CMOS based microdisplays, imager and sensors enhanced by OLED/OPD integration

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Outline

Introduction Fraunhofer FEP

OLED Microdisplays
- Motivation
- Key Technology: OLED-on-Silicon
- Applications

Bidirectional Microdisplay
- Introduction
- Technology
- Applications

Platform for Enhanced Image Sensors

Conclusion
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**Conclusion**
Who we are – Fraunhofer FEP: Facts and Figures

- Employees: 189
- Total budget: 24.3 M€
- Industry returns: 7.4 M€
- Public funding: 8.6 M€
- Investments: 1.5 M€

(April 2017)

Director

- Prof. Dr. Volker Kirchhoff

Locations in Dresden

Core Competencies

- ELECTRON BEAM TECHNOLOGY
- PLASMA-ACTIVATED HIGH-RATE DEPOSITION
- SPUTTERING TECHNOLOGY
- HIGH-RATE PECVD
- TECHNOLOGIES FOR ORGANIC ELECTRONICS
- IC AND SYSTEM DESIGN
**Our Focus:** Device Development, Prototyping and Manufacturing

Software development, e.g. eye-tracking

Electronics and system design

IC Design

OLED Design

OLED-on-Silicon post-processing

Technical Consulting

Test

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Motivation for OLED-Microdisplays: Data Glasses

Microdisplays
Introduction to OLED-Microdisplays

OLED Microdisplays
- High resolution, tiny screen size <1"
- Self-emissive display
- No add. illumination → simplified optics
- High contrast >10’000 : 1

Monolithic OLED Integration
- Highly efficient light source
- All colors, white, NIR, UV

Silicon Backplane
- Precise structures, high pixel density, typ. 1000 – 3000 dpi
- System-on-Chip, integration of electronics, driving and sensors

⇒ Ideal image source for AR/VR and electronic viewfinders
OLED-Microdisplays
Made in Germany

Fraunhofer FEP

- Design and manufacturing of OLED microdisplays
- Based on customer order, or within publicly funded or internal projects
- More than 10 years experience in various concepts and applications
- Sophisticated concept for high resolution microdisplays
- Unique position: Bidirectional microdisplays
- Novel concept for ultra-low-power displays
- Upcoming Evaluation Kit for HD+

device selection: 2007 - 2017

- 1st German OLED microdisplay
- QVGA analog concept
- VGA digital concept
- SVGA mixed concept
- 304x256 ultra-low-power
- WUXGA 1920x1200 mixed concept
Use-Case 1: Full Video Display

Key Applications
- AR, VR, electronic viewfinders

Typical target for OLED microdisplays
- Higher resolution (720p, HD, 4k…)
- Smaller pixels (chip size…)
- Higher framerates (60Hz…120Hz)
- More functions…

Latest Development
- LOMID Project
  - 1920x1200, 1”
  - High framerate for VR
  - Improved VR optics

Example how the form factor will be improved by using LIM’s optics.
Use-Case 2: Ultra-Low-Power-Displays

Key Applications
- AR in Industry 4.0, mobile navigation, logistics, sports...

Main Requirements
- Small, light, no heat, long battery life

New Concept
- Reduce content, resolution and refresh rate
- Static memory inside the pixels → No refresh
- Free addressable pixels → Smart image update
- Simple serial interface → Low pin-count

Result
- Dramatically reduced power consumption 😊
- Long battery run time 😊
- Low number of external components 😊
- Lightweight and small sized system 😊
Summary

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<tr>
<th><strong>Full Video Displays</strong></th>
<th><strong>Information Displays</strong></th>
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<tr>
<td>High resolution (720p, HD, 4k…)</td>
<td>Medium resolution (QVGA…VGA)</td>
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<td>High framerate (60Hz…120Hz)</td>
<td>Low framerate (0Hz…30Hz)</td>
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<td>Medium power</td>
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<td>Complex System</td>
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Choose the right display and system concept according to application
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Introduction: **Bidirectional OLED Microdisplays**

OLED microdisplay with embedded image sensor → **intelligent** microdisplay
Technology: **Bidirectional OLED Microdisplays**

- CMOS top metal defines OLED pixel structure
- Si-photodiode
- Light source
- Light detector

**OLED-on-Silicon: cross-section with unpatterned OLED on top**
Use Case 1: Interactive Data Glasses

→ Bidirectional OLED microdisplay
→ Added functionality: Eye-Tracking
Use Case 2: Bidirectional Microdisplays as Sensor

→ Example: Optical fingerprint sensor.

First prototype

▪ **OLED display:**
  ▪ Controlled illumination
  ▪ Outside sensor-mode normal display

▪ **Embedded image sensor:**
  ▪ Optical fingerprint sensor
  ▪ 1600 dpi resolution (FBI-standard is 500 dpi)
  ▪ Detection of 3rd level features of identification

Further applications

▪ Optical stimulation and detection of biomarkers, cells etc. in a compact form at high resolution
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Motivation for Enhanced Imagers

**SWIR - Short Wave Infrared**

- Inspection for semiconductors, food ...
- Security and surveillance vision
- Machine and automotive vision

**Hyperspectral Imaging**

- Precision Farming

**SWIR Spectroscopy**

→ w/o III-V / InGaAs ! ($)
Technology: **Organic Detector on Silicon**

**OPD-on-Silicon: Simplified cross-section.**

- CMOS top metall defines pixel structure
- monolithic integration of organic photodiodes on top of silicon wafers
- interconnection layers
- active CMOS devices
- cover glass
- adhesive
- thin film encapsulation
- transparent electrode
- organic photodiode
- CMOS top metal
Image Sensors with Enhanced Spectral Behavior

Development Target
- Extended sensitivity vs. Si-imagers
- Significant lower costs vs. hybrid III-V on Si-imagers
- Organic detector on Si-backplane (OPD-on-Si)
- Adjustable wavelength, spectral width, ...
- High fill factor, monolithic integration

Current Status
- Readout-ASIC designed and tested
- SVGA image sensor platform available

Platform allows to perform
- Material Evaluation on 200 mm wafers
- Customer specific material / stack development
- Initial tests without NRE costs for new silicon chip

Mid term target for future R&D
- Extension of wavelength and hyperspectral imaging
Conclusion

OLED-on-Silicon
- Well suited technology for microdisplays and sensors
- Typical application for OLED microdisplays:
  - Image source for AR/VR, electronic viewfinders
  - Optical sensors
- Wide range
  - from HD to bidirectional up to ultra-low-power
→ The right microdisplay for each application.
→ Evaluation Kits available!

Advanced Imagers
- 1st results of OPD-imager presented
- Readout ASIC available for customer specific OPD development
What We Offer

- Prototyping
  - Idea
    - Concept
    - Schematic
  - Development
    - Simulation
    - Layout
  - Manufacturing
    - Start up and Test
  - Packaging and Assembly

Volume production with external manufacturing partners

Small Series

providing all-over process flow
Thank you!

Contact
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Silicon Saxony Joint Booth
Hall B1-416

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