Testing of EMCM-3-2 on Wafer Level

-ATG Flying Needle Prober and Probe Station PA 200-

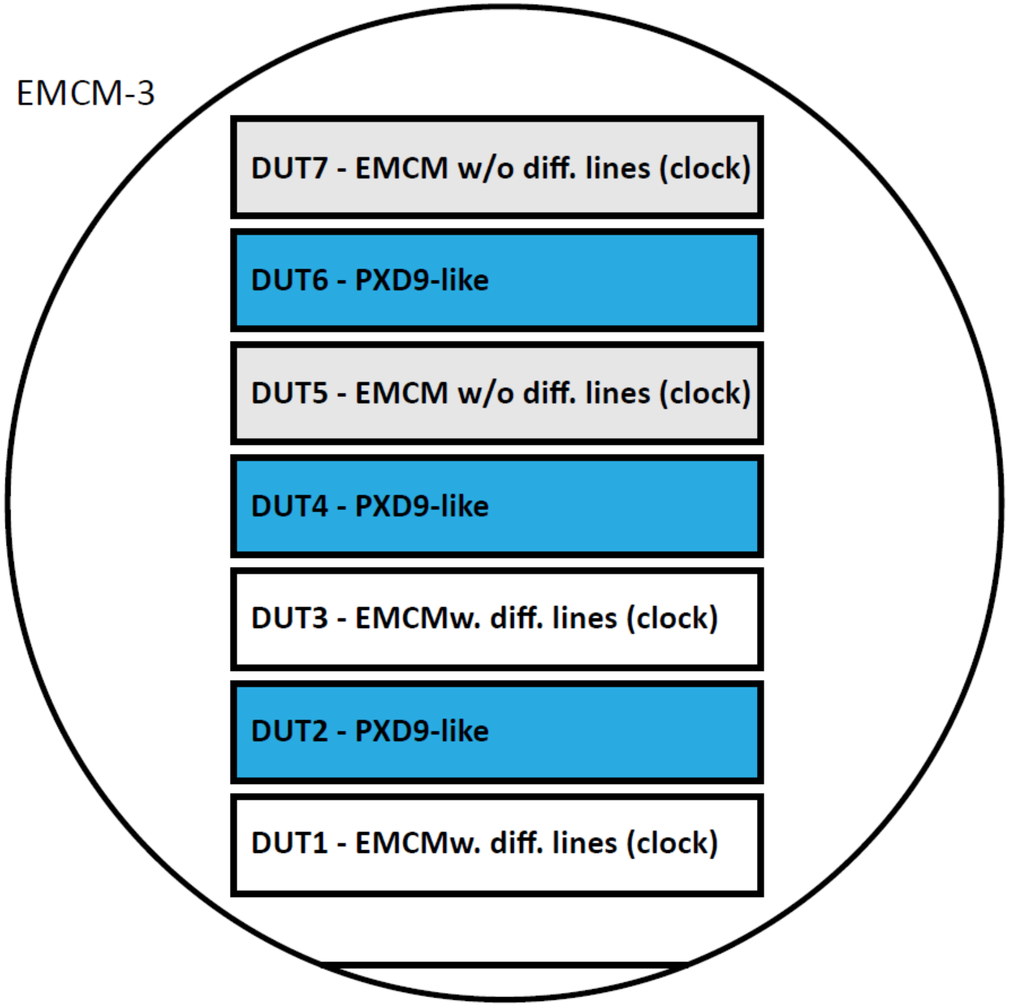
Andreas Ritter, Paola Avella and Christian Koffmane

Kloster Seeon, 26.05.2014

Outline

1. Introduction
2. Part 1: Copper tests on EMCM-3-2
3. Part 2: Aluminum tests on EMCM-3-2
4. Summary and conclusions

Layout of EMCM-3-2 wafer



Test overview

What to test on an EMCM wafer:

1. Insulation between structures on the same metal layer and between layers (i.e. Aluminium1 and Aluminium2)
   1. Contact chain structures
   2. Breakdown structures
   3. Comb structures
   4. PXD9-like structures (long metal lines)

      ➔ Done with "conventional" probe station PA 200
2. Copper connections
   1. Electrical nets present where they should be (→ Open test)
   2. Electrical nets shortened to neighboring nets (→ Short test)

      ➔ Done with ATG Flying Needle Prober

➔ Many measurements to be done in order to test the various technological versions of the EMCM-3-2 run

Part 1

- ATG Flying Needle Prober for Copper Tests -

ATG prober description

- Originally designed for electrical tests of Printed Circuit Boards (PCBs)

- Test on electrical nets:
  - open nets (discontinuities in lines)
  - neighboring nets shorted

- Modified to handle semiconductor wafers/modules (e.g. pressure of probe needles must be smaller, test speed reduced) → Thanks to Christian Koffmane

- Needs layout data of a PCB (i.e. gerber files)

- Needles can probe where pads are accessible (e.g. Cu pads via openings in the BCB (Benzocyclobutene, C_8H_8, photosensitive coating))

ATG flying needle prober - workflow

Wafer layout

- Design files from Cadence Virtuoso

Conversion of files

- *.gds files to gerber files
- And gerber files to *.ipc files (Adam software)

ATG Prober

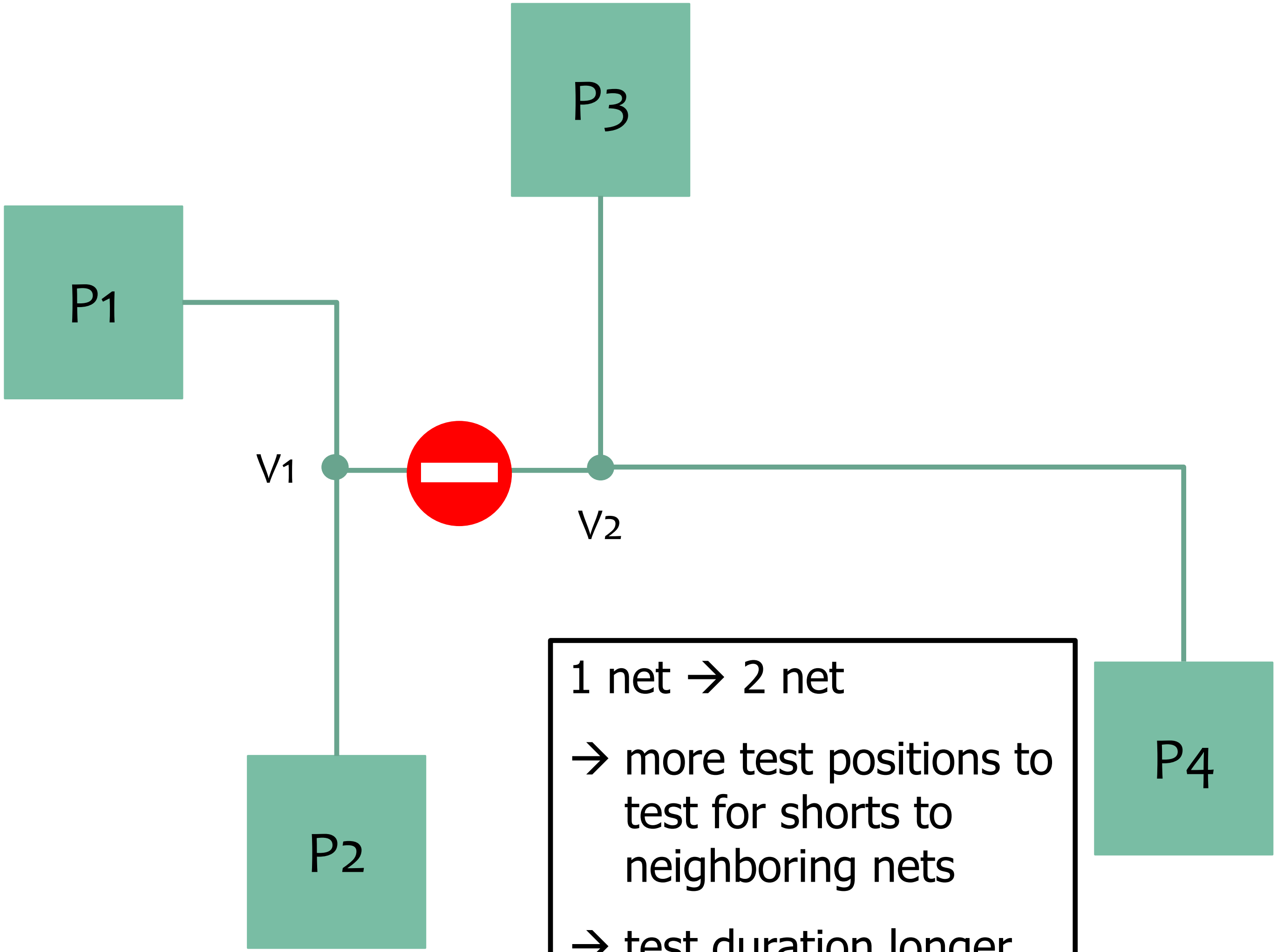
- Loads *.ipc files (here test is specified in spatial coordinates, pad and net numbers)
- Build test project (e.g. combine substructures, set alignment marks)

Testing

- Align wafer via cameras and flash LEDs
- Run test

Results as faults in open test and short test

Discontinuities (opens) in electrical nets



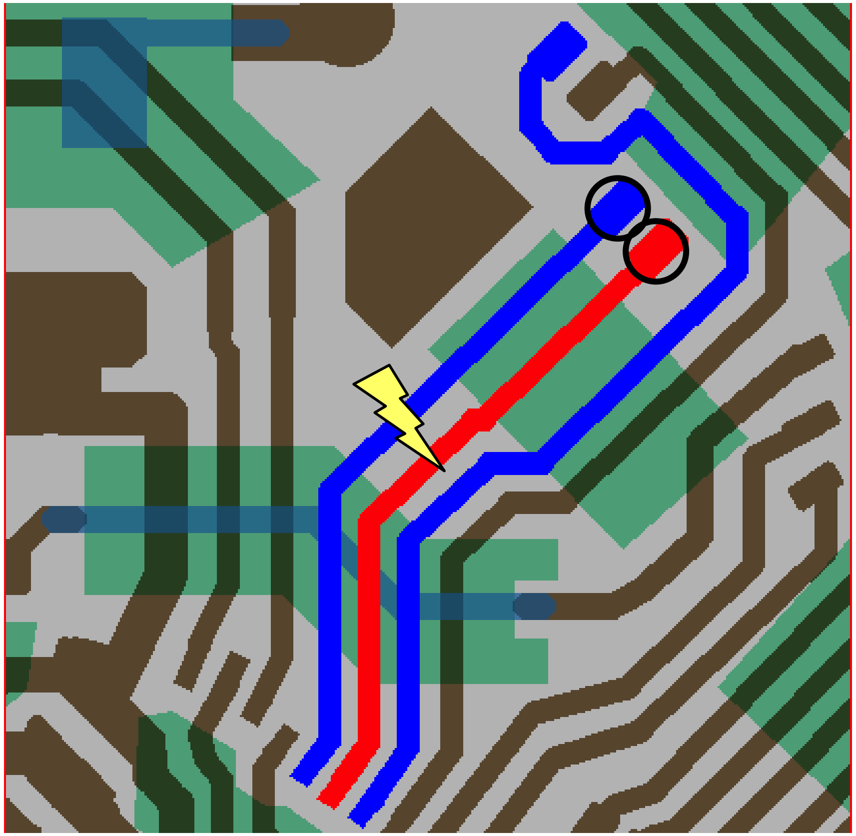
1 net → 2 net

→ more test positions to test for shorts to neighboring nets

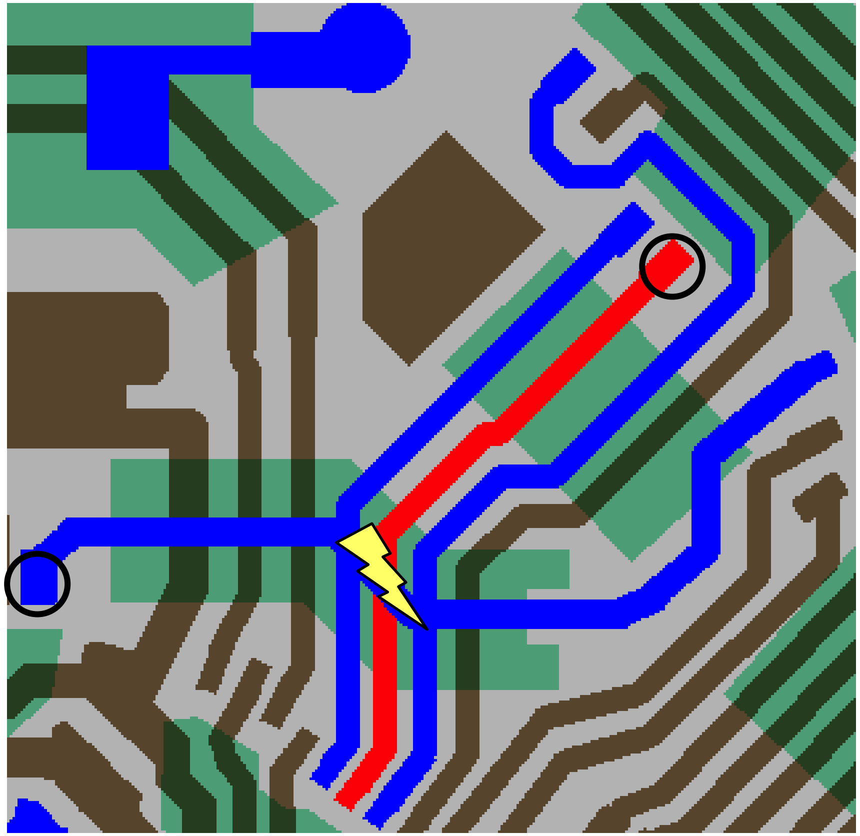
→ test duration longer

Short/adjacencies tests

Shorts/adjacencies in same layer (2D)



Shorts/adjacencies to top/bottom layer (3D)



Video

(play here ATG videos)

Copper Tests

Results of 7 DUTs of 7 wafers

Wafer	Technology	DUT 1		DUT 2		DUT 3		DUT 4		DUT 5		DUT 6		DUT 7		Total
		opens	shorts	opens	shorts	opens	shorts	opens	shorts	opens	shorts	opens	shorts	opens	shorts	
17	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7/7
18	A	0	0	0	0	0	0	0	0	0	0	0	0	0	1[b]	7/7
29	B	0	5[a]	0	1	0	0	0	0	0	0	0	5	0	0	4/7
30	B	0	0	0	0	0	0	0	5	0	0	0	0	0	0	6/7
13	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
14	D	0	0	0	0	0	0	0	0	2	0	0	2	0	1	5/7
31	E	0	0	3	5	0	0	0	1	0	0	0	0	4	0	5/7
32	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7/7

Number of measuring points e.g.

→ DUT2: Opens 1,912 Shorts 14,246

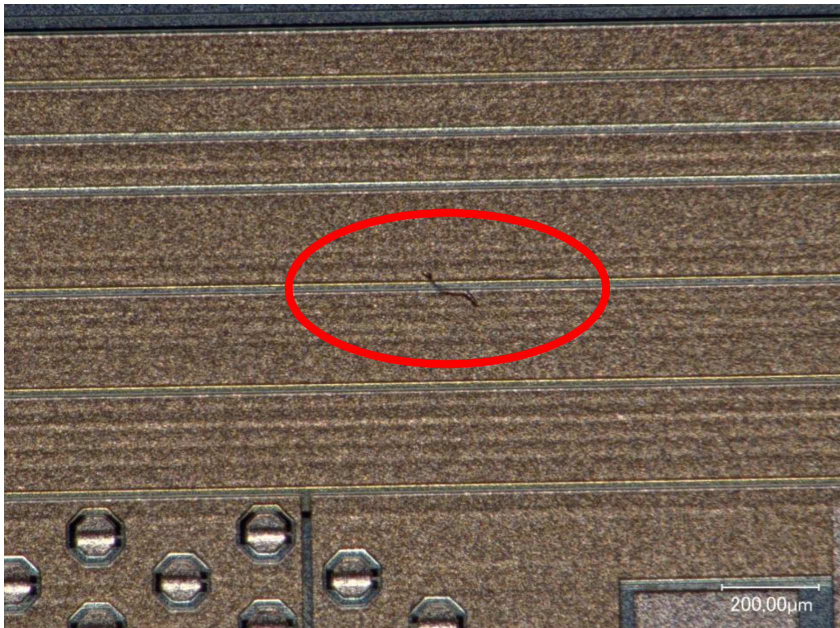
→ DUT5: Opens 2,406 Shorts 112,966

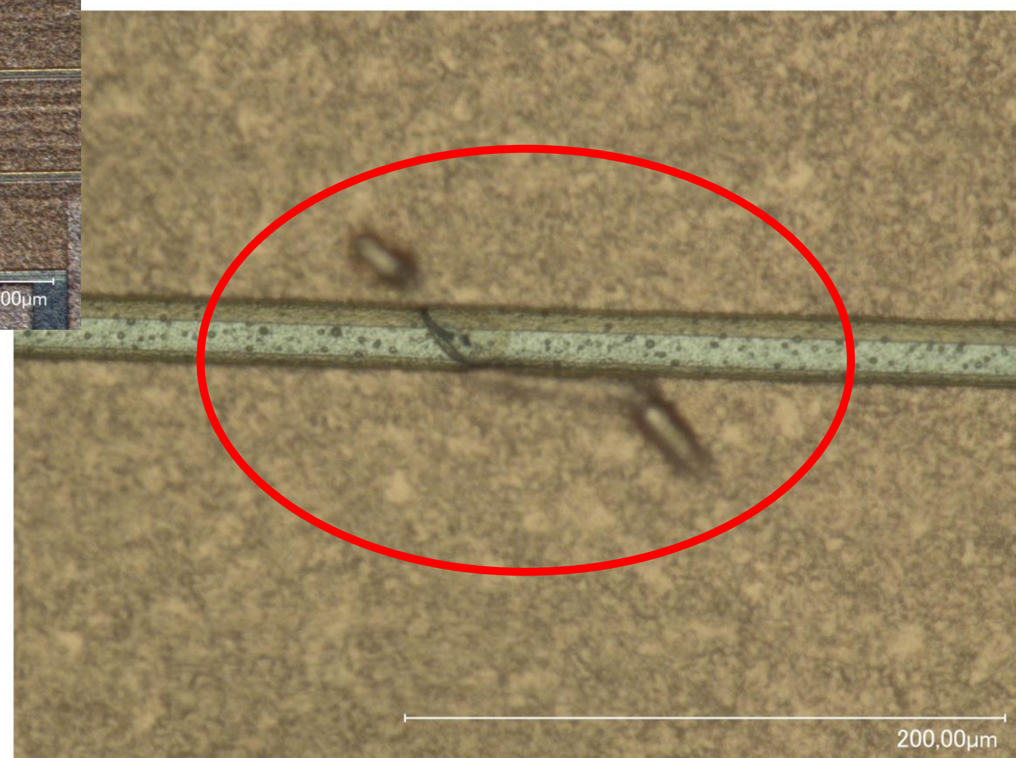
Technology option “A” showed the best results and even the short in DUT7 (b) turned out to be high ohmic

➔ Technology of choice (focus on this technology during presentation)

Short in wafer 18

Short between two gate lines





Short is independent of technology, fiber during production

Part 2

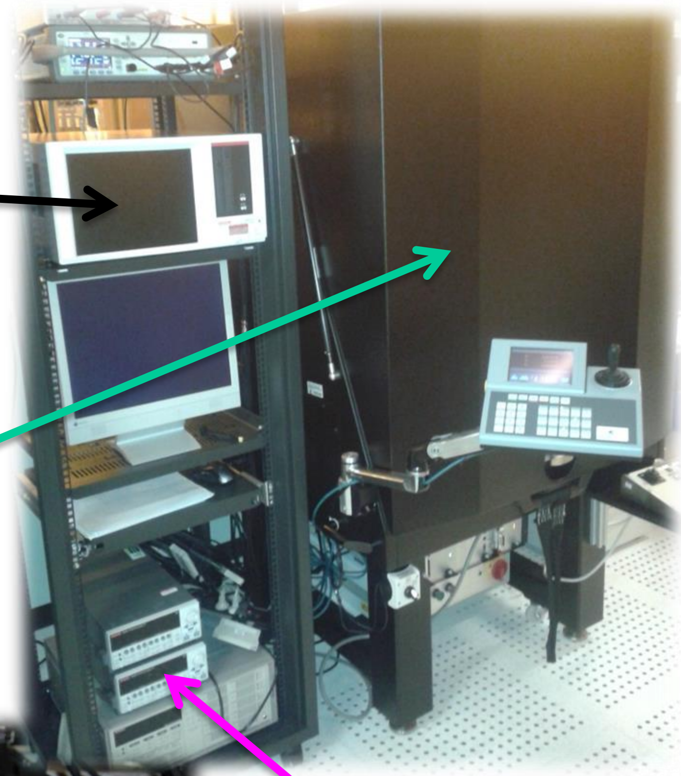
- Aluminum metal test with probe station PA 200 -

Measurement setup

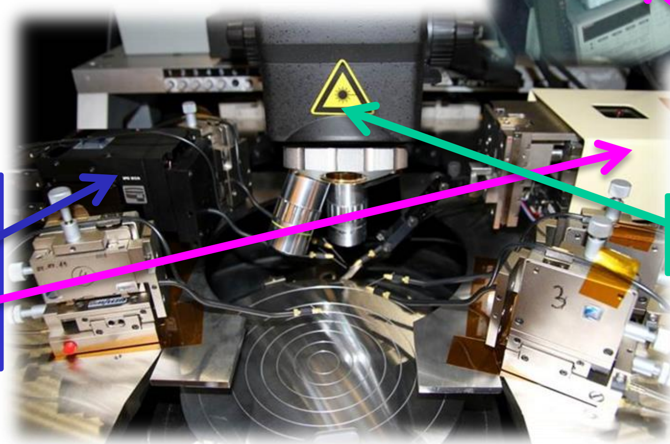
Measurement tools:

Keithley 4200-SCS, powerful measurement device, a PC with 4 (now 8) SMUs. All testing on the probe station can be controlled from this device

Probe station PA 200. Automatic movement + rotation of wafers



2 automatic **manipulators** (needles): Cascade PH 510 (new), SUSS PH 600 (old)

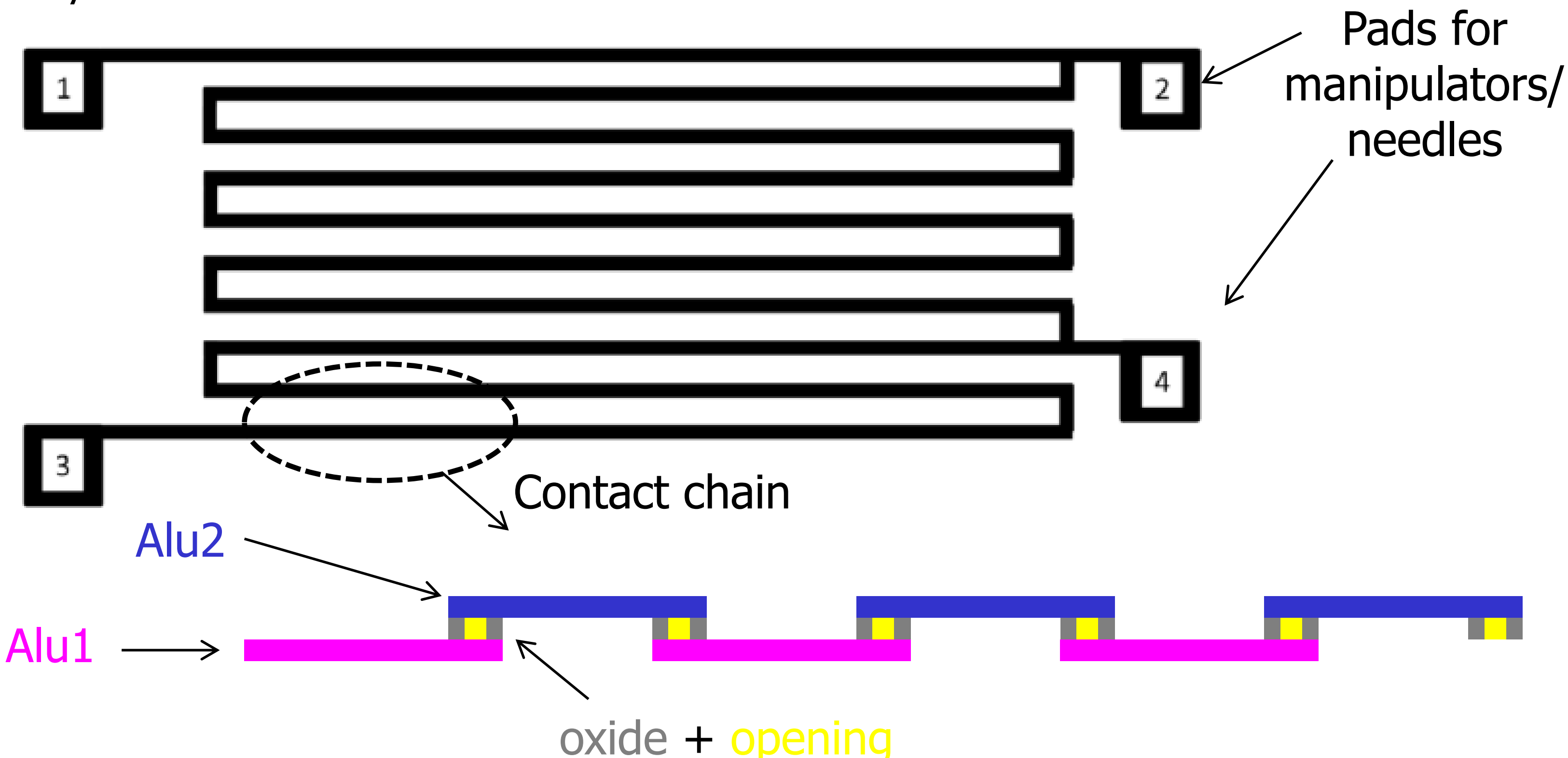


Switching system,

Microscope + camera

Contact chain - layout

1. Purpose: How reliable is contact opening in our processes, which size is critical
2. Layout of the structure



3. Openings vary in size
   (8 diff. contact sizes available, #contacts = 5980, total length = 1.79 m)

Contact chain - results of wafer 17 and 18

Contact chain tested with V_{Sweep} = -10V…+10V, corresponding pad set to grounding

Wafer 17:

Pads\ChipID	D01	D04	F05
1 vs. 2	2x2 µm²	All OK	2x2 µm²
1 vs. 4	2x2 µm²	2x3 µm²	2x2 µm²
2 vs. 4	2x2 µm²	2x3 µm²	2x2 µm²

Wafer 18:

Pads\ChipID	D01	D04	F05
1 vs. 2	All OK	All OK	All OK
1 vs. 4	All OK	All OK	All OK
2 vs. 4	All OK	All OK	All OK

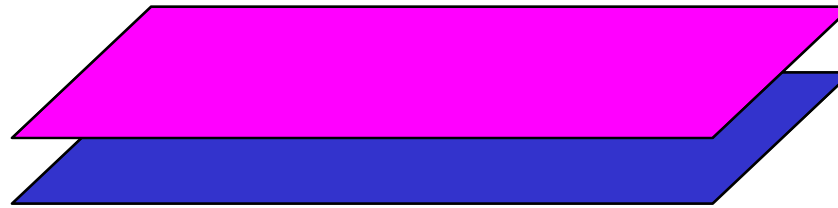
Wafer 17: some small contacts not open, min. contact size of PXD9: 3x4 µm²

Wafer 18: all contacts open

Breakdown structures

Structured Alu1 + layer Alu2

(also called Comb)



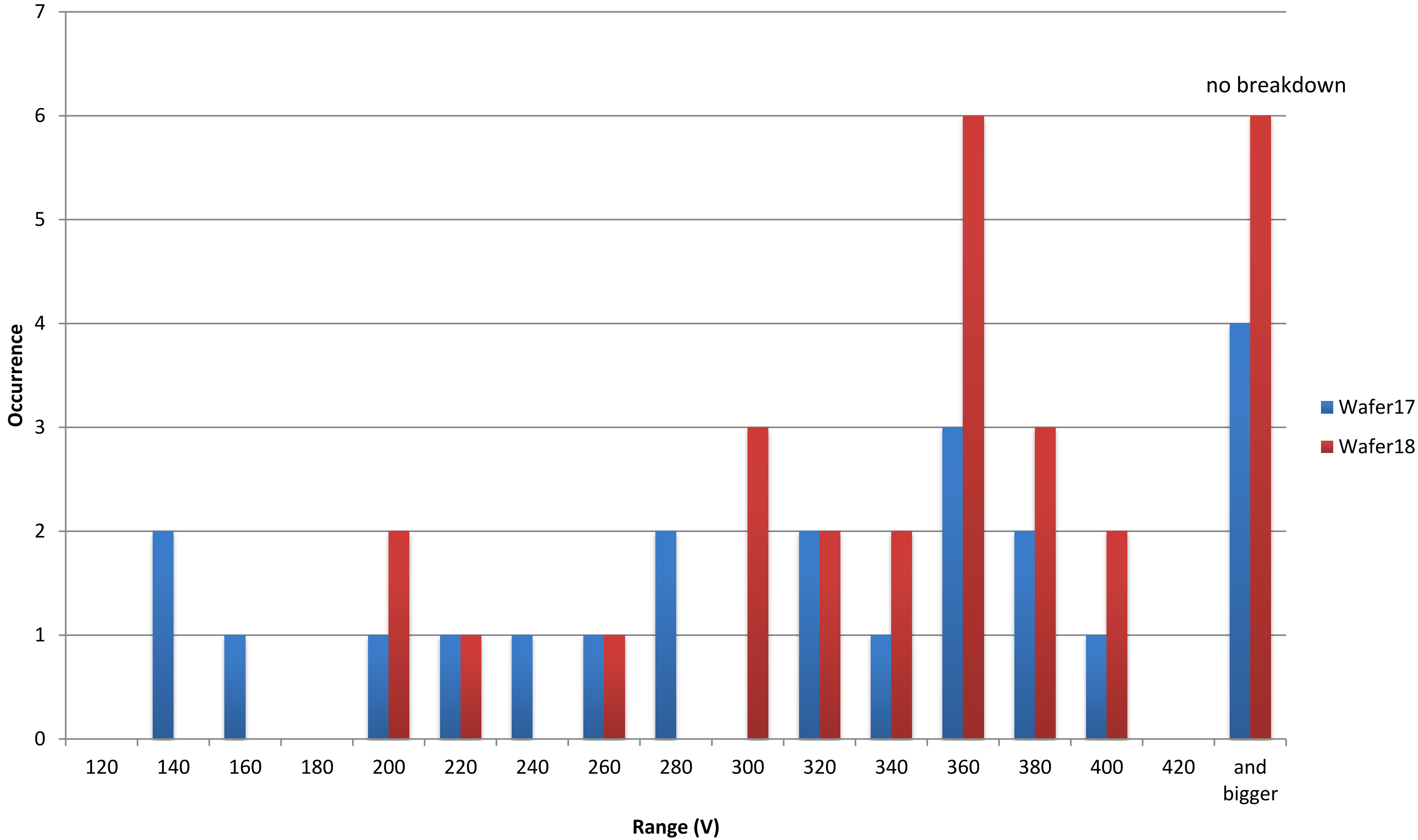
Layer Alu1 + layer Alu2

(also called Flat, worst case → no possibilities for stress relief)

Purpose determine max. strength of insulation between the two metal layers,

Sweep of voltage between the two layers, max. V_{Sweep} = 420 V

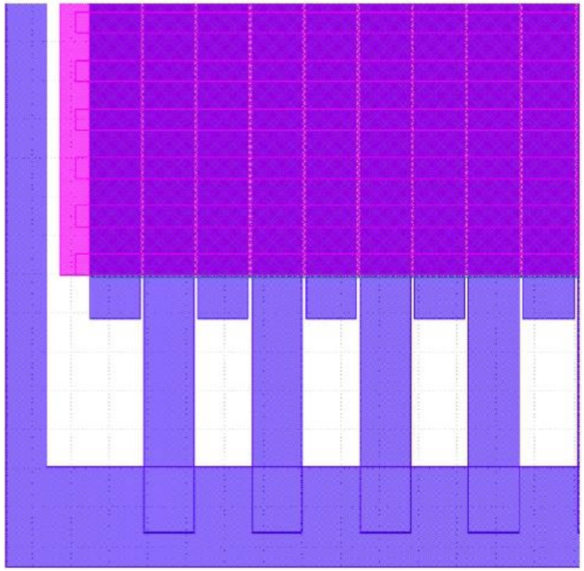
Breakdown structures - results



➔ Good insulation layer (max. voltage diff of Al1/Al2 in PXD9 ~80V, only in few areas such an Alu1/Alu2 crossing is present)

Comb structures in aluminum

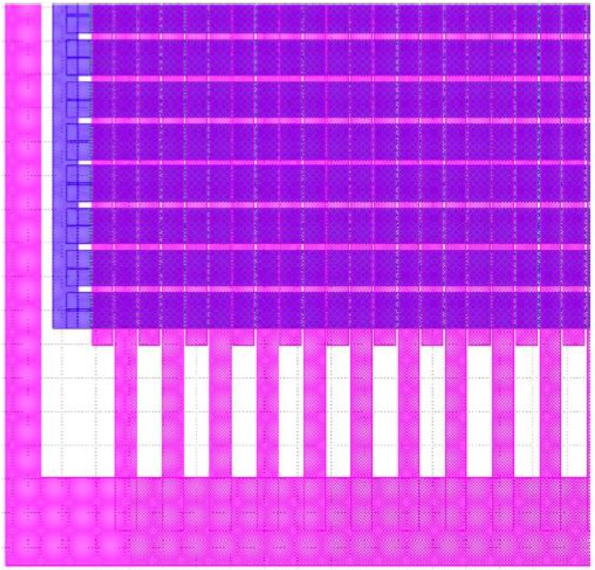
Purpose: a) Detect shorts between the two Alu layers, b) Detect lateral shorts



Substructure Comb+plane

i. Comb in Alu1 (blue) + Alu2 (pink) plane on top

ii. Difference in trace width and pitch



Substructure Comb + Comb

i. Comb in Alu1 (blue) + Comb in Alu2 (pink) on top

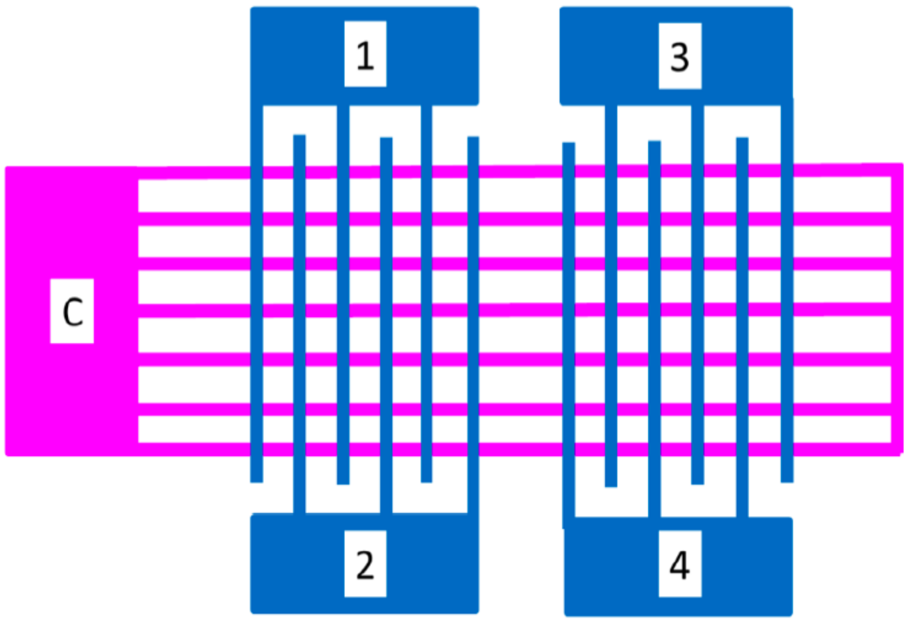
ii. Difference in trace width and pitch of Alu2 Comb

Comb structures - test details

Two test:

a) Vary voltage (up to 100 V) between Alu layers → shorts/hillock detection

b) Vary voltage (up to 100 V) between neighboring combs → lateral short detection



Comb structures - results of inter-metal dielectric (Test a)

Test	D02 ME2	E02 ME1	E03 ME2	F03 ME2	F04 ME2	E05 ME1	D05 ME1
				W17			
C vs 1	✓	✓	✓	✓	✓	✓	✓
C vs 2	✓	✓	✓	✓	✓	✓	✓
C vs 3	✓	✓	✓	✓	✓	✓	✓
C vs 4	✓	✓	✓	✓	✓	✓	✓
				W18			
C vs 1	✓	✓	✓	✓	✓	✓	✓
C vs 2	✓	✓	✓	✓	✓	✓	✓
C vs 3	✓	✓	✓	✓	✓	✓	✓
C vs 4	✓	✓	✓	✓	✓	✓	✓

→ No hillocks detected

Comb structures - results of lateral–short investigation (Test b)

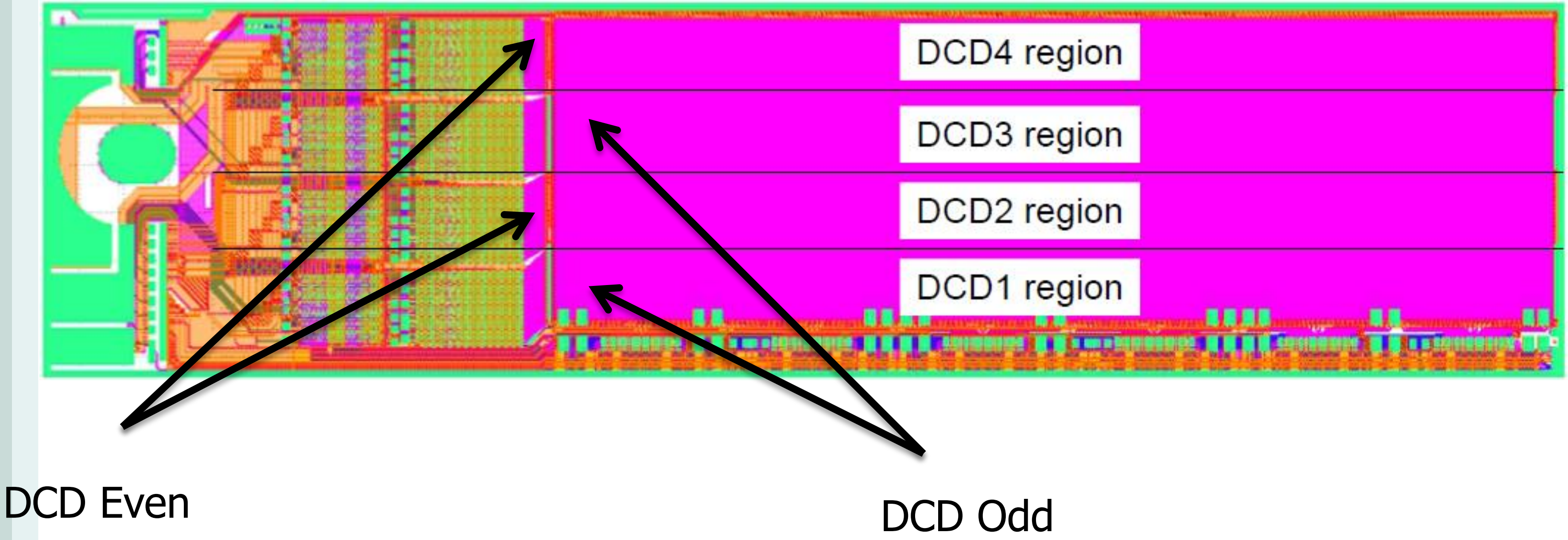
Test	**D02** ME2	**E02** ME1	**E03** ME2	**F03** ME2	**F04** ME2	**E05** ME1	**D05** ME1
				W17			
1 vs 2	✓	✓	✓	✓	✓	✓	✓
3 vs 4	✓	✓	✓	✓	✓	✓	✓
				W18			
1 vs 2	✓	✓	✓	✓	✓	✓	✓
3 vs 4	✓	✓	✓	✓	✓	✓	✓

→ No lateral shorts detected

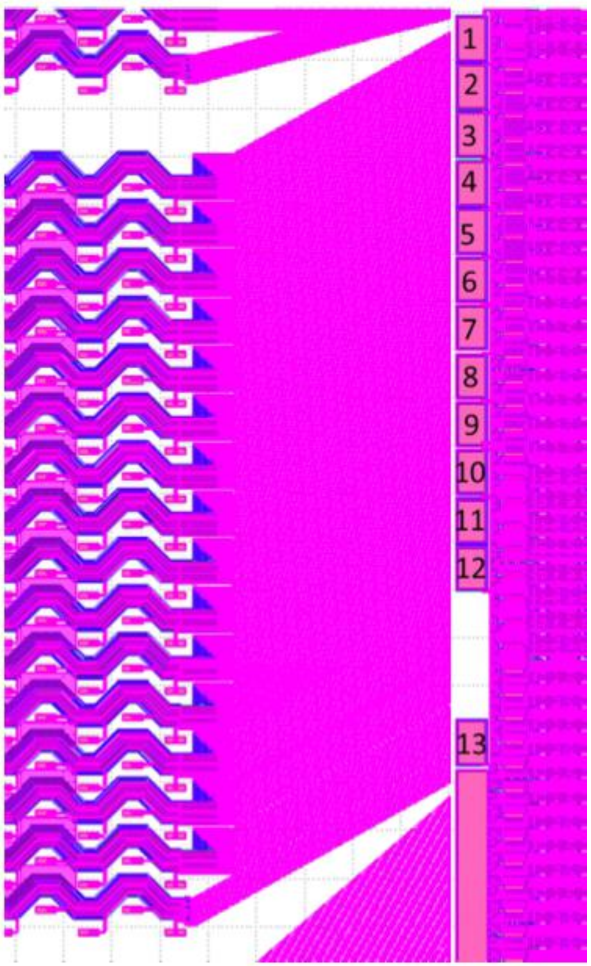
PXD9-like structures - tests

Tests on this structures allows to qualify mainly the Alu2 layer:

1. Discontinuities in the long drain lines (Alu2)
2. Lateral shorts between neighboring drain lines (Alu2)
3. Inter-metal shorts between overlapping lines (Alu2 to Alu1)



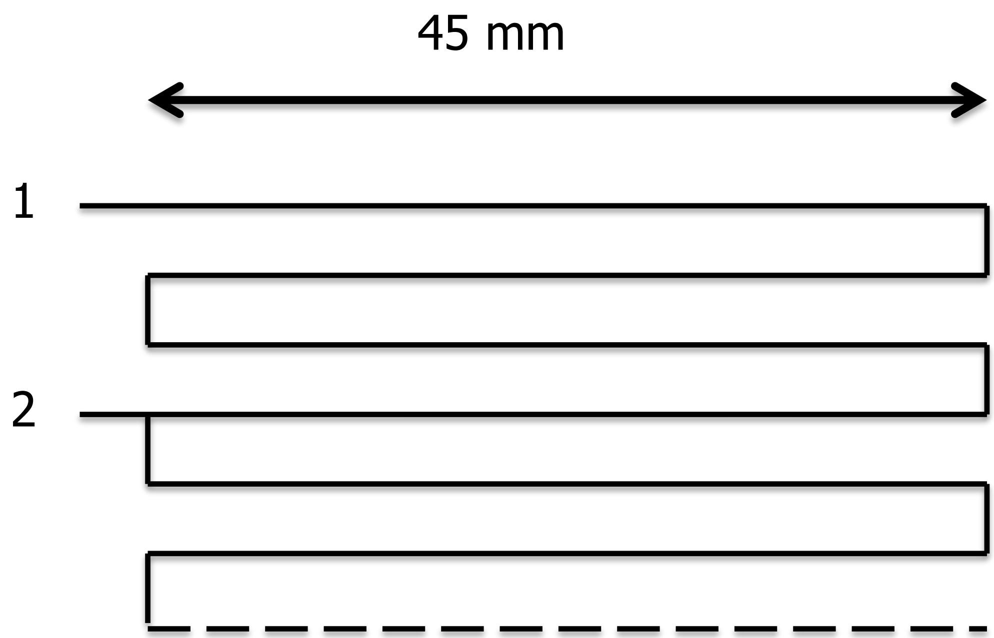
Tests in the DCD even regions



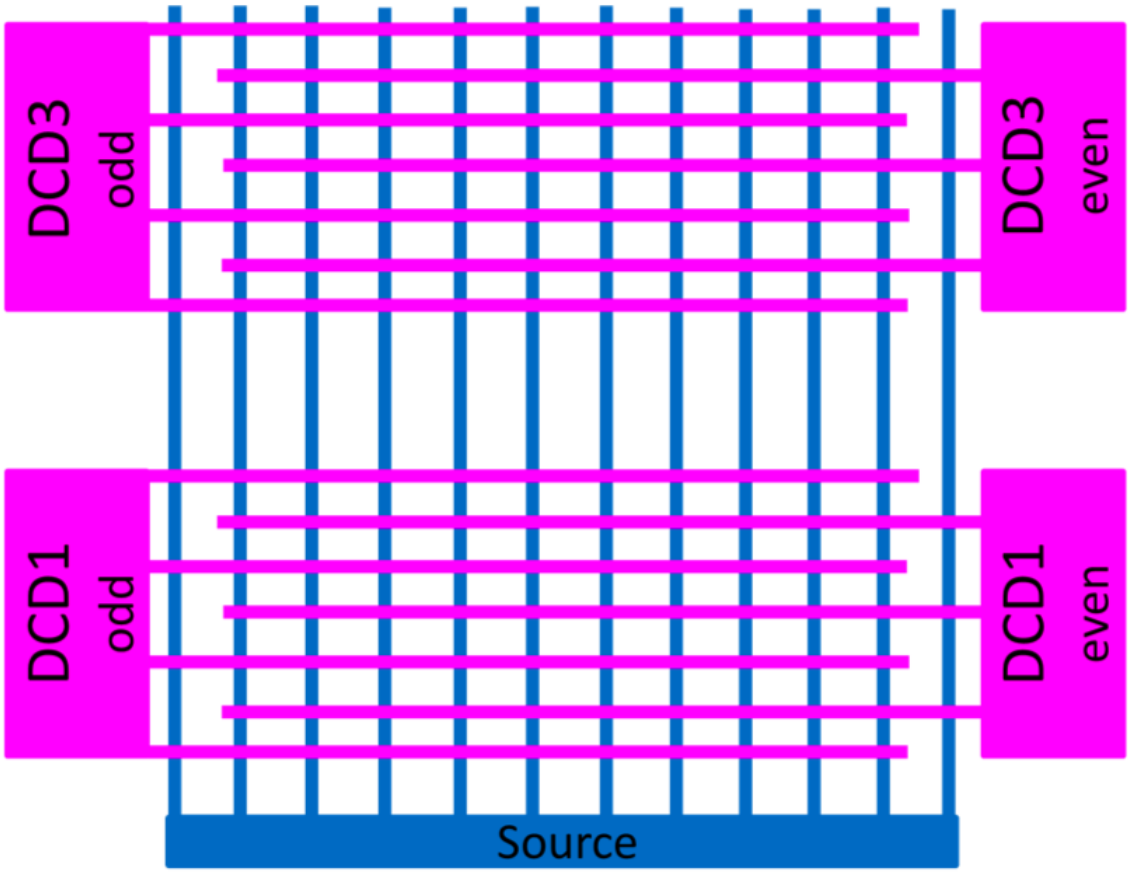
Pads 1…13 are connected in a meandering way

Pads in between → region in which drain line might be broken

V_{Sweep} = -2 V…+2 V → **no discontinuities**



Sub-layout of the DCD odd regions



1. V_{Sweep} = 100 V between odd and even lines of Alu2 → neighboring shorts
2. V_{Sweep} = 100 V between Alu2 lines and Alu1 (Source) → inter-metal shorts

PXD-9 like structures - results

1. Lateral shorts

Wafer	DUT6 (Module1)		DUT4 (Module2)		DUT2 (Module3)	
	DCD1	DCD3	DCD1	DCD3	DCD1	DCD3
17	OK	Hi-Ohm	OK	OK	OK	OK
18	OK	OK	OK	OK	OK	OK

2. Inter-metal shorts → Tested all possibilities of Alu2 against Alu1 → **No inter-metal shorts detected**

Summary and conclusions

Back to the beginning…

1. Insulation between structures on the same metal layer and between layers (i.e. Aluminium1 and Aluminium2) (PA 200)
   1. Contact chain structures → **only few contacts of the smallest size not open**
   2. Breakdown structures → **High breakdown voltages (> 200 V)**
   3. Comb structures → **No inter-metal or lateral shorts**
   4. PXD9-like structures (long metal lines) → **No discontinuities**
2. Copper connections (ATG)
   1. Electrical nets present where they should be (→ Open test) → **OK in technology option "A"**
   2. Electrical nets shortened to neighboring nets (→ Short test) → **"No" shorts in this technology**

→ Technology option "A" chosen for PXD9