Summary of electrical tests on 3D sensors

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On behalf of FBK (Maurizio, Sabina, Nicola)
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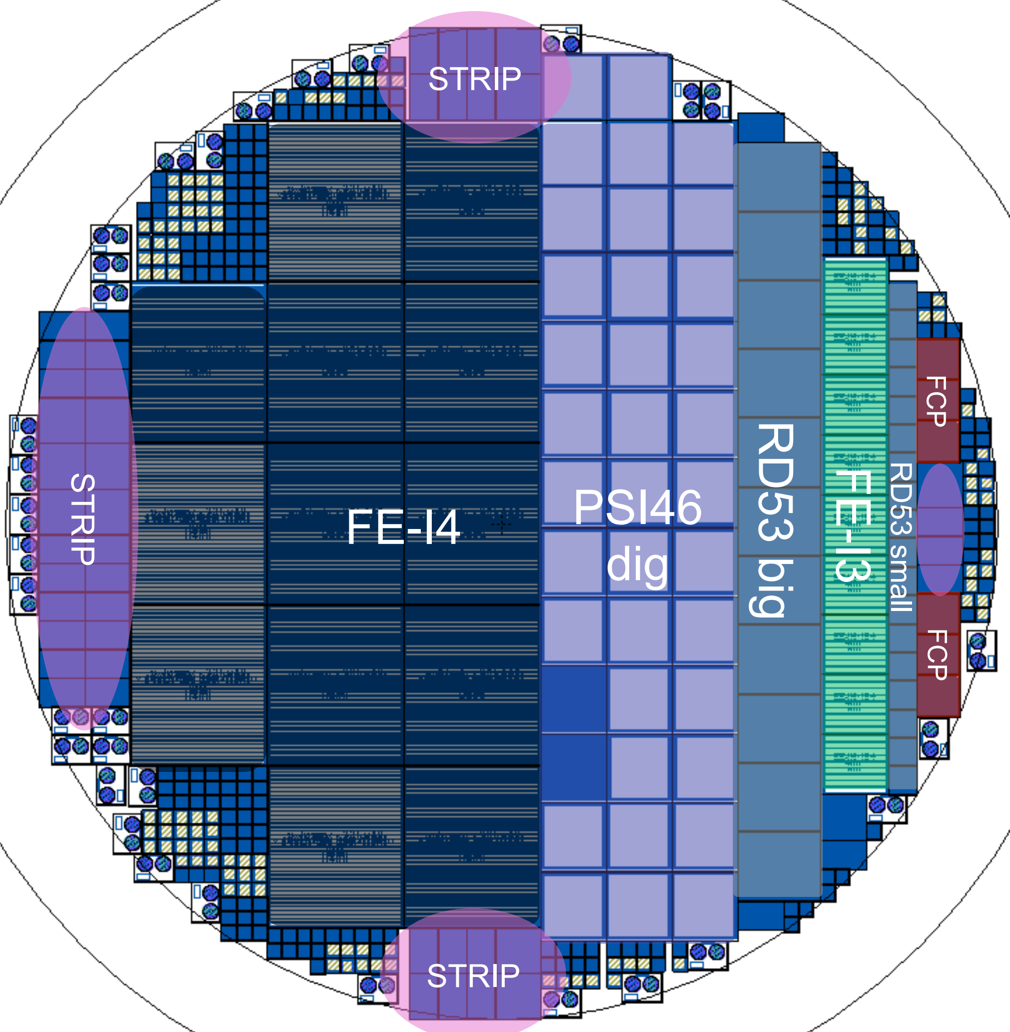
3D Pixel Wafer Layout

Final version



+ Test structures (strip, diodes, etc)

Many different pixel geometries and pitch variations:

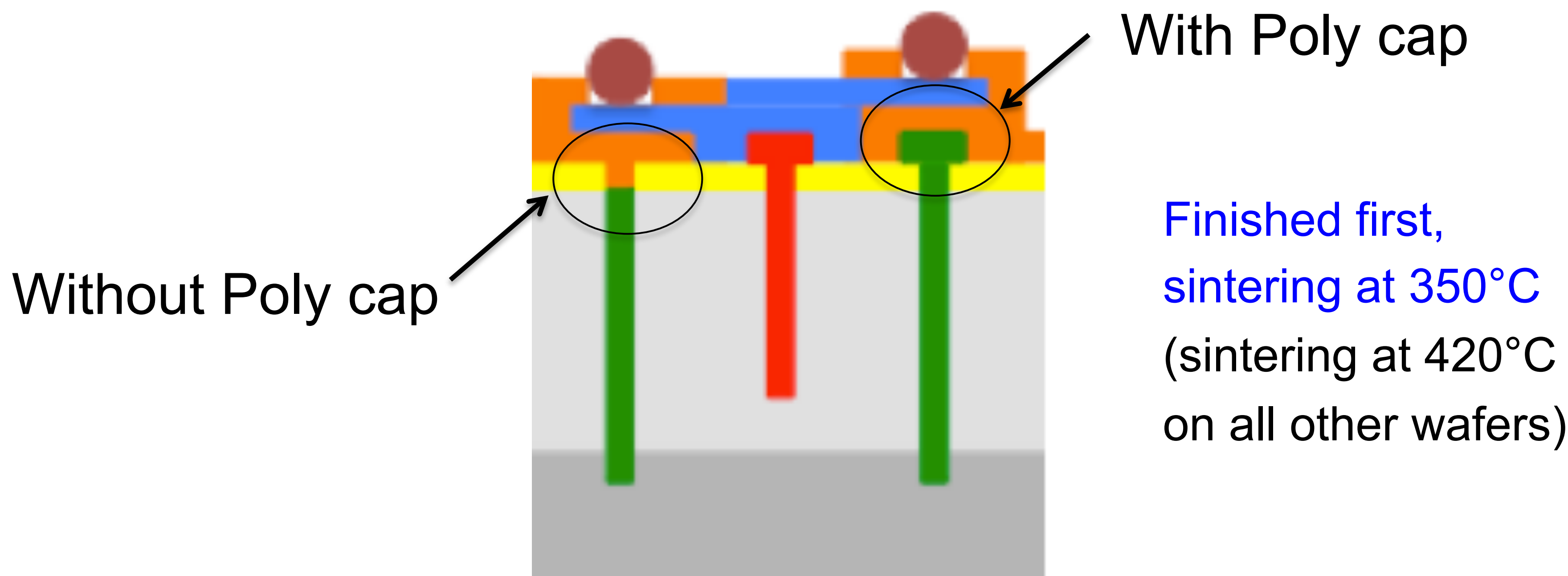
- FE-I4
  - 50 x 250 (2E) std
  - 50 x 50 (1E)
  - 25 x 100 (1E and 2E)
  - 25 x 500 (1E)
- FE-I3
  - 50 x 50 (1E)
  - 25 x 100 (1E and 2E)
- PSI46dig
  - 100 x 150 (2E and 3E) std
  - 50 x 50 (1E and 2E)
  - 50 x 100, 100 x 100 (2E + 4E)
  - 50 x 100, 100 X 150 (2E + 6E)
  - 25 x 100 (1E and 2E)
- FCP
  - 30 x 100 (1E)
- RD53
  - 50 x 50 (1E)
  - 25 x 100 (1E)
  - 25 x 100 (2E)

Processed wafer: splits

Two active thicknesses, w. and w/o poly “cap”

Active Thickness	Poly cap	Wafers		
100 um	Yes	36	41	48
	No	50	54	
130 um	Yes	60	76	77
	No	78	82	

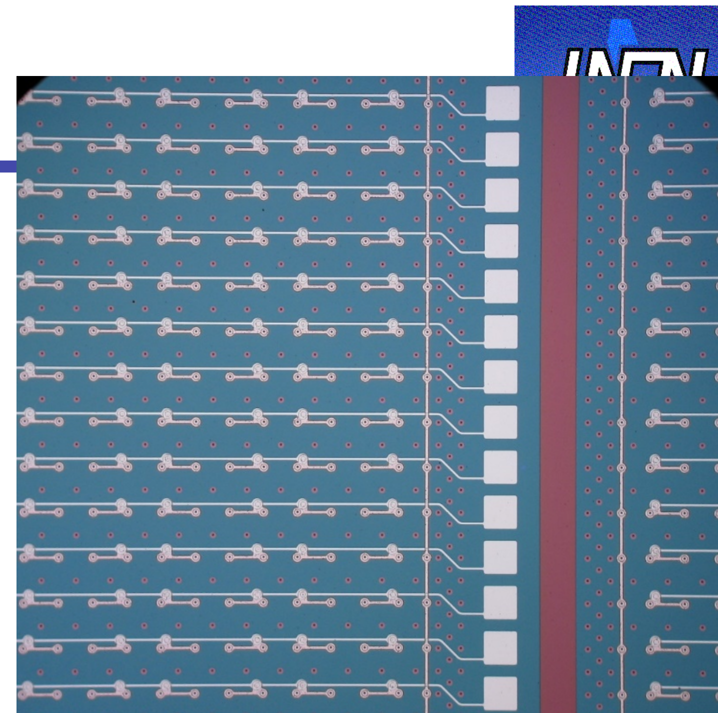
W82 broken, finished without temp metal

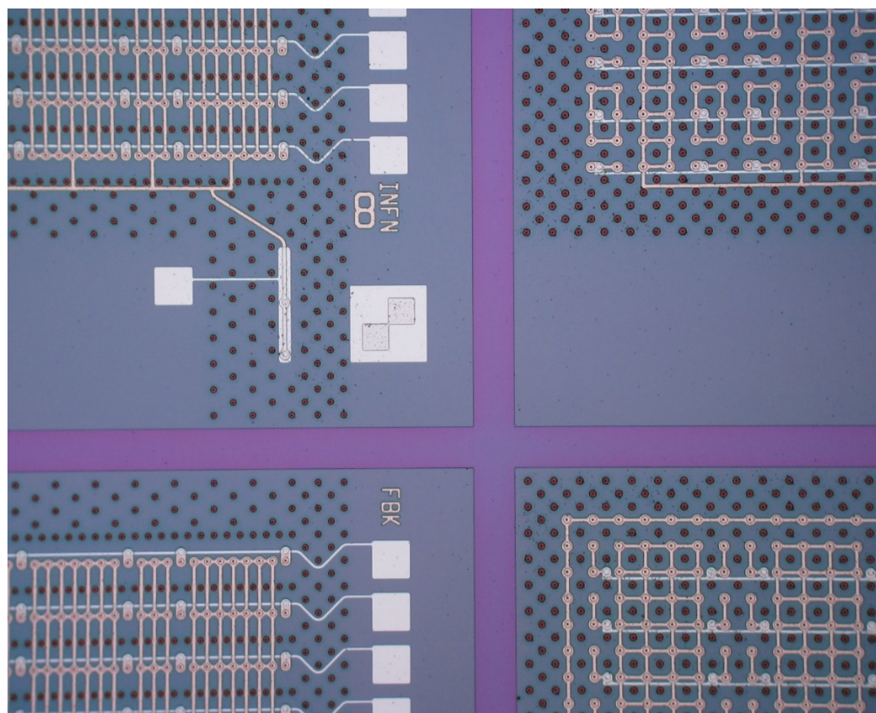


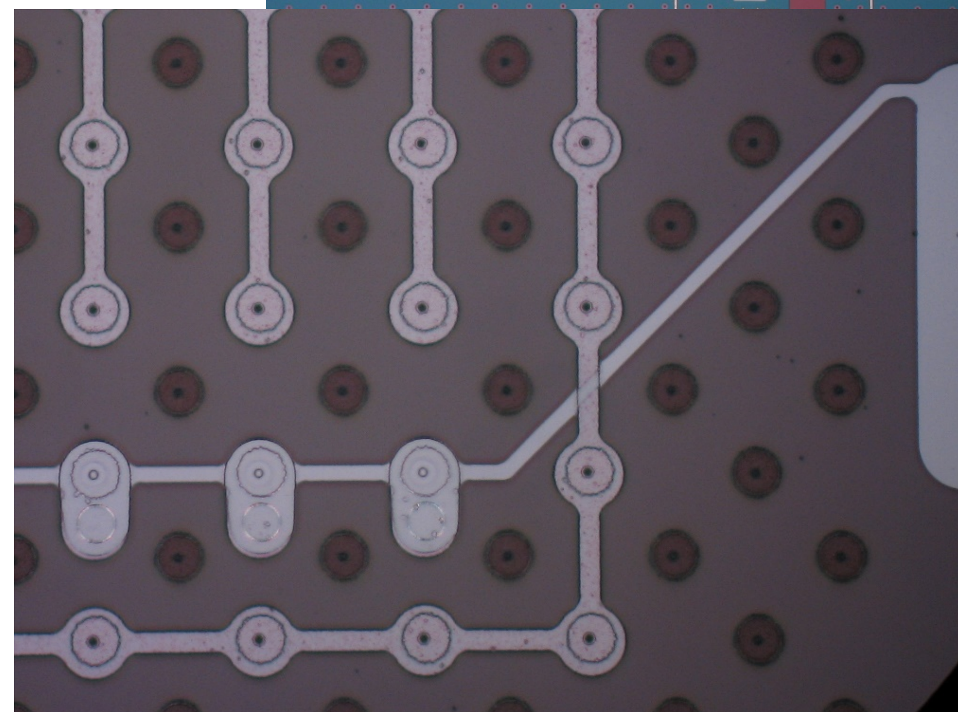
Finished first, sintering at 350°C (sintering at 420°C on all other wafers)

A few pictures

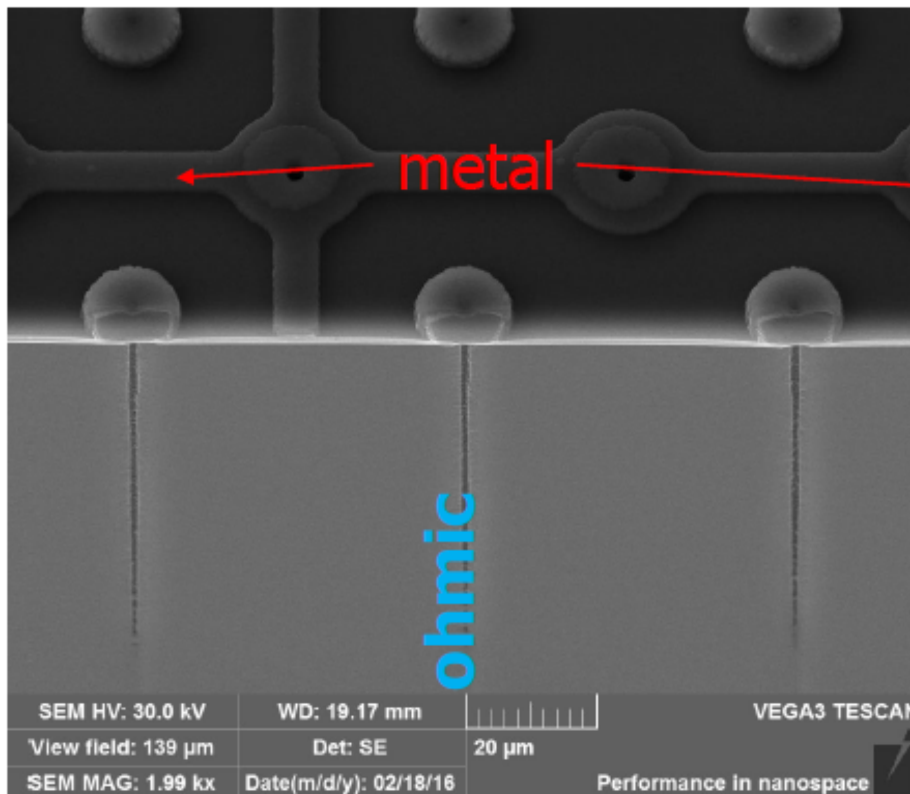
- Wafers with temporary metal
- Good lithographical quality

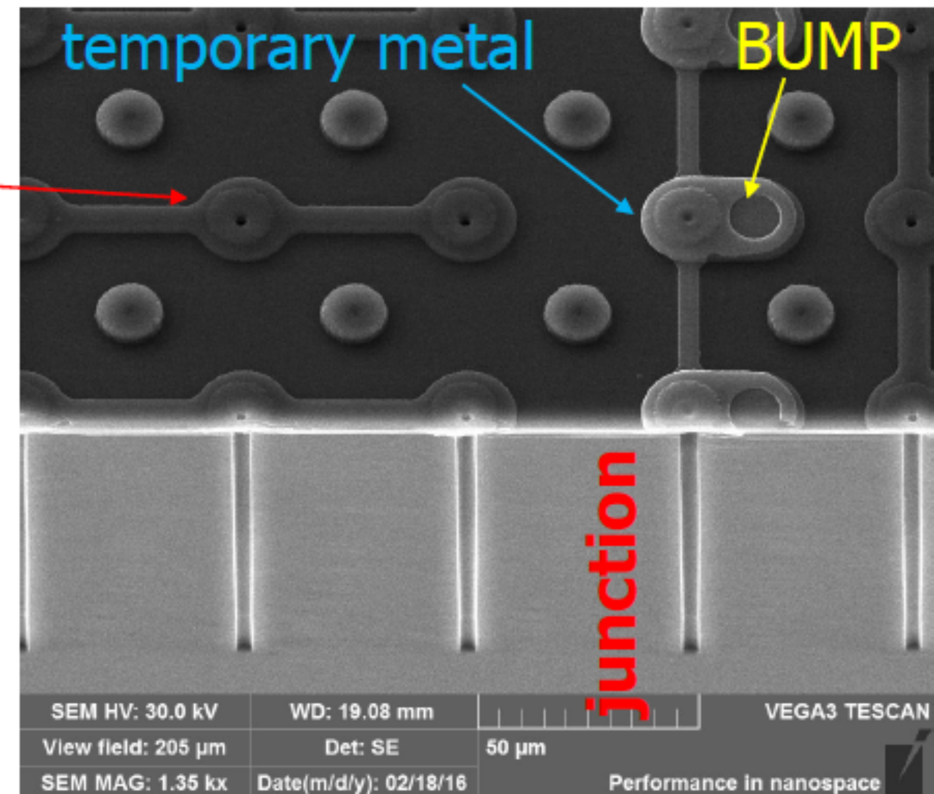






SEM pictures (1)

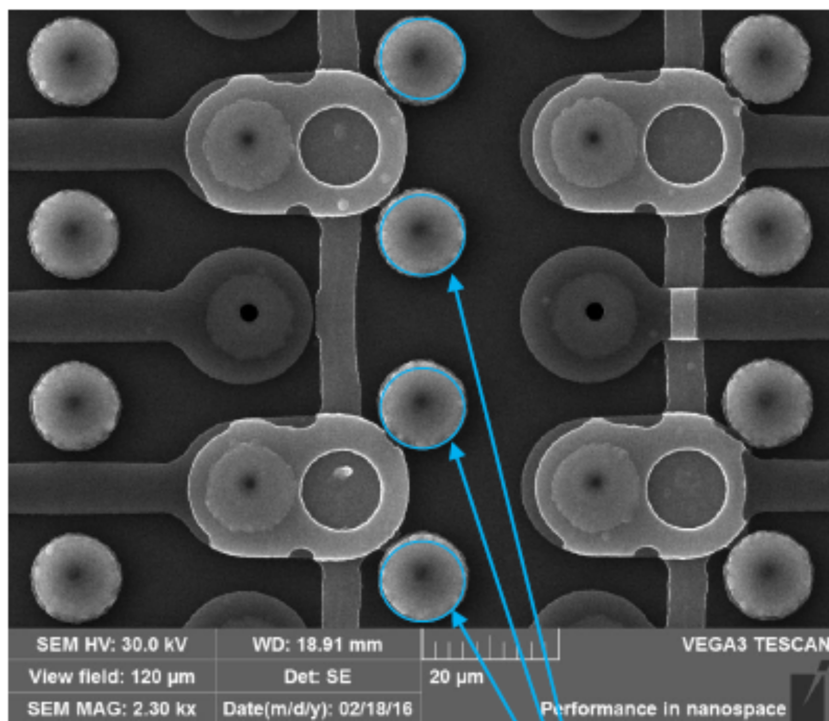


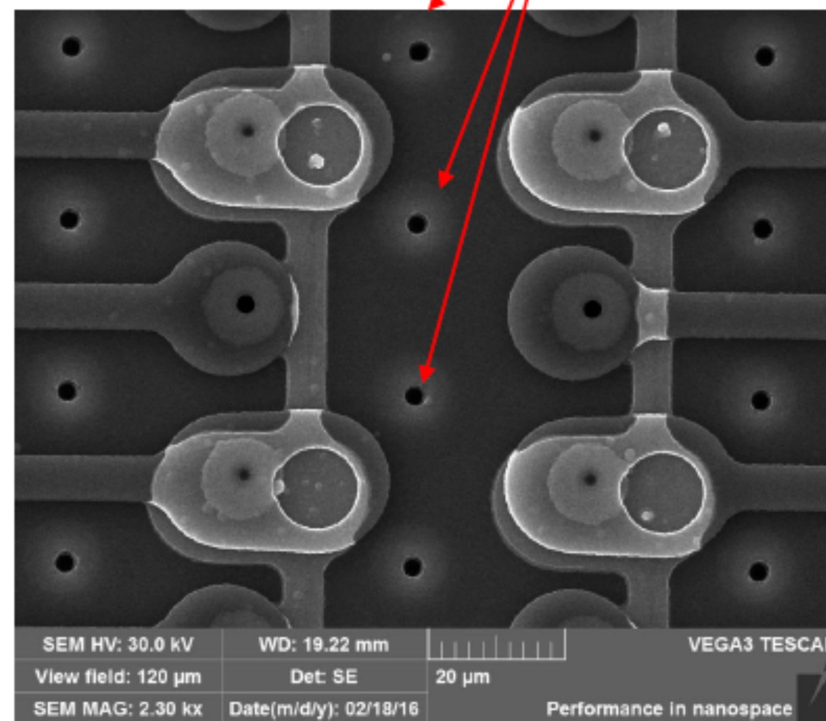


SEM pictures (2)

without poly cap

On test wafer: bad alignment





with poly cap

A problem

- First electrical tests on diodes have shown a strange behavior: sharp, irreversible breakdown, also recognizable by optical inspection (volcano effect …)
- It could be attributed to dielectric breakdown of the oxide layer present between the p+ poly-cap and the metal when they overlap in 25x100 cell structures
- The oxide layer deposited was too thin (300 nm), and, from C-V of dedicated test structure, the effective oxide thickness was found to be even thinner ~220 nm
- These devices cannot withstand more than ~100 V

Preliminary results (1): W48 diode IV

Thickness 100 um, poly-cap, sintering 350°C

1,E-07
1,E-08
1,E-09
1,E-10
1,E-11

Current (A)

0,0 20,0 40,0 60,0 80,0 100,0 120,0 140,0

Reverse voltage (V)

<<1pA per column

- 50x50 66GR
- 25x50 24GR
- 50x125 64GR
- 50x90 73noGR
- 25x100 2E 13
- 50x90 65GR
- 50x50 81
- 50x50 37noGR
- 50x50 25GR

Preliminary results (2): W77 diode IV

Thickness 130 um, poly-cap, sintering 350°C

Current (A)

1,E-07
1,E-08
1,E-09
1,E-10
1,E-11

0,0 20,0 40,0 60,0 80,0 100,0 120,0 140,0

Reverse voltage (V)

25x50_77
25x50_123
50x125 griglia
50x125_145
50x125_142
50x50_99
50x50_177
50x50_168
50x50_153
25x125_54

Preliminary results (3): W48 diode CV

100 um

43 fF per column

53 fF per column

25x50_35GR

50x50_36GR

Capacitance (F)

1,4E-10
1,2E-10
1,0E-10
8,0E-11
6,0E-11
4,0E-11
2,0E-11
0,0E+00

0 -5 -10 -15 -20 -25 -30 -35 -40

Voltage (V)

Preliminary results (4): W77 diode CV

130 um

25x50_35GR
50x50_37

48 fF per column

57 fF per column

Capacitance (F)

1,6E-10
1,4E-10
1,2E-10
1,0E-10
8,0E-11
6,0E-11
4,0E-11
2,0E-11
0,0E+00

0 -5 -10 -15 -20 -25 -30 -35 -40

Voltage (V)

Preliminary results (6): W82 diode IV

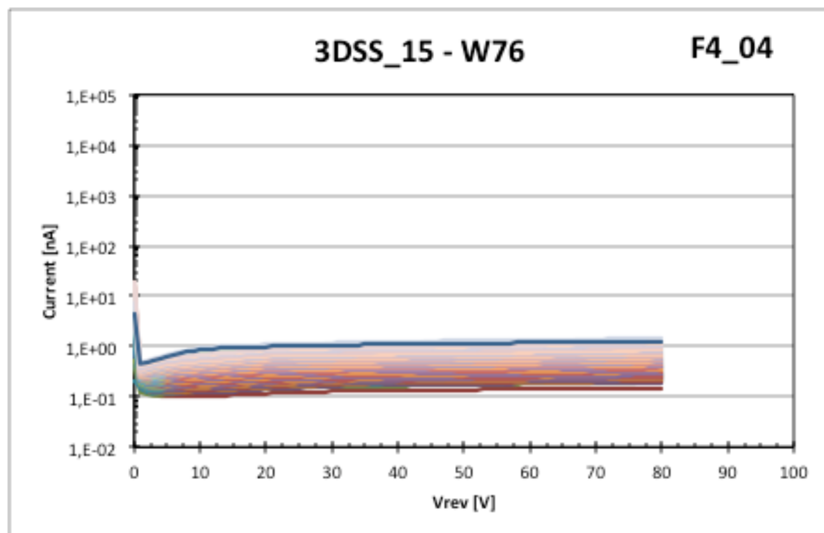
Id 25x50_gr_195
Igr 25x50_gr_195
Id CMS_2E_146
Id 50x125_147
Id 50x125_147
Id 50x90_188
Id 50x50A_182
Id 50x50A_165_gr
Igr 50x50A_165_gr
Id FERMILAB_30x100_133
Id 50x50_gr_155
Igr 50x50_gr_155
Id 25x50A_156
Id CMS_3E_172
Id FERMILAB_30x100_gr_140
Igr FERMILAB_30x100_gr_140
Id rd53_25x100_gr_127
Igr rd53_25x100_gr_127

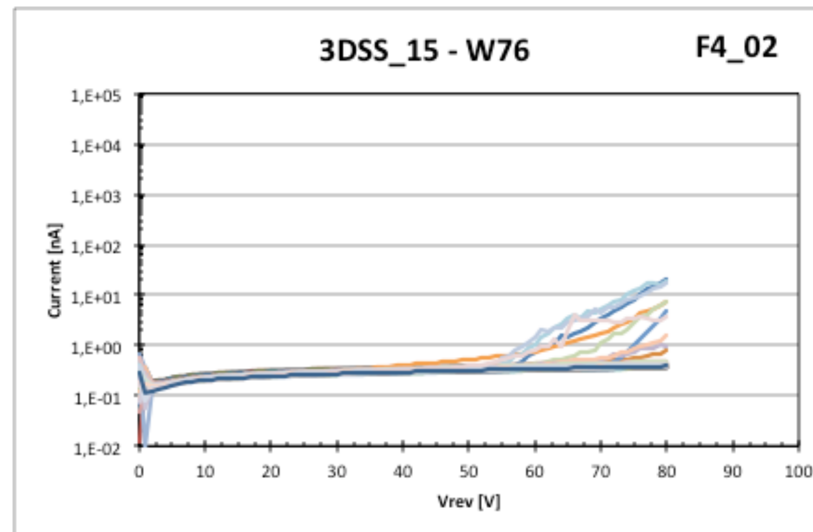
Current (A)
1,E-07
1,E-08
1,E-09
1,E-10
1,E-11

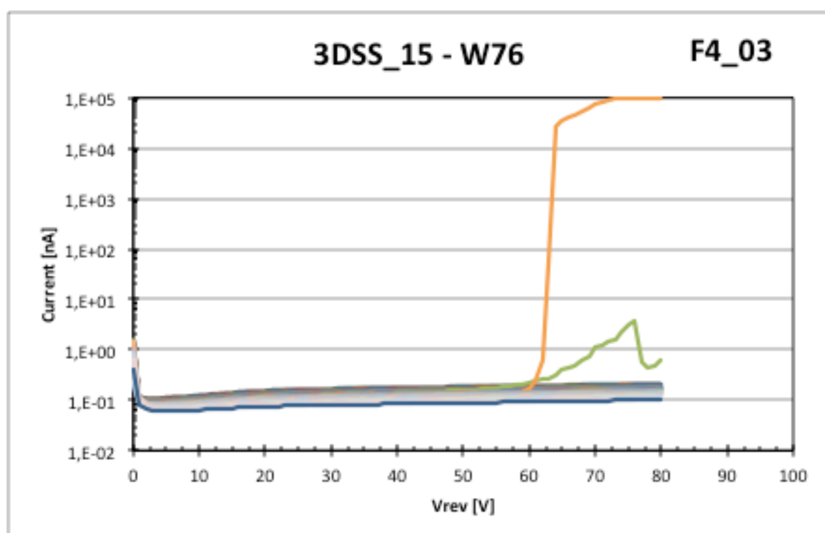
0
20
40
60
80
100
120
140
Reverse voltage (V)

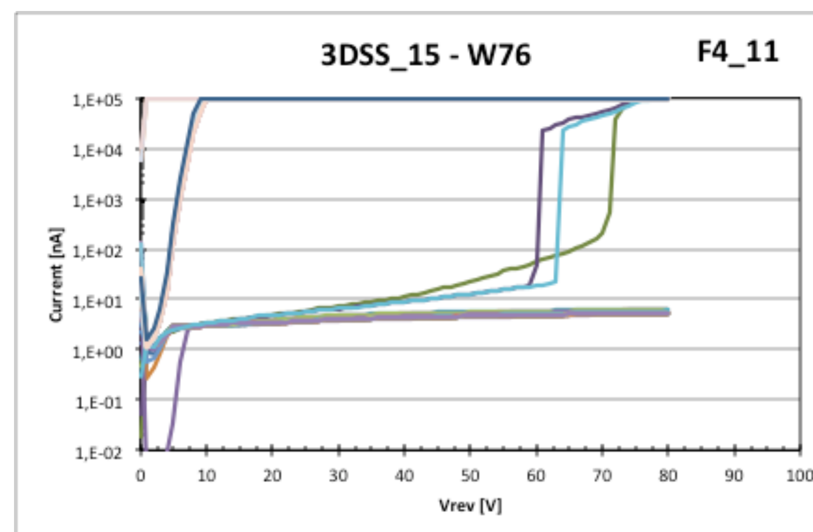
Sintering at 420°C

Pixel sensors (1): FEI4 strips + grid









Pixel sensors (2): FEI3 grid

3DSS_15 - W76

FEI3_grid

Current [nA]

1,E+05
1,E+04
1,E+03
1,E+02
1,E+01
1,E+00
1,E-01
1,E-02

0 10 20 30 40 50 60 70 80 90 100

Vrev [V]

F3_01_g
F3_02_g
F3_03_g
F3_04_g
F3_05_g
F3_06_g
F3_07_g
F3_08_g
F3_09_g

Pixel sensors (3): CMS grid

3DSS_15 - W76

CMS_grid

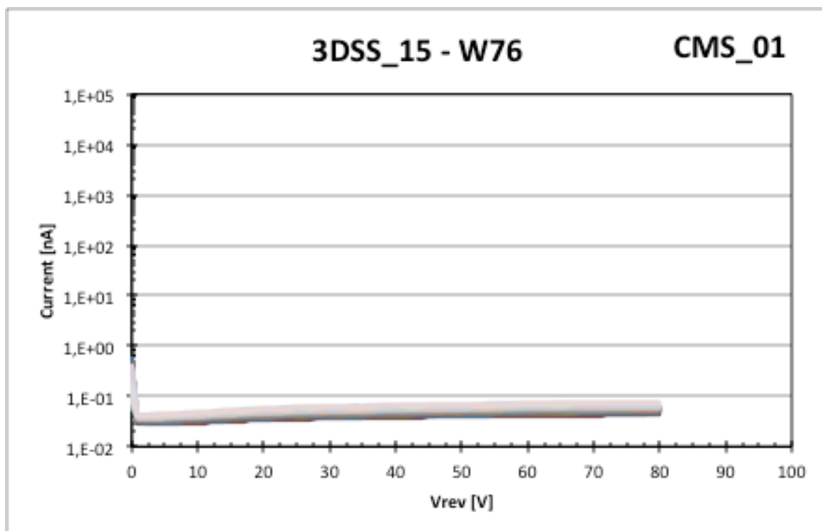
Current [nA]

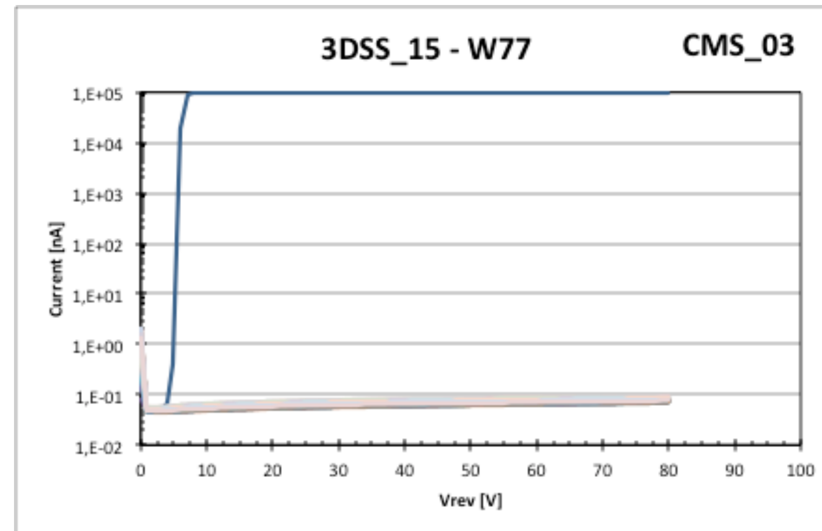
1,E+05
1,E+04
1,E+03
1,E+02
1,E+01
1,E+00
1,E-01
1,E-02

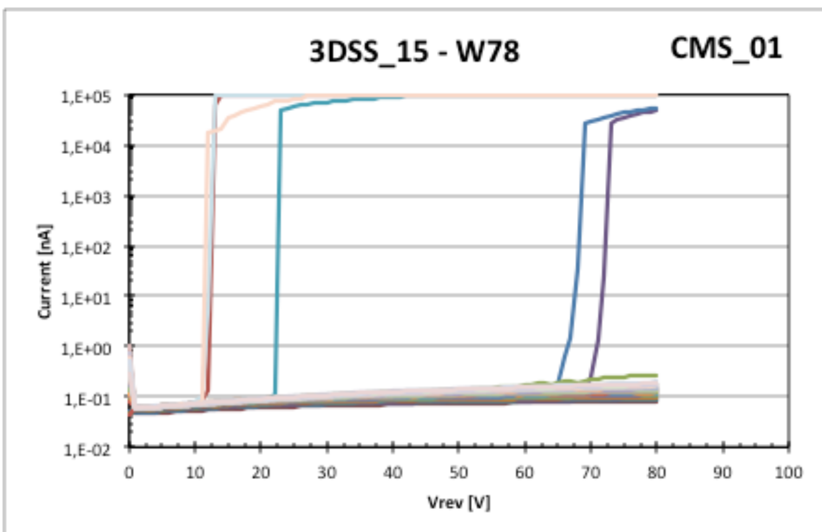
0 10 20 30 40 50 60 70 80 90 100

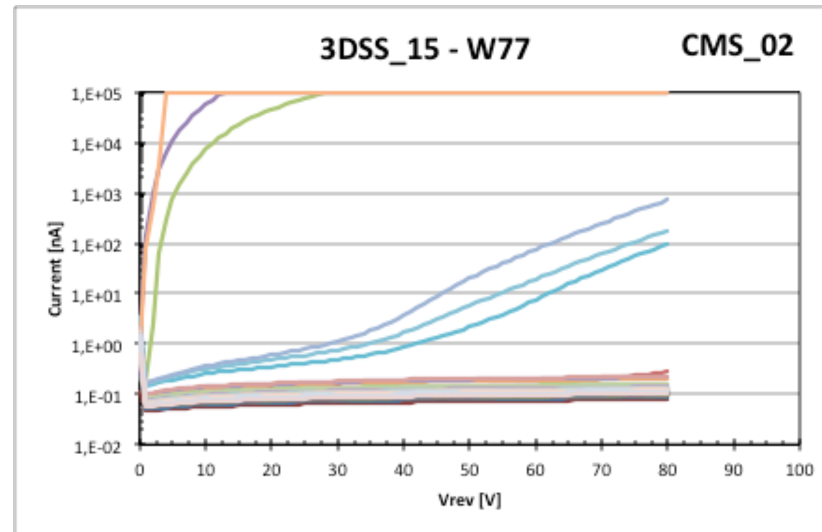
Vrev [V]

Pixel sensors (4): CMS strips

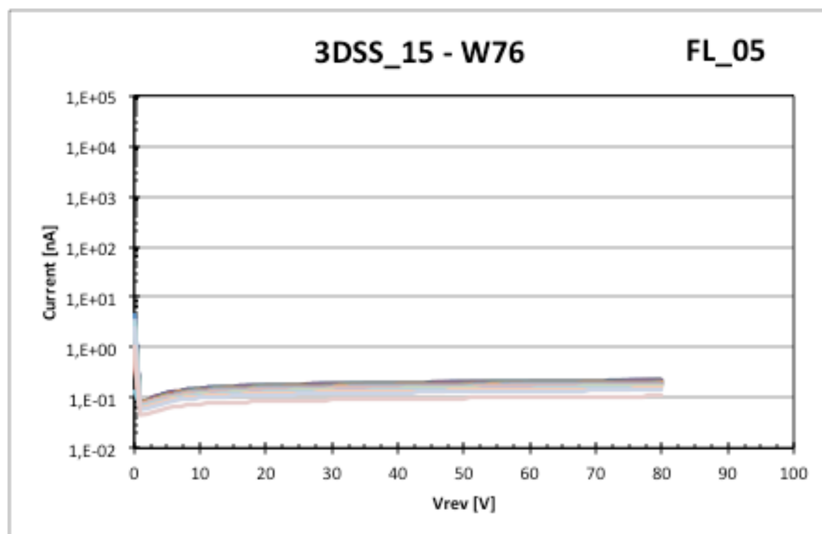


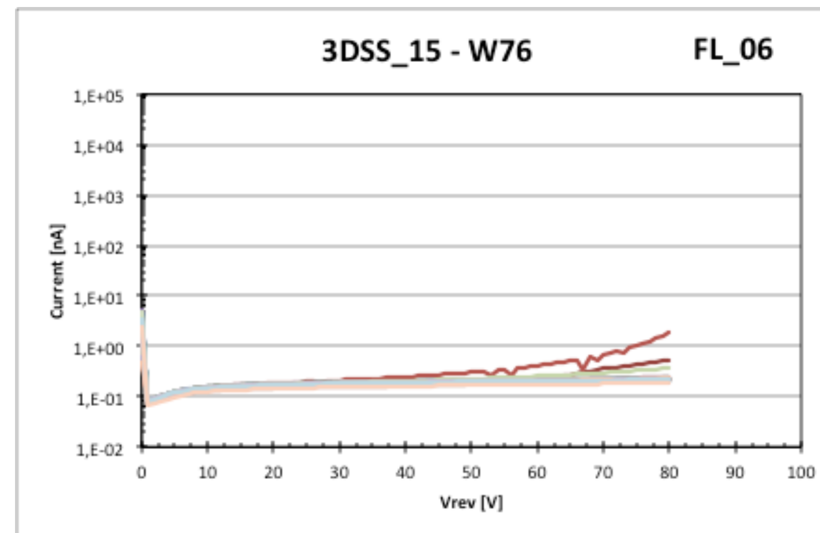


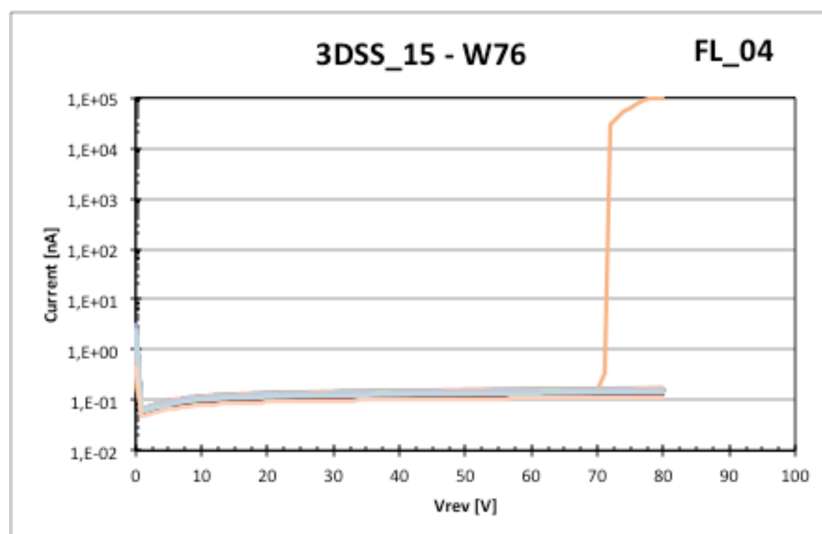


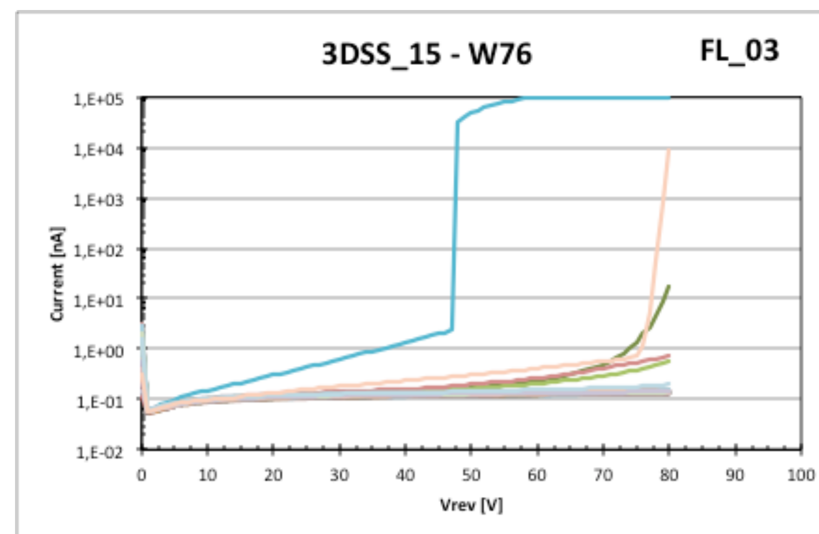


Pixel sensors (5): FCP strips

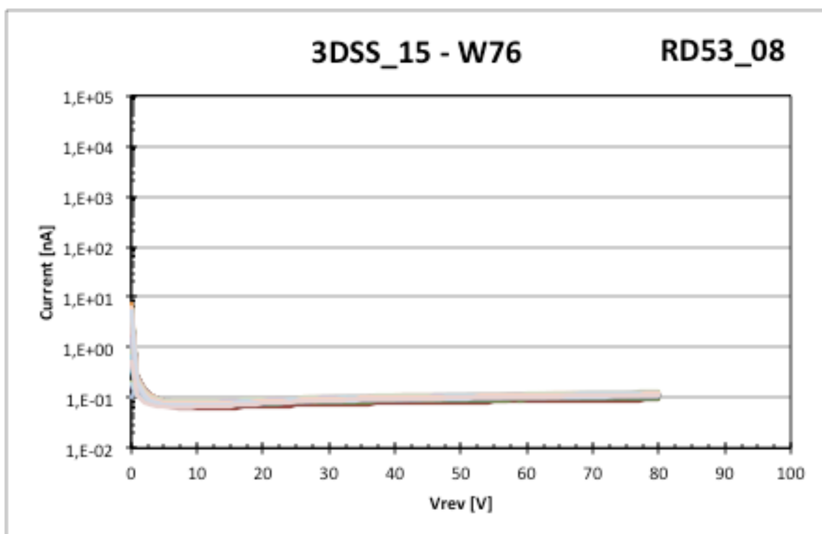


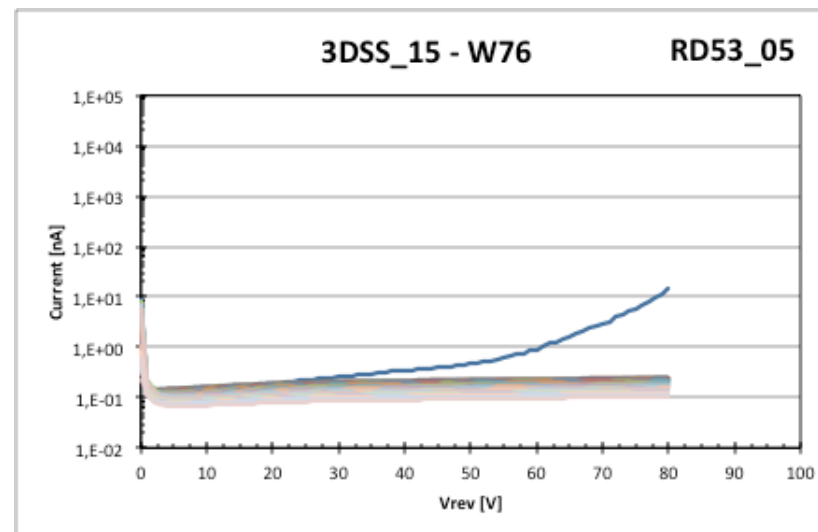


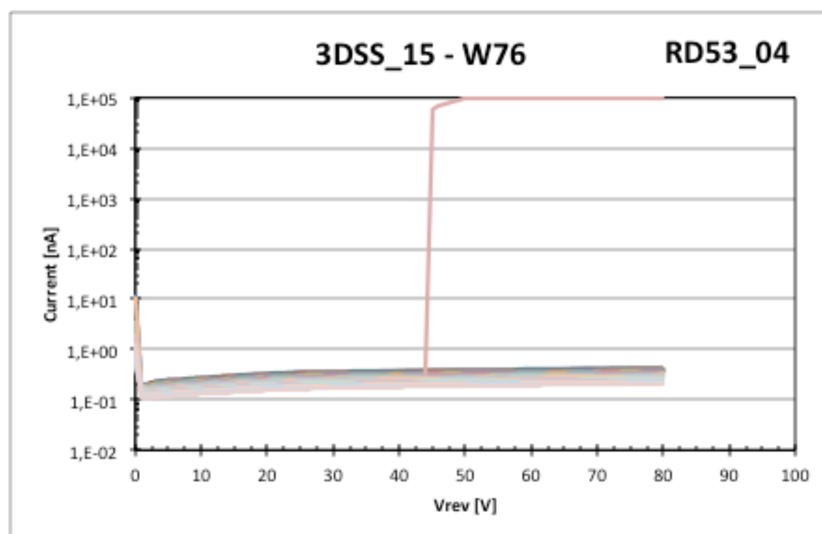


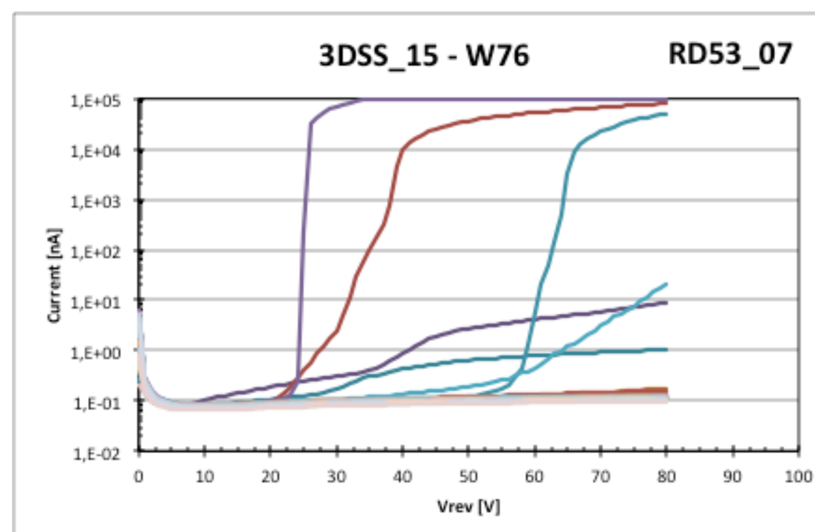


Pixel sensors (6): RD53-big strips









Summary of usable sensors

Usable sensors defined as those sensors allowing for a wide operation bias range (at least 50 V) that is good enough before irradiation.

Sensor	# per wafer	W36	W41	W48	W50	W54	W60	W76	W77	W78
FEI4 IBL pixels	3	3	1	0	1	1	2	3	2	3
FEI4 small pixels	10	3	3	1	1	2	3	5	0	4
FEI3 small pixels	9	6	6	5	5	5	5	7	8	7
CMS PSI46 (27, 28)	6 +2	6	4	5	5	5	6	6	3	2
CMS small pixels	30	22	24	20	23	27	20	24	23	22
RD53-big	11	6	6	3	6	10	8	6	7	5
FCP	6	6	6	6	4	5	6	3	5	5
RD53-small	18									

Conclusions

- From initial electrical tests, good intrinsic sensor quality observed:
  - low depletion voltage
  - low leakage current
  - high breakdown voltage
- 25x100 pixel layout confirmed to be critical (metal misalignment, low oxide thickness, …)
- Automatic I-V curve tests of all sensors highlighted the presence of defects, but there are a number of sensors usable for functional testing