Sensor Production Status

PXD9 Production Status

Results of Test Project ZMI5
(triple metal system)

PXD6 Status for DESY Testbeam

R. H. Richter
for the MPG Semiconductor Lab.

Progress Table
Mask Steps

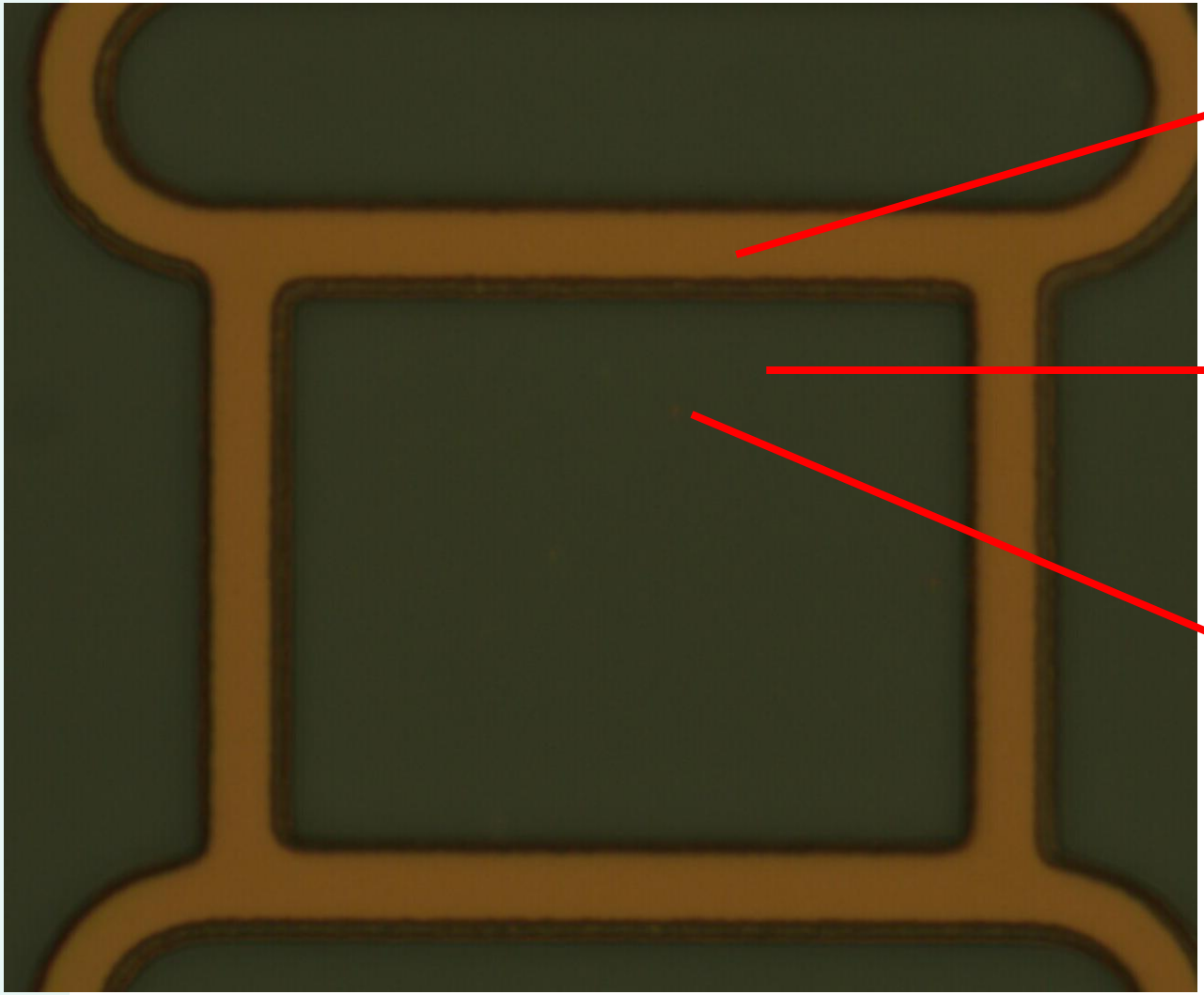
SOI and alignment →	Poly and implants →	Contacts and Metallization →	Thinning and Cutting
Masks	Masks	Masks	Masks
Alib	**Po1n**	Nitn	Winp
Poxp	Pshn	**Co1n**	(Conp)
Alip	**Pdpn**	Al1n	(Alup)
Alin	Nd1n	Freckn	Cutn
	Noxn	Co2n	Cutp
	Po2n	Al2n	
	Ps0n	Co3n	
	Poxn	Cu1n	
		Bcbn	

in total 23 mask steps

PXD9-2 **12 wafer** - waits for metal design validation (EMCM results)
PXD9-3A **8 wafer**
PXD9-3B **8 wafer**

Reminder: 1 wafer contains: 1 inner forward half module and 1 inner backward half module -> **28 (8)**
2 outer forward half module and 2 outer backward half module -> **56 (12)**

Changes of the implantation sequence

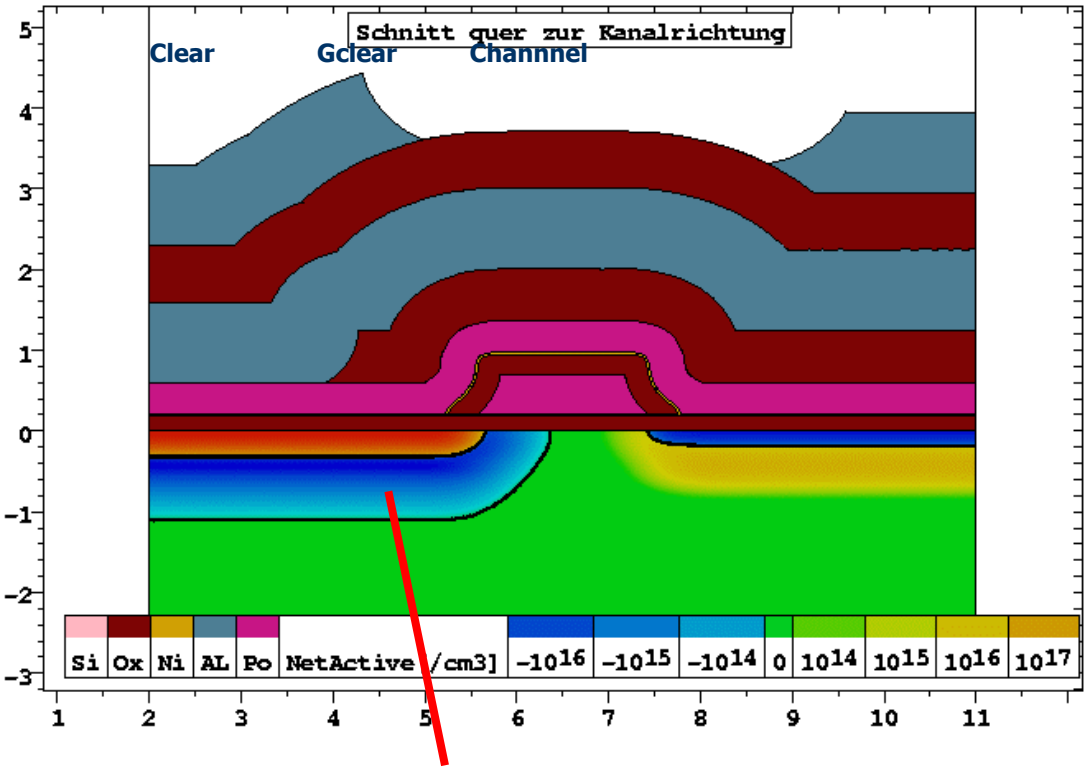


Clear Gate
Poly I

Clear regions formed by
1.) Deep P shield and
2.) N+ Clear

Relicts from poly etching with a certain height modulate implantationdepth

Cross Section



weaker potential barriers lead to noisy/bright pixel

Change od process sequence

Old process sequence

- Deep P Implantation through nitride and poly relicts ☹
- Poly oxidation (relicts are oxidized)
- Short oxide etch (removes oxidized poly)
- Nitride etch
- N+ Clear implantation through a much cleaner surface

New process sequence

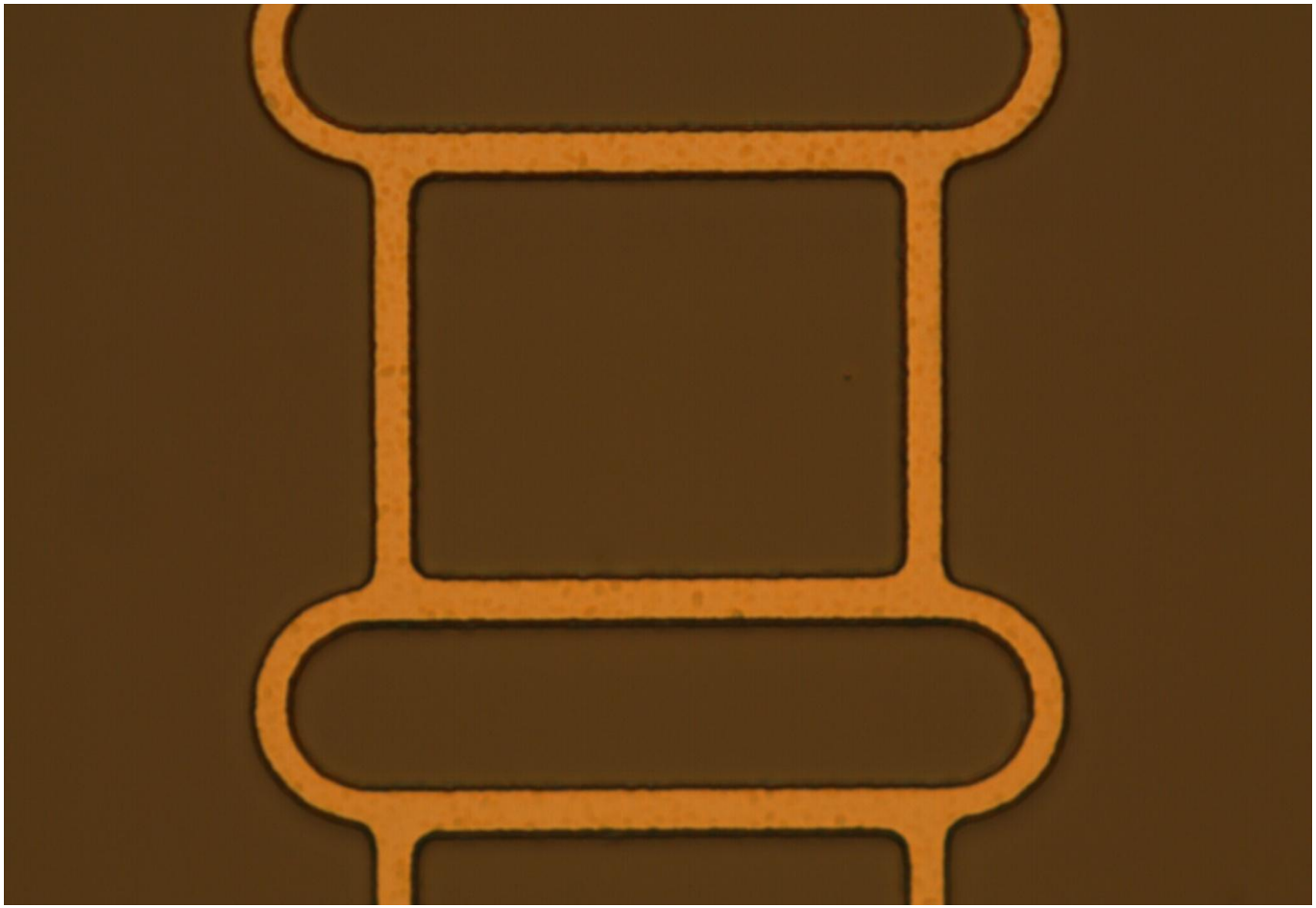
- Poly oxidation (relicts are oxidized)
- Short oxide etch (removes oxidized poly)
- Nitride etch
- Deep P Implantation through nitride
- N+ Clear implantation

Both through a cleaner surface ☺

Same procedure for the shallow p channel implantation (shifts threshold voltage to 0V)

Adaption of the implantation parameters necessary !

Surface after Nitride etching



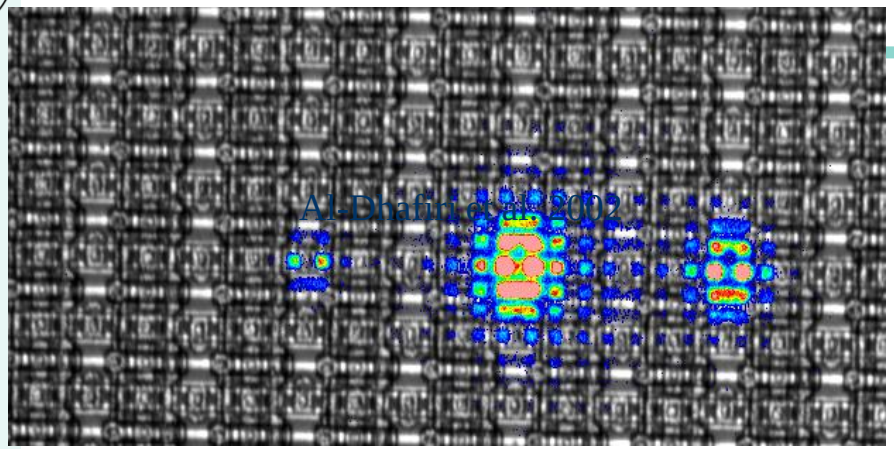
Crucial technology part: metallization

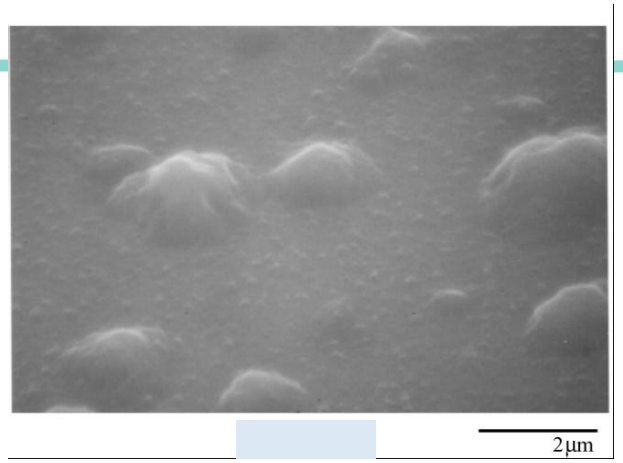
not yet done

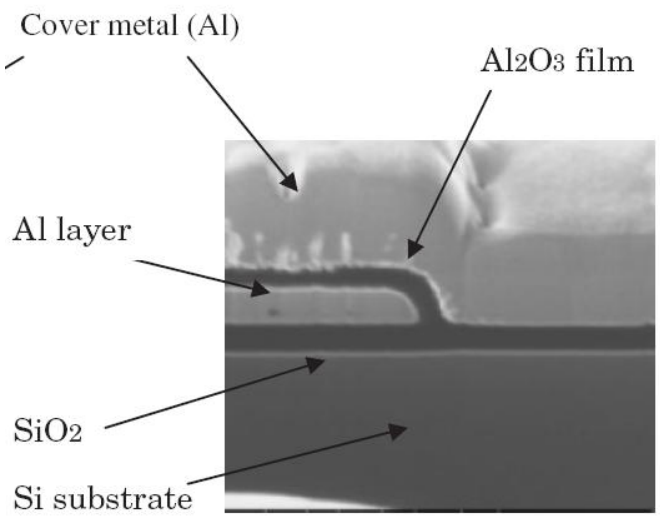
But we learned some lessons

(copper technology -> Laci's talk)

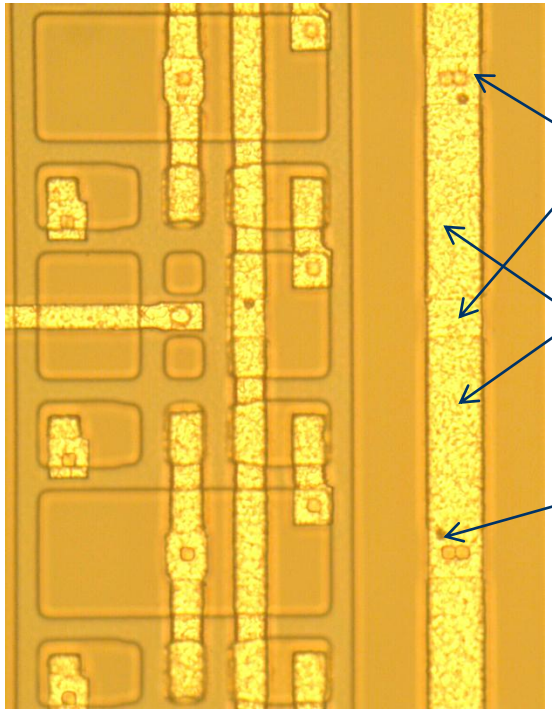
Yield improvement – hillock suppression with Al_2O_3



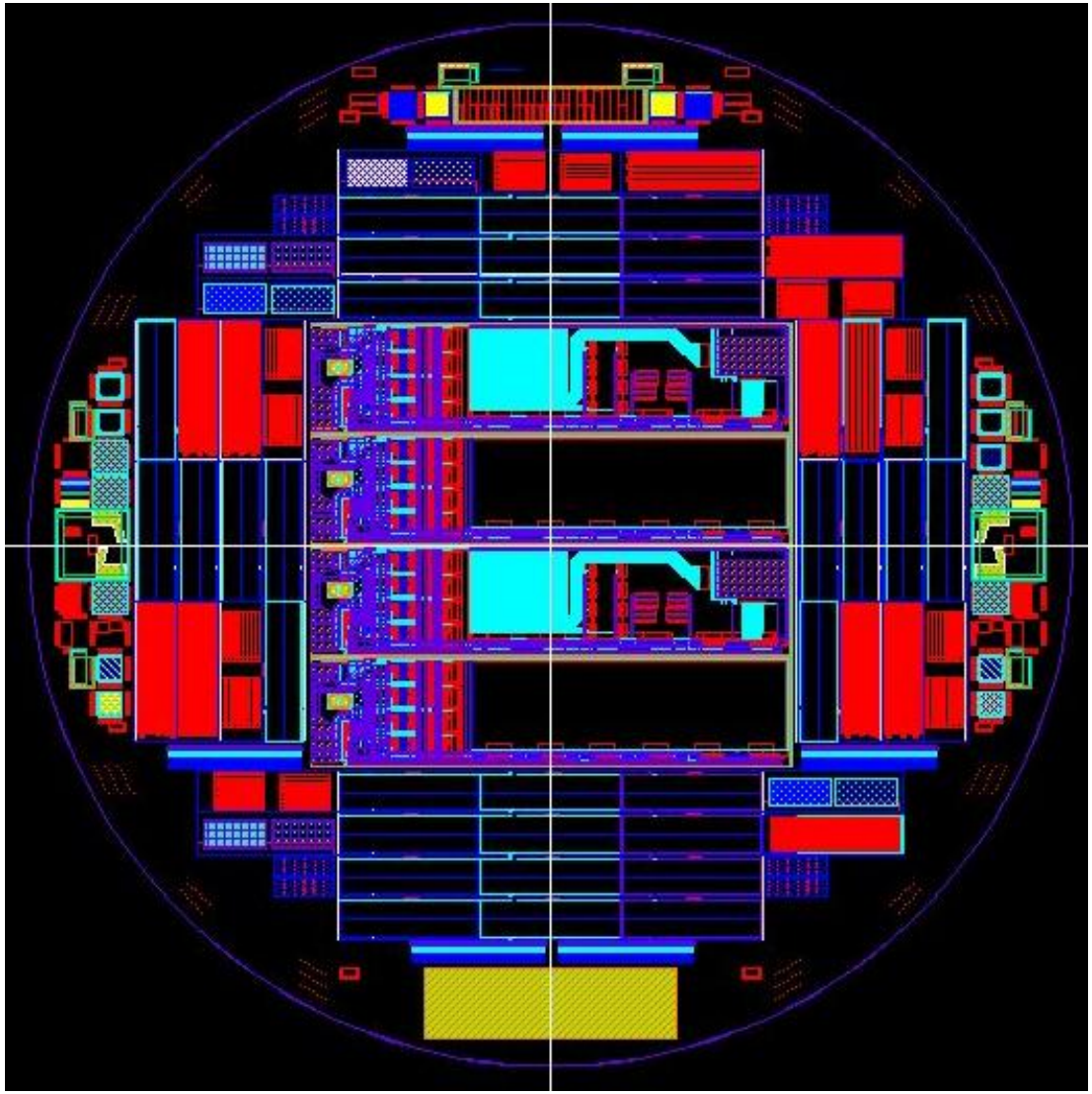




Asai and Goto, JJAP, 2008



Test project ZMI 5 – Yield Optimization



Technology:

Only contact and metal system and one poly layer (topology)

Structures:

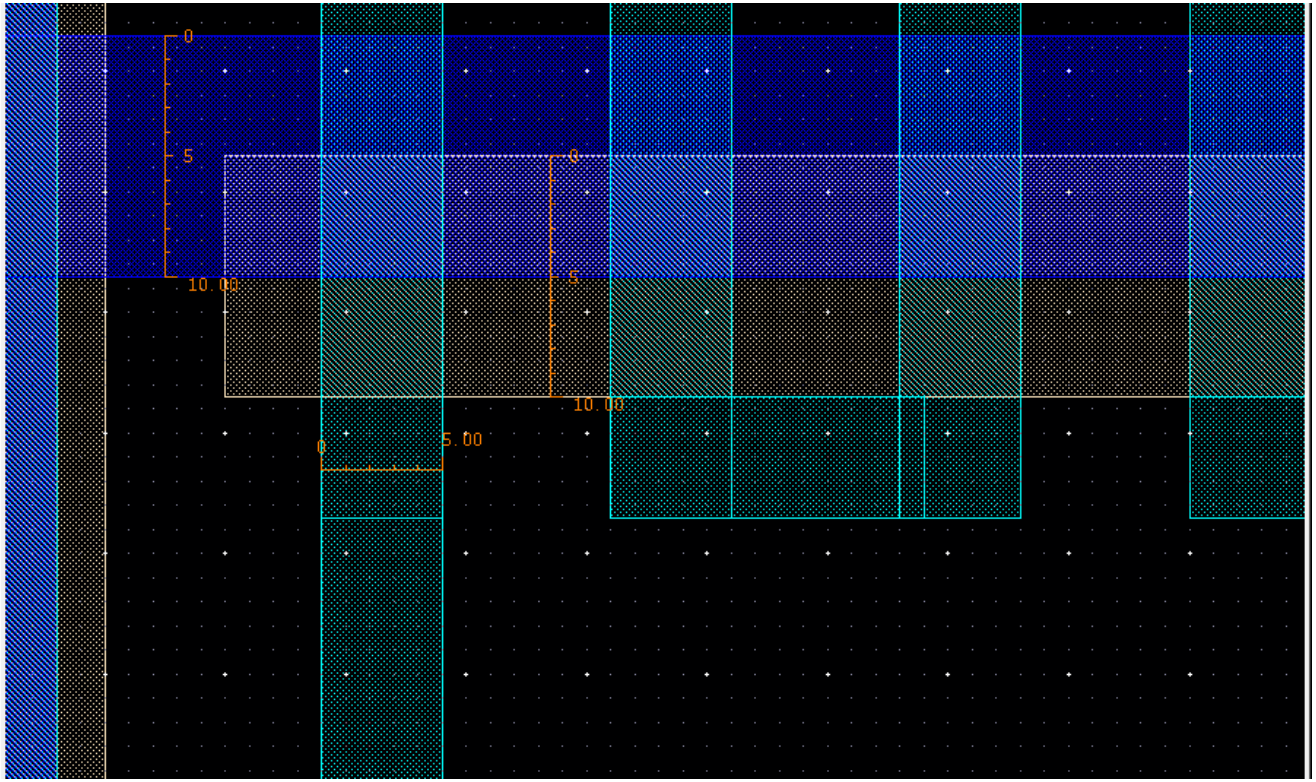
2 EMCMs
2 'inner modules'
- Many simple yield structures of relevant size

'Simple' in order to clearly distinguish fault mechanisms

ZMI5 test structures (i)

Meandered metal lines climbing over crossing lines

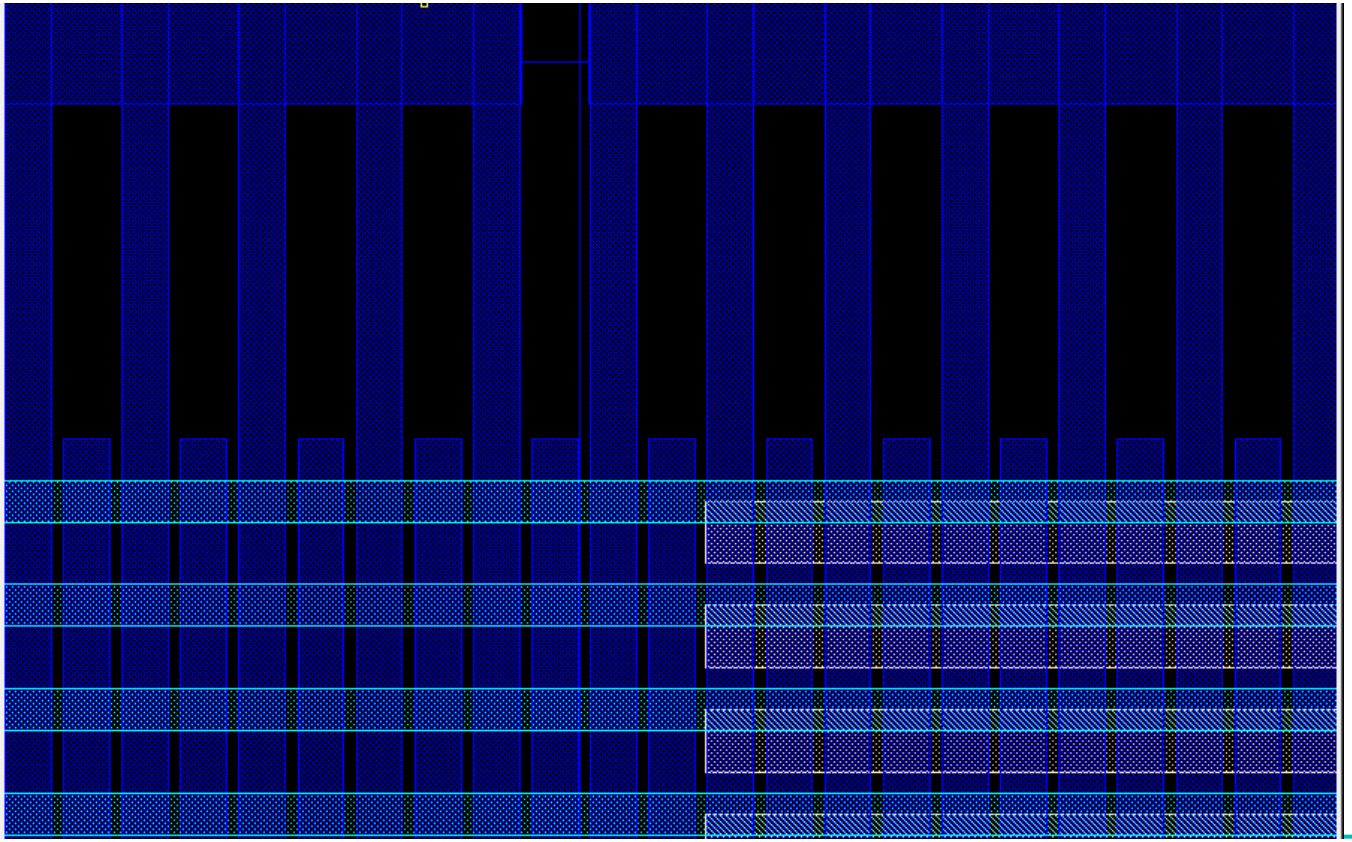
Check for interrupts (opens)



ZMI5 test structures (ii)

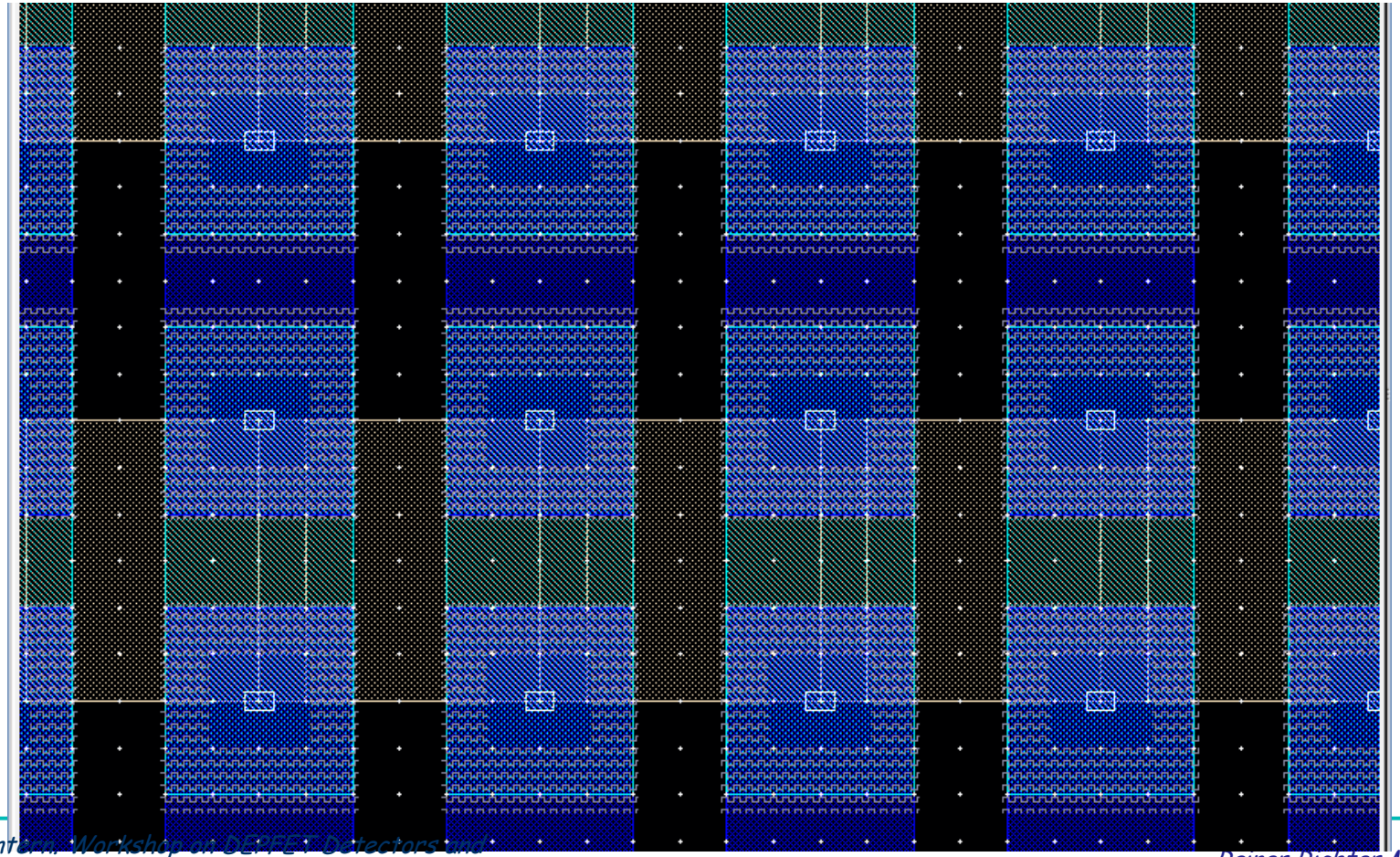
Interleaved combs climbing over crossing lines or crossed by upper lines

Check for lateral shorts (adjacencies) and breakdowns

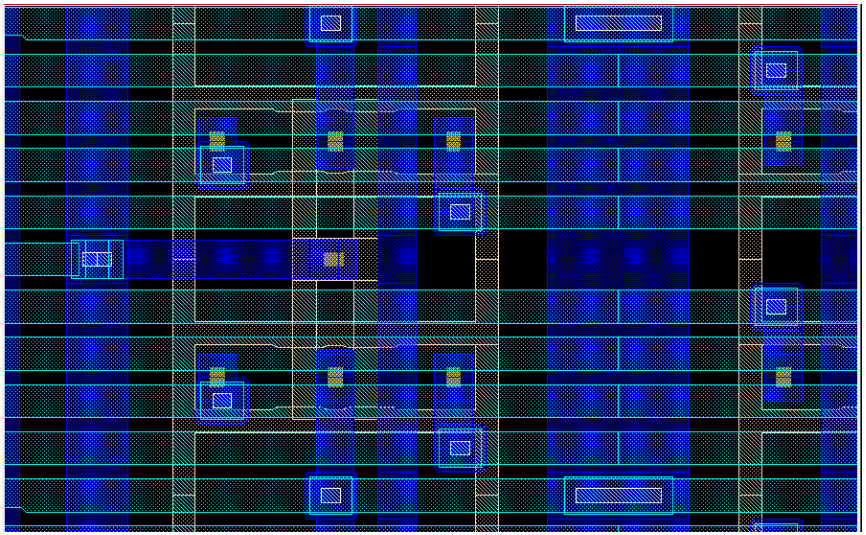


ZMI5 test structures (iii)

Contact chaines (6000 contacts in serial)
for all (three) contact layers

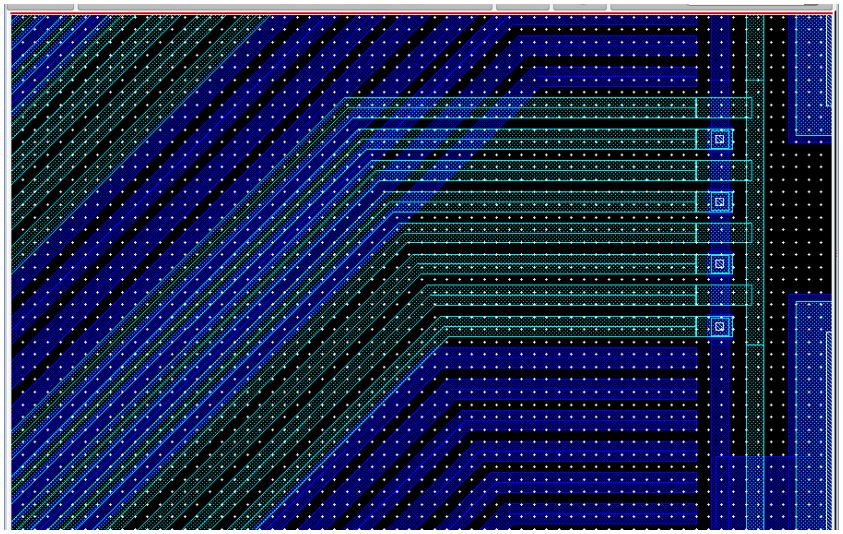


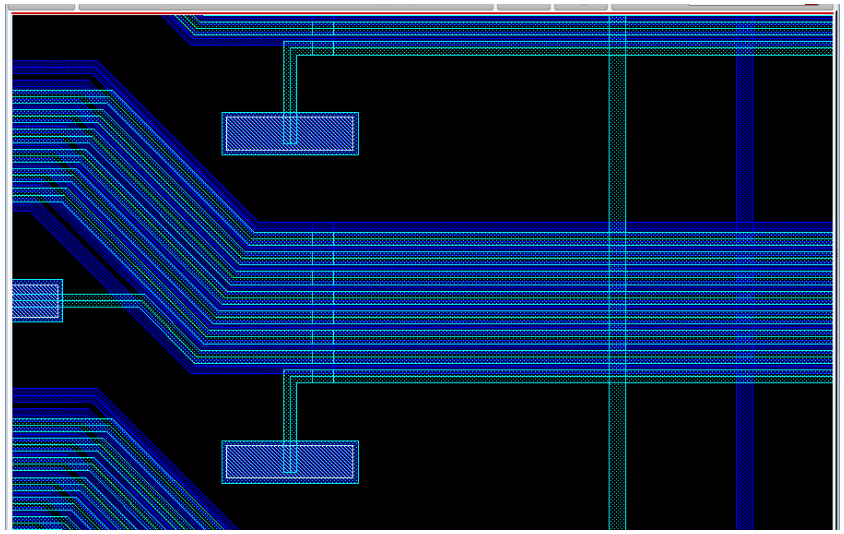
ZMI5 test structures (iv)
matrix tests



Meander and comb test philisophy
is applied for (narrow spaced) Drain lines

and for crucial regions in the DCD fanin





Simple measurements:

Often with a Good or Bad result

Measurements with automatic probe station - high statistics

Most important results (i)
Breakdown of large plane Al2/Al1 plates most proned to hillocks

Two ILD (LTO) thicknesses: 600nm and 1000nm

Vbreak(V)	Chip	V=100V	V=-100V	V=200V	V=-200V
P1	D00	5	-5	-	-
	H04	G	-95	-	-
P2	D00	5	-5	-	-
	H04	5	-5	-	-
P3	D00	G	G	G	G
	H04	G	G	G	G
P4	D00	G	G	G	G
	H04	G	G	G	G
P5	D00	G	G	G	G
	H04	G	G	G	G
P6	D00	G	G	G	G
	H04	G	G	G	G
A1	D00	G	G	-	-
	H04	G	G	-	-
A2	D00	G	G	160	-
	H04	G	G	-	-

Most important results (ii)
Breakdown on edges (+/- 100V) – highest field

Each entry represents about 500.000 crossing over edges

LTO 600nm LTO 1000nm

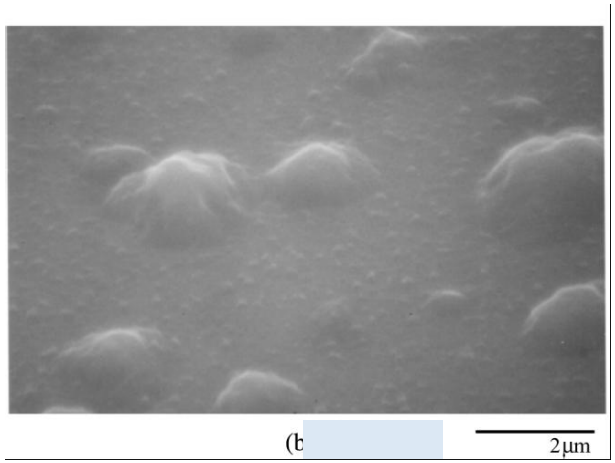
J or V_{gp}		P1		P2		P3		P4		P5		P6*	
Chip	Structure	-100V	+100V	-100V	+100V	-100V	+100V	-100V	+100V	-100V	+100V	-100V	+100V
H01	alin 2u	-4,0E-7	5,8E-8	-8,3E-7	7,1E-8	-3,9E-9	5,0E-9	-7,8E-9	8,8E-9	-6,1E-9	5,6E-9	-5,2E-9	5,1E-9
	with poly	-1,0E+2	5,2E-8	-9,0E+1	7,3E-8	-7,1E-9	6,4E-9	-1,2E-8	1,1E-8	-1,3E-8	8,3E-9	-5,8E-9	6,9E-9
I01	alin 2.5u*	-7,0E+1	9,0E+1	-6,0E+1	1,0E+2	-1,6E-8	8,7E-9	-1,0E-8	1,2E-8	-1,2E-8	9,2E-9	-1,3E-8	2,2E-8
	with poly	-6,5E+1	2,3E-7	-5,5E+1	3,0E-7	-5,5E-8	1,6E-8	-1,7E-8	1,7E-8	-3,7E-8	1,3E-8	-1,4E-8	2,2E-8
J01	alin 3u	-5,6E-9	1,0E-8	-5,3E-9	7,7E-9	-3,4E-9	3,9E-9	-3,9E-9	4,5E-9	-3,9E-9	4,5E-9	-4,6E-9	6,1E-9
	with poly	2,2E-9	1,0E+2	-5,1E-9	6,6E-9	-2,6E-9	2,3E-9	-4,7E-9	4,9E-9	-2,2E-9	2,1E-9	-3,7E-9	5,6E-9
K01	alin 4u	-5,7E-9	9,0E-9	-4,6E-9	6,9E-9	-3,3E-9	3,8E-9	-3,8E-9	4,3E-9	-3,7E-9	4,3E-9	-5,1E-9	6,8E-9
	with poly	-2,9E-9	4,4E-9			-2,0E-9	1,9E-9	-4,7E-9	4,7E-9	-1,8E-9	1,6E-9	-3,8E-9	5,2E-9
H02	al2n 2u	-1,3E-7	6,8E-7	-1,3E-7	4,5E-7	-2,3E-9	3,2E-9	-1,9E-8	1,1E-7	-1,3E-9	1,2E-9	-4,5E-9	3,3E-9
	with poly	-1,6E-7	9,0E+1	-2,1E-7	8,5E+1	-3,7E-9	6,3E-9	-2,0E-8	1,1E-8	-5,1E-9	1,1E-8	-5,0E-9	4,9E-9
I02	al2n 2.5u	-2,8E-9	7,5E-9	-3,8E-9	1,4E-8	-1,3E-9	1,1E-9	-2,1E-9	3,9E-9	-1,3E-9	1,2E-9	-3,0E-9	1,8E-9
	with poly	-9,6E-8	1,0E+2	-1,2E-7	9,5E+1	-2,5E-9	4,8E-9	-1,4E-8	9,5E-8	-3,1E-9	6,2E-9	-3,1E-9	2,6E-9
J02	al2n 3u	-4,0E-9	9,7E-9	-3,9E-9	1,3E-8	-1,2E-9	1,3E-9	-2,9E-9	4,5E-9	-1,5E-9	1,7E-9	-3,3E-9	2,4E-9
	with poly	-8,7E-8	1,0E+2	-1,0E-7	9,8E+1	-2,7E-9	5,0E-9	-1,3E-8	6,8E-8	-3,7E-9	7,5E-9	-3,8E-9	3,0E-9
K02	al2n 4u	-5,6E-9	1,6E-8	-4,5E-9	1,5E-8	-1,5E-9	1,7E-9	-3,1E-9	7,3E-9	-1,9E-9	2,1E-9	-4,3E-9	2,9E-9
	with poly	-7,2E-8	8,8E-7			-2,9E-9	5,0E-9	-1,1E-8	4,7E-8	-3,7E-9	7,2E-9	-4,7E-9	3,7E-9
B01	alin 2.5u	-5,7E-7	7,5E-8	-8,1E-7	9,2E-8	-1,3E-8	7,8E-9	-1,7E-8	1,6E-8	-1,1E-8	8,1E-9	-7,0E-9	8,3E-9
	with poly	-9,8E+1	6,4E-8	-9,0E+1	1,3E-7	-4,8E-9	4,8E-9	-1,9E-8	1,7E-8	-4,1E-9	4,8E-9	-6,3E-9	7,5E-9
C01	alin 3u	-5,9E-7	7,7E-8	-8,1E-7	9,4E-8	-1,2E-8	8,1E-9	-1,4E-8	1,4E-8	-1,1E-8	7,9E-9	-6,3E-9	6,1E-9
	with poly	-1,0E+2	6,2E-8	-9,0E+1	1,3E-7	-5,5E-9	5,5E-9	-1,9E-8	1,6E-8	-5,4E-9	5,8E-9	-5,8E-9	7,0E-9
D01	alin 4u	-1,0E+2	1,2E-7	-9,5E+1	1,5E-7	-1,3E-8	7,4E-9	-5,0E+0	5,0E+0	-6,2E-9	6,0E-9	-5,1E-9	6,2E-9
	with poly	-9,8E+1	9,6E-8	-9,0E+1	1,8E-7	-3,0E-8	1,1E-8	-5,5E-8	2,4E-8	-2,1E-8	1,3E-8	-6,1E-9	6,9E-9
B02	al2n 2.5	-2,7E-9	9,4E-9	-2,3E-9	9,8E-9	-6,5E-10	7,2E-10	-1,7E-9	3,2E-9	-1,0E-9	8,6E-10	-3,8E-9	2,0E-9
	with poly	-1,1E-7	9,8E+1	-1,7E-7	9,0E+1	-1,9E-9	2,9E-9	-1,8E-8	5,5E-8	-3,3E-9	6,9E-9	-4,3E-9	2,9E-9
C02	al2n 3u	-2,7E-9	8,2E-9	-2,8E-9	1,0E-8	-7,4E-10	6,2E-10	-2,3E-9	3,7E-9	-1,3E-9	8,4E-10	-3,2E-9	2,1E-9
	with poly	-9,4E-8	9,8E+1	-1,6E-7	9,0E+1	-2,0E-9	2,9E-9	-1,8E-8	4,5E-8	-3,0E-9	6,0E-9	-3,8E-9	2,9E-9
D02	al2n 4u	-3,2E-9	6,9E-9	-2,9E-9	8,5E-9	-1,3E-9	1,3E-9	-2,3E-9	3,1E-9	-1,7E-9	1,7E-9	-3,2E-9	
	with poly	-6,5E-8	1,0E+2	-1,2E-7	9,5E+1	-2,1E-9	2,7E-9	-9,1E-9	2,0E-8	-3,1E-9	7,4E-9	-3,8E-9	2,4E-9

Metal 1 / Metal 2 Breakdown

1) Thicker (1000nm) LTO does the job

2) No difference between oxidized and non oxidized first aluminum layer

Conclusion: hillocks can be encapsulated by thicker oxide

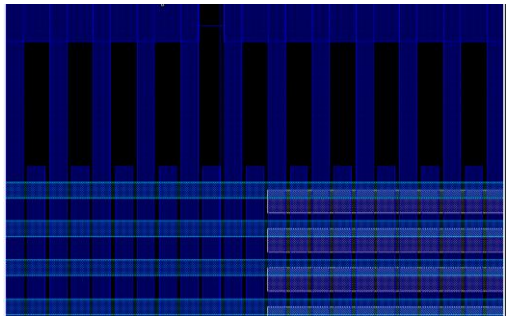


Confirmed already by a first test project
but willl be checked again by EMCM2
(talk by Laci)

Our problems

Comb meas.	comb layer/gap	A1*	A2*	P1	P2	P3	P4	P5	P6**
DOWN	below matrices								
H01	al1n 2u	B	G	G	G	G	G	G	B
	with poly	B	G	B	B	B	B	B	B
I01	al1n 2.5u*	G	G	G	G	G	G	G	B
	with poly	G	G	G	G	G	G	G	B
J01	al1n 3u	G	B	G	G	G	G	G	G
	with poly	G	G	G	G	G	G	G	G
K01	al1n 4u	G	B	G	G	G	G	G	G
	with poly	G	M	G	G	G	G	G	G
H02	al2n 2u	B	G	B	B	B	B	B	B
	with poly	B	B	B	B	B	B	B	B
I02	al2n 2.5u	B	G	G	G	B	G	G	B
	with poly	B	G	B	B	G	B	G	G
J02	al2n 3u	G	G	B	G	G	B	G	G
	with poly	B	G	B	G	G	G	G	G
K02	al2n 4u	G	G	G	G	G	G	G	G
	with poly	B	G	G	B	G	G	G	G
UP	above matrices								
B01	al1n 2.5u	G	G	G	G	G	G	G	G
	with poly	G	G	G	G	G	G	G	B
C01	al1n 3u	G	G	G	G	G	G	G	G
	with poly	G	G	G	G	G	G	G	G
D01	al1n 4u	G	G	G	G	G	G	G	G
	with poly	G	G	G	G	G	G	G	G
B02	al2n 2.5u	B	G	G	G	G	G	G	G
	with poly	B	B	B	B	G	B	B	G
C02	al2n 3u	G	G	G	G	G	G	G	G
	with poly	B	G	B	B	G	G	G	G
D02	al2n 4u	G	G	G	G	G	G	G	G
	with poly	B	G	G	G	G	G	G	G
LEFT	left from matrices								
F00	al1n 2u	B	G	G	G	G	G	B	B
	with poly	B	G	B	B	B	B	B	B
F01	al1n 2.5u	G	G	G	G	G	G	B	G
	with poly	G	G	G	G	G	G	B	B
F02	al1n 3u*	G	G	G	G	G	G	G	B
	with poly	G	G	G	G	G	G	B	B
F03	al1n 4u*	G	G	G	G	G	G	G	B
	with poly	G	G	G	G	G	G	B	B
RIGHT	right from matrices								
F04	al1n 2u*	B	G	G	G	G	G	B	B
	with poly	B	G	B	B	B	B	B	B
F05	al1n 2.5u	G	G	G	G	G	G	G	G
	with poly	G	G	G	G	G	G	B	B
F06	al1n 3u	G	G	G	G	G	G	G	G
	with poly	G	G	G	G	G	G	B	G
F07	al1n 4u	G	G	G	G	G	G	G	G
	with poly	G	G	G	G	G	G	G	G

Comb structures



Some times shorts between adjacent lines

within the same Al layer !

If: crossing other lines and at small distances

Short (adjacencies) test in Matrices

Wafer	P1		P2		P3		P4		P5		P6		A1*		A2*	
Chip	up	do	up	do	up	do	up	do	up	do	up	do	up	do	up	do
aGvsSo	B	G	G	G	B	G	G	G	G	G	B	B	B	B	G	G
aGvsaC	G	G	G	G	G	G	G	G	G	G	G	G	G	B	G	G
aCvsSo	G	G	G	G	G	G	G	G	G	G	G	G	G	B	G	G
1.D-Co	G	G	G	G	G	G	B	G	G	G	B	B	B	B	G	G
2.D-Co	G	G	G	G	G	G	G	G	G	G	B	B	B	B	G	G
1.leCovsSo	-	-	-	-	-	-	-	-	G	-	B	B	-	-	-	-
2.leCovsSo	-	-	-	-	-	-	-	-	-	-	B	B	-	-	-	-
1.riCovsSo	G	G	G	G	G	G	G	G	G	G	B	B	B	B	G	G
2.riCovsSo	-	-	-	-	-	-	-	-	-	-	B	B	-	-	-	-
1.riCovsC	G	G	G	G	G	G	G	G	G	G	G	G	-	-	-	-
2.riCovsC	-	-	-	-	-	-	-	-	-	-	G	G	-	-	-	-
1.riCovsG	G	G	G	G	G	G	G	G	G	G	B	B	-	-	-	-
2.riCovsG	-	-	-	-	-	-	-	-	-	-	B	B	-	-	-	-

Shorts mainly on two wafers, different lithography paramters were used within the batch

Only 1 open was found on all matrices

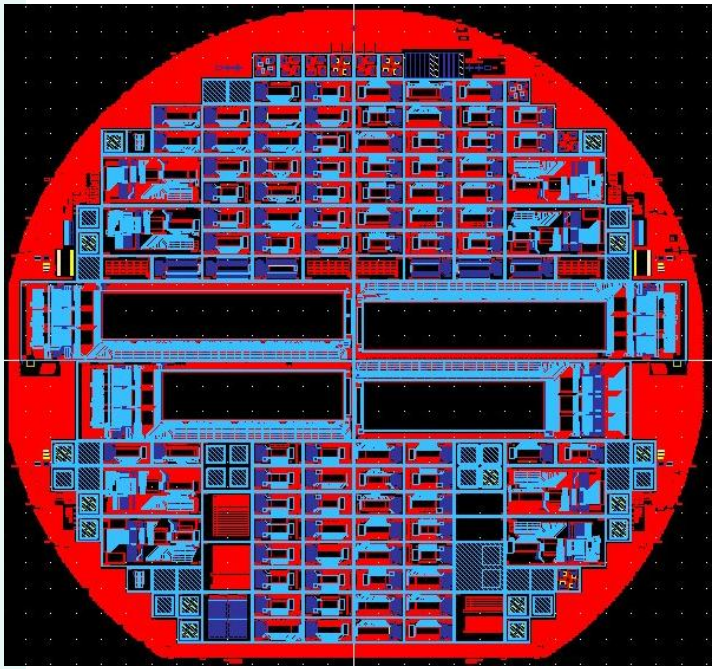
100% yield of dcd fanin (for shorts as well as for breakdowns)

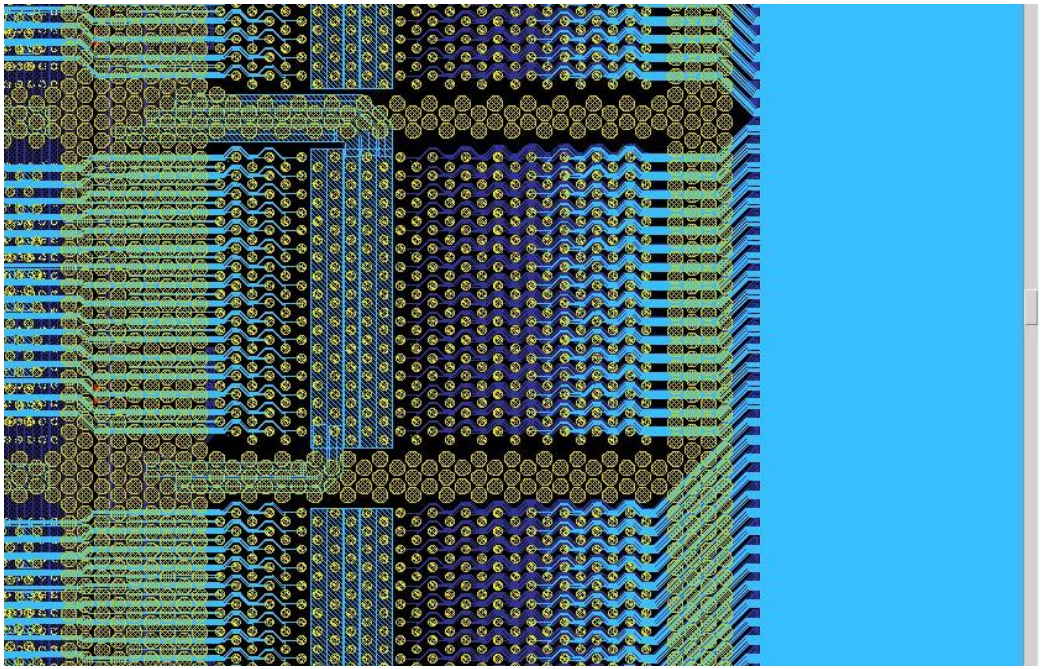
PXD6 status

Two last wafers were cut -> test matrices available

Very last two wafers 4 and 5 dedicated for the DESY test beam

are in the copper process - BCB mask written – ILD (Al2/Cu)

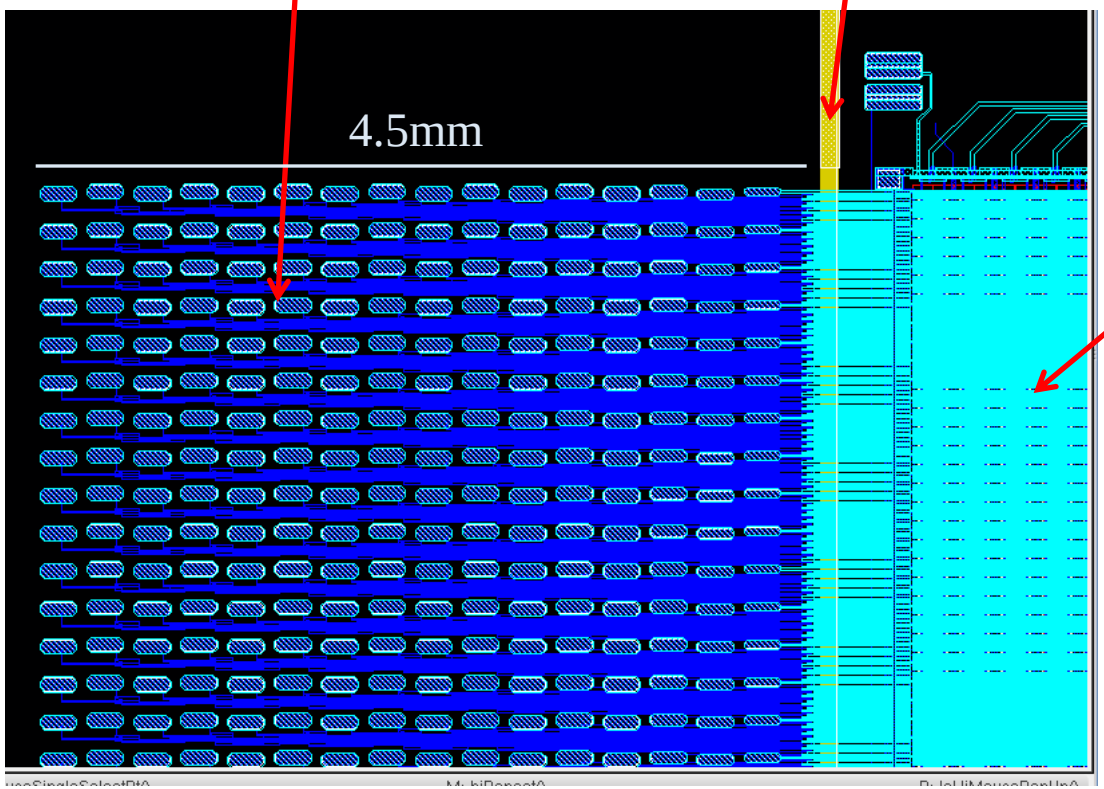




Summary

- PXD9 is running smoothly and still in time
- Contact and metal system is crucial in terms of yield
  - A special test project ZMI5 was processed
    - No need of AlO
    - Careful with Al lithography to avoid shorts
- PXD6 wafers 4 and 5 with large matrices for the DESY testbeam are getting the copper process

Design for testability



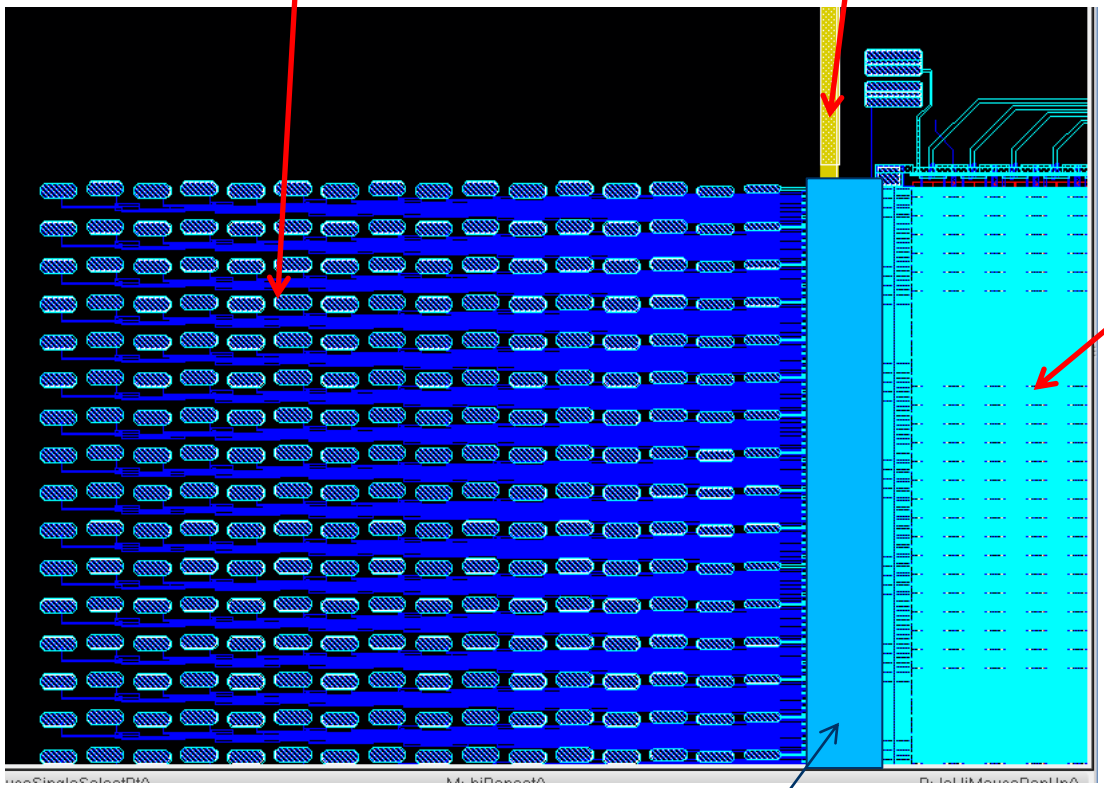
Aim: test all drain lines after 2nd metal with a probe card or ‘flying needle‘
(repair if necessary by overetching, or repeating the litho),
A significant number of Depfet IV ca be taken.

Test matrices and structures to provide the space

Removing of the metal 2 connections after the tests

‘removable‘ test pad array
16 x 64

Cutting edge



Matrix

coarse mask to disconnect the test pads by etching the 2nd metal traces