CiS - Technologies for Radiation Hard Silicon Detectors

Ralf Röder, CiS Instut für Mikrosensorik gGmbH Erfurt / Germany

April 2003: Restart of the clean room and wafer processing faciltities after move to new buildings in Erfurt

- Equipment
- Processing capabilities
- Design pad-diode
- Radiation Hard Detecors:
  - DOFZ, epi
  - Defect engineering

Equipment & processing capabilities

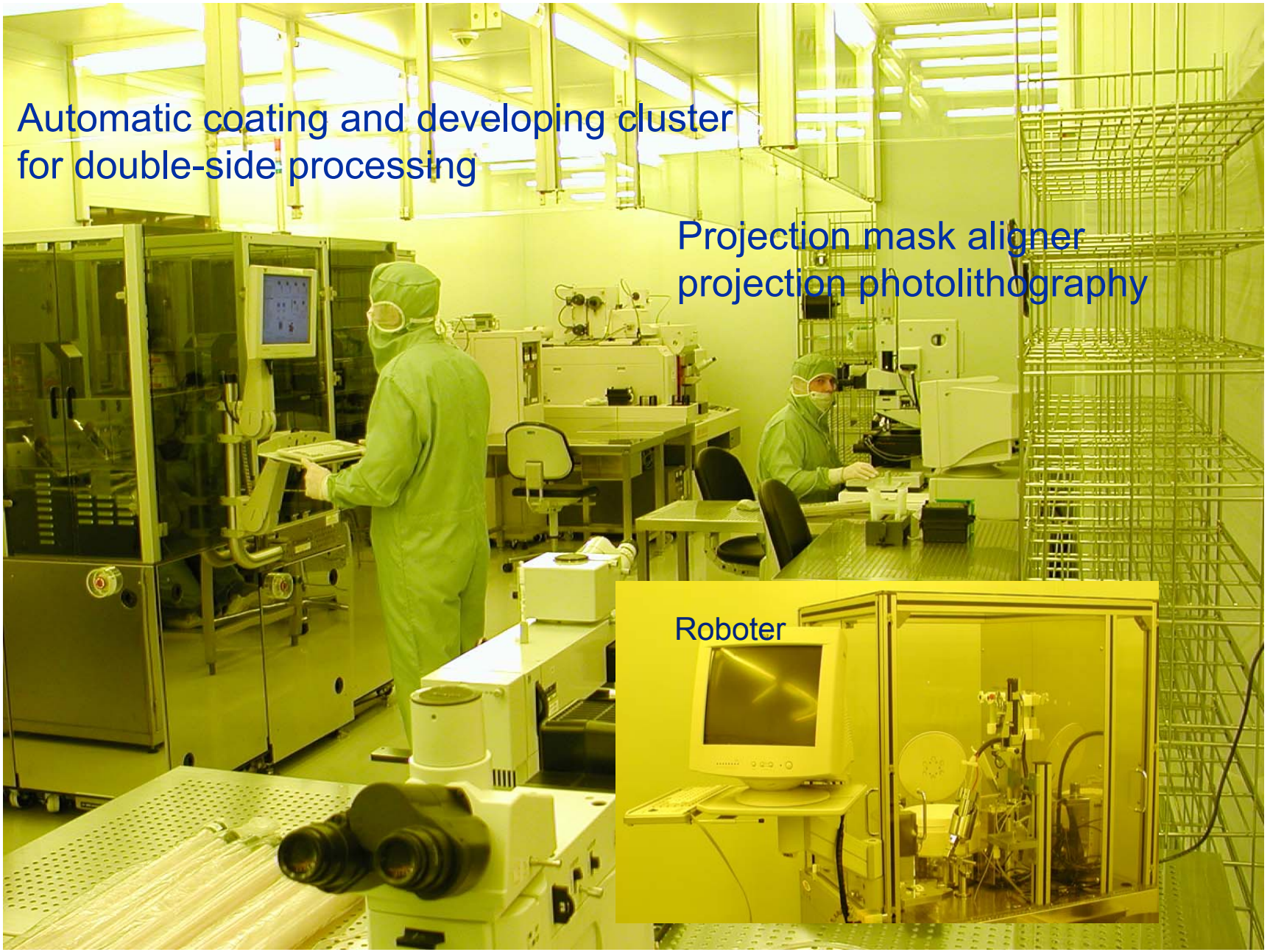
- **4 inch n- or p- typ silicon wafer, single or double-sided polished**
  - double side process and test equipment
  - Automatic coating and developing cluster for double-side processing
  - Projection mask aligner, projection photolithography
  - Spray coating equipment

    ...

  - partly 6 inch compatible
- up to 2000 detector wafer p.a.
- high ohmic (1 - 30 kOhmcm) STFZ or DOFZ
- CZ (>600 Ohmcm), epi (for example 50 Ohmcm) on CZ
- **Thickness:** (200 µm) ... **250 µm ... 285 µm ... 300 µm** ... 500 µm ... (800 µm)

High temperature facility Oxydation
Oxygen enrichment

LP - CVD SiO_2, SION, Si_3N_4
stress reduced
Poly-silicon


Automatic coating and developing cluster
for double-side processing
Projection mask aligner
projection photolithography
Roboter

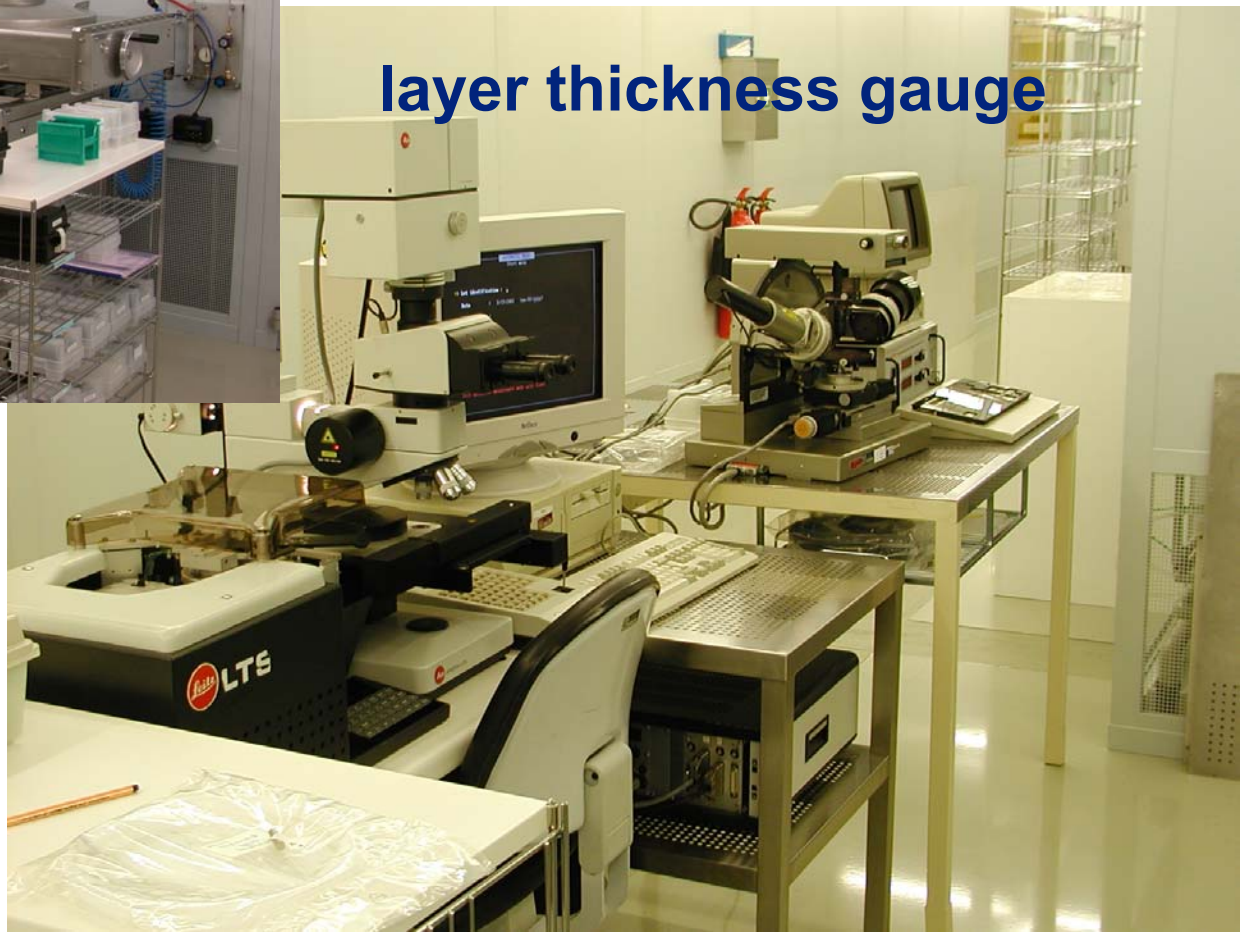
Improved conditions for

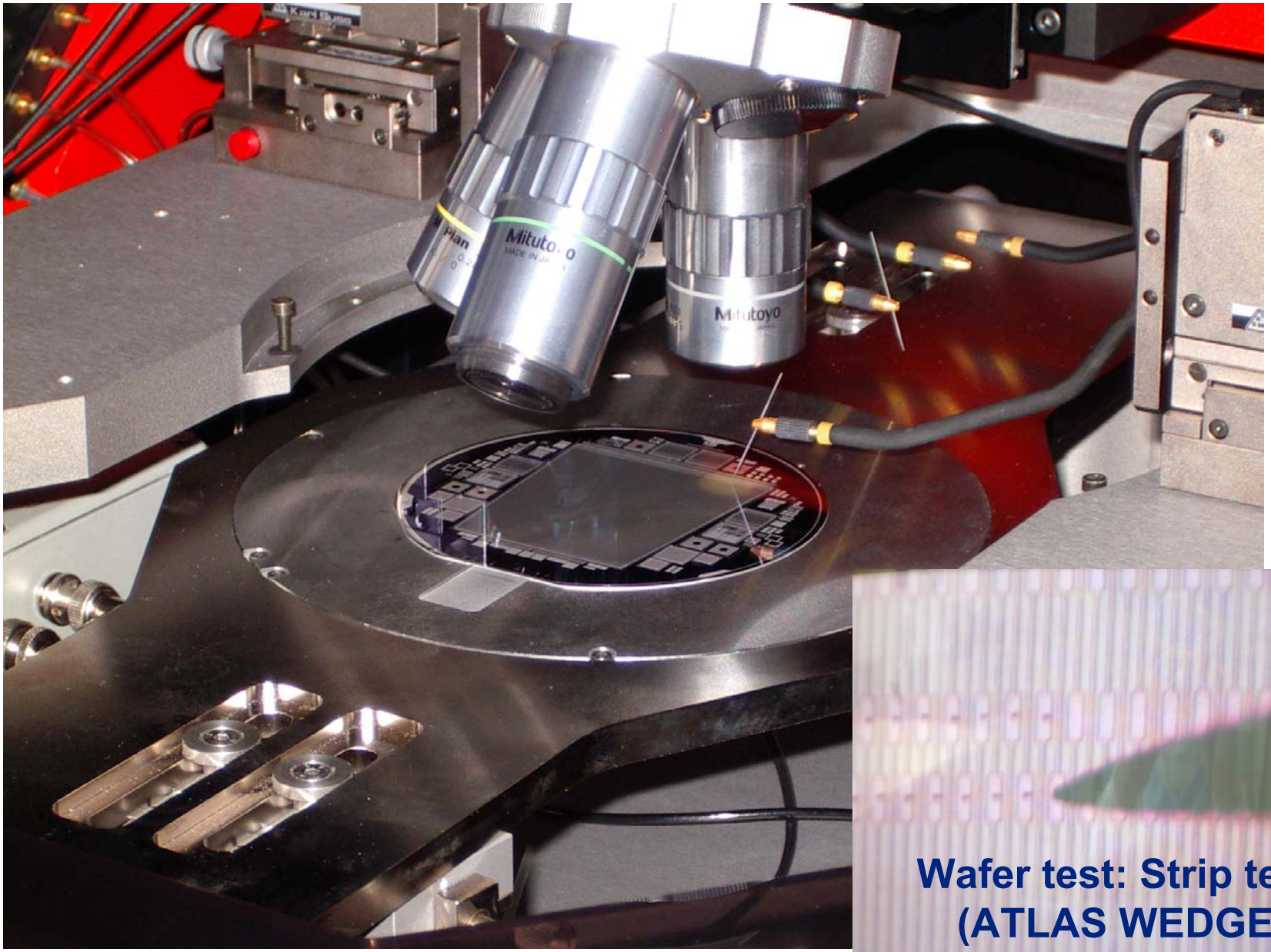
- wafer cleaning
- wet etching
- photoresist wet structuring

Improved qualtity of

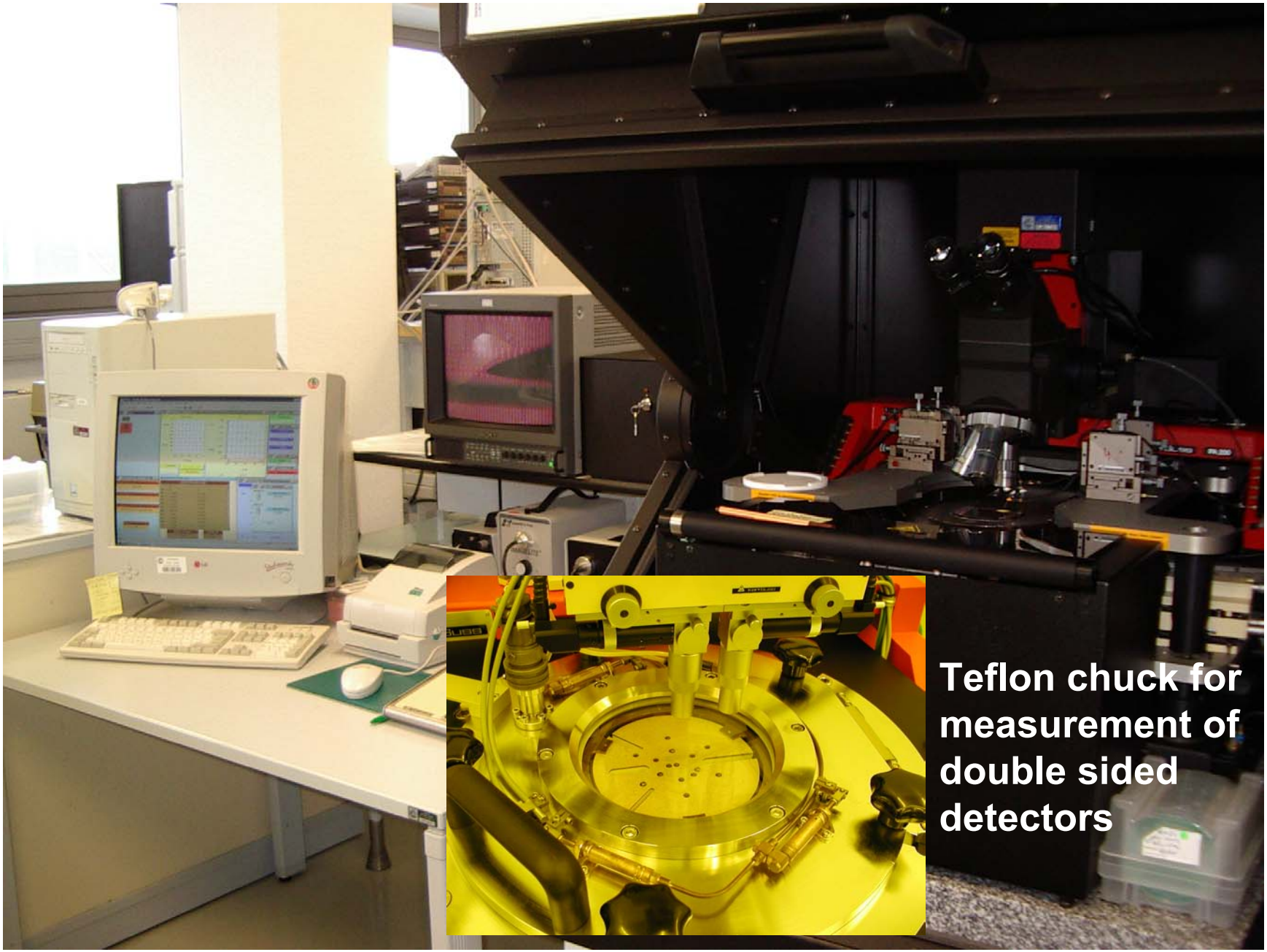
- gases
- photoresist (less Na ions)
- DI water


CVD


layer thickness gauge
LTS

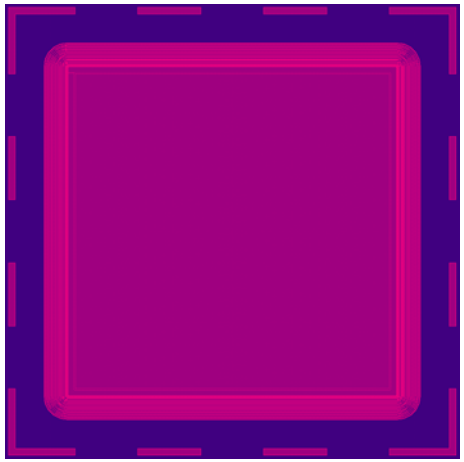


Wafer test: Strip test (ATLAS WEDGE)

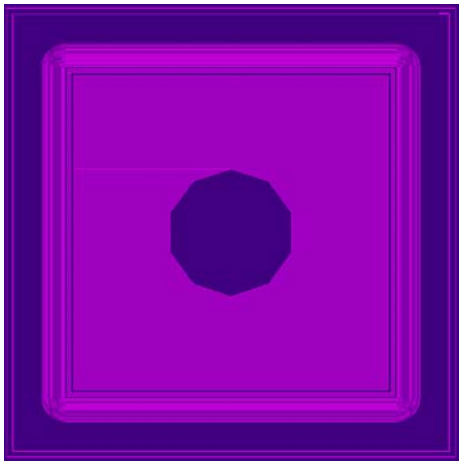


Teflon chuck for measurement of double sided detectors

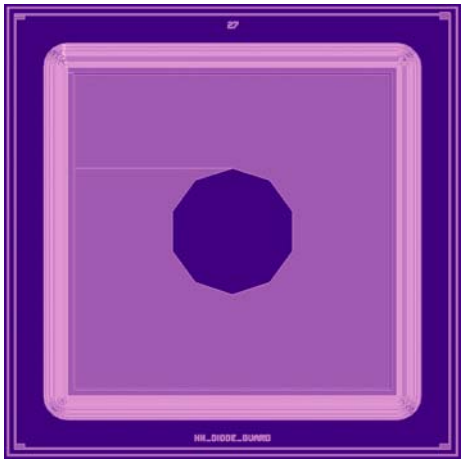
pad - diode



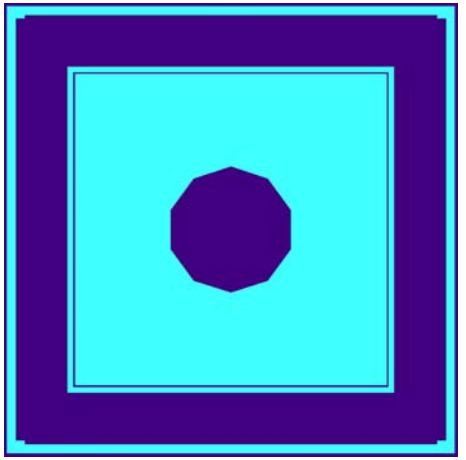
Mask A:
borus implantation



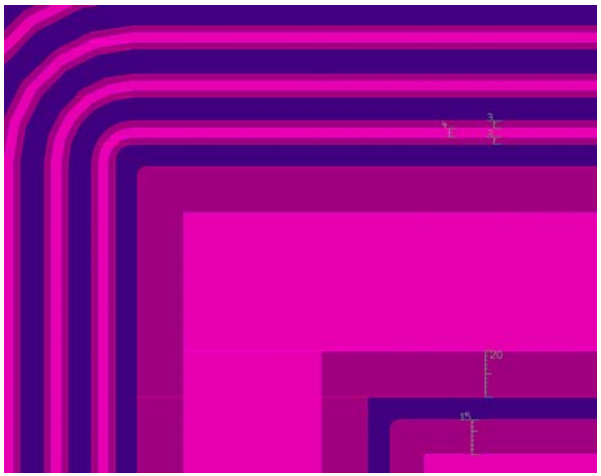
Mask C:
contacts
opening of field oxyd

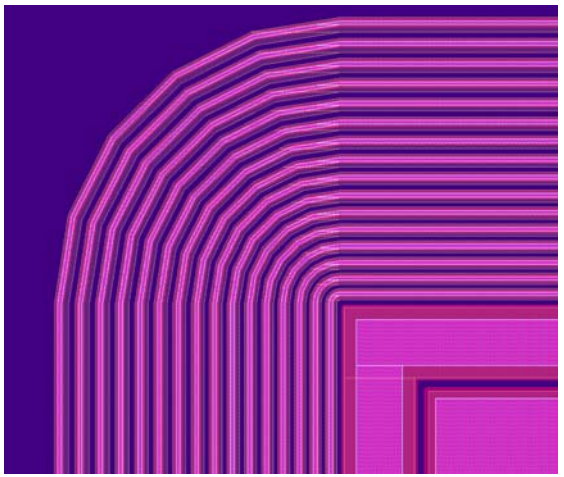


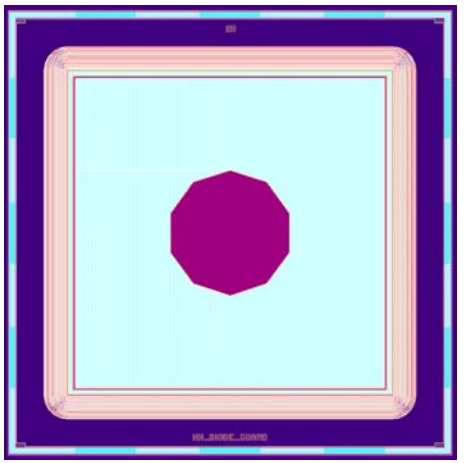
Mask D:
metal AlSi 1 µm



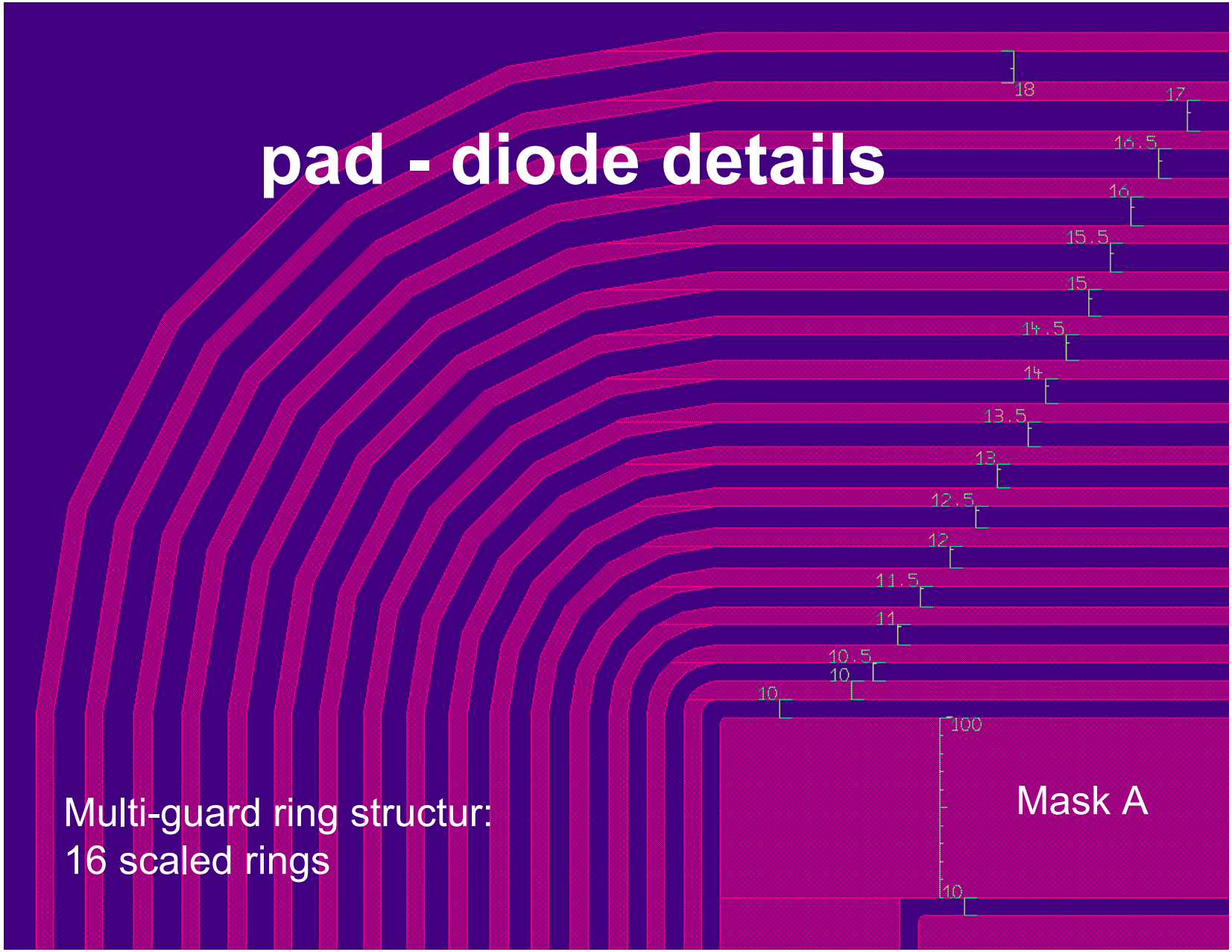
Mask E:
passivation opening



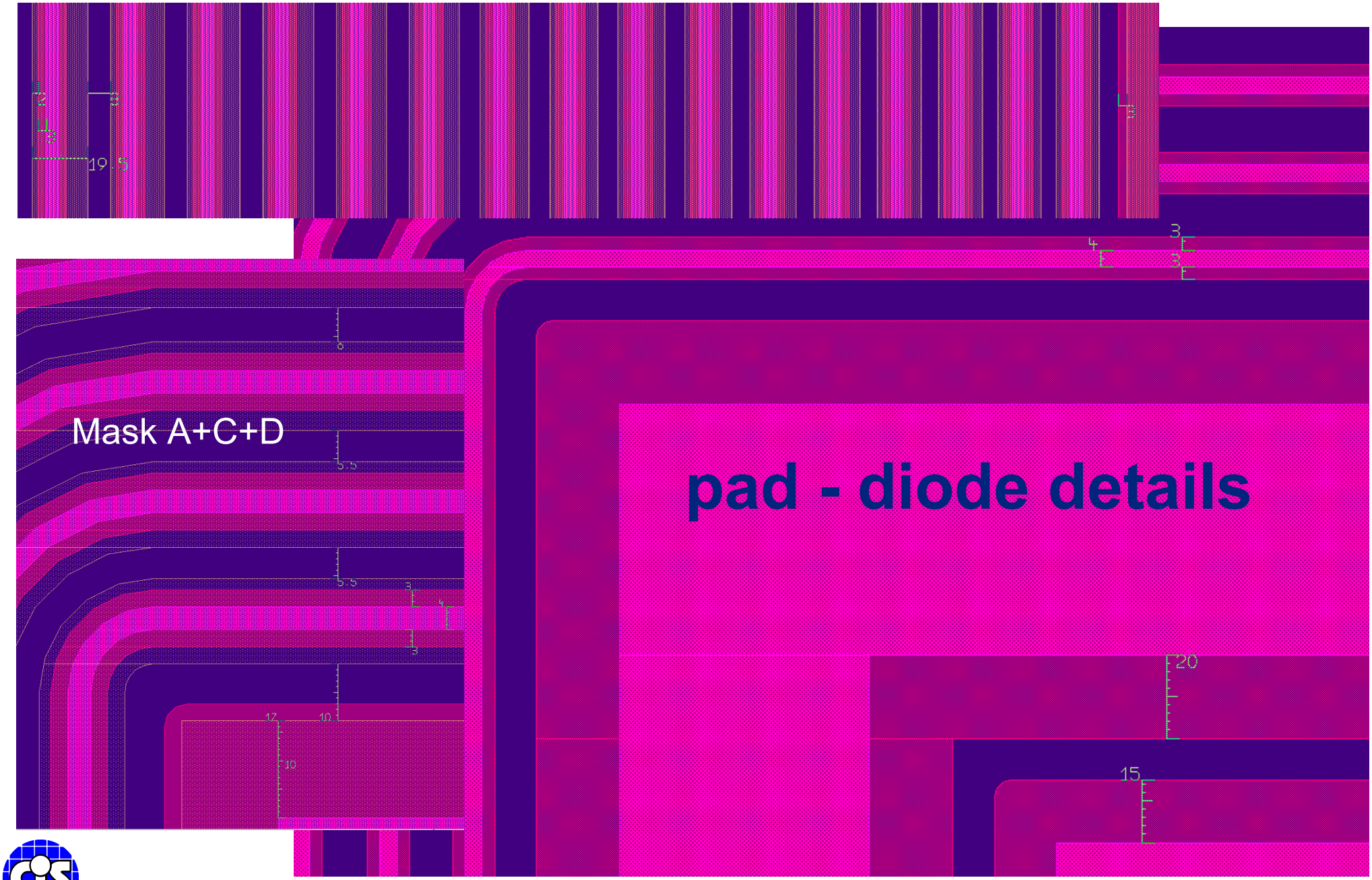




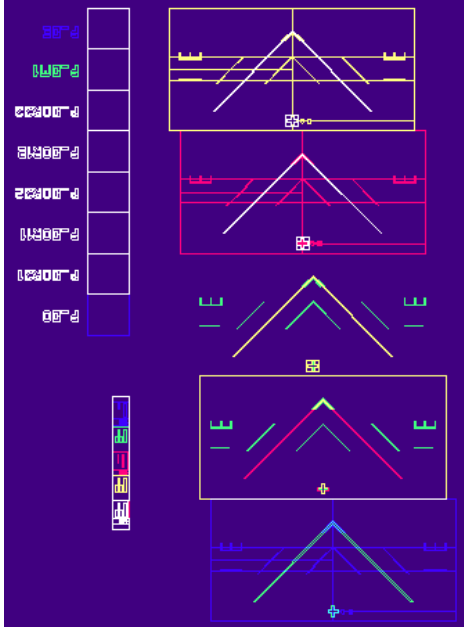
pad - diode details

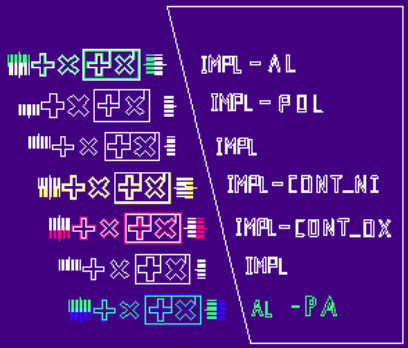


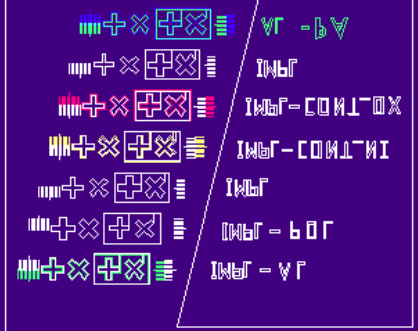
Multi-guard ring structur:
16 scaled rings


Mask A+C+D
pad - diode details

Structures
for automatic alignment

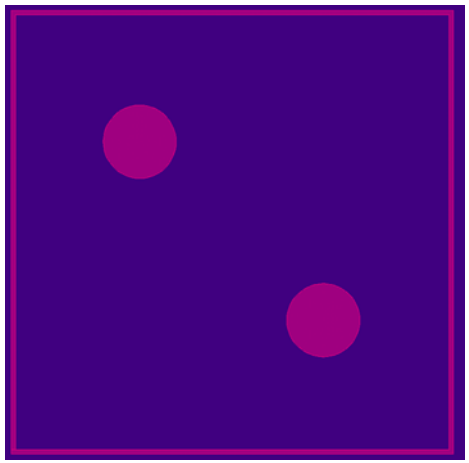




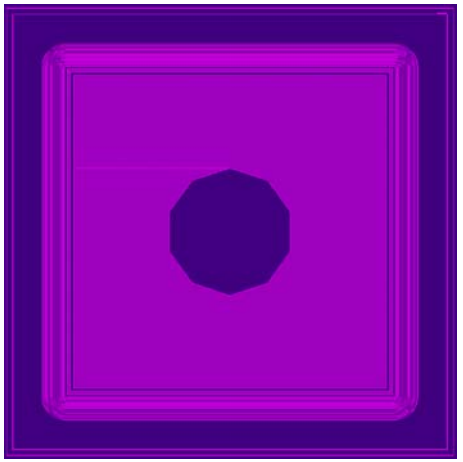


Optical control
strucures
of mask alignment

Test structures details

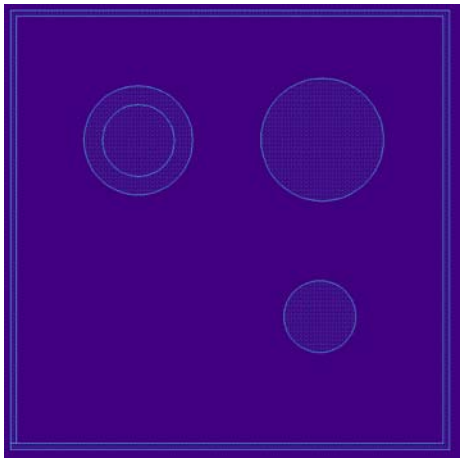


Mask A:
borus implantation

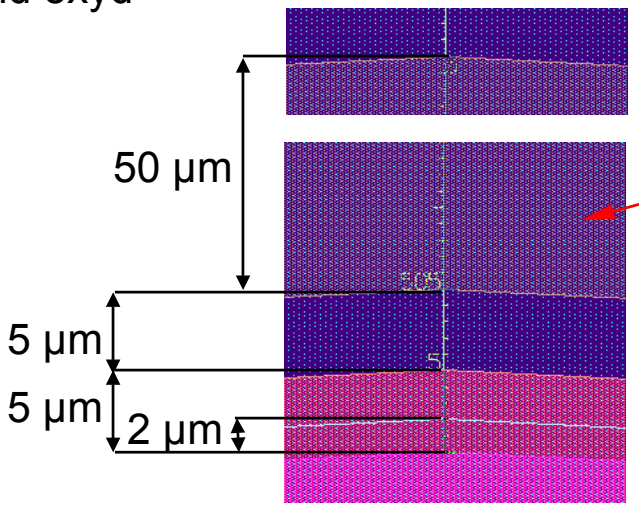


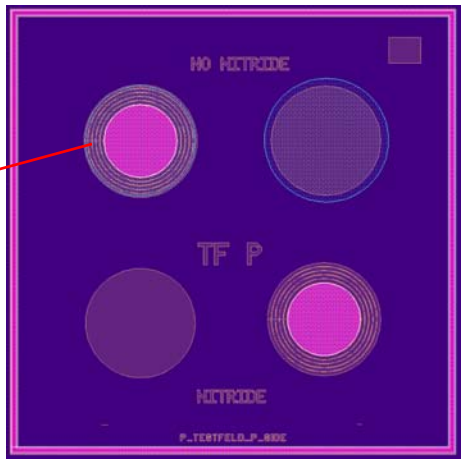
Mask C:
contacts
opening of field oxyd

Mask D:
metal AlSi 1 µm

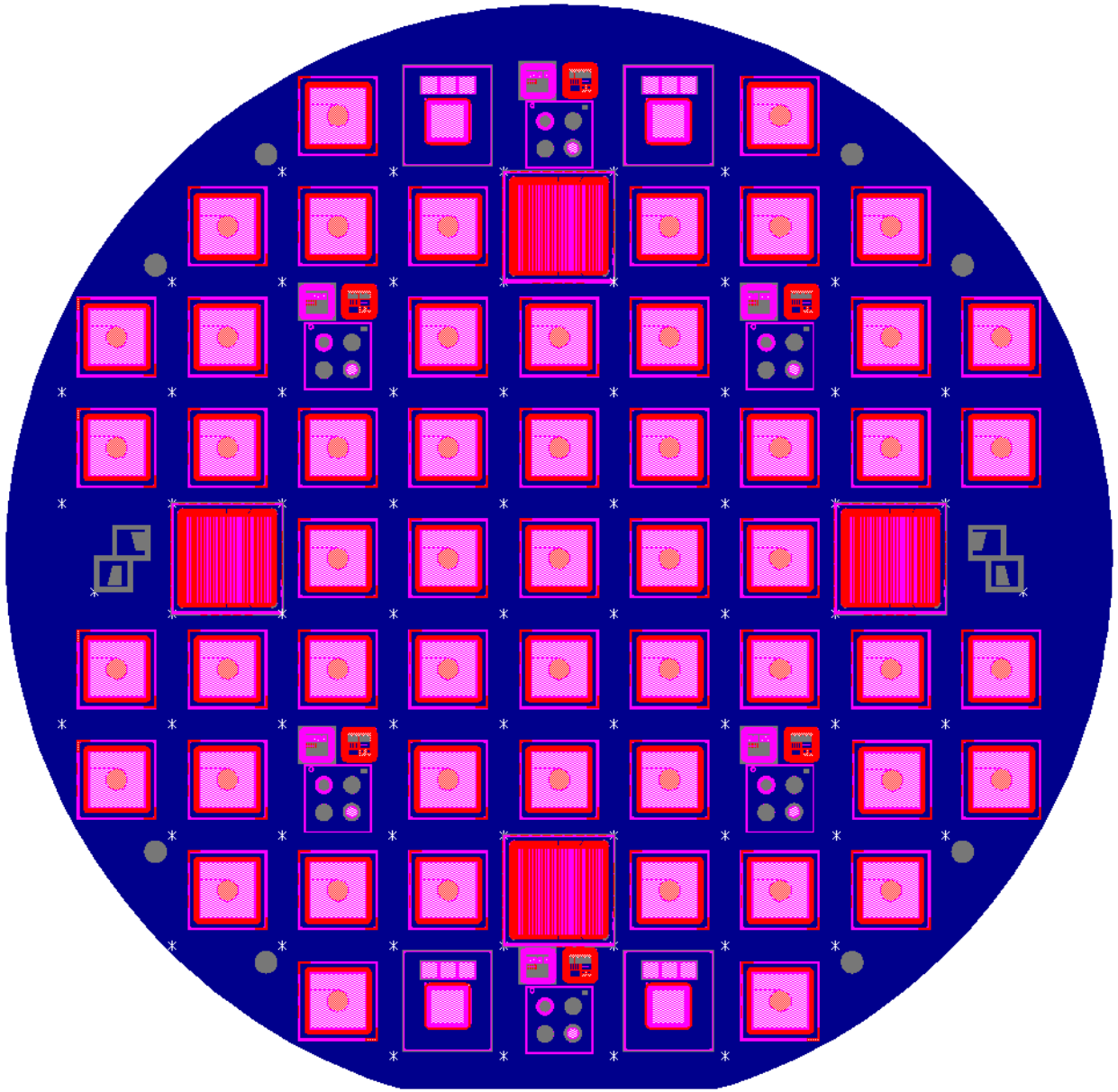


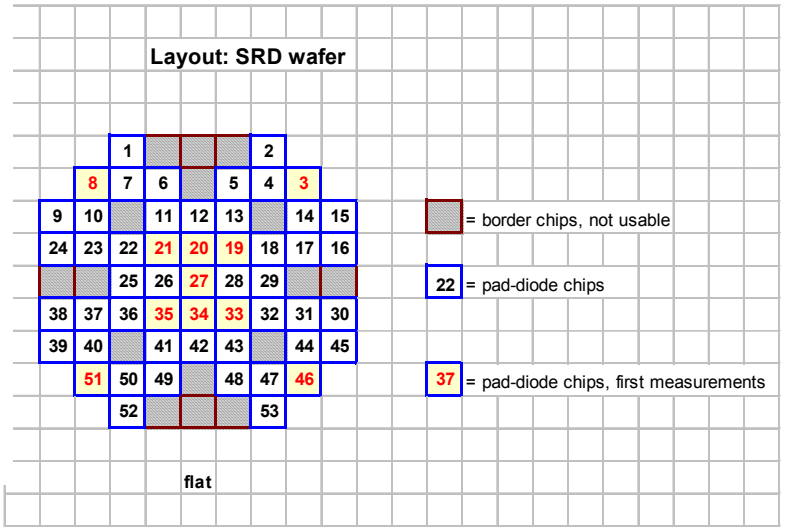
Mask E:
passivation opening





Test wafer SDTW01-2





SRD - test wafer program 2000 - 2002

	n/P, FZ <100>, 1-6 kOhmcm (Wacker)	n/P, FZ <111>, 1-6 kOhmcm (Wacker)	n/P, FZ <111>, 4-7 kOhmcm (Topsil)
Standard	26 wafer	28 wafer	6 wafer
DOFZ 24h	22 wafer	22 wafer	
DOFZ 48h	18 wafer	18 wafer	
DOFZ 72h	24 wafer	24 wafer	12 wafer

	highohmic CZ >600 Ohmcm (Sumitomo)	CZ+epi
Standard	48 wafer	9 wafer

Used technology:
like
ATLAS WEDGE
W12

Next steps:
- MCZ
- CZ+epi
- FZ <111>, 3-4 kOhmcm

Results of processing of SRD and oxygen enriched ATLAS detectors (> 250 wafer) (ca 900 wafer)

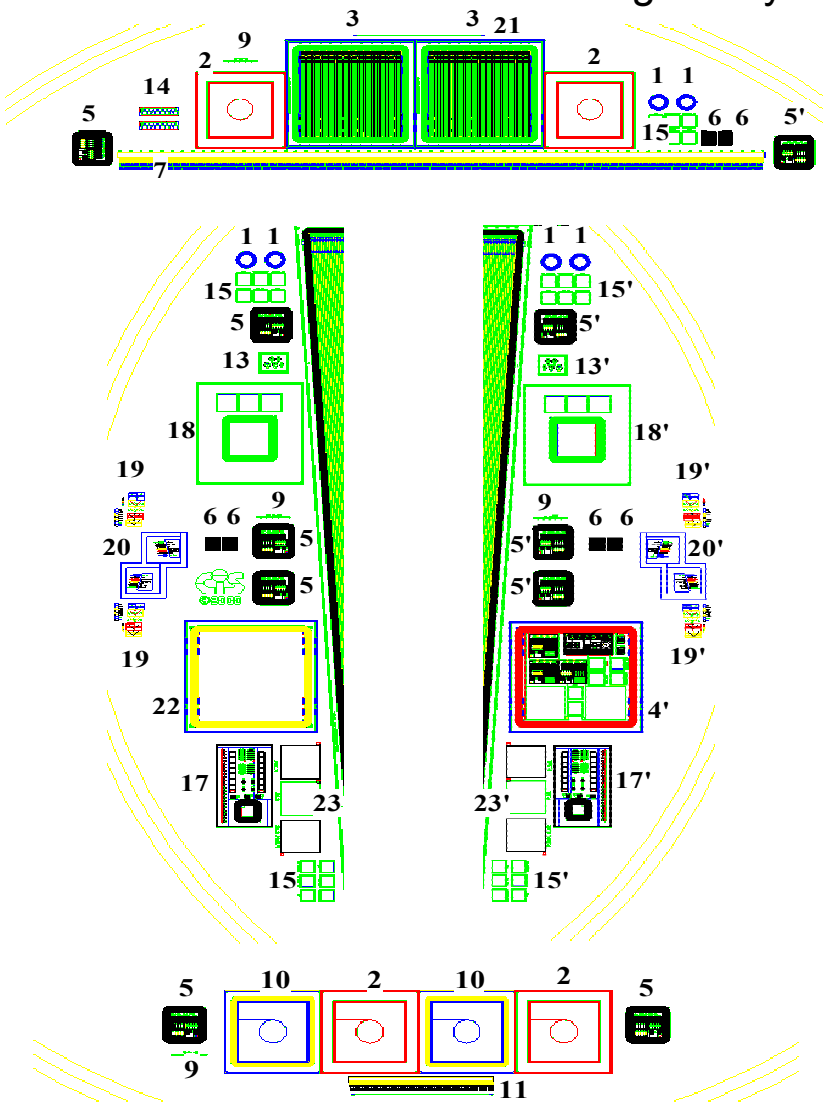
- We have recognized:
  - quality and yield of the DOFZ detectors fundamentally depends of
    - charge of the wafer delivery (manufacturer/distributor, ingot [region])
      - for example: since 2002 Wacker wafer have saled by Wafernet -> significant deterioration (for STFZ wafer it was far less important)
    - grinding and polishing of the wafers has also a basic influence
      - surface defects, metal contaminations by grinding and polishing pastes
    - the effects of different behavior of various wafer zones (ca 3“ center, outer zone)
      this effect we have seen particularly at DOFZ wafers
  - high ohmic CZ wafers from Sumitomo: two strongly different qualities
- Thesis: denuded zones play a important rule
  in respect of wafer processing
  => defect engineering in various layers
  could be conceivable, advisable

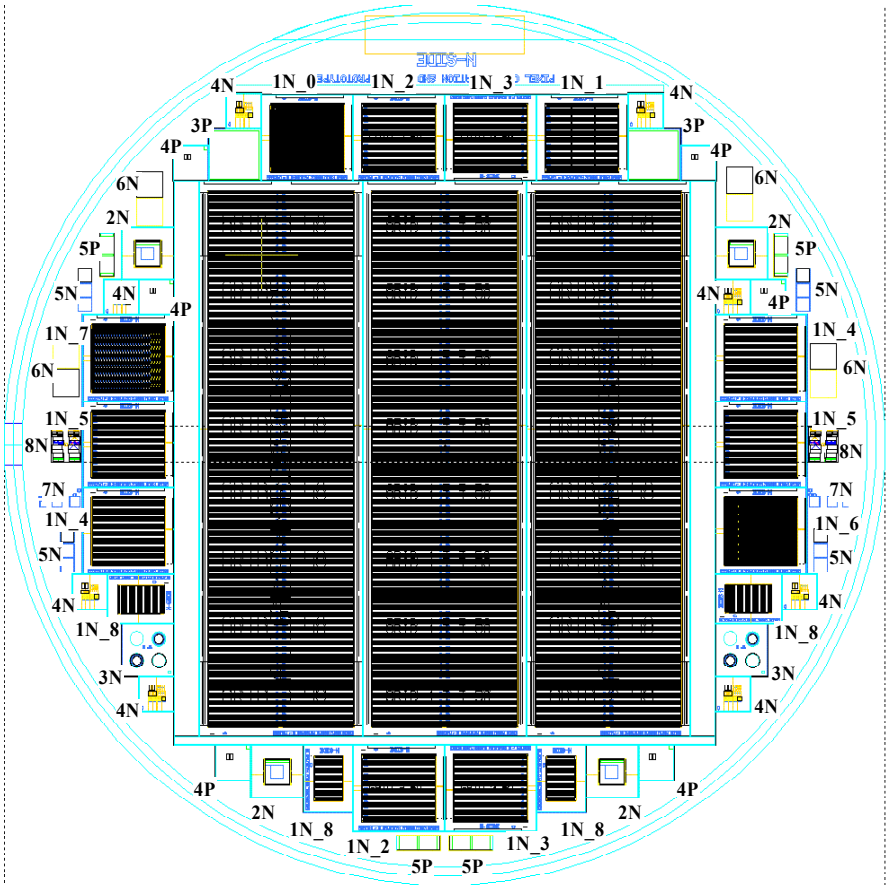
What CiS can offer for Rd50?

- Prozessing of wafers for R&D
  - HCZ/MCZ, STFZ, DOFZ.
  - oxygen enhancement by high temperature diffusion (1150C, N2, 16 - 72 hours; if necessary also longer temper times for R&D
  - double side prozessing, structuring of back side metalization (mesh)
- some additional services:
  - sawing, bonding (US, thermo compression, stud bumping), mouting & hausing
  - mask design, mask set (fabrication by ML&C Erfurt)
  - test structure design
- "bad" wafers of detector production, for instance ATLAS PIXEL and ATLAS WEDGE (if the ATLAS calloboration / CERN agrees):
  - 24 hour DOFZ - pad-diodes, mini strip-detectors, test structres (gated-diodes,...) perhaps "one tile" - pixel wafer (n/P, <111>, 2 - 5 kOhmcm)

ATLAS Test structures

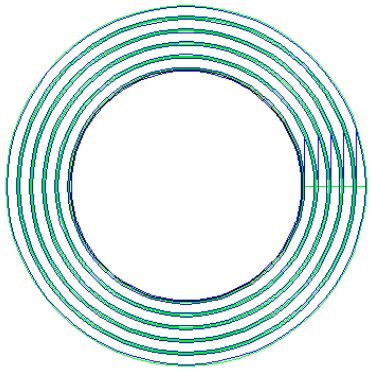
designed by MPI Halbleiterlabor Munich





gate controled diode:

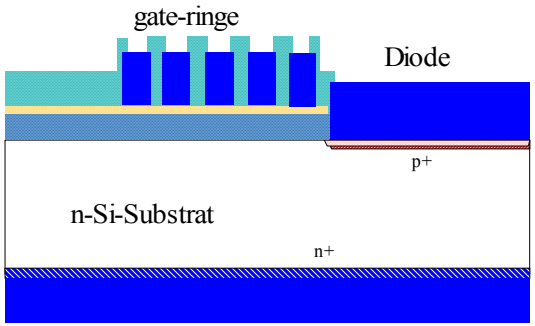
kreisförmige Diode (∅=1mm),
ganzflächig geöffnet und mit Metall bedeckt
umgeben von 5 Metallringen auf Feldoxid und Nitrid



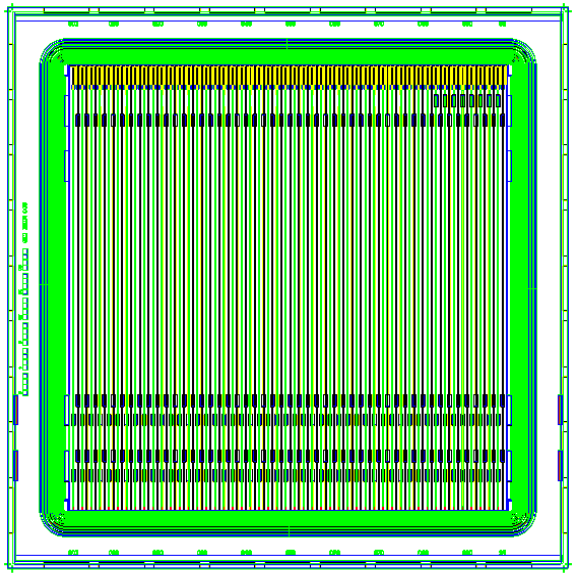
Gruppe: TEST_DO

ws: p+ - Diodengebiet ∅=1mm
ganzflächig kontaktiert: Kontaktloch rt: ∅=1mm
Metall: gn: ∅=1,01mm über der Diode und 5µm über A-Kante
mit bias- p- Implamntation: ∅=1,004mm
Passivierungsöffnung: ∅=0.99mm (5µm von A-Kante entfernt)

5 Metallringe auf 300nm Feldoxid und 50nm Nitdrid
Breite der Ringe je 50µm, Abstand 5µm
Passivierungsöffnung mittig und 40µm breit



BABY_DET_CIS

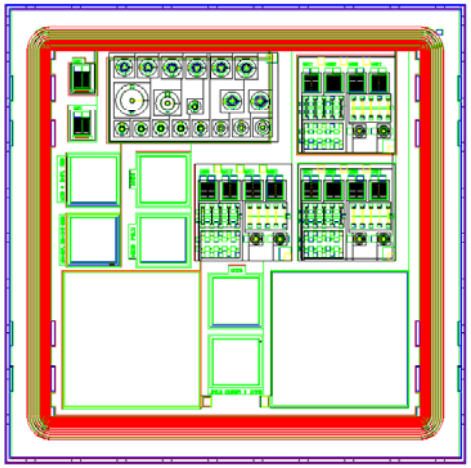


98 parallele Streifen mit integriertem bias-Widerstand (ge,am oberen Ende der Streifen) und Auslesekondensator analog W21-Detektor

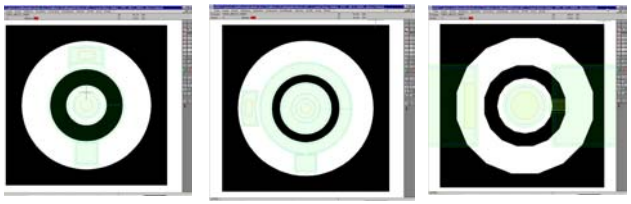
- Länge der p+ -Gebiete 7.99mm, Breite 18µm,
- umlaufend um p+ -Streifen mit 0.1µm Abstand p-Bias-Implantation mit 2.7µm Breite
- Abstand der Streifen (p+ -Gebiete): 62µm
- Kontakt zu p+ je am oberen und unteren Ende der Streifen (Metall: 65x75µm^2 oben, 18x40µm^2 unten)
- Auslesekondensator Metall über p+ auf Implantationsoxid und Nitrid Länge 7,508mm, Breite 19µm (mit je 3 Pads, unten 2 und oben 1, Metall 69x213µm^2):
-

Guard-Ring_Struktur wie W21-Detektor, die bias-Widerstände laufen gegen den bias-Ring, der, oben links und rechts neben den Pads der Auslesekondensatoren kontaktiert werden kann.

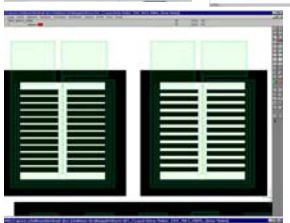
TEST_MULTI_PURPOSE



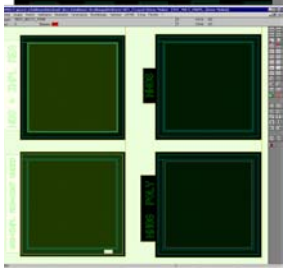
Oben-Mitte: kreisförmige Dioden mit umlaufender Guardringdiode in unterschiedlichen Abständen (Detailbild-**A**) und MOS-Trasistoren (**B**)
Oben-rechts und Mitte/Mitte-rechts: 4-Draht-Messung p+ -Streifen 4,10,20,30 und 40µm Breite, 2-Draht-Messung bias-Streifen 5.2, 11.2, 21.2, 31.2 und 41.2µm, kreis-förmige Dioden mit umlaufender Guardringdiode und bias-Brücke (**C**), oben: Kammförmig Diode mit Metallabdeckung für die Untersuchung der Beeinflussung der Randeigenschaften der Diode durch eine Oberflächenladung auf dem Oxid (**D**)
Oben-links: Kammdiode ähnlich Oben-rechts
Mitte-links: MOS-Strukturen (**E**)
unten-links: Metall über p+ und bias-Impl auf Impl-Oxid ohne Nitrid
unten-rechts: Metall über p+ auf Impl-Oxid mit Nitrid
unten-mitte: Metall und Metallring über Substrat auf Feldoxid+Nitrid (oben) und mit Metallring mit kl. p+Gebiet zum absaugen der generierten Löcher (unten)



von links nach rechts:
Detailbild A, B, C



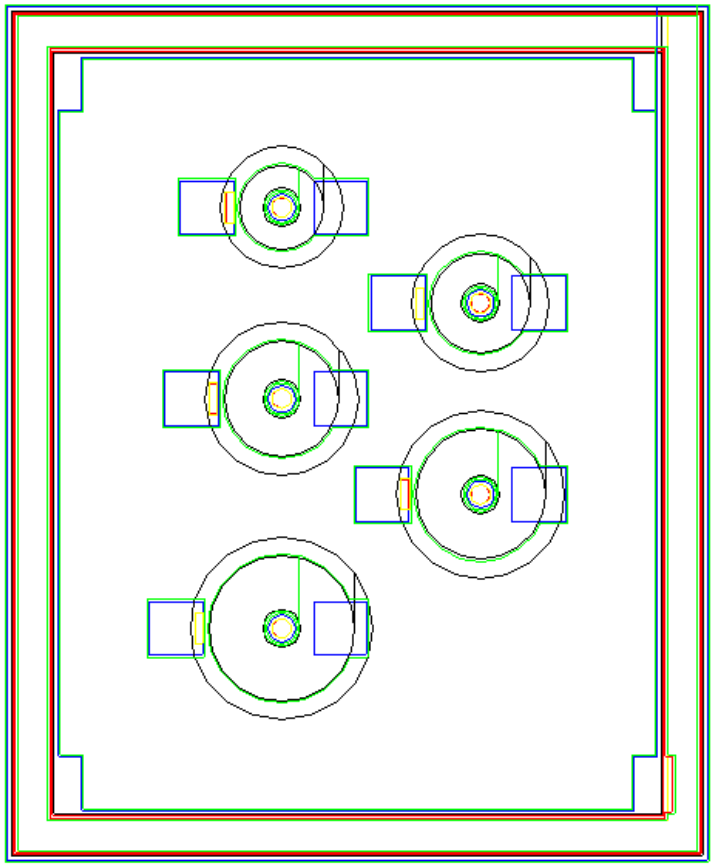
Detailbild D



Detailbild E:
oben links: Metall über bias-Implantation auf Feldoxid mit Metallring über Substrat auf Feldoxid+Nitrid
oben rechts: Metall über Substrat auf Feldoxid+Nitrid mit Metallring über Substrat auf Feldoxid+Nitrid
unten links: Metall und Metallring über bias-Implantation auf Feldoxid Metallring mit kl. p+ -Gebiet
unten rechts: Metall über Substrat auf Feldoxid+Nitrid mit Metallring über Substrat auf Feldoxid+Nitrid (C???)

ts_most_p_csem

5 MOS-Transistoren mit unterschiedlichen Gatelängen

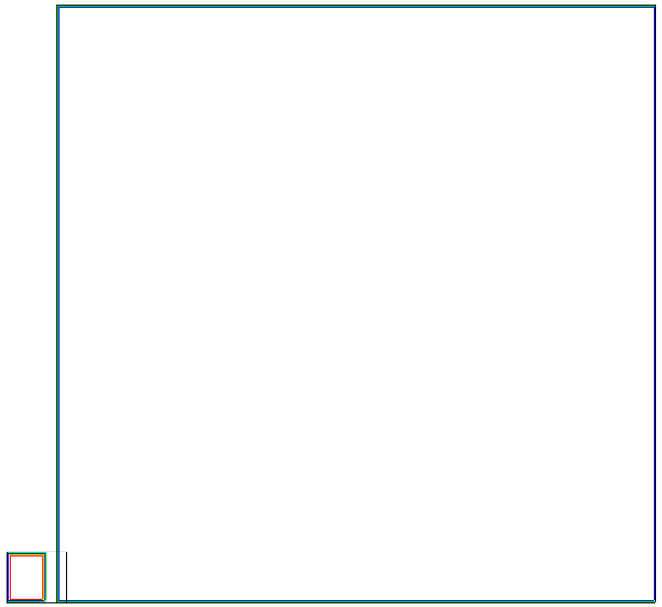


MOS_block

oben links/ unten rechts: Metall 1x1mm^2 und Metallring (Breite 60µm, Abstand 10µm) über Substrat auf Feldoxid + Nitrid

oben Mitte: Metall 1x1mm^2 und Metallring (Breite 60µm, Abstand 10µm) über Substrat auf Feldoxid + Nitrid
Metallring , Metallring ist mit kl. p+ -Gebiet bebunden, um in tiefer Verarnung Minoritäten abzusaugen
oben rechts: Metall 1x1mm über bias-Implantation (nicht kontaktiert !) auf Feldoxid und Metallring auf Feldoxid+Nitrid: (Serienschaltung MOS und bias-Impl.-Diode)
unten links: Metall 1x1mm und Metallring über bias-Implantation auf Feldoxid Metallring. Metallring ist mit p-bias –Implantation verbunden
unten Mitte: Metall 1x1mm über Substrat auf Restfeldoxid (C im Feldoxid) und Metallring auf Feldoxid+Nitrid

ts_nioxbreak_p



MOS-Struktur: Metall (2.99x2.99mm^2)
über p+ - Gebiet auf Implantationsoxid + Nitrid

Metall ist ganzflächig geöffnet
Das p+ - Gebiet ist unten-links kontaktierbar

RD50 additional remarks

- Common mask set vs. CiS projection lithography
- Technology key parameters may be coordinated:
  - implant dose
  - annealing parameters
  - process variations of lateral structures (distortion, undercutting, ...)

Our next R&D projects

- Super Radiation Hard Silicon Detectors (Surad)
  - wafer concept: DOFZ, CZ + epitaxial layers (perhaps variation of the epi-layer thickness resp. resistivity)
  - defect engineering
    - oxygen, carbon, hydrogen, ...
    - zone engineering (denuded zone engineering, bulk layers with various defect concentration [especially oxygen])
    - studies of precipitations: perhaps making of free zone of [O]-precipitations
  - optimalization of process parameters + processing steps vs. behavior
  - problem: epi-layer double-side devices
  - Monitoring wafer: various test resp monitoring structures:
    - radial distribution of the behavior of some electrical parameters
- Analysis by Hamburg University, MPI Halle, ?
- Microskopic analysis (microstructure also in bulk: HREM, ...) of wafers bevor and after various processing steps