DC-LGAD progress at NCU

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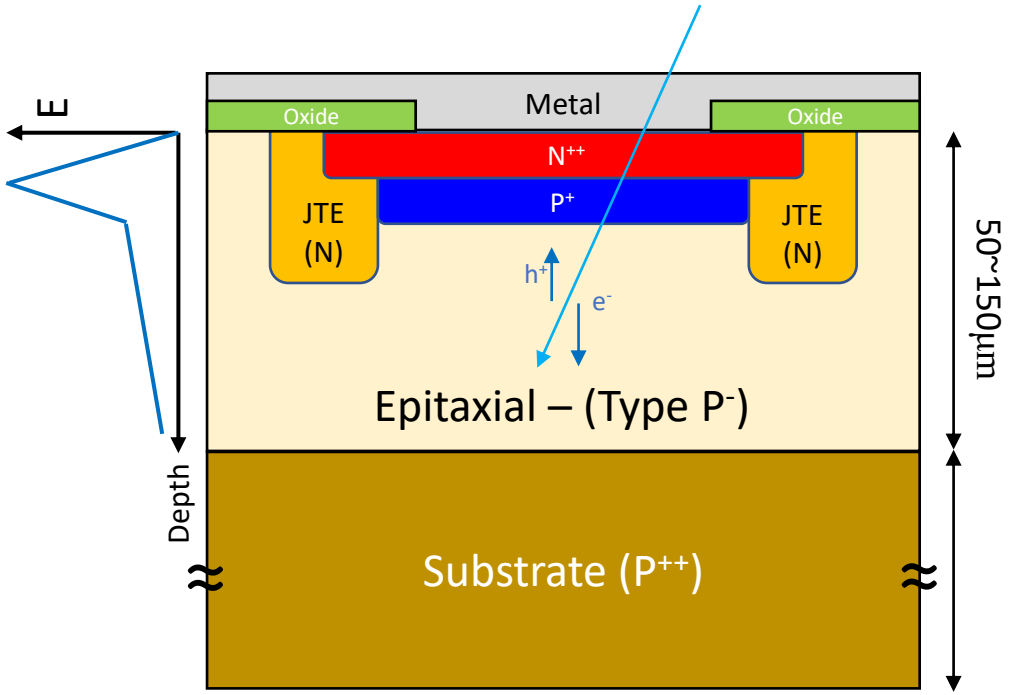
Outline

- ✓LGAD process flow
- ✓LGAD Process parameter decision by TCAD simulation
- ✓Layout design
- ✓LGAD CV & IV characteristics
- ✓Future plans : AC-LGAD

Low Gain Avalanche Detector (LGAD)

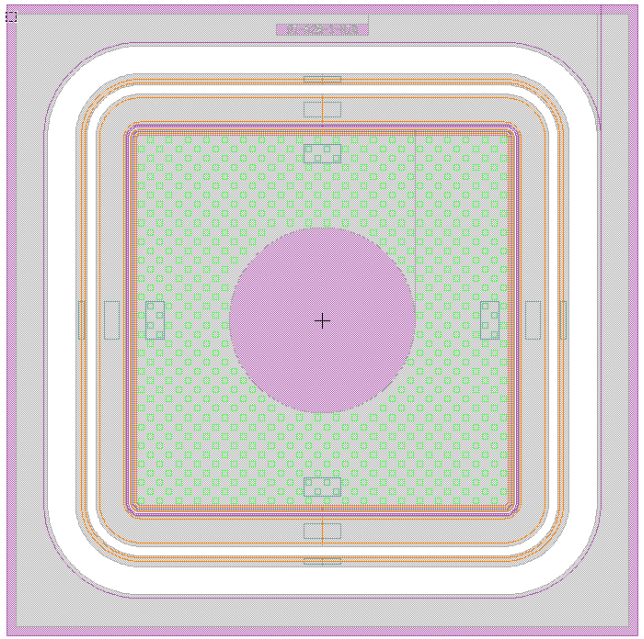


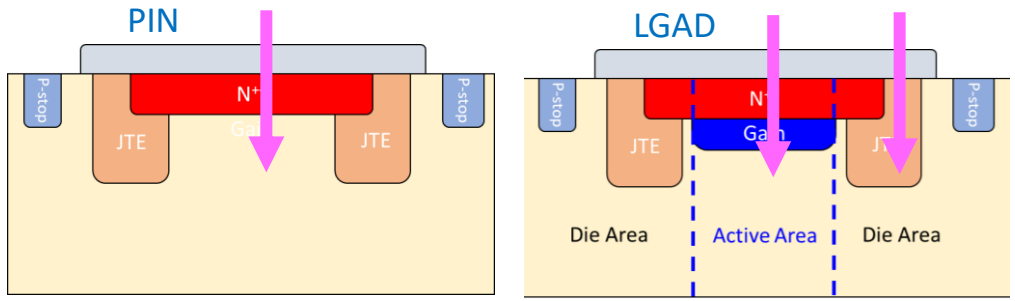
Feature

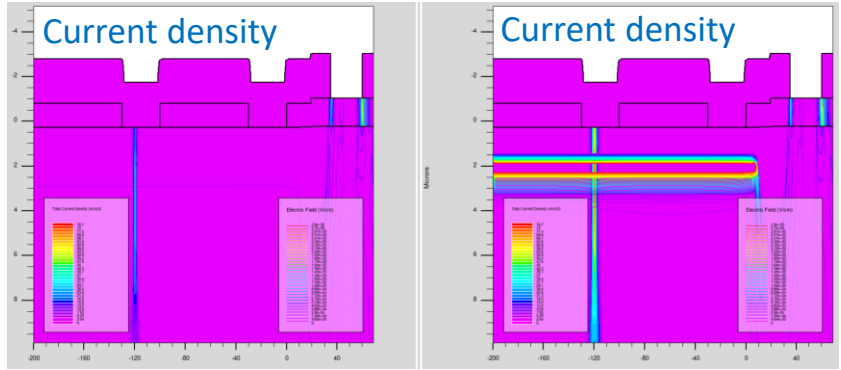
- High field obtained by adding an extra p^+ below the n^+
- controllable moderate internal gain ~10
- High time resolution of ~30ps
- Thin active layer

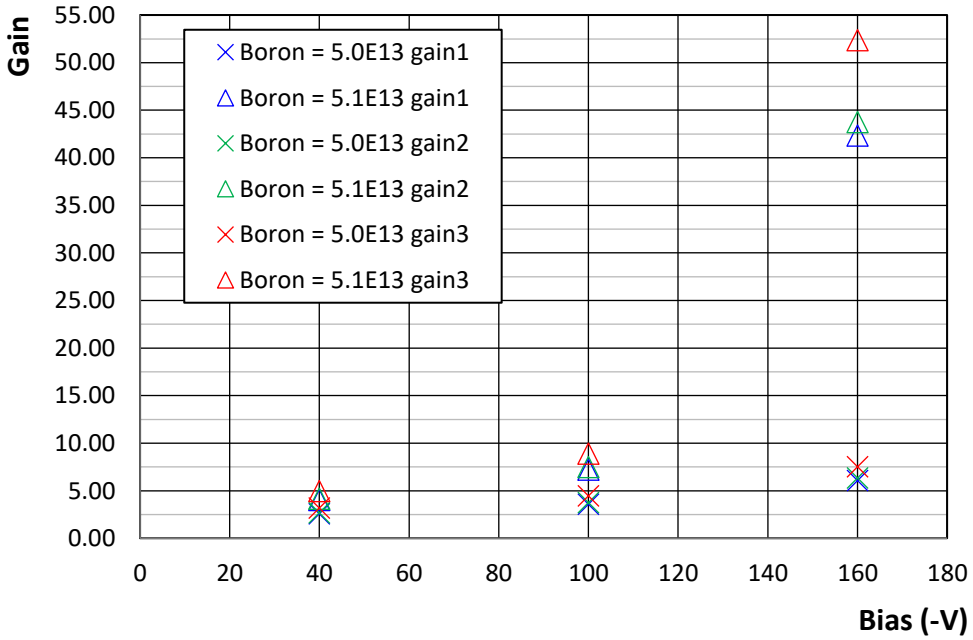
Gain and Signal Simulation

1. Set a laser to illuminate sensor and calculate gain :
   - Gain1 = Current produced by laser/ photon current
2. Laser illuminate on active and die area to calculate :
   - Gain 2 = Active area current / Die area current
3. Laser illuminate on LGAD and PIN structure to calculate :
   - Gain 3 = LGAD current / PIN current





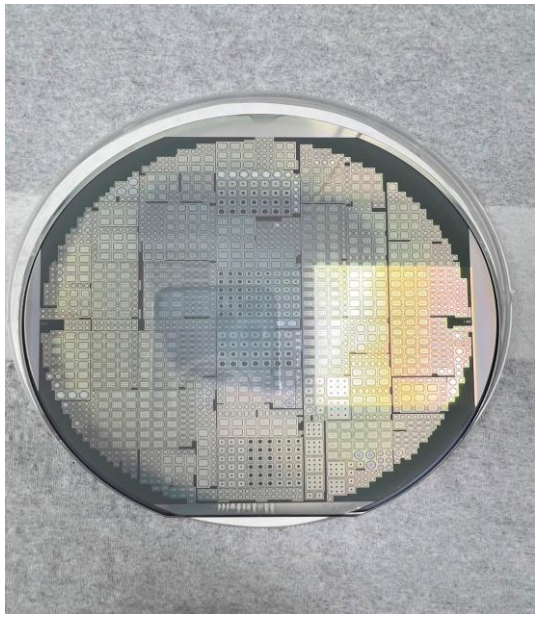


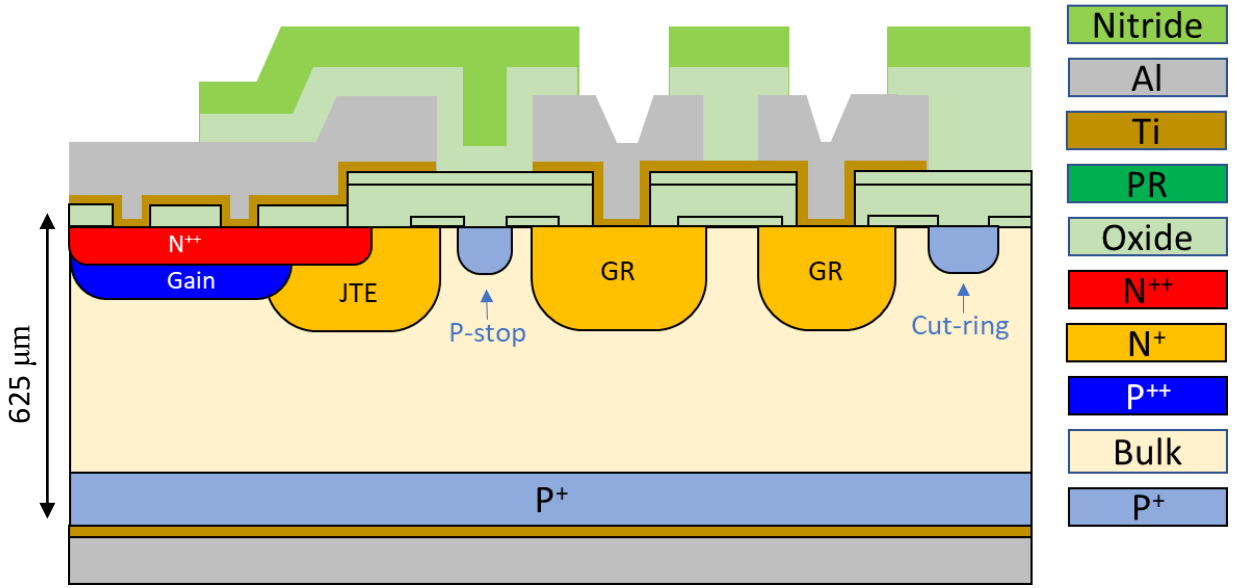


LGAD Manufacture in TSRI

- Wafer :
  - Type : 6” FZ <100> Resistivity : 3k Ω-cm Thickness : 625µm
- 12 Wafers and 6-different parameters conditions.
- Delivery date : 12/28

finish wafer



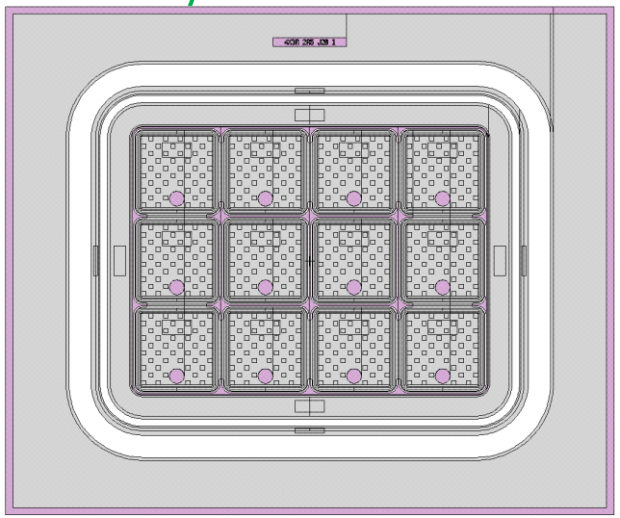


1	Backside imp.
2	JTE&GR imp.
3	P-stop imp.
4	Drive in 1 (Wet Oxide)
5	Gain layer imp.
6	Drive in 2
7	N^{++} imp.
8	Drive in 3
9	PECVD oxide
10	Contact etch
11	Front Metal dep.
12	Front Metal etch
13	alloy
14	Passivation dep.
15	Passivation etch
16	Back Metal dep.
17	alloy

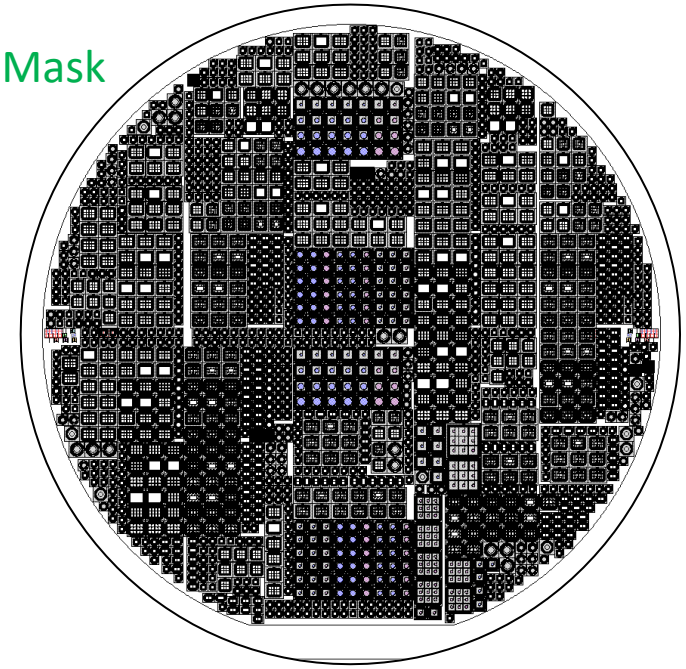
Mask Design

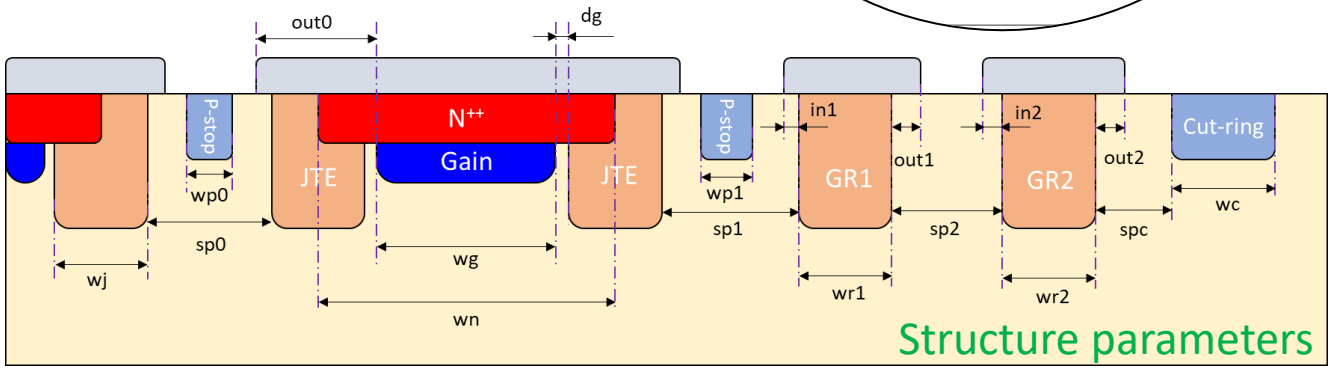
- Type : pixel DC-pad structure
- Purpose: Study the structure for breakdown voltage and cross talk.
- There are ~180 different structure in mask.
- Almost parameters are studied in the small single test keys.
- The variables in pixel arrays usually are pitch and p-stop or collect ring design.
- Parameters (showed on right bottom pictures):
  - Area (width of gain layer) : 500*500 μm^2 ~ 2*2mm^2
  - Array size (1x1~3x4)
  - Pattern width
  - Pitch
  - GR : numbers, width and pitch
  - P-stop
  - Collect ring

4x3 Array

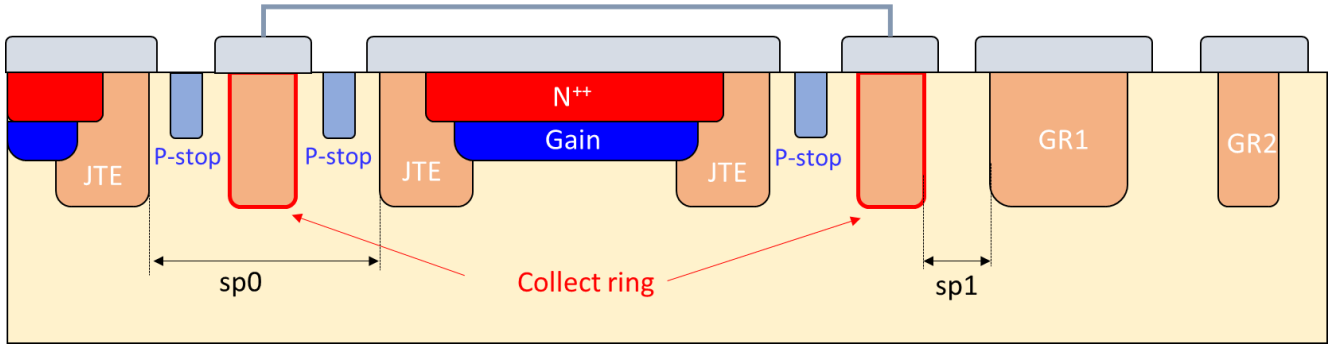


Mask





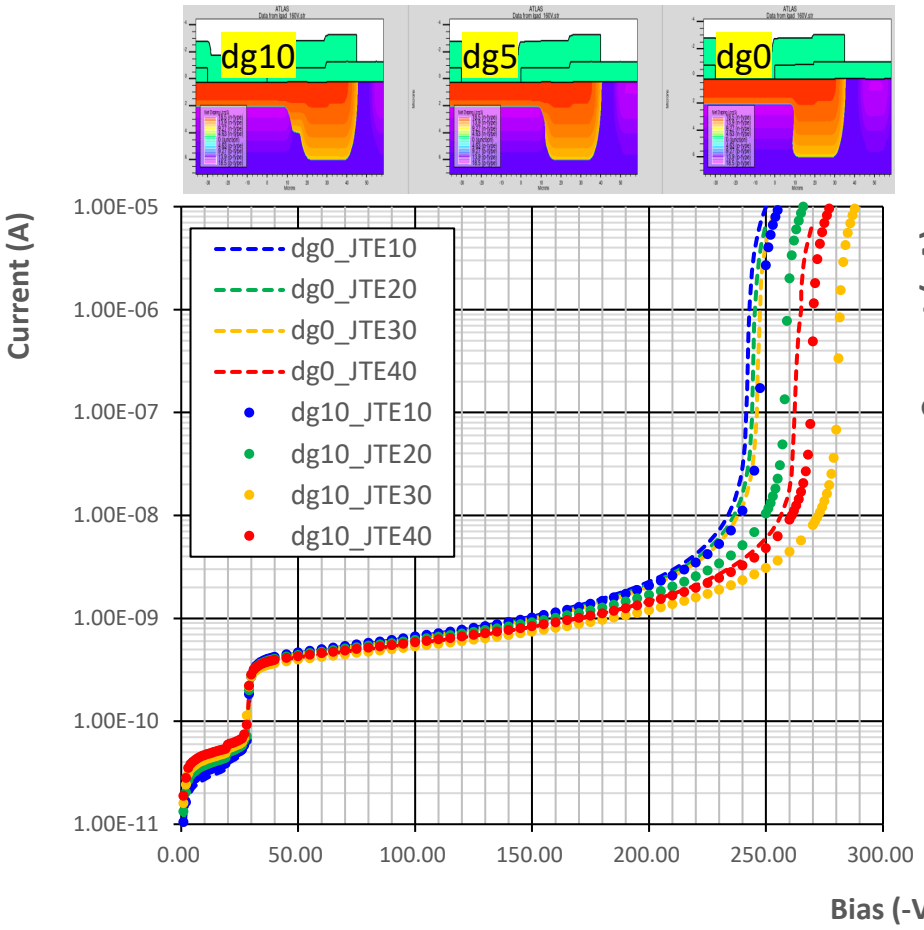
Structure parameters



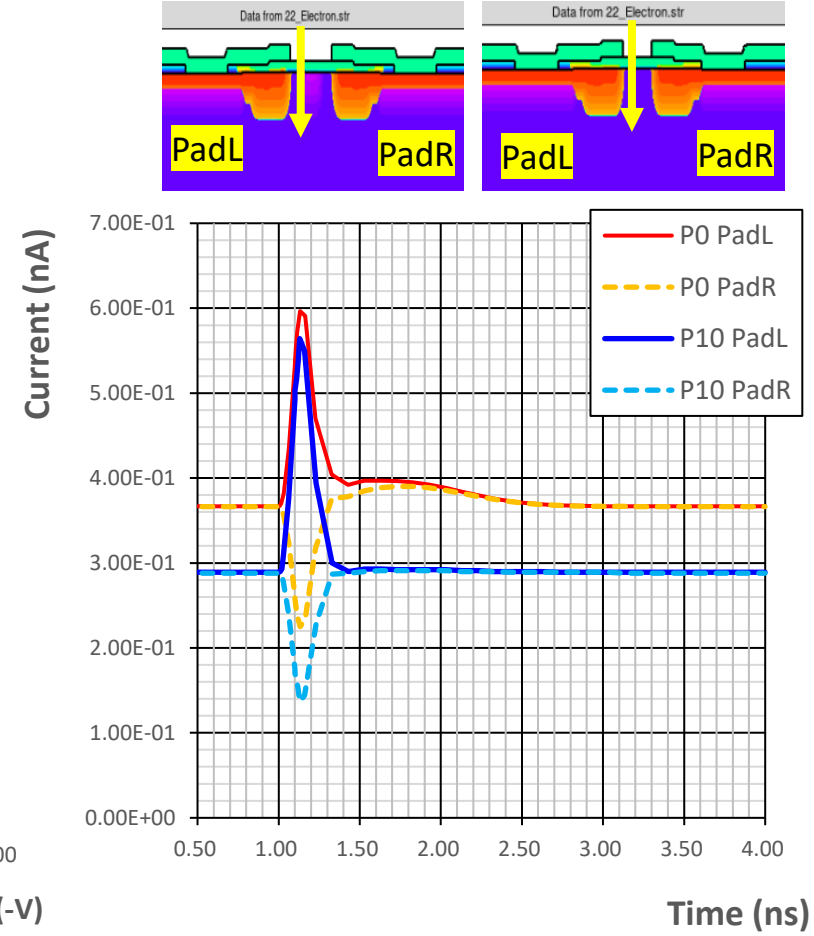
Structure Simulation

- There are some simulation results about different structure design to expect the variety.

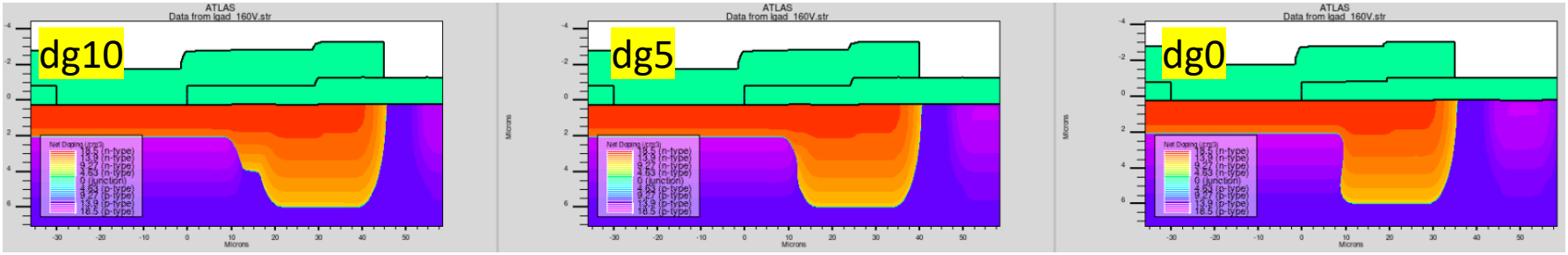
JTE structure

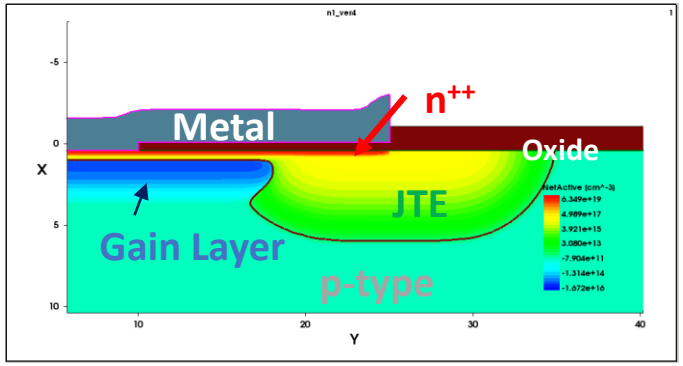


P-stop structure

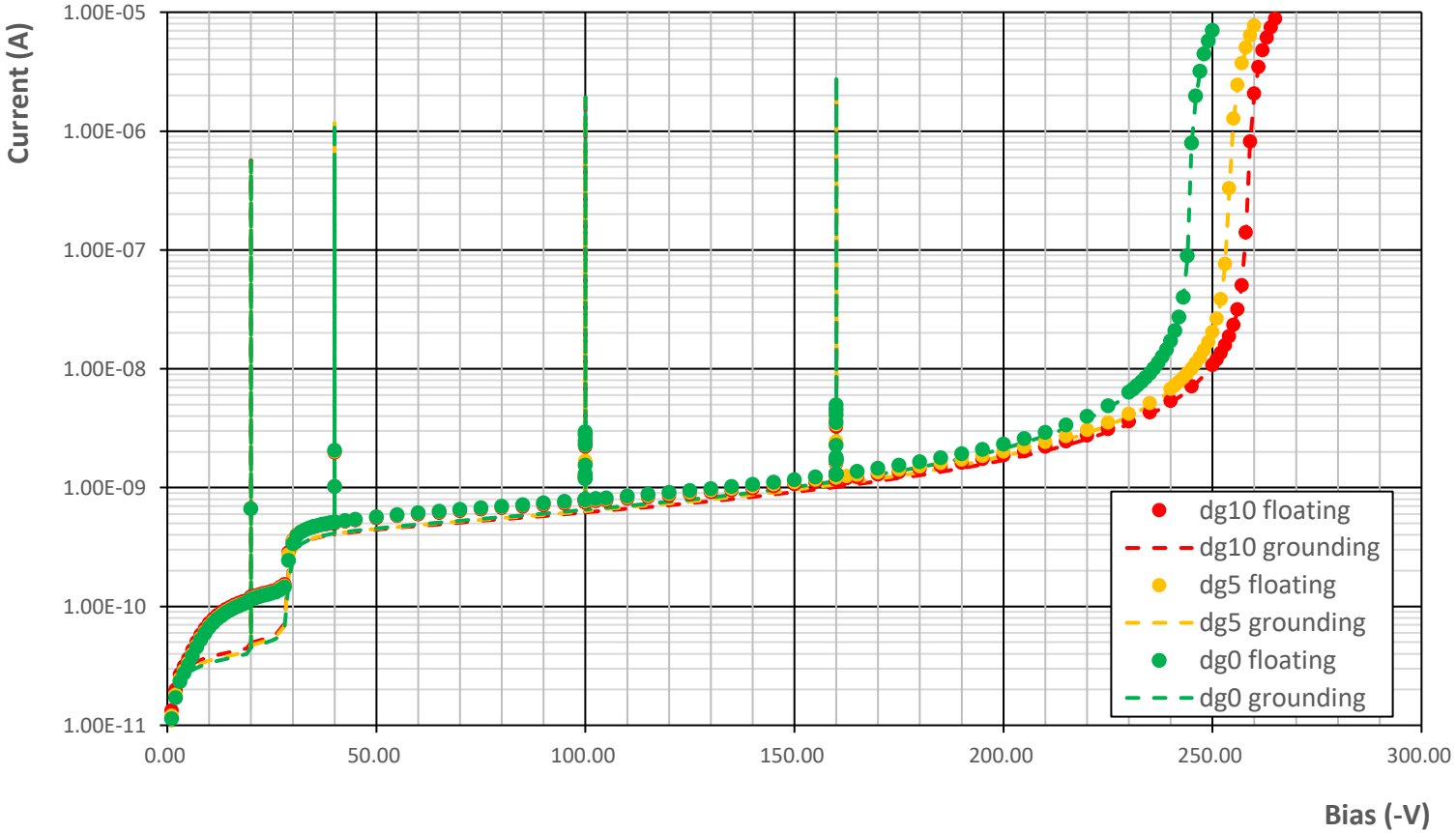


Various of dg





JTE and gain layer will form a S-shaped junction boundary

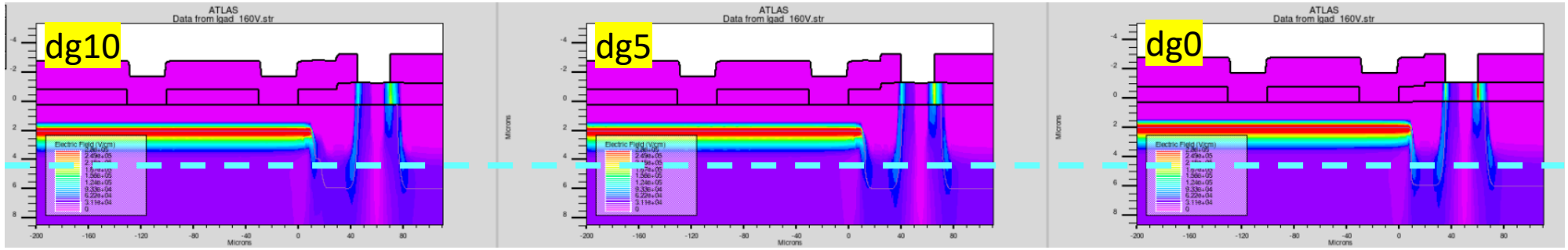


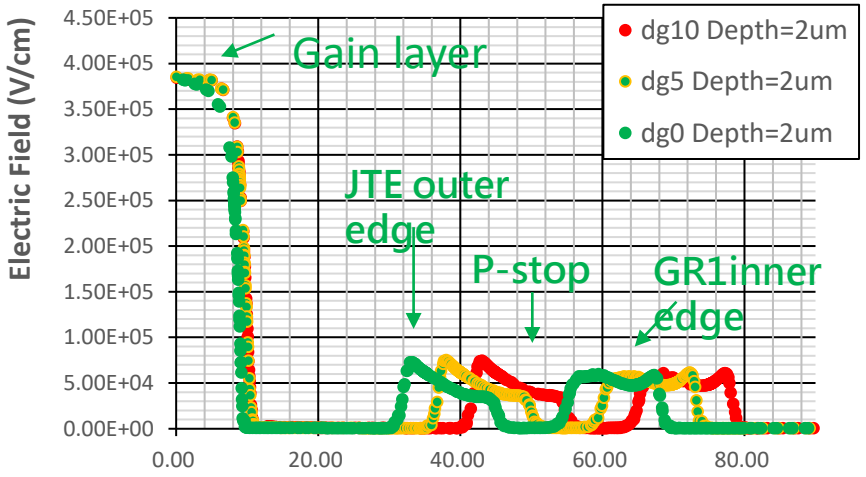
Dg-horizontal electrical field

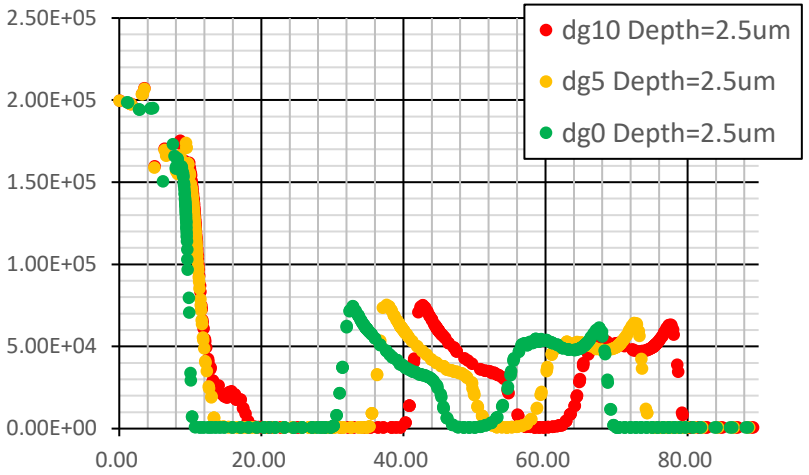
parameter： JTE 20 um

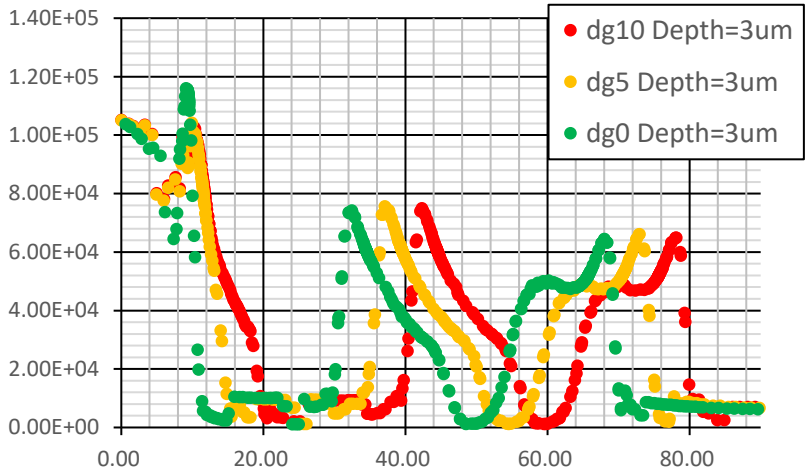
Boron 5E13/1100C/200min

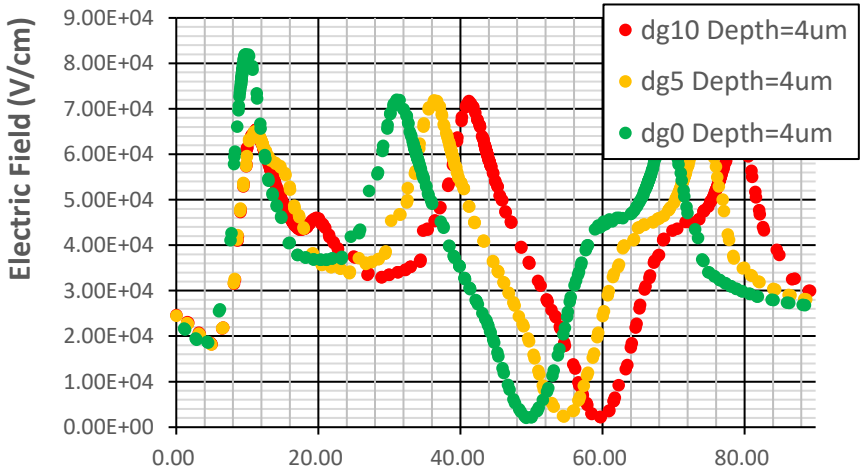
Phos. 2E14/1100C/200min

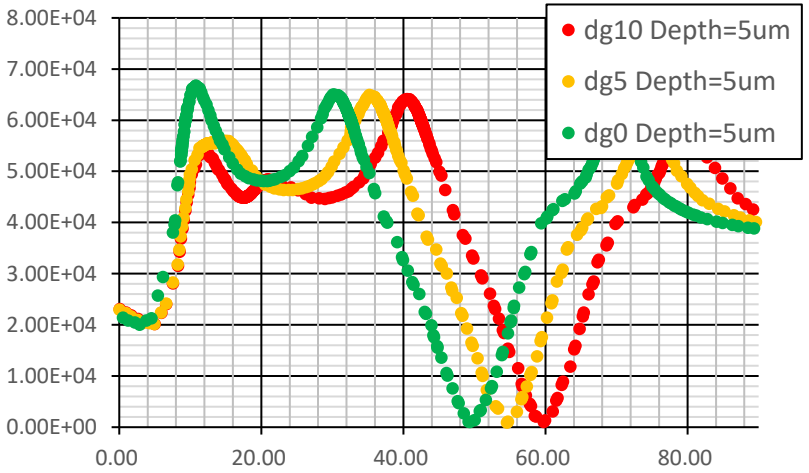


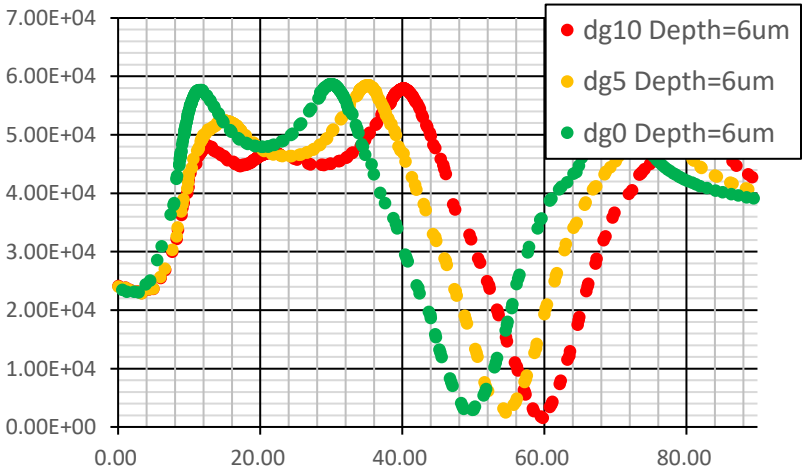








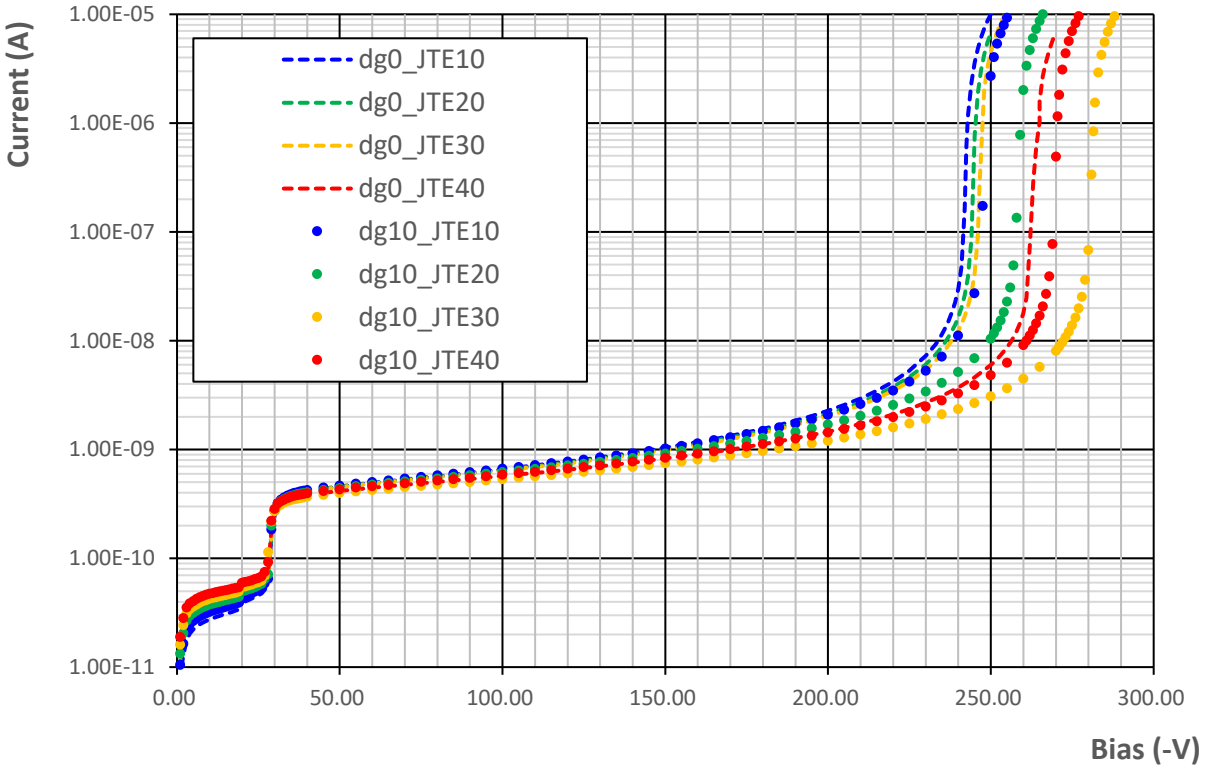




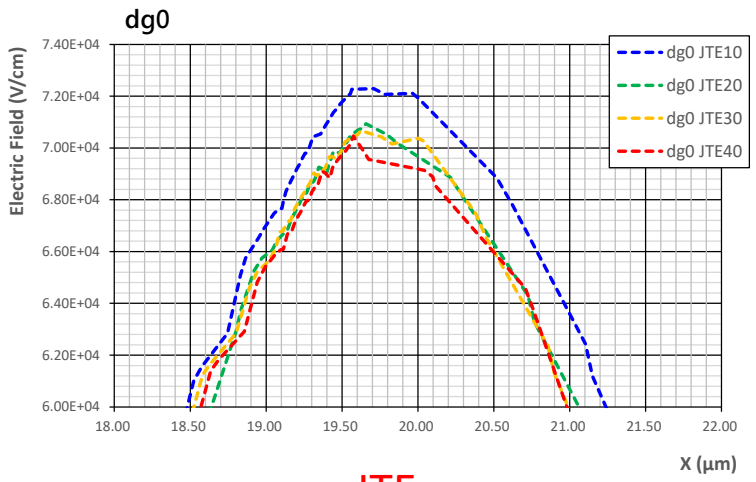
X (μm)

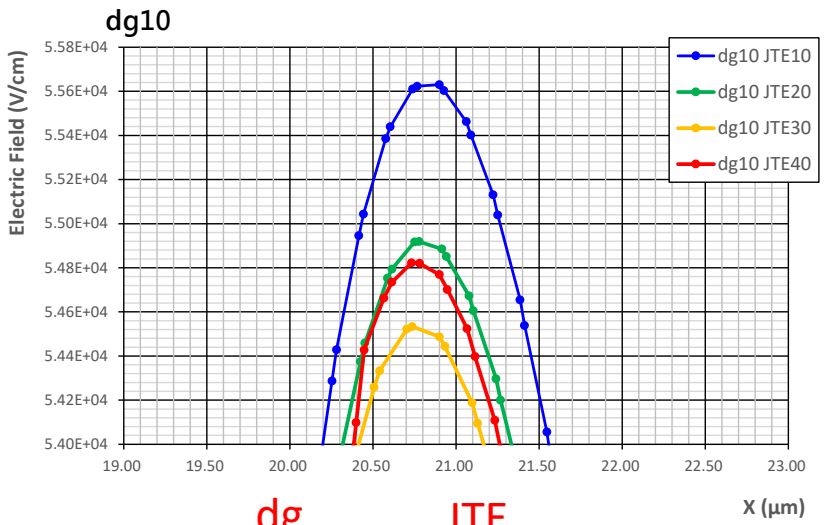
X (μm)

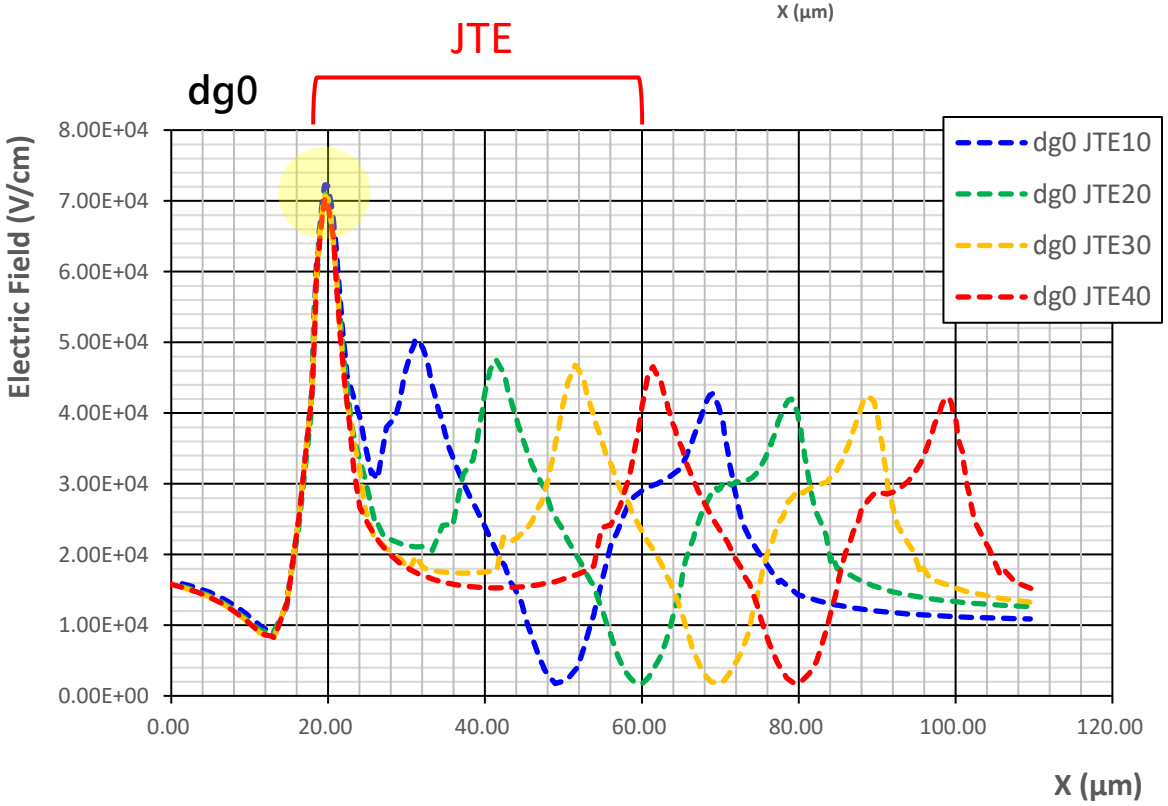
X (μm)

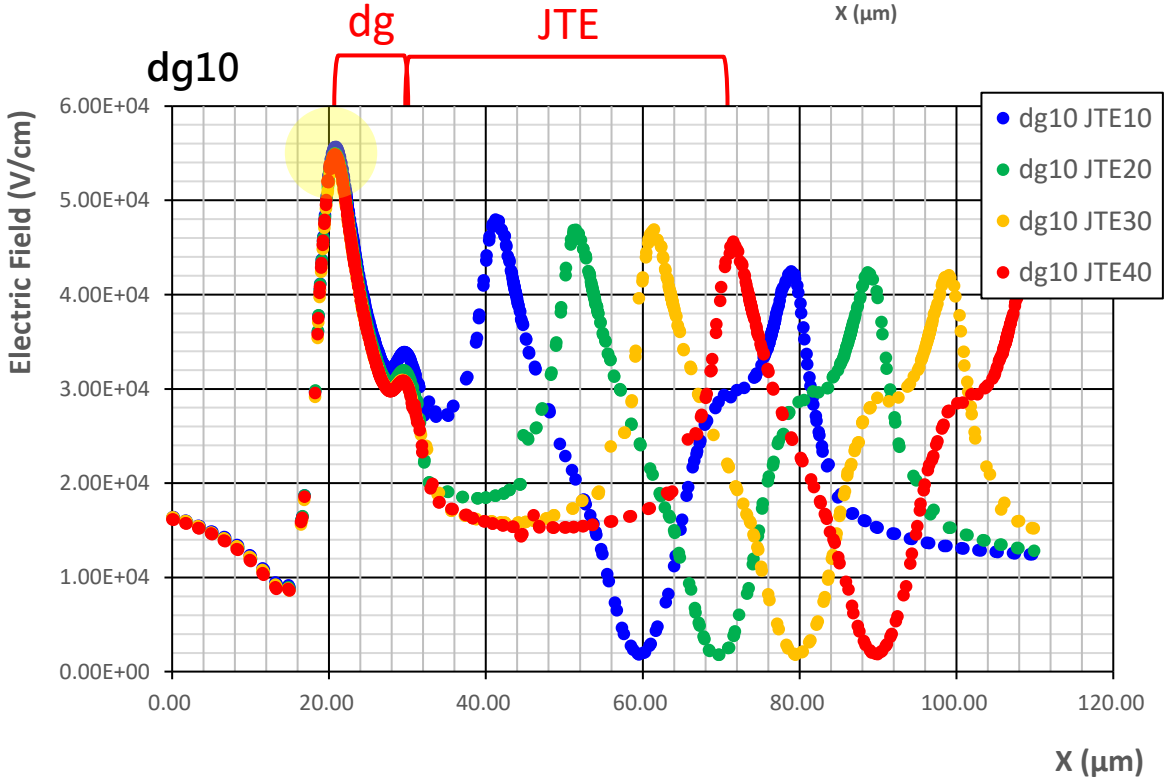


dg	JTE	BV(V)	E(V/cm) at gain layer edge
0	10	242	7.23E4
0	20	245	7.09E4
0	30	247	7.07E4
0	40	263	7.05E4
10	10	248	5.56E4
10	20	259	5.49E4
10	30	281	5.45E4
10	40	270	5.48E4


dg0
Electric Field (V/cm)
7.40E+04
7.20E+04
7.00E+04
6.80E+04
6.60E+04
6.40E+04
6.20E+04
6.00E+04
18.00
18.50
19.00
19.50
20.00
20.50
21.00
21.50
22.00
X (µm)
dg0 JTE10
dg0 JTE20
dg0 JTE30
dg0 JTE40

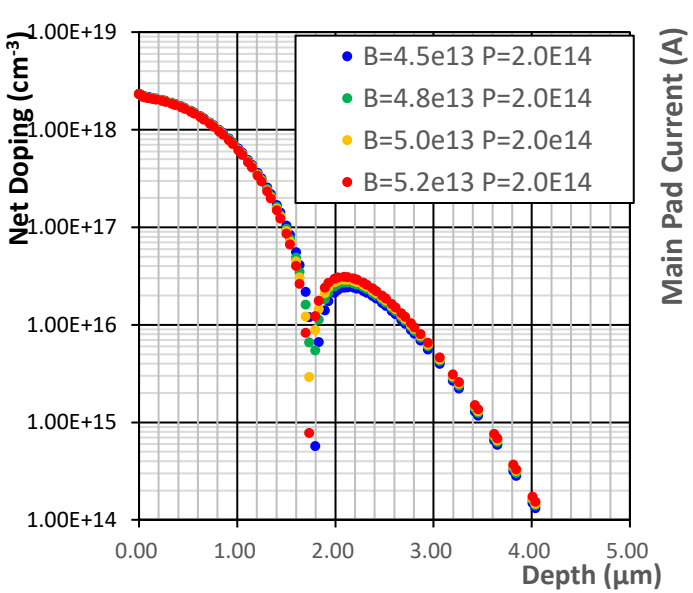

dg10
Electric Field (V/cm)
5.58E+04
5.56E+04
5.54E+04
5.52E+04
5.50E+04
5.48E+04
5.46E+04
5.44E+04
5.42E+04
5.40E+04
19.00
19.50
20.00
20.50
21.00
21.50
22.00
22.50
23.00
X (µm)
dg10 JTE10
dg10 JTE20
dg10 JTE30
dg10 JTE40

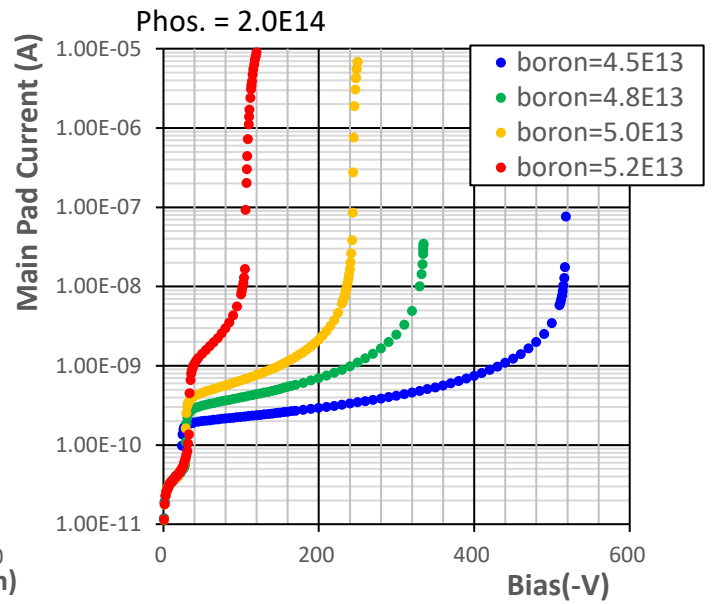

JTE
dg0
Electric Field (V/cm)
8.00E+04
7.00E+04
6.00E+04
5.00E+04
4.00E+04
3.00E+04
2.00E+04
1.00E+04
0.00E+00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
X (µm)
dg0 JTE10
dg0 JTE20
dg0 JTE30
dg0 JTE40

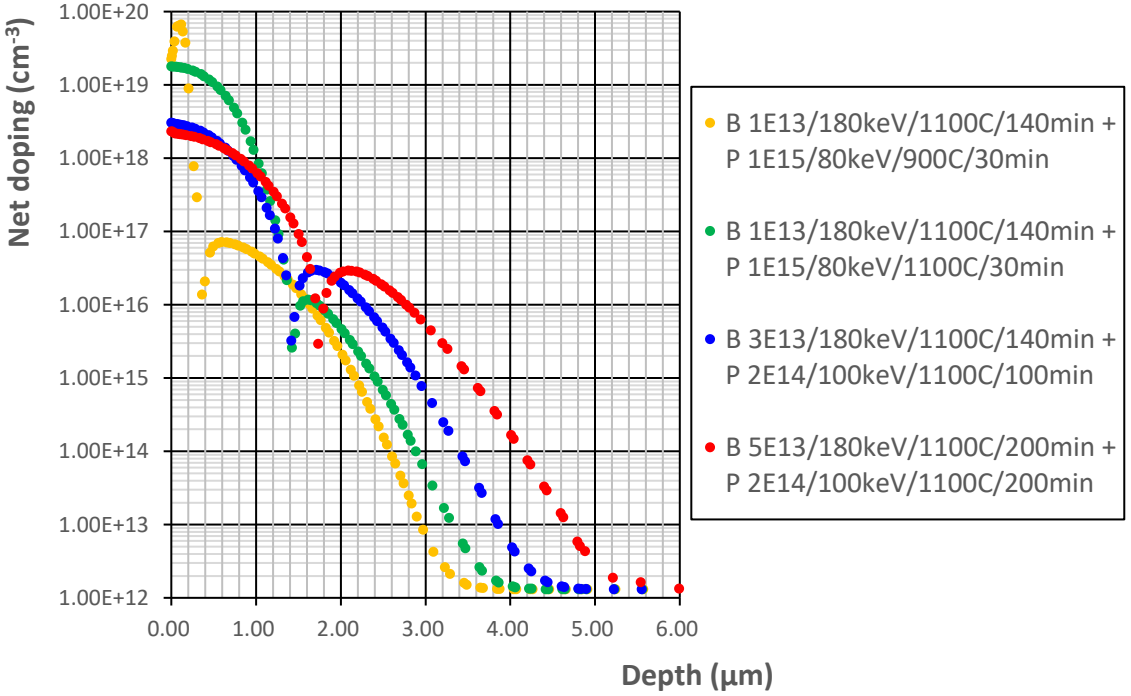

dg
JTE
dg10
Electric Field (V/cm)
6.00E+04
5.00E+04
4.00E+04
3.00E+04
2.00E+04
1.00E+04
0.00E+00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
X (µm)
dg10 JTE10
dg10 JTE20
dg10 JTE30
dg10 JTE40

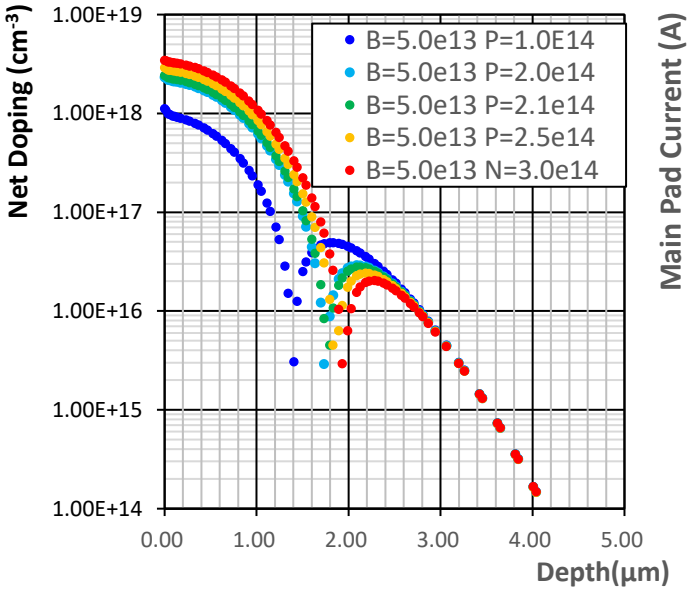
Process Flow Simulation

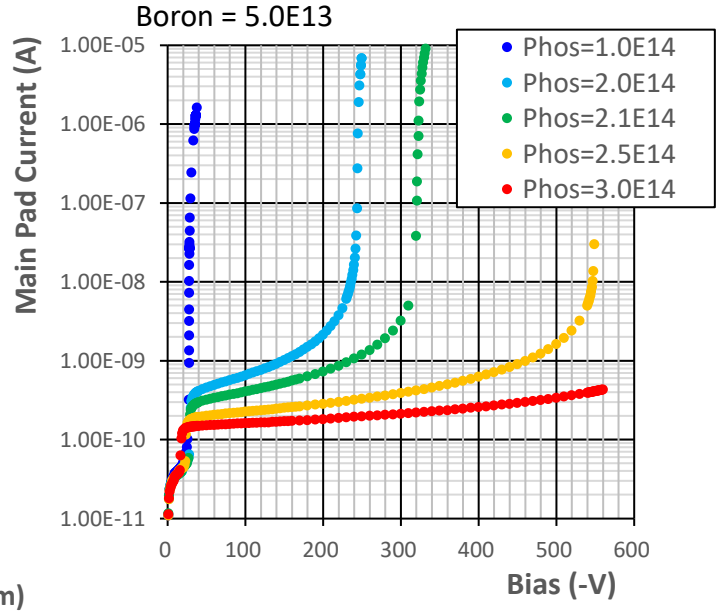
- Simulate different process flows to determine the actual flow.
- Find out the appropriate dosage range by using simulation.











Dosage of N^{++}

- The higher the dosages of N^{++}, the lower effective of p-type concentration, the lower the gain, but the higher the breakdown voltage

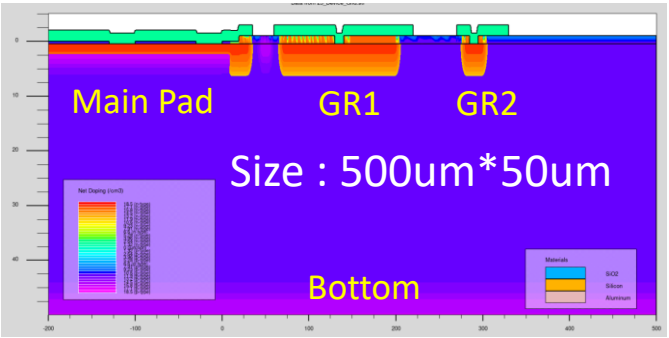
N++ dose(cm^{-2})	V_B(V)	Breakdown loaction	Gain 1 at 100V	N_b(cm^{-3})	E(V/cm)
3.0E14	556	GR2	1.20	2.0E16	2.5E5
2.5E14	547	Main Pad	1.61	2.4E16	3.1E5
2.1E14	320	Main Pad	2.89	2.8E16	3.5E5
2.0E14	237	Main Pad	4.45	2.9E16	3.7E5
1.0E14	28	Main Pad	-	4.9E16	4.3E5

Gain = LGAD current / PIN current

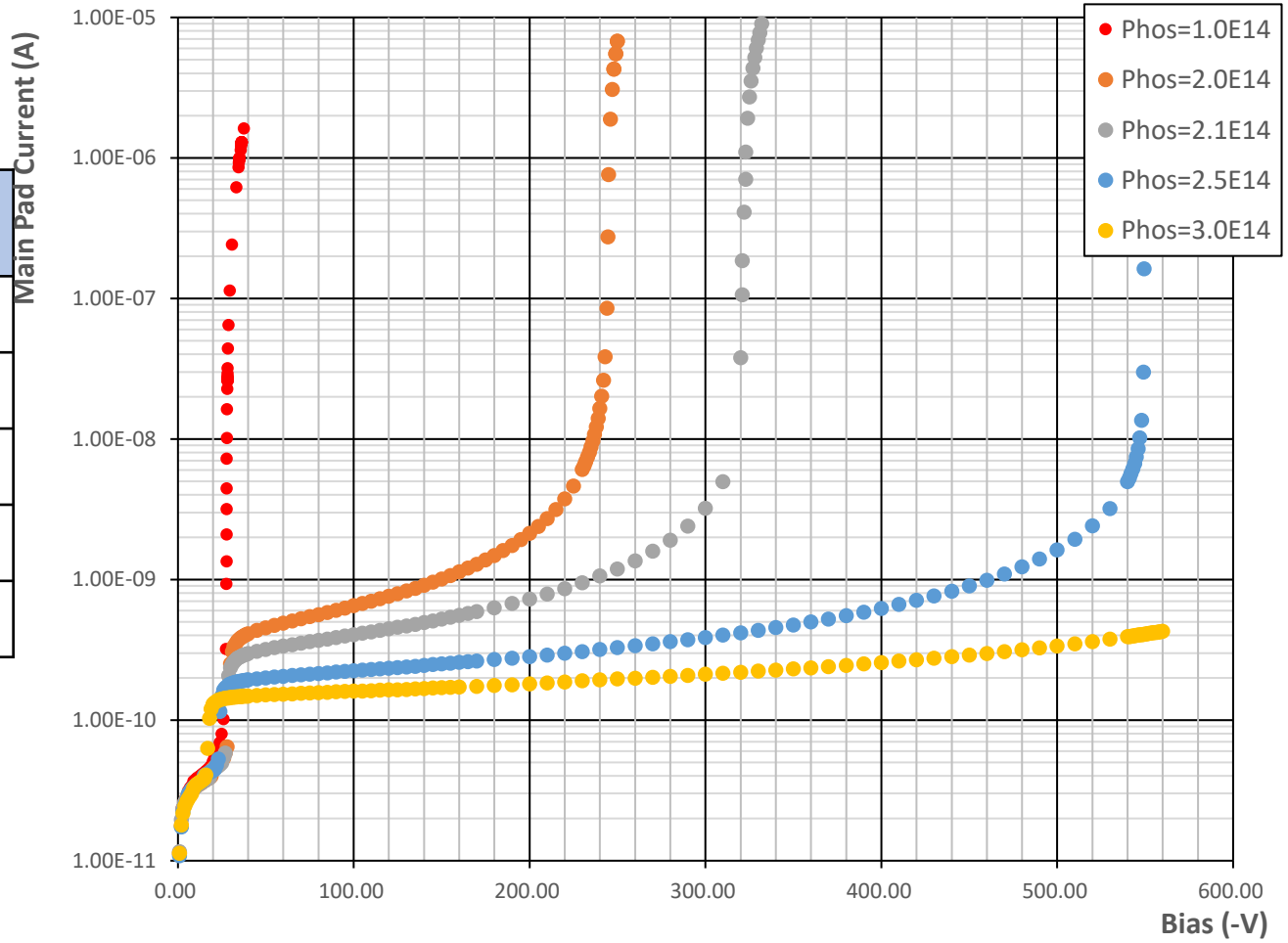
parameter :

Boron: 5E13/1100C/200min

Phos.: 1100C/200min

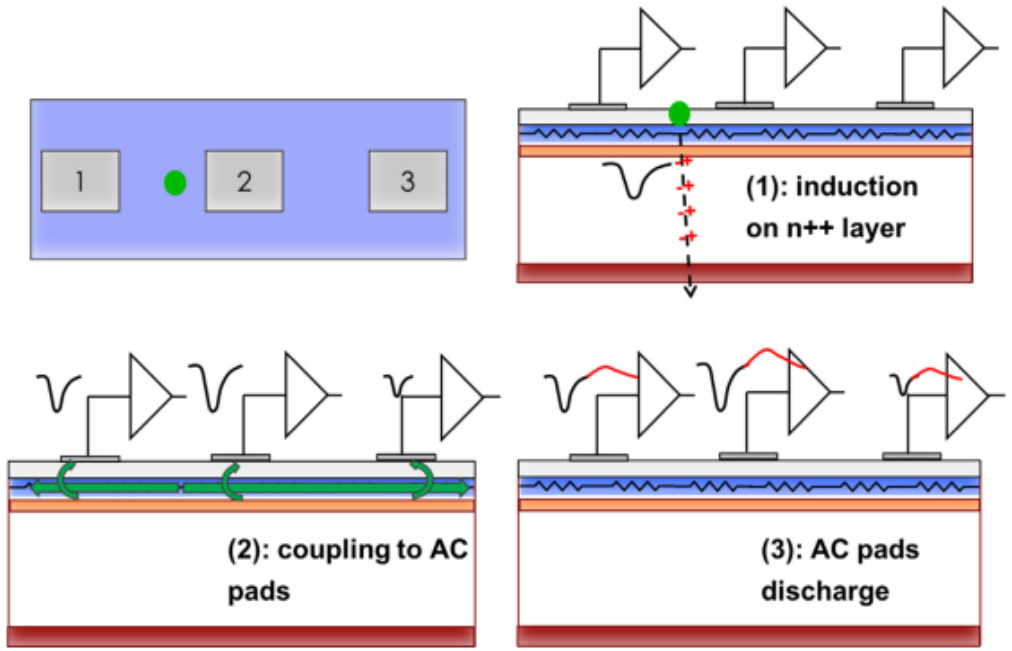


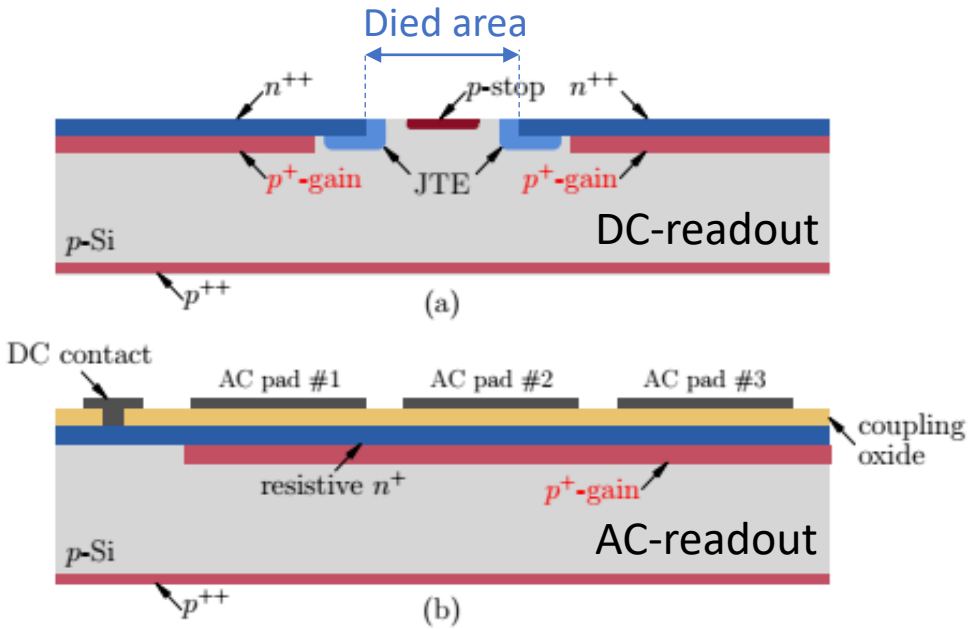
Boron = 5E13 cm^{-2}

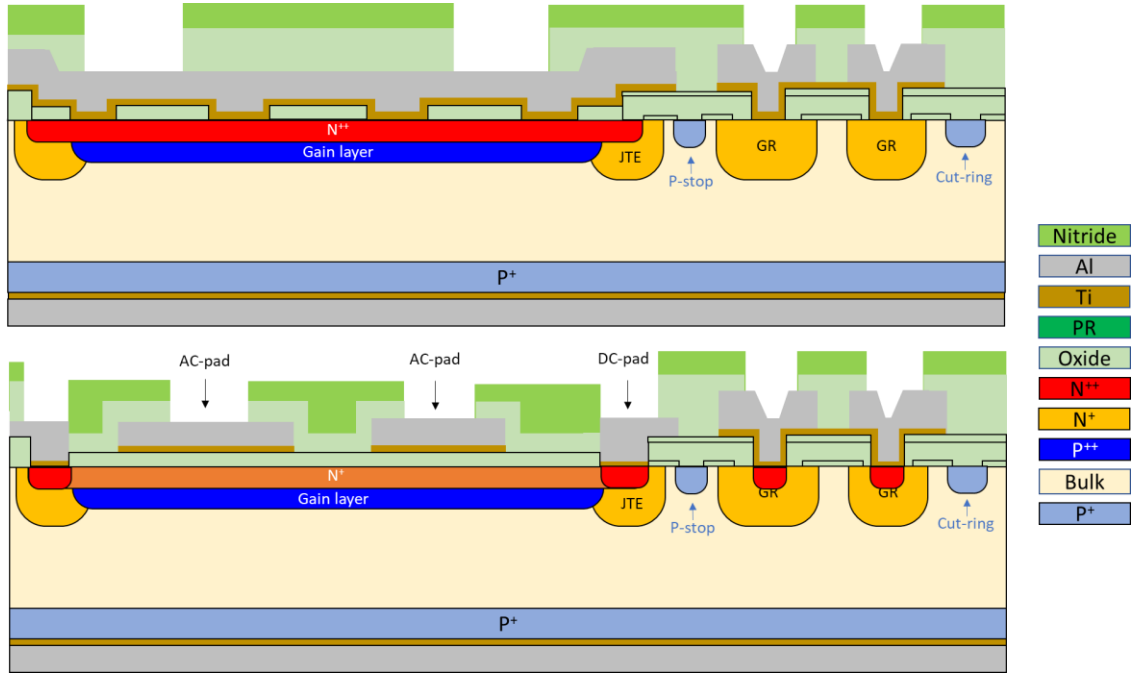


Future plans: AC-LGAD

- Almost 100% Fill Factor can be
- The signal is collected on the n++ electrode
- The metal AC pads act as capacitors, they are charged by the signal
- AC-PAD LGAD by change three masks of the DC LGAD masks :1. metal, 2. contact, 3. passivation







Ref. First demonstration of 200, 100, and 50 µm pitch Resistive AC-Coupled Silicon Detectors (RSD) with 100% fill-factor for 4D particle tracking; IEEE Electron Device Letters PP(99):1-1, September 2019
Ref. LGAD designs for Future Particle Trackers; NIMA, volume 979, 2020, 164383

Thank you for your attention !!