

**Technology platforms and building blocks –
a key element for shorter time-to-market of innovative micro sensors**

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Content

1 CiS at a glance

mission – experiences - motivation

2 The expectations of SMEs for smart sensor systems

crossing the „valley of death“

3 Open platform – a common denominator

signal system– building blocks – technology platform

4 MORES™ - technology platform

product driven platform – examples of products

5 Summary

MORES™ - Microoptical Remission Sensor



Germany

Sensor components for

- *integrated optical encoder sensor
- *integrated dew point sensor
- *radiation detector
- *reflective pulse oximeter
- *pressure sensor
- *roughness sensor
- *optical hybrid encoder sensor
- *optoelectronical pO₂-sensor
- *optoelectronical NH₃- sensor
- *particle sensor

Most important demands
of our customer
SMEs and larger enterprises

- High performance parameters
- Low volume/low cost
- Innovation in system components
- Fast market entrance

1 CiS at a glance



– **Founded in 1993**

– **Turnover 2013**

- Public sector and strategic programs
- Industrial contracts R&D and prototyping

12,8 Mio€

54 %

46 %

– **Employees 2013**

123

– **Quality system approved to ISO9001:2008**



Certificate of Registration

– **Clean room:**

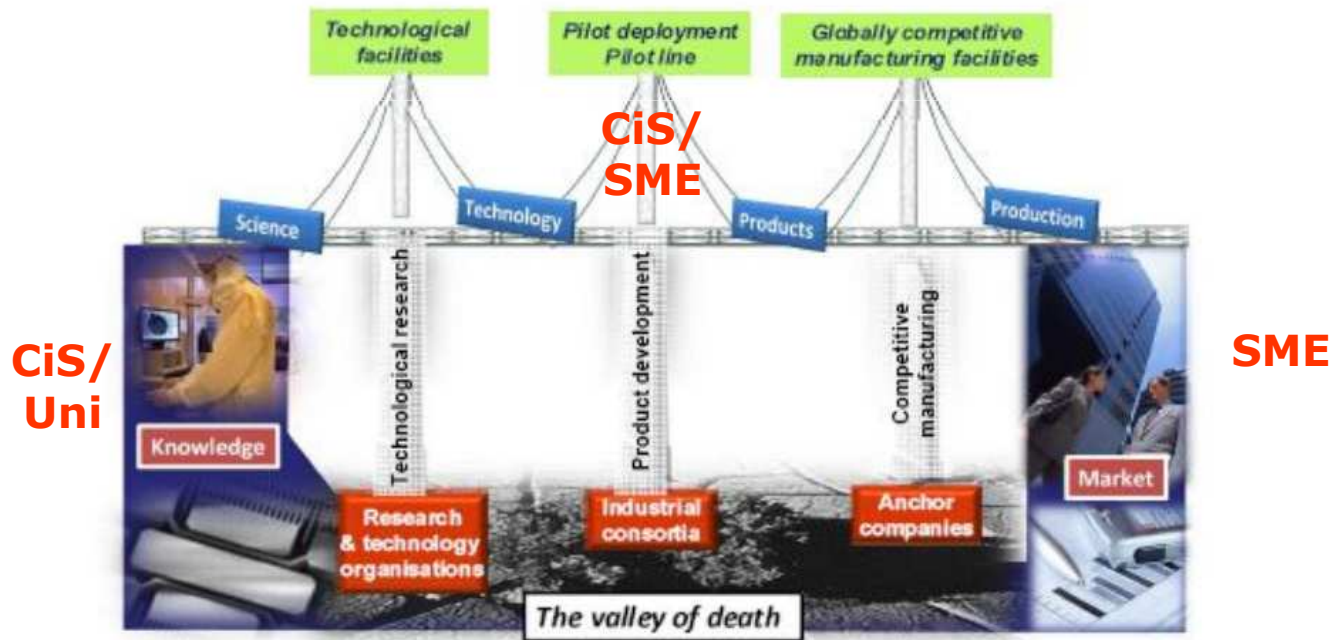
- *100 m² cleanroom-class 10*
- *500 m² cleanroom-class 100*
- *1000 m² cleanroom-class 10,000*
- *1000 m² climated laboratory*





Mission as a non-profit research institut
in the field of microsensor systems

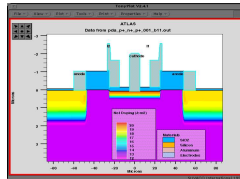
European "three pillars bridge" to pass the "Valley of death"



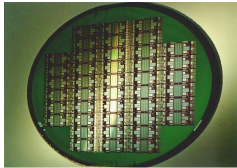
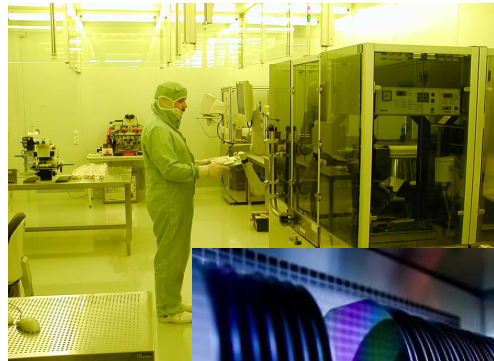
EU industrial policy strategy - The role of Key Enabling Technologies (KETs) and ICT, ICT Committee 25, September 2013
Gavino, Murgia, DG Enterprise & Industry- European Commission

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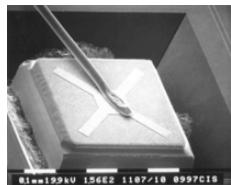
CiS at a glance



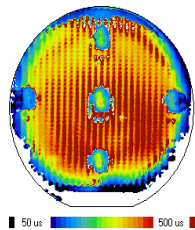
Simulation and Design



Wafer processing



Assembly



Measurement and analytic



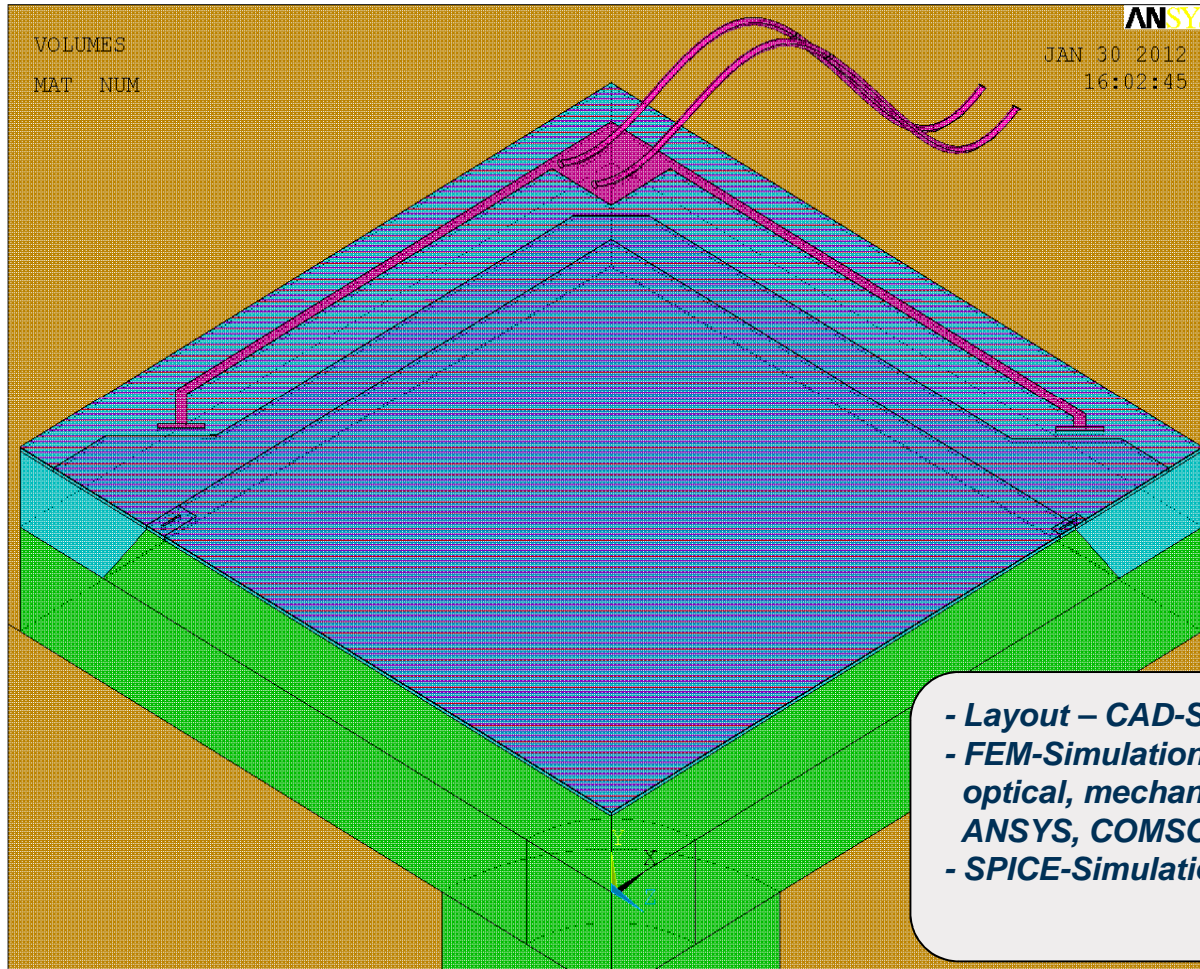
*Certified QM System
DIN EN ISO 9001*

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CiS at a glance



Simulation and Design



ANSYS Model
pressure sensor

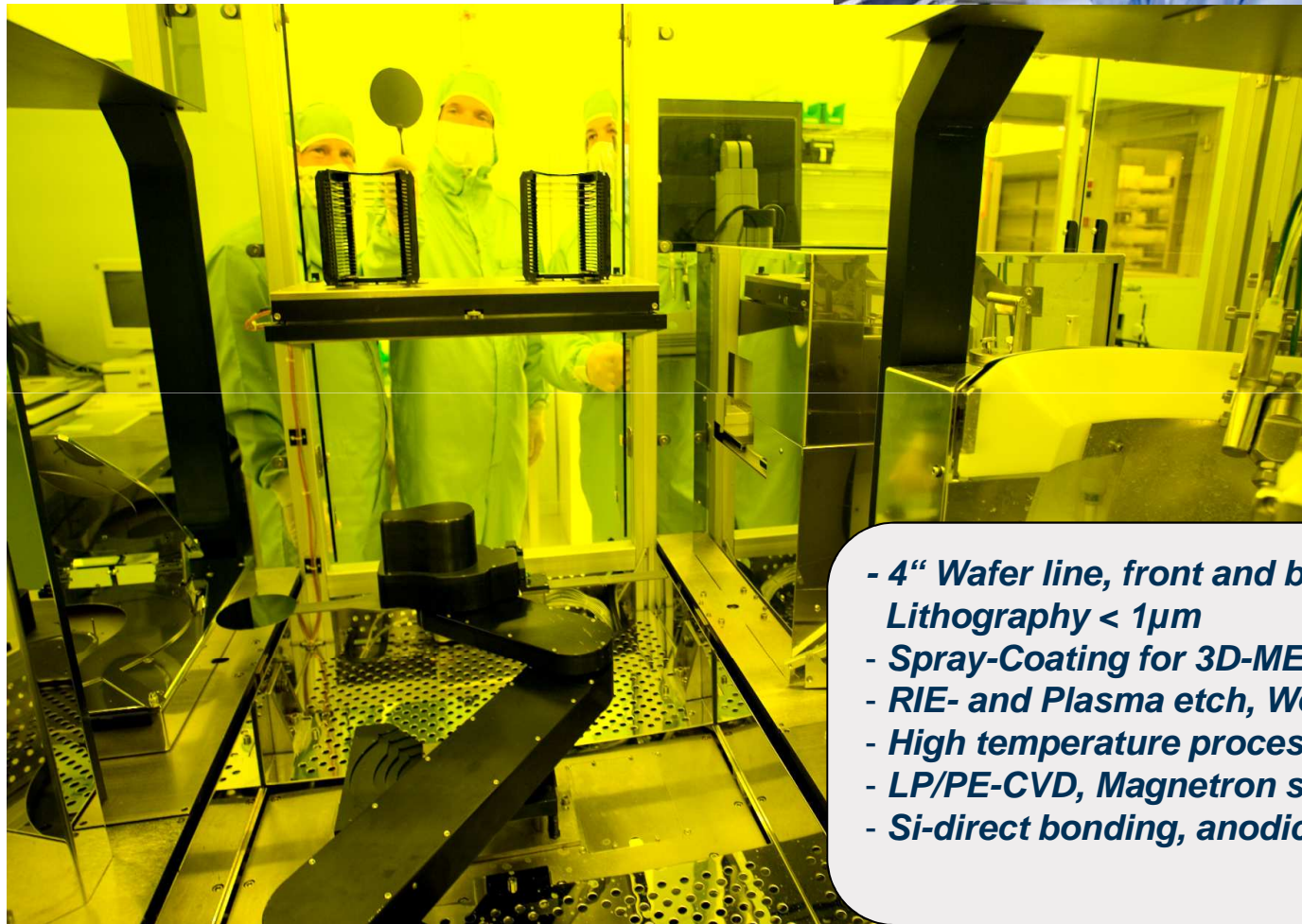
- *Layout – CAD-Software*
- *FEM-Simulation tools for electrical, optical, mechanical and thermal calculations e.g. ANSYS, COMSOL, ATLAS, ATHENA, TESCA*
- *SPICE-Simulations (HSPICE, CADENCE pSPICE)*

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CiS at a glance



Waferprocessing



Patterning by
UV-photolithographie

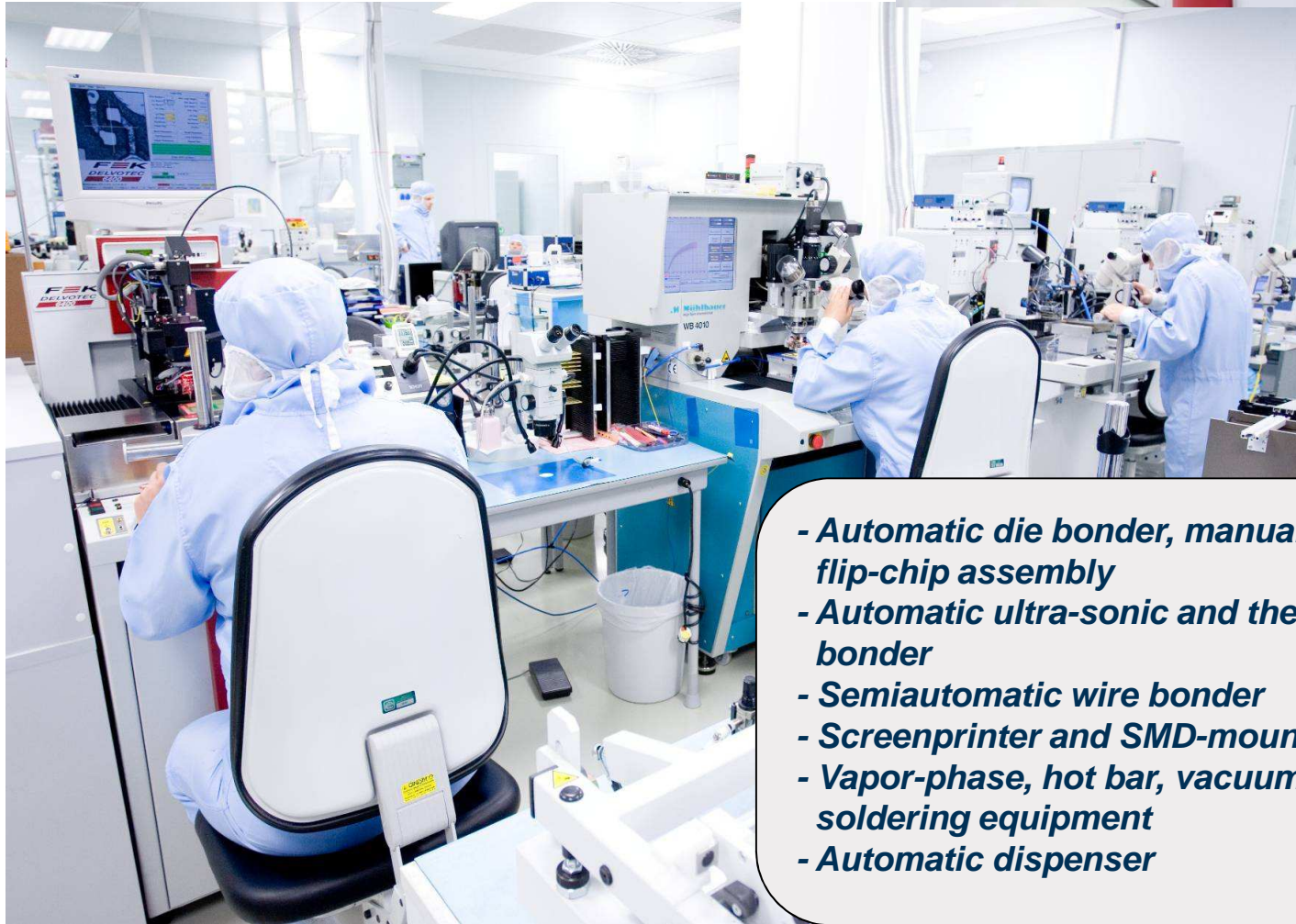
- 4" Wafer line, front and backside processing, Lithography < 1 μ m
- Spray-Coating for 3D-MEMS/MOEMS
- RIE- and Plasma etch, Wet-Bench
- High temperature processes
- LP/PE-CVD, Magnetron sputtering
- Si-direct bonding, anodic bonding

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CiS at a glance



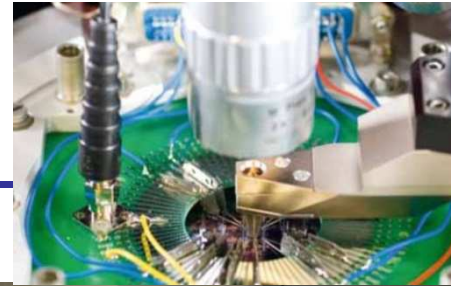
Assembly



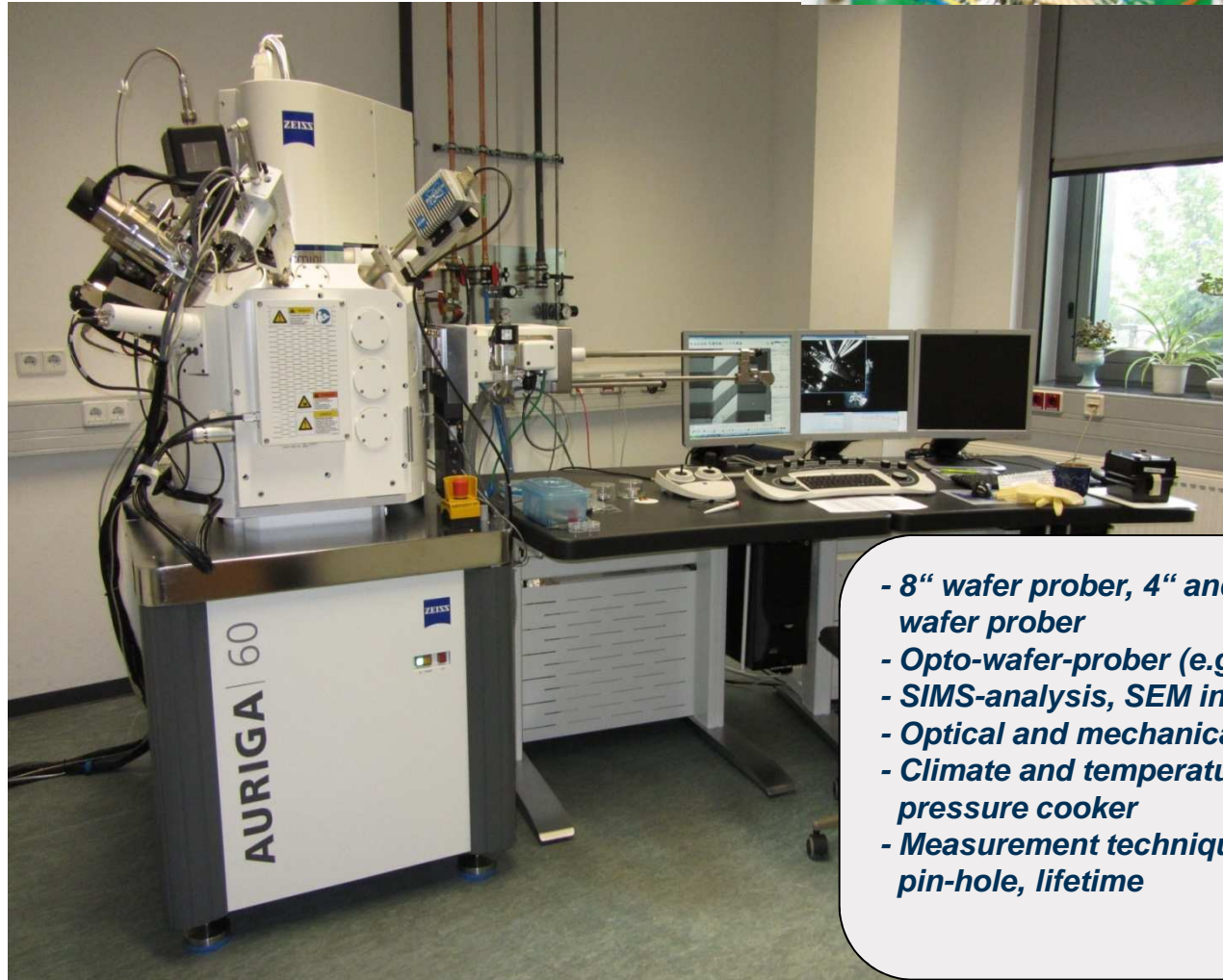
Assembly and test of sensors

- **Automatic die bonder, manual fine placer for flip-chip assembly**
- **Automatic ultra-sonic and thermosonic wire bonder**
- **Semiautomatic wire bonder**
- **Screenprinter and SMD-mounter**
- **Vapor-phase, hot bar, vacuum and laser soldering equipment**
- **Automatic dispenser**

1 CiS at a glance



Measurement and analytics



*Zeiss Auriga 60
Crossbeam®
Workstation*

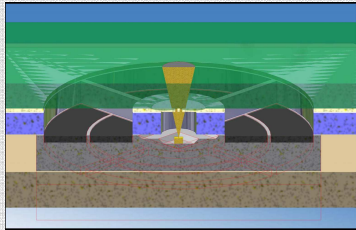
- 8" wafer prober, 4" and 6" front and backside wafer prober
- Opto-wafer-prober (e.g. OBIC)
- SIMS-analysis, SEM including EDX, AFM
- Optical and mechanical profilometer
- Climate and temperature shock test chambers, pressure cooker
- Measurement techniques e.g. CV, TVS, UBR, pin-hole, lifetime



Business Unit amos: MORES® Technology platform

Particle Sensors

- Measurement of particle concentration in fluidics
- Customer specific solutions
- Simulation and design



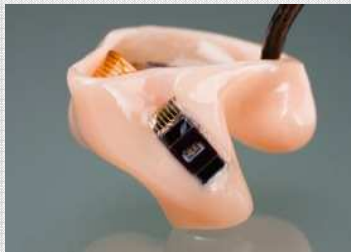
Levelling Sensors

- Levelling for balances
- +/- 10° accuracy for levelling
- Customer specific solution



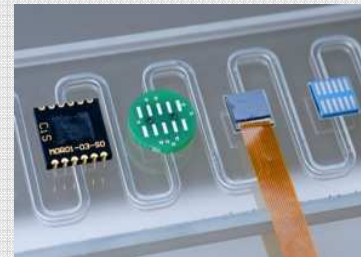
Life Science Sensors

- Monitoring of cardiovascular parameters
- Customer specific solutions
- Simulation and design



Fluorescence Sensors

- Biological and chemical sensors
- Measurement in micro fluidic systems
- Customer specific solution

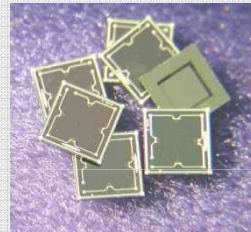
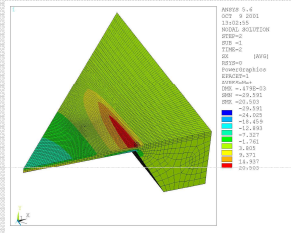




Business Unit MEMS: piezoresistive & impedimetric platform

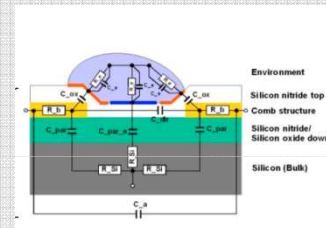
Piezoresistive Sensors

- High stability pressure sensors
- Customer specific solutions
- Simulation and design



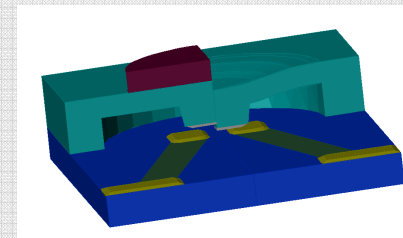
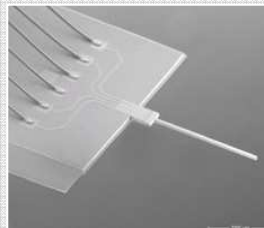
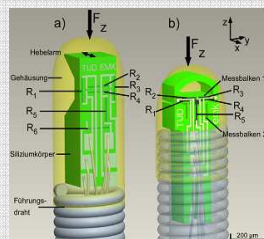
Impedimetric Sensors

- Micro condensation / Dew point sensors
- sensitive layer based sensors
- in-line micro fluidic sensors



Micro mechanical Components / Modules

- Cantilever, probe tips, force sensors
- Bi-stable zero power sensors

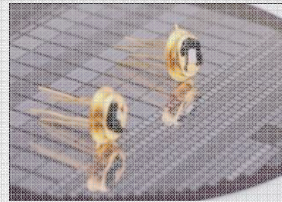
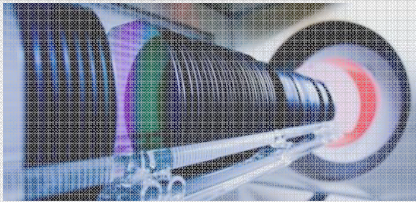




Business Unit: Silicon Detectors

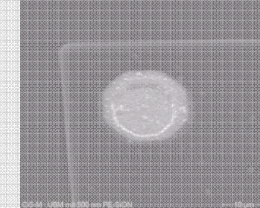
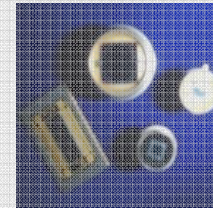
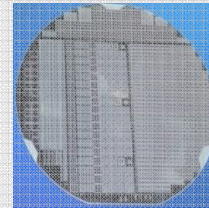
Silicon-Photodiodes

- planar photodiodes and photodiode arrays: custom specific geometry / layout and housing
- Silicon-Photomultiplier
- Avalanche Photodiodes, Geiger-Mode-APD
- On-chip Filter



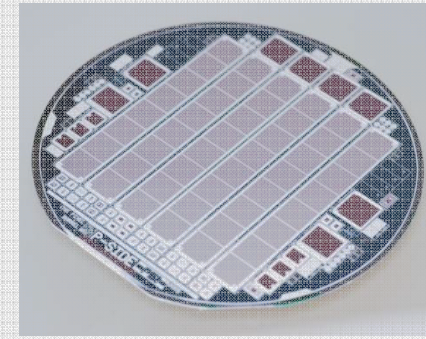
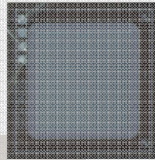
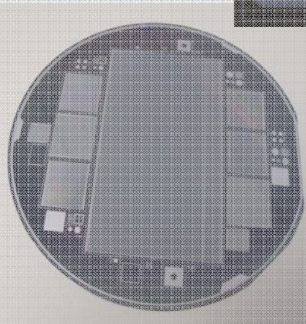
Additional Services

- Multi-Project-Wafer Services
- Device and defect analysis
- Under-Bump-Metallization, coating & plating, Through-Silicon Vias



Radiation and Particle Detection

- large area Micro-strip detector chips
- Pixel detector chips
- Thin detectors
- detection of high energy and cosmic radiation
- detection of low light flux and scintillator pulses
- detection of alpha, beta and gamma radiation
- X-ray detection
- instrumentation for high-energy and space astrophysics,
- nuclear medicine, nuclear safety, security, environment, material science



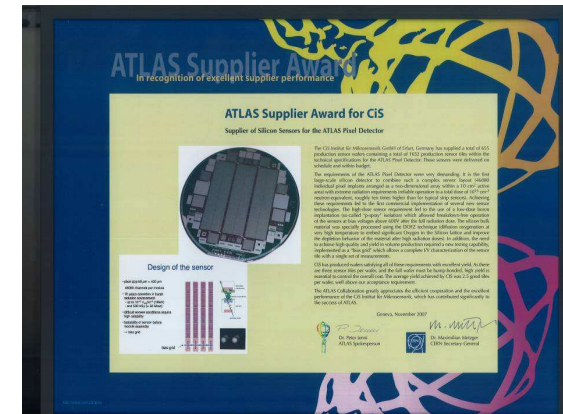
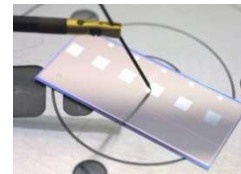
1 CiS at a glance



Research and development of technologies and radiation detectors for High-energy physic experiments

CiS Research Institut produce high-end radiation silicon detectors for installation in experiments at the CERN Large Hadron Collider, esp. ATLAS and MS experiments.

ATLAS PIXEL IBL



CiS has been awarded with the "Industrial Supplier Award" as a series supplier of highly sensitive radiation detectors for the particle accelerator at CERN



Summ up from the fact of

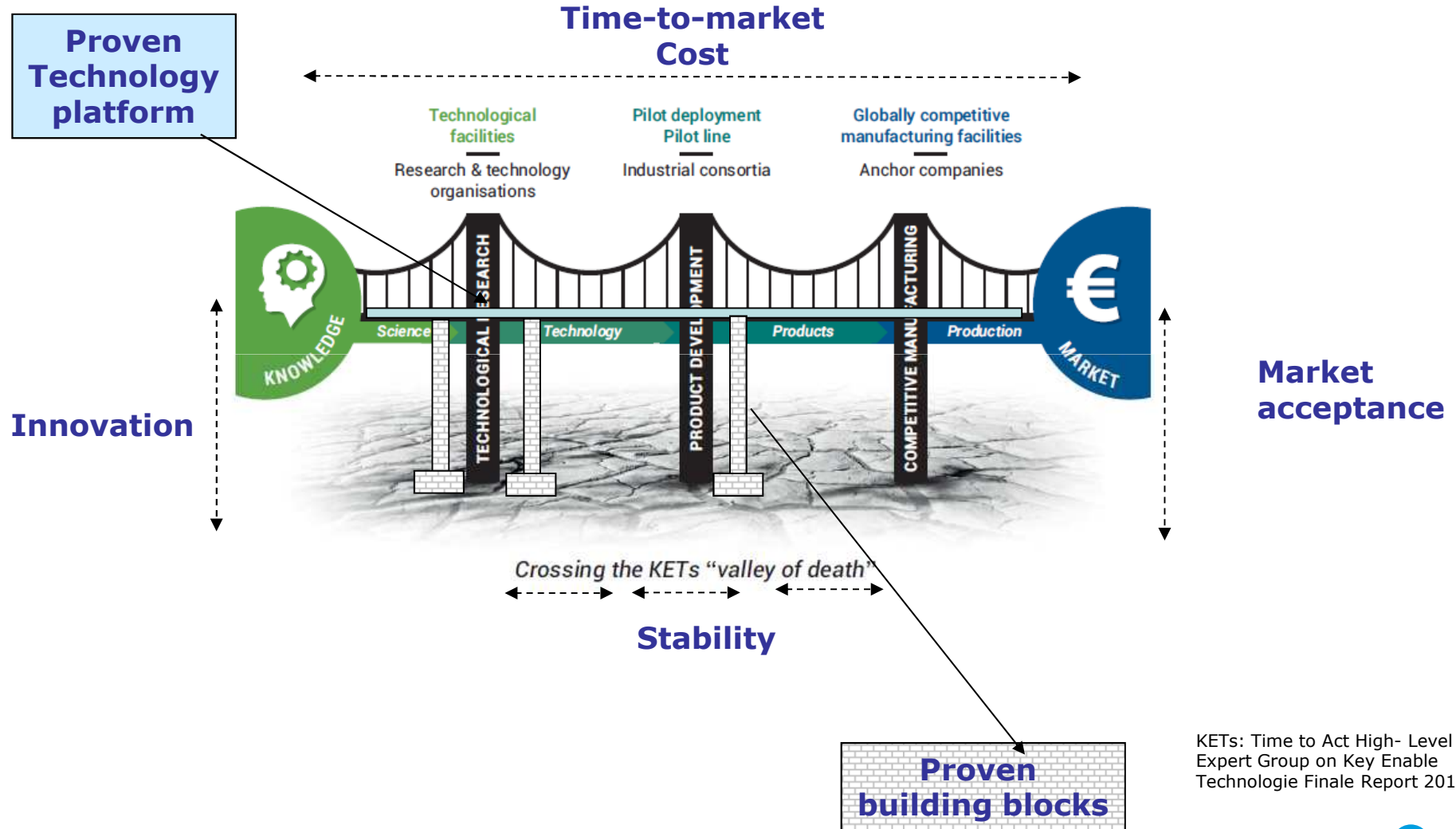
- Wide field of different sensor transducers
- Realization on the same waferprocessing line
- Expensive microelectronic processing

To find

- A multiplier
- A common denominator

1

CiS at a glance





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mission – experiences - motivation
- 2 The expectations of SMEs for smart sensor systems**
crossing the „valley of death“
- 3 Open platform – a common denominator
signal system– building blocks – technology platform
- 4 MORES™ - technology platform
product driven platform – examples of products
- 5 Summary

MORES™ - Microoptical Remission Sensor

2

The expectations of SMEs for smart sensor systems



What are our SMEs looking for?

At the start of cooperation

High performance

Low cost

Fast market entrance

Low volume

Demands for future cooperation

Further miniaturization

Increasing numbers vs. red. costs

Confidence in technology (non-exotic)

High reproducibility/accuracy

Platform

Value Chain

Interested in components only!!

Assurance of own product know-how

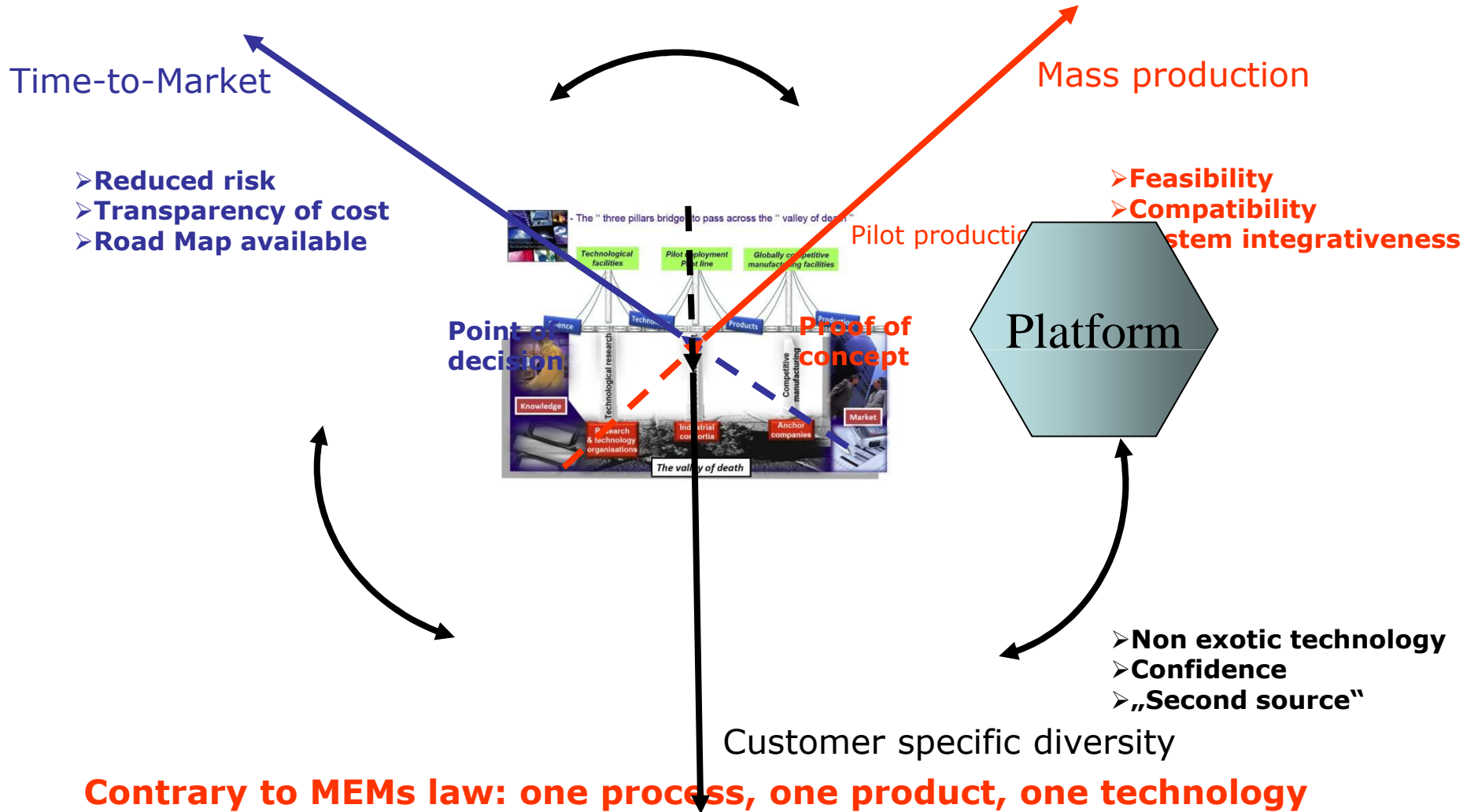
A.Steinke, A.Albrecht, O.Brodersen,
Th.Ortlepp; MORES™ - an example of a
product driven technology platform;
EPoSS AnnualForum 2013, Cork

2

The expectations of SMEs for smart sensor systems

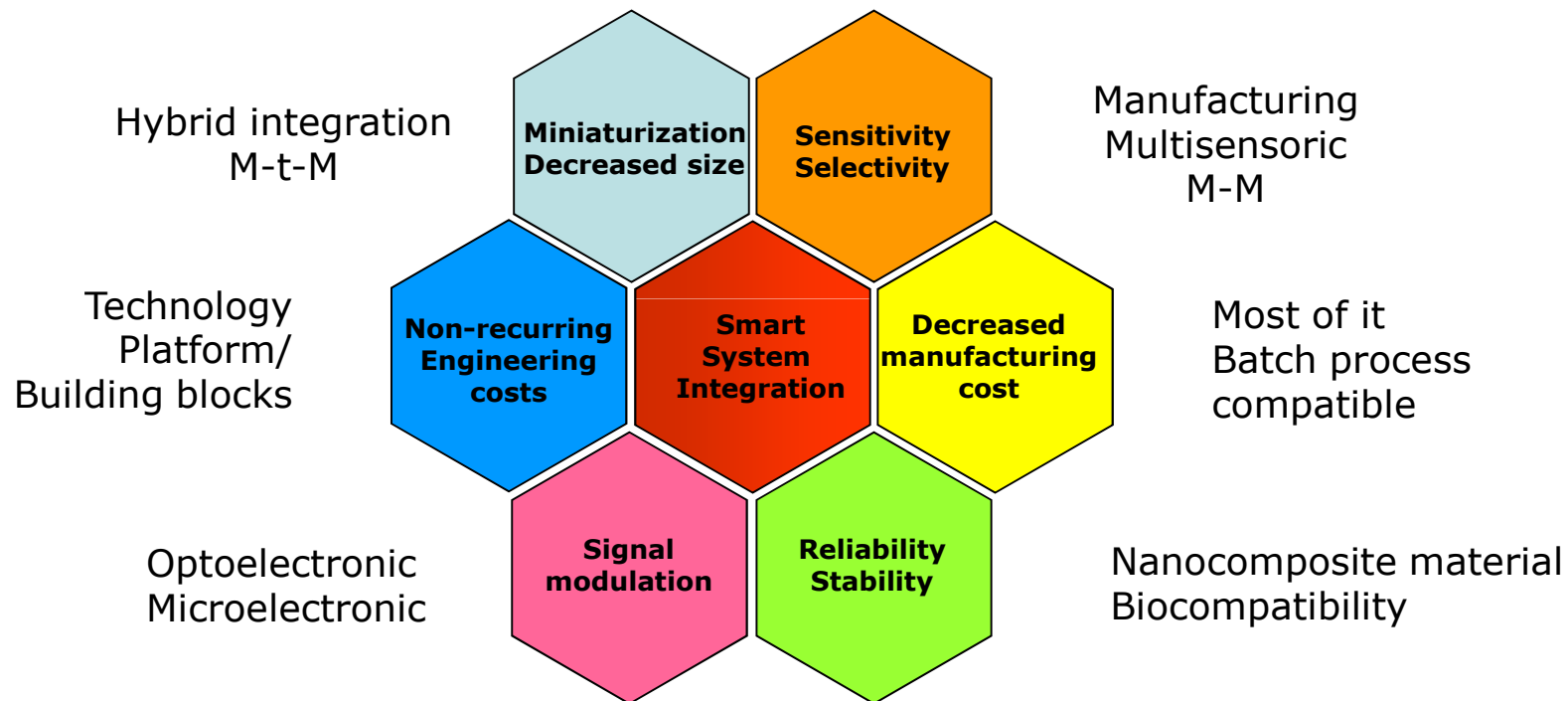


What are our SMEs looking for?





To bring all these **needs/innovation** under one roof



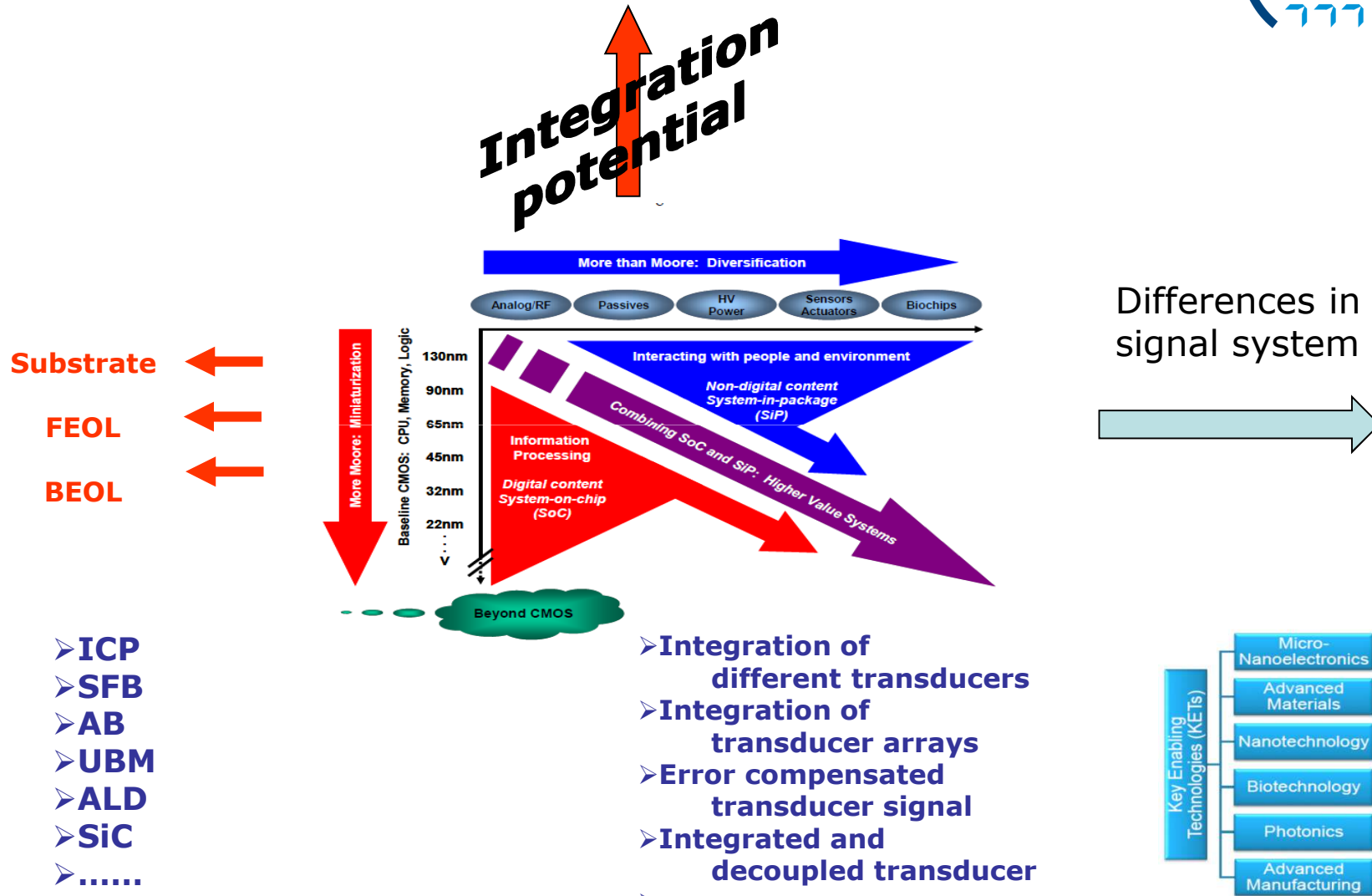
Integration of knowledge from different disciplines necessary



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MORES™ - Microoptical Remission Sensor



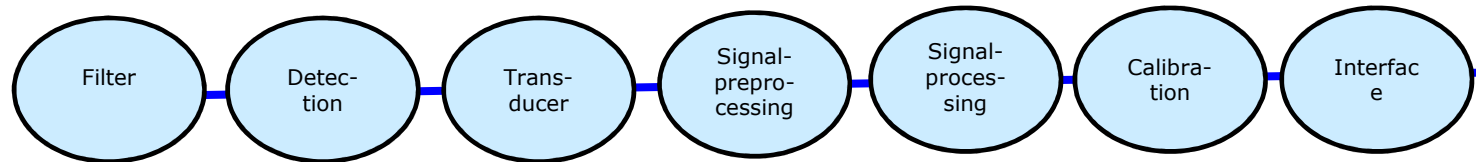
- ICP
- SFB
- AB
- UBM
- ALD
- SiC
-

- Integration of different transducers
- Integration of transducer arrays
- Error compensated transducer signal
- Integrated and decoupled transducer
-

Source: "SiP- ,White Paper"



Sensor signal components of micro sensor system



Pressure sensor	oil	membran	piezoresistive bridge	amplifier
Humidity Sensor	porous metal	Polymide	Interdigital electrode	C/f converter

+

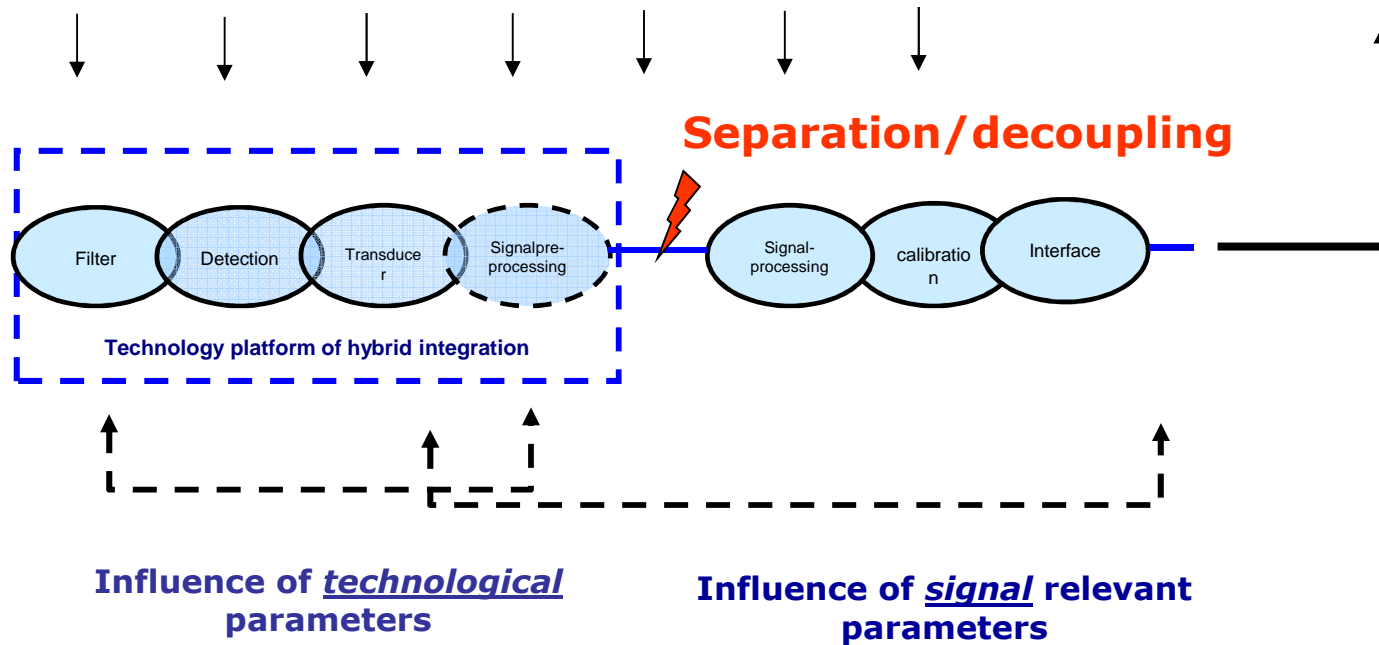
Linearization
+
Error compensation
+
Adjustment
+
Interface



High temperature
High humidity
Contaminated air
Polluted condensate
High pressure
Corrosive liquids
UV irradiation

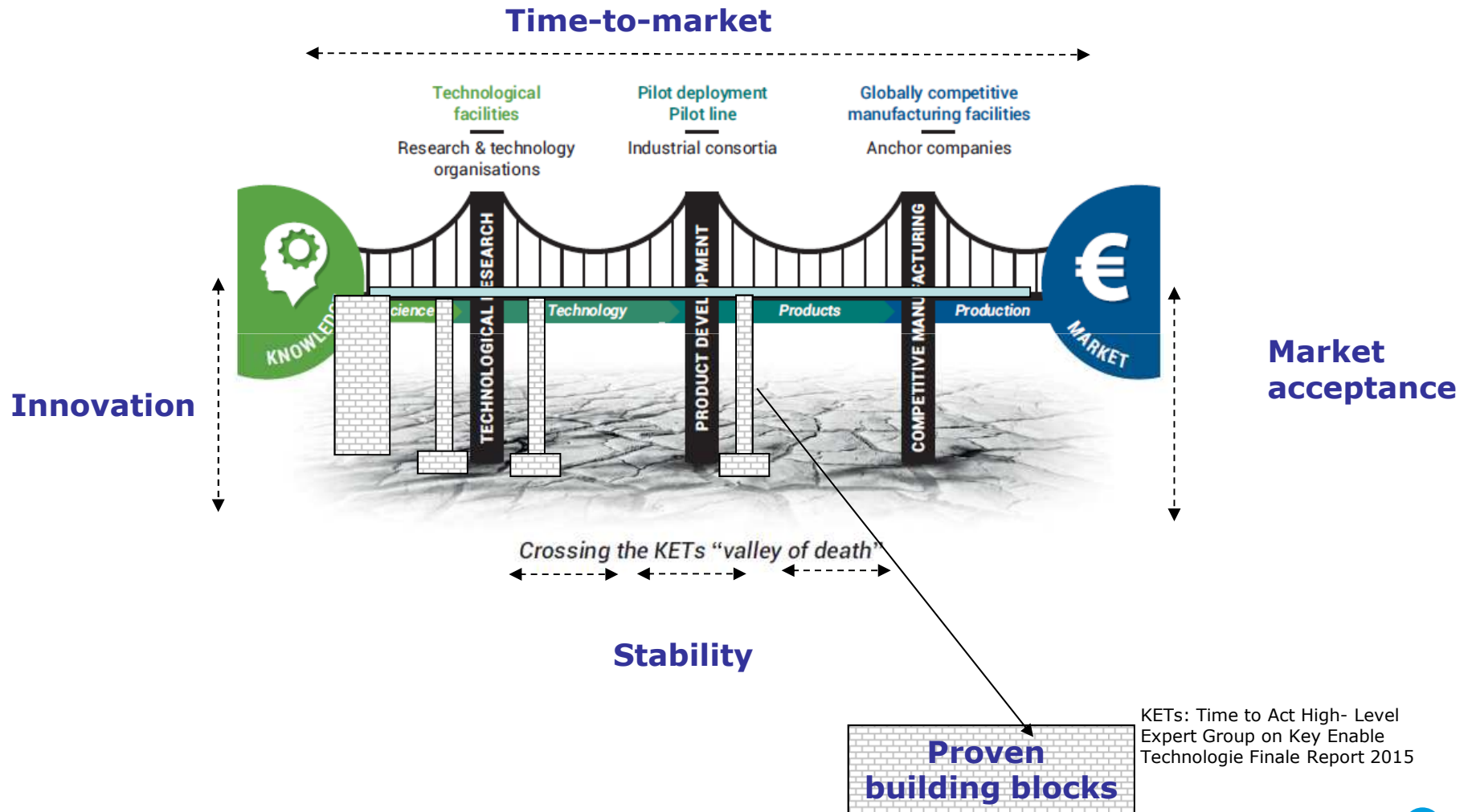
.....

Higher selectivity
Higher sensitivity
Higher long term accuracy
Higher reliability



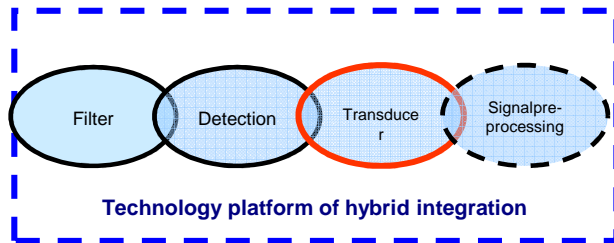
3

Open platform – building blocks



3

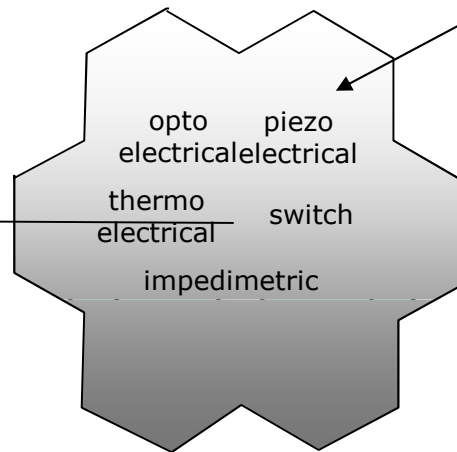
Open platform – building blocks



High performance

- high temperature
- high humidity
- polluted condensate
- contaminated air
- high pressure
- UV irradiation

Multimodality



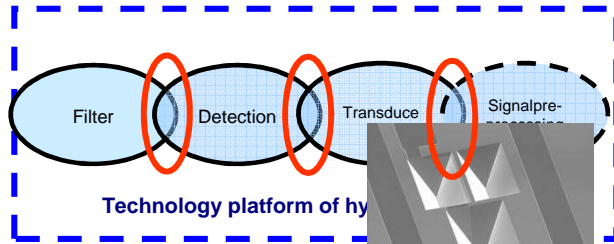
- integration of different transducers
- integration of transducer arrays
- error compensated transducer signal
- integrated and decoupled transducer

Example:

- Optoelectrical: Si- photo multiplier
- Impedimetric: 3D IDE/array
- Piezoresistive: SOI- substrate

3

Open platform – building blocks



Selection of building blocks

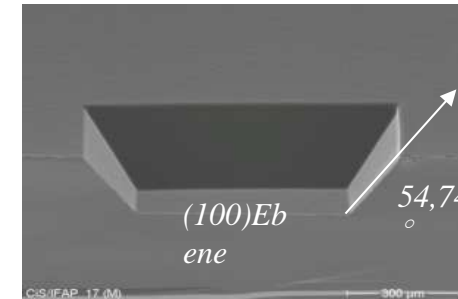
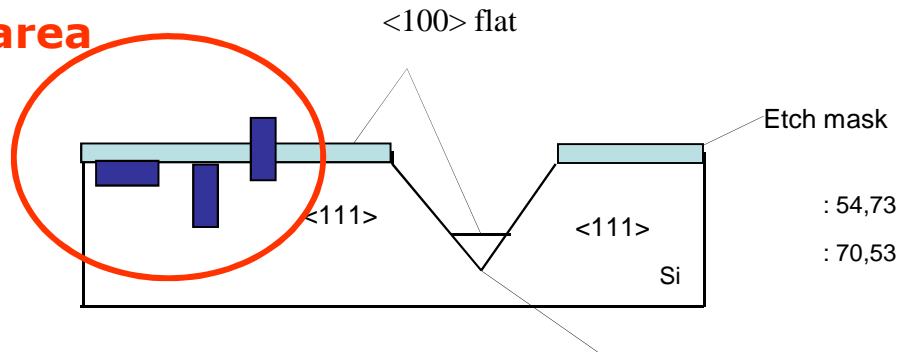
 Chip-Wire	 MESA	 Chip-in-Chip	 TSV	 SprayCoating
 3D metal etch	 Deep access	 Lift off	 TSV	 3D-Si etch
 Chip-in-chip	 Lowered bond pads	 SFB	 Deep access	 3D-IDE
 force	 Cantilever	 3D-UBM	 TSV	 Membrane

3 Open platform – building blocks



Building block: 3D wet etching

Active area



Technology:

Etch mask: LP Si₃N₄
 anisotropic etching of silicon
 standard grooves
 several etchants available
 (e.g. TMAH, KOH)
 mask aligning in several directions
 using <100> wafer

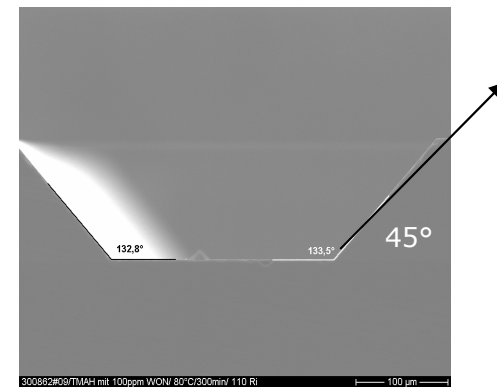
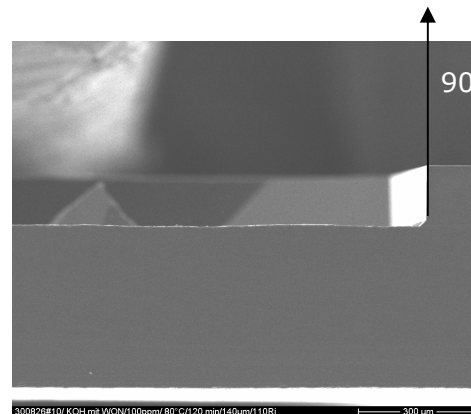
Advantage:

Zero defect in active area
 several angles between wafer surface
 and etched slope 54,73°, 45°, 90°
 possible

Application:

interposer
 micro tip

Etch stop

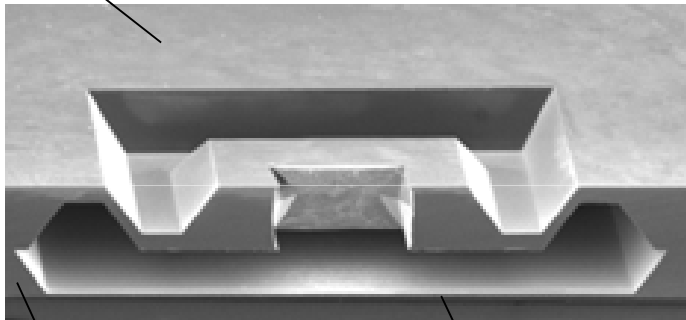


3 Open platform – building blocks



Building block: Silicon Fusion Bonding

Thermo-mechanical
Decoupling (back plate)



Sensor chip

membrane

SFB bonded pressure sensor

Silicon – Silicon Bonding

- Temperatures 120 - 400°C
 - back-end process possible
- High fracture toughness
 - high strength packages even for sensitive materials
- No mismatch in Young's modulus
 - no influence of static pressure
- No mismatch in TCE
 - low thermal hysteresis
 - low signal drift
 - low temperature coefficient

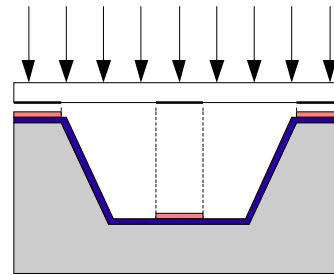
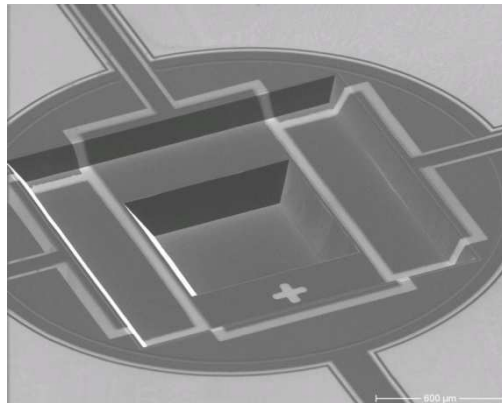
Source: E.Hiller, R.Täschner; Activation methods for low temperature silicon fusion bonding, Mikrosystemtechnik Kongress 2011, 10.-12.10.2011, Darmstadt

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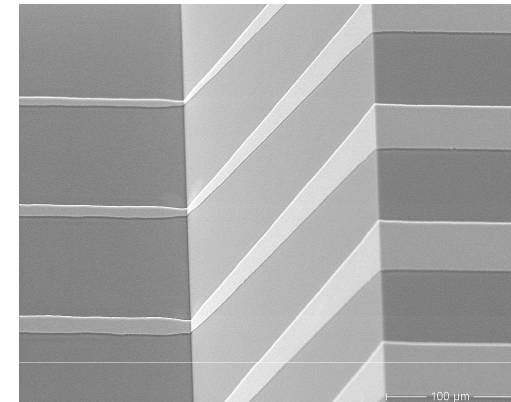
Open platform – building blocks



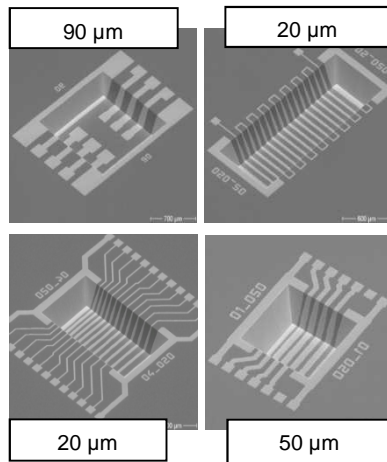
Building block: 3D lithography and etching



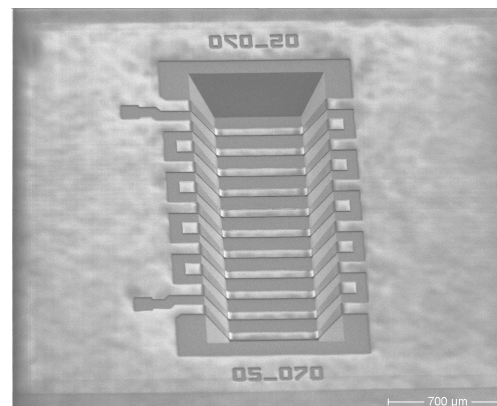
ca. 10 μm @ 250 μm deth



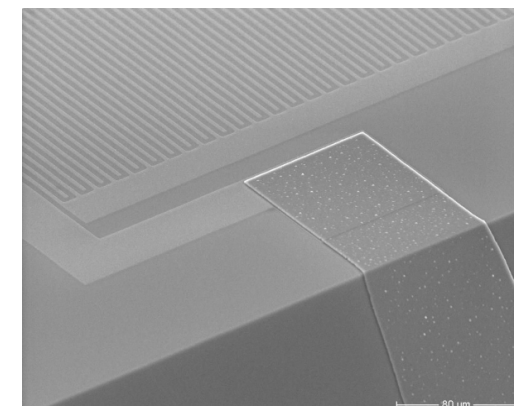
Patterning



Positive-tone photoresist



Negative-tone photoresist

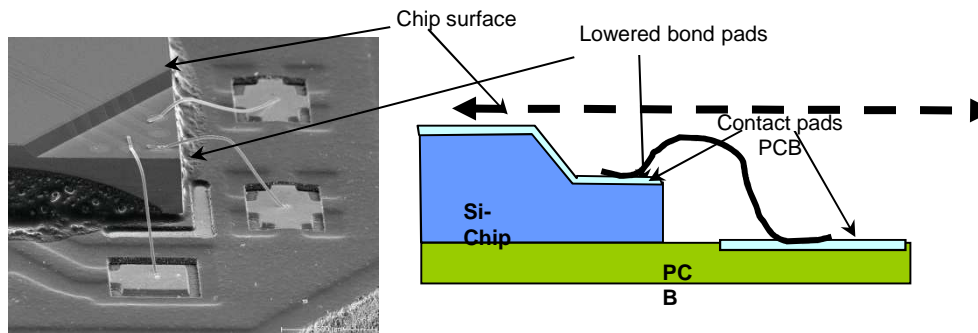


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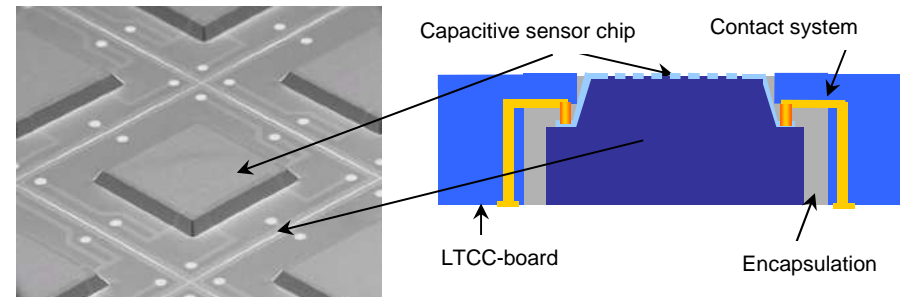
Open platform – building blocks



Building block: Lowered bond pads (or active elements)



In combination with module „MESA“



Advantage:

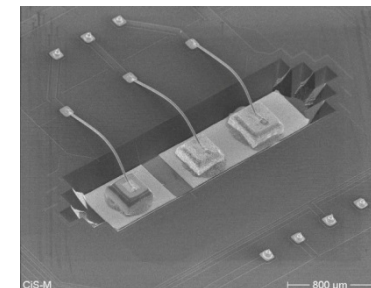
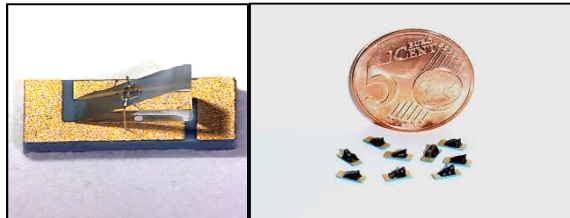
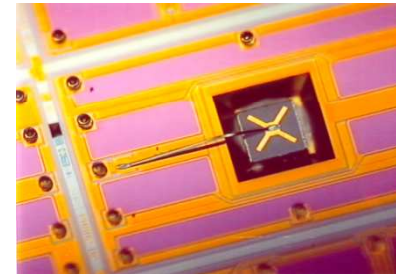
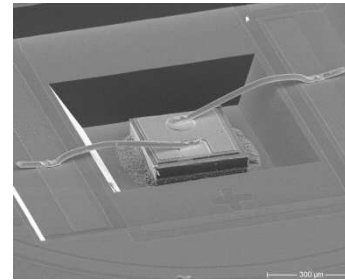
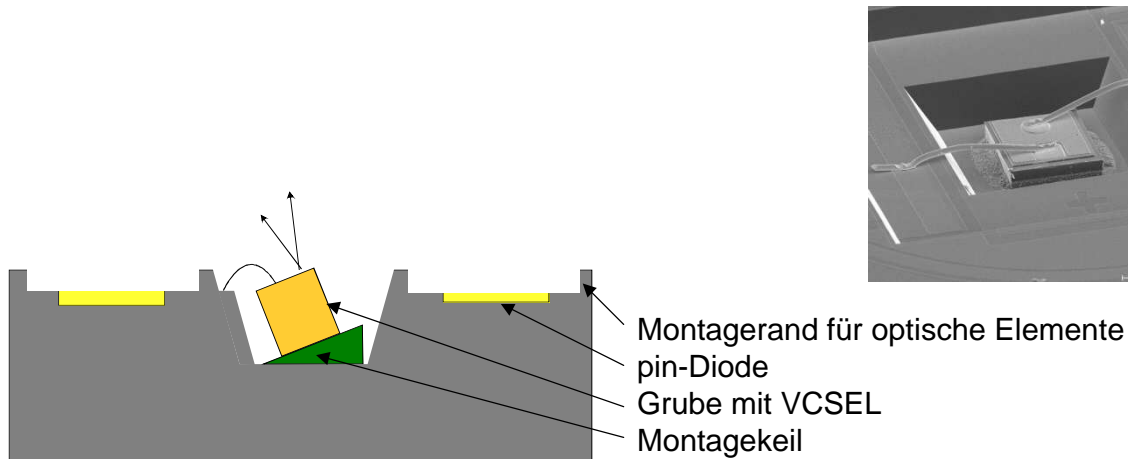
- Higher functionality of sensor surface (without disturbances)
- Surface without any bond pads
- Planarity of chip and assembly substrate
- Protection of contacts and wires

3

Open platform – building blocks



Building block: Chip(s) – in - (active) chip(s)

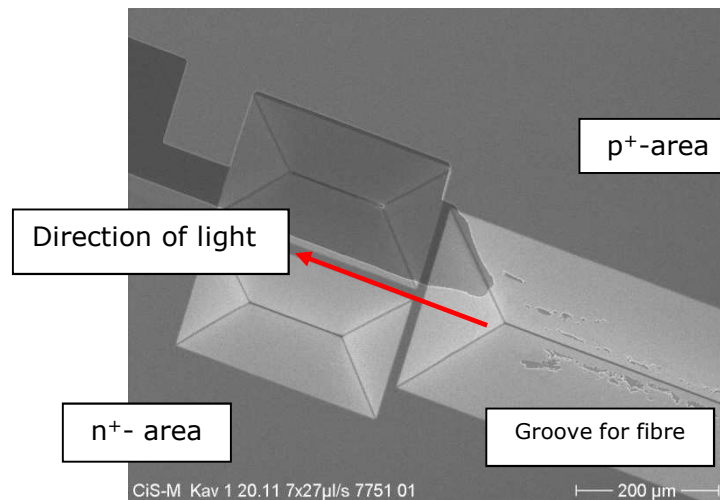


Advantage:

- flip chip and stacking compatible (planar surface)
- high positioning accuracy of chips into the cavity ($< 20 \mu\text{m}$)
- high reproducibility and signal stability
- high functionality by modular combination of several elements of the kit such as filters, membranes, lenses, apertures, LEDs, lasers, fibres



Building block: Chip-to-wire connection



Advantage:

Self positioning

Application specific design

Array of grooves, transducer

Close to transducer, short distance

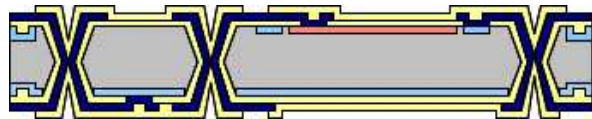
(optoelectronic, impedimetric, piezoresistive)



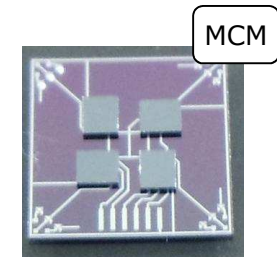
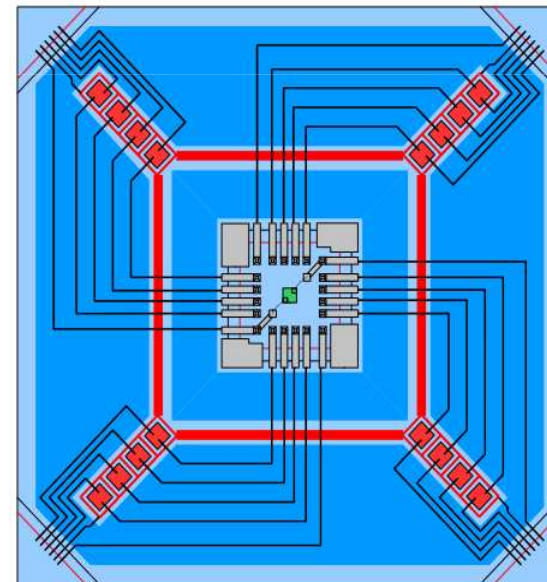
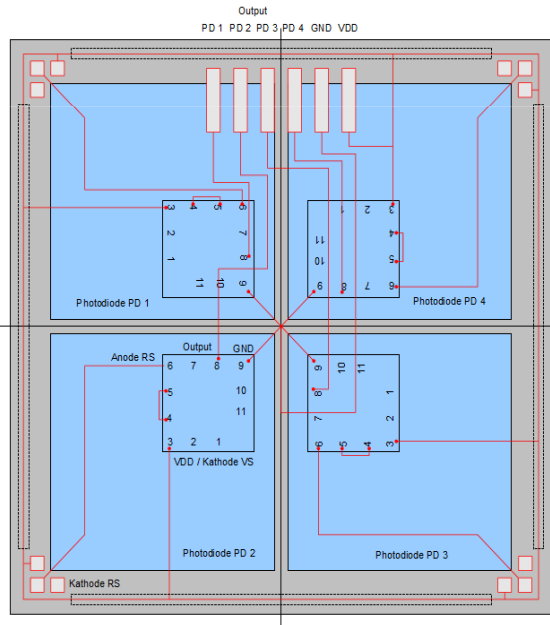
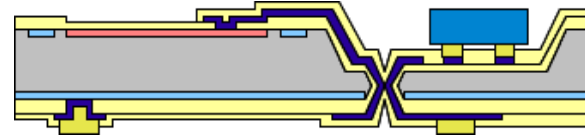
Building block: Through Silicon Vias

Example: Optical Sensor Systems with TSV

Photodiode Arrays



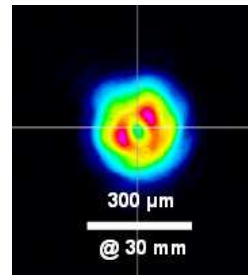
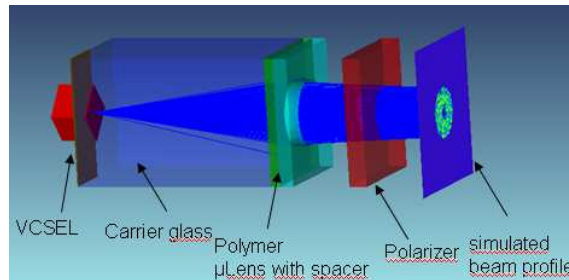
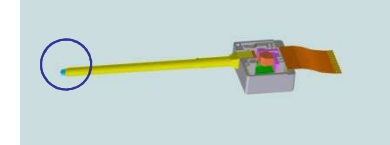
Radiator Receiver Devices



3 Open platform – building blocks



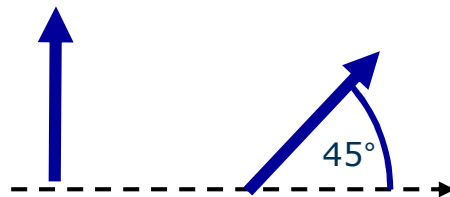
Building block: illumination component



measurement @ 30 mm distance

technical features

- beam diameter below 300 μm @ 0 to 30 mm
- polarization ratio 1:10⁵
- size: 0.6 x 0.7 x 1.4 mm³



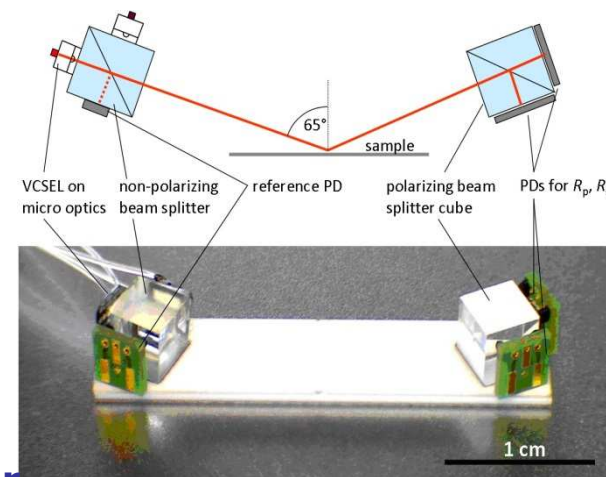
Manufacturing

Innovative technologies

- Polymer On Glass (POG)
- Bonding with reactive multilayers (RML)
- metal to optics adjustment

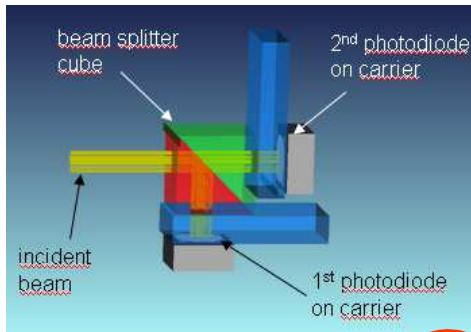
Steinke, Het al, 3D Miniaturization of optical polarimetric principle used for subcutaneous glucose monitoring, EPoS Annual Forum 2014

Miniaturized optical film thickness monitor

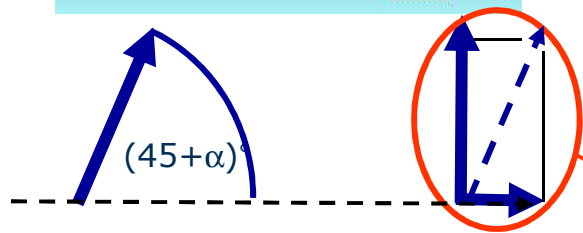




Building block: Receiver component



μ-Beam divider with high-performance photodiodes

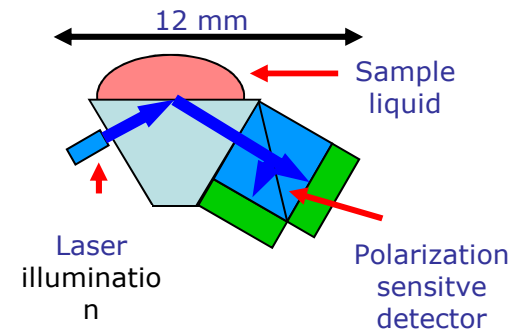


$$c = const. \cdot \text{ArcTan} \left(\sqrt{\frac{I_1}{I_2}} \right)$$

Manufacturing

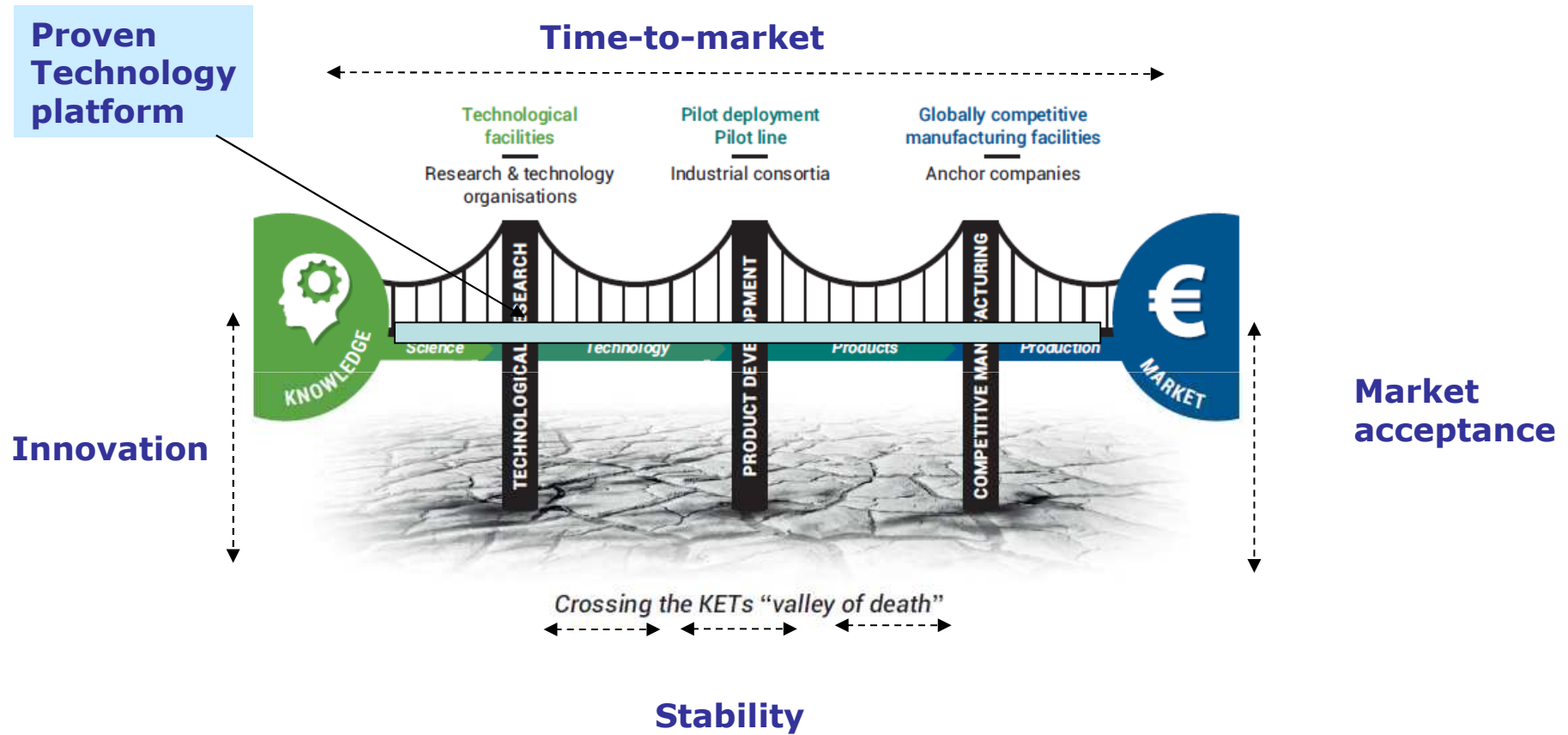
Innovative technologies for batch processing polarizing beam splitters & batch assembly

Miniaturized refractometer
Measurement of concentration in pure medium e.g.



3

Open platform – technology platform



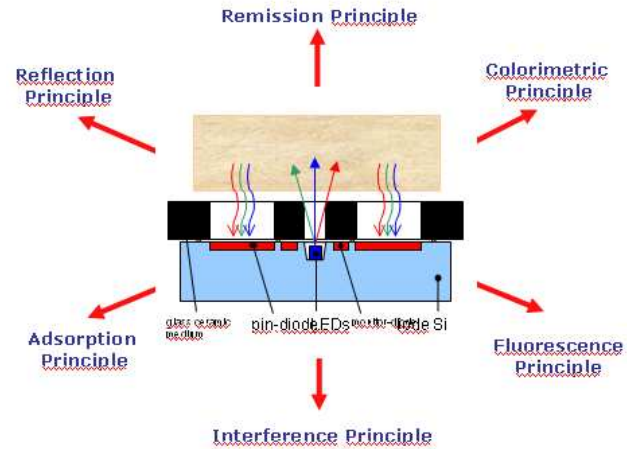
KETs: Time to Act High- Level Expert Group on Key Enable Technologie Finale Report 2015

3

Open platform – technology platform

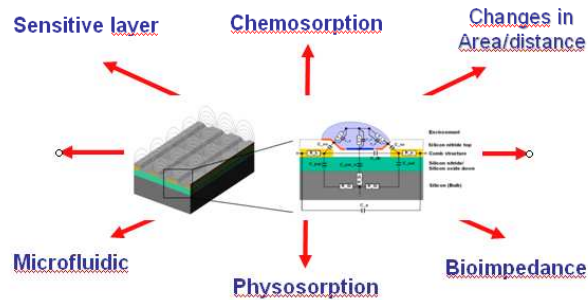


MORES™
microoptical
re^umission sensor



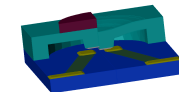
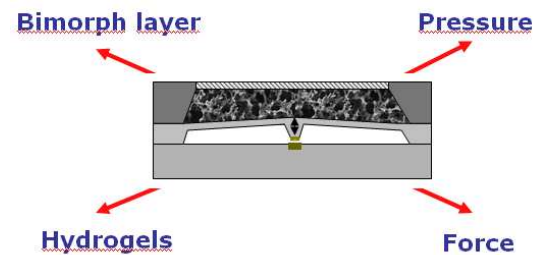
Example:
Bubble level sensor

CCC™
condensate controlled
capacitance



Example:
Dew point sensor

BiZEPS™
bistable zero power
sensor



Example:
Hygostat



Content

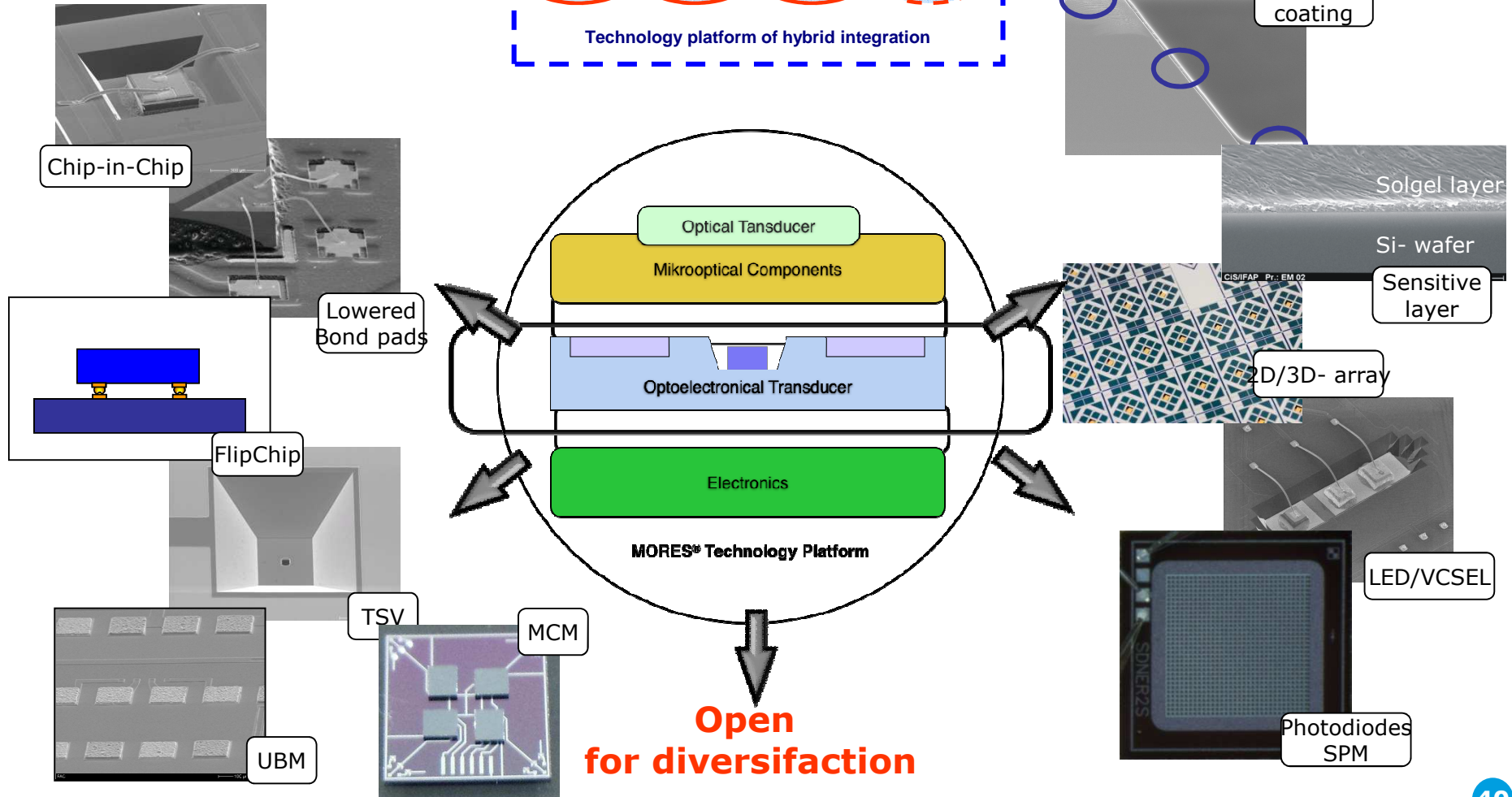
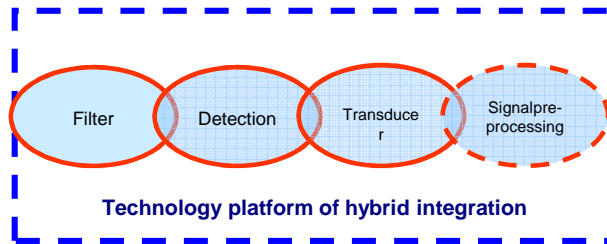
- 1 CiS at a glance
mission – experiences - motivation
- 2 The expectations of SMEs for smart sensor systems
crossing the „valley of death“
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product driven platform – examples of products
- 5 Summary

MORES™ - Microoptical Remission Sensor



Open for interfaces

Open for components

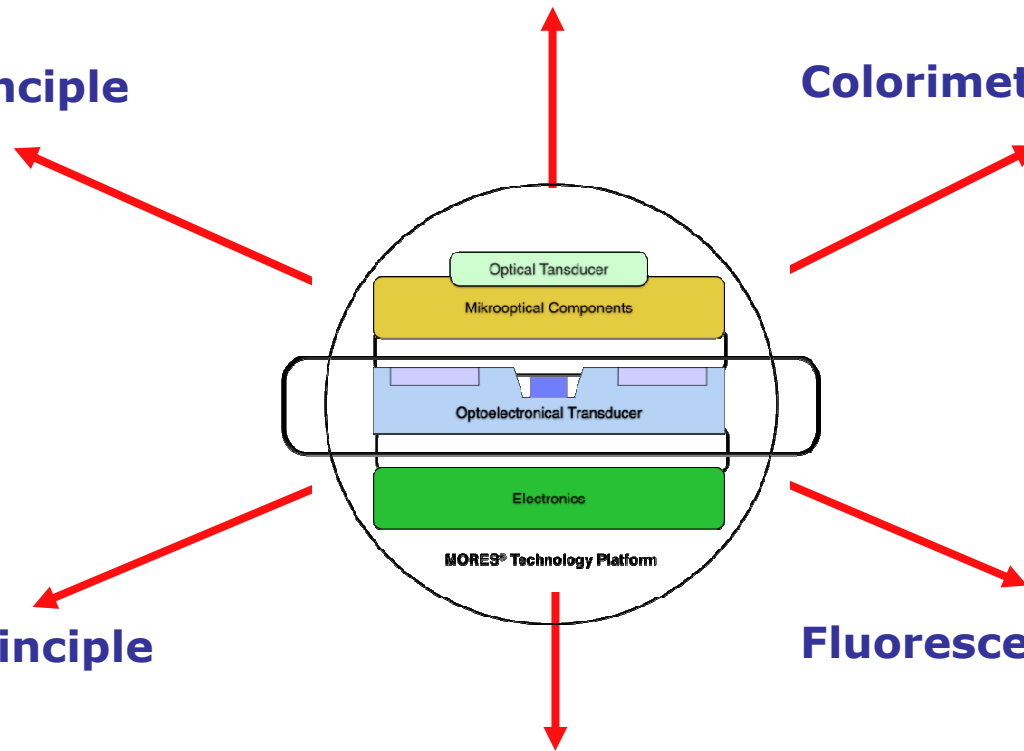




Remission Principle

Reflection Principle

Colorimetric Principle



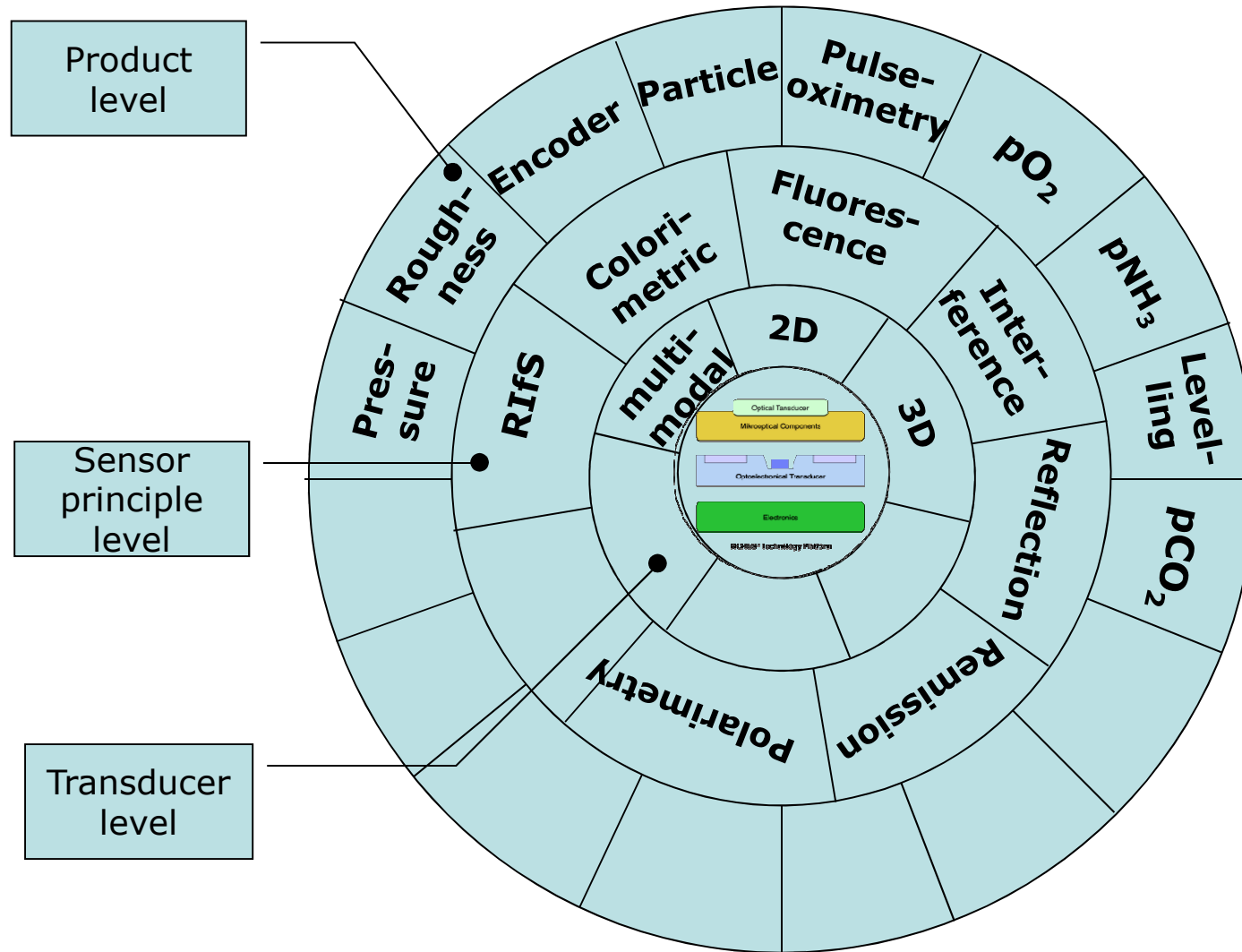
Adsorption Principle

Fluorescence Principle

Interference Principle

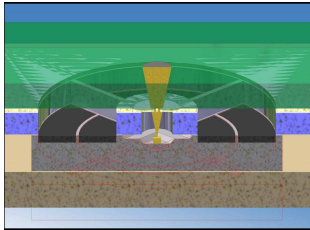
4

MORES™ - technology platform





Examples

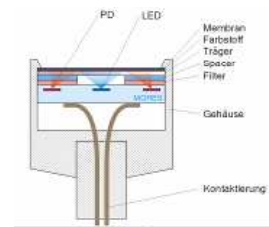


Levelling sensors

- Levelling for balances
- +/- 10° accuracy for levelling

Particle sensors

- Measurement of particle concentration in fluidics

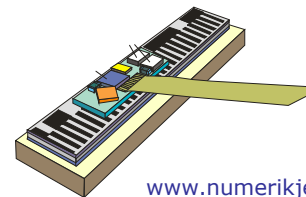


Oxygen sensors

- Fluorescence based sensors
- Measurement in micro fluidic systems

Life science sensors

- Monitoring of cardiovascular parameters



www.numerikjena.de

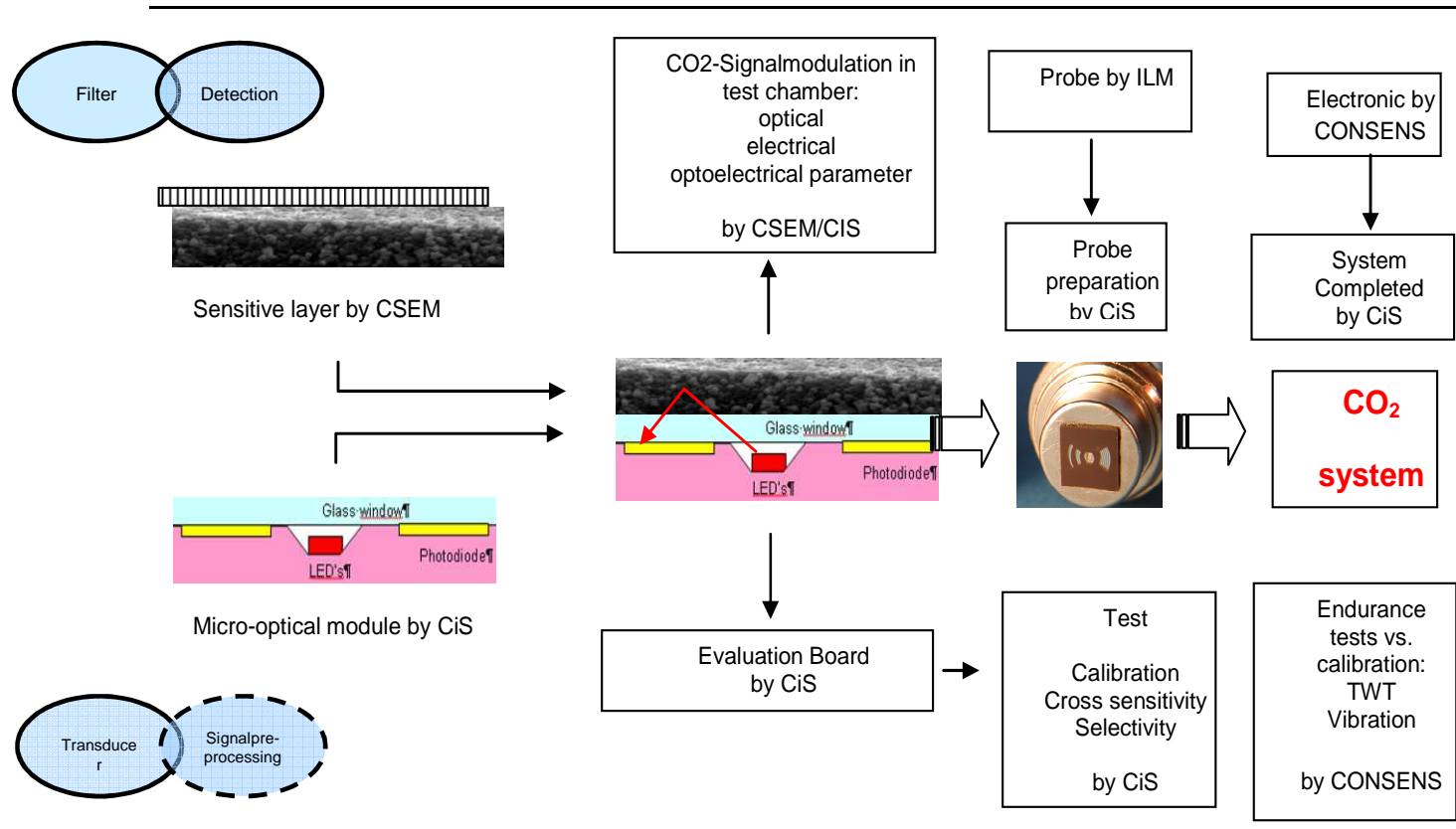
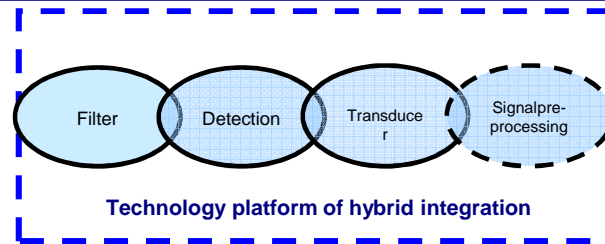
Linear encoder

- High interpolation
- Compensation of misalignment

Source: A.Steinke, A.Albrecht, O.Brodersen, Th.Ortlepp; MORES™ - an example of a product driven technology platform – a key for SMEs featuring microsystem innovation, EPoSS Annual Forum 2013, Cork, Ireland, 26th September 2013



Example: CO₂- sensor



©SMARTER SI 2015



Partners of the project



RTO: ● SME: ● Other: ●

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„Smart Anything Everywhere“ Launch Event, Grenoble, 27.03.2015

5



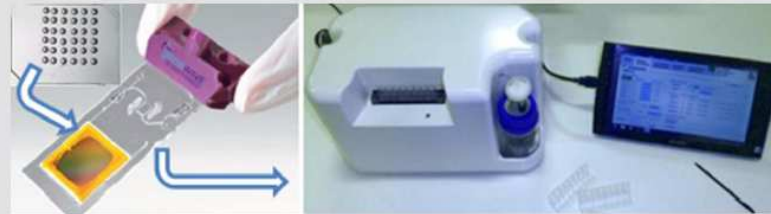
Application Experiments

Implement market ready solutions in small lots
Demonstrate cooperation between project partners

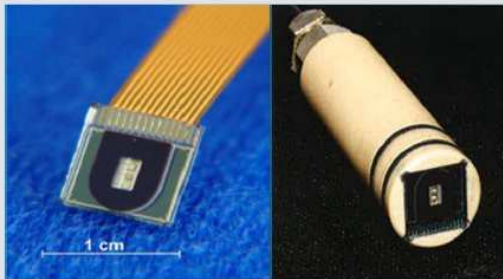


Point of care testing (POCT) device

IK4-IKERLAN, HSG-IMIT, CiS and two SME's



Modular system for multi-parametric optical detection using an automatised biological protocol. First validation by detection of several microtoxins



Carbon Dioxide measurement system

CIS, CSEM and two SME's

A sensitive polymer-layer is combined with a micro-optical module to reduce cross sensitivity. Benefits: Maintenance free, low power consumption, high accuracy, wide operation range

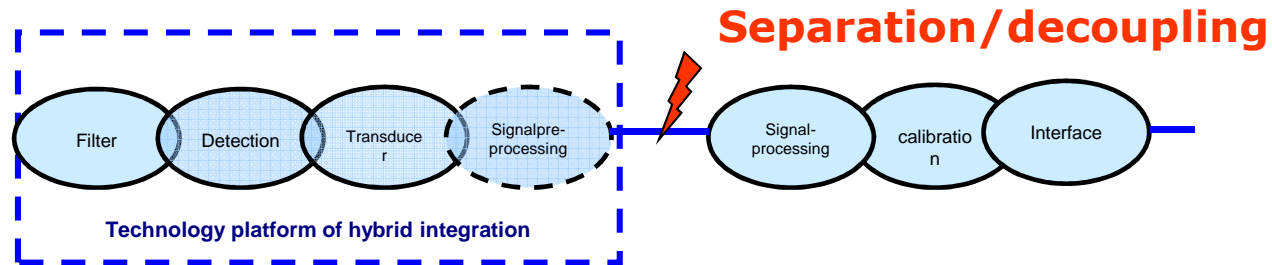


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MORES™ - Microoptical Remission Sensor

Building block + platform strategy



- High performance parameters
- Low volume/low cost
- Innovation in system components
- Fast market entrance

1. SMEs play a key role in the European landscape of innovation and employment
2. It is absolutely necessary to reduce the entrance barriers (technological, commercial,..) for SMEs regarding access to smart system technology (e.g. high performance)
3. We have to accept the boundary conditions of SMEs (e.g. low volume, system components only, fast market entrance)

An open platform and has a high leverage for SMEs` strength

Let`s talk about it!



Thank you very much for your attention



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