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Corporate Technology

Design and Development of Microsystems within a Corporate Research Environment by Utilizing COMSOL Multiphysics

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Comsol Conference, Stuttgart, 26th-28th October 2011

Outline

Introduction: Siemens Corporate Technology

Microsystem Design Examples

- Miniaturized optical gas sensor
- MEMS based piezoelectric energy harvesting module
- CMOS based sensor arrays for biochemical analysis

Summary and Conclusions

Introduction:
Siemens Corporate Technology

Corporate Technology
Networking the integrated technology company

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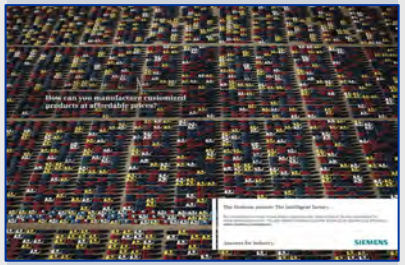
Customers

Chief Technology Officer (CTO)
- Review innovation strategies
- Drive technology based synergies
- Secure innovation power
- Technology assessments
- Governance and guidance

Sectors / Divisions

Industry



Energy

Healthcare

Regions

Siemens IT Solutions and Services (SIS)
Siemens Financial Services (SFS)

Chief Technology Office (CT O)
- Direct support of CTO

Corporate Research and Technologies (CT T)
- GTFs with multiple impact
- Pictures of the Future
- Accelerators

Corporate Development Center (CT DC)
- Software-Entwicklungs-partner für die Sektoren

Corporate Intellectual Property and Functions (CT I)
- Intellectual Property services & strategy
- Standardization, environmental affairs
- Global information research

Corporate Technology (CT)

Corporate Technology
World wide locations

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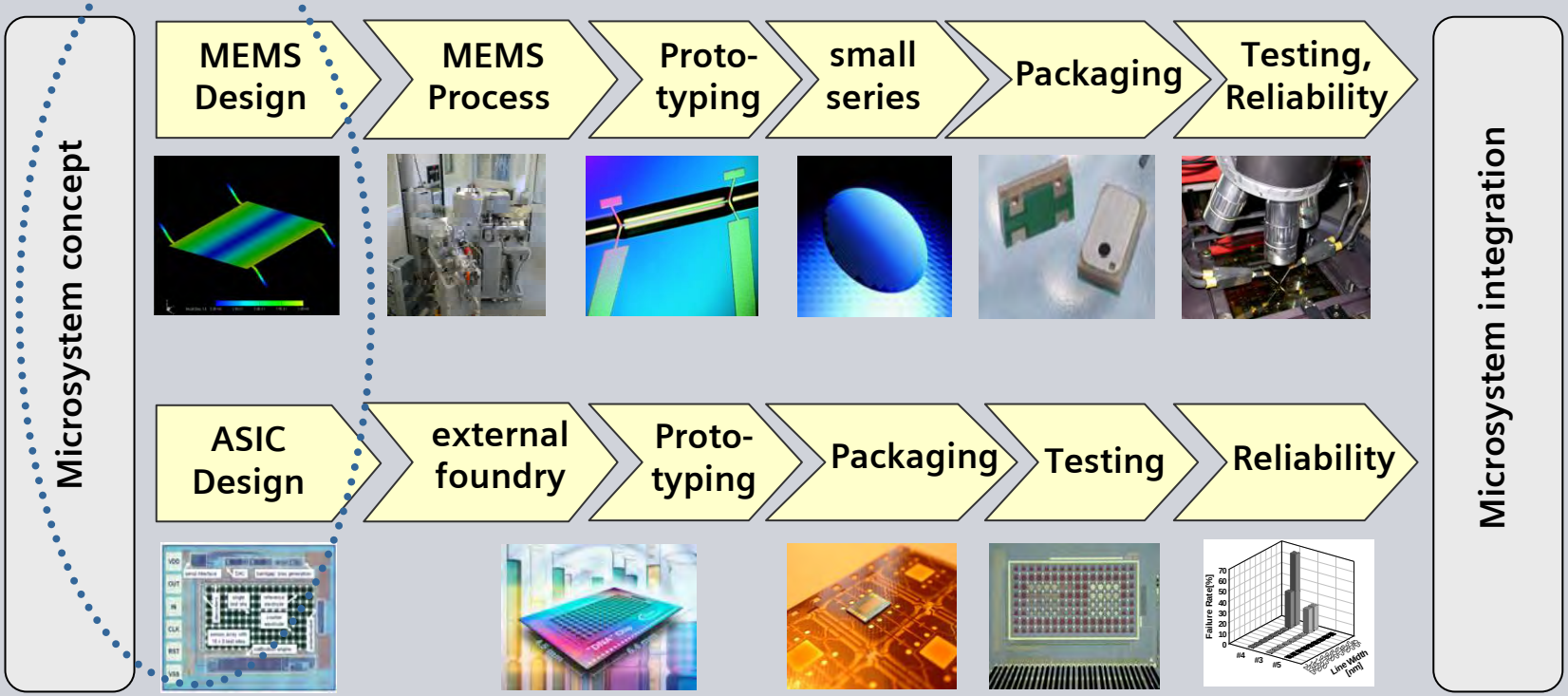
Utilization of COMSOL Multiphysics



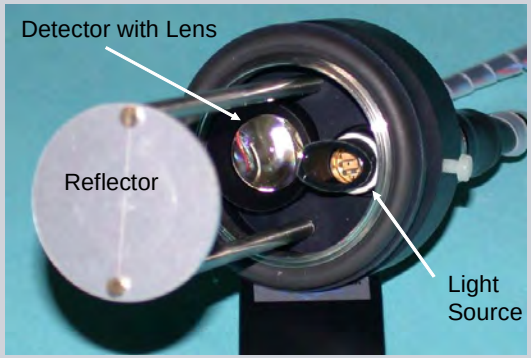
Microsystem Design Examples

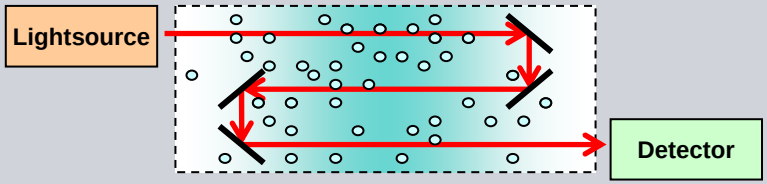
Miniaturized optical gas sensor

Miniaturized optical gas sensor

Motivation

Conventional

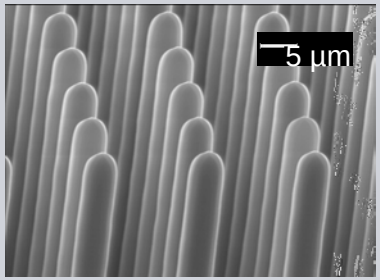


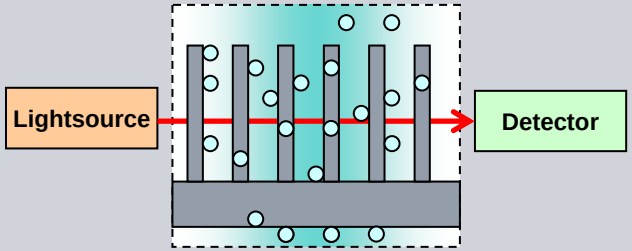


Size: 100 – 1000 mm

Microsystem

Photonic crystal microstructure



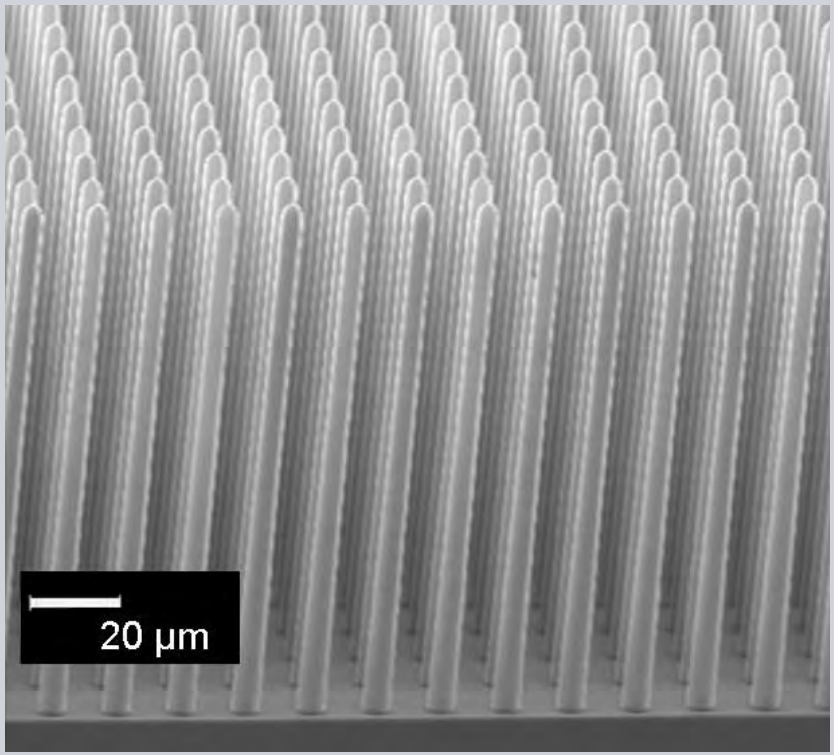


Size: 1 – 10 mm

Miniaturized optical gas sensor

Innovative device concept

Photonic crystal structure (Si rods in air)



Source: M. Schieber, Siemens CT T DE HW1, GTF MHM MSY

Miniaturization enabled:

by creating a waveguide (removing of rods) within the photonic crystal.

➡

- increased absorption length by an appropriate waveguide geometry
- increased absorption coefficient by exploiting “slow light” (light propagates with an extremely slow group velocity)

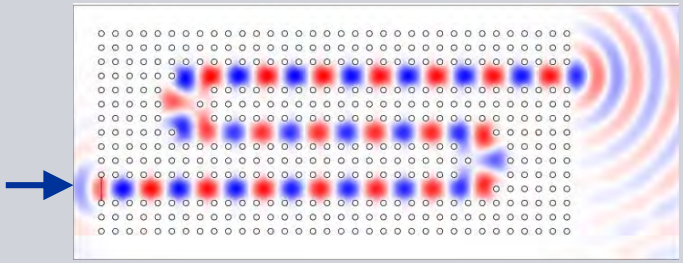
Miniaturized optical gas sensor

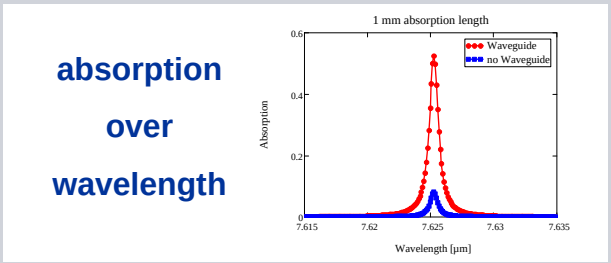
Concept evaluation and device design

C. Kraeh, H. Hedler, "FEM Simulations of Rod-Type Photonic Crystals as Resonant Microsystems for Optical Gas Sensors", COMSOL Conference, Stuttgart, October 2011.

COMSOL Multiphysics simulations with *RF Module, In-Plane Waves* to evaluate:

- Optical properties of a photonic crystal
- Photonic crystal waveguide properties
  - Slow light
  - Coupling into photonic crystals
- Absorption properties (gas detection)





MEMS based piezoelectric energy harvesting module

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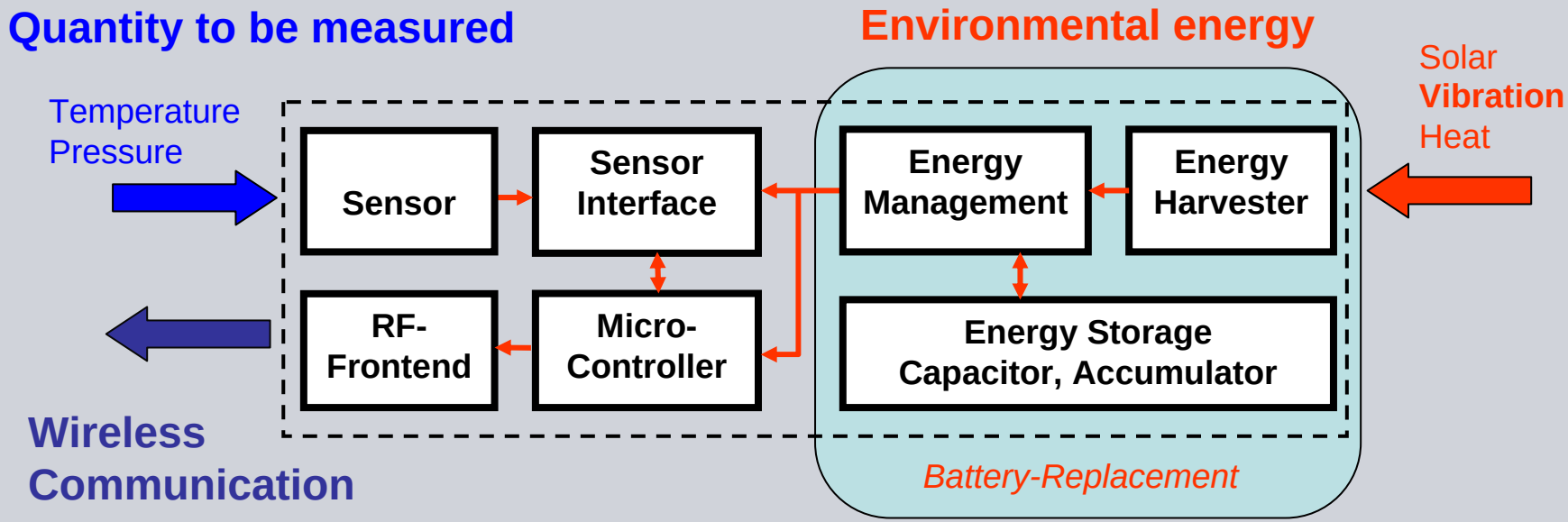
MEMS based piezoelectric energy harvesting module

Motivation: Energy autonomous sensor node



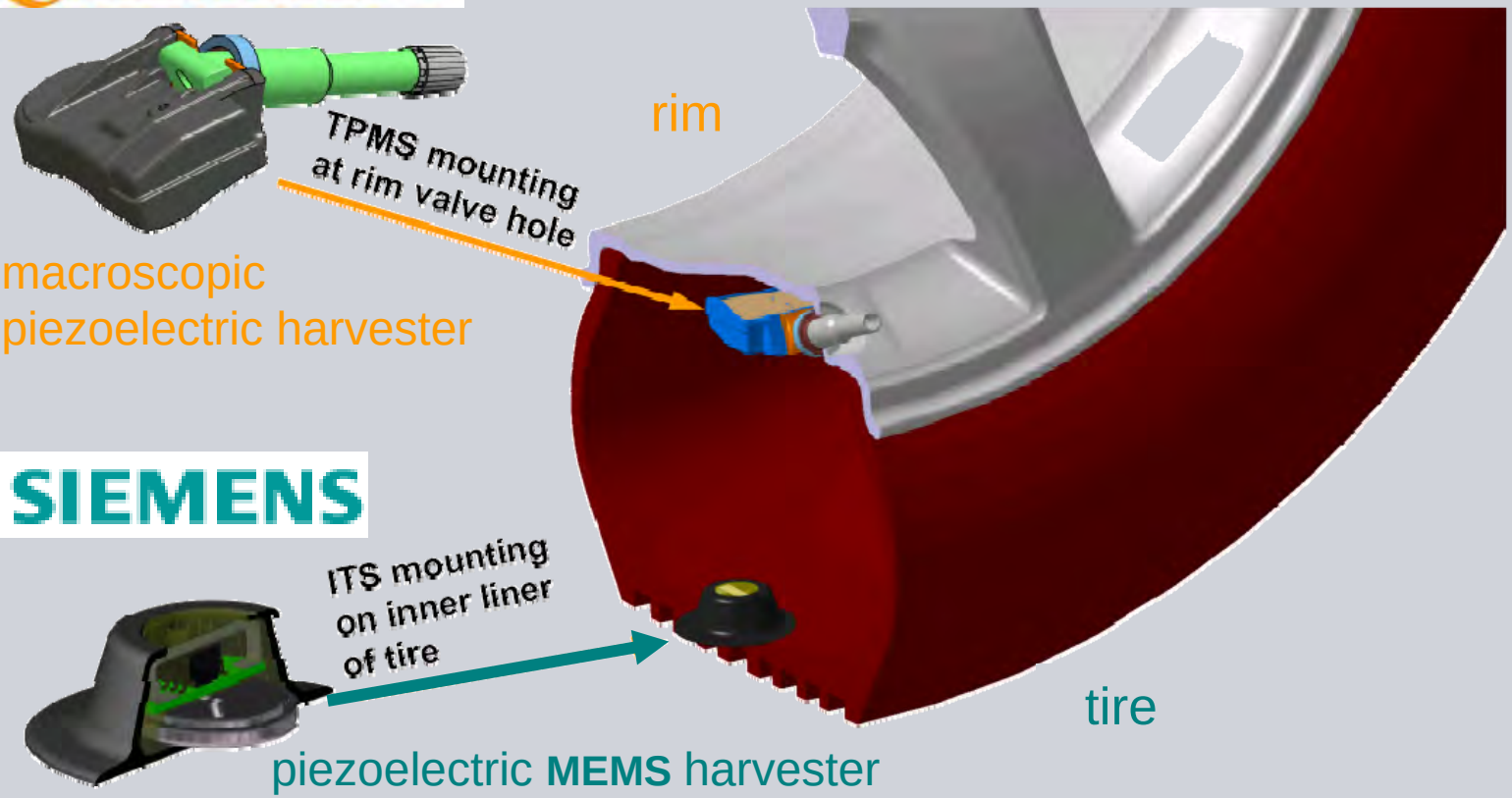
Benefits:

- Maintenance free
- Costs
- Environmental friendly

Tire pressure monitor system (TPMS) for automotive applications

Continental

Source: Continental

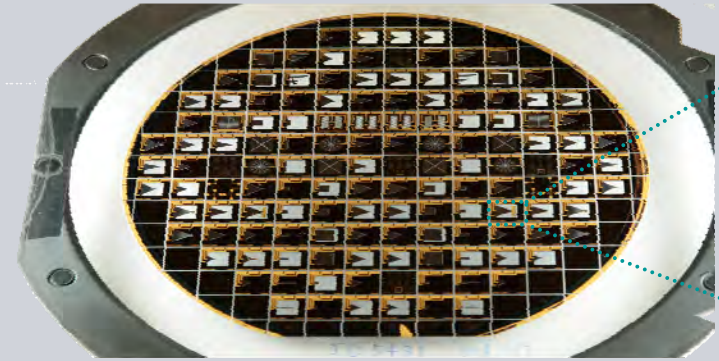


MEMS based piezoelectric energy harvesting module

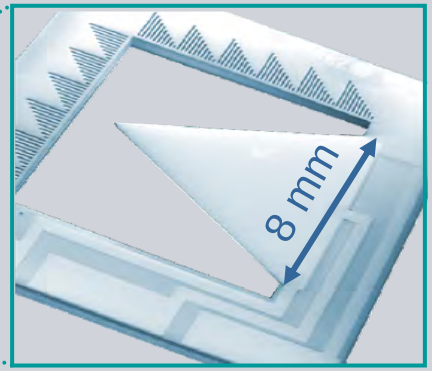
Innovative MEMS harvester device concept for TPMS application

Properties of MEMS harvester to enable tire-based TPMS application:

- Minimized mass in the micro gram range
- Non-resonant excitation scheme
- Overload protection
- Provides inherently CMOS compatible voltage level



6“ wafer with MEMS structures



piezoelectric MEMS harvester

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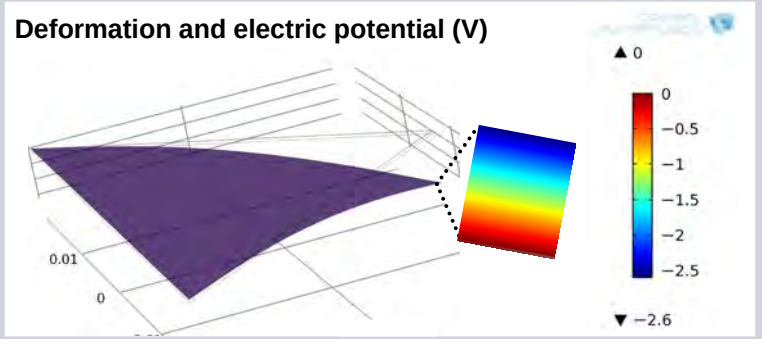
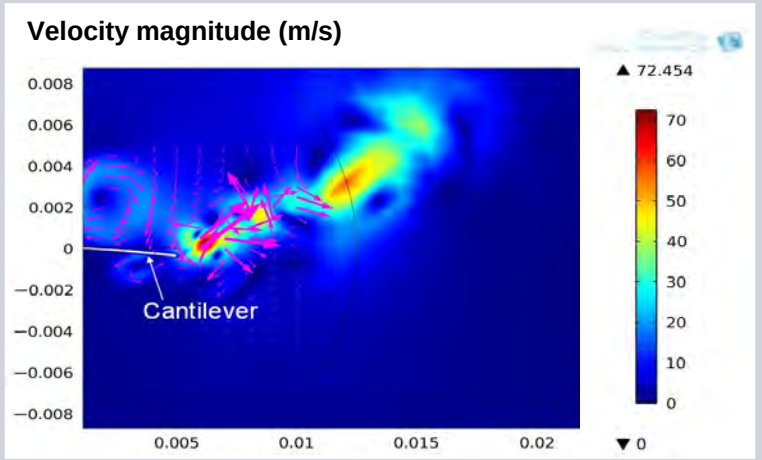
MEMS based piezoelectric energy harvesting

Concept evaluation and device design

COMSOL Multiphysics simulation to evaluate:

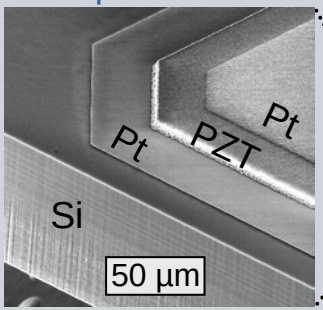
- Optimized cantilever geometry regarding mechanical stress distribution (*Structural Mechanics Module, Solid Mechanics*)
- Design of piezoelectric thin film (*Structural Mechanics Module, Piezoelectric Devices*)
  - material parameters
  - geometry
- Cantilever damping behavior (*Fluid Flow Module, Fluid-Structure Interaction*)



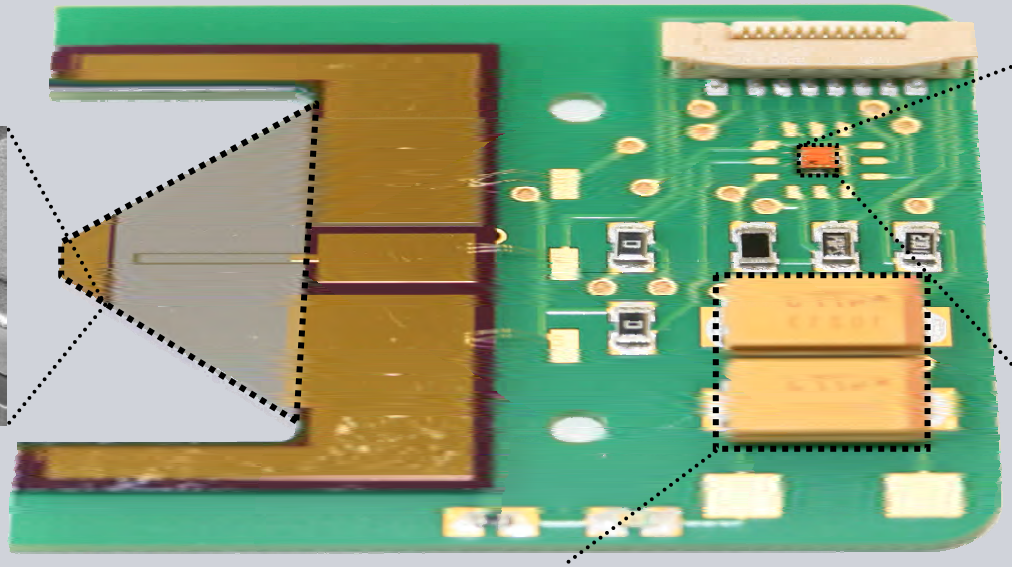


Piezoelectric MEMS energy harvesting module implementation

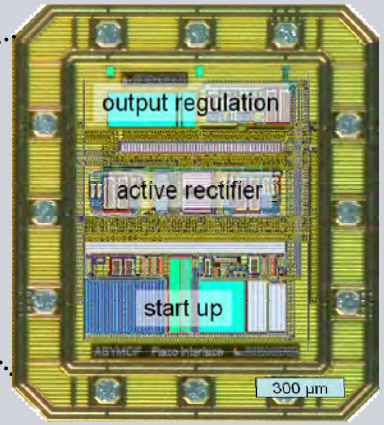
REM photo



piezoelectric MEMS harvester



energy storage capacitors



low-power energy-management ASIC

PCB level integrated energy harvesting module realized

CMOS based sensor array for biochemical analysis

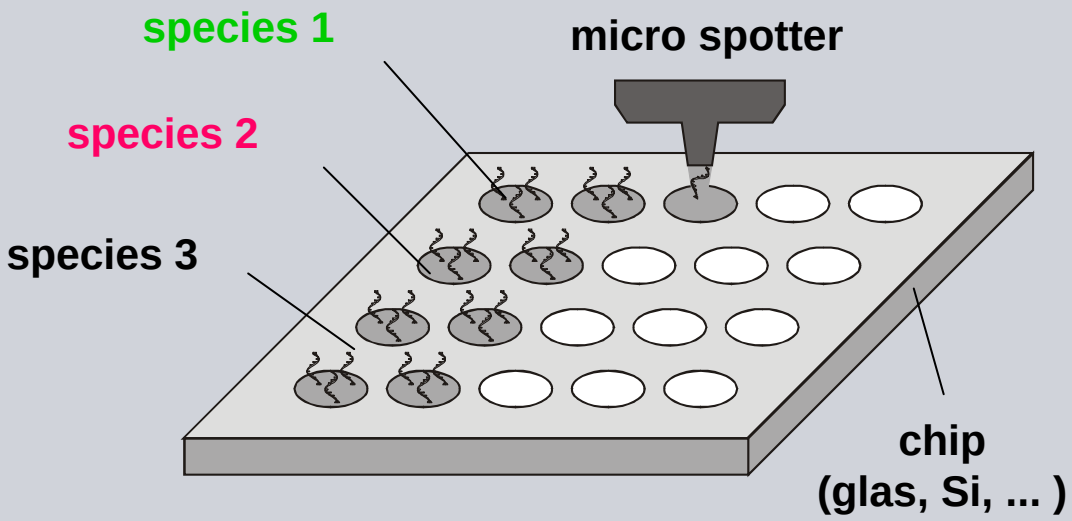
CMOS based sensor array for biochemical analysis

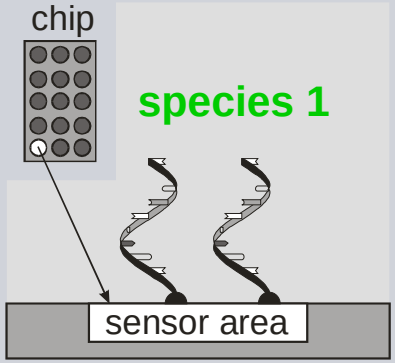
Motivation: Operation principle of DNA-Sensor (I)

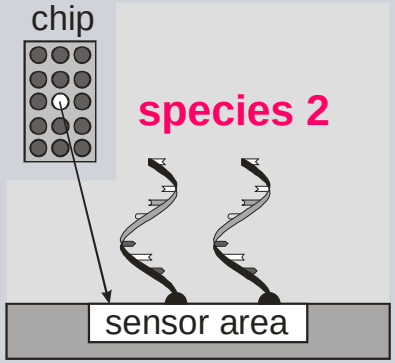
Immobilization of different known sequences of single-stranded DNA

(or other specific bio molecules like antibody)

at known positions on a substrate:

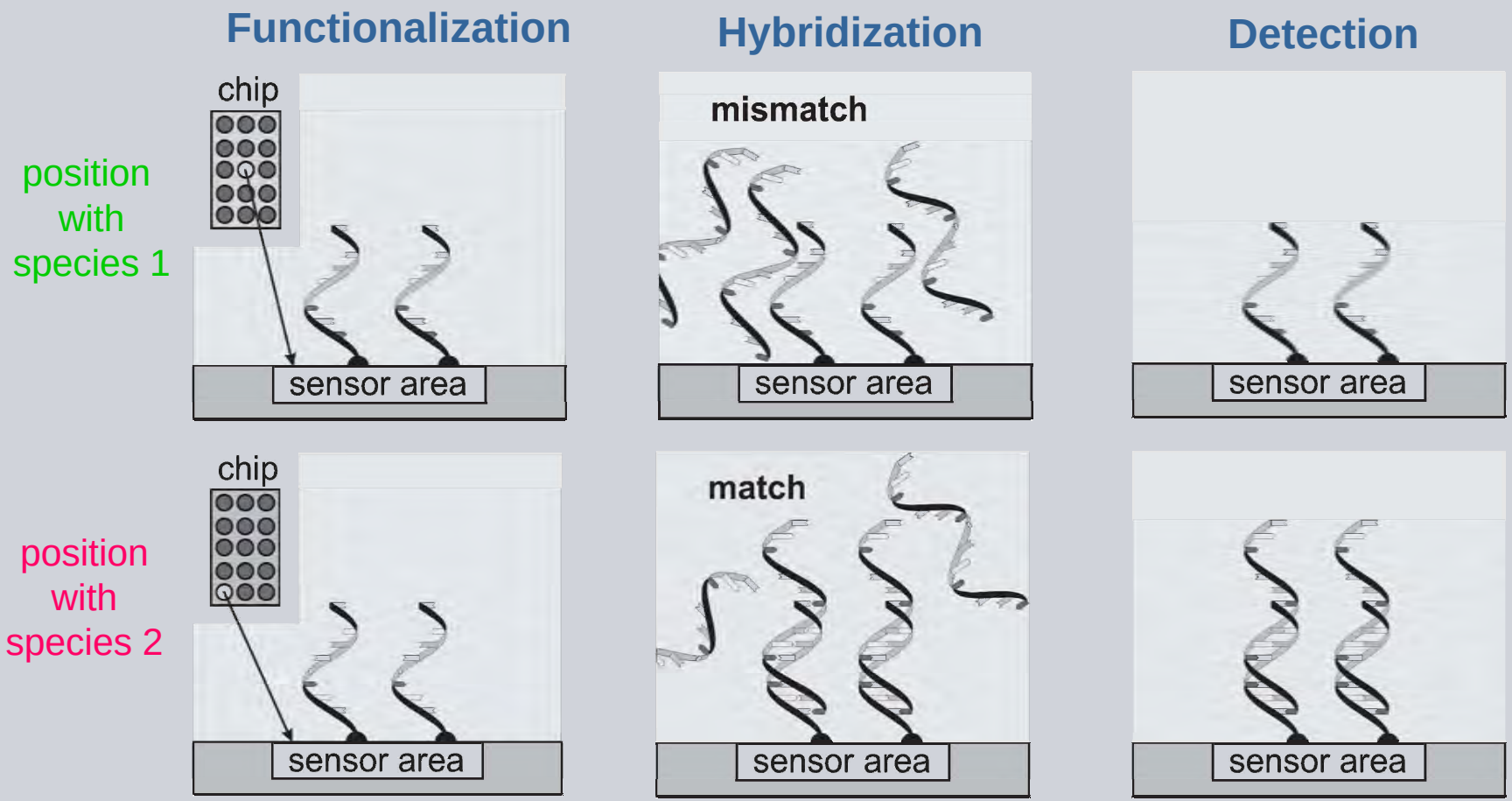






CMOS based sensor array for biochemical analysis

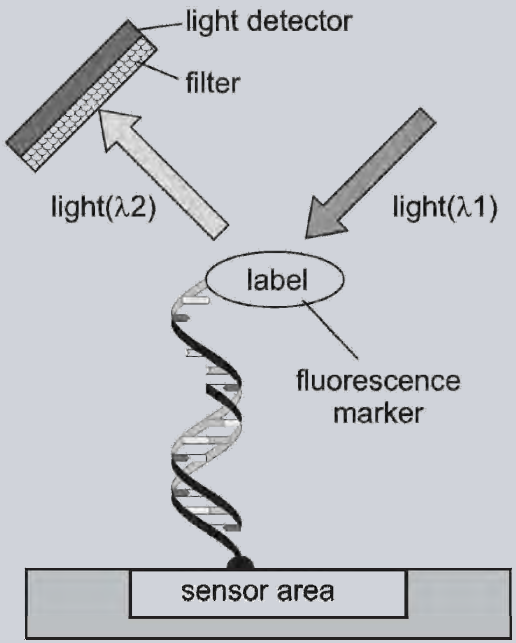
Motivation: Operation principle of DNA-Sensor (II)



CMOS based sensor array for biochemical analysis

Motivation: Operation principle of DNA-Sensor (III)

Conventional molecular diagnostic is based on optical detection with fluorescent labels.



However, alternative electrochemical methods offer several advantages:

- direct integration with microelectronics and microfluidics systems (miniaturization)
- digital implementation enables robust operation and easy workflow

Electrochemical bio sensors can enable new fields of applications, such as point of care medical diagnostics, rapid food and water control.

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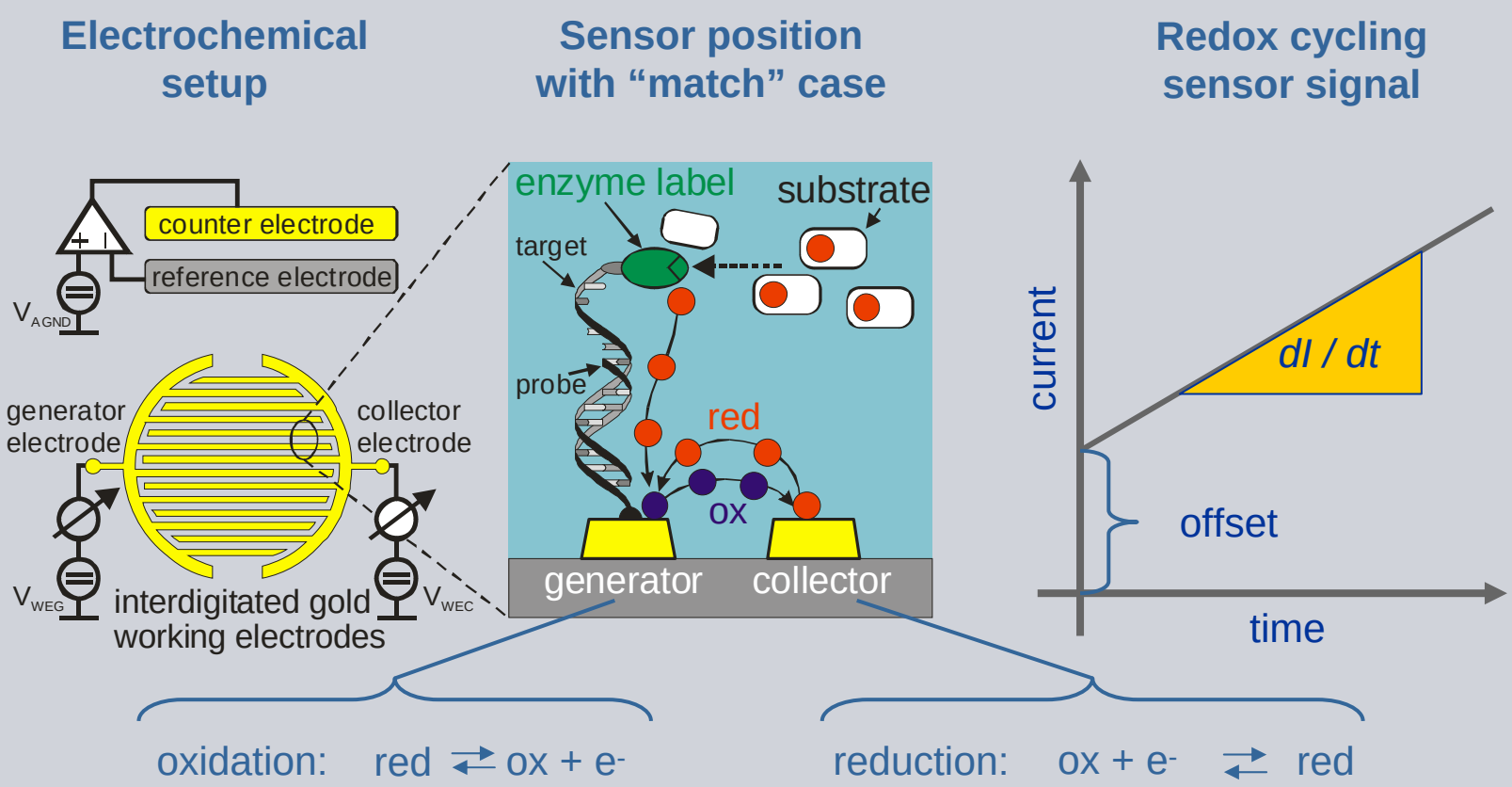
CMOS based sensor array for biochemical analysis

Innovative device concept: electrochemical detection

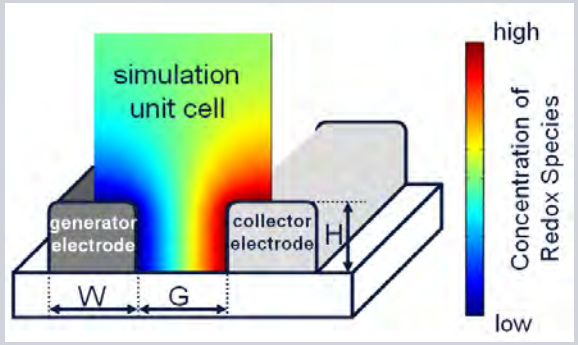


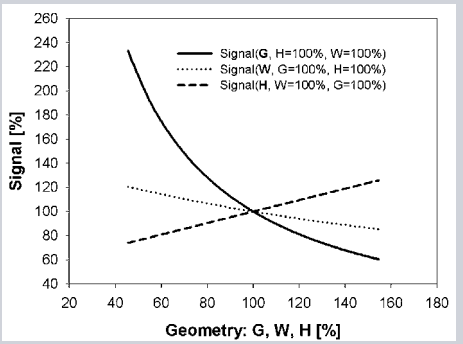
CMOS based sensor array for biochemical analysis

Concept evaluation and device design

COMSOL Multiphysics simulations with *Chemical Engineering Module, Mass Transport* to evaluate:

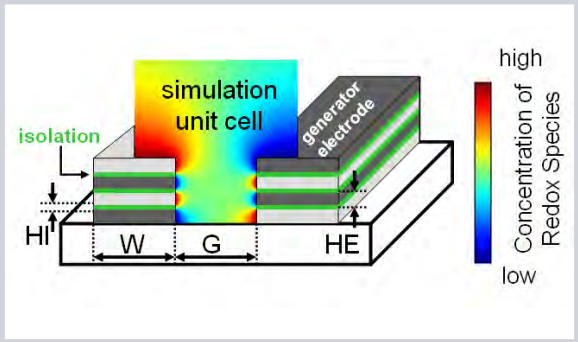
- the geometry impact of a conventional sensor electrode design on the sensor signal

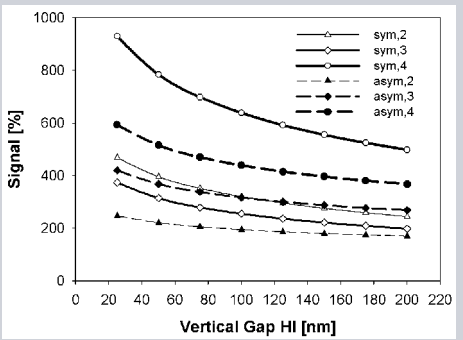




- an innovative stacked electrode design and the:
  - topology
  - geometry

  impact on the sensor signal





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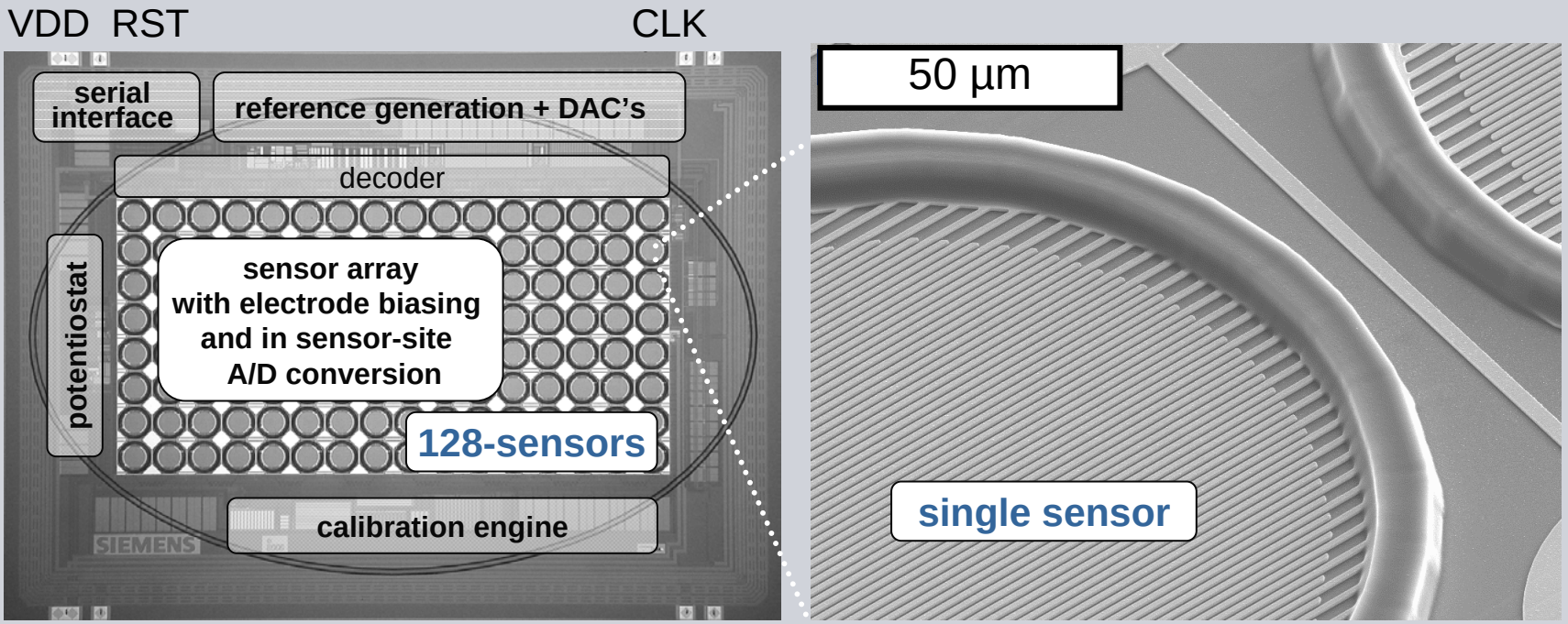
CMOS based sensor arrays for biochemical analysis

Implementation



Optimized fully integrated microsystem for biochemical analysis

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Summary and Conclusions

The Siemens CT Microsystems department is focused on developing innovative microsystem solutions. Examples presented in this talk are:

– Miniaturized optical gas sensor

– MEMS based piezoelectric energy harvesting module

– CMOS based sensor array for biochemical analysis

During the concept finding and evaluation phase FEM-simulation is an efficient method.

For the MEMS and ASIC design COMSOL Multiphysics is used as an development tool for a cost optimized process.

Thank you for your attention