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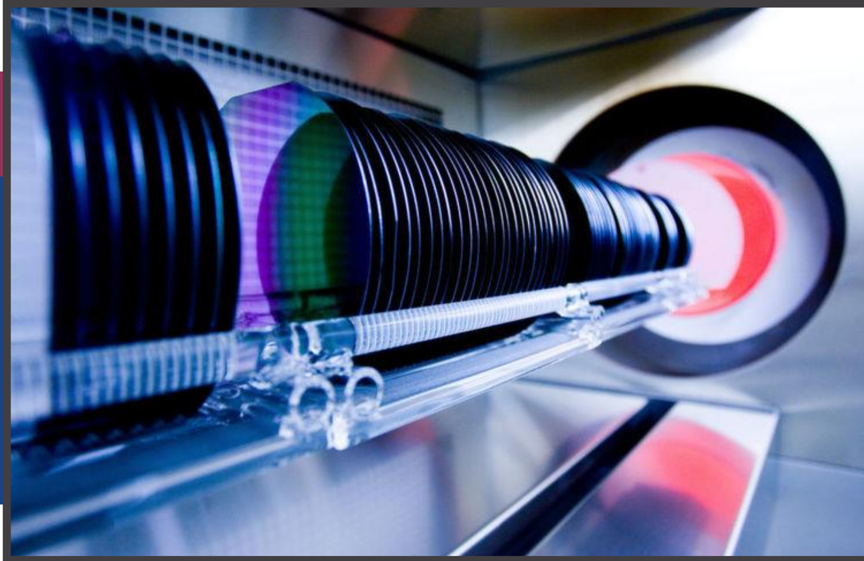

Competence in Silicon

CiS Silicon detectors

Development, Prototyping, Production, Test, Assembly

Ralf Röder

ZUSE-GEMEINSCHAFT
FORSCHUNG, DIE ANKOMMT.
GRÜNDUNGSMITGLIED

NICA Days 2019, Warzaw 24.10.2019

Overview

- CiS Forschungsinstitut für Mikrosensorik GmbH in facts
- Areas of activity
- Silizium detector examples
- Current work

NICA Days 2019, Warzaw 24.10.2019

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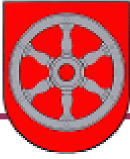

Location

Erfurt southeast industrial park

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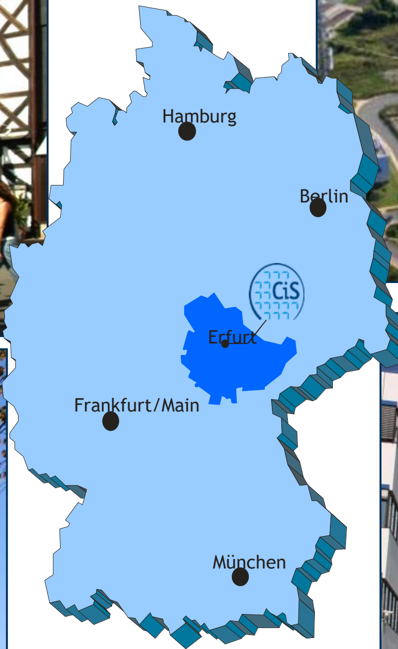
Hamburg
Berlin
CiS
Erfurt
Frankfurt/Main
München

CiS Research Institut

CiS Forschungsinstitut für Mikrosensorik GmbH

- Founded in 1993: spin-off of former microelectronics company
- Non-profit research institution under private law (GmbH), independent
- Employees 2018: 91 R&D + 24 skilled workers, assistants
- Turn over 2018: about 16 Mio EUR

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Silicon sensor solutions

Silicon detectors

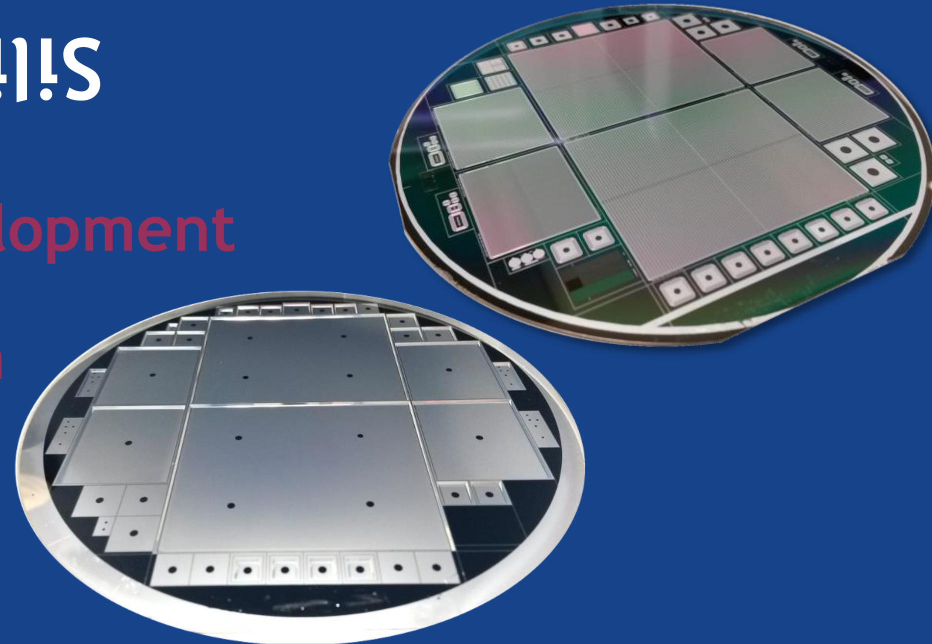
Offer **one-stop services**

in the fields of **research and development**

accomplished by simulation, design,

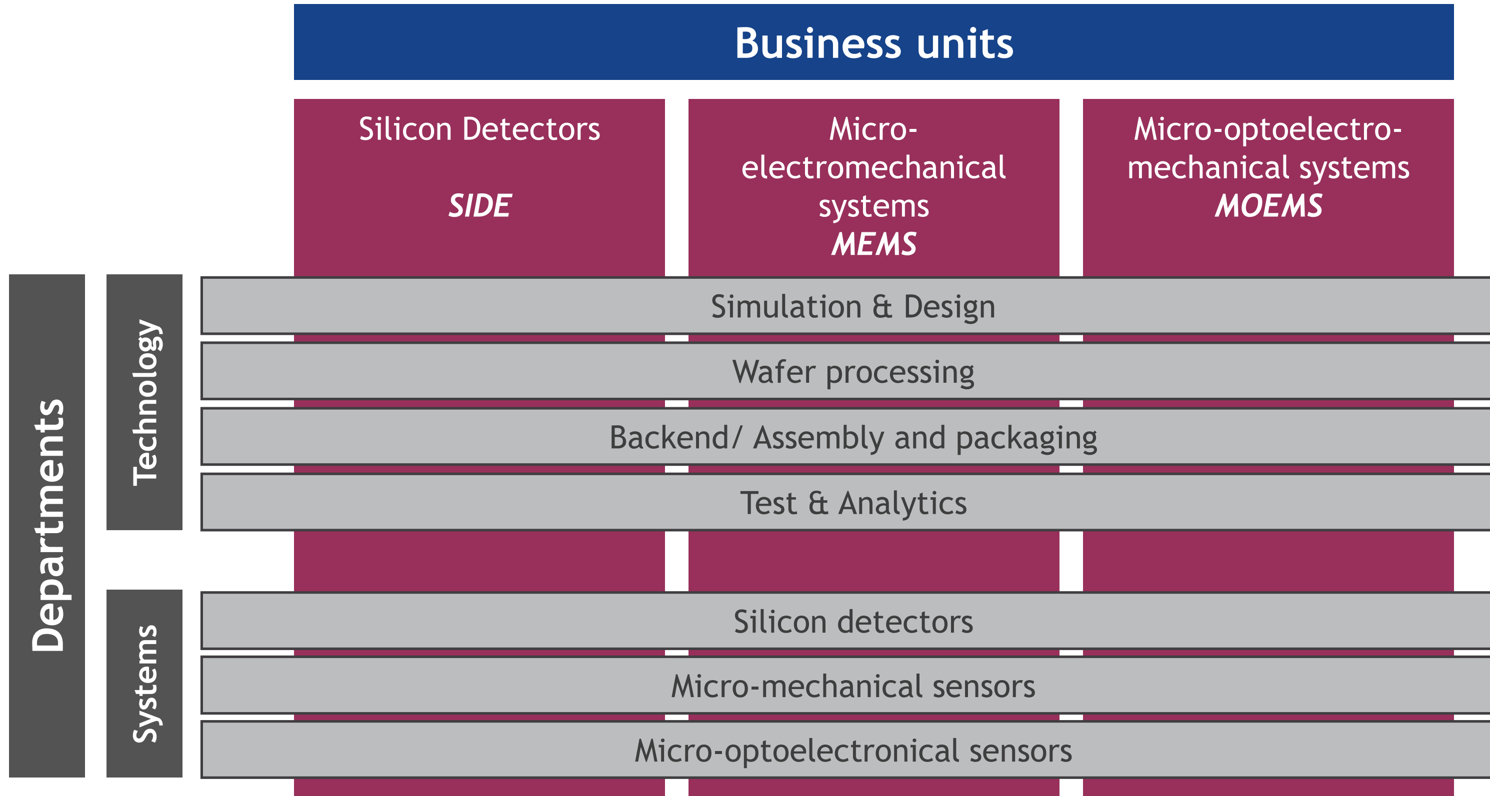
our **in-house wafer fabrication**

from small up to medium numbers
including wafer-back end processing,
by assembly and packaging as well as
product qualification.



FULL CUSTOM specific solutions – highest flexibility in technology and design.

Structure



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Silicon sensor solutions

MEMS

Pressure Sensors

- Piezoresistive silicon sensors
  - 1 mbar … 1000 bar
  - silicon membrans
- long-time stable
- temperature compensat

Micro-Force Sensors

- Micro climate, dew point
- Temperature diodes
- Impedance spectroscopy

Impedance Sensors

- Cantilever
- precision force sensors

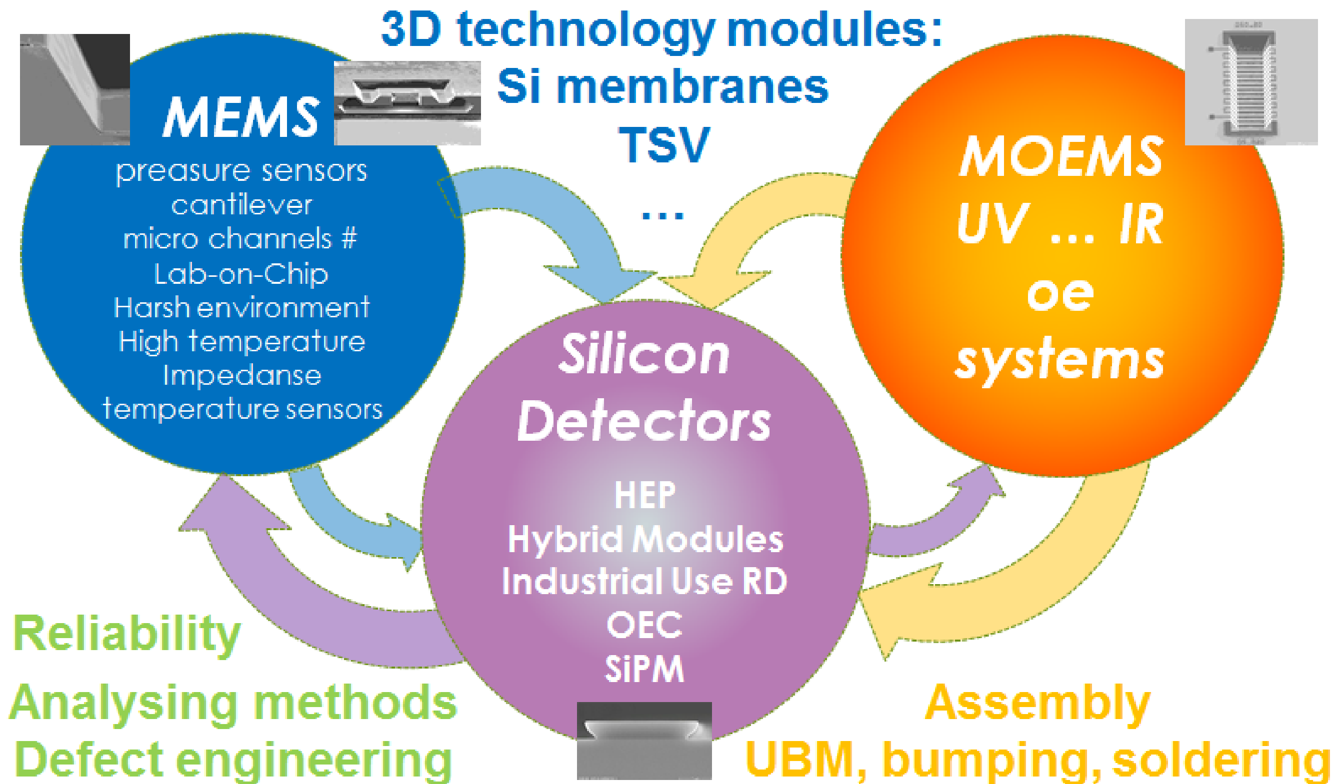
MOEMS

3d opto-ectronical devices and modules
based on custom specific photodiode (arrays) and micro-optic components
Functionalized microoptical emitter-receiver sensor module (MORES)
Life science components, Leveling sensors and other solution for scientific and industrial use

Silicon particle detection

CiS R&D and industrial services

Design ⇨ Wafer processing ⇨ Assembly ⇨ Test & Analysis



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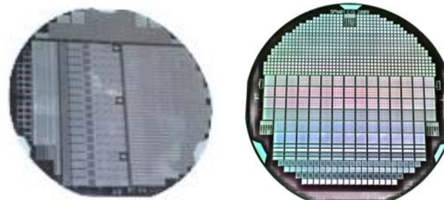
Silicon detectors

Opto-electronical converter

- Planar and 3D silicon-photodiodes: pn, pin, Avalanche, Low Gain Avalanche
- Silicon-Photomultiplier (SiPM)
- High flexibility in
  - size, shape, …
  - performance (technology)
  - sensibility 1keV … (deep) UV … NIR
- Multi-Project-Wafer-Service
- Wafer-Level-Integration
  - Microoptics
  - Scintialtors
  - on-chip filter

Analytics and sServices

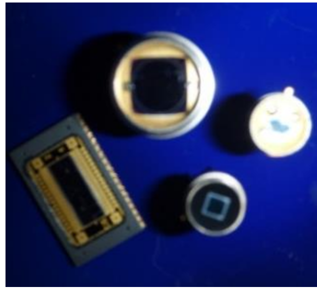
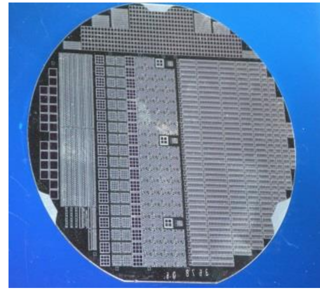
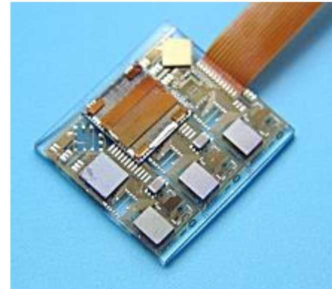
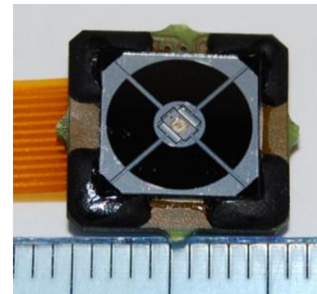
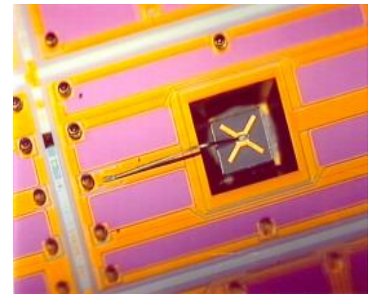
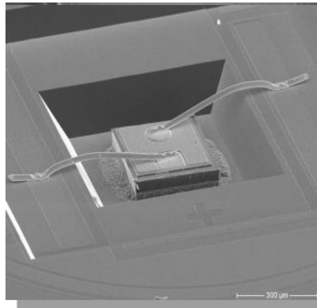
- Semiconductor analysis
- Structure analysis (REM, FIB, SIMS, RAMAN, US)
- Through silicon vias TSV
- Under-Bump-Metallisierung, Bumping, Coating and Plating
- Soldering
- Assembly
- Flip-Chipping
- Wiring, Stud-bumping

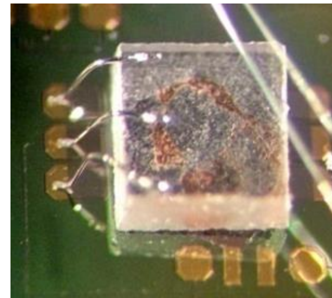


Radiation and Particle Detectors

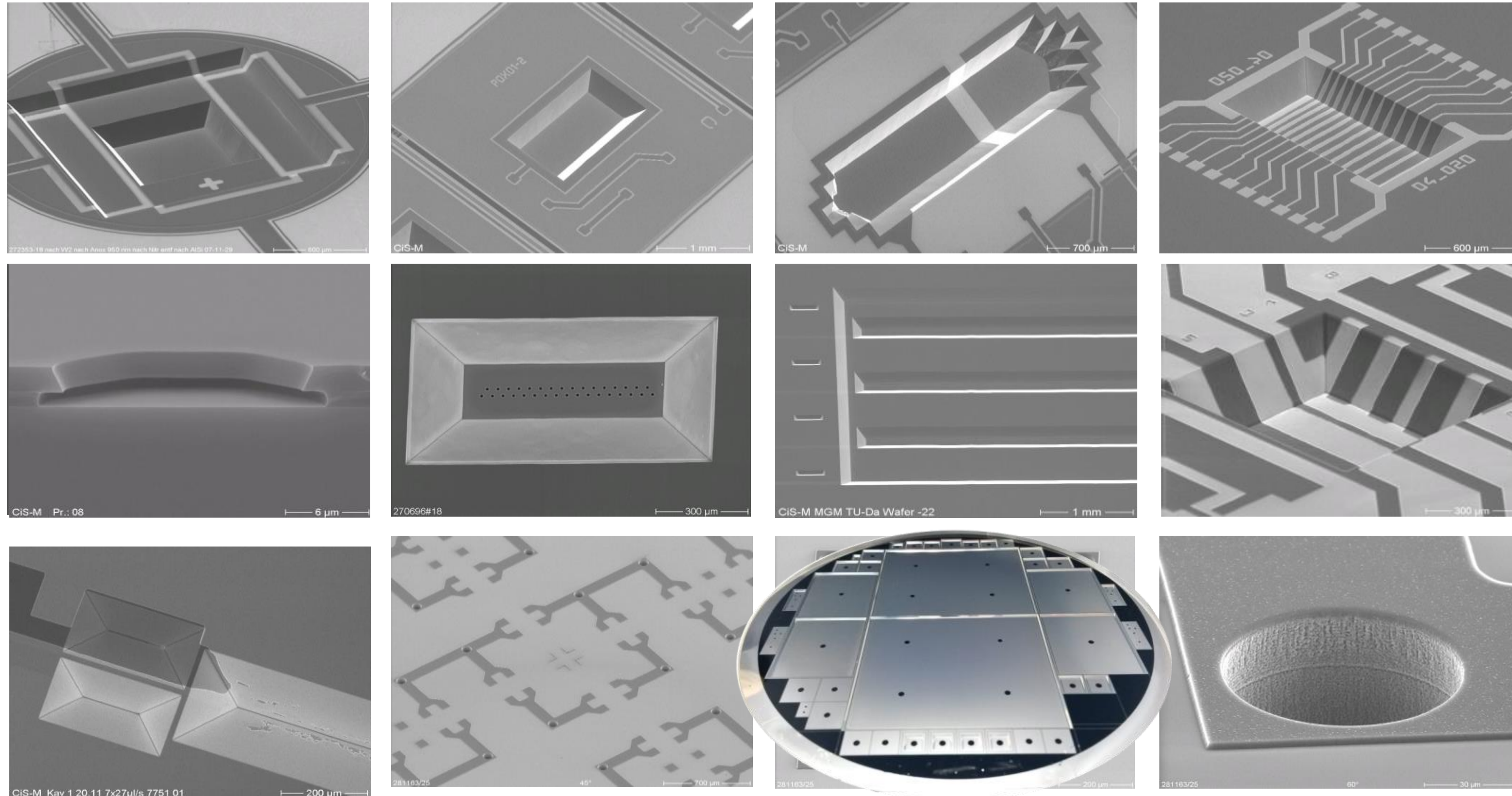
- Silicon detectors:
  - single and double sided
  - Pixel
  - Micro-strip
- Extremely radiation hard detectors by defect engineering
  - Single Photon detection
  - chip size up to 100 cm^2
- Detector / chip thickness thin 50 … 100 … 250 µm standard 285 … 525 …700 µm
  - Active chip edges

Photodiode and module examples



Examples for 3D- Silicon structuring



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Extremely radiation hard detectors

- Particle detectors for High-energy physic experiments and cosmic rays
- Pixel and Micro-Strip detectors: chip size up to 100 cm^2
- Double-sided and 3D detectors
- Customized and highly flexible detector layouts
    - Option: non-orthogonal chip geometry
- Large area thinned single and double sided detectors
- ac or dc coupled devices
- Very small leakage current $\leq$ 1 nA / cm^2 @ 20°C
- Extremely high radiation hardness by defect engineering
- Multi-Guard-Ring structures: supply voltages up to > 500 V
    - Option: active chip edges
- Various isolation and biasing techniques available
- Wafer-backend Optionen: Under-Bump-Metallization

Detector modules

- Hybrid integration of radiation detectors and read-out circuits (ROC)
  - Under-Bump-Metallization and Bump deposition
    - Mask based processes: Lift-off mask on.chip or stencil printing
    - electroplating or mask-less & electro-less (wet chemical)
    - Various materials: Ti, Ni, Cu, Pd, Pt, Ag, Au, solder, filled adhesives et al
  - Assembly: chip bonding, wire-bonding, bumping
    flip chip assembly
    (soldering, adhesive or thermal compression bonding)
  - Optional additional features:
    - Micro channel cooling
      - integrated in silicon interposer
      - Silicon large area plates with micro channels

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Sensor modules

- Hybrid / polylithic Multi-layer modules
  - Chip or wafer stacks
  - Large area silicon leadframe,
    especially detector modules for high energy physic experiments
  - Available technology modules
    - Stencil printing
    - electroplating
    - mask-less
    - electro-less (wet chemical)
- Through-Silicon Via
    - X-Typ (minimum size up to 0,1 mm^2)
    - I-Typ: low space requirements, high number per chip

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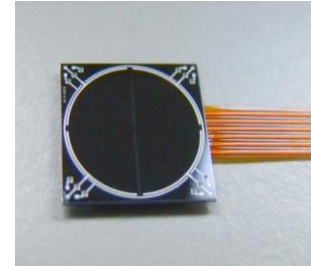
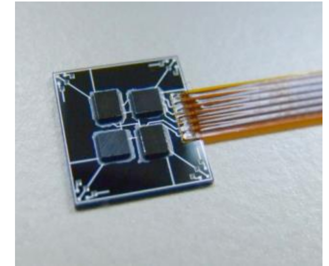
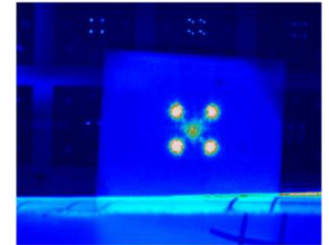
Customized pn and pin photo diodes

- Customized design and technology
    - size and shapes of sensing elements
- Chip size and shape
    - Option: edge-less chip design
    - Differential : double or quadrant diodes
    - Diode row or arrays
    - Circle annular structures, sectoring available
    - combined with 3D technology modules
        - Through Silicon Vias
        - Cavities with structured metallization
        - inclined surfaces / beveling (for example 45°)
    - optically adapted passivation, on-chip optical filters and micro optics
    - adaptable spectral sensitivity and dynamic behavior
- **Customized Assembly**
- **Multi-Chip Waferservice**



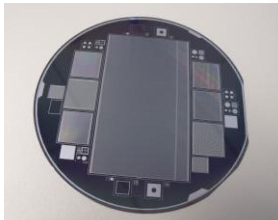




Silicon detector examples

Micro-strip detectors for science instrumentation

H1PHI@DESY	single-sided detectors, ac coupled	about 360 pcs
ATLAS WEDGE@CERN 11,21,22,23	single-sided detectors, ac coupled	about 2950 pcs
ALICE-S2@CERN	double-sided detector, ac coupled	about 1350 pcs
AMS-2@ISS	double-sided detector, FOXFET	about 240 pcs



Micro-strip detectors for heavy ion experiments developed

BONN01@Panda double-sided detector, ac coupled

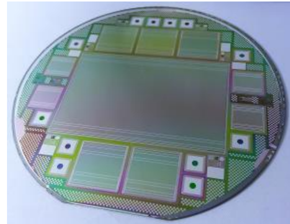
3 chip sizes

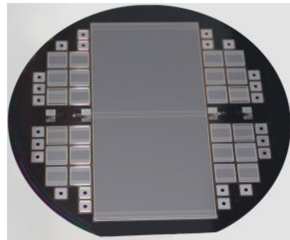
CBMxx@FAIR double-sided detector, ac coupled

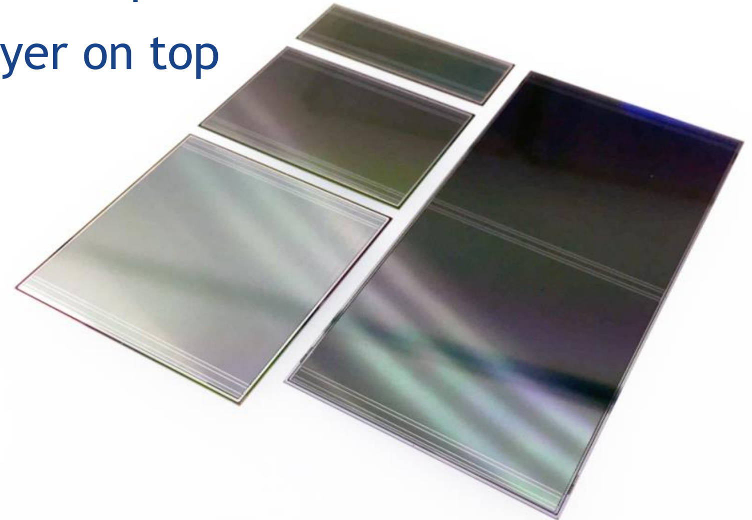
option: second metal layer on top

4 chip sizes

- $2 \times 6\ cm^2$
- $4 \times 6\ cm^2$
- $6 \times 6\ cm^2$
- $12 \times 6\ cm^2$







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Silicon detector examples

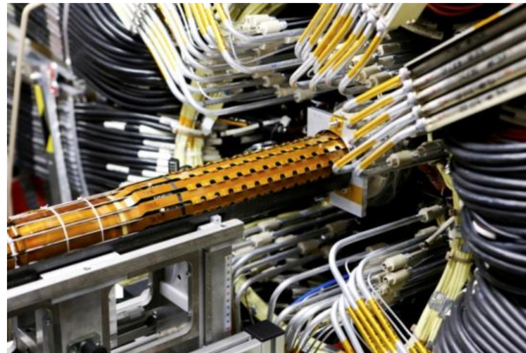
Pixel detectors for science instrumentation

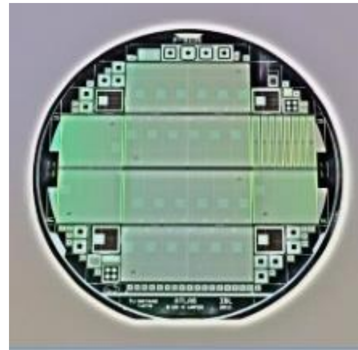
ATLAS PIXEL @CERN n-in-n, double-sided detector, 250 µm thick

about 1200 pcs

ATLAS IBL@CERN n-in-n, double-sided detector, 150 … 200 µm thick

about 200 pcs





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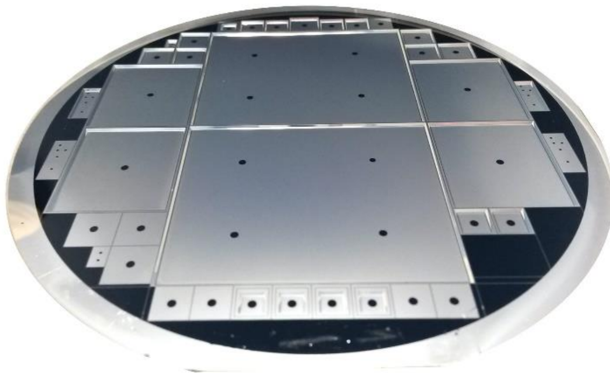
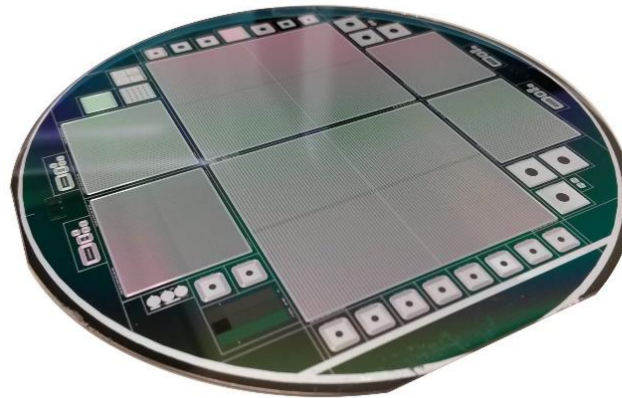
Silicon detector examples

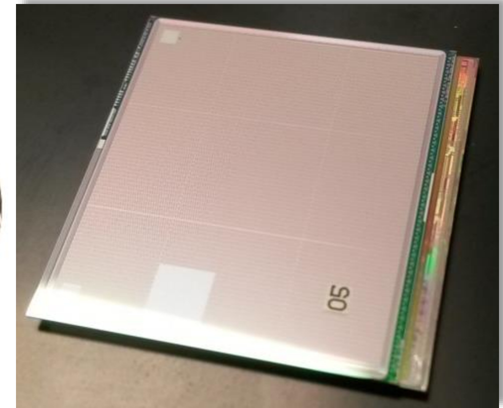
Pixel detectors for science instrumentation

ATLAS PIXEL @CERN

p-in-n, in process thinned down to 100 and 150 µm
quad sensor design
chip size 4,2 mm x 4,0 mm





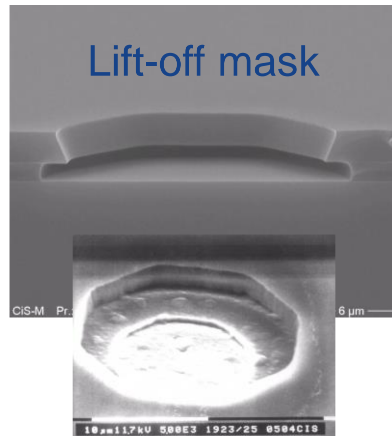


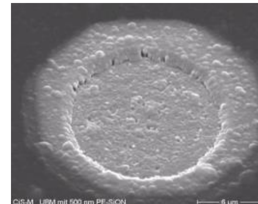
Silicon detector examples

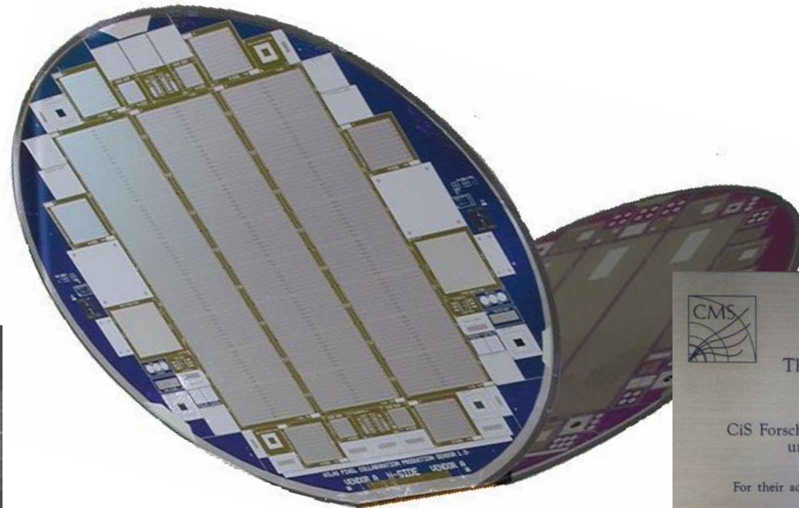
Pixel detectors for science instrumentation

CMS PIXEL@CERN n-in-n, double-sided detector about 1200 pcs

Under Bump Metallization







CMS
CERN
The CMS Collaboration
presents
The CMS Gold Award
of the Year 2009
to
CiS Forschungsinstitut für Mikrosensorik
und Photovoltaik GmbH
Erfurt, Germany
For their achievement of the Silicon Pixel Sensors
for the CMS Pixel Barrel
Dr. Daniel Green
Chairperson of the CMS Collaboration Board
CMS Industry Award 2009

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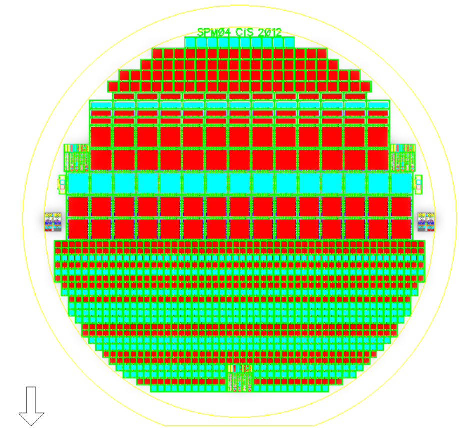
Ongoing detector developments

- Defect engineering (higher radiation hardness) ↔ RD50
- Alpha and beta detectors
- SiPM
- LGAD
- UV photodiodes
- detectors for particularly low-energy electrons
- $\triangle$E detectors
- E-Rest detectors
- 3D pixel detectors
- Underbump metalization and soldering processes, pillar structures



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Development of Delta-E-detectors for TREX

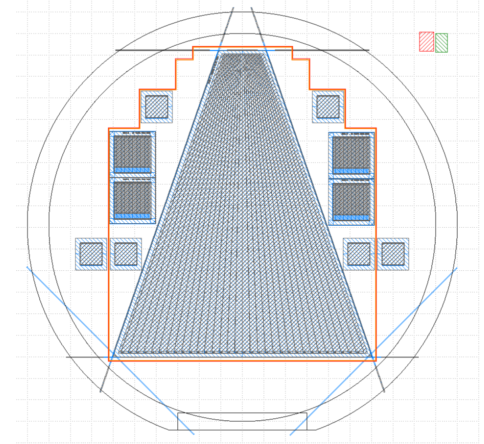
Requirements

1. **thin sensors**

- large area (large fraction of the wafer)
- target thickness: 100µm or less (<140µm)
- high homogeneity of the sensor thickness
- double sided processed (strips)
- Poly-Si resistors included

2. shallow, homogeneous dead zone (in active area)

- thin metal
- thin oxide
- shallow p+ doping



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Dziękuję za uwagę !

Спасибо за внимание!

Thank you for your attention !

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