

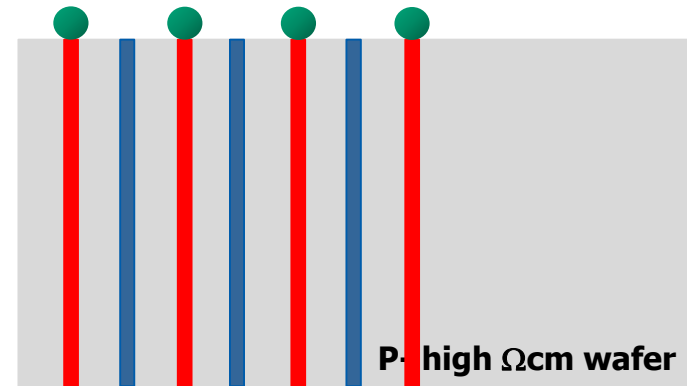
3D silicon sensors at FBK: first results on the last production

Sabina Ronchin

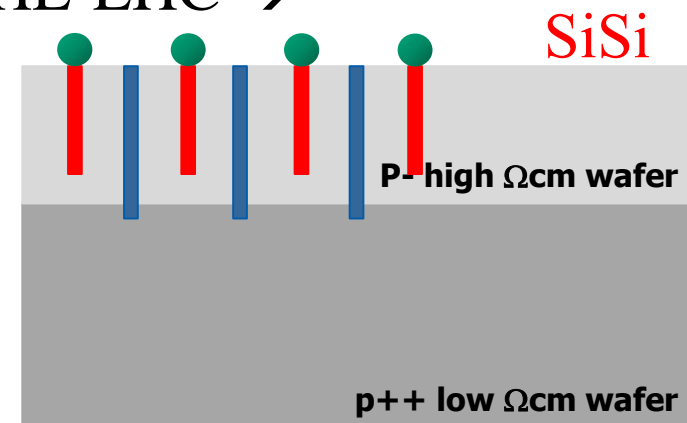
On behalf of the INFN (ATLAS - CMS) - FBK Pixel R&D
Collaboration and WP7 - AIDA-2020

Si3D technology at FBK:

- Double-side 3D, produced by FBK for IBL →
 - 4 inch Fz wafers
 - 230 μm thick
 - “large” electrodes ($12\ \mu\text{m}$)

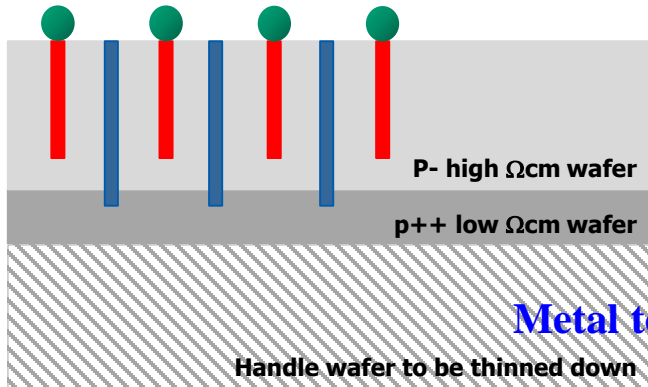


- New single-side 3D technology/design for HL-LHC →
 - 6 inch Si-Si and SOI wafers
 - thinner sensors ($100\text{-}150\ \mu\text{m}$)
 - narrower electrodes ($5\ \mu\text{m}$)
 - reduced inter-electrode spacing ($\sim 30\ \mu\text{m}$)

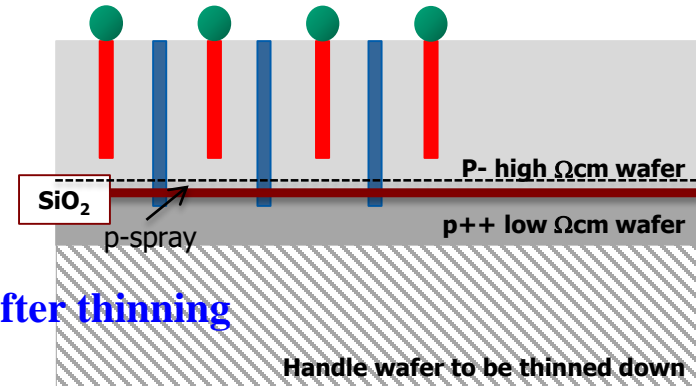


New single-side approach to 3D pixels

Si-Si DWB



SOI

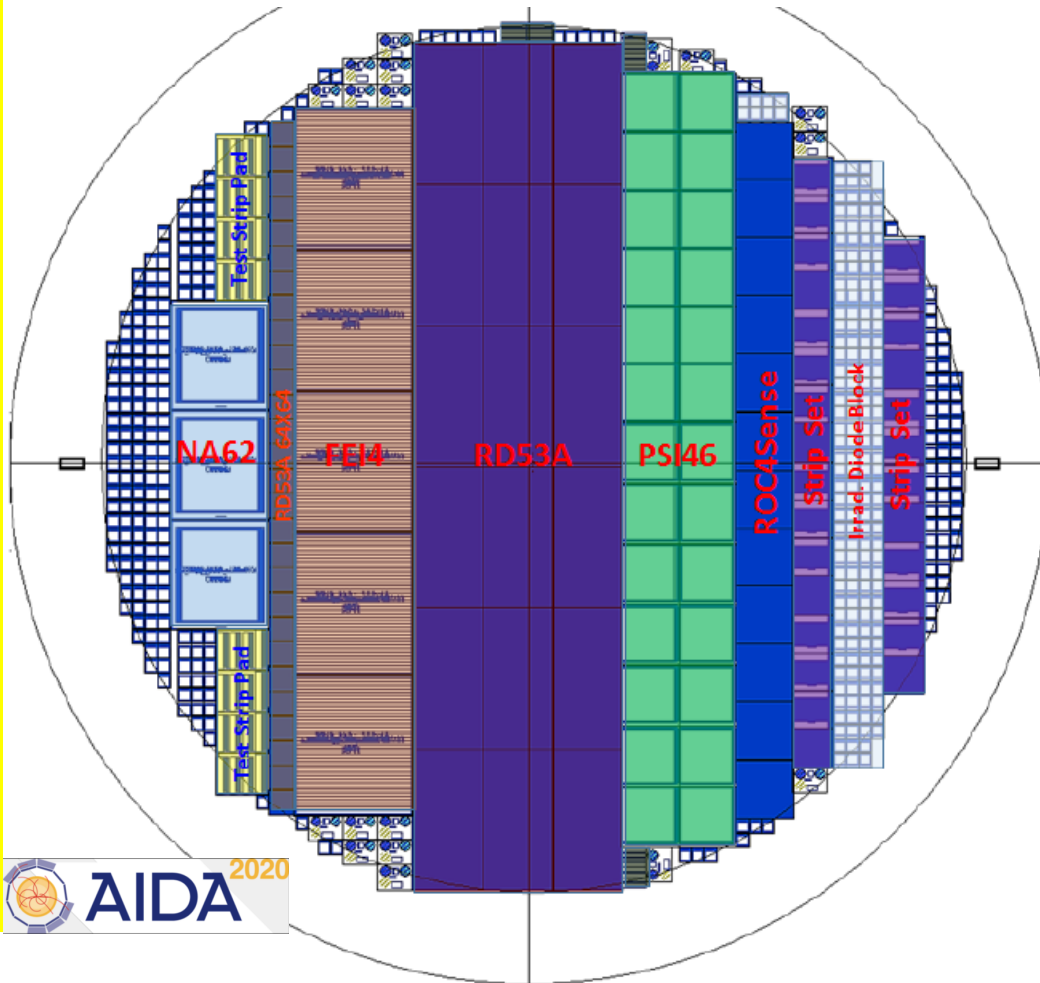


Metal to be deposited after thinning

- Thin sensors on support wafer: SOI and Si-Si
- Target active layer thickness: 130-150 μm
- Ohmic columns depth $>$ active layer depth (for back side bias)
- Junction columns depth $<$ active layer depth (for high V_{bd})
- Hole diameters 5 μm
- Holes (partially) filled with poly-Si

3D Pixel Wafer

- SiSi DWB and SOI
- Active thickness: 130 μm

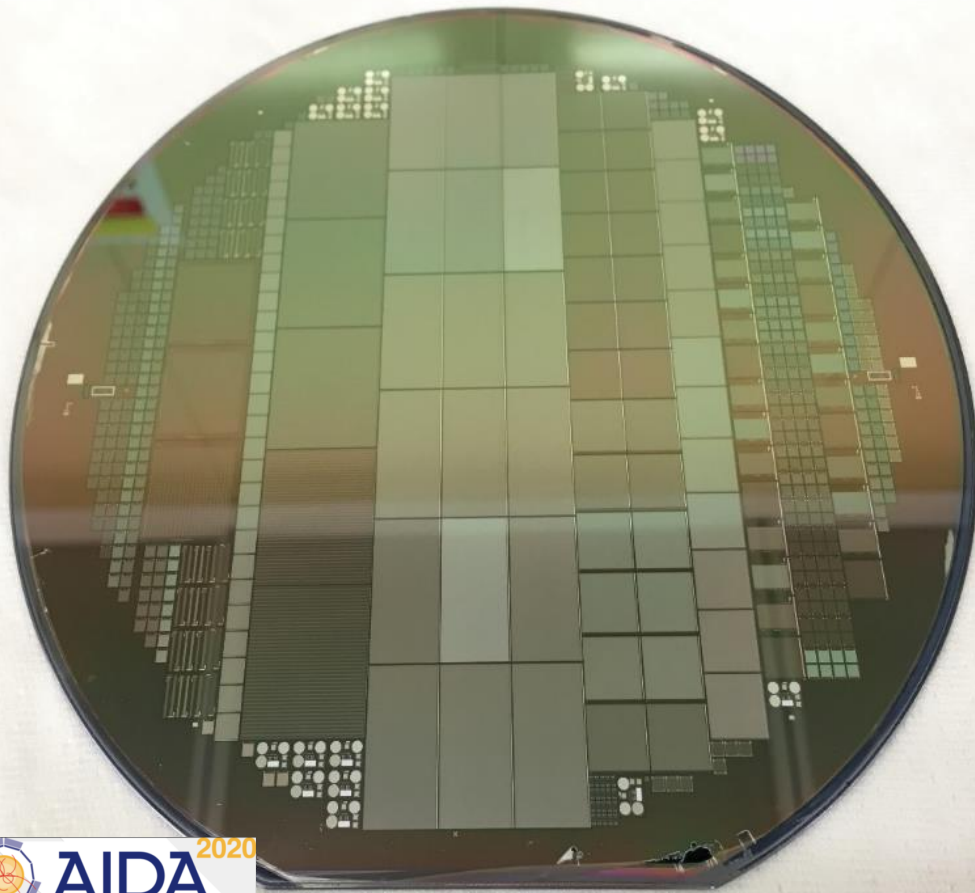


- **FE-I4**
 - 50 x 250 (2E) std
 - 50 x 100 (1E+9E)
 - 50 x 50 (5E)
- **PSI46dig (also with BOC option)**
 - 100 x 150 (2E and 3E) std
 - 50 x 50 (1E)
 - 25 x 100 (1E and 2E)
- **R4S**
 - 50 x 50 (1E)
 - 25 x 100 (1E and 2E)
- **RD53A (also with BOC option)**
 - 50 x 50 (1E)
 - 25 x 100 (1E and 2E)
- **CHIPIX65**
 - 50 x 50 (1E and 2E)
 - 25 x 100 (1E and 2E)
- **NA62**
 - For timing studies

3D Pixel Wafer

- SiSi DWB and SOI
- Active thickness: 130 μm

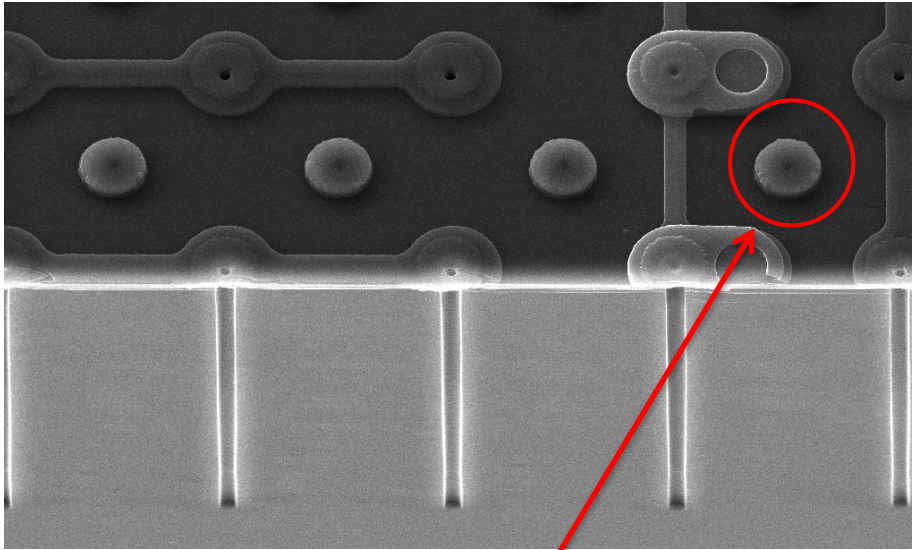
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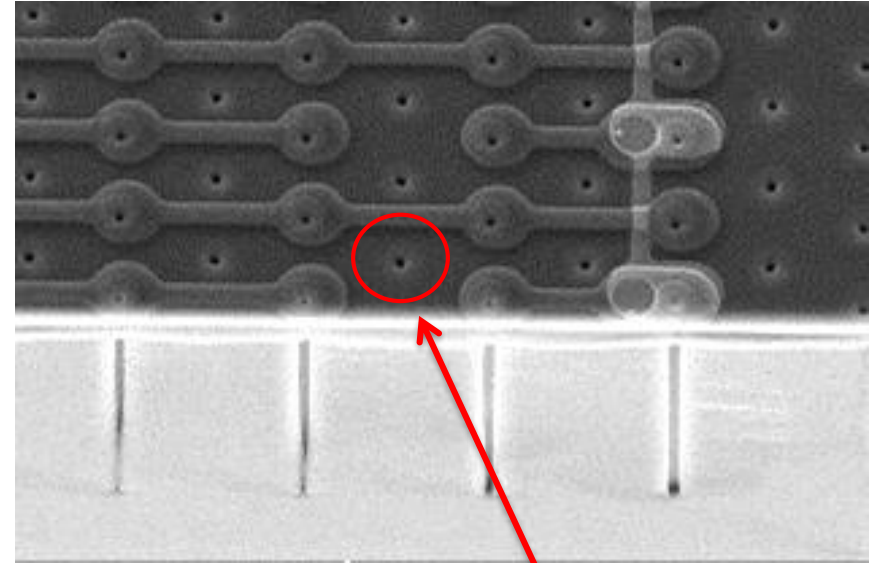
Project AIDA-2020 and INFN-FBK "RD_FASE2"



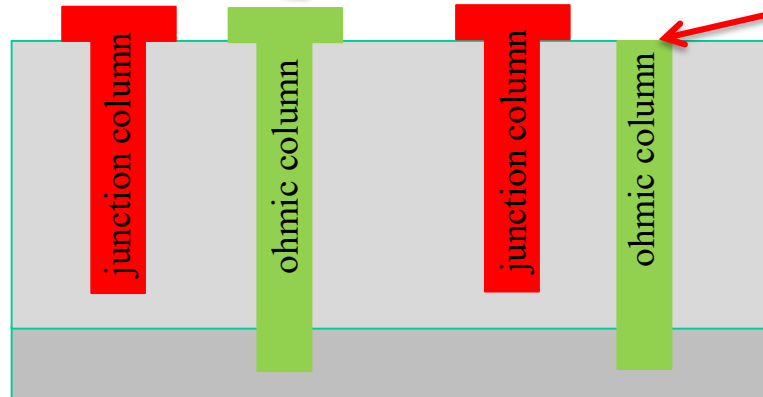
Poly cap splitting – SEM images



Ohmic column
with poly cap

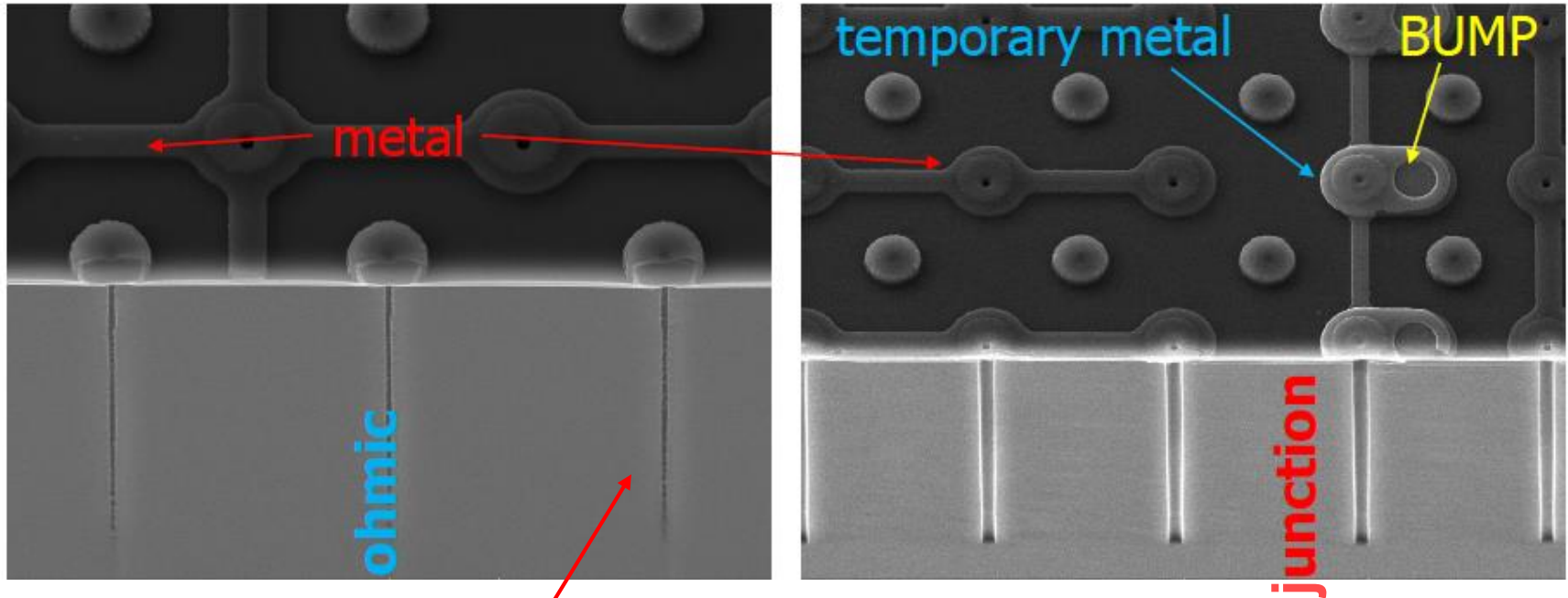


Ohmic column
without poly cap



- ⇒ Reduction of one mask
- ⇒ Increase the effective «distance» between poly and metal

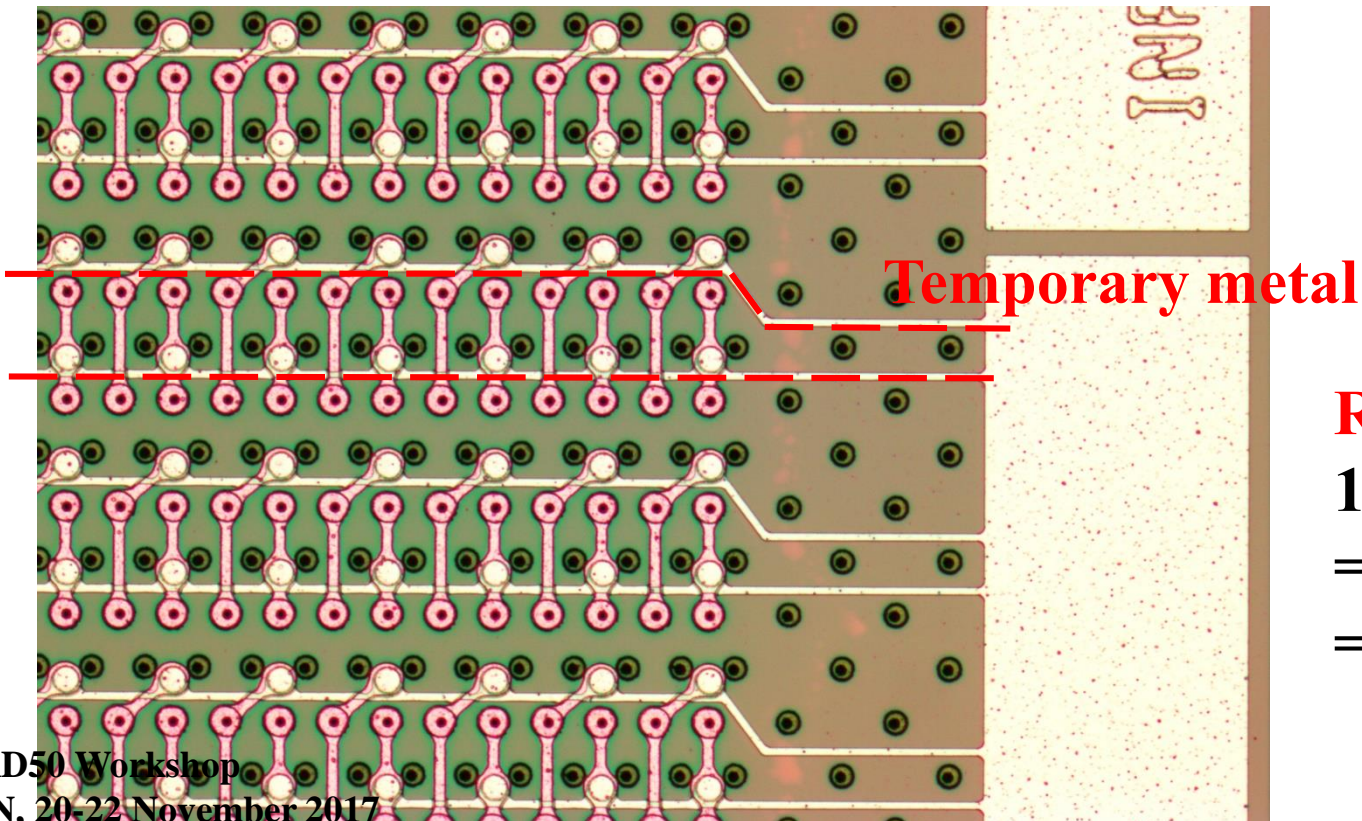
Metal and columns – SEM images



Partially filled
with poly-Si

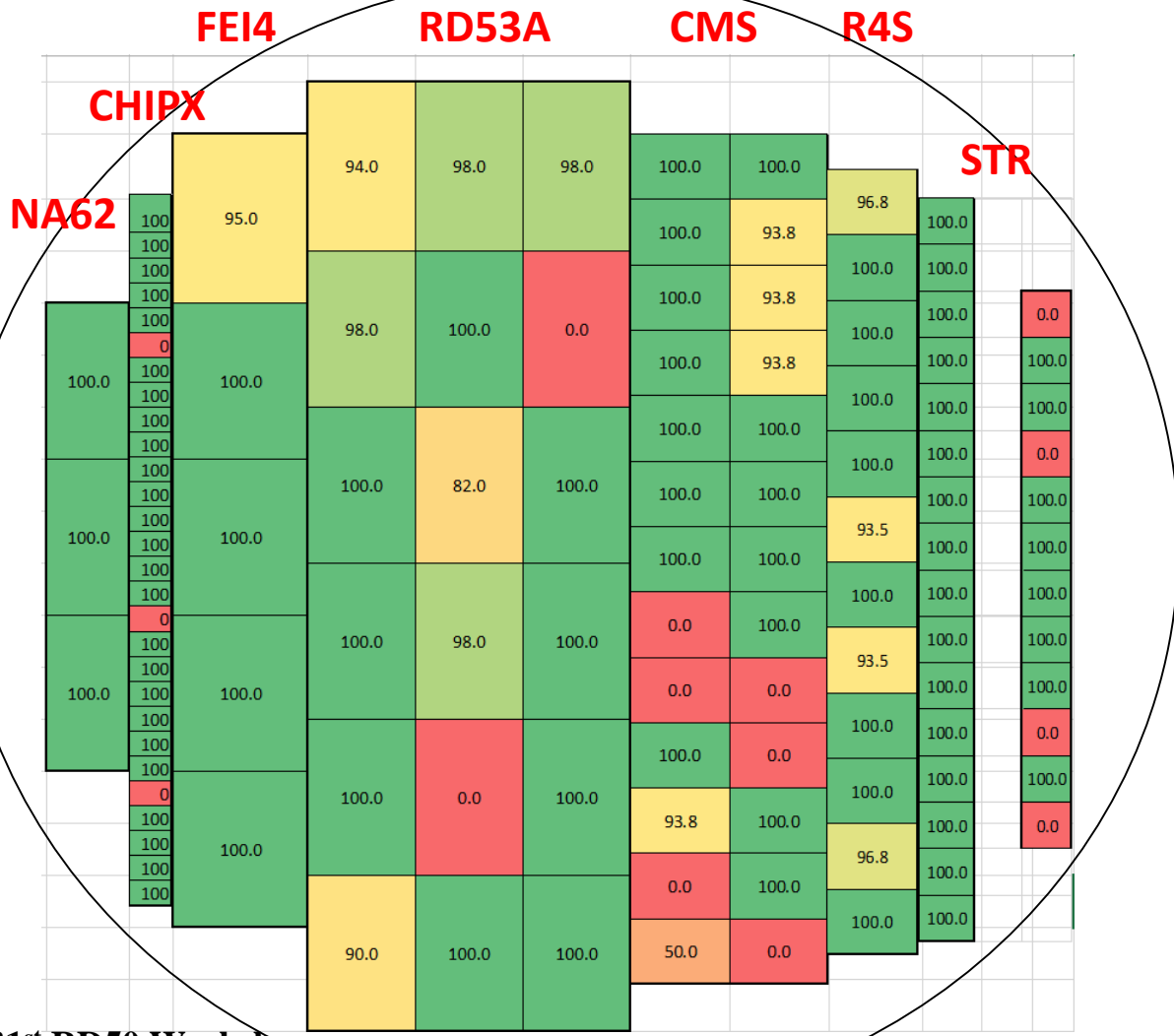
Temporary metal for tests on pixels

- A lot of pixels are shorted together in a “strip” like row by temporary metal
- Total currents is a sum of all single-row
- Temporary metal removed after testing



RD53A 2E:
1channel
= 8 strips
= 3072 holes

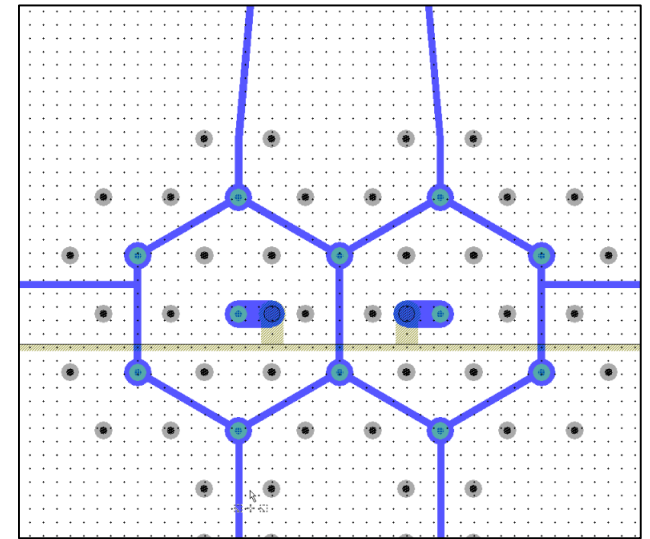
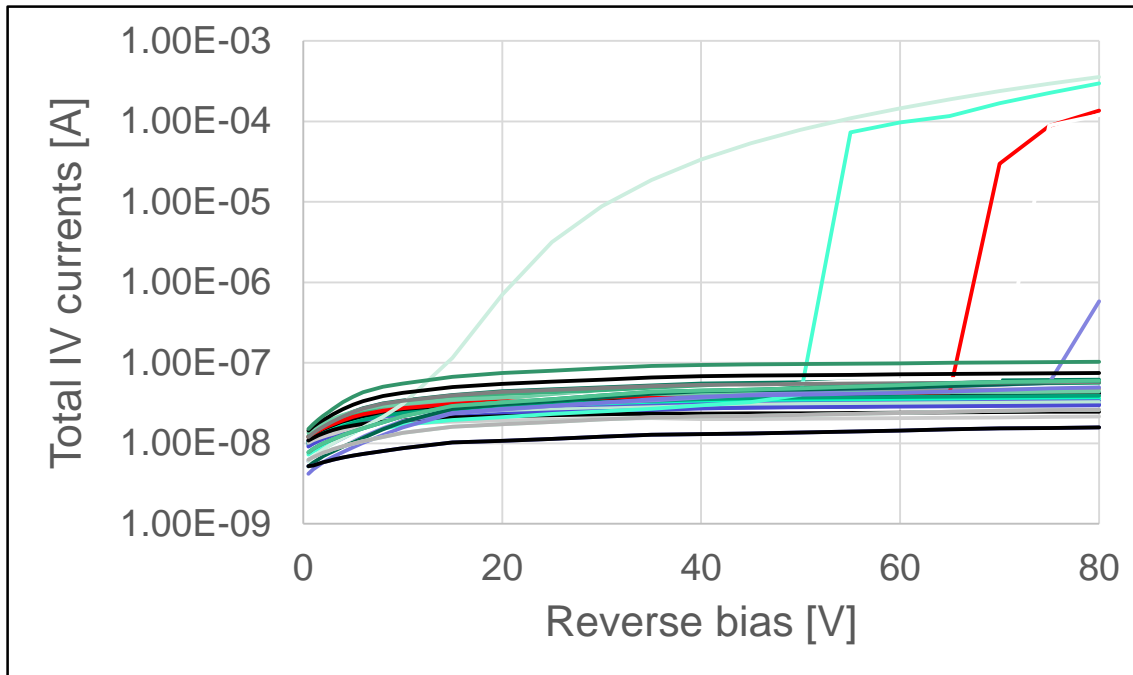
Strip yield map on one wafer (w03)



Strip yield=
% of strips with a
leakage lower than
20 nA

- ⇒ Several designs with a good yield!
- ⇒ Some designs are critical

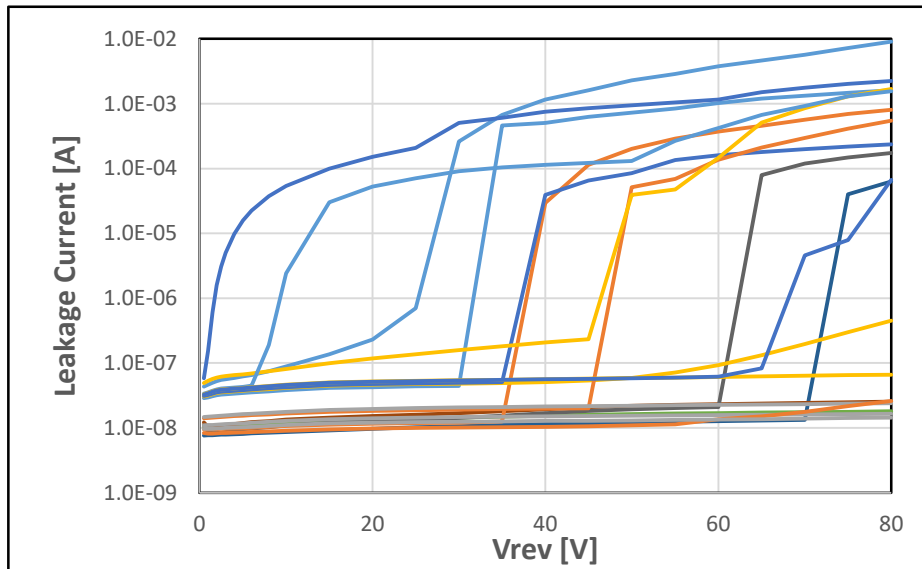
Na62 total IV characteristics for all devices on all wafers



 **For this layout the process yield is close to 100%!!!**

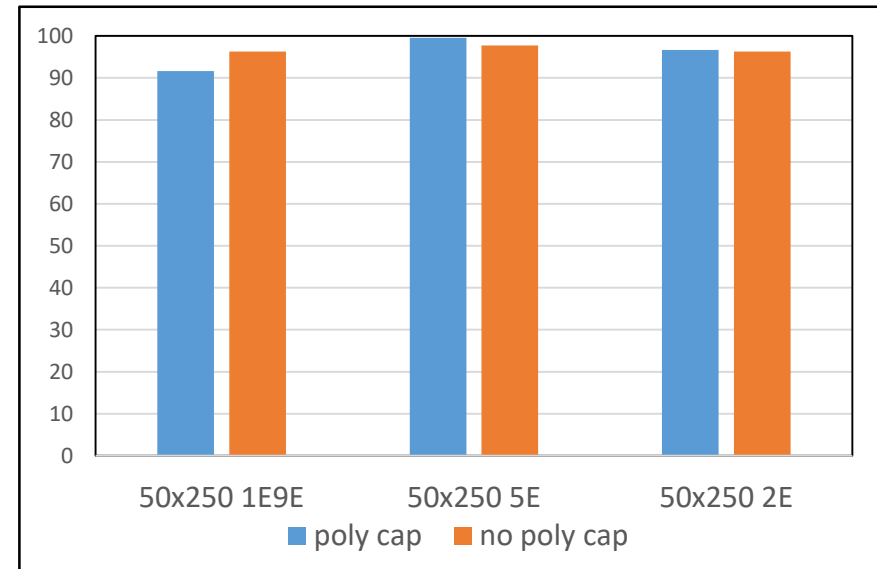
FE-I4 IV Characteristics and strip Yield [%]

FEI4 – IV Total currents on 20 sensors



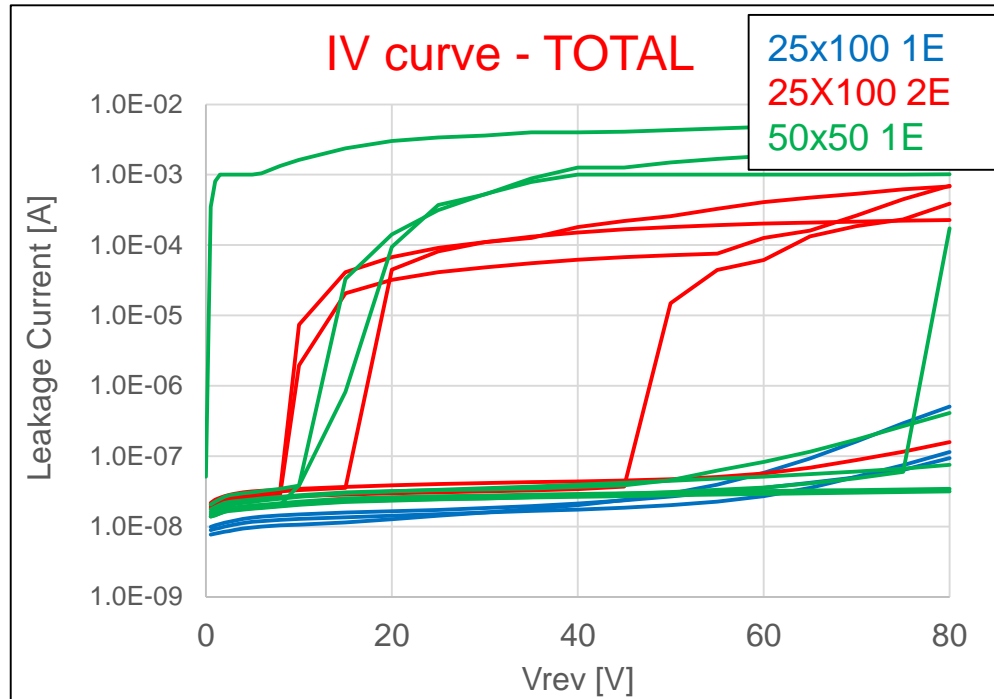
Several working sensors have been realized

"strip" yield% of ALL FE-I4

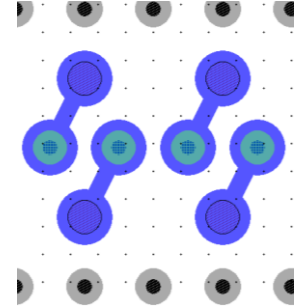


The % of «strips» with a leakage lower than 20 nA is **higher 90%**

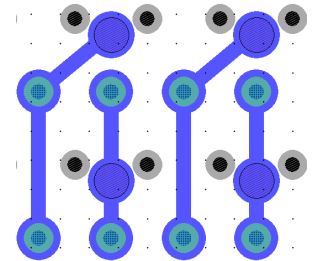
Total IV characteristics for 18 RD53A devices (W3)



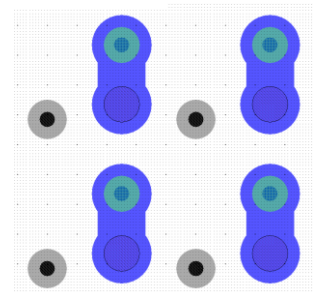
25x100 1E



25X100 2E

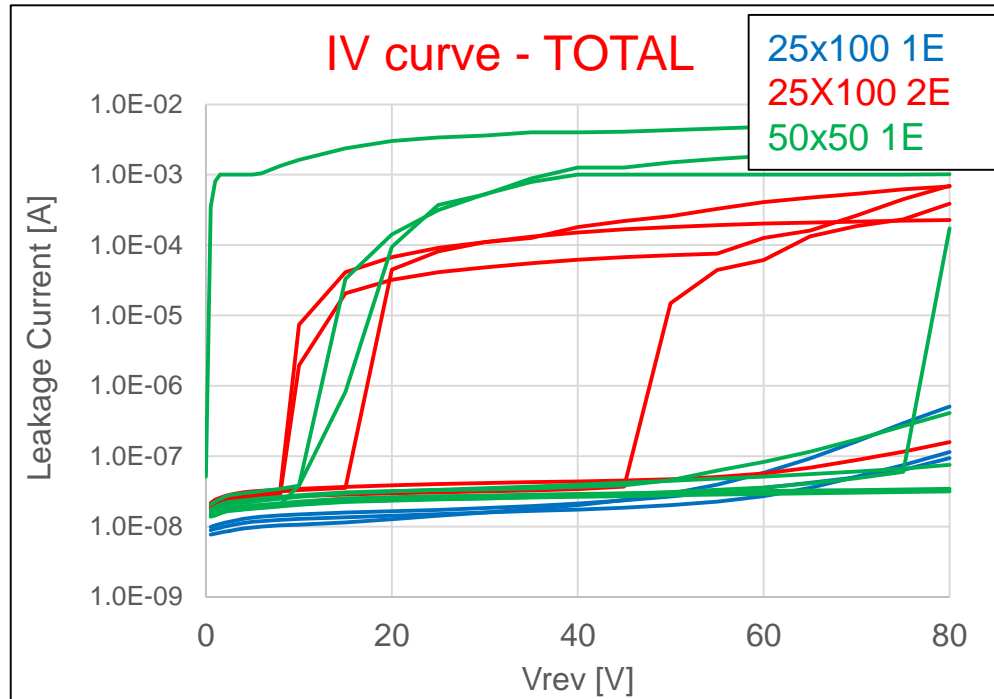


50x50 1E

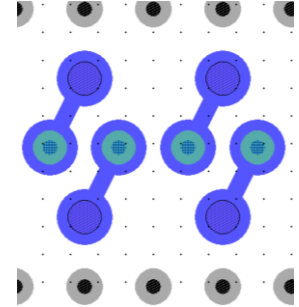


- Several working sensors are present
- It is confirmed that the 25x100-2E design is critical

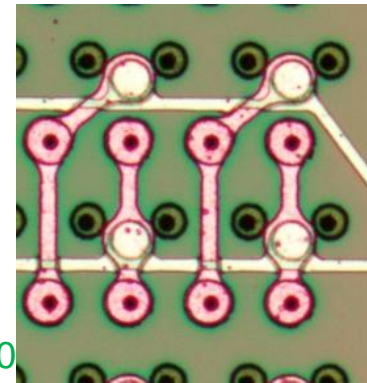
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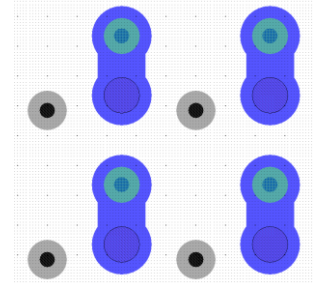
25x100 1E



25X100 2E

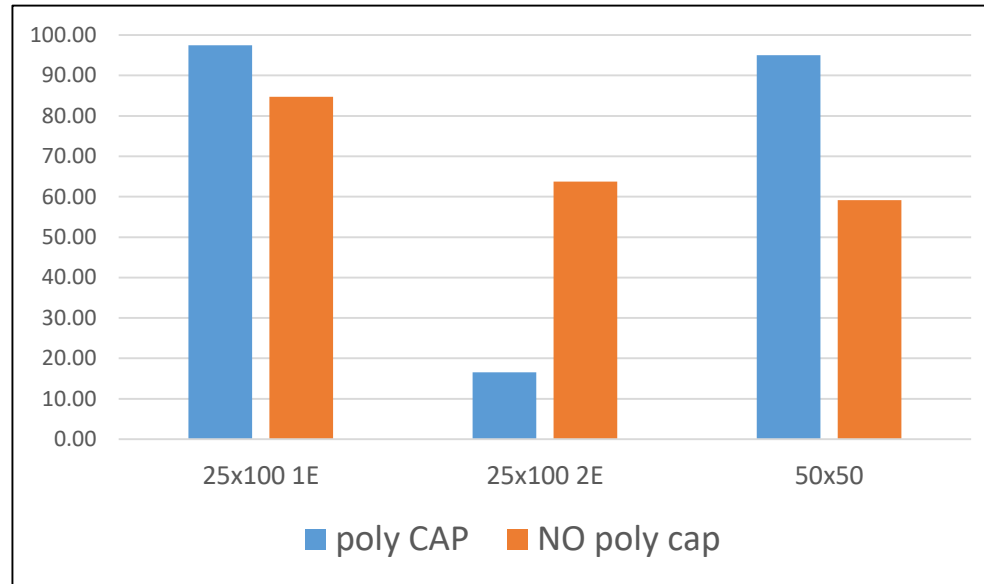


50x50



- Several working sensors are present
- It is confirmed that the 25x100-2E design is critical

RD53 “strip yield”



- In the figure are shown the % of «strips» for each sensor design which have a leakage lower than 20 nA
- A strip consists of 8 rows of pixels shorted together
- Note that for 25x100-2E the best results are for the "no poly cap" technology
- We suppose that the use of a better lithographic tools (Stepper) can increase the yield for the 2E geometry

Conclusions 1/2

A new batch of 3D silicon sensors have been completed in FBK:

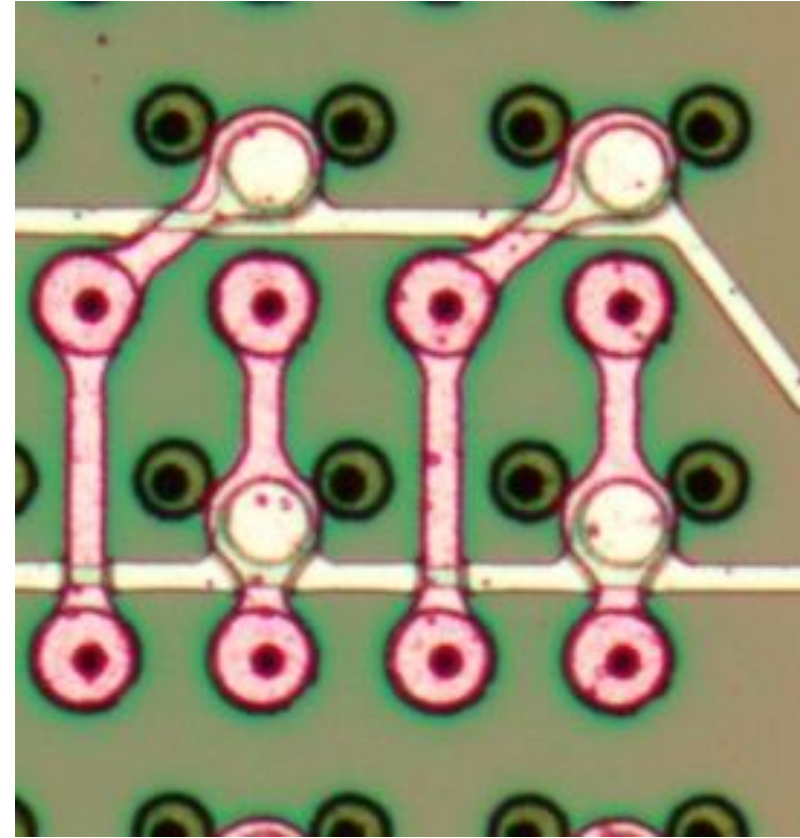
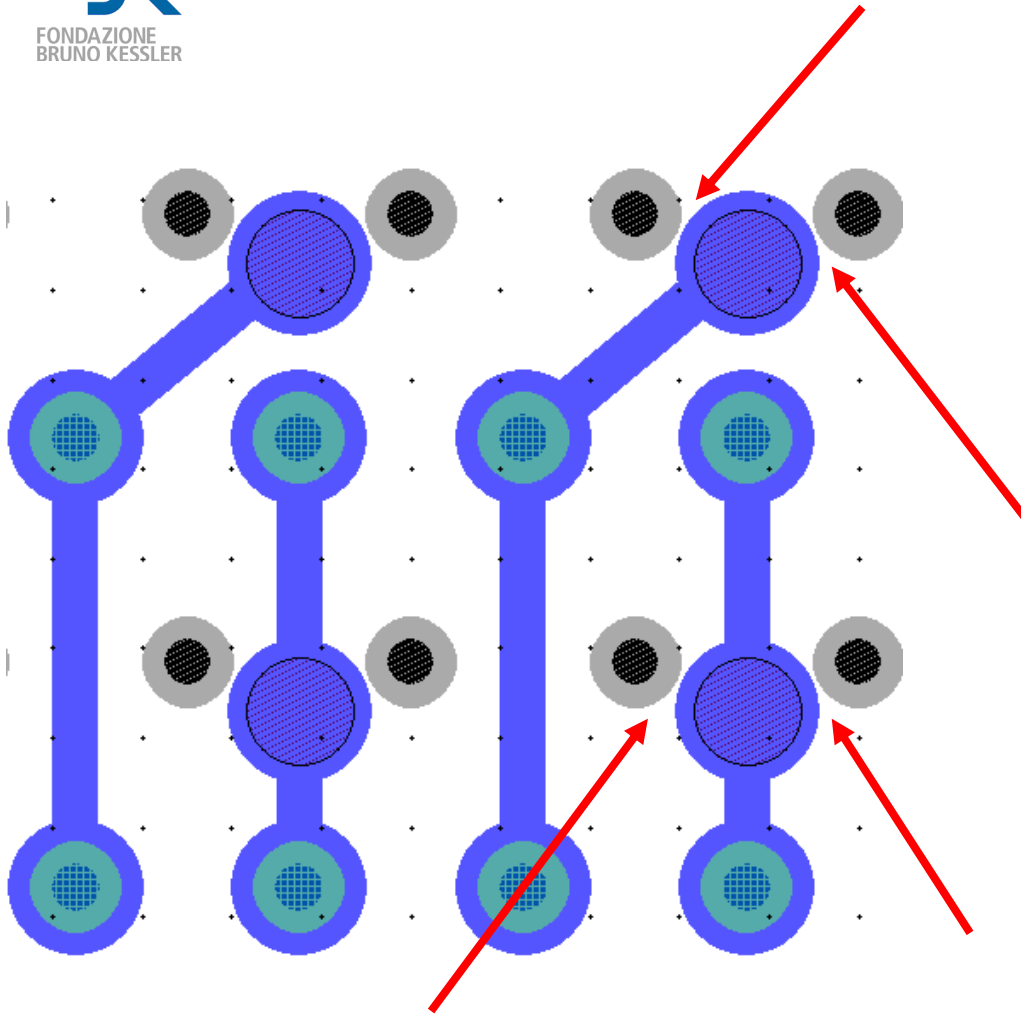
- Many working sensors are present
- Some designs show a low yield, in particular RD53 25x100 2E due to short distance between metal and poly-Si on ohmic column

Conclusions 2/2

- After temporary metal removal FBK is **ready to send wafers to IZM** and Leonardo for Bump Bonding
- Fabrication Si 3D based on **stepper lithography** with photo-composition in order to increase the yield, for the 25x100-2E geometry:
 - **Increase the yield** (better alignment, reduction of defects,...)
 - **Increase the throughput** (stepper is a fully automatic equipment)

Acknowledgements:

" Part of this work has been financed by the European Union's Horizon 2020 Research and Innovation funding program, under Grant Agreement no. 654168 (AIDA-2020) and and INFN."



Poly Cap (grey) Metal (blue) distance is about 0.5um