ADMONT

Fraunhofer close to industry: research results under ADMONT and further exploitation

ADMONT is an ECS (European Electronic Components and Systems) ecosystem for Europe in agreement with the EFRE strategy from Saxony with a strong influence on economic growth and employment in the Union. It can affect employment rate (locally and Europe wide), energy efficiency in end products – manufactured and sold in Europe – as well as energy and resource efficiency in the industrial production itself. ADMONT was planned and is an incubator centre for SME innovations in Europe for electronic systems and solutions based on semiconductor technologies. The overall goal of ADMONT has been to implement a distributed More-than-Moore pilot line for products and services based on a wide-ranging set of technologies or essential capability modules (ECM) not available within one manufacturing facility. A virtual facility – capable of providing diverse process flows as a 'one-stop-shop' – needs to be carefully specified, planned and implemented to allow development and industrialisation of innovation projects.

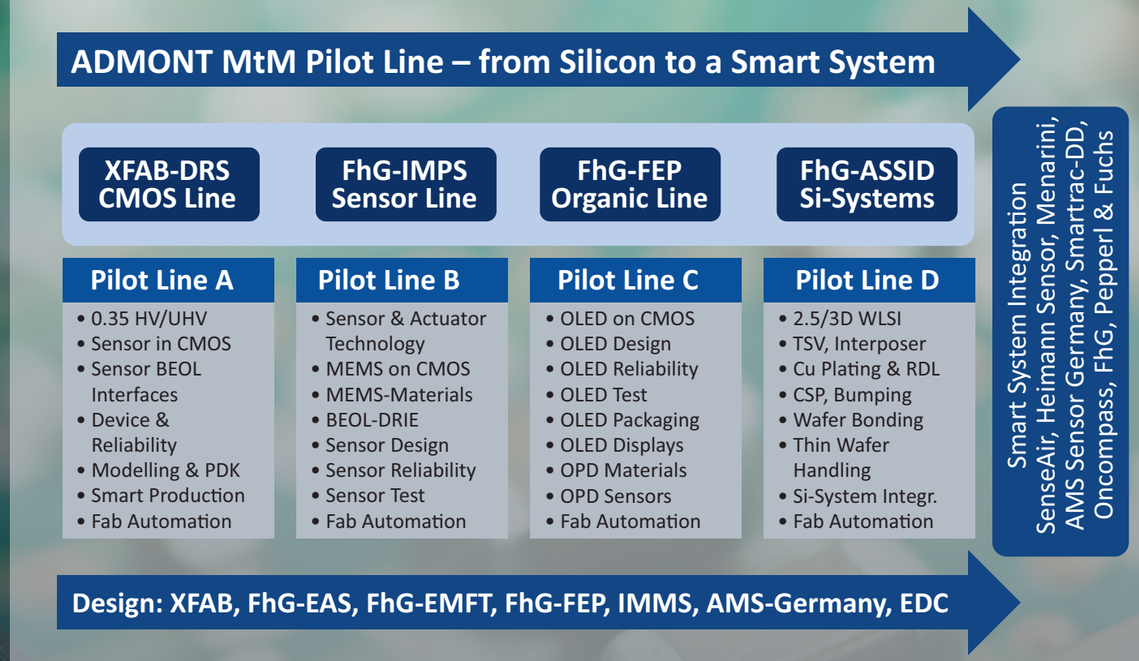

Fig. 1: ADMONT destributed pilot line members and internal user for system integration

The intended Advanced Distributed Pilot Line has been practically established and is 'up & running' as an open platform to customers following the 'one-stop-shop' approach. By allowing different business models in parallel, it provides the necessary flexibility to handle different customers and cooperation with subcontractors. ADMONT is a vivid cooperation framework enabling the involved Fraunhofer institutes to extend technology and services beyond their existing essential capabilities. This framework is also connected and aligned with the Research Fab Microelectronic Germany (FMD) – an association of the Fraunhofer-Gesellschaft and Leibniz institutes – allowing for a broader offer of customised technologies and services. As well as improving essential overall (technology) capabilities, ADMONT has driven significant improvement in standardised working procedures for the associated Fraunhofer institutes; specifically data and material exchange, e.g. wafer logistics, contamination management and common key performance indicators to continuously measure and improve the distributed pilot line's performance. By bringing together their existing capabilities with essential know-how of other pilot line members and fabs, advanced (smart) system integration features are emerging, e.g. MEMS-on-CMOS specifically relevant for the Fraunhofer Institute for Photonic Microsystems (IPMS) or Organic LED-on-CMOS at the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology (FEP).

Selected success stories:

CMUT (Capacitive Micromachined Ultrasonic Transducers):

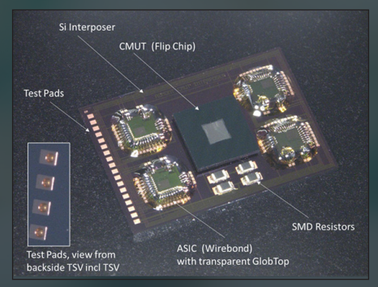

Fig. 2: Portable CMUT system design with ASIC and SMD resistor, system integration with TSV's and interposer

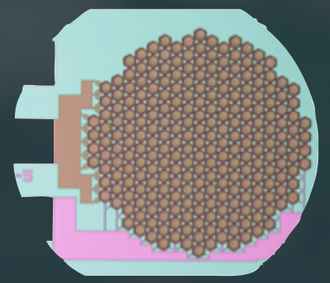

Fig. 3a: CMUT actuator layout

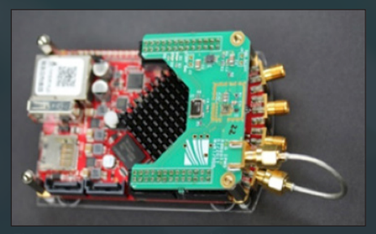

Fig. 3b: CMUT system for mobile ultrasonic monitoring

One of the major goals of ADMONT was the introduction of next-generation ultrasonic transducers CMUTs (Capacitive Micromachined Ultrasonic Transducers) (Fig 2.). The underlying MEMS-technology is compatible with CMOS-production processes and therefore offers several advantages compared to state-of-the art piezo-based systems, e.g. enhanced miniaturisation and system integration in conjunction with the capability of low-cost at high volume fabrication. The CMUTs have been developed using a silicon system platform within the ADMONT ECM (essential capability module). The system allows in combination with 2.5/3D integration and packaging completely new mobile ultrasonic solutions especially for medicine, robotic and material analysis.

Main results of the CMUT development are:

- Access to CMUT technologies including CMOS-compatible process flows for the BEoL (Back-End of Line) integration onto read-out circuitry over a wide frequency range (from 400kHz up to 40MHz) and for applications in fluid and gaseous environments with a technology-readiness level up to TRL 6.
- Simulation models for MEMS design and layout upon the CMUT technology platform
- A cascadable and configurable CMOS driver IC integrates electronic functional blocks to control the CMUT unit
- Integration and packaging solutions based on (i) Through-Silicon-Vias for hetero-integration of CMUT, ASIC and other passive components and (ii) an interface module for the pilot-line with X-Fab Dresden for the monolithic CMUT-on-CMOS integration.
- An infrastructure for fabrication and evaluation of MEMS-based sensor and actuator devices
- Demonstrators addressing key applications in industrial and medical fields such as range control and ultrasonic imaging.

To bring the CMUT platform to the market follow-up activities target both public-funded projects, e.g. the Saxony cluster project "Transfer Center – Functional integration in Micro- and Nanoelectronics" and industrial collaborations".

Thermopile

Thermoelectric IR sensor arrays generating thermal images (Fig. 5) consist of a matrix of thermoelectric sensor pixels and a monolithically integrated CMOS ROIC for voltage amplification, AD conversion and data transfer. IR sensor arrays are used for various applications such as big building surveillance, food industry and security in public area as well as in transportation. In medicine, IR sensor arrays are applied for the analysis of blood circulation and early breast cancer detection. Heimann Sensor, X-FAB and Fraunhofer IPMS have been developing and fabricating thermoelectric IR sensors arrays for more than ten years starting with arrays comprising 8 x 8 pixels and a pitch of 250 µm.

Based on the existing know-how, Heimann Sensor, X-FAB and Fraunhofer IPMS developed an IR array with 80 x 64 pixels and a pitch of 90 µm. Picture 4, shows an 80 x 64 IR sensor array mounted on a TO-socket.

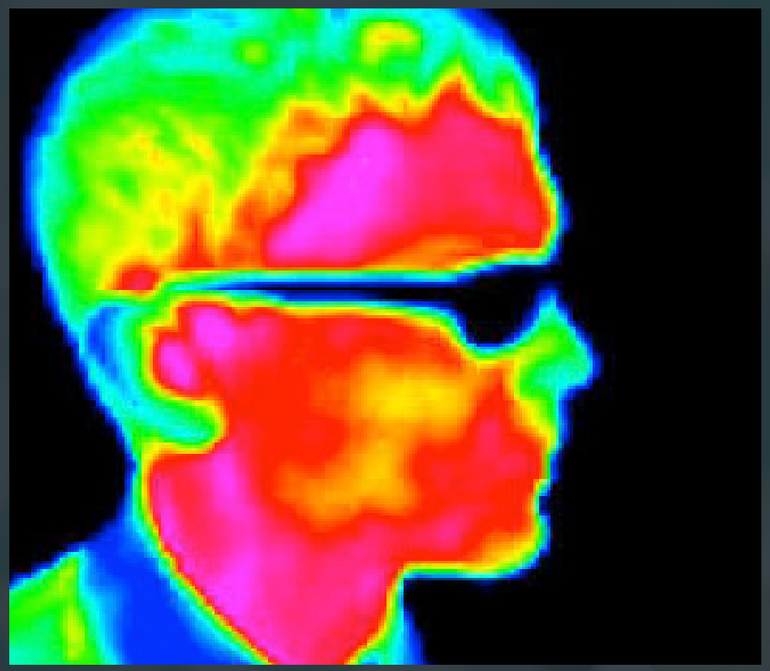

Fig. 5: Thermography of human face, obtained by a customer evaluation kit consisting of an 80 x 64 IR sensor.

The performance regarding NETD has been significantly improved due to technology development and design optimisation of the ROIC and the sensor pixel. The integration of a novel absorber structure has increased the NETD performance by a factor of 3 compared to existing solutions. Finally, an NETD of about 100 mK in vacuum was realised. Picture 5, shows an IR image of a man wearing glasses obtained by a customer evaluation kit equipped with an 80 x 64 IR thermopile array.

In parallel to the sensor development, Fraunhofer IPMS carried out material investigations to provide thermocouple materials that can be used for next-generation IR sensor arrays with improved performance. The most promising materials are in-situ doped microcrystalline and polycrystalline silicon films. Based on the results achieved in the ADMONT project, long-time partners Heimann Sensor, X-FAB and Fraunhofer IPMS started a Saxony funded project to develop next generation IR sensor arrays. By September 2021, the underlying technology is to be optimised by the integration of thermocouple materials having been investigated within the ADMONT project. In parallel, the MEMS part of the technology will be further developed towards reduced pixel sizes. The developed technology will be demonstrated by a new generation IR thermopile array (no IR sensor array) with 120 x 84 pixels and a pixel size of 60µm.

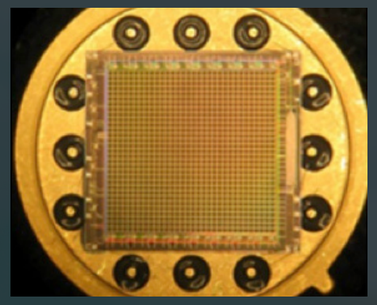

Fig. 4: Thermopile 80 x 64 IR sensor array mounted on a TO-socket.

Organic semiconductors on CMOS

Organic semiconductors on CMOS wafers are currently used for OLED-microdisplay fabrication. A multilayer of organic materials is deposited onto the CMOS wafer and electrically contacted by evaporation of a semi-transparent electrode on top of the organic device. Depending on the organic materials used within the OLED, the emission wavelength can be tuned from near UV to the visible and near-infrared spectral range. Examples of different emission spectra are shown in the chart (Fig. 4).

Within the ADMONT project, the Fraunhofer FEP developed a sensor chip using OLEDs as the excitation source and the optical sensing circuitry within the CMOS chip (Image 3). The sensor is used to measure the oxygen concentration in air.

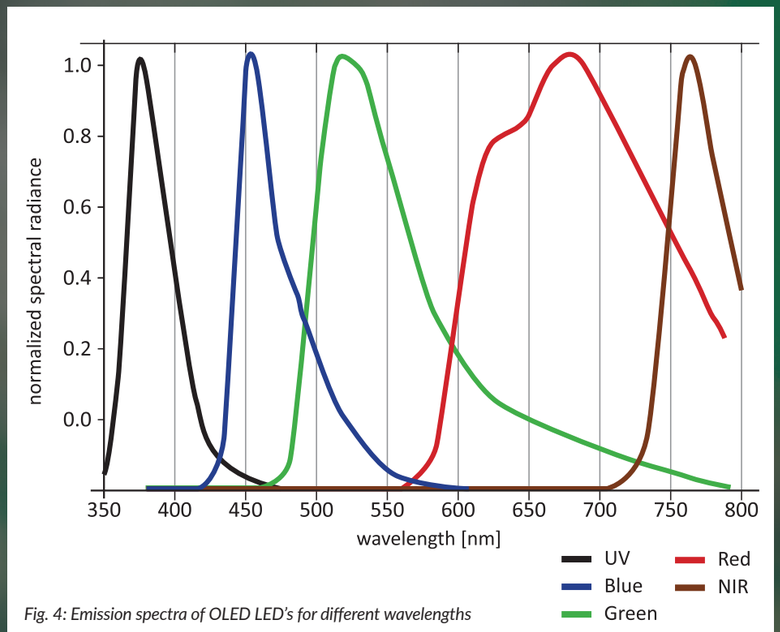

Fig. 4: Emission spectra of OLED LED's for different wavelengths

Using a blue OLED the sensor chip excites an oxygen sensitive emitter material which emits within the red spectral range. Depending on the oxygen content in the air, the sensor material changes its photoluminescence decay time. The photodiodes within the CMOS measure the time depending on luminescence, and a microcontroller calculates the phase difference between the excitation light and the sensor response signal. After calibration of the sensor, the sensor calculates the oxygen concentration depending on the measured phase difference. The following picture shows the oxygen sensing chip in a package, (Image 4).

The ADMONT project enables the combination of organic semiconductor with CMOS wafers, whereas the technology has high potential for other sensor devices. For example, organic photodiodes with spectral sensitivity > 800nm can be used to realise an OPD-imager with near-infrared sensitivity. Combining the stealth dicing through silicon via and colour filter technology, the ADMONT consortium can offer all processes needed to further miniaturise the organic on silicon technology towards small sensor devices.

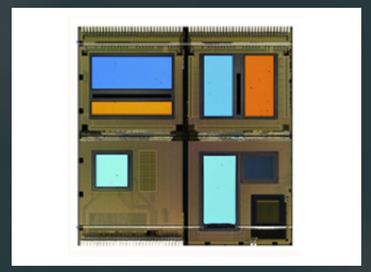

Image 3: OLED evaluation chip with different OLED material for light emission

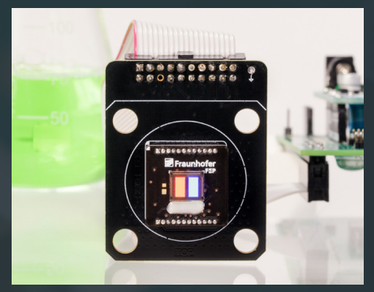

Image 4: Oxygen gase sensor based on OLED technology

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SUMMARY

The project results show that the heterogeneous integration of technologies and different fabs to final virtual production lines can boost technological development and fabrication. It was verified that joint developments could be realised which would be impossible in single fabs. Completely new ways are opened now. Combinations of leading edge-technologies in different research units and fabs are possible now. The benefit of these ways makes the industrial place Germany in the middle of Europe much more attractive for future developments and strengthen its position in a global competition.

PROJECT PARTNERS

Project Coordinator: X-FAB Dresden GmbH & Co. KG. **Partners:** Hellmann Sensor GmbH, Okmetic Oy. Systems Systementwicklung Dipl Inf.Manfred Austen GmbH, Fabmatics GmbH, Smartrac Technology GmbH, SenseAir aB, Menarini Silicon Biosystems S.p.A., AMS Sensors Germany GmbH, EDC Electronic Design Chemnitz GmbH, Technikon Planungs - und Forschungsges-ellschaft mbH, Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., IMMS Institut für Mikroelektronik-und Mechatronik Systeme GmbH, and OnCompass Medicine Hungary Koriatolt Felelossegu Tarsasag.

PROJECT LEAD

X-FAB is the leading analog/mixed-signal and MEMS foundry group manufacturing silicon wafers for automotive, industrial, consumer, medical and other applications. X-FAB offers worldwide marketing and sales support for foundry business with production facilities in Asia, America and Europe.

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