Test of the metallization of the EMCM for Belle II Pixel Detector

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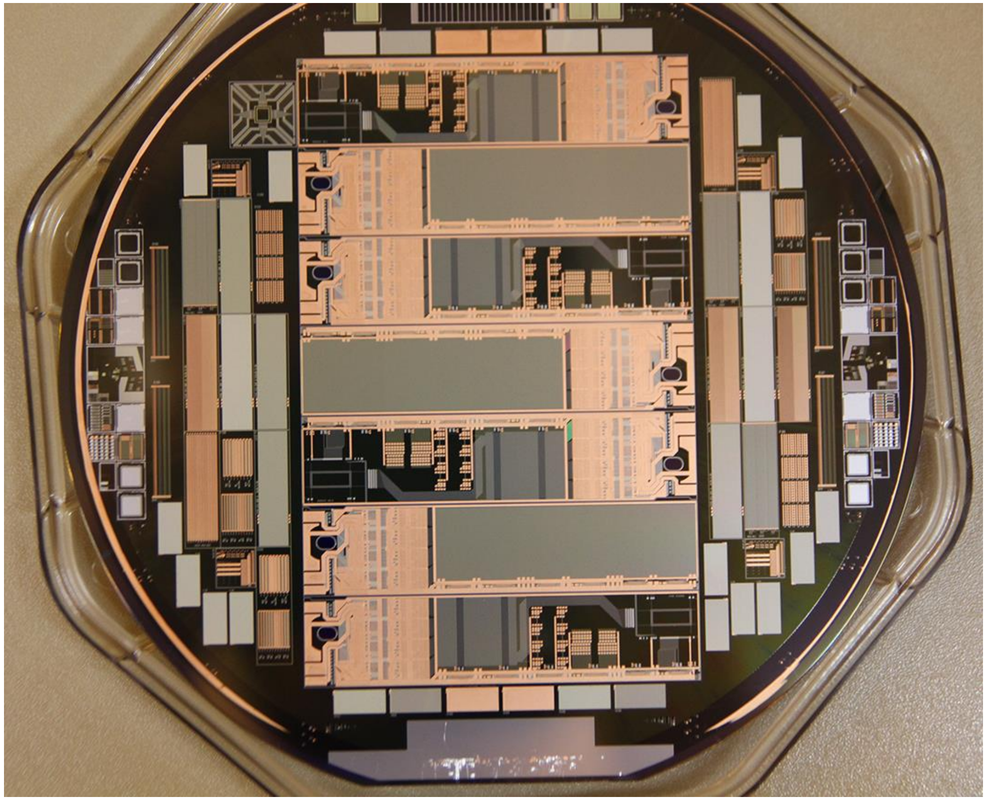
Outline

- EMCM wafer
- Metallization
- Defects
- Test structures, test strategies and results
- Summary and conclusion

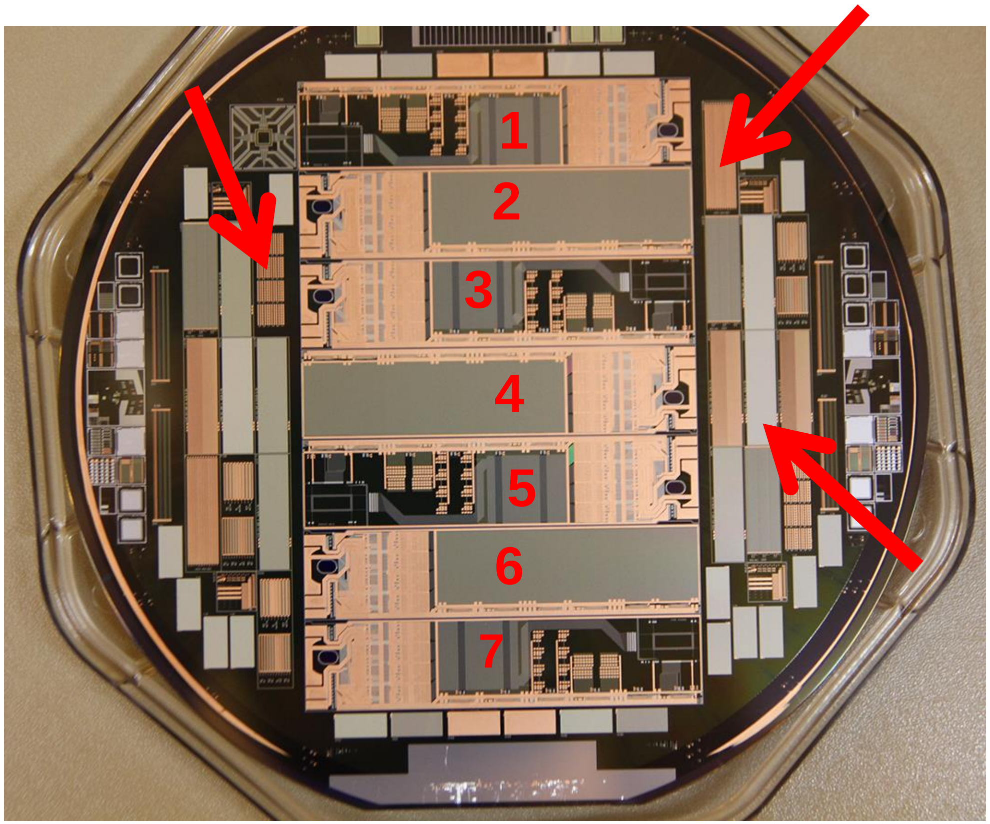
EMCM wafer



EMCM:

- Like the PXD9, but without the implantations => just the metal system => Easier to process
- For a better understand of processing and soldering
- For electrical tests (i.e. ASICs = Application Specific Integrated Circuit)
- For mechanical tests
- For “communication” tests
- Quality test of the metallization system equivalent to the PXD9 detectors

EMCM wafer

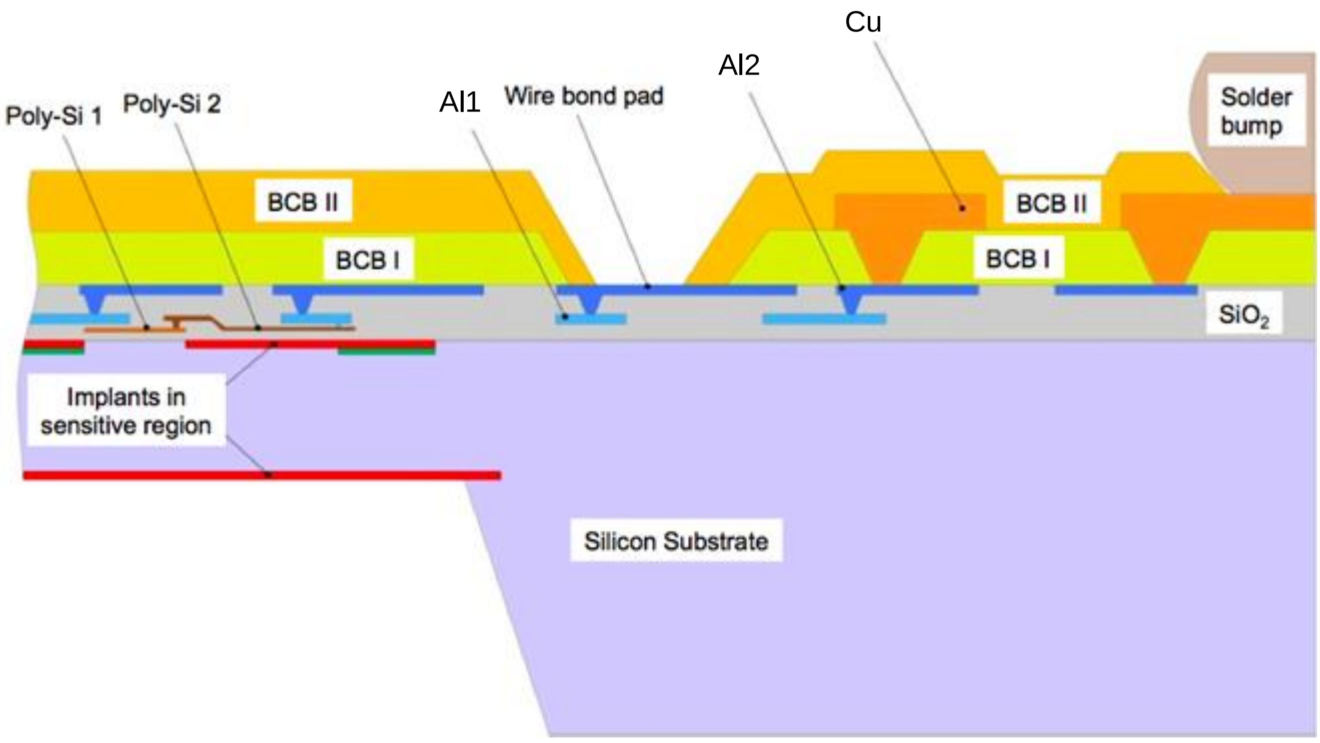


1. **EMCM 3/4 CH1**: EMCM w/o diff. clock
2. **1**: PXD9-like
3. **EMCM 3/4 CH2**: EMCM w/o diff. clock
4. **2**: PXD9-like
5. **EMCM 3/4 CH3**: EMCM w diff.clock
6. **3**: PXD9-like
7. **EMCM 3/4 CH4**: EMCM w diff. clock

Plus:

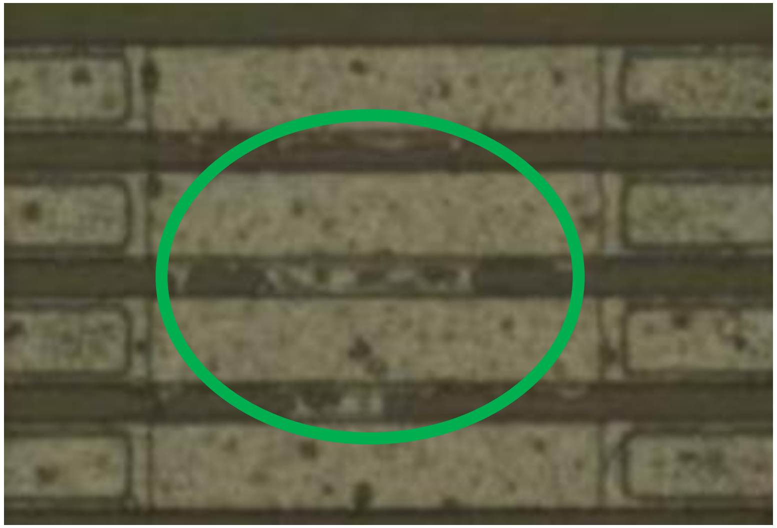
- 5 contact chain structures
- 10 comb structures
- 2 Kelvin structures

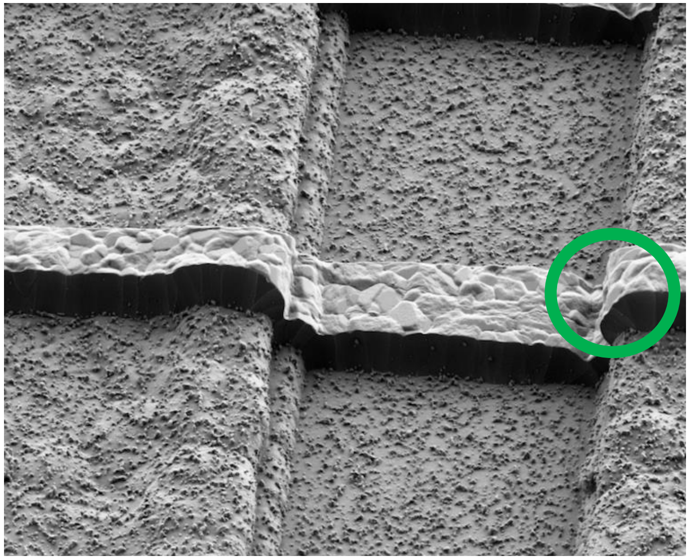
Metallization

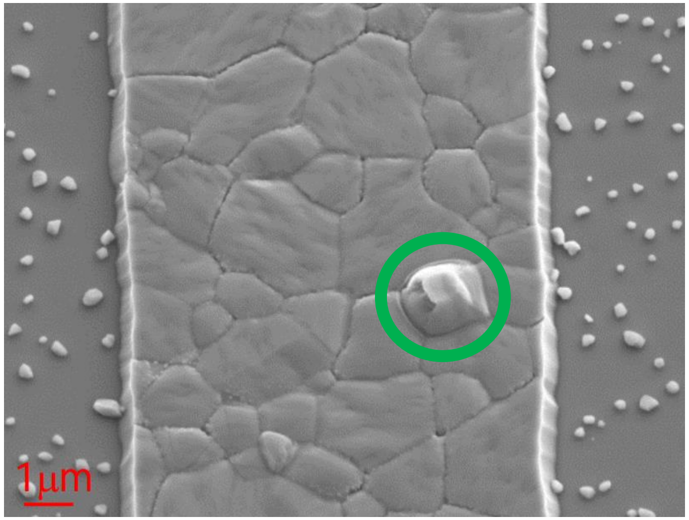


- Metallization done layer by layer with alternating of dielectric and routing material (Al1, Al2 and Cu)
- SiO_2 & BCB (BenzoCycloButene) as dielectrics between the layers
- Connection between the layers done per vias/contacts/tunnel
- Poly1 & Poly2 not present on EMCM

Defects



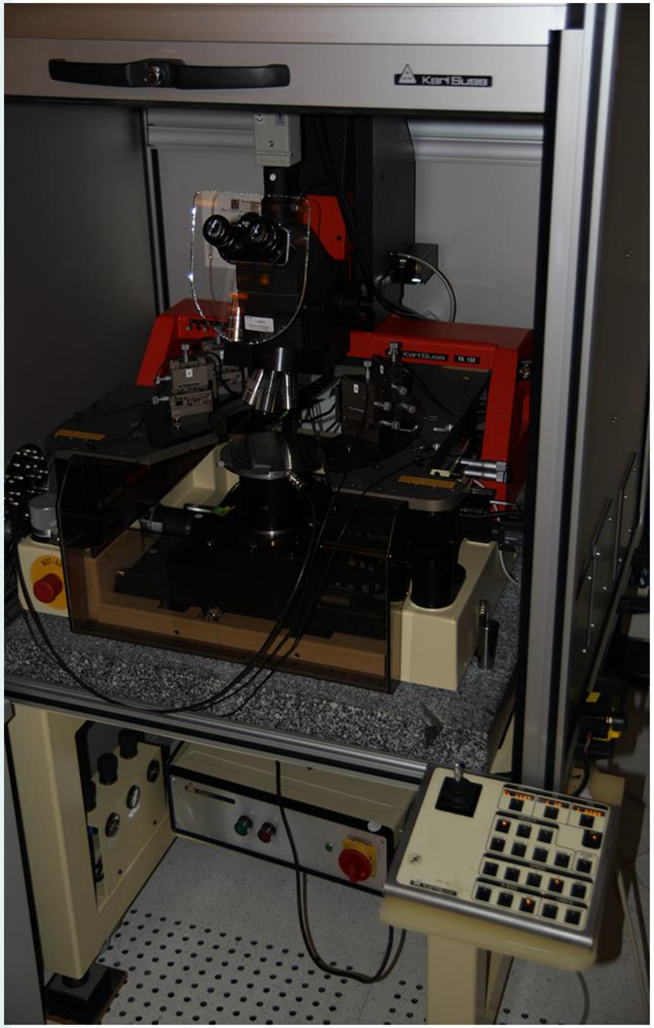


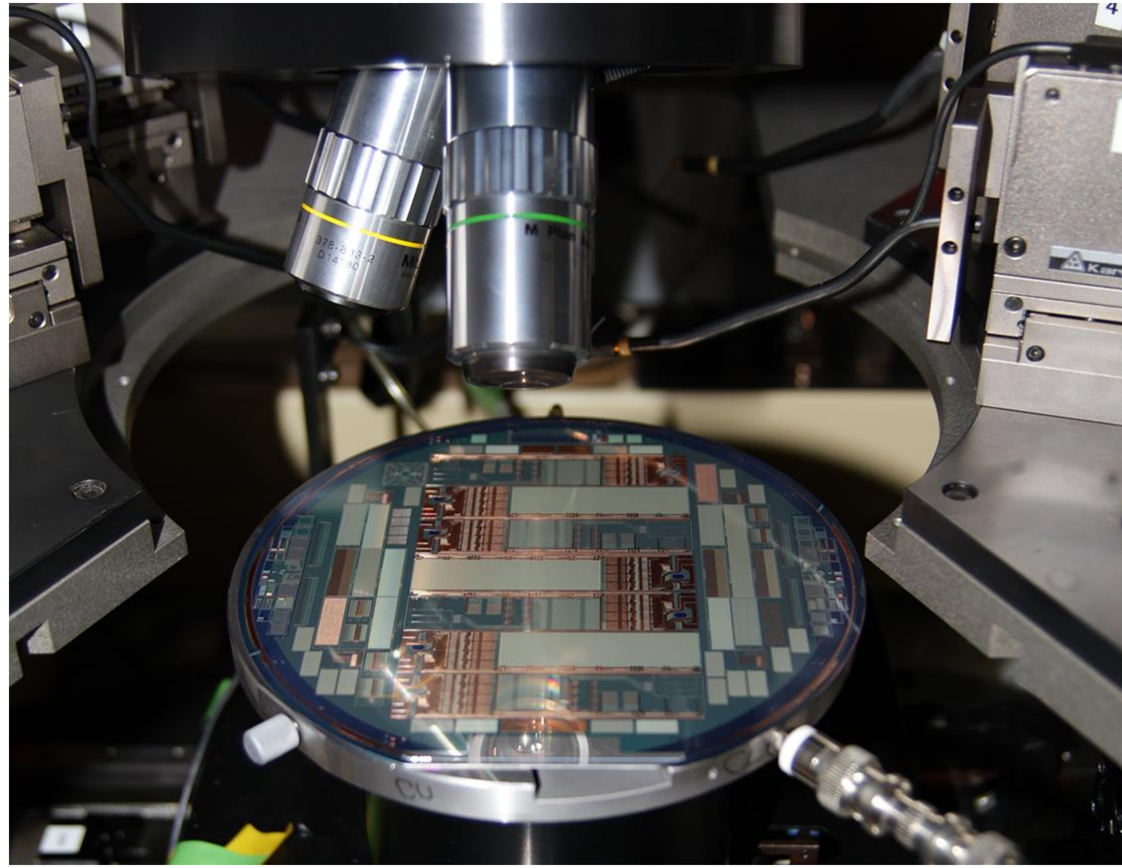


- Lateral shorts (Stringers)
- Discontinuities (Topographie)

- Hillocks
- Etching of contacts might lead to missing contacts
- Breakdown of the dielectric

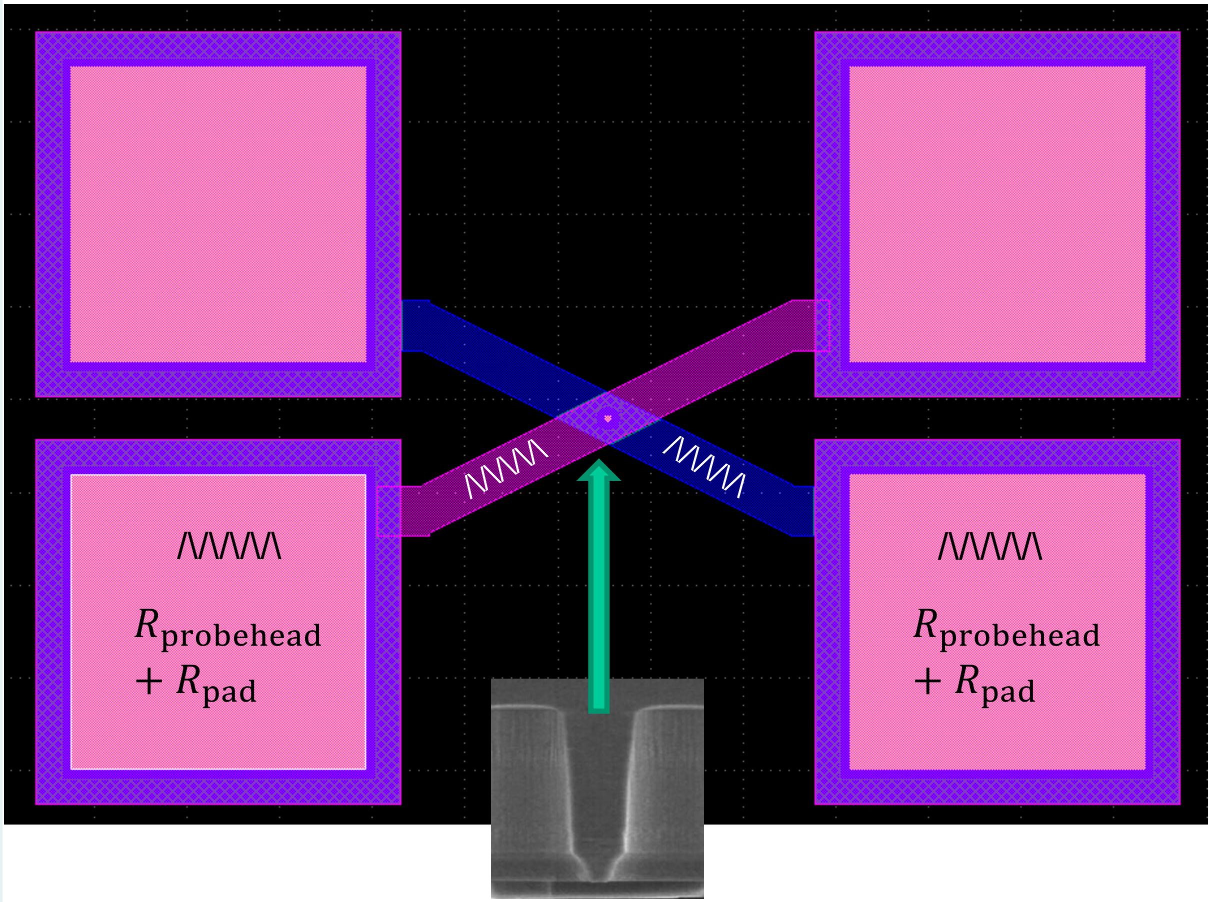
Experimental setup





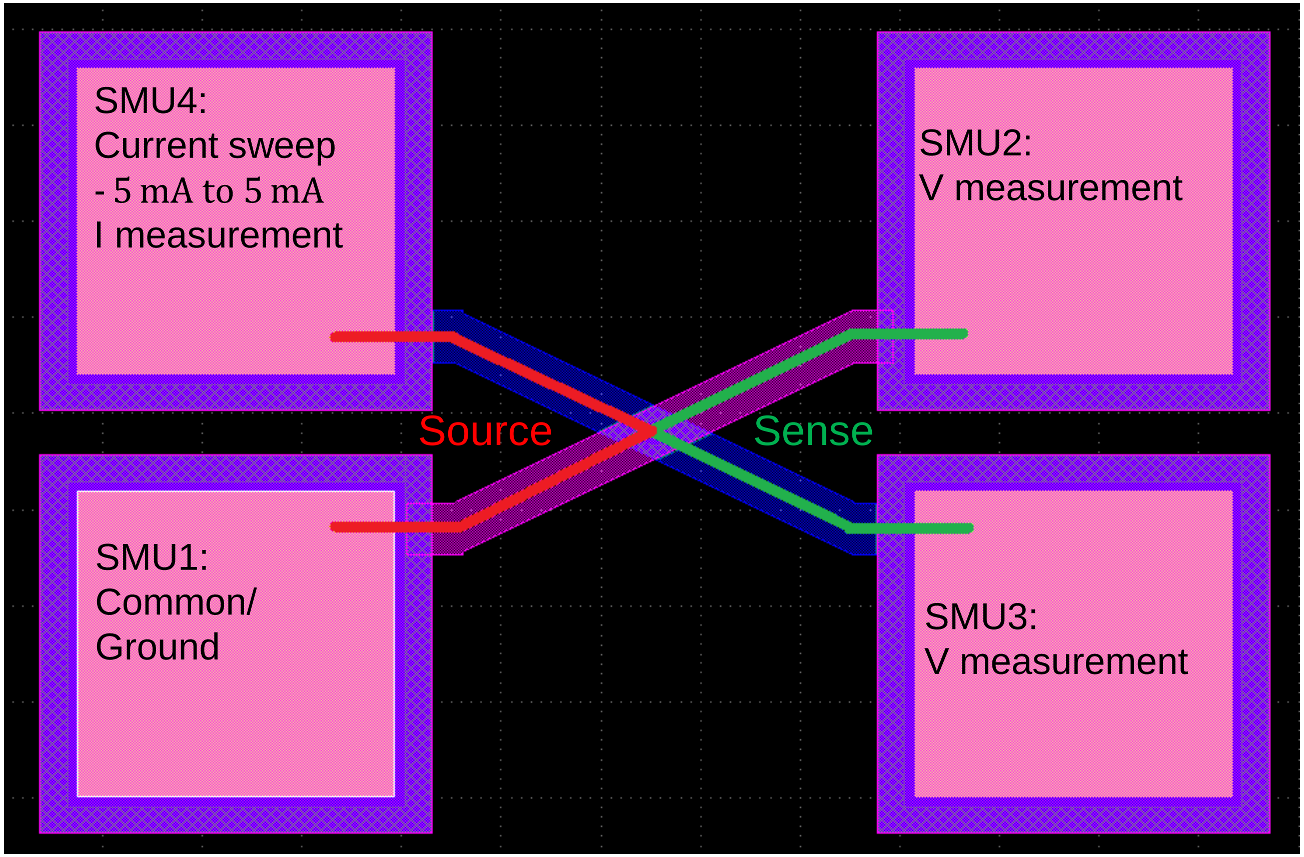
- Left: semiautomatic probe station PA 150, with Keithley 4200 and up to 4 out of 6 SMUs (Source Measurement Unit)
- Right: wafer with EMCM modules and test structures to verify different aspects of the processing steps

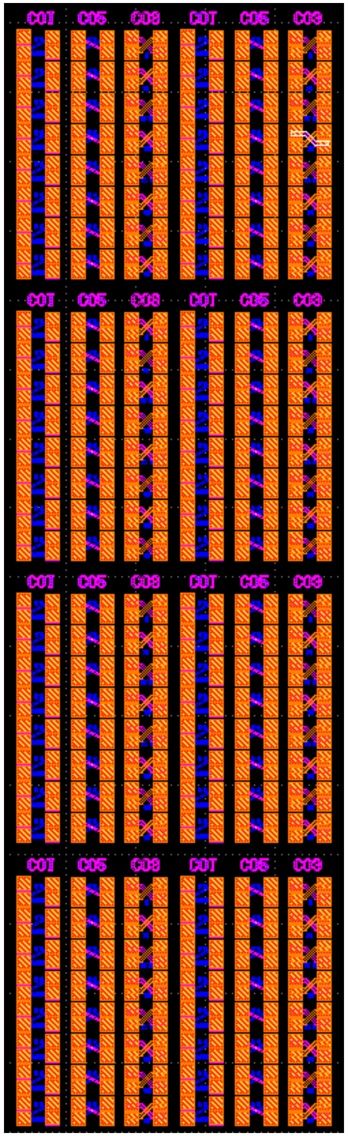
Kelvin structures – normal resistance test



- Purpose of the Kelvin structure: Precision measurements of the resistance of different contact sizes
- Kelvin measurement = Four wire measurement!
- Left:
  - One contact in a Kelvin structure
  - The resistance of all the elements sums up >> contact resistance

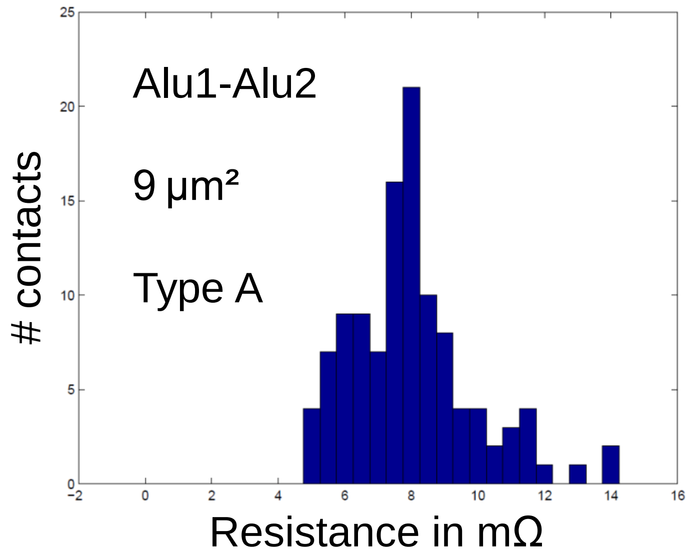
Kelvin structures – Four wire measurement

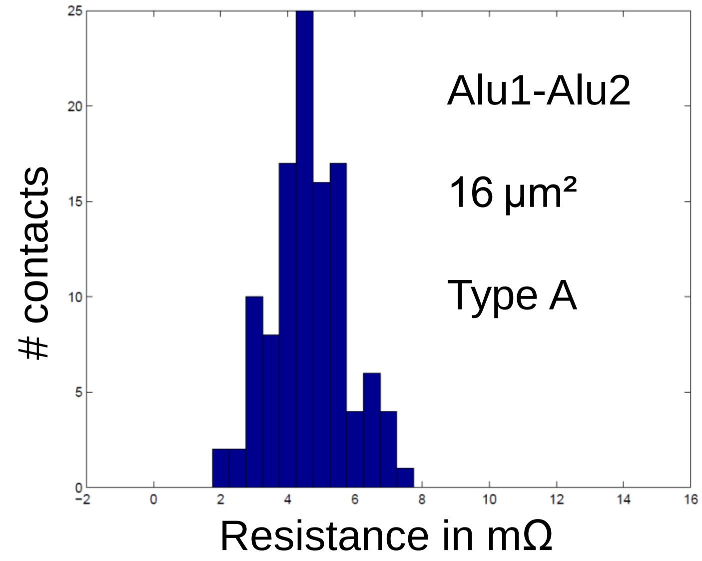


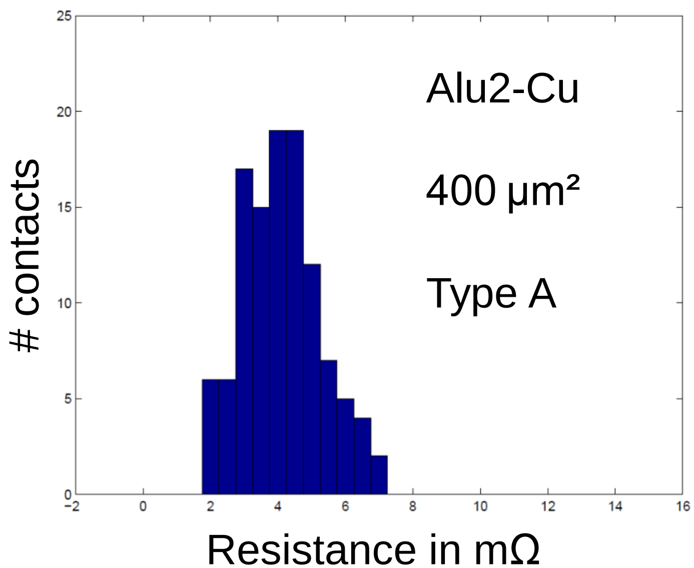


- Red: Source line delivers the current
- Green: Sense line measures the voltage. Just a small current in the sense line
  - Low voltage drop at the contact
  - Just the resistance of the contact is measured
- Right: array of Kelvin structures

Results Kelvin structures

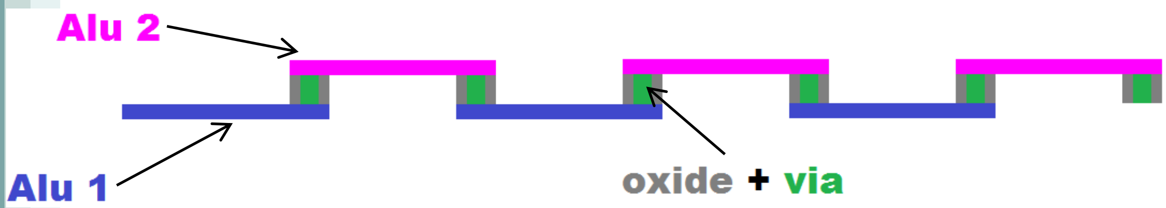


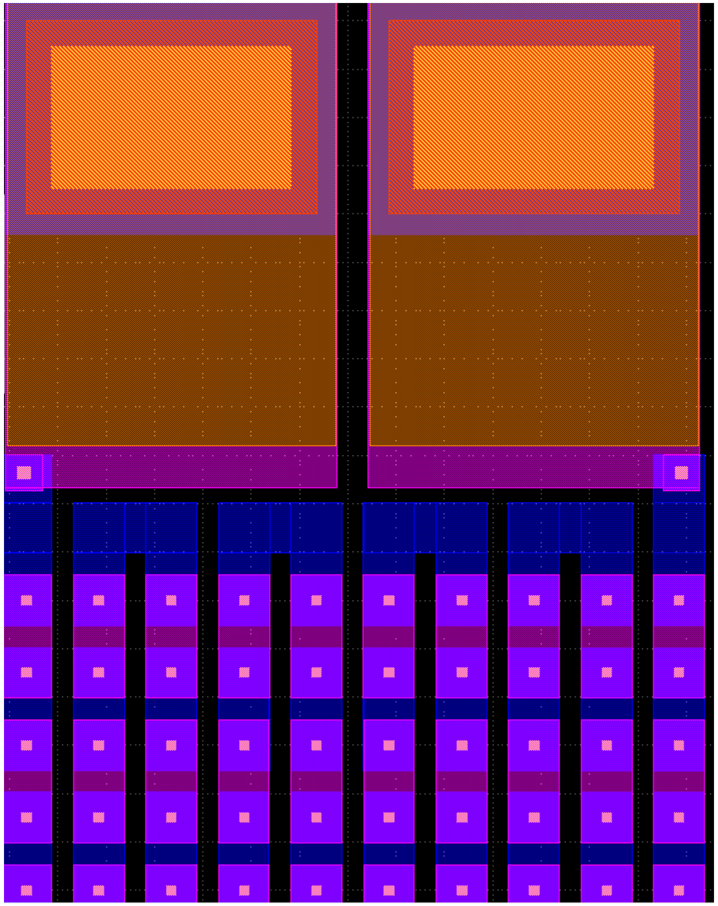




- Resistance in the desired range of just a few mΩ
- All contacts are closed for the chosen contact sizes = yield of 100%
- 112 contacts of same size measured on the 7 wafers with the PXD9 technology

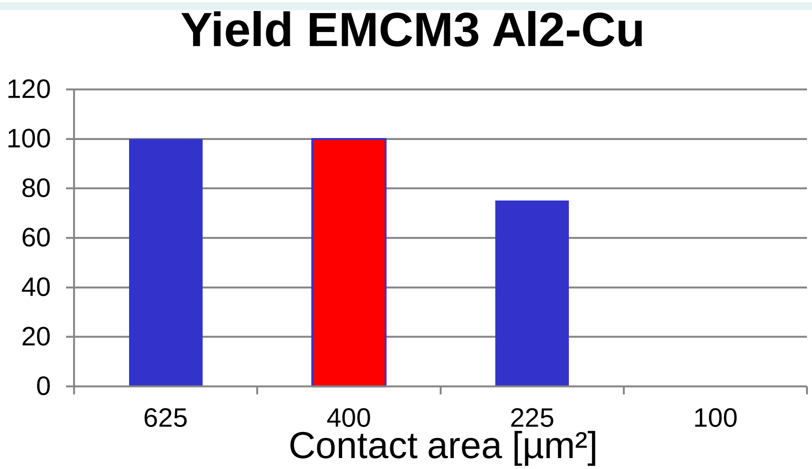
COntact CHain (COCH) structure

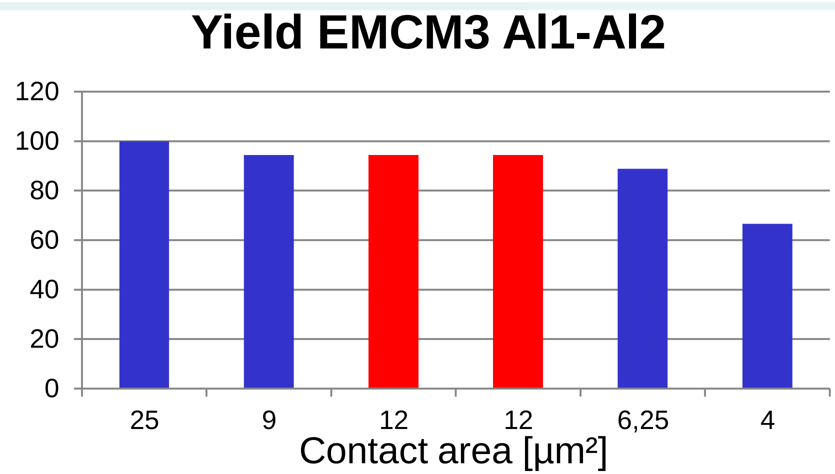


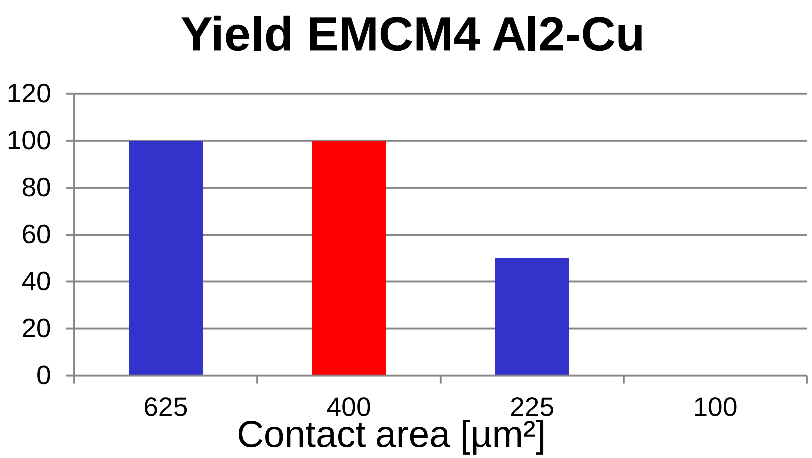


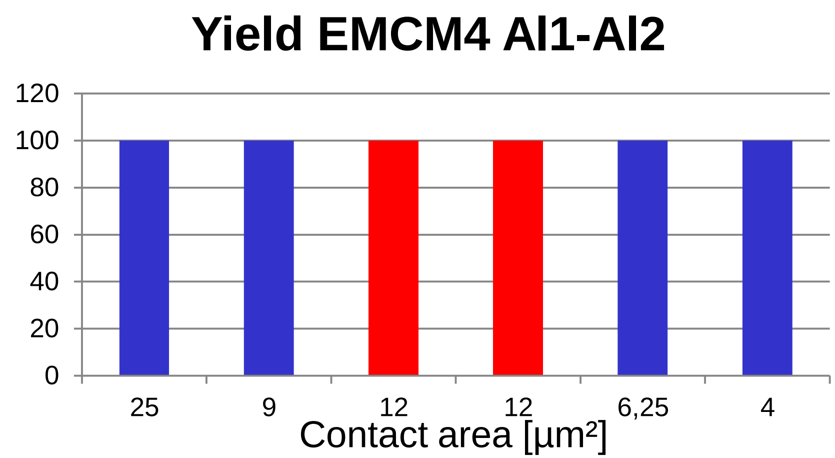
- Purpose of the COCH structure:
  - Testing the reliability of the contact sizes with good statistics: 1500 contacts (Al2-Cu) or 3500 contacts (Al1-Al2)
  - This gives information on the quality of the processing

Yield of the COCH structure



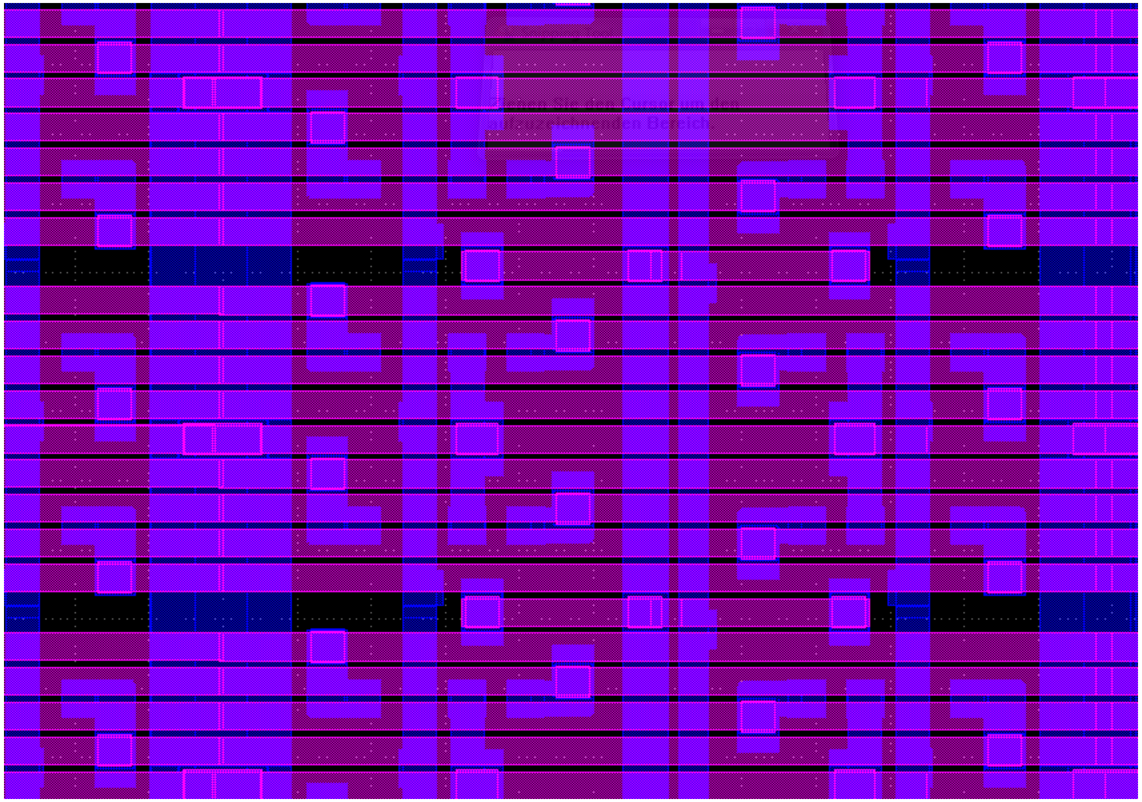






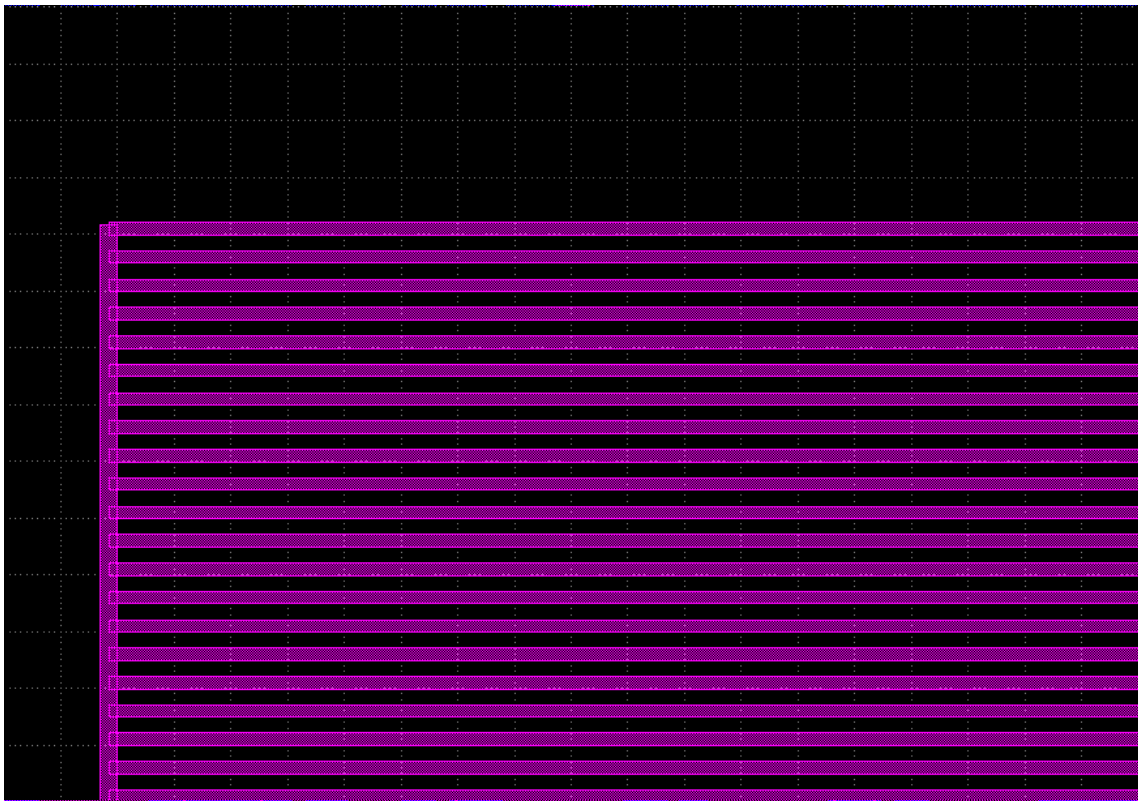
- Red bars: The chosen contact sizes 400 µm² (Al2-Cu) and 12 µm² (Al1-Al2) are safe for PXD9 also in the COCH structure
- $\mathrm{Rel}_{\mathrm{al1-al2\_contacts}} \approx 1.16$ (Al1-Al2) (EMCM3), $\mathrm{Rel}_{\mathrm{al1-al2\_contacts}} \approx 1.00$ (Al1-Al2) (EMCM4)
- Threshold for broken chain: 1 kΩ

Comb structure



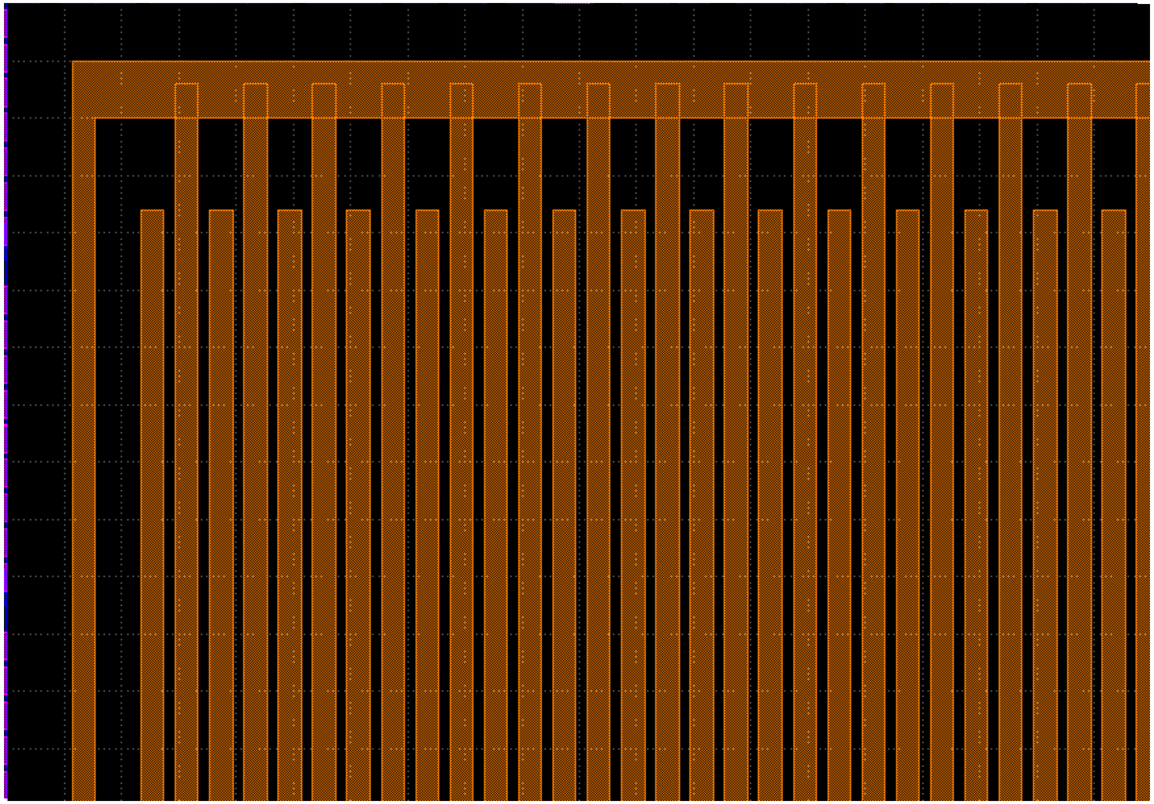
- Test structure for:
  - Lateral shorts/ stringers
  - Breakdown of the dielectric

Comb structure



- Test structure for:
  - ➢ Lateral shorts/ stringers
  - ➢ Breakdown of the dielectric
- Variations in:
  - ➢ Layer thickness
  - ➢ Gap between lines
- Minimal gap size for PXD9 Al2: 3 µm
- Results:
  - ➢ All the tested structures/ wafers stated stable results

Comb structure



- Test structure for:
  - ➢ Lateral shorts/ stringers
  - ➢ Breakdown of the dielectric
- Variations in:
  - ➢ Layer thickness
  - ➢ Gap between lines
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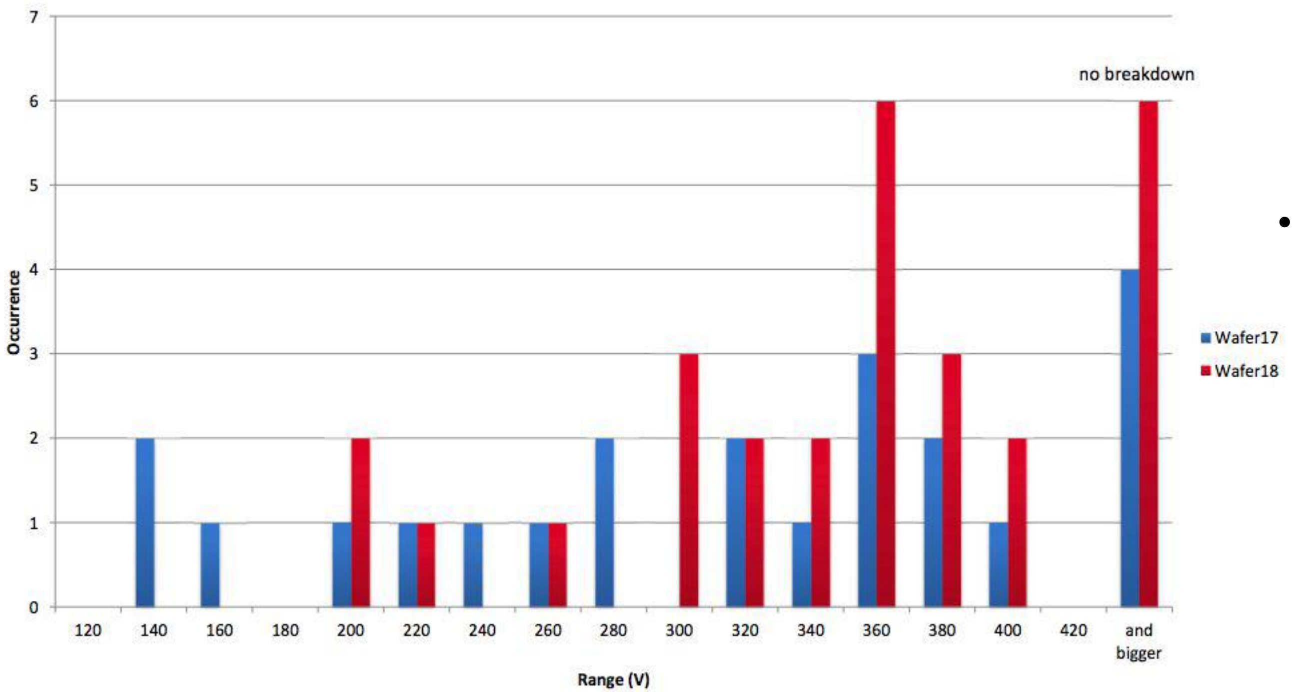
Breakdown structures



- Two different typologies:
  - Unstructured Al1
  - Structured Al1

- Used to determine the strength of the inter-metal dielectric for structures with ‘extreme’ designs (no stress relief)

- Breakdown structures and Comb structures tested up to +420 V → very robust technology as max voltage applied for PXD9 normal function is less than 50 V

Summary and conclusion

- Different aspects of the metallization for the later PXD9 wafers were tested
- From the results of the Kelvin and COCH structures it can be stated that the chosen contact sizes are reliable (yield = 100%) and therefore safe for use for the PXD9 wafers
- A combination of the measurements on Kelvin, COCH and Comb structures stated that the chosen technology and design exclude the most common defects