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FEP

FRAUNHOFER INSTITUTE FOR ORGANIC ELECTRONICS, ELECTRON BEAM AND PLASMA TECHNOLOGY FEP

CUSTOMIZED OLED DESIGN

ORGANIC ELECTRONICS AT FRAUNHOFER FEP.

Fraunhofer FEP combines research and development work 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, bidirectional 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. Fraunhofer FEP has an extensive know-how along the entire value chain for the development of flexible OLED-modules: from a bare substrate to an integrated luminaire.

We offer our customers and partners R&D services for each step of the value chain up to customized layouts on prototypes for small batch series.

OLED.FLEXIBLE

Organic Light-Emitting Diodes (OLED) offer unique features for luminaire designs and technical lighting applications. OLED technology allows white and monochrome emission in nearly every color. Additionally, OLED can be quasi transparent when switched off. Next to their appearance another aspect is of importance: OLED technology is nearly independent of the substrate they are processed on. Beside rigid glass OLED can be processed on flexible substrates like polymer webs, metal strips and thin flexible glass. Such flexible OLED modules allow much more freedom of design for integration into curved surfaces. In the last years the Fraunhofer FEP – a wellestablished institute of the European OLED research – has developed fabrication technologies for OLED devices by sheet-to-sheet and roll-to-roll processing on different type of flexible substrates.

Fraunhofer FEP offers the following research and development topics from concept studies to sample production in the field of sheet-to-sheet and roll-to-roll fabrication of organic-based devices on flexible substrates, e.g.:

- Optical defect inspection by means of CCD line scan cameras (pixel resolution 14 µm) or with moveable optical microscope (point resolution 1 µm)
- Lamination of flexible substrates on rigid glass carriers for sheet-to-sheet processing
- Cleaning tests
- Vacuum coatings of metal- and metal oxide layers, e.g. TCO coatings as electrode
- Electrode patterning by printing of metal- and dielectric layers or laser ablation
- Vacuum deposition of the OLED layer stack
- Slot-die coating for individual layers
- Deposition of barrier layers by magnetron sputtering or ALD
- Lamination experiments of barrier foils
- OLED device integration
- System engineering for OLED luminaires
- Electro-optical characterization including lifetime measurements

The device development on flexible glass opens the opportunities of OLED developments for smart signage and lighting integrations, especially on curved surfaces with the potential of high OLED lifetime.

	Substrate size	**Polymer film**	**Metal strips**	**Thin flexible glass**
Sheet-to-sheet	max. 200 × 200 mm²	PET, PEN or PI, from 50 µm thickness	Stainless steel, aluminium, etc., any thickness	thickness between 25 µm and 100 µm
Roll-to-roll	max. 300 mm width	PET, PEN or PI, from 50 µm thickness	Stainless steel, aluminium, etc. up to 200 µm thick	thickness between 50 µm and 100 µm (sheet substrates up to 300 × 700 mm²)

Substrate types for flexible OLED

OLED.COLOR-TUNABLE

Ultrathin light sources with high efficacy and very good color quality can be realized based on OLED technology on rigid as well as on flexible substrates. Furthermore OLED technology has a unique position due to its characteristic as a non-glaring planar solidstate- lighting source. A characteristic that cannot be realized with current inorganic LEDs, namely point light sources. A variety of novel applications appear to be possible based on this existing technology.

Target of the research and development work at Fraunhofer FEP is a further broadening of the application fields of OLED technology. Recently, researchers at Fraunhofer FEP were able to realize a color-tunable OLED.

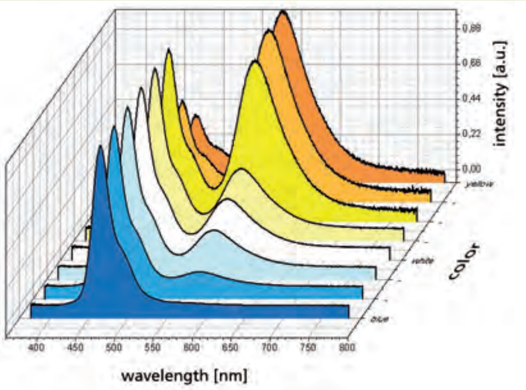
The color-tunable OLED is desirable for various lighting applications e.g. integrated in the interior of trains, cars or planes. It will be possible to simulate e.g. the ambient lighting conditions of each time slot of the day: a highly blue light in the morning, white around noon, and comfortable warm reddish or yellowish light in the evening.

Furthermore Fraunhofer FEP is working on the integration of additional functions into the OLED for further niche markets. We are able to integrate customer specific needs for the development and implementation of new technologies.

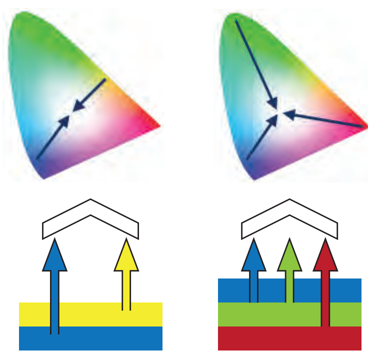
The previous approaches to realize colortunable OLED have been performed by dividing the lighting plane into extremely small pixels such as display technology or narrow stripes for the realization of each color (blue, green, red) and driving them with different voltages. In contrast to this technology Fraunhofer FEP developed so-called »stacked« OLEDs.

The technology is based on a vertical stacking of OLEDs where each OLED can be controlled separately. A lateral patterning is not required. By using this technology, the color of the emitted light can be tuned continuously. According to the application combinations of two or three colors are possible. Using different process technologies Fraunhofer FEP was able to achieve the right stack architecture including the optimized thickness of the individual OLEDs for an appropriate efficacy.

Emission spectrum of two-color OLED



Schematic layout of a white-emitting two-color (right) and three-color (left) OLED



OLED.DYNAMIC

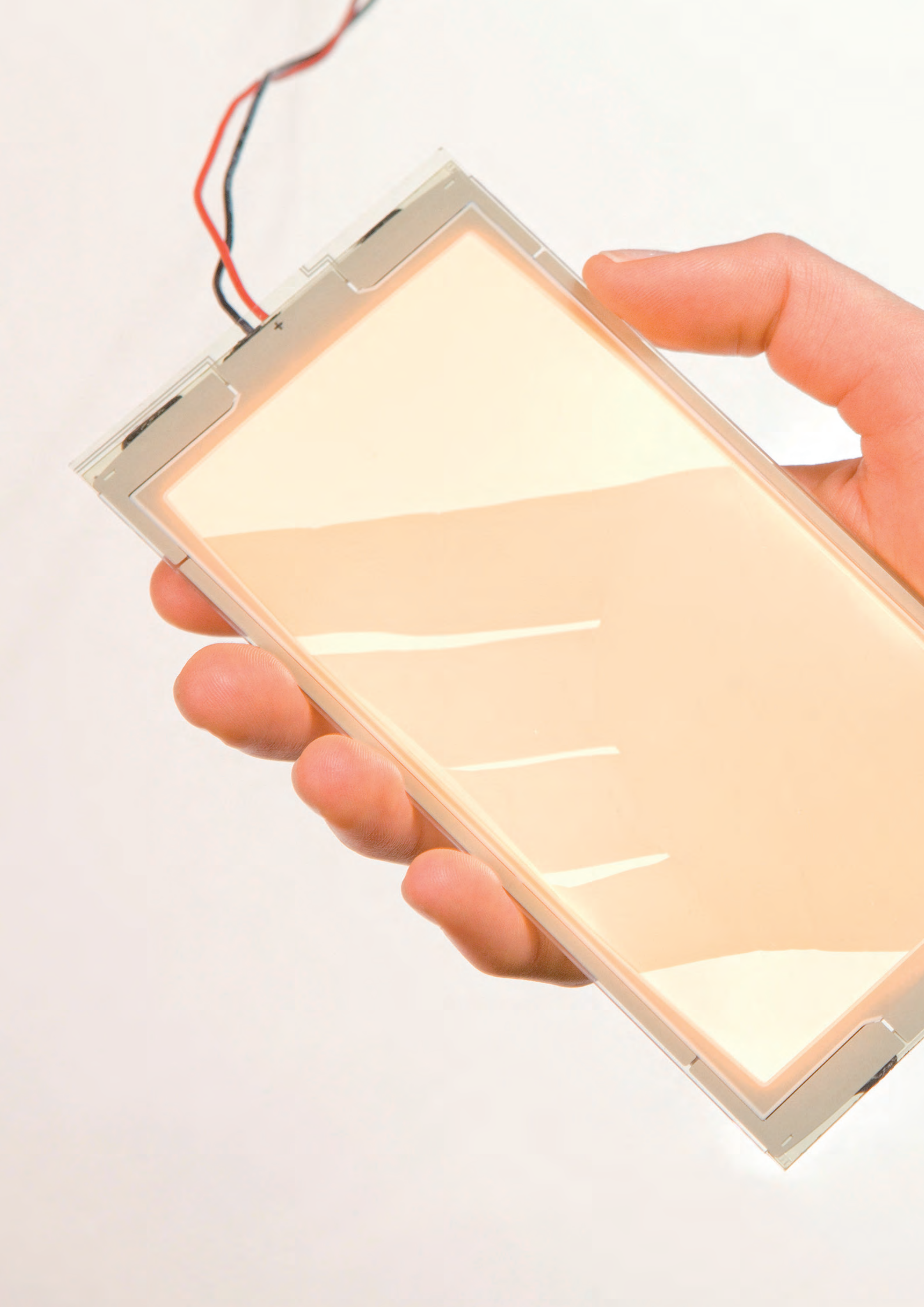
The organic light-emitting diode (OLED) is the first ever real area light source, only two millimeters thin and optional transparent. The light emitting area offers lots of design opportunities. Grids as graphics, multiple colors on one substrate, independent segments and lots more.

Fraunhofer FEP provides OLED designs with multiple independent OLED segments to customers. We call it monlithic dynamic area lighting.

Every segment on a dynamic OLED has its own anode and a shared cathode. In combination with intelligent control a lot of dynamic lighting effects can be realized and the possibilities are unlimited.

So Fraunhofer FEP e.g. shows the largest monolithic dynamic area lighting module available worldwide with 72 independent segments on a 320 mm diameter substrate. Lighting designers and manufacturers can use Fraunhofer FEP's design experiences and OLED pilot production ability to realize their own OLED design within short time.

Please contact us for consulting on OLED design!

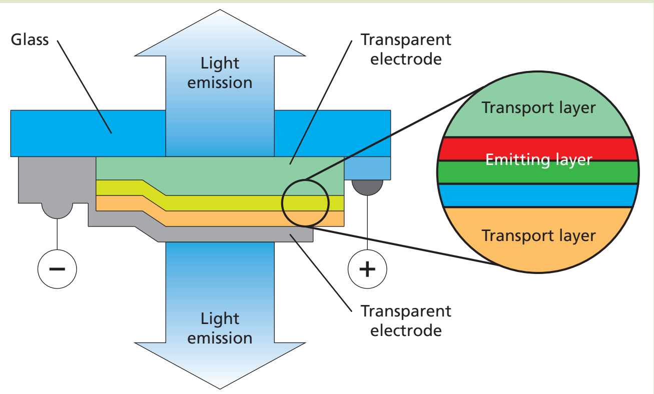


OLED.TRANSPARENT

A special unique feature is the realization of transparent signage and lighting panels. In off-state the device is transparent, in on-state the OLED panel generates light in both directions. This new feature gives the opportunity for the realization of totally new applications like lighting partitions or bidirectional signage.

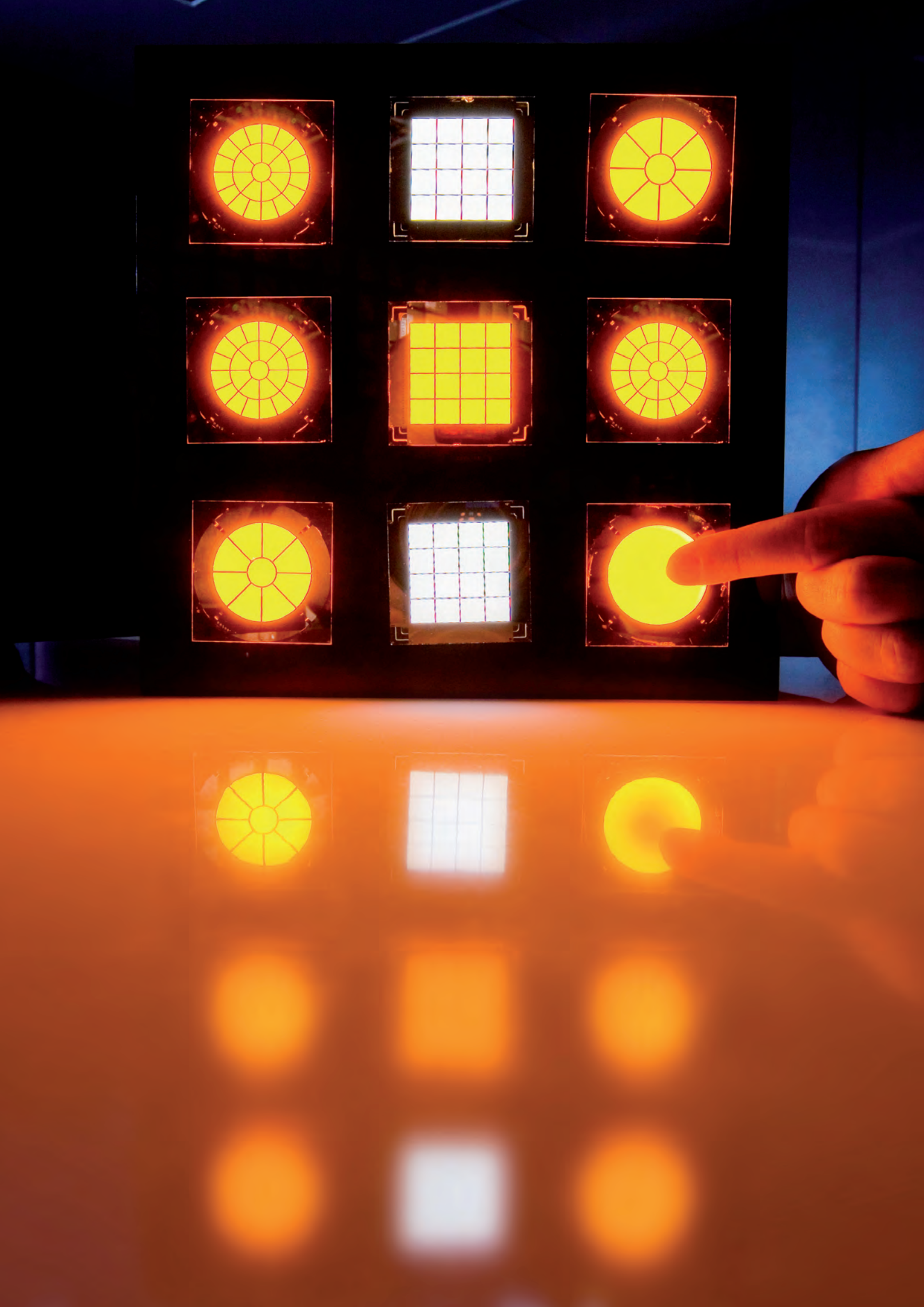
OLEDs consist of stacks of organic layers (thickness about 100 nm), which are connected by electrodes. In the usual case the substrate is glass with a transparent conductive indium tin oxide layer, whereupon follows the organic stack, that consists of hole transport and electron transport materials. Afterwards follows the inorganic transparent cathode. Based on the integration of two transparent electrodes, the OLED device is transparent in off-state, the transparency could be up to 60% in the range of 400 to 800 nm wavelength. Additionally the bottom electrodes can be structured, which allows for signage applications with individually switched elements. The light generation ratio for both directions can be varied between 50% / 50% till 20% / 80% based on OLED cavity design. This could be used for unidirectional signage and lighting applications with transparent feature.

Schematic of a transparent OLED



Fraunhofer FEP offers particularly the following service:

- Customized transparent OLED signage and lighting design with finite element simulation of lighting substrates
- Customized OLED backplane design and fabrication
- Fabrication of OLED lighting solutions for demonstrator and prototype applications
- Development of driving electronic for signage and lighting applications



OLED.TOUCH SENSITIVE

The OLED technology is the first real area light source technology. It overcomes traditional restrictions of point source lighting technologies (e.g. light bulbs or LED). Their special features could be the starting point for highly efficient homogenous area light sources. Beside the area aspects, OLED show also the possibility for innovative lighting applications, e.g. structured light sources for signage or color-variable, transparent and flexible light sources.

Due to the OLED construction, the implementation of an integrated interactive touch interface is possible in a simple way, an additional unique feature of OLED. This allows the realization of novel interactive lighting and signage devices without the use of additional hardware like touch foils which reduces the overall efficacy.

Organic light-emitting diodes are composed of a stack of organic layers (thickness about 100 nm), which are connected on both sides by electrodes. Usually an OLED consists of a glass pane with a transparent conductive oxide layer, whereupon follow several layers of organic emitting, hole transport, and electron transport materials. Afterwards follows the inorganic cathode. Substantial advantages of the organic luminescence are the chemical variability of the organic light-emitting diodes and the thin film system (extremely low material expense).

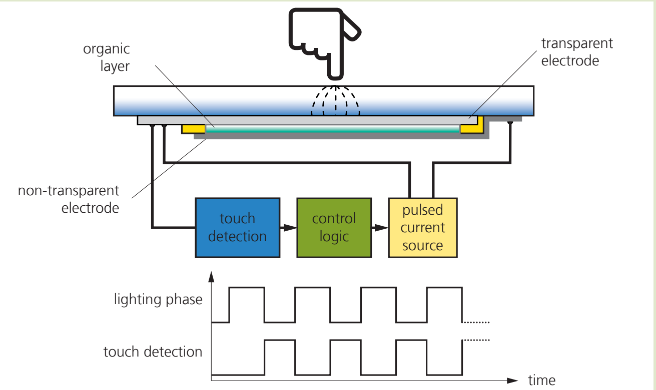
OLED are a flat light source, emitting diffuse light from a potentially large active area. OLED do not need light distribution elements, thus reducing the cost for the whole lighting panel. In contrast, LEDs are a point source technology which needs light distribution elements to disperse the light evenly on large areas. Additionally OLED use low peak brightness on large area, LEDs provide very high brightness on a small area, which often causes glares.

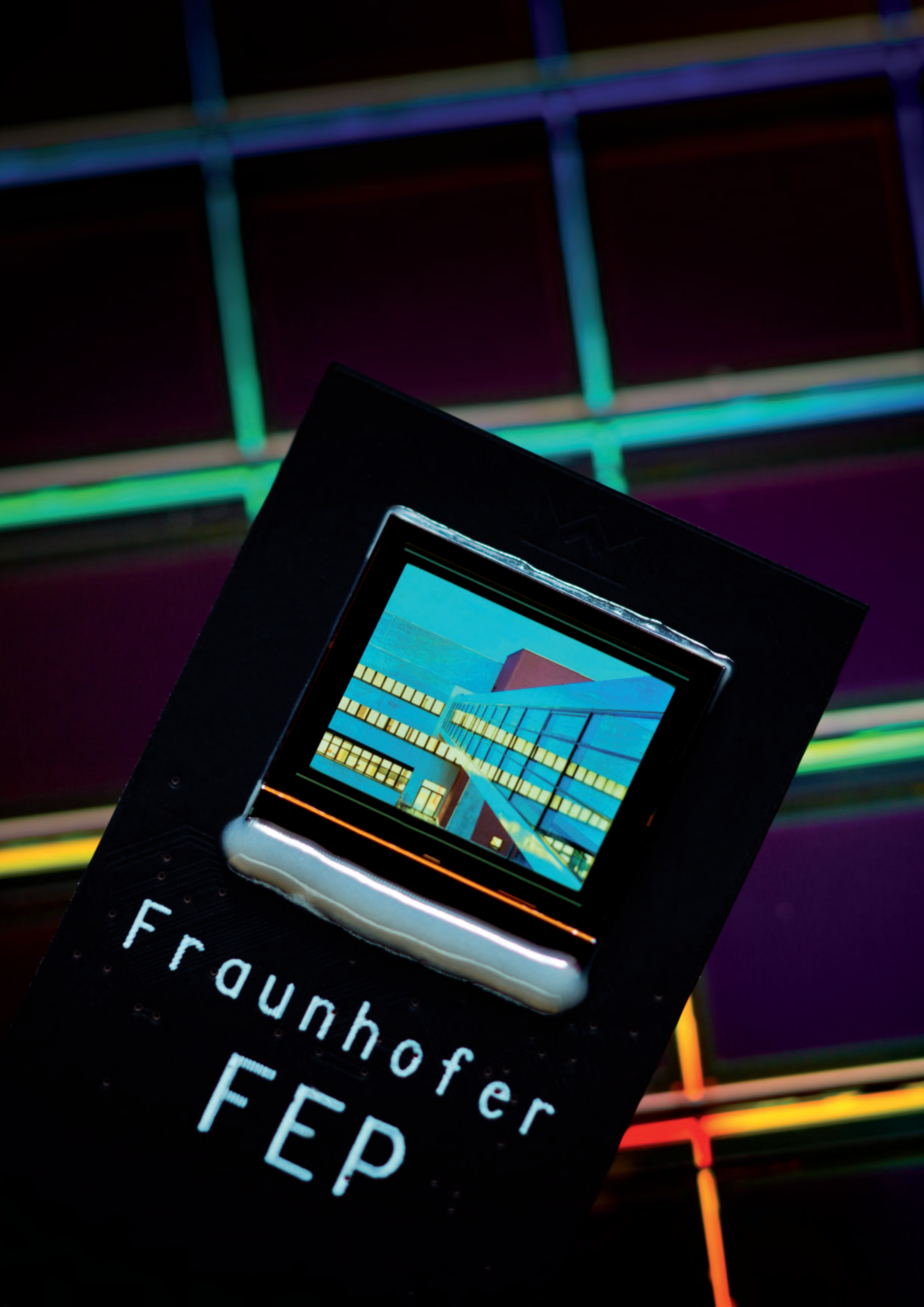
Touch-OLED operation principle

To achieve the touch function, the ground transparent electrode is used as sensing electrode for capacitance sensing. A touch sensing electronic connected to the electrode, charges this sensing electrode to a known potential. The resulting charge Multi-touch signage applications could be realized by the integration of several sensing channels. Due to the operation principle no technology modification for the OLED is necessary, every OLED could be used for touch operation. is transferred into a measurement circuit. Placing a finger on the touch surface introduces external capacitance that affects the flow of charge at that point, this registers as a touch. To use in parallel the OLED for lighting, the operation is subdivided in a touch sensing phase and a lighting operation phase. Based on a high frequency change of phases of 60 Hz and above the user will not recognize the touch sensing (off-state) phase.

Multi-touch signage applications could be realized by the integration of several sensing channels. Due to the operation principle no technology modification for the OLED is necessary, every OLED could be used for touch operation.

Schematic view of touch-sensitive OLED device

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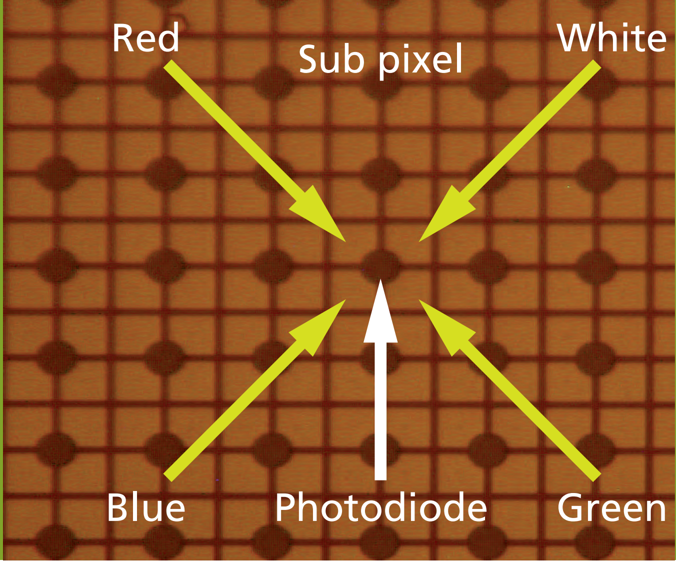


Bidirectional Microdisplay

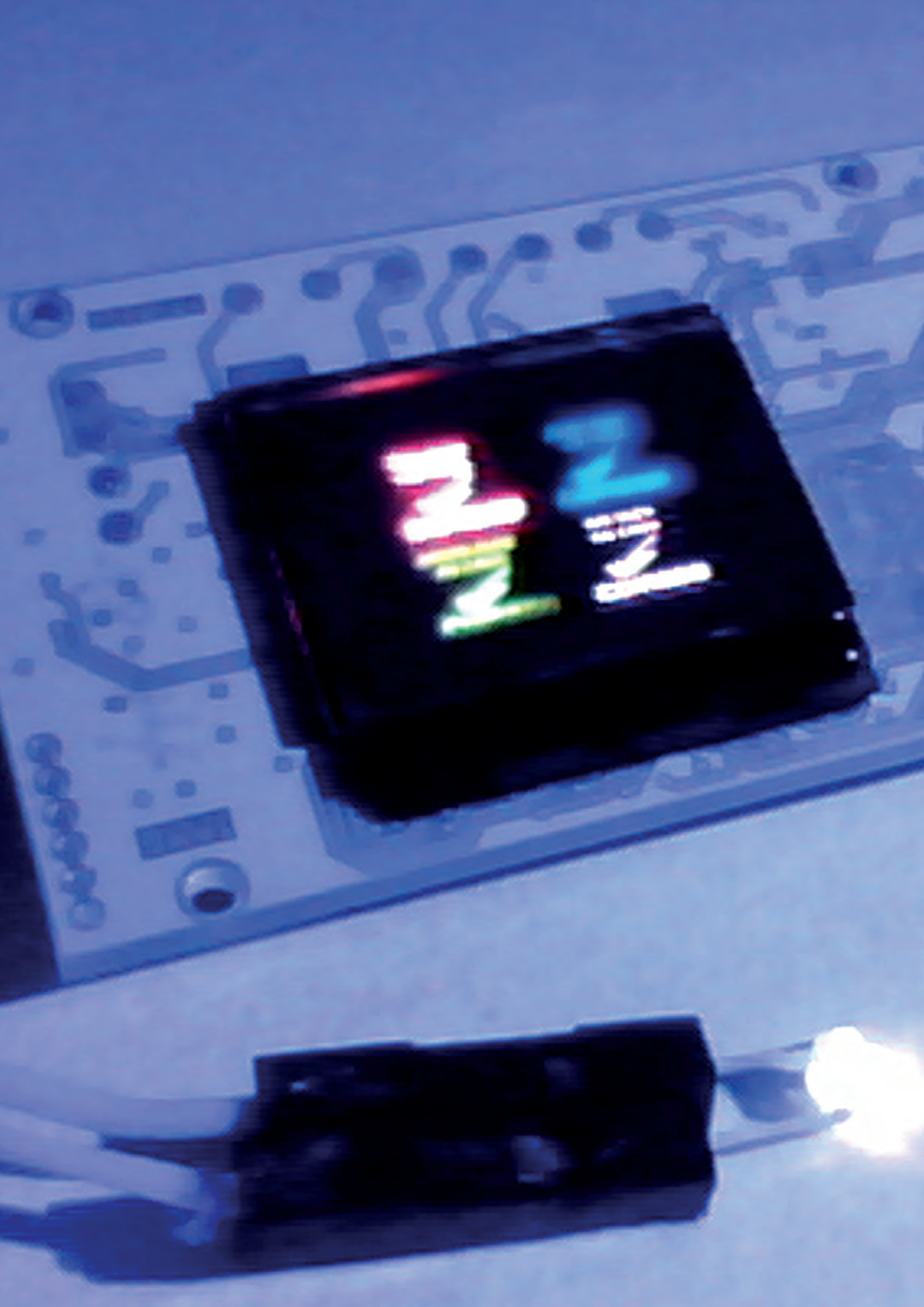
OLED-ON-CMOS.

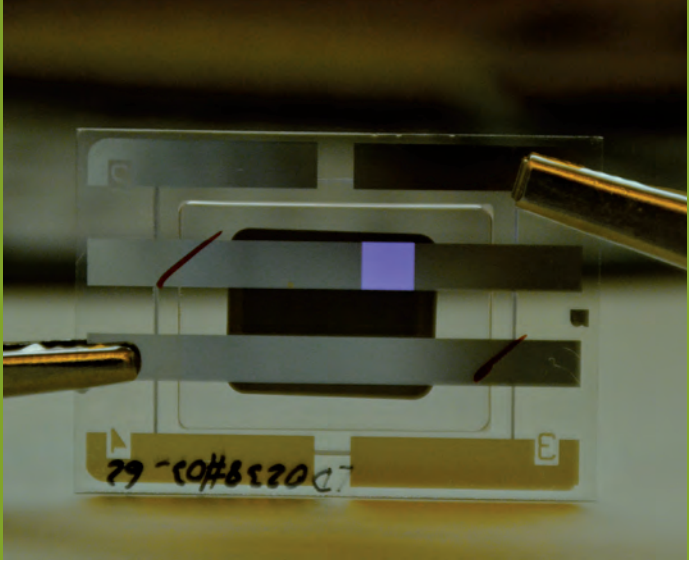
Fraunhofer FEP offers its customers the development of complete prototypes and systems of OLED-based microdisplays and sensor components. The entire range of activities for OLED-on-Silicon applications, from CMOS design, OLED stack tuning, optic design, system integration, interface programming is covered by our scientists and engineers.

Microdisplays based upon OLED-on-Silicon are especially of interest for camera viewfinders, overhead projectors, video goggles, and the emerging market of wearable displays. For instance, one can create a bidirectional microdisplay with micro-scale optical emitters and receivers on the same chip in an array type of organization, i.e. a device that displays and captures images at the same time. It presents information to the user and at the same time optically recognizes user interaction. The user perceives his or her environment as normal, but additional information is presented via an advanced type of glass which bear bidirectional microdisplays (Augmented Reality, AR). This visual information can be deliberately and unconsciously adapted to the context of the system's operation, and the user can interact without the need for hands or speech. Simple eye-movement or expression is sufficient.

Our offer:
- CMOS design as a basis for control of OLED-image or -sensor elements
- Organization of fabrication through cooperation with external foundries
- Development of a system concept based on novel set-up and connection technologies
- Development of processes and methods for structured, application specific OLED, for instance OLED microstructures, OLED for medical applications as well as for organic photodiodes
- Customized OLED silicon wafer development

Parameters	
Display resolution	800 × 600
Active area	12.8 mm × 9.6 mm
Display diagonal	15 mm
Pixel setup	RGBW + photo diode
Pixel pitch	16 µm × 16 µm
Color depth	24-bit
Display interface	24-bit RGB digital, parallel + synchronization signals CLK, HS, VS and DE
Display brightness	250 cd/m² (typ.)
Camera resolution	800 × 600
Camera interface	8-bit grayscale digital, parallel + synchronization signals CLK, HS, VS and DE
Configuration interface	TWI (two-wire-interface)
I/O voltage	1.6 V … 5.5 V
Core voltage	1.6 V … 2.0 V
Temperature range	-20°C – +65°C
CMOS technology	0.18 µm





OLED.WAVELENGTH SPECIFIC

NIR light emission

The OLED-on-CMOS technology allows the integration of organic light emitting devices and inorganic photodetectors in silicon-CMOS substrates. By use of the complex current sourcing logic of CMOS technology the realization of 'smart' optoelectronic devices is possible. This covers OLED microdisplays for image rendition in video or data glasses as well as electronic viewfinders in cameras. In combination with integrated photodetectors the implementation of an embedded camera for inactive display applications will be possible. Besides, the application field for OLED-on-CMOS technology is currently expanding to sensoric applications, e.g. for the structured illumination of a surface and on-chip registration as well as the analysis of the resulting image for the determination of the surface topology. In particular in the field of sensors, there is often a requirement for emission and detection beyond the visible spectral range of light (VIS) in the direction of the near-infrared (NIR) region. This is necessary for higher penetration depths in human tissues in the photoplethysmography, in the photodynamic therapy or for invisible light barriers.

At the Fraunhofer FEP the first, polychromatic, bidirectional OLED microdisplay has been developed with a local emission in the NIR regime. An OLED microdisplay with 0.6'' screen diagonal and QVGA-display-resolution (320 × 240 pixel) and integrated camera (160 × 120 pixel) has been divided in four segments and has been deposited with blue, green, red and NIR emitting (730 – 850 nm) organic layers. The NIR segment remains invisible for the observer, while the NIR emission can only be detected with a camera without NIR filter.

Fraunhofer FEP is now ready for the integration of NIR and VIS OLEDs-on-CMOS technology in customized devices or applications. For the realization of NIR emission, an NIR capable emitter system has been integrated into the pin-OLED technology. Here, external power conversion efficiencies of EPCE = 2.5% could have been achieved. The pin-concept can be recognized by the low operating voltage (3.5 V at 10 mA/cm^2). The determined lifetime results from the first investigations are very high and hence, very promising. After 950 h, the initial luminance has decreased only by 10% (LT90 = 950 h at 100 mA/cm^2). For comparison, if an orange pin-OLED is driven at 100 mA/cm^2, it reaches an LT50 of 161 h. Therefore, with respect to the lifetime the NIR active OLED is able to compete with their (visibly) colored analogs.

UV active light emission

Near ultra-violet emission from an OLED is demonstrated for bottom- as well as from top-emitting device architectures for biomedical and biotechnical sensing in lab-on-chip applications.

Scientists from Fraunhofer FEP combined a green top-emitting OLED with a thin-film optical filter and thin-film encapsulation so that a sample substance can be brought in proximity to the excitation source. Both developed devices are suitable for large area deposition and integration on silicon-backplanes like wafers as light source for optical excitation to detect fluorescence or phosphorescence signals.

Illustration produced by Frank Hahnewald using Fraunhofer FEP OLED

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