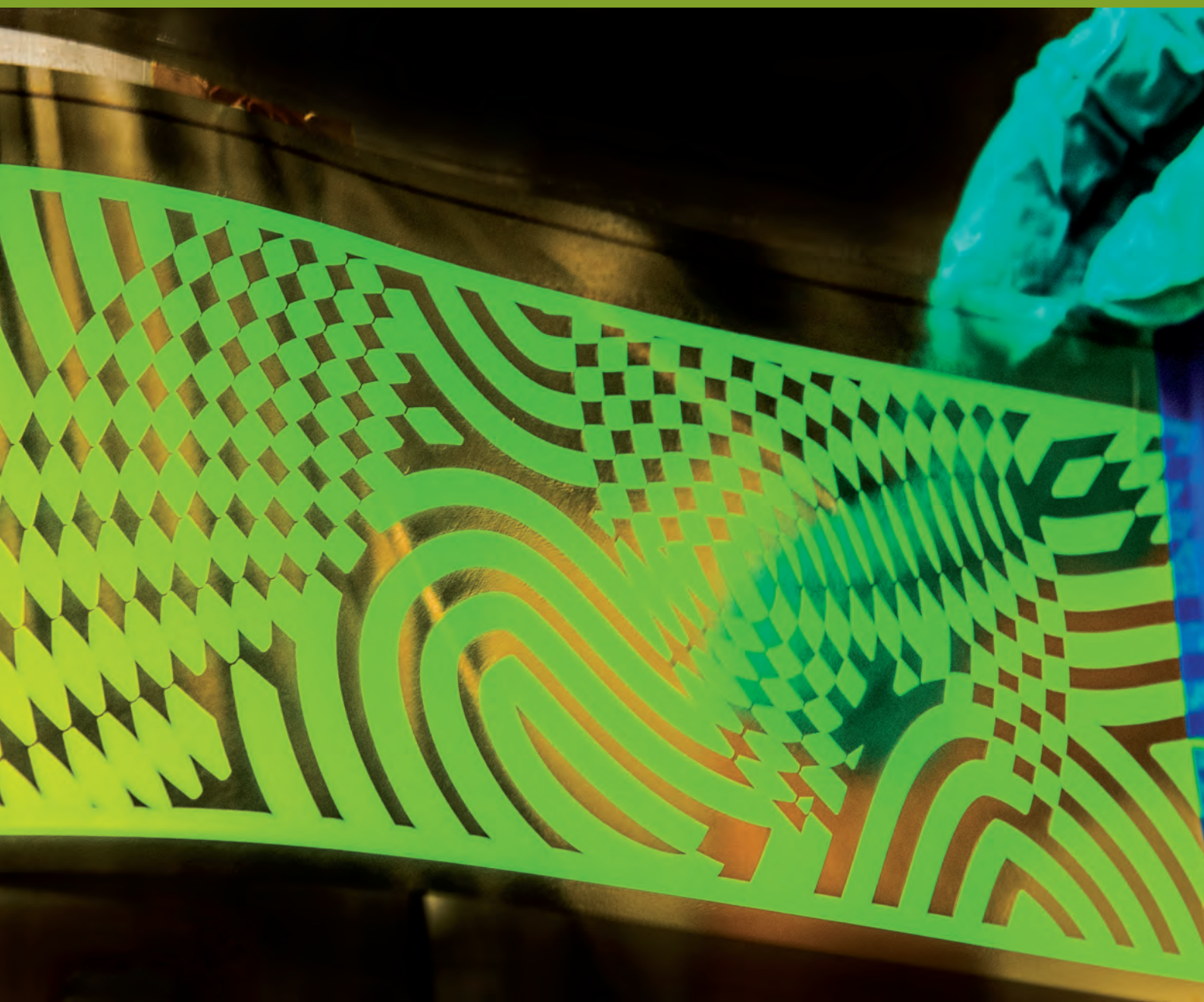
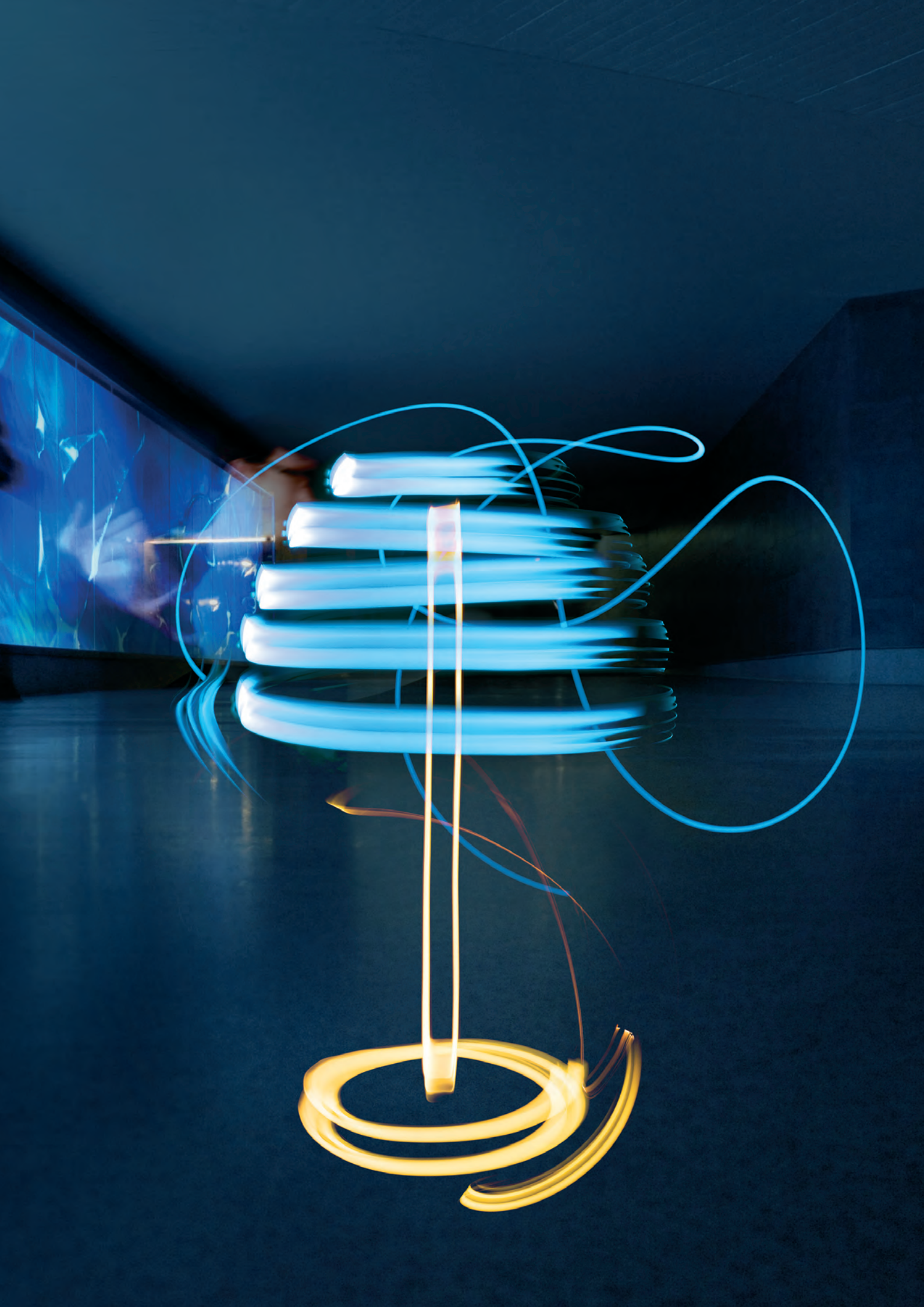


## ORGANIC ELECTRONICS

PROCESS DEVELOPMENT  
AND ENCAPSULATION TECHNOLOGIES









## PROFILE

Fraunhofer FEP combines research and development works for the production, integration and technology of organic electronic devices. The focus is on diverse applications entering industrial production as well as consumer goods applications based on semiconducting organic materials – e.g. in lighting, information, automotive, medical and environmental technologies, as well as safety technology; really almost every sphere of life.

Processes for flexible OLED lighting at various substrates, bi-directional OLED microdisplays and ultra-high barrier films for encapsulation are under development.

Fraunhofer FEP can be partner for customer- and application orientated research, development and pilot fabrication of novel module concepts and fabrication methods for these organic electronic devices.

The institute provides full service – from system design and technological development to pilot production of small batches including substrate structuring, deposition technology, encapsulation and system integration.

### SERVICES AT A GLANCE

Feasibility and market studies

Simulations

Complete process development

Device & system development

Prototypes & demonstrators

Characterization & test

Pilot fabrication

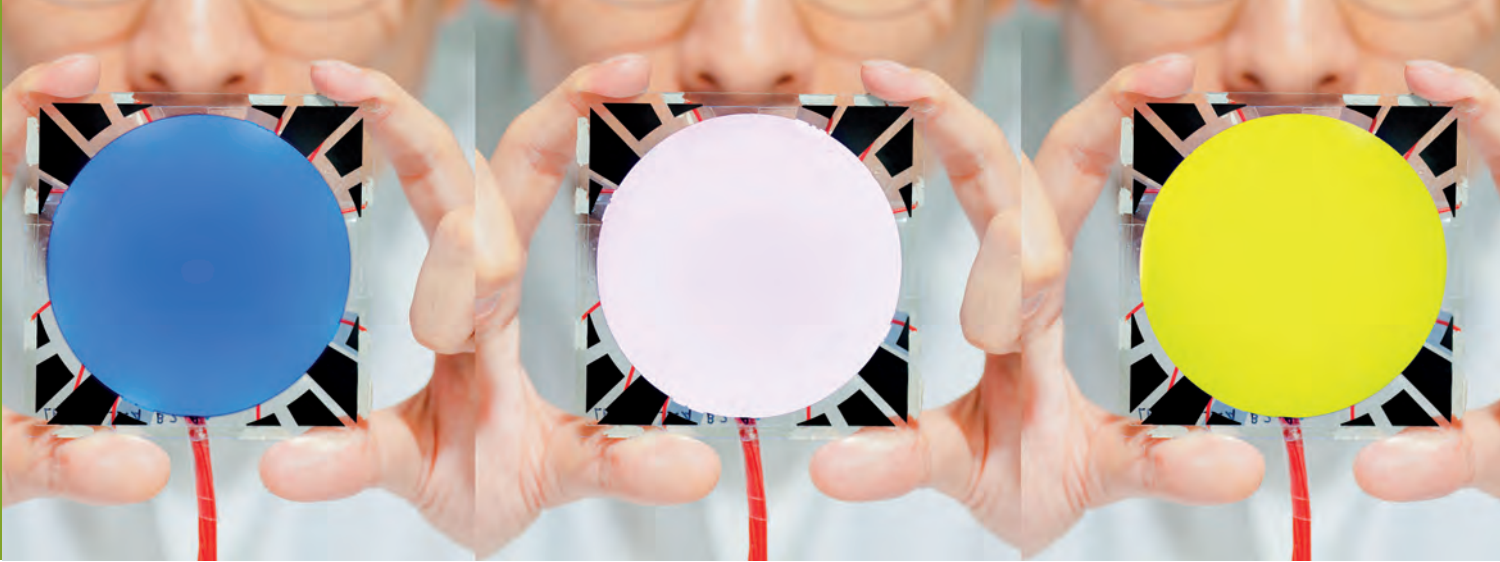
Trainings

Consulting services









# FLEXIBLE ORGANIC ELECTRONICS

## TECHNOLOGY

- Process development of OLED and organic solar cells
- Vacuum thermal evaporation (VTE)
- Litho-free substrate patterning
- Sputtering
- Material evaluation, stack integration
- Encapsulation
- Characterization
- Roll-to-roll technology for SM-OLED
- System design

## COMPONENTS

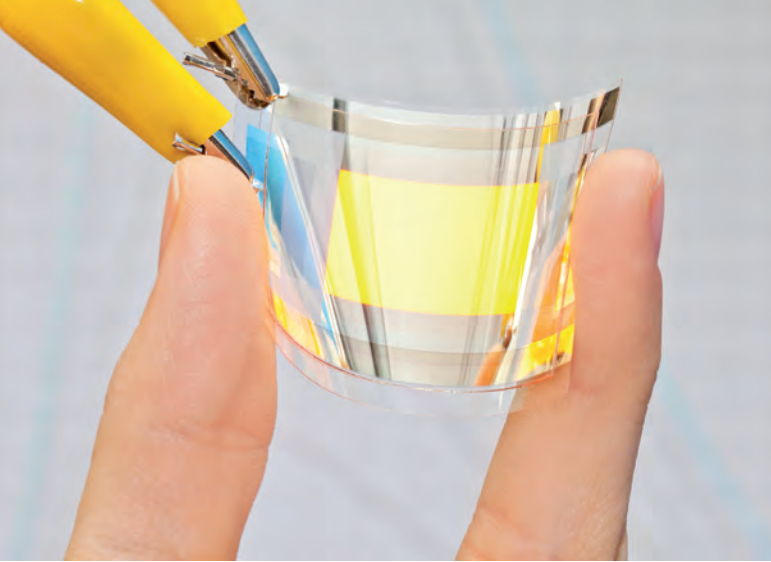
- Monochrome and white OLED modules
- Large area lighting panels
- Transparent OLED modules
- Flexible OLED on polymer web, metal strips, thin flexible glass
- Customized layouts

## APPLICATIONS

- General lighting, automotive lighting, professional lighting
- Signage
- Display
- Sensorics

## MATERIAL EVALUATION

- |  |  |
|--|--|
| <ul style="list-style-type: none"> <li>■ Transparent conducting oxides (TCO)</li> <li>■ Silber nanowires (AgNW)</li> <li>■ Graphene</li> <li>■ "Synthetic metals", conductive polymers, metals</li> <li>■ Carbon nanotubes (CNT)</li> <li>■ Benchmarking of "active" materials</li> <li>■ Hole transport / electron transport materials</li> </ul> | <ul style="list-style-type: none"> <li>■ Singlett/triplett emitter</li> <li>■ Light absorber for OPD/OPV</li> <li>■ Climatic chamber with or without sun simulator</li> <li>■ Passive materials:</li> <li>■ Substrates rigid/flexible, e.g. polymer films, paper, glass, thin-glass, metalband, silicon wafer</li> <li>■ Barrier films, glues, desiccants</li> </ul> |
|--|--|



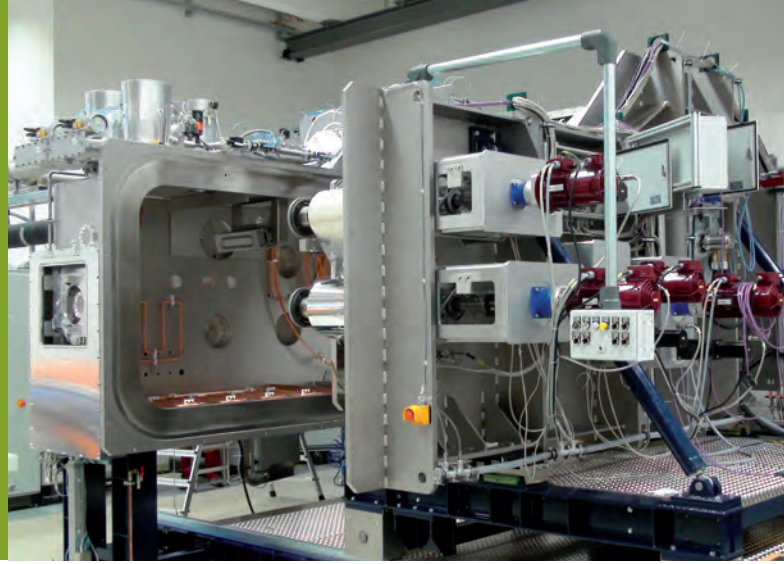
# SHEET-TO-SHEET PROCESS TECHNOLOGY

## TECHNOLOGY

- Vacuum thermal evaporation (VTE)
- Organic vapor phase deposition
- Atomic layer deposition (ALD)
- Slot die coating
- Spin coating
- ITO sputtering
- Screen printing (metal and passivation layer)
- Gravure printing
- Lamination of barrier films
- Laser ablation / laser patterning
- Thin film encapsulation
- Foil and glass encapsulation
- Scribe and break
- Foil lamination (ambient or inert)
- Automated optical inspection
- Customized wet cleaning
- Etching

## APPLICATIONS

- OLED lighting
- Organic photovoltaic (OPV)
- Organic photodiodes (OPD)
- All modules available on flexible or on rigid substrates
- All OLED-modules available transparent or opaque
- Color-tunable modules



# ROLL-TO-ROLL PROCESS TECHNOLOGY

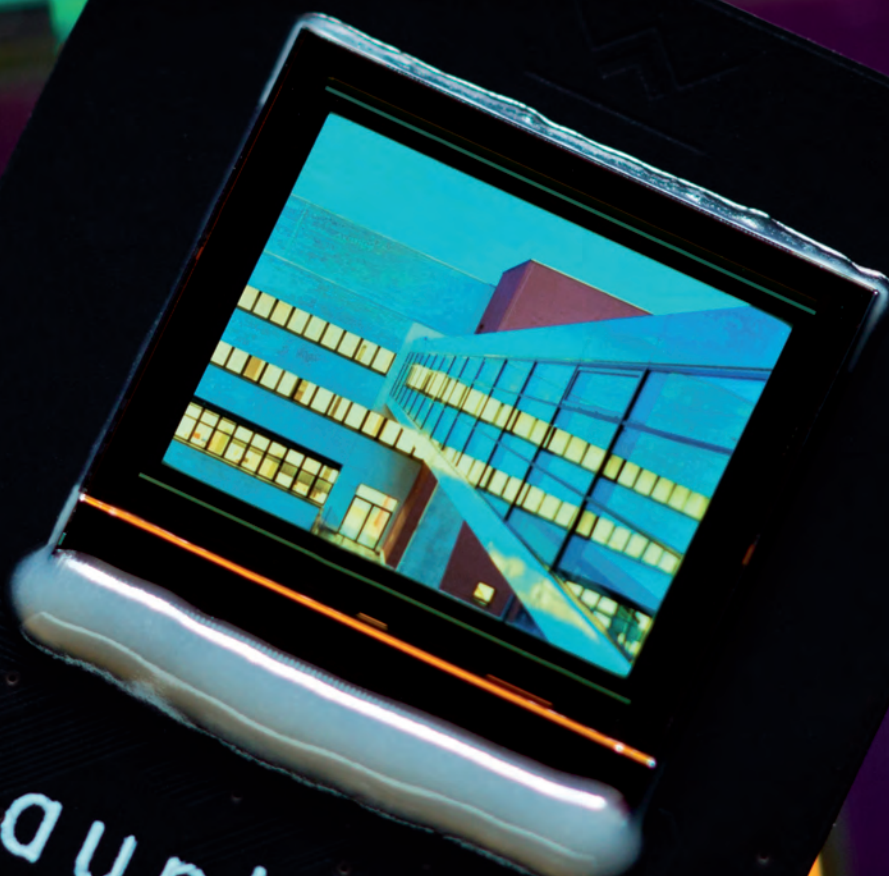
## TECHNOLOGY

- Vacuum thermal evaporation (VTE)
- Organic electronic devices on metal and plastic web
- OLED small-molecule evaporation
- Sputtering process of metal and metal oxide layers
- Plasma pre-treatments
- Gravure printing and slot die coating
- Web cleaning
- Lamination of barrier films

## APPLICATIONS

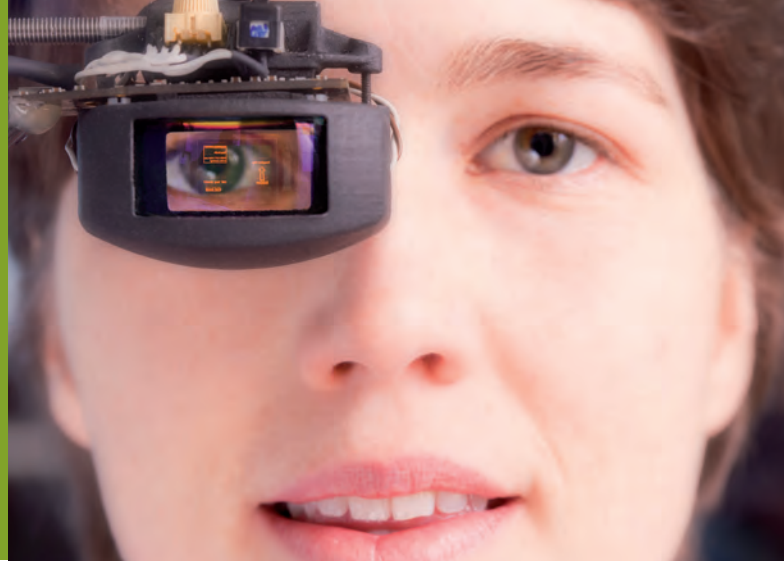
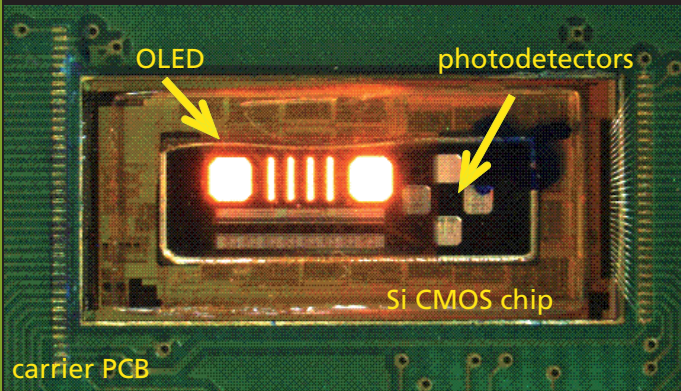
- OLED lighting
- Organic photovoltaic
- Organic photodiodes
- All modules available on flexible or on rigid substrates
- All OLED-modules available transparent or opaque
- Color-tunable modules





Fraunhofer  
FEP





# MICRODISPLAYS AND SENSORS

## TECHNOLOGY

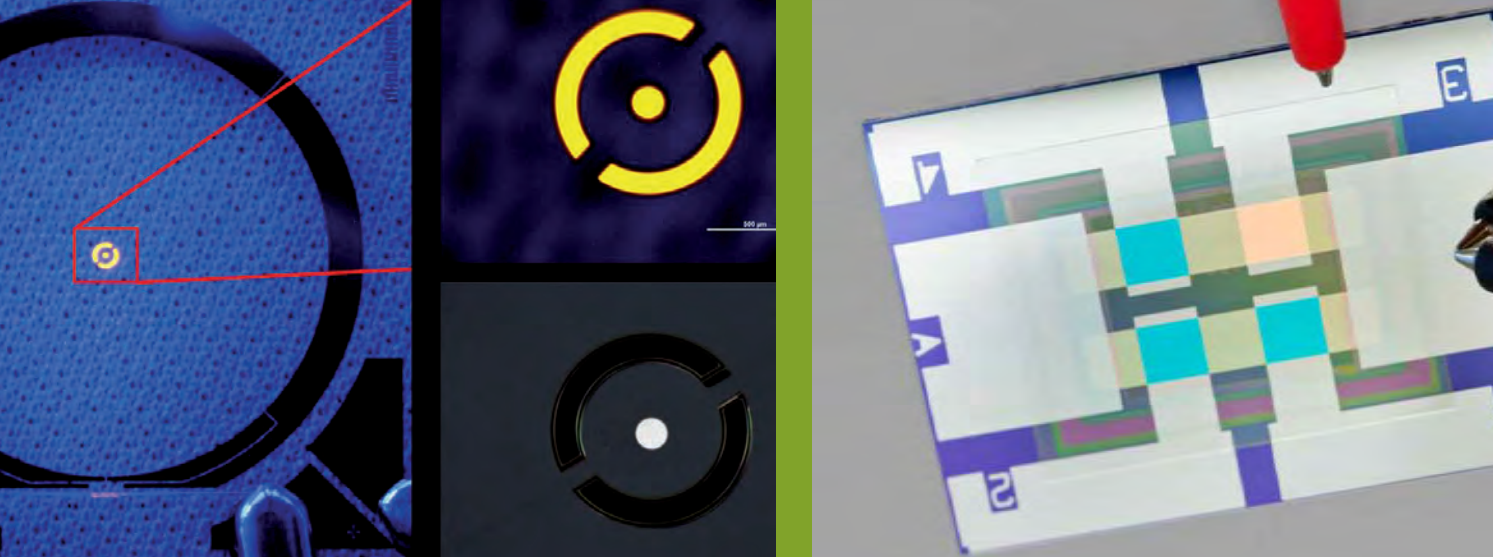
- Process development of small-molecules (OLED) and polymers (PLED)
- Silicon-CMOS/OLED interface definition (with silicon foundry)
- Encapsulation including wafer-level color filter integration
- Pilot line OLED/PLED-on-silicon (8" Si wafer)

## COMPONENTS

- OLED microdisplays (QVGA, VGA, XGA, ...)
- Bidirectional OLED microdisplays (with embedded image sensor)
- OLED as silicon-embedded patterned light source and CMOS photodetectors
- Silicon-CMOS backplane IC design (CMOS processes (0.6 ... 0.11  $\mu\text{m}$ ))
- System design (electronics, optics)
- Device characterization

## APPLICATIONS

- See-through head-mounted displays (ST-HMD)
- Interactive ST-HMD (embedded eye-tracking/gaze-control)
- Electronic view-finder (EVF)
- Optical inspection
- Optical sensors (fluorescence, flowmetry, color, ...)
- Autostereoscopic 3D displays



# ORGANIC MICROELECTRONIC DEVICES

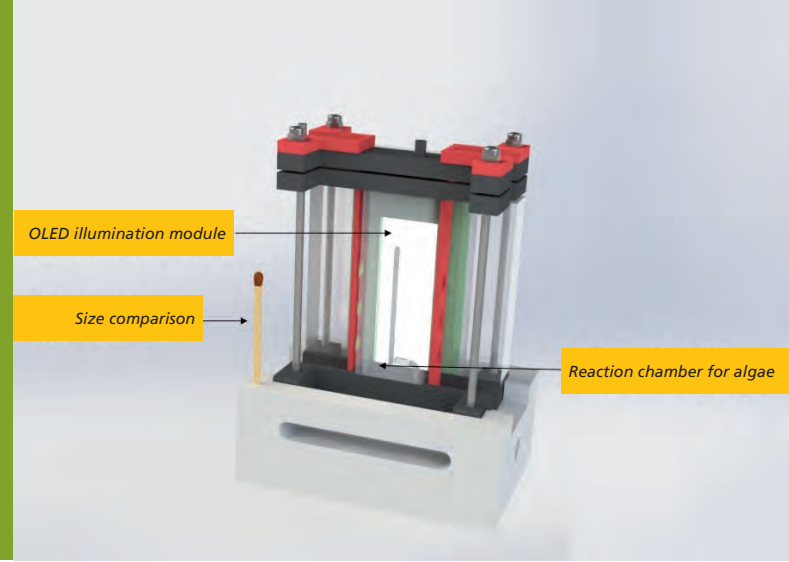
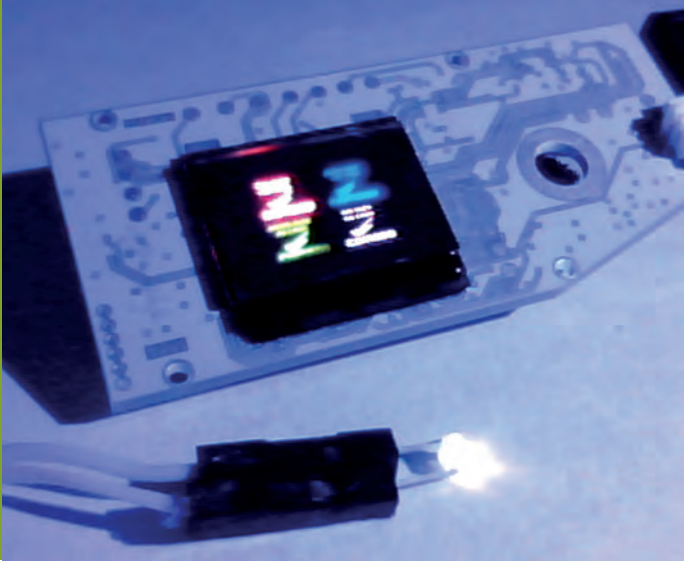
## TECHNOLOGY

- Technology on 200 mm wafer
- 1:1 lithography process to structure organic and inorganic layer
- Orthogonal photolithography
- Thermal evaporation of organic materials
- Electron beam evaporation
- Sputter processes
- Structuring of layers via etching, lift-off or shadow masks
- Shadow mask fine alignment with  $\pm 10 \mu\text{m}$  alignment accuracy
- Barix™ encapsulation
- Fully automated wafer bonding
- Wafer prober for electro-optical characterization
- Ellipsometer for thin-film characterization
- Lamination of foil onto wafer for flexible devices
- Various substrates possible (glass, silicon wafer, foil)
- Optical inspection via microscope

## APPLICATIONS

- OLED microdisplays
- Organic photodiodes (OPD)
- Organic devices for sensor applications
- Flexible organic devices
- Inorganic color filters





# IC AND SYSTEM DESIGN

## TECHNOLOGY

- Development of integrated circuits
- Analog, digital, mixed-signal
- Typical CMOS processes: 0.13  $\mu\text{m}$ /0.18  $\mu\text{m}$ /0.35  $\mu\text{m}$
- Concept, system design, schematic, simulation, layout, verification
- Coordination with external silicon wafer manufacturer, test and start-up
- Development of discrete electronics
- Based on commercial ICs, FPGA, microcontroller etc.
- Concept, system design, schematic, PCB layout
- Coordination with external manufacturer, test and start-up
- Software design
- C, C++, VHDL
- Microcontroller firmware, embedded systems, application software

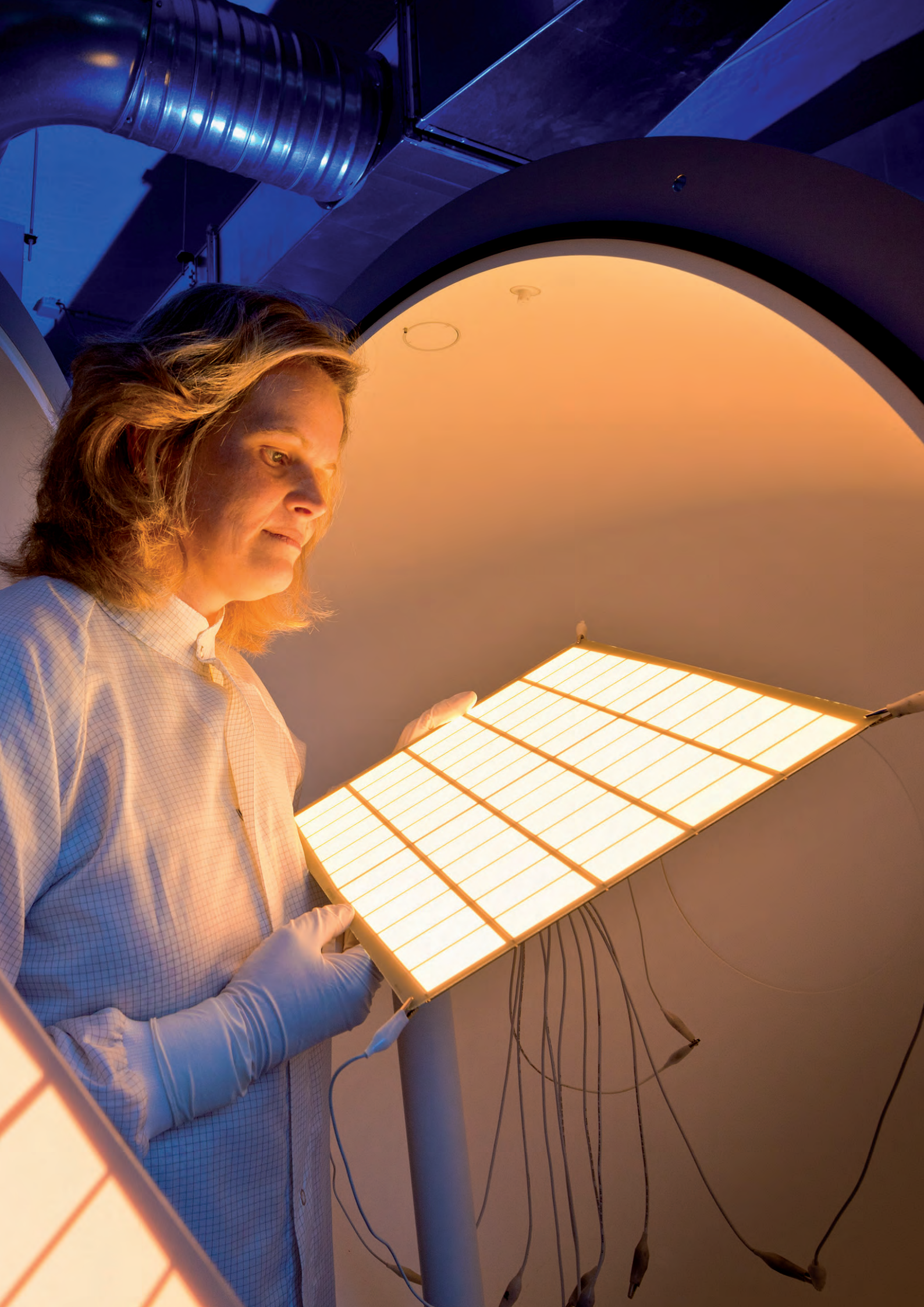
## COMPONENTS

- Microdisplay and sensor backplane
- Driving and readout electronics for microdisplays, sensors, OLED and OPD
- Device driver, software libraries and applications

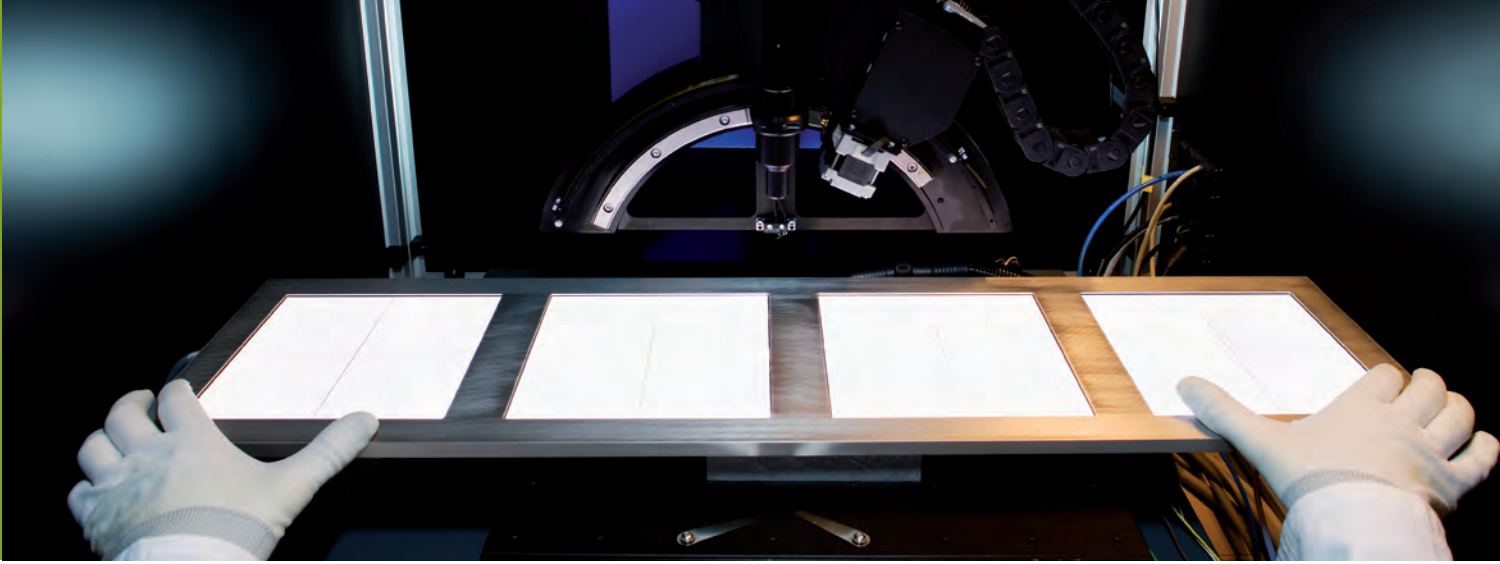
## APPLICATIONS

- Head mounted displays
- Image processing, focus on eye-tracking
- Sensors
- Lab on chip









# CHARACTERIZATION AND ANALYTICS

## PHOTOMETRIC CHARACTERIZATION

- 1 m-integrating sphere measurements  
(absolute spectral radiant flux and related parameters, e.g. luminous efficacy and color coordinates)
- Near field goniometer measurements  
(angular dependent absolute spectral radiance and related parameters, e.g. luminance and color coordinates)
- Calibrated CCD camera measurements  
(spacial luminance distribution)

## SPECTROSCOPIC THIN FILM CHARACTERIZATION

- Transmission and reflection spectroscopy in UV-VIS-NIR range
- Variable angle spectroscopic ellipsometry
- Photoluminescence spectroscopy
- Thin-film modelling for analysis of spectroscopic data

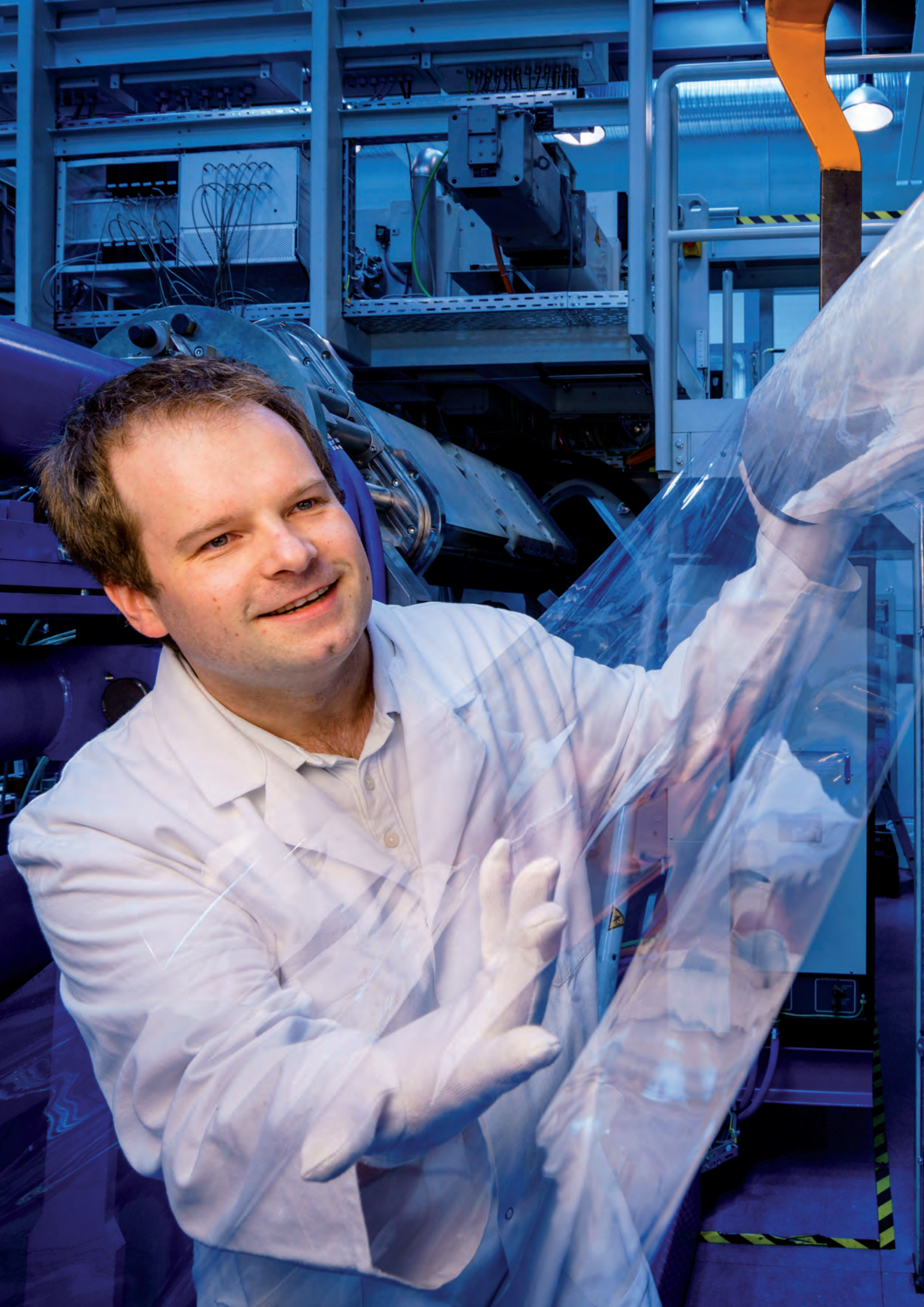
## SOLAR CELL CHARACTERIZATION

- Solar cell test system (IV-characteristics with sun simulator)
- Photocurrent mapper

## GENERAL DEVICE CHARACTERIZATION

- Lifetime and reliability testing of OLED modules
- IR imaging for thermal characterization and failure analysis
- Climatic chamber testing









## PERMEATION BARRIERS

The department “Flexible Products” pursues various technological approaches to manufacture high quality and cost-efficient water vapor and oxygen barrier coatings on flexible substrates.

For each application, we can provide the best suitable technological approach taking into account technical requirements and economic targets. Our technologies include:

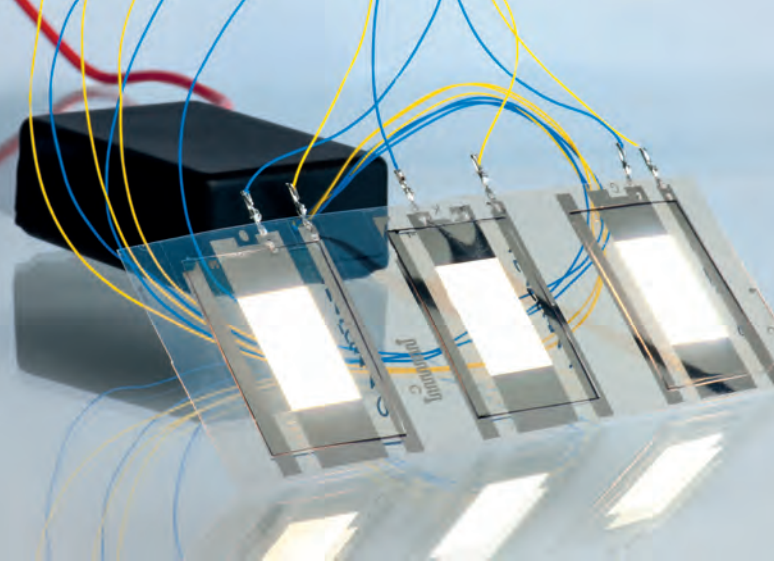
Technology	Productivity (line speed) m/min	WVTR at 38°C/90% r.h. [g/(m <sup>2</sup> d)]
Hollow-cathode plasma-assisted evaporation (HAD)	600	1
Reactive sputtering of oxides	1	0.005
Multi-layer stack: sputtering + wet coating of ORMOCER®*	1	0.0002
Multi-layer stack single pass. sputtering + arcPECVD	≥ 4	0.005
Atomic layer deposition	Static process	< 0.001

\* Cooperation within Fraunhofer Polymer Surfaces Alliance POLO

### OUR OFFER

Our services and products around permeation barrier coatings, their application and related products include, but not limited to:

- Evaluation of polymer substrates for barriers
- Sampling, material provision and feasibility studies
- Roll-to-roll pilot production of barrier film rolls
- Adaption of barrier films to specific application
- Functional film design and deposition (including electrodes, adapted optics or protection layers)
- Product integration
- Technology transfer and licensing
- Key components for barrier layer deposition
- Direct thin-film encapsulation of devices
- Barrier film and device characterization



## FILM AND DEVICE CHARACTERIZATION

In our “Flexible Organic Electronics Lab” we are able to test permeation barriers directly on a device.

Our analytical portfolio comprises:

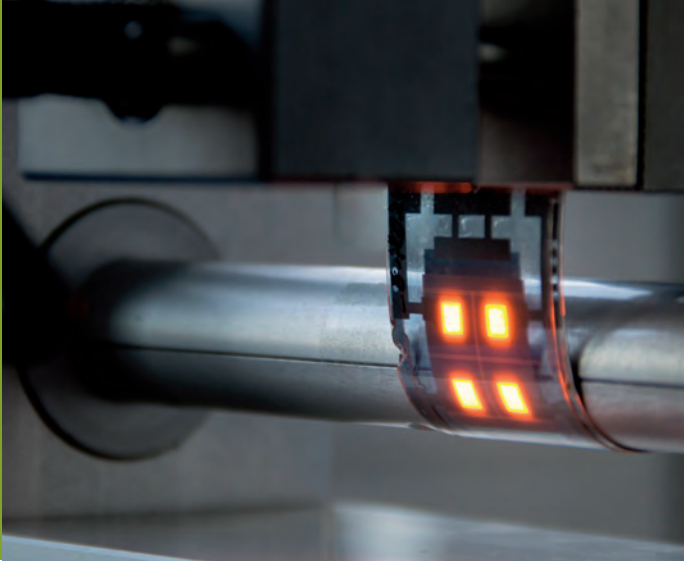
- Coulometric permeation measurement (BRUGGER WDDG, Mocon OX-TRAN)
- Calcium-mirror test for WVTR and defect characterization
- OLED degradation and lifetime studies
- (Roll-to-roll) particle and defect inspection
- Mechanical bending and strain tests

## APPLICATIONS

Beside our lead applications, flexible smart packaging and flexible organic electronics, our technologies can be easily adapted to:

- Flexible and organic photovoltaic devices
- Electrochromic systems
- Thin film energy harvesting and energy storage devices
- Holographic systems on polymers
- Sensors and flexible/organic transistors
- Quantum dot and OLED lighting and displays
- Wearables and other flexible electronic devices





## EQUIPMENT

### **labFlex® 200**

- 220 mm web width
- sputtering and PECVD
- Roll-to-roll OLED encapsulation without roller contact of coated side

### **coFlex® 600 and novoFlex® 600**

- 650 mm web with (pilot scale)
- sputtering, PECVD and evaporation
- multilayer deposition in one run
- web speed up to 10 m/s
- double-side coating

### **Production line OLED on Silicon**

- Etching / sputtering
- Spin coating
- Nitrogen oven
- Deposition by thermal evaporation and Barix™ thinfilm encapsulation
- Full-automated wafer bonding system
- Wafer prober
- Microscopes
- Ellipsometer

### **Roll-to-roll OLED line**

- Deposition by thermal linear evaporation
- Reactive sputter magnetron and plasma pre-treatment
- Rewinding unit with integrated optical inspection system
- Coating and printing unit under inert atmosphere
- Barrier film encapsulation under inert atmosphere
- 300 mm width; metal, polymer, thin glass

### **Pilot line for organic devices on sheet level (rigid or flexible)**

- Vacuum thermal evaporation systems
- Organic vapor phase deposition system
- Slot die coater
- Atomic layer deposition tool
- Magnetron sputter source
- Automated screen and stencil printer
- Laserablation system
- Wet cleaning tools
- Glass scribe and break tool
- Foil lamination systems (ambient or inert)
- Automated optical inspection
- Rigid and flexible substrates up to 200 × 200 mm<sup>2</sup>  
(several processes up to 370 × 470 mm<sup>2</sup>)



## OUTLOOK

### OLED ON SILICON

- Smart microdisplays (e.g., embedded eye-tracking)
- R,G,B-micropatterning full color/without color filter
- Cost-efficient manufacturing techniques
- High brightness, high resolution microdisplays
- Extended temperature range (sensors)
- Applications e.g. food quality, point-of-use diagnostics, ...
- Extended spectral emission/detection (UV, IR, ...)
- Inorganic colour filter
- Organic photodiodes in UV/VIS/NIR
- Lithography structuring of organic layer
- Bendable devices

### FLEXIBLE ORGANIC ELECTRONICS

- Stable flexible OLED
- Seamless tiling, back side contact
- Novel outcoupling concepts
- Hybrid processing (wet/vacuum)
- Next generation transparent conducting layer (ITO replacement)
- Heterogenic system integration
- Development of biological degradable electronic devices





## CONTACT

### LOCATION WINTERBERGSTRASSE

Fraunhofer Institute for  
Organic Electronics, Electron Beam and Plasma Technology FEP

Winterbergstr. 28 | 01277 Dresden, Germany

Phone +49 351 2586-0

Fax +49 351 2586-105

[info@fep.fraunhofer.de](mailto:info@fep.fraunhofer.de)

[www.fep.fraunhofer.de](http://www.fep.fraunhofer.de)

### CONTACT PERSON

Ines Schedwill

Phone +49 351 8823-238

Fax +49 351 8823-394

[ines.schedwill@fep.fraunhofer.de](mailto:ines.schedwill@fep.fraunhofer.de)

### LOCATION MARIA-REICHE-STRASSE

Fraunhofer Institute for  
Organic Electronics, Electron Beam and Plasma Technology FEP

Maria-Reiche-Str. 2 | 01109 Dresden, Germany

Phone +49 351 8823-238

Fax +49 351 8823-394

[info@fep.fraunhofer.de](mailto:info@fep.fraunhofer.de)

[www.fep.fraunhofer.de](http://www.fep.fraunhofer.de)

### PICTURE CREDITS

Fraunhofer FEP

Jürgen Lösel

André Wirsig



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