Printing technologies

2023, March 22nd

Didier GALLAIRE

CEA // FRENCH ALTERNATIVE ENERGIES AND ATOMIC ENERGY COMMISSION

6 *MAIN RESEARCH DOMAINS*

13 *SCIENTIFIC FIELDS*

- Nuclear weapons & propulsion
- **Low-carbon energy production**
- Energy networks Management
- **Resources Efficiency**
- Micro and nano-electronics
- Climate and environmental changes
- **New Materials**
- Remediation, dismantling & **waste management**
- **Medical Imaging** & related developments
- Prevention, **diagnosis** & Therapeutic innovations

KEY FIGURES

21000 EMPLOYES	**5.6 B€** BUDGET	**37** JOINT RESEARCH UNITS
710 PATENTS FILED in 2019	**9** RESEARCH CENTRES	**228** START UPS since 1972

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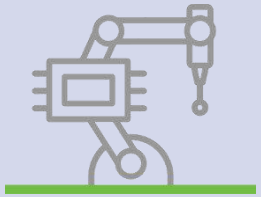
CEA: A Key Player in Technological Research to Support Business Competitiveness, Job Creation & National Technological Sovereignty

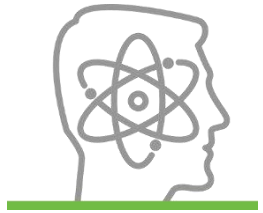
4 *RESEARCH DIVISIONS*

Defense & National Security

Free Carbon Energies



Technological Research for Industry



Fundamental Research

3 *INSTITUTES OF TECHNOLOGICAL RESEARCH*

leti cea tech — Micro & Nanotechnologies

liten cea tech — **Renewable Energies & Advanced Materials**

list cea tech — Intelligence & Numerical Systems

Our technological and digital platforms

Spread over our research campuses in Bourget-du-Lac and Grenoble

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GreEn GRENOBLEENERGIE

13 PLATFORMS

- SOLAR PHOTOVOLTAIC
- SMART GRID SYSTEMS
- BUILDING & ENERGY
- NETWORK AND THERMAL STORAGE
- BATTERIES
- H2 PRODUCTION & STORAGE
- FUEL CELLS
- ELECTRIC MOBILITY
- POUDR'INNOV 2.0
- BIO RESOURCES
- NANO SECURITY
- NANO-CHARACTERIZATION
- STRUCTURAL ELECTRONICS

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- **STRUCTURAL ELECTRONICS**

Flexible and structural electronics: a dedicated platform

World Class Research Facilities for Flexible and structural Electronics
Towards Interactives objects and smart surfaces

OBJECTIVE:

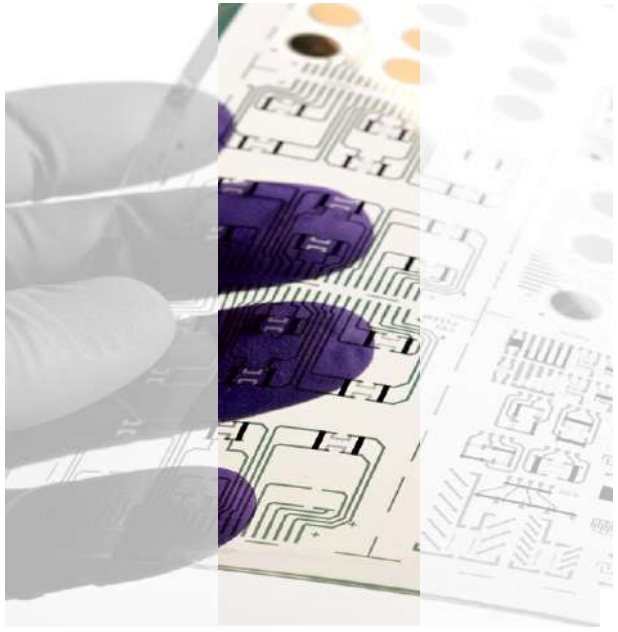
Develop electronic components and industrialize processes, to functionalize large flexible surfaces (320 x 380 mm) with electronic functions.

ADVANCED PROCESS:

Printing techniques

Vacuum deposition

Back-end



40 engineers and technicians

8M€ investment

800 m² clean rooms, class 10 000, Standard sheet format G1 : 320mm x 380mm

State-of-the-art equipment

Up to ~100 patents +High level journals & conferences (ISSCC, IEDM,..)

Large partnership including start-ups, material , tool suppliers ,RTO and End Users

Flexible and structural electronics: a dedicated platform

A complete set of printing and patterning tools

- Screen printers (x3)
- Gravure printing
- Inkjet
- Slot die
- Digital photo-lithography
- UV-curing

Material deposition

- Sputtering
- Evaporation
- Laser Ablation
- Laser cutting
- ALD deposition
- Film lamination
- Thermo-forming
- ACF connection
- Pick & Place

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Post-processing tools

- Profilometer
- Ellipsometer
- Electrcal tests

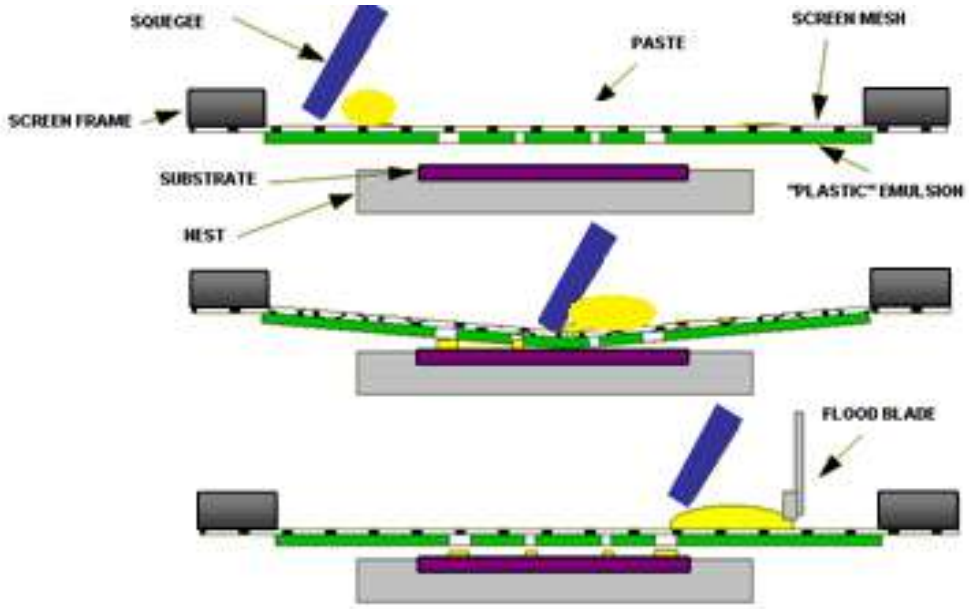
Characterization tools

- Contact angle
- Automatic Inspection
- Surface analysis

Printing technologies: screen-print

Screen printing tool with loader and unloader conveyor (EKRA)

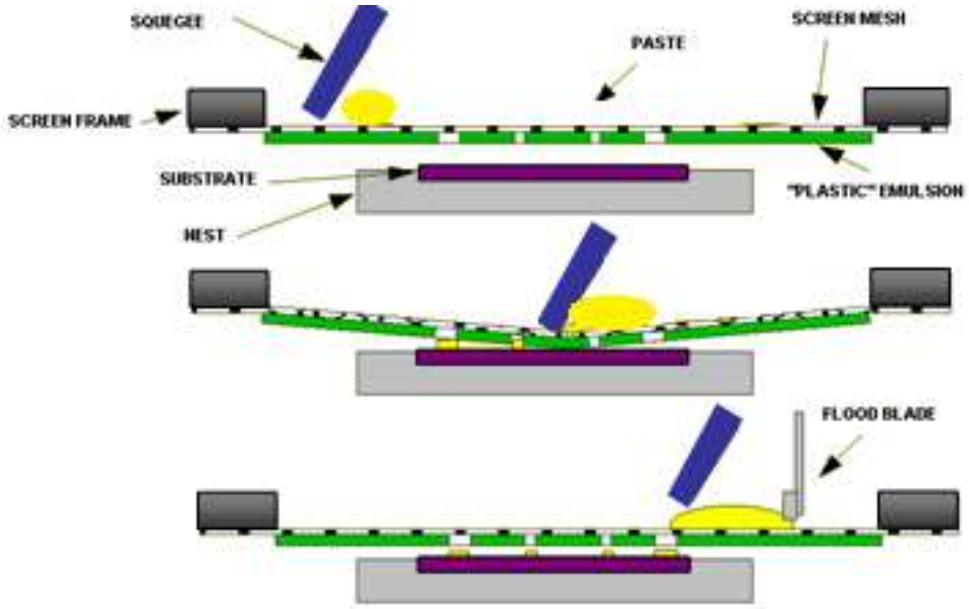
- Non-contact printing technique
- Sheet to sheet
- Free-standing / sheets on glass carrier
- Alignment : +/- 100 µm
- Material : OSC, Dielectrics, Conductive ink, resist deposition, chemical patterning…



Printing technologies: automatic screen-printing line

Automatic screen-printing line (NEWLONG)

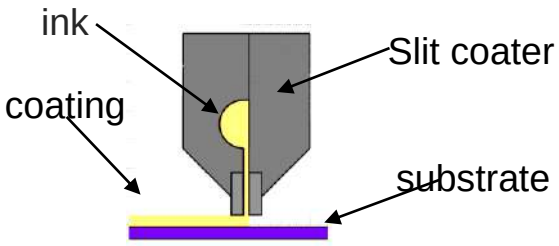
- Non-contact printing technique
- Cassette to cassette / Free standing
- Can be used in semi-automatic mode (manual loading)
- Max Throughput: 1 sheets / 45 s
- Infrared oven in-line
- Alignment : +/- 50 µm
- Material: PVDF, dielectrics, conductive ink, photoresist

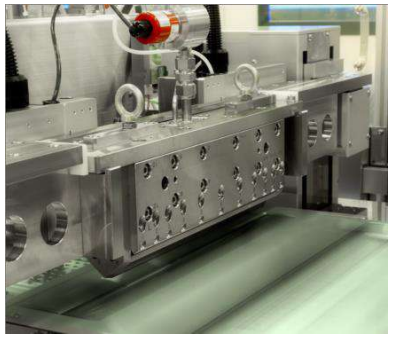


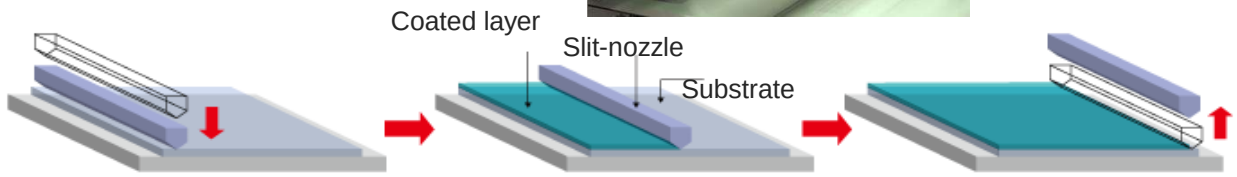
Printing technologies: slot-die coating

Slot-die (TAZMO)

- Non-contact printing technique
- Blanket coating for large area
- Layer thickness 100 nm < e <2 mm
- Thickness uniformity = 7 % for 300 nm
- Material : OSC in organic or aqueous solvant, dielectric material, inks with nanoparticles
- Transfert robot, VCD (no heating), Hotplate (up to 200°C), Cooling plate.







Head moving above substrate (from 50 to 300 µm

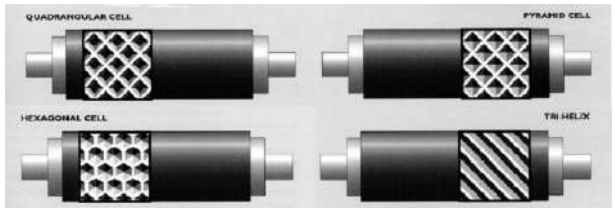
Coating

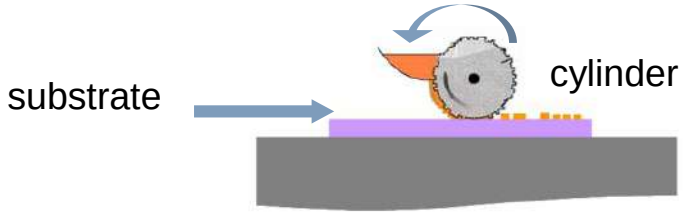
Head moving up

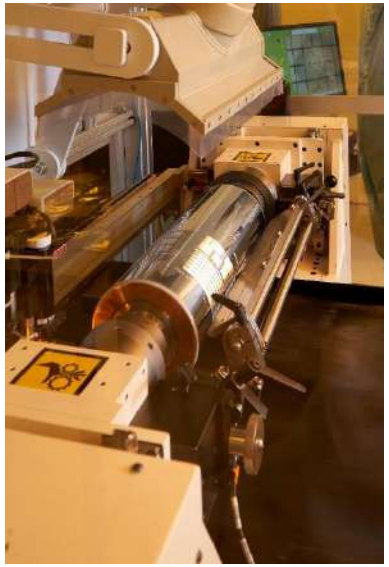
Printing technologies: gravure printing

Gravure Printing (OHIO)

- Contact printing technique
- Engraved cylinders
- Layer thickness : 40 nm< e < 1µm
- Typicaly 10-500 cps
- Material : OSC, dielectrics, conductive ink



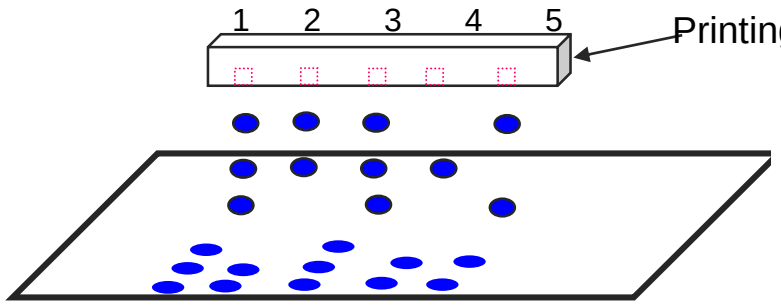


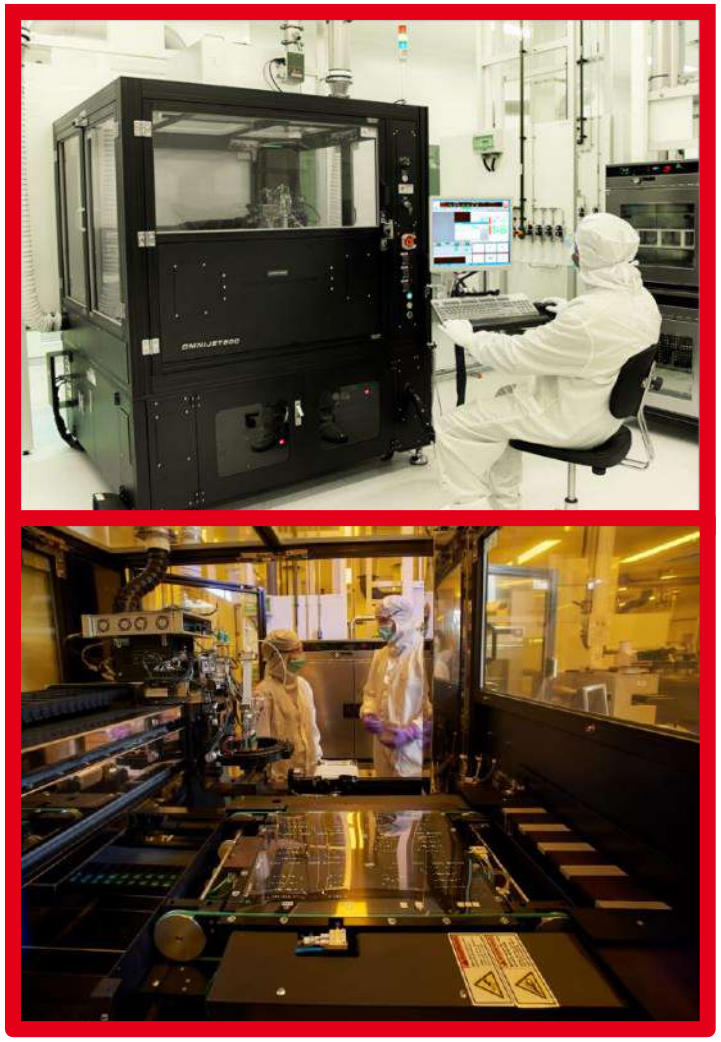


Printing technologies: inkjet printing

Ink Jet printing (UNIJET)

- Non-contact printing technique
- Drop On Demand – 16/128/256 nozzles
- Layer thickness ~10 nm < e <1 µm
- Material: low viscosity fluids 5-20 cP
  with or without nanoparticules



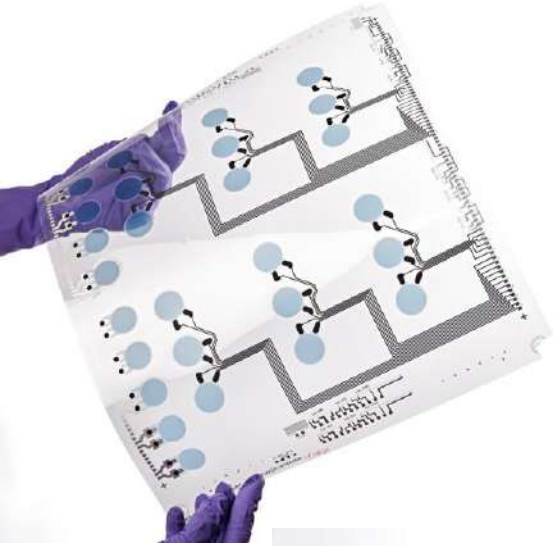


Printing technologies overview

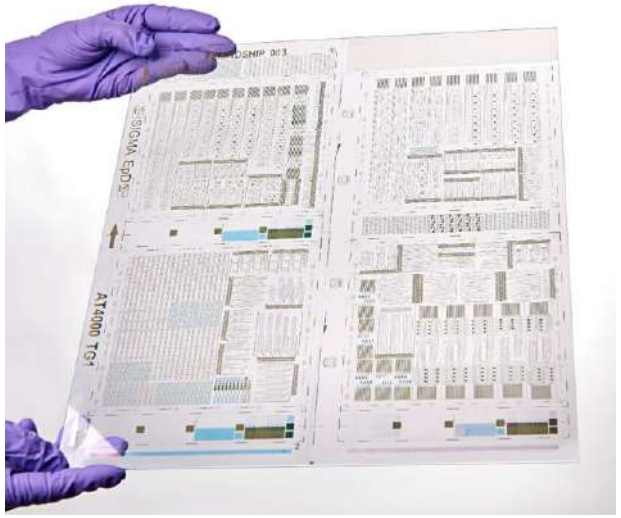
Printing techniques	Ink viscosity (cP)	Thickness	Feature size	Comments
Screen-printing	50-50 000	0,05µm – 100µm	~100 µm	Robust, simple, thick layer, large feature size, high ink viscosity
Slot-Die	1-100	0.1µm – 200 µm	-	Fast printing, High homogeneity, blanket coating
Gravure	~400	<0,05µm – 1µm	~50 µm	Fast printing, direct contact of the anilox
Inkjet	5 - 20	0,01µm – 1µm	20 – 50µm	Non contact, small ink quantities, digital printing, low viscosity, slow speed, high resolution

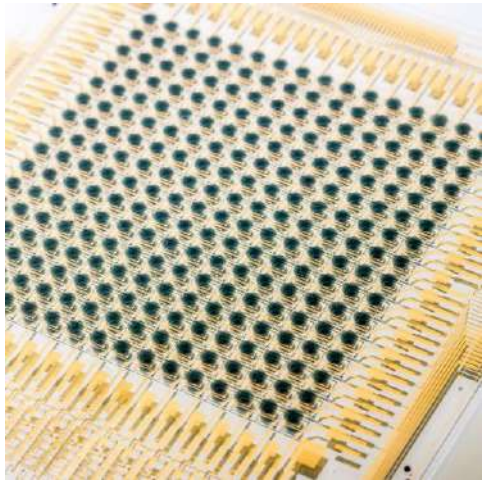
Printing technologies: most representative results

Screen-printing



Gravure printing

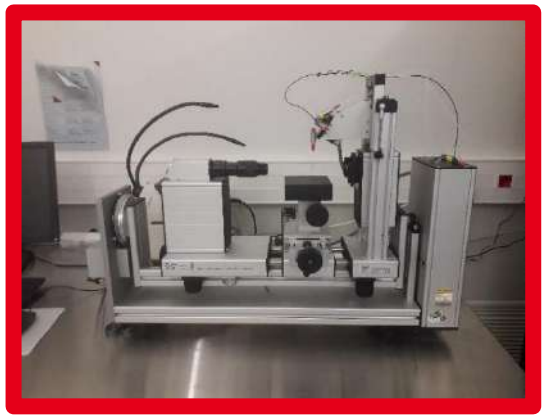




Slot-die coating

Characterization tools

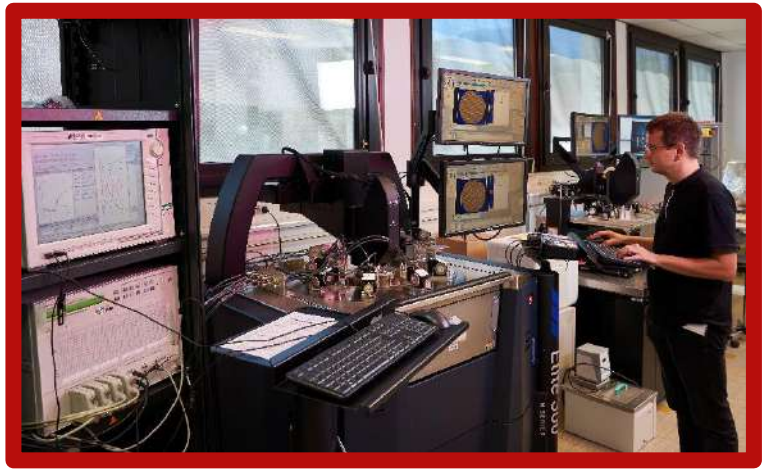
Surface energy (contact angle)



Thickness measurement (ellipsometer, profilmeter)

Surface analysis (WYKO interferometer)

Electrical tests on devices



Complementary toolset: vacuum deposition

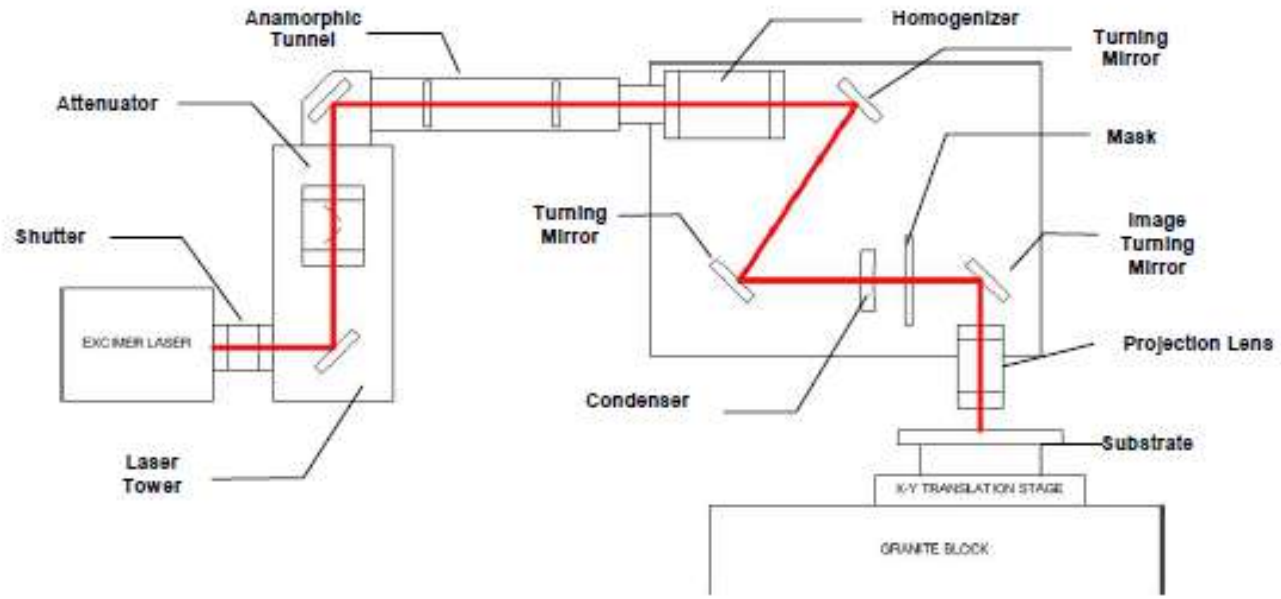
Sputtering:

- TCO: ITO, ZnO
- Metal: Au, Ti, Cr, Mo, Al, Cu, Ni
- Thickness: 10nm to 1µm
- RF, DC

Complementary toolset: laser ablation

Mask projection excimer laser ablation:

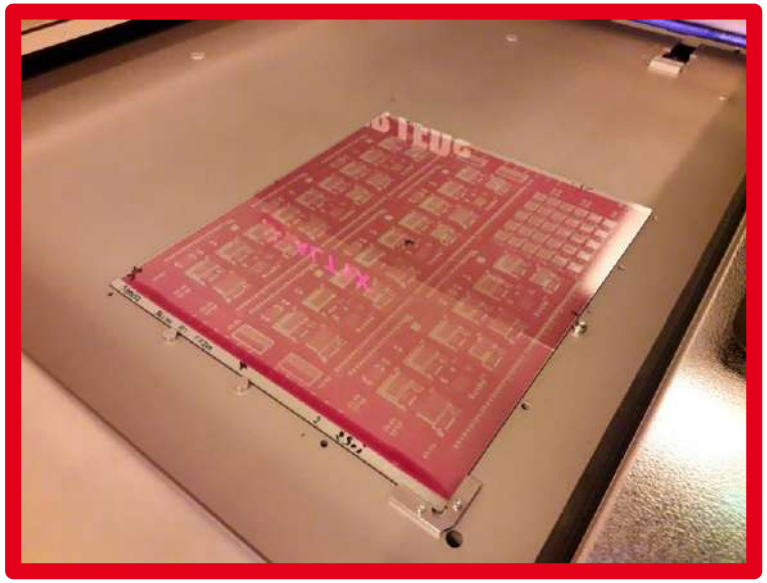
- Pattern resolution: down to 5µm (upon material)
- Alignment: +/- 5 µm
- Ablated Material: Metal, TCO, polymer …



Complementary toolset: digital photolithography

Tool specifications:

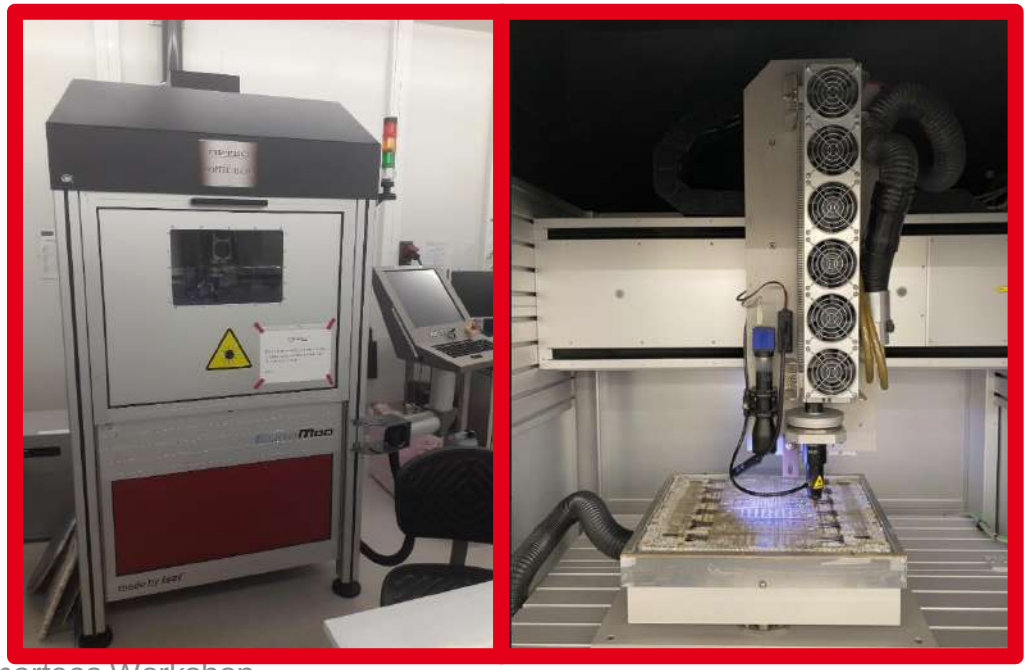
- **No mask required for insolation**
- Standard UV Wavelengthes: 365nm, 385nm, 395nm & 405 nm
- Pattern resolution: down to 10µm (upon material)
- Alignment: +/- 5 µm
- Compatible with dry photosensitive film or any photoresist



From printed electronics to structural electronics: backend process

Laser cutting

- CO_2
- P = 45W @ 10,4µm
- Speed: 1 to 100 mm/min
- Optical alignment by camera : +/- 50µm
- Materials: plastics (PET, PI, PEN, PC…) up to 3mm thick



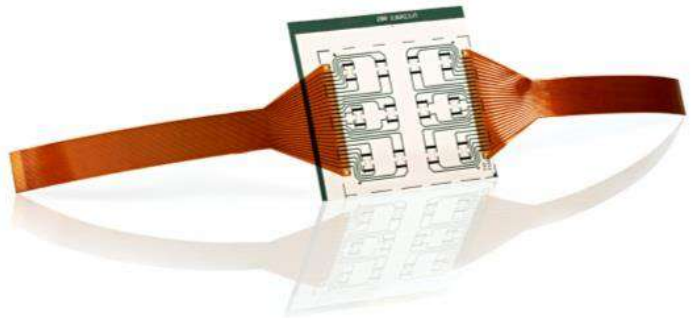
S2S film lamination

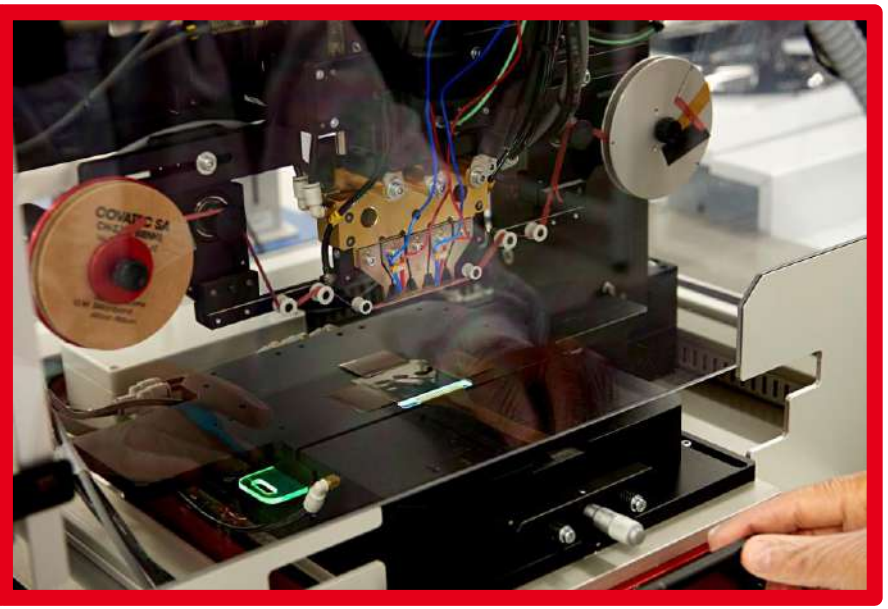
- Alignment: +/- 100 µm

From printed electronics to structural electronics: backend process

ACF bonding

- Pulse heat thermomode : 50mm x2,5mm
- Manual alignment down to an interconnection pitch of 100µm
- Flex on plastic / glass / PCB / silicon

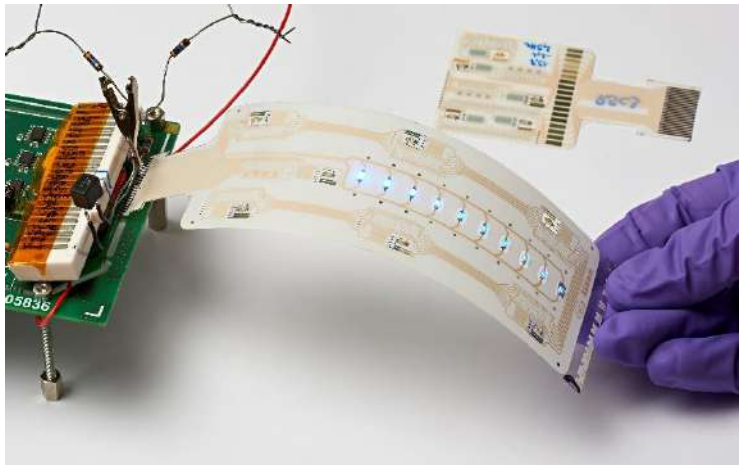


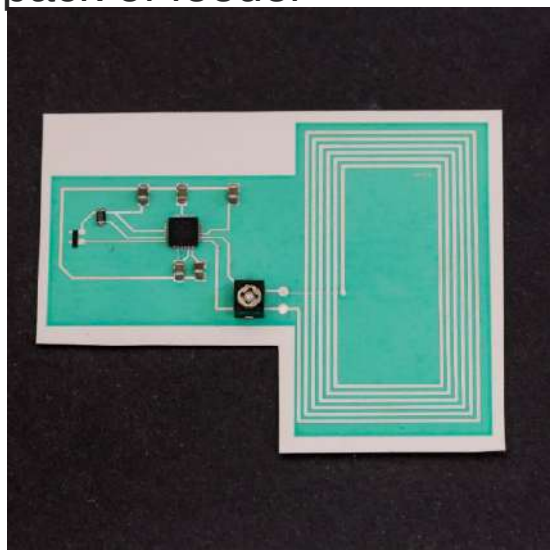


From printed electronics to structural electronics: backend process

Pick & Place

- Highest accuracy: +/- 10µm
- Die size: 0,17mm – 50mm
- Die thickness: 0,02mm – 7mm
- Bond force: up to 7,5kg
- Bonding heat: up to 350°C
- Work area 320mm x 380mm
- Integrated pressure / time dispensing system
- Capabilities: die from wafer, waffle pack of feeder





From printed electronics to structural electronics: backend process

Thermoforming

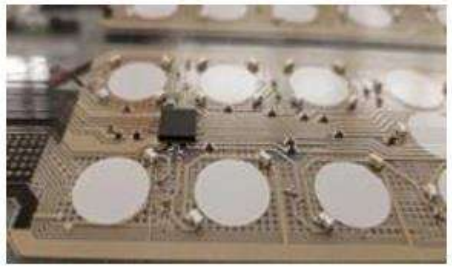
- High pressure thermoforming (up to 120 bars) for high geometrical accuracy
- Localized radiative heating with temperature control on foil by IR camera
- High production throughput (~ 20s per sheet)
- Materials: thermosftening polymers from 125µm to 1mm thickness

Transparent capacitive sensor

Antenna

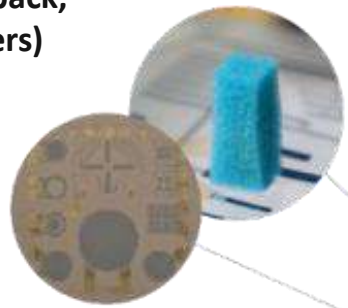
Technology process

Printing → **Post processing (Hybrid)** → **Thermoforming** → **In-Molding**



Example of devices

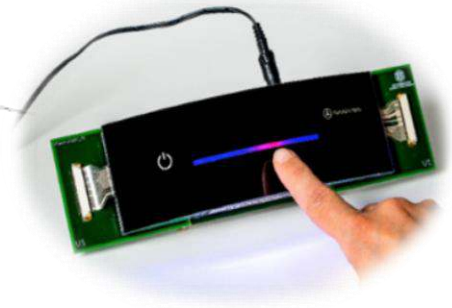
Piezoelectric actuators (haptic feedback, loudspeakers)



Chemical and biochemical sensors (pH, glucose, lactate)

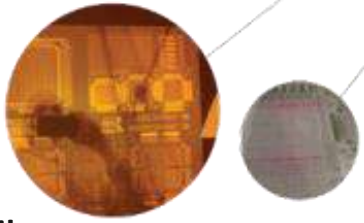
Resistive sensors (temperature, strain, acoustic)

Smart paper surfaces



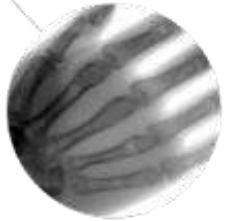
Smart plastic surfaces (Human Machine interface)

Organic thin film transistors and passive devices



Stretchable devices

Photodetectors X-ray imaging



Thanks for your attention

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