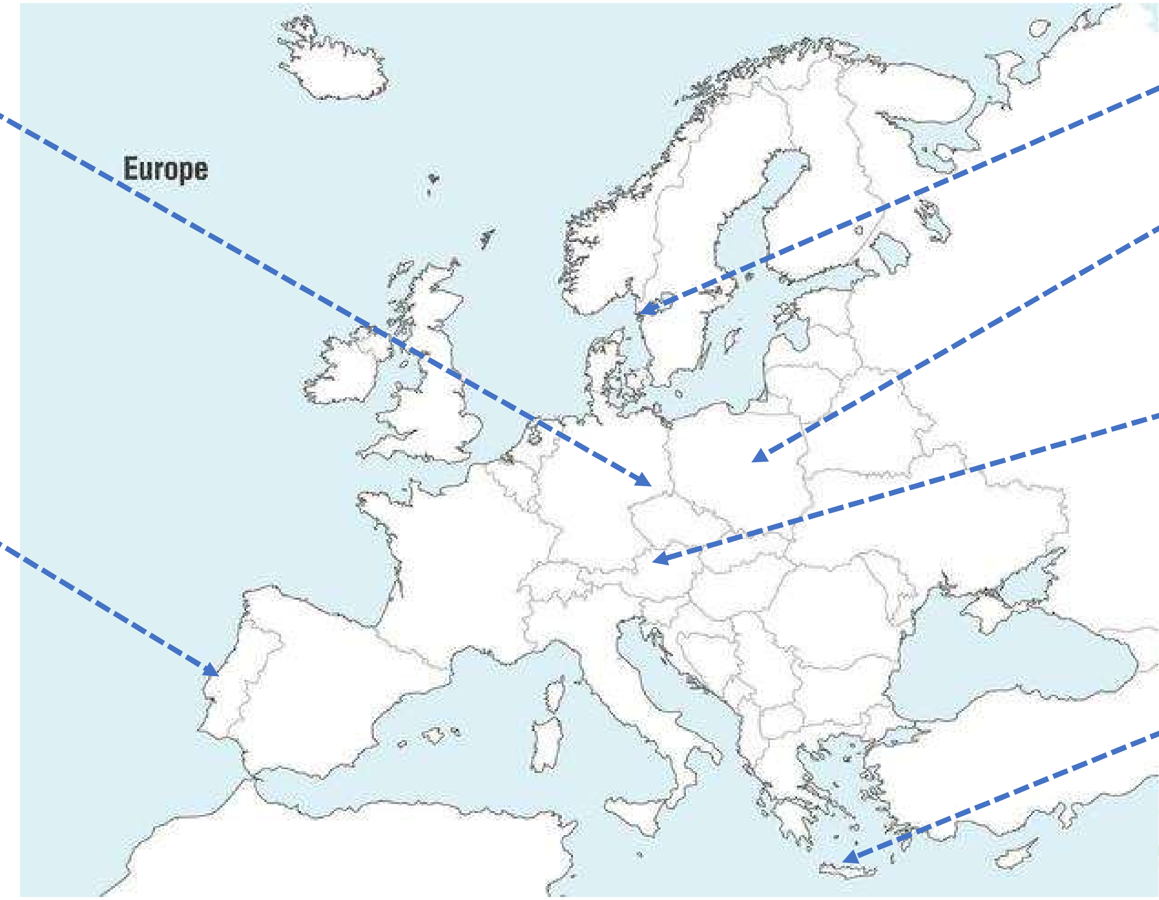
TA2 : Participants

6 frontier European research institute share their knowledge and infrastructure

TUD-IAPP (Dresden, DE)
TUD-FM (Dresden, DE)



RISE (Norrköping, SE)

CEZAMAT WUT (Warsaw, PL)

MCL (Leoben, AT)

UNINOVA (Lisbon, PT)

(Heraklion, GR)

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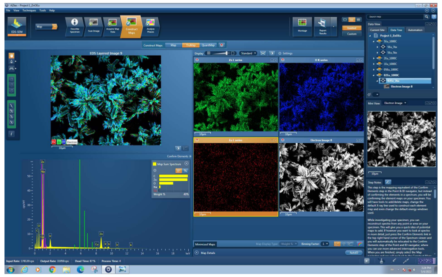
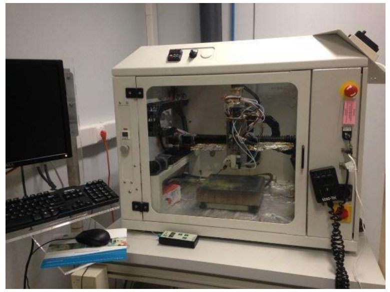
TA2. Material Synthesis & Characterization

- Access to **materials synthesis and characterization facilities** devoted to faster, cheaper and more sustainable ink/ pastes formulation with improved quality control dedicated to specific application scopes.



TA 2.1. Materials Characterizations

TA 2.2. Chemical and Physical Techniques



Spray Coater

XPS

Four Probe Station

MALDI-ToF

Screen printer

Vaccum mixer

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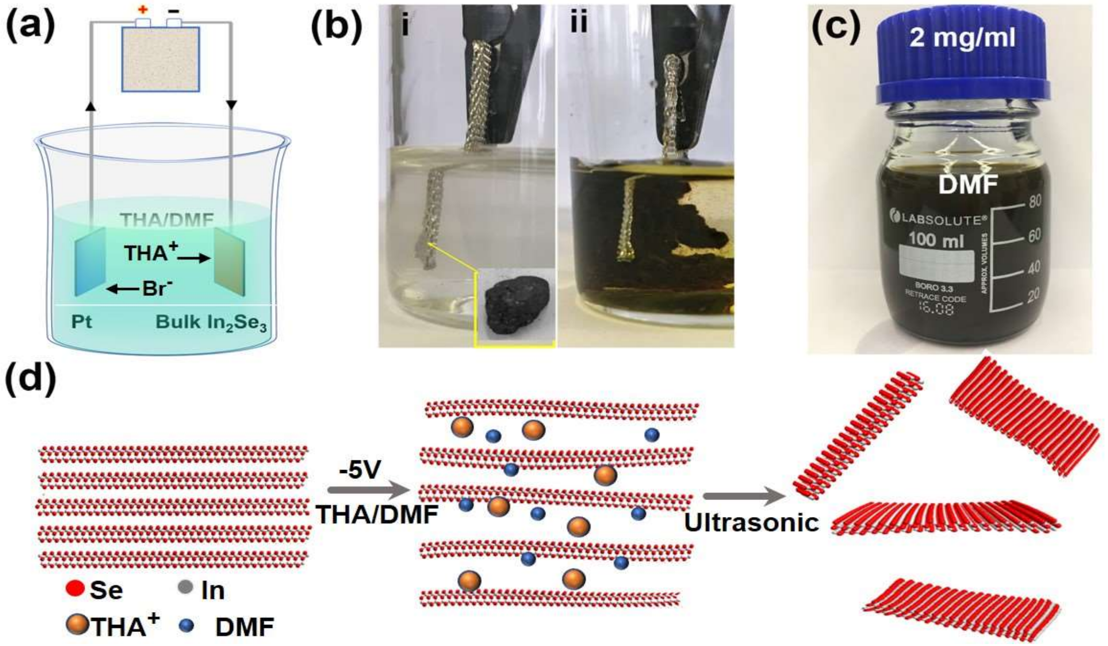
TA2 : 2D materials (inorganic and organic) preparation, characterization, and ink preparations

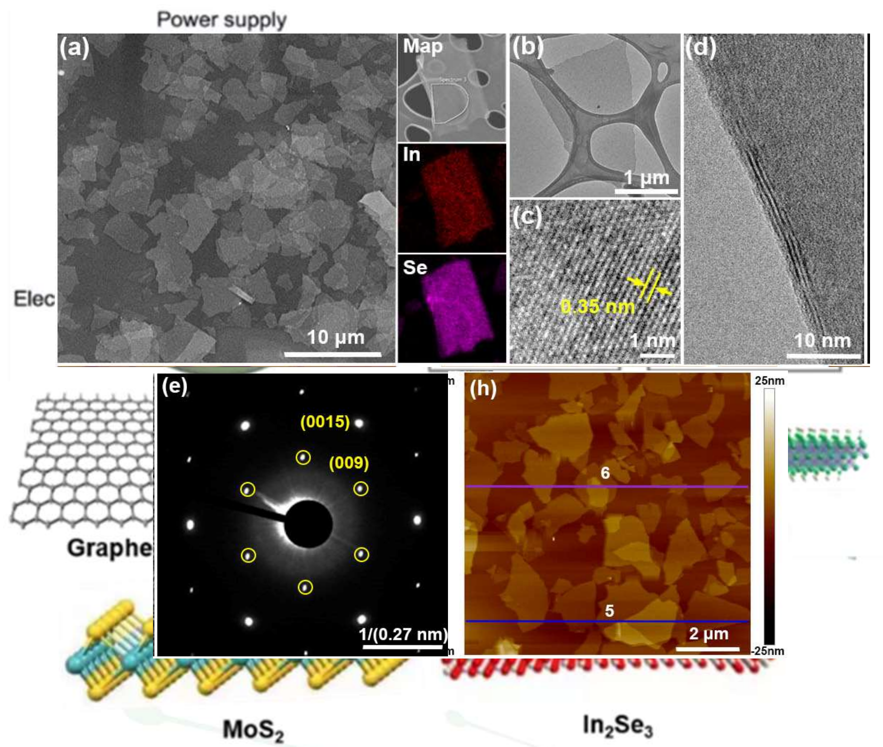
TECHNISCHE UNIVERSITÄT DRESDEN

TA2.2. Wet Chemical Preparation of 2D Materials & their Inks



- high-yield (83%) production
- Stage-3 intercalation (three-layer flakes)
- Average flake size of 8.6 µm

Development of other 2D Inorganic Materials & their Chemistry / TA2.1. 2D material characterization via SEM, TEM, AFM



Adv. Mater. 2020, 32, 1907857

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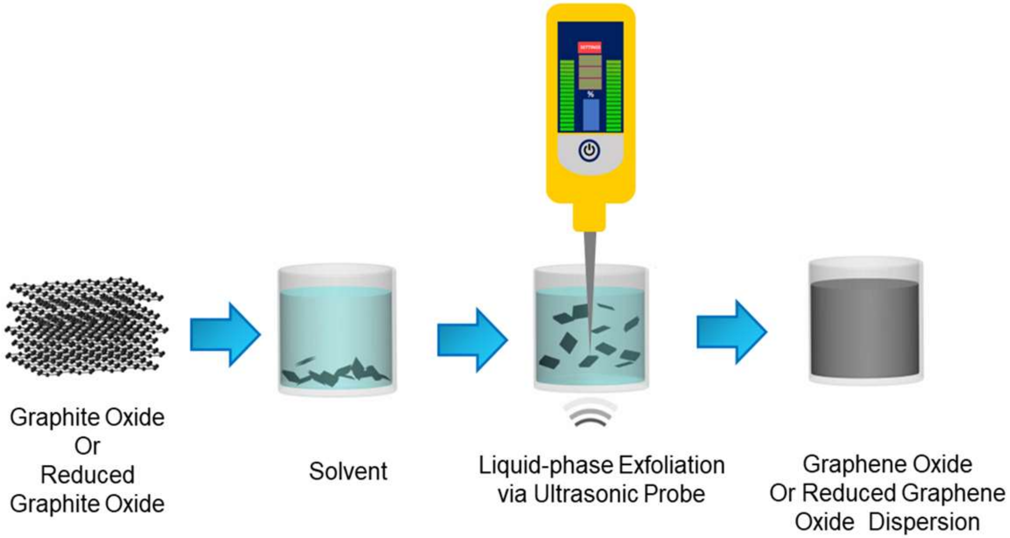
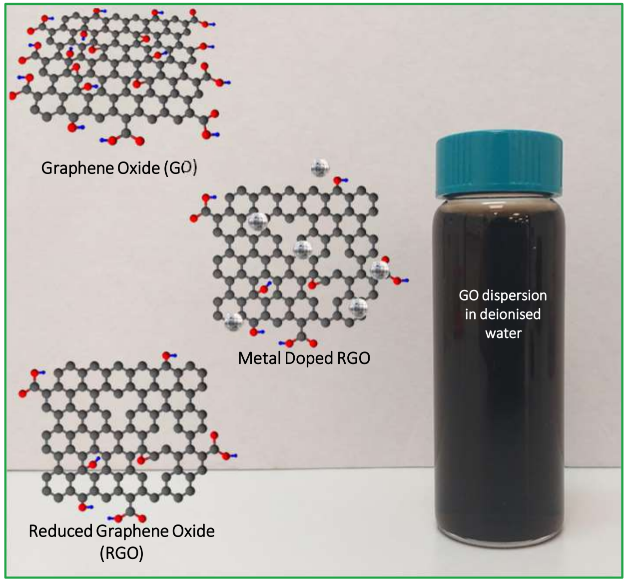
Adv. Mater. **2020,** *32* (8), 1907244.

TA2 : Graphene oxide (GO) preparation and ink formulations

Ultrasonic Probe





- Using **cost effective** precursor materials
- **Easy to operate** equipment
- Capability for **large-volume ink** preparation

- Graphene Oxide (**GO**)
- Reduced Graphene Oxide (**RGO**)
- **Metal doped** GO and RGO
- **Non-metal doped** GO and RGO

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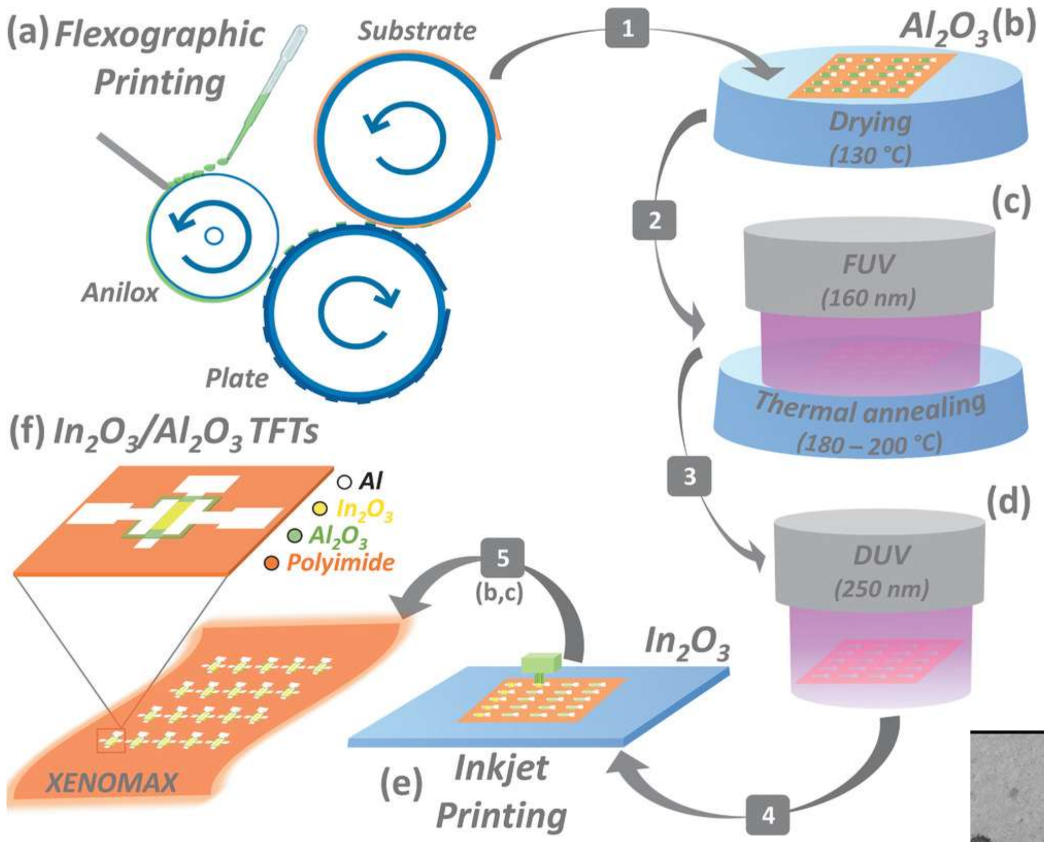
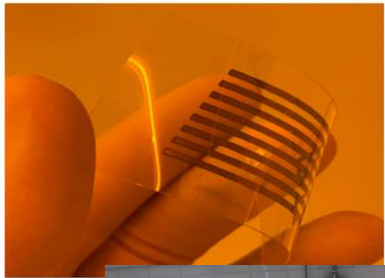
TA2 : Ink development, processing & characterization

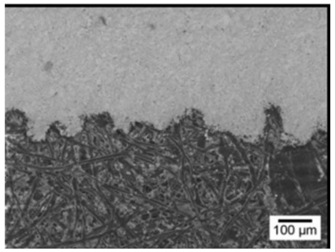


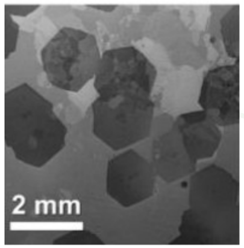
Adv. Electron. Mater. **2020, 6, 1901071**

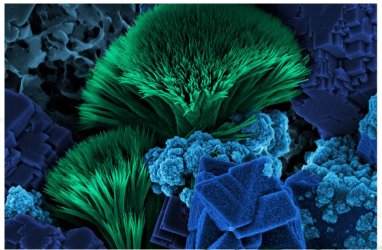


- **Ink properties' optimization** for different fabrication techniques such as screen, inkjet, and flexographic printing (interaction with **TA3**. **Prototype Fabrication**)

- **Characterization** of inks and fabricated/printted patterns (interaction with **TA3**. **Prototype Fabrication**)







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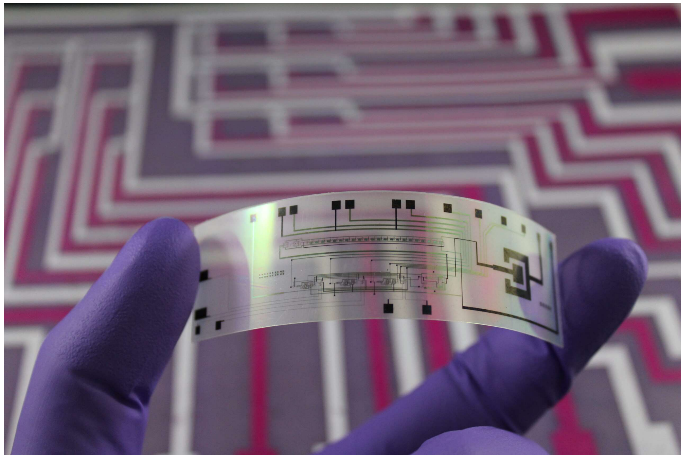
TA3. Prototype fabrication



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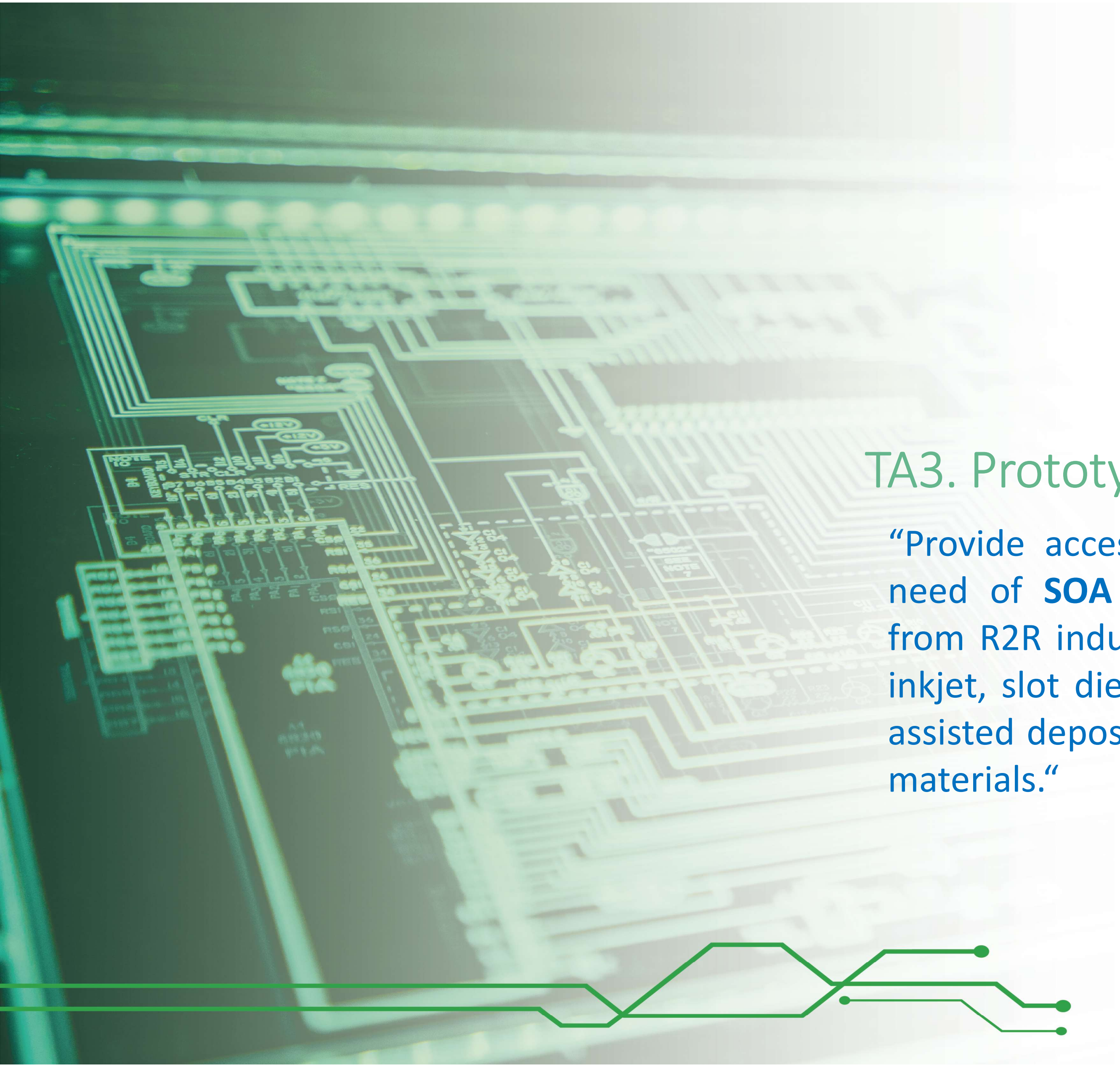

TA3. Prototype fabrication

"Provide access to European researchers who are in need of **SOA large-scale fabrication techniques**. (…) from R2R industrially compatible Pilot lines, to various inkjet, slot die, aerosol jet printers, as well as vacuum assisted deposition incorporating eco-friendly ink/paste materials."

The EMERGE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 101008701

Installation 6: Industrially compatible R2R printing setups

Installation 7: Nanoimprinting / Laser patterning

Installation 8: Vacuum assisted deposition processes

Installation 9: Functional 2D and 3D printing

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TA3 : Participants

6 frontier European research institute share their knowledge and infrastructure

TECHNISCHE UNIVERSITÄT DRESDEN

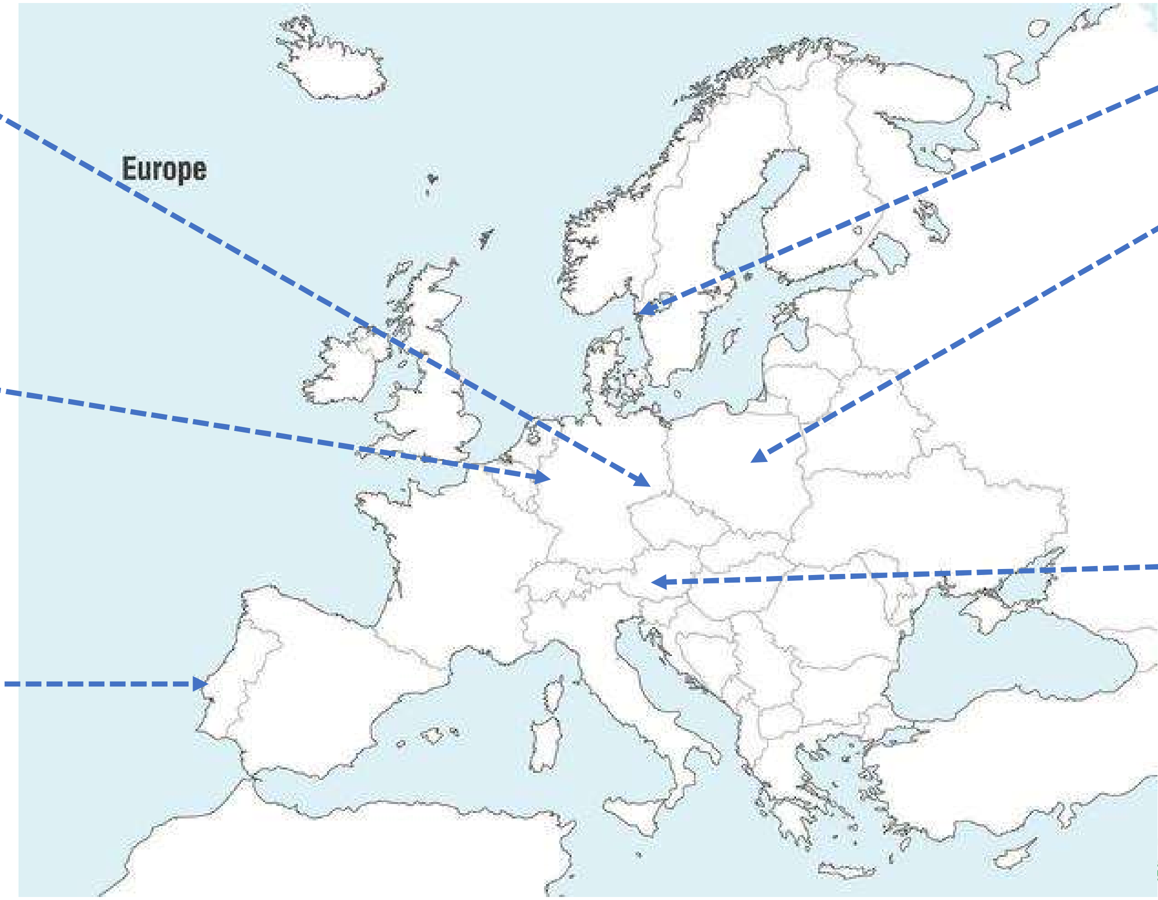
TUD-IAPP (Dresden, DE)
TUD-FM (Dresden, DE)

HI ERN Helmholtz Institute Erlangen-Nürnberg

FZJ-HPG
(Julich, DE)

ALMASCIENCE

(Lisbon, PT)



RI. SE (Norrköping, SE)

CEZAMAT WUT
(Warsaw, PL)

JOANNEUM RESEARCH

(Graz, AT)

EMERGE Emerging Printed Electronics Research Infrastructure

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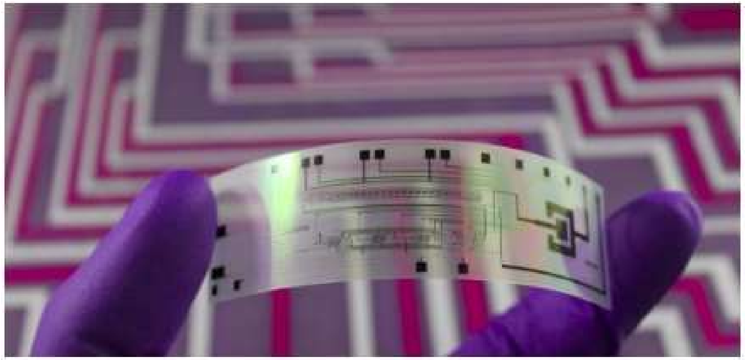
TA3. Prototype fabrication

- Access to **prototypes fabrication facilities** will focus on highly efficient production of sophisticated and complex **flexible large-area printed electronics and photonics systems** with high conformability and integrability dedicated to specific application needs allowing **upscaling and technology transfer processes** towards industrial production.



TA3 - Prototype fabrication

- TA 3.1 Device preparation
- TA 3.2 Functional 2D & 3D printing
- TA 3.3 Industrial printing
- TA 3.4 Nanoimprint and laser patterning
- TA 3.5 Vacuum assisted deposition

Interactions:

- TA2 - Ink development, processing & characterization
- TA4 - Access do demonstrators' characterization and validation

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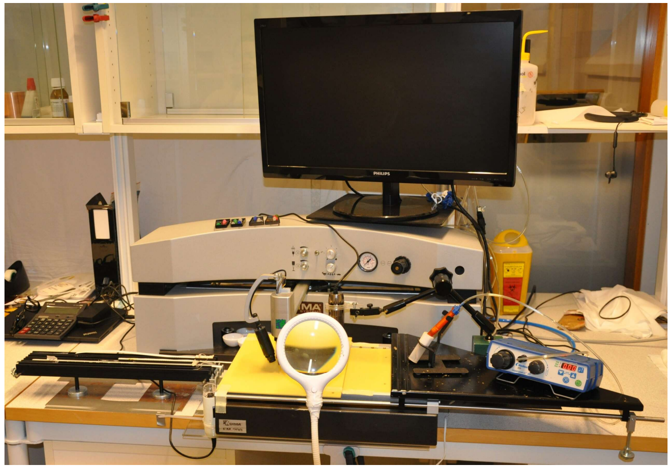
TA3. Prototype fabrication

TA3.1 Device preparation

Systems for integration, preparation or modification of prototypes



- Equipment for surface mounting device, SMD. Mount components on the printed circuit board.
- Laser cutter to cut or engrave materials (e.g., wood, metal, and polymer)
- Manual pick and place station and equipment for surface mounting of devices. Compatible with wide variety of substrates.

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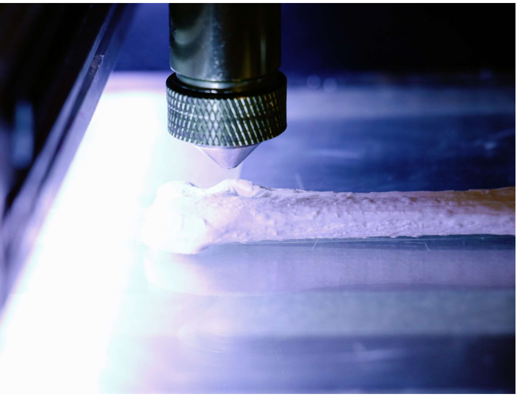
TA3. Prototype fabrication



TA3.2 Functional 2D & 3D printing

Systems for 2D, 3D printing of circuits functional
Multi-material 3D printing

- Multiple coating and printing tecnhiques and sizes available
- Low and high resolution techniques
- Aerosol Jet technology enables printing of functional inks on both 2D and 3D substrates
- Bioinks and biofluids
- Functionalization of 3D printed optical elements

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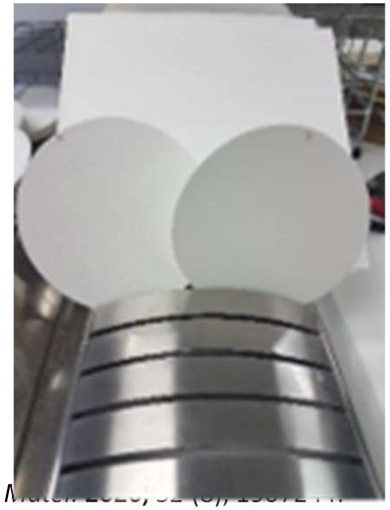
TA3. Prototype fabrication

TA3.3 Industrial printing

Paper technology

- Functional paper coatings
- Fiber composite materials
- Nanofibers and nanomaterials
- 3D formable paper
- Thermoplastic biopolymers coatings



Width up to 24 cm and a maximum speed of 350m/min.

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TA3. Prototype fabrication

TA3.3 Industrial printing

S2S printing

Ink-Jet – PixDro LP50
- Maximum substrate size: 227 x 327 mm
- Maximum substrate thickness: 25 mm
- Substrate heating up to 90 °C
- Print speed: Up to 500 mm/s
- Printheads: 16 - 2048 nozzles; 1 - 80 pL dropsize

Screen Printing – Aurel C920
- Double squeegee head
- Speed & Pressure digital control
- Automatic shuttle table
- Printing area up to 350 x 400 mm

Flexography – Flexiproof 100UV
- Use any flexible substrate: Flexible paper, board, film and foil
- Substrate size: 297x105mm –half A4
- Print area up to 240x75 mm

- UV curing option

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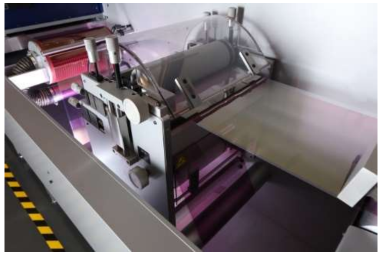
TA3. Prototype fabrication

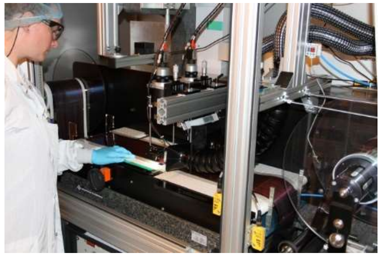
TA3.3 Industrial printing

R2R Prototyping Line

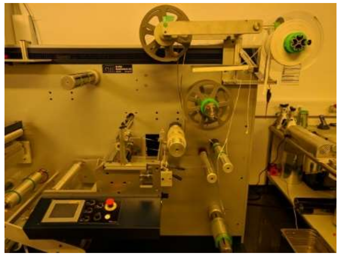
Roll to Roll printing



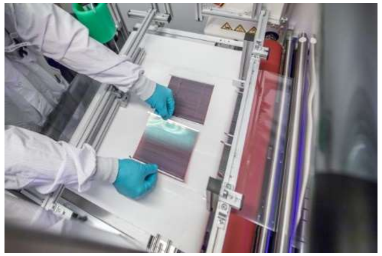
Roll to Roll laser patterning



Roll to Roll Bus Bar lamination



Roll to Sheet lamination



Production Line

- Substrate unwind, cleaning, surface activation
- Up to 4 coating & drying stations
- Slot-die coating, Gravure printing, Offset printing
- Up to 40cm Web-width, no facing rollers

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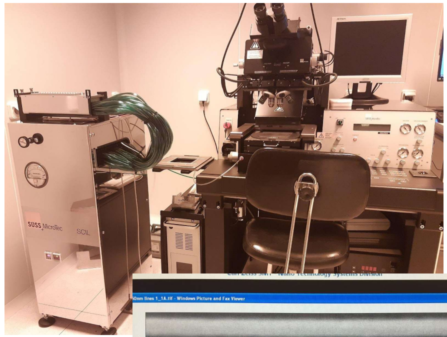
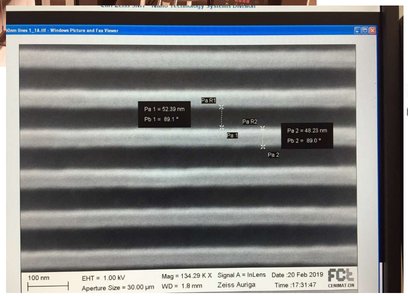
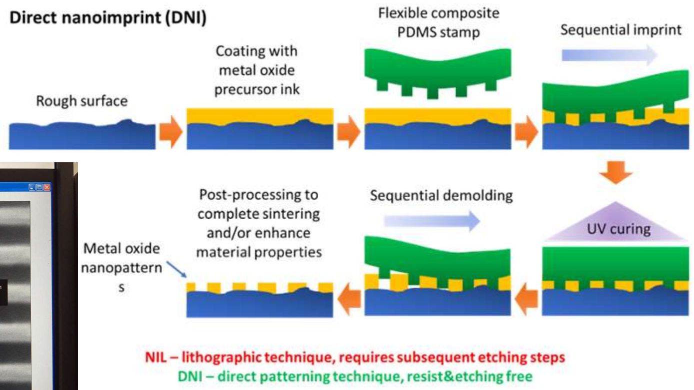
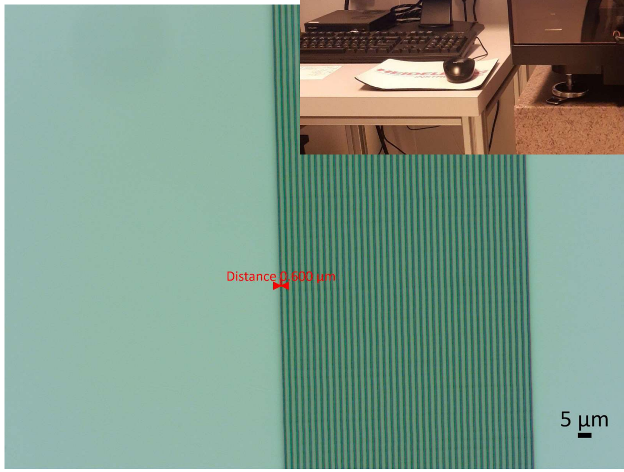
TA3. Prototype fabrication

TA3.4 Nanoimprint and laser patterning









Suss substrate conformable nanoimprint lithography (SCIL)

- Work area: up to 4”
- UV curing of resin, low pressure, RT (compatible with paper substrates)
- Sequential stamping and demolding for enhanced pattern fidelity in rough surfaces
- <50 nm resolution in resist

Heidelberg µPG 101 tabletop micropattern generator

- Work area: up to 150 mm x 150 mm
- UV laser diode, 375 nm
- 600 nm resolution in resist
- Built-in LayoutEditor CAD software for pattern design/editing

TA3. Prototype fabrication

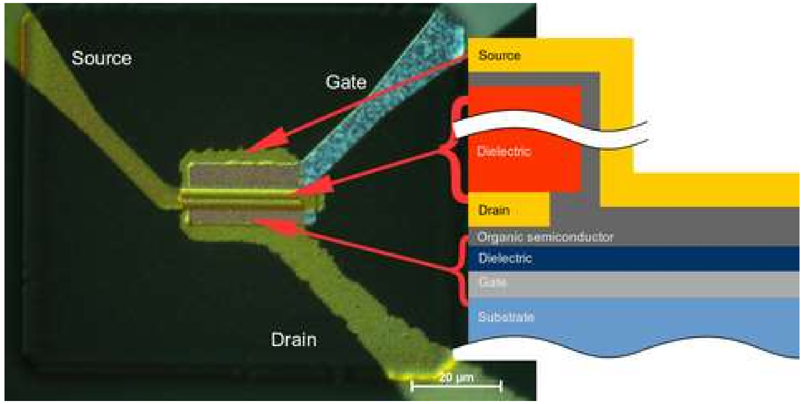
TA3.5 Vacuum assisted deposition

Different types of vacuum evaporation for a vast variety of materials

➢ System for fabrication of OLED/OSC/ OTFT in UHV.
Suitable for standard perovskite materials and organic materials.

➢ Fabrication of perovskite solar cell in UHV
Up to 5 organic materials + 3 metals, heatable substrate

➢ OLED/ Organic Solar Cells in UHV on large area substrates.
System to large scale: hundreds of OLEDs, Solar cells, or transistors in one run ensuring high reproducibility and precise control over thicknesses and blending ratios
Encapsulation robot and thin-film encapsulation process available



Integrated vertical organic thin-film transistor device (TUD-IAPP)

UFO system

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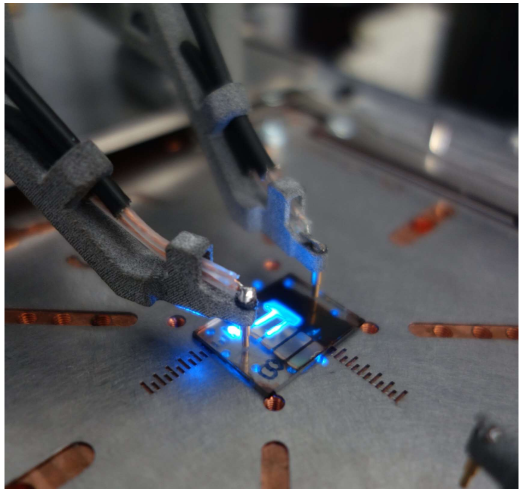
TA4. Access to demonstrators' characterization and validation



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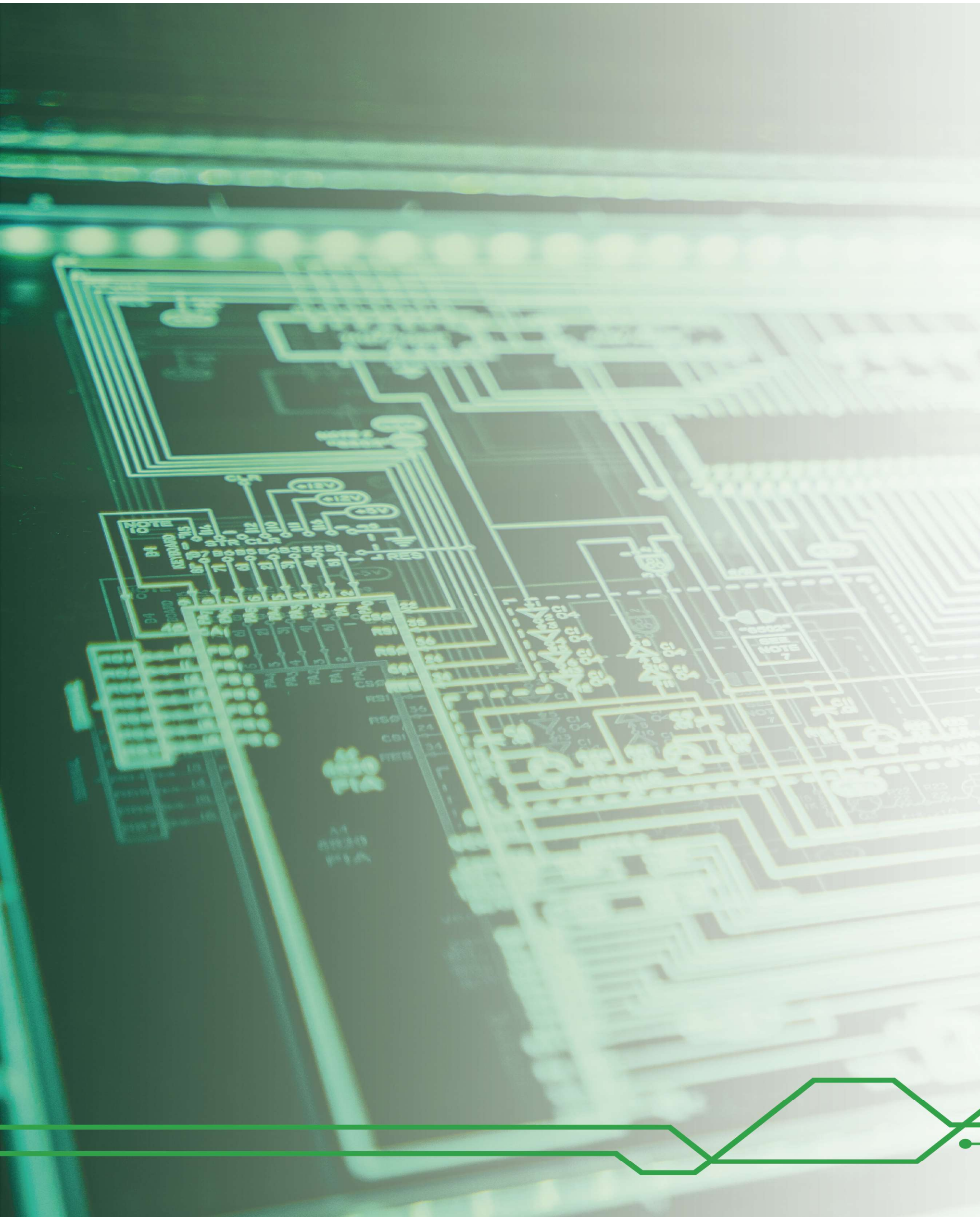

TA4. Characterization of prototypes and demonstrators

Access to demonstrators' test, validation and characterization to establish performance and stability tests under industrial protocols in simulated and real conditions for various types of devices. Solutions on encapsulation processes and investigations of ageing.

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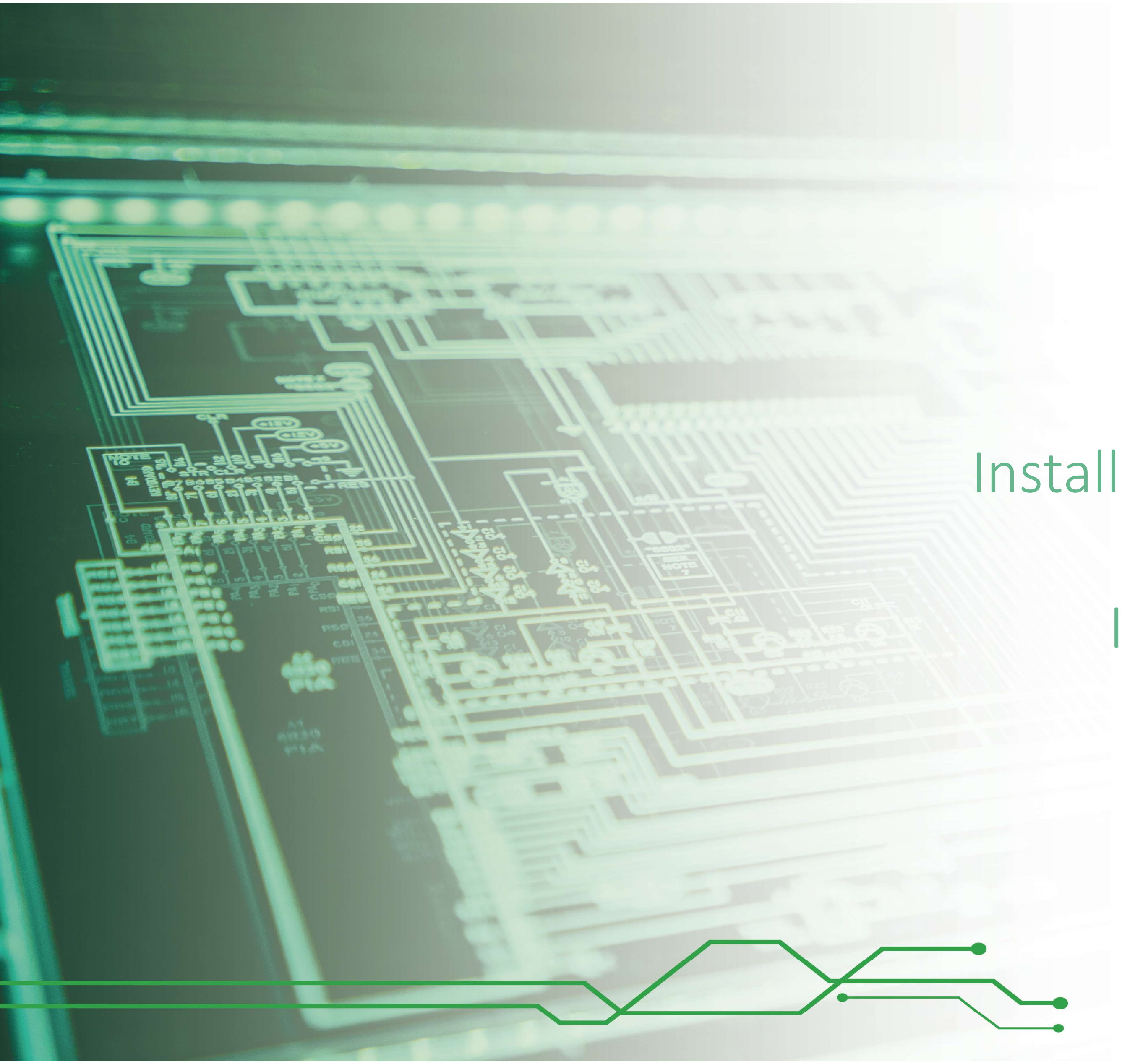

Installation 10: Device metrology & characterization

Installation 11: Validation and standardization

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TA4 : Participants

7 frontier European research institute share their knowledge and infrastructure

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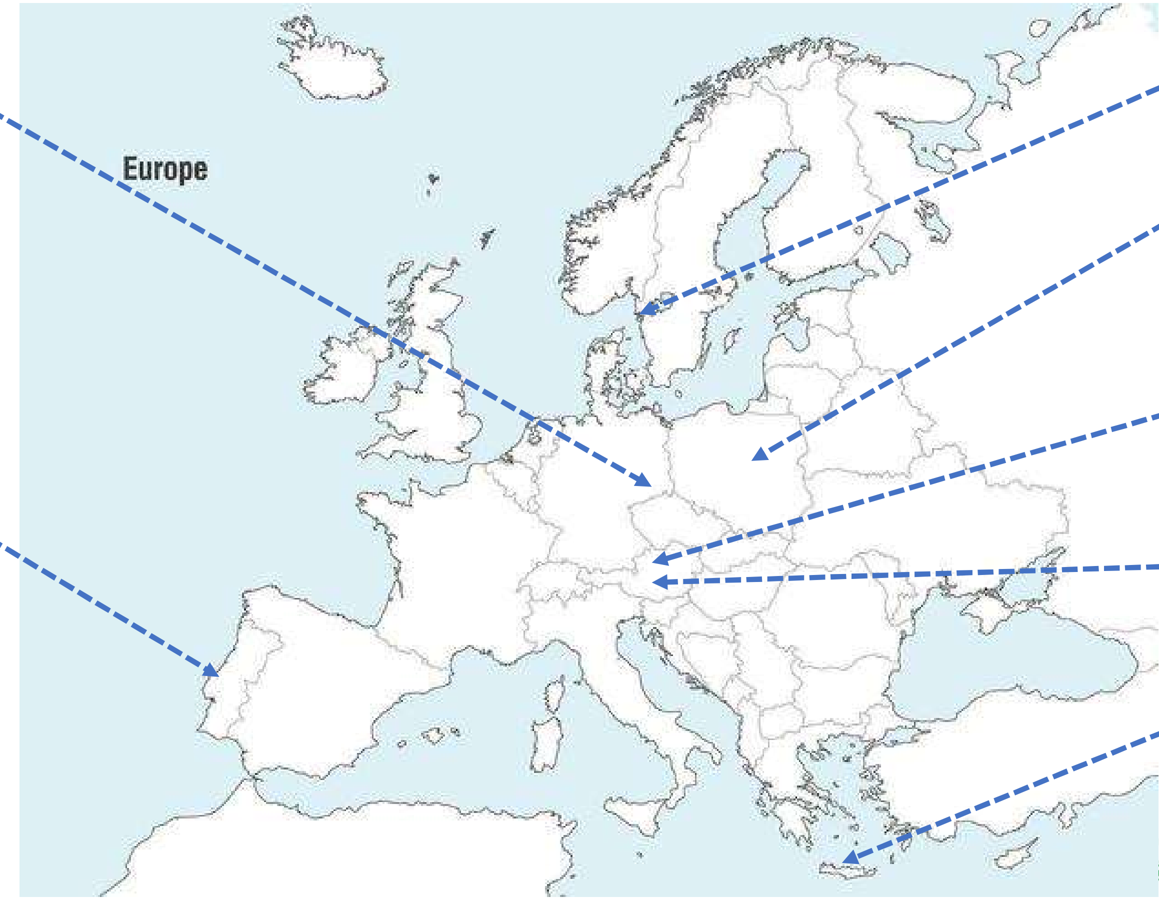
UNINOVA



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TA4 : Objectives

Installation 10: Devices validation & standardization

- Novel structuring, interconnect and packaging technologies
- Quality and reliability assessment of produced materials
- Environmental and life cycle testing

Installation 11: Access to device metrology

- Structural, electrical and mechanical properties characterization
- Simulation of real conditions and industrial protocols
- Characterization at each product development step

Testing of full demonstrators developed in TA2 and TA3

Specific component characterization to investigate origin of degradation

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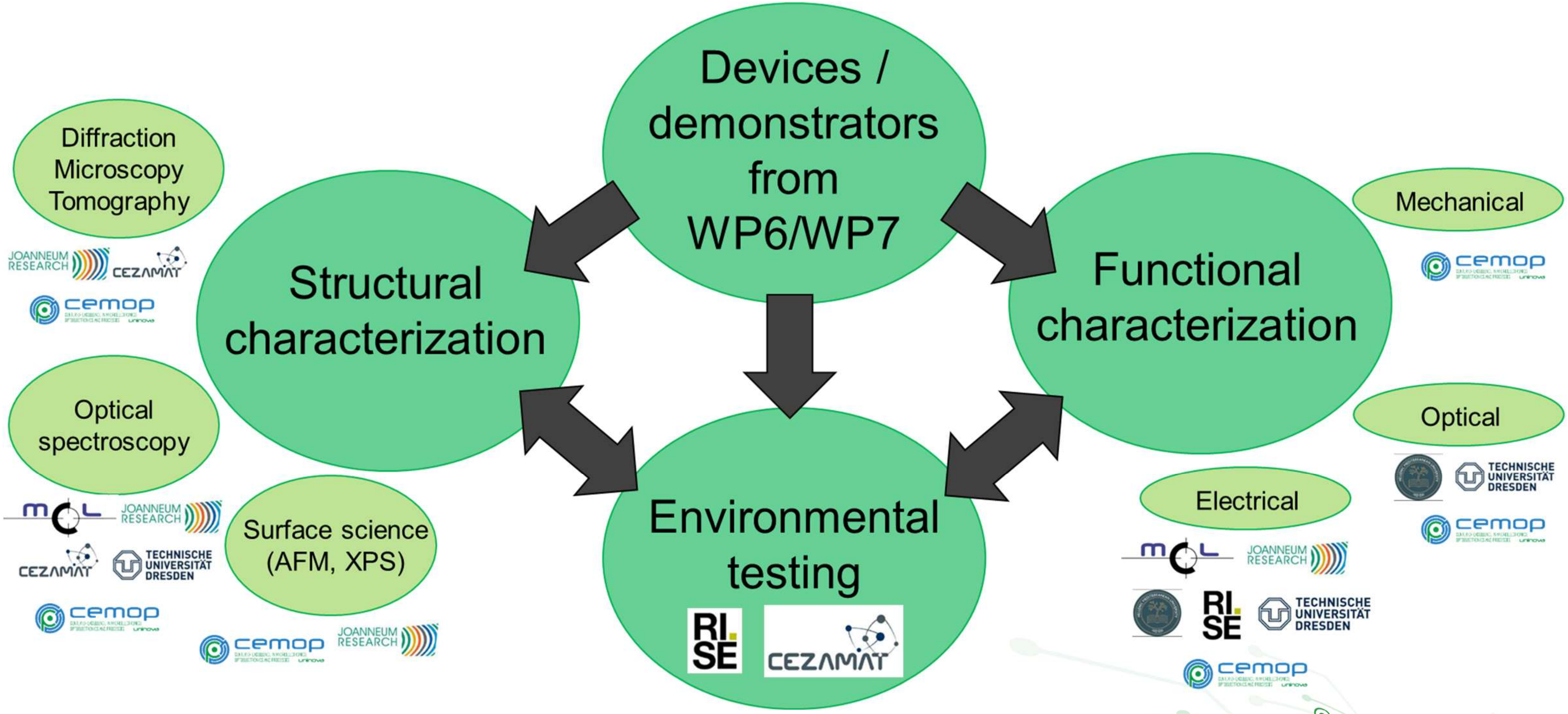
TA4 : Activity interactions



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TA4.1 : Device metrology and characterization

OLED/PV lifetime setup: relative luminance change, voltage, CIE of OLEDs over long time. 6 racks with 8 measurement slots for 1 inch x 1 inch OLED each (48 in total)

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Probe stations/semiconductor analyzers: I-V, C-V time dependent and pulsed-IV measurements in substrates up to 4”. Cryo and optical-dependent measurements

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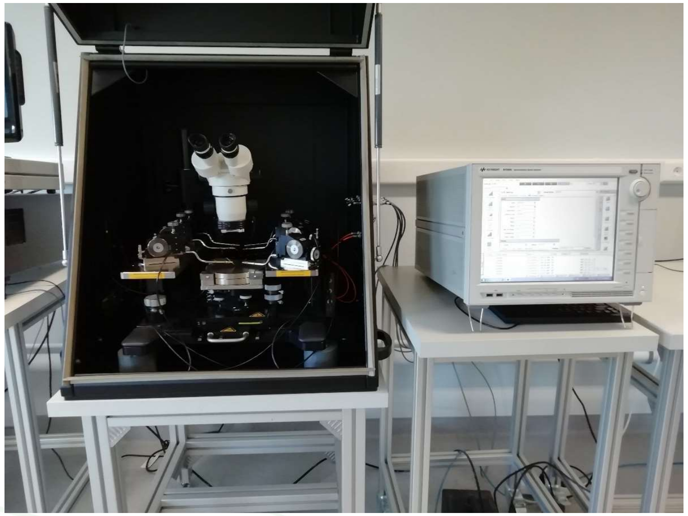

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TA4.1 : Device metrology and characterization

Microscopy: multiple scales (mm to nm), from optical to electronic microscopes, for quality control, monitoring of contaminations…

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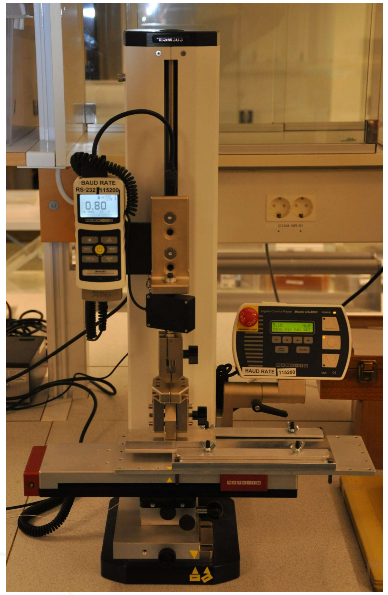
Delamination/defect identification: Light Beam Induced Current (LBIC) system to investigate failure modes as ingress, delamination, bubble formation. Mechanical peel tester.



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TA4.2 : Validation and standardization

Outdoor PV monitoring: all the supporting infrastructure, such as power electronics and automatic data acquisition systems for continuous monitoring of the performance of PV panels

Environmental testing: test the effects of environmental conditions (T, Humidity) on products, materials, or electronic devices

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Thank you

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Linkedin: https://www.linkedin.com/company/emerge-infrastructure/

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