DC-LGAD Manufacture and Simulation at NCU

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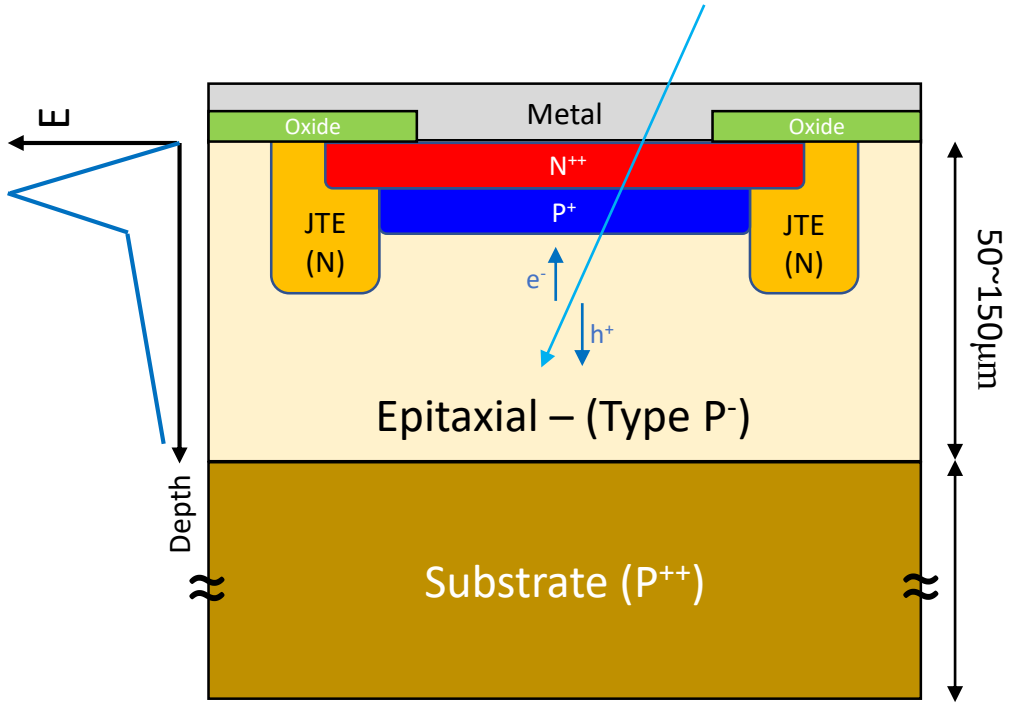
Low Gain Avalanche Detector (LGAD)

Characteristic :

- High time resolution (~30ps)
- Controlled gain produced by gain layer (P^+ layer)

What we do in NCU?

- Simulating the LGAD process and electric behavior with TCAD to build a possible process flow and parameters.
- The sensor was produced by ***Taiwan Semiconductor Research Institute (TSRI)***, the sensor could be done in this year.
- Designing the mask for DC-LGAD test sensor.
- The mask had be produced by ***Taiwan Mask Corporation (TMC)***.
- Prepare to measure LGAD sensor IV, CV and gain.
- In the first LGAD manufacture, we want to verify our TCAD simulation and real product. It can help us to improve the senor in the future.



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Taiwan Semiconductor Research Institute

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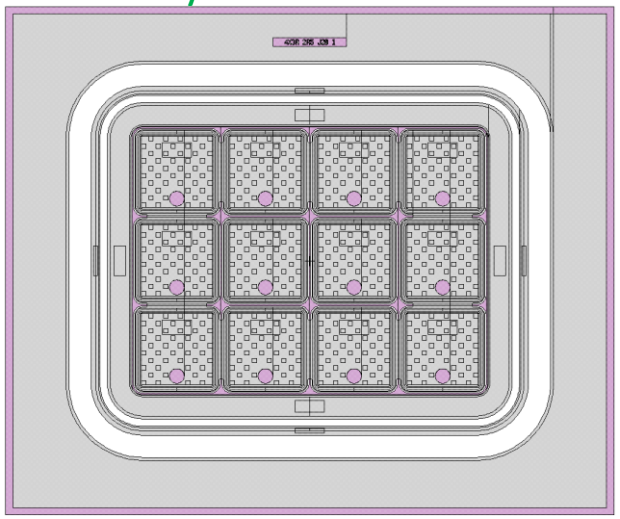
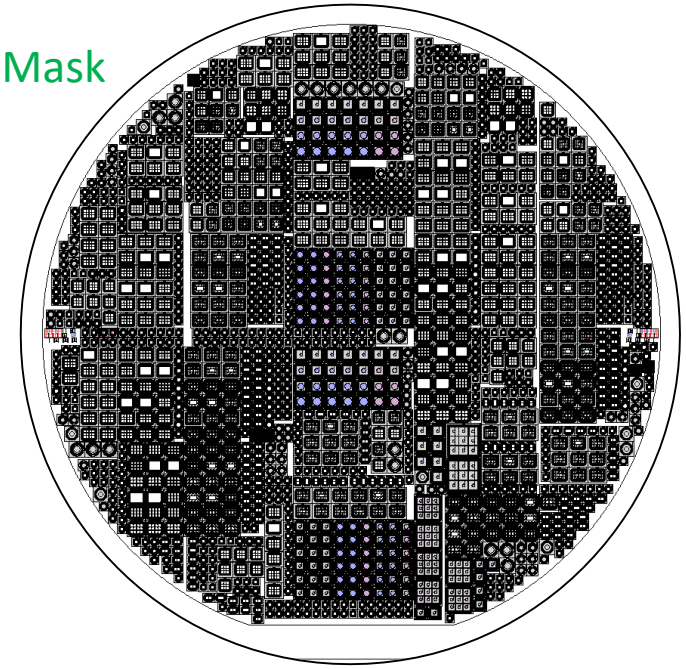
Mask Design

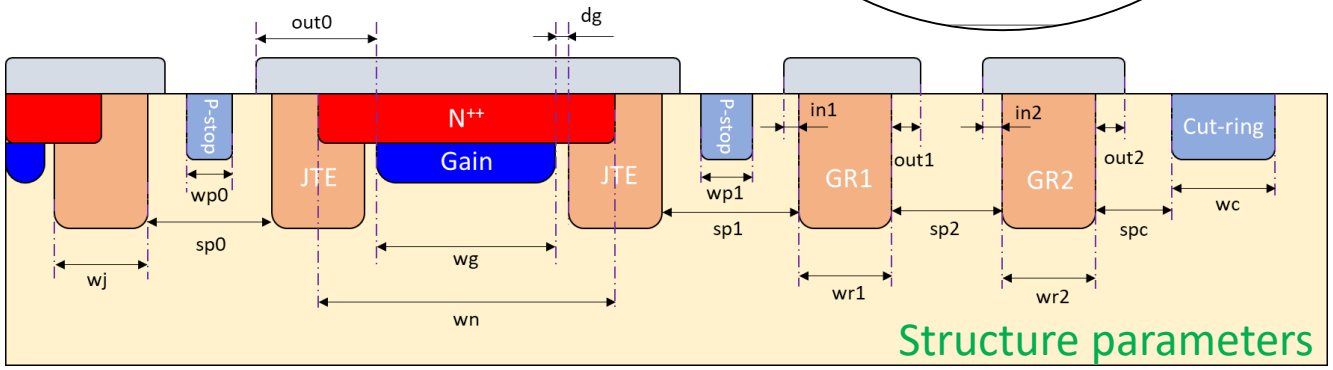
- Type : pixel DC-pad structure
- Purpose: Study the structure for breakdown voltage and cross talk.
- There are ~180 different structure in mask.
- Almost parameters are studied in the small single test keys.
- The variables in pixel arrays usually are pitch and p-stop or collect ring design.
- Parameters (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

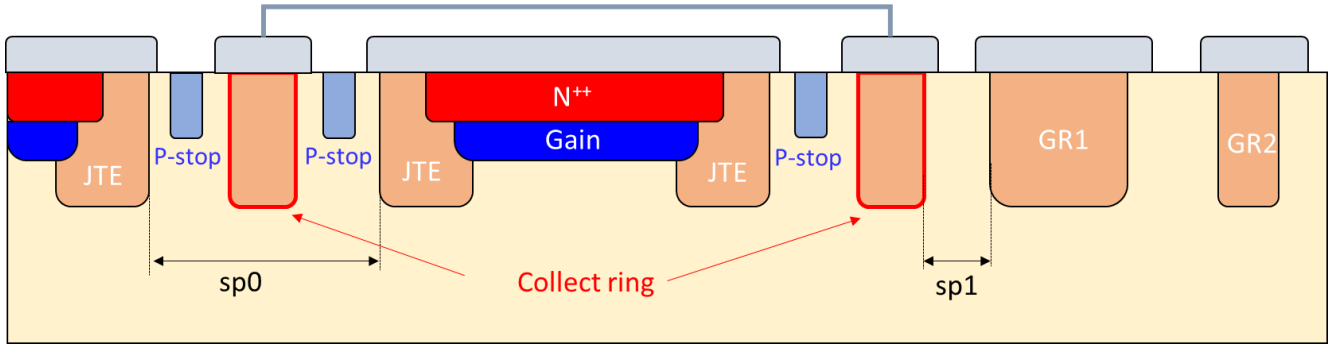
4x3 Array



Mask



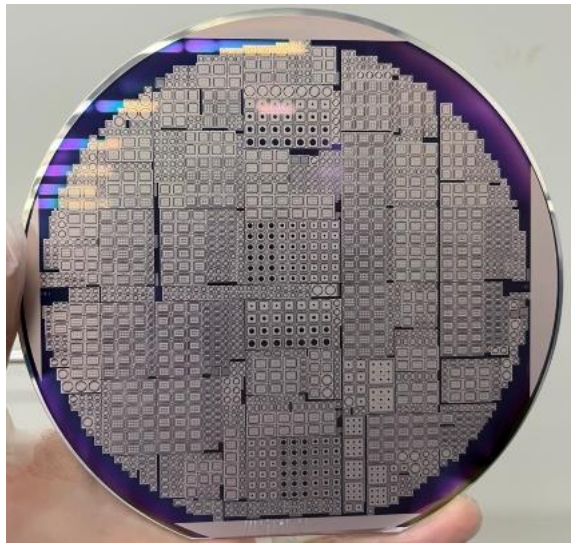


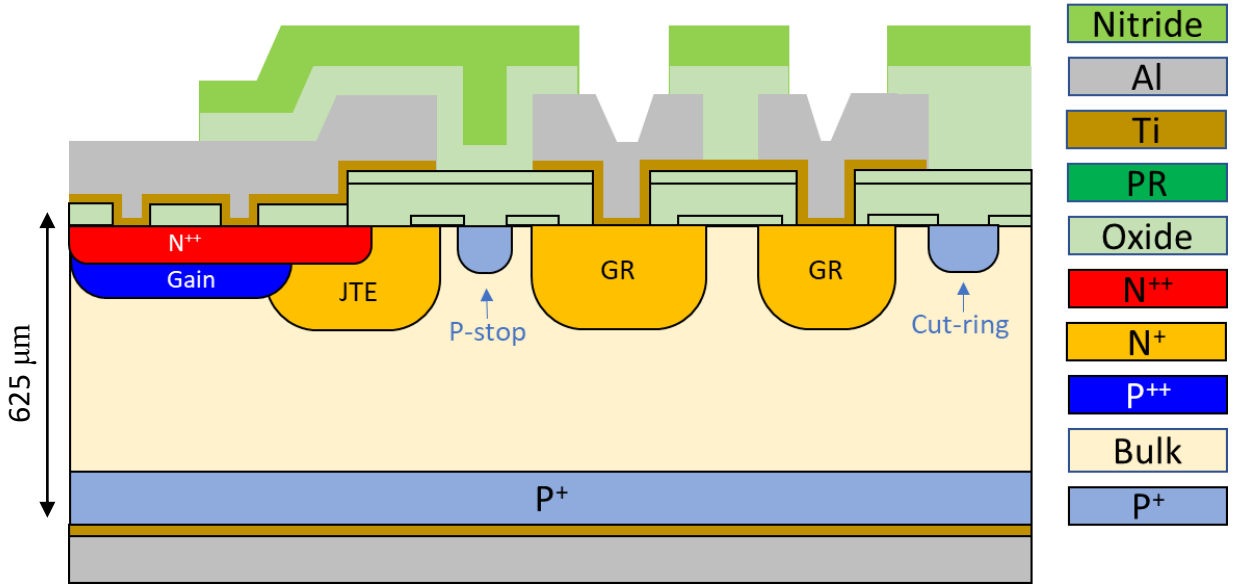


LGAD Manufacture in TSRI

- Wafer :
  - Type : 6” FZ <100> Resistivity : 3000 Ω-cm Thickness : 625µm
- 12 Wafers and 6-different parameters.
- Right table shows the our process flow of LGAD.
- Delivery date : around 12/28

Test wafer (in metal etch)





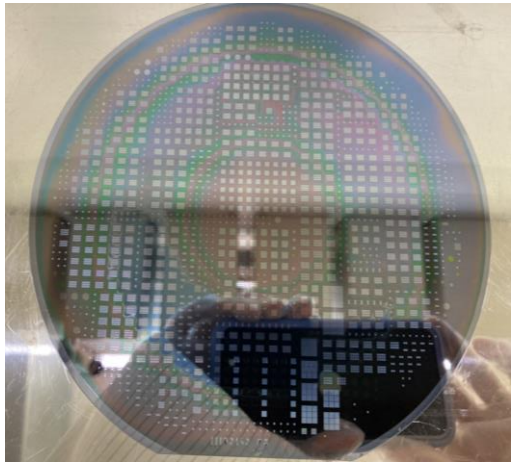
■ Done ■ Doing

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

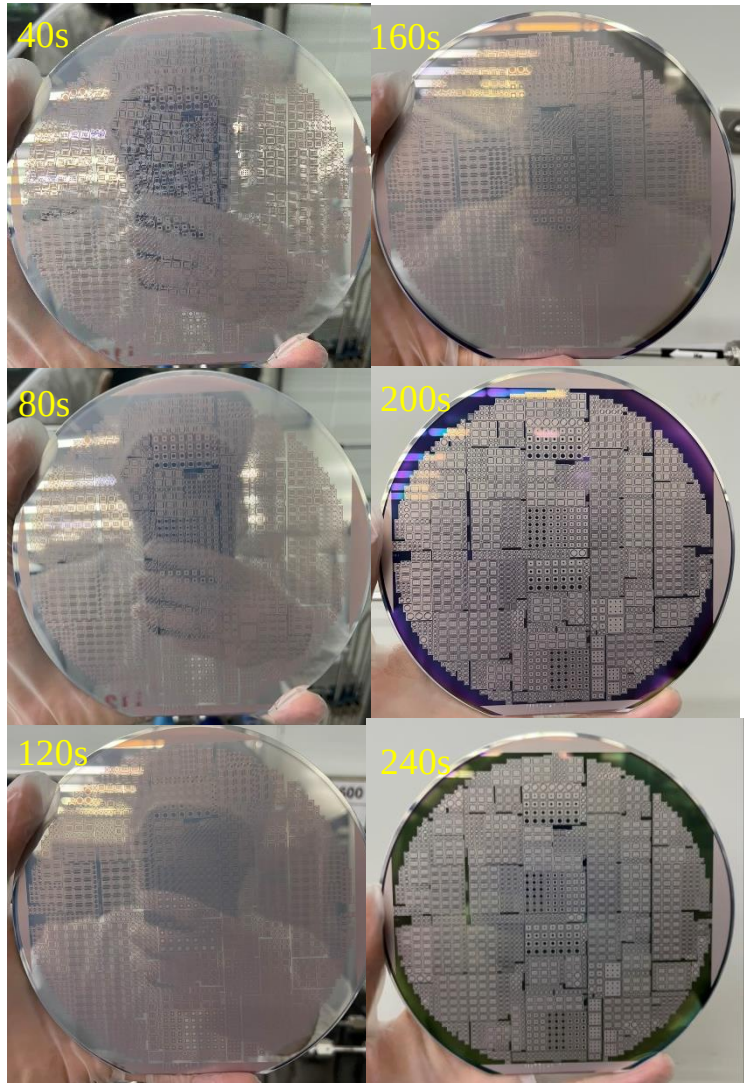
Report from TSRI

- TSRI could give more information during the manufacture.
- Have some wiggle room to fix error based on status reports.
- The pictures shows the some check at different step.

Oxide etch testing

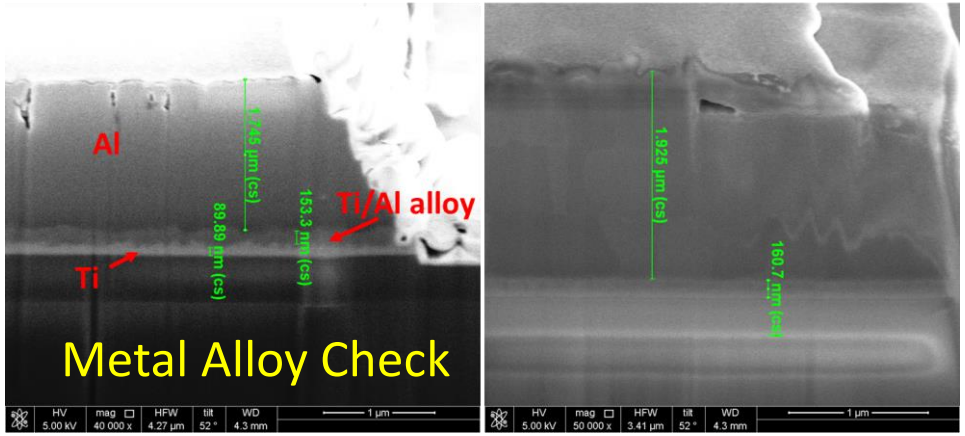


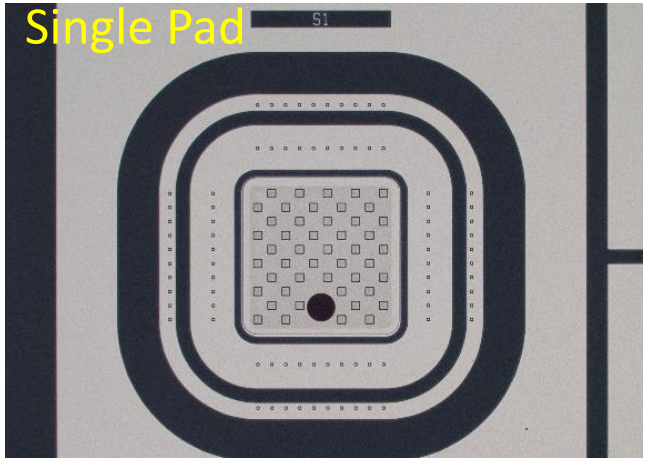
Metal etch testing



600°C 10min

410°C 30min

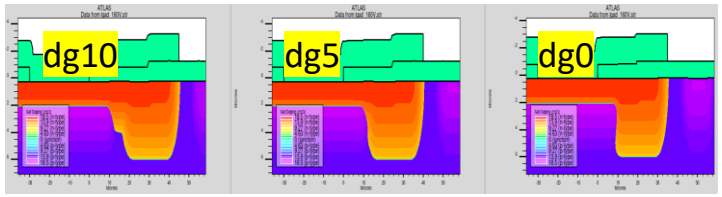


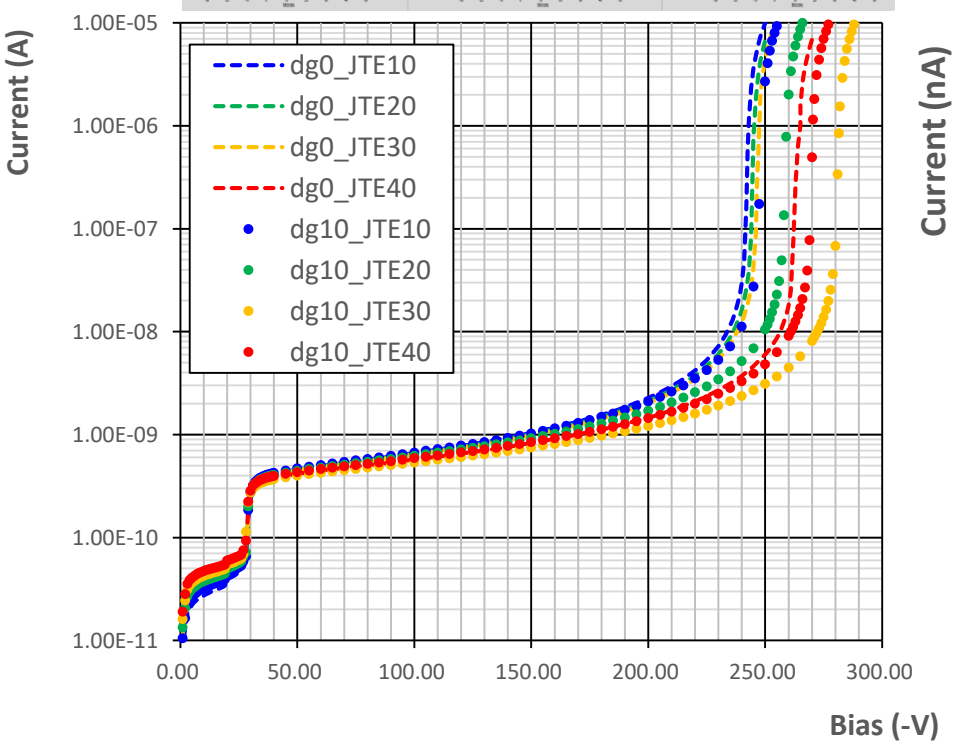


Structure Simulation

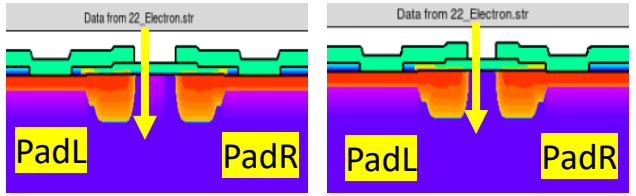
- There are some simulation results about different structure design to expect the variety.

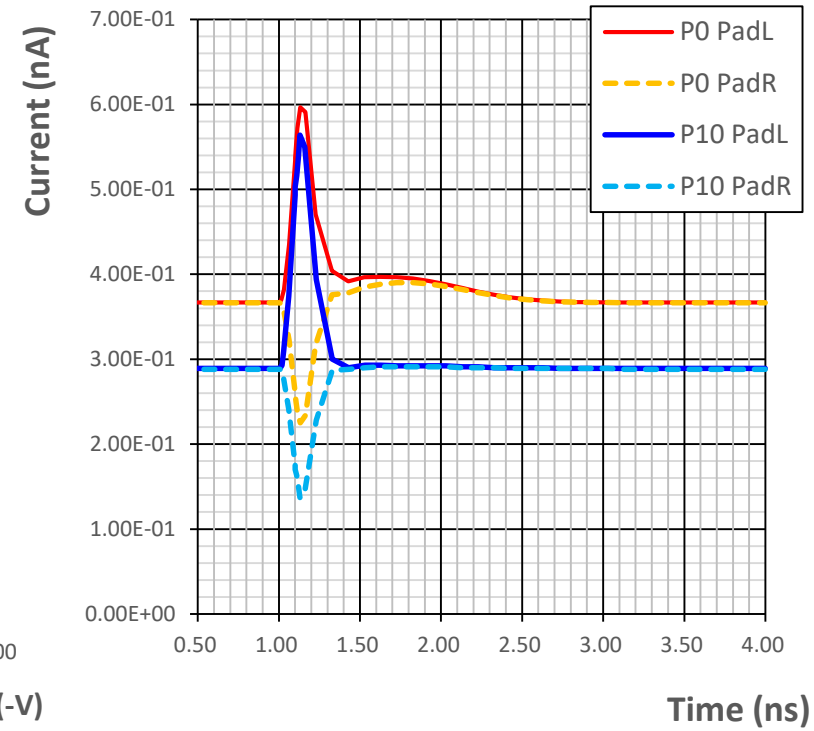
JTE structure



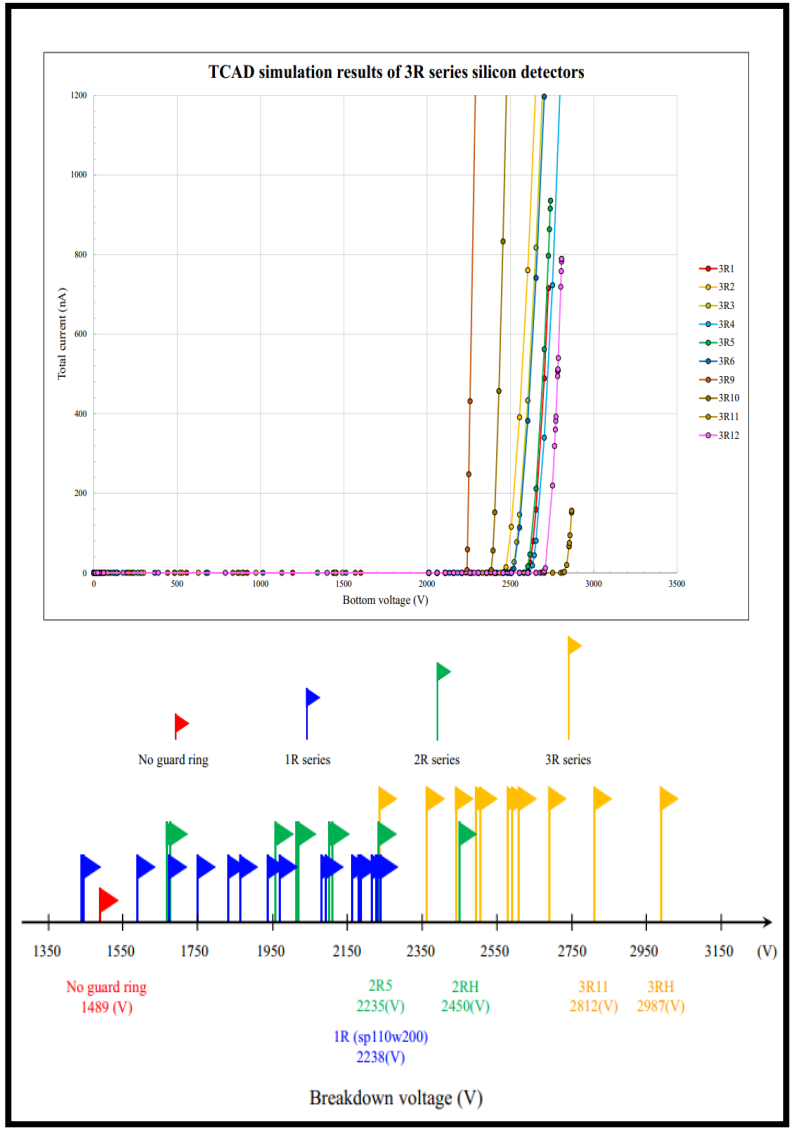


P-stop structure



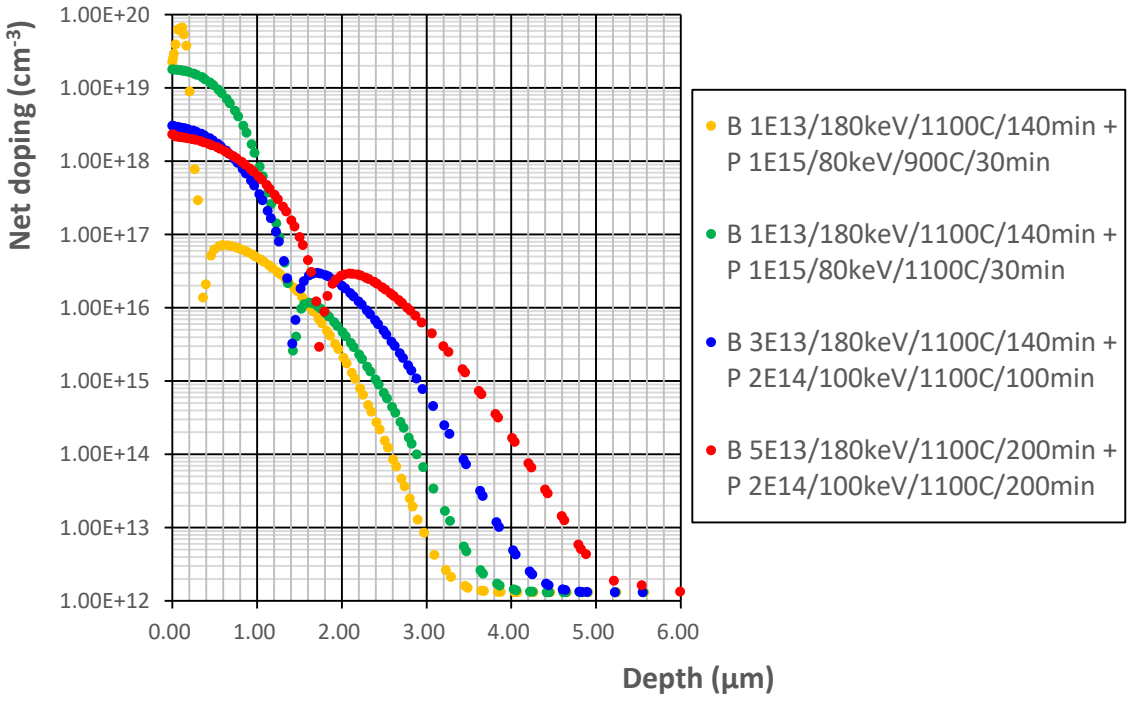


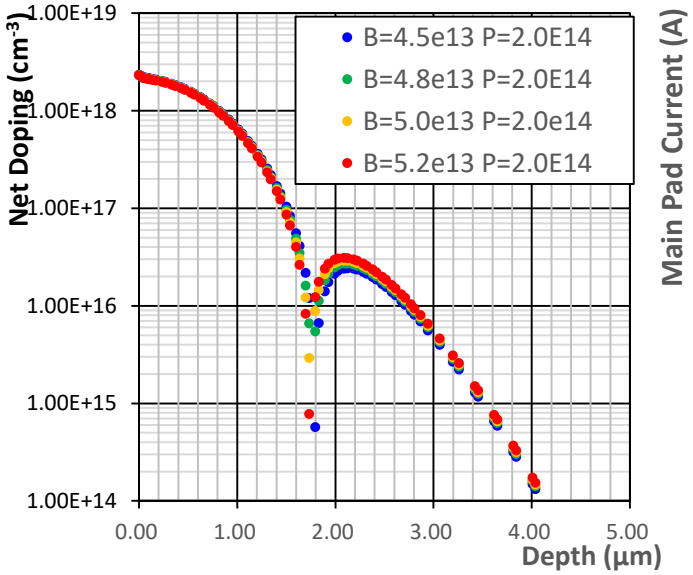
Guard rings simulation (PIN structure)

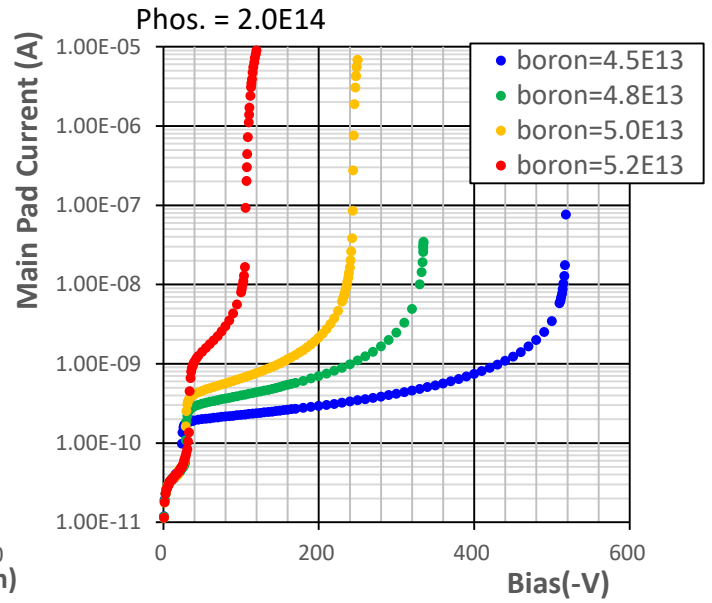


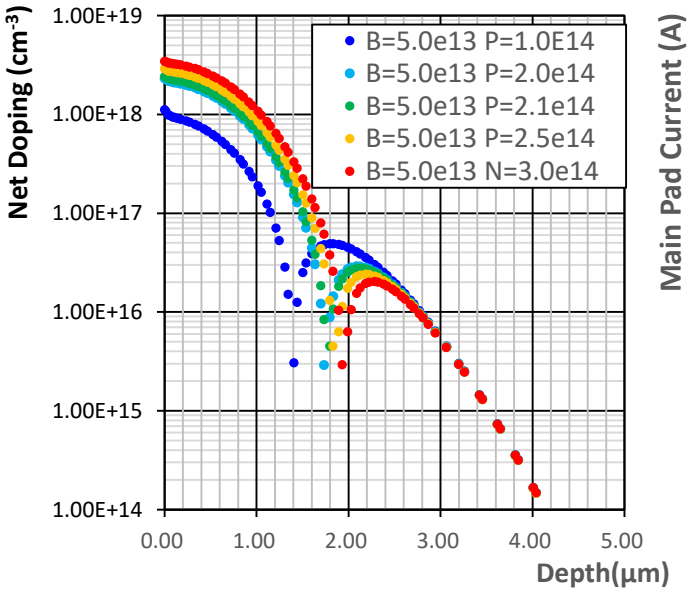
Process Flow Simulation

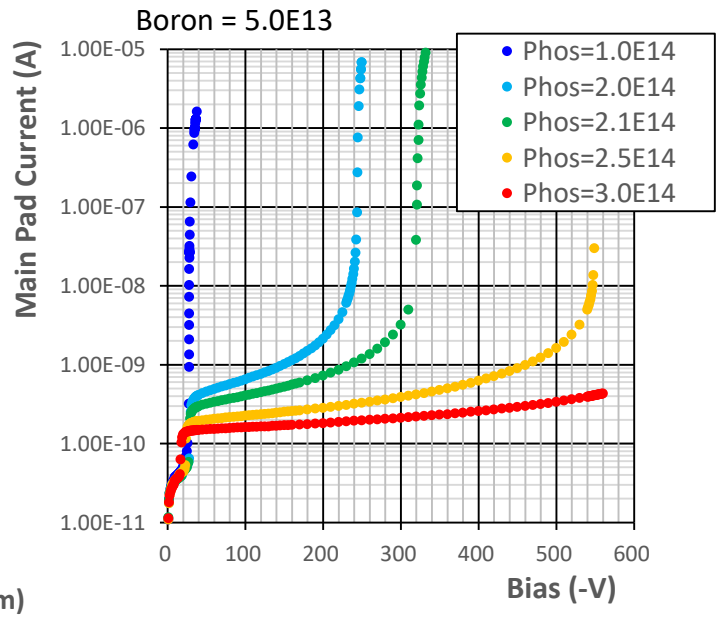
- Simulated the different process flows for decide the real flows.
- Found the suitable range of dosages with simulation.









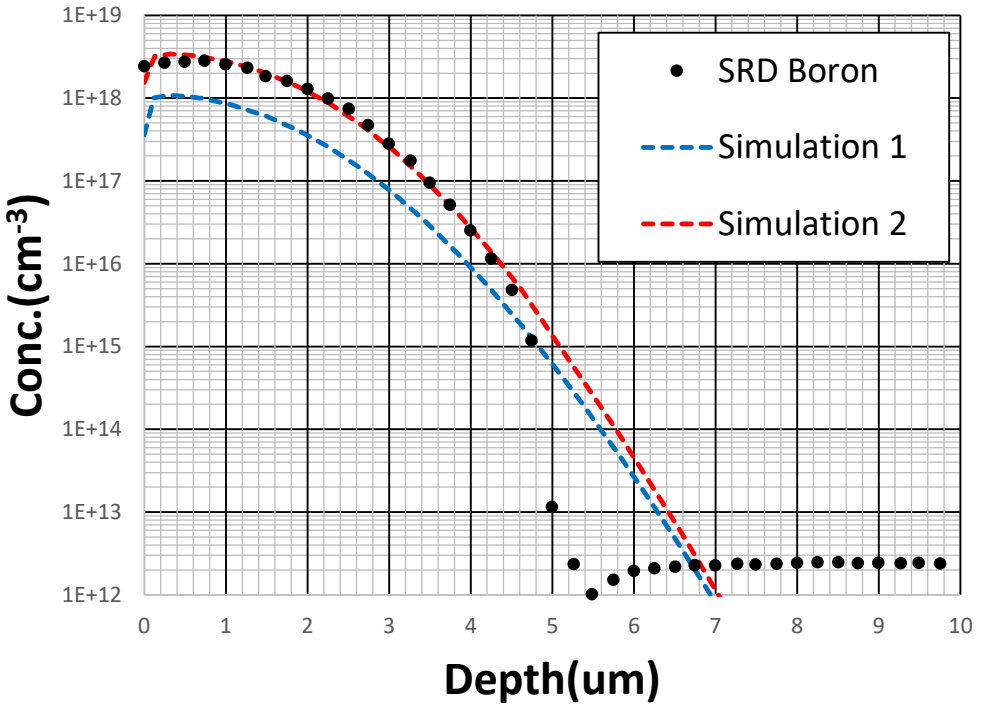


Process Flow and Doping Profile

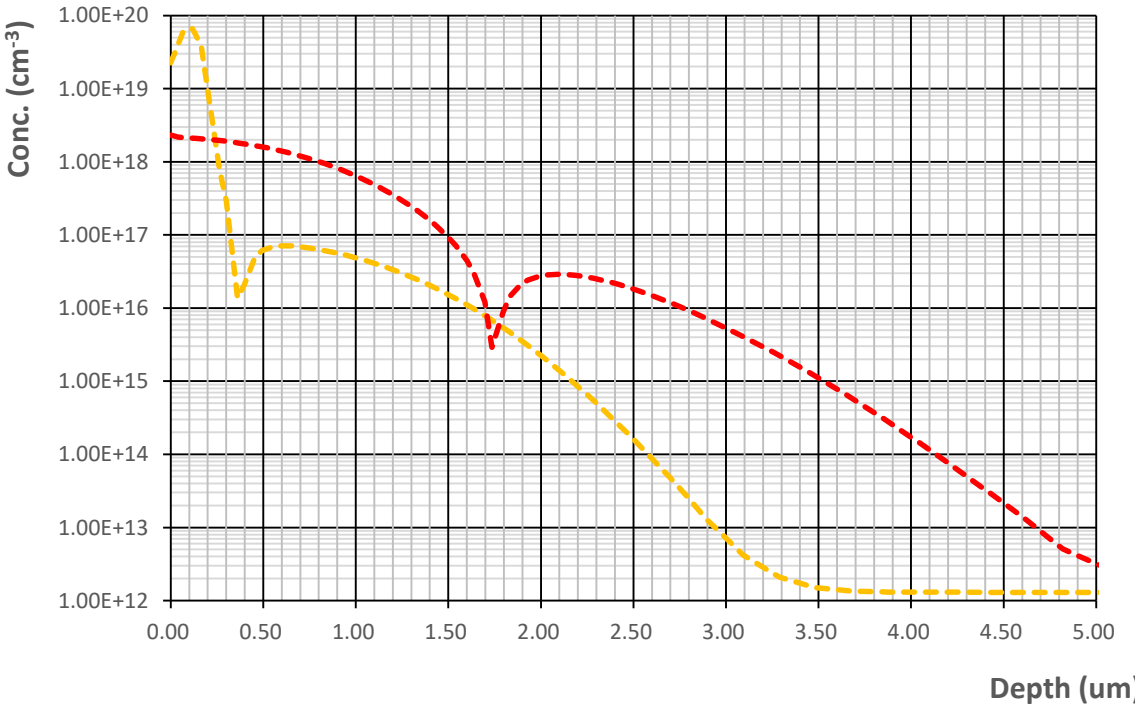
- The table shows 6 process that have different born dosage and diffusion time in this manufacture. Base on diffusion time, the doping profile could divide into two types shown on right bottom.
- Left plots shows the previous SRD profile and our simulation of PIN structure, but there are many detail parameters guessed.

Wafer	Dosage of Boron.	Diffusion time of Phos.
#1,7	N	long
#2,8	N+	long
#3,9	H	long
#4,10	L	short
#5,11	N	short
#6,12	H	short

Other Manufacture SRD data & TCAD

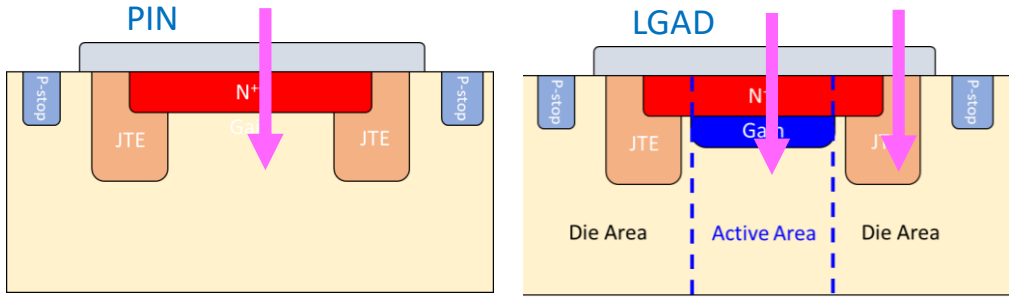


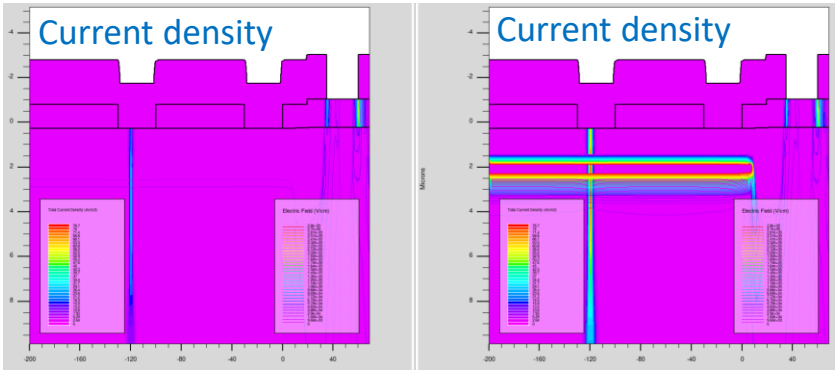
LGAD TCAD simulation

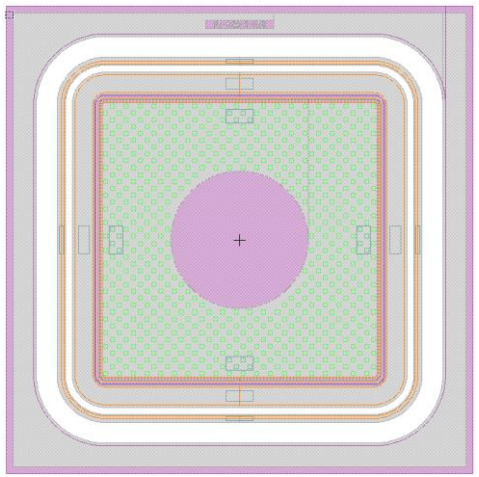


Gain and Signal Simulation

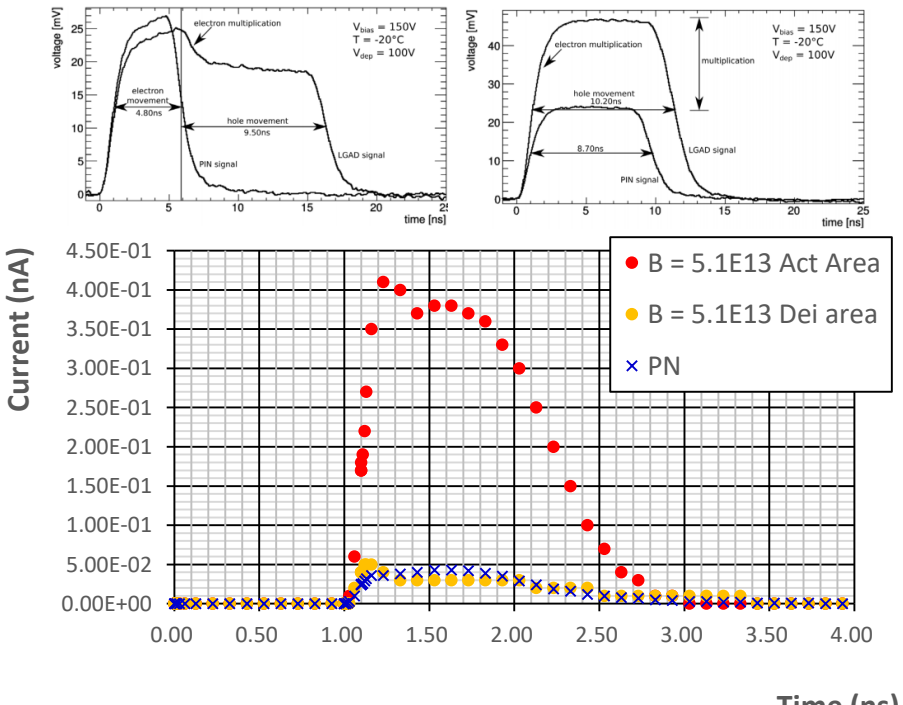
1. Set a laser to illuminate sensor and calculate gain :
   - Gain1 = Current produced by laser/ photon current
2. Laser illuminate on active and die area to calculate :
   - Gain 2 = Active area current / Die area current
3. Laser illuminate on LGAD and PIN structure to calculate :
   - Gain 3 = LGAD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

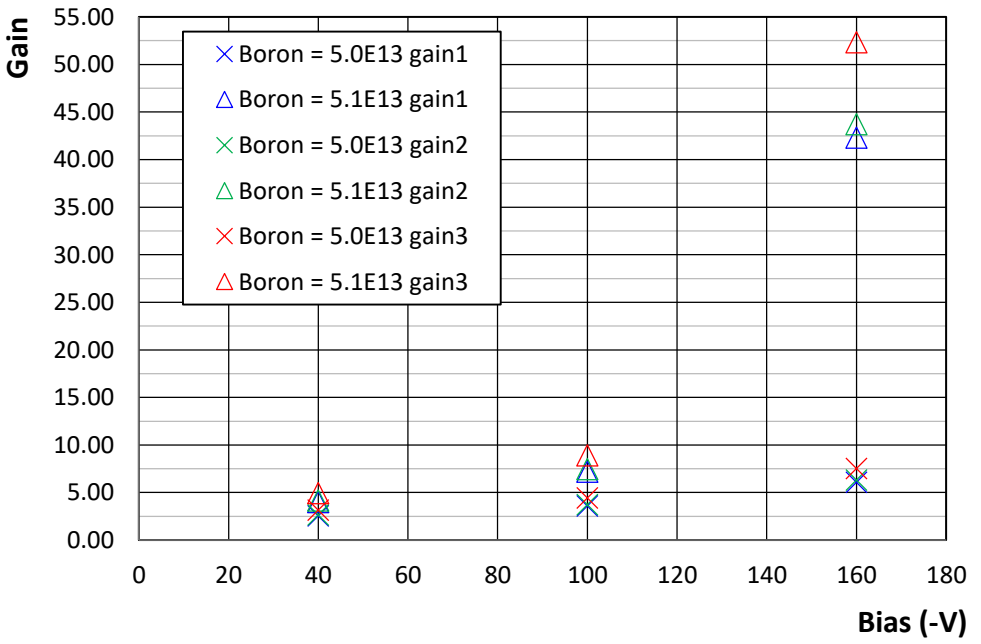






Ref. C. Gallrapp, *NIMA, Volume 875, 11 December 2017, Pages 27-34*





Measurement System

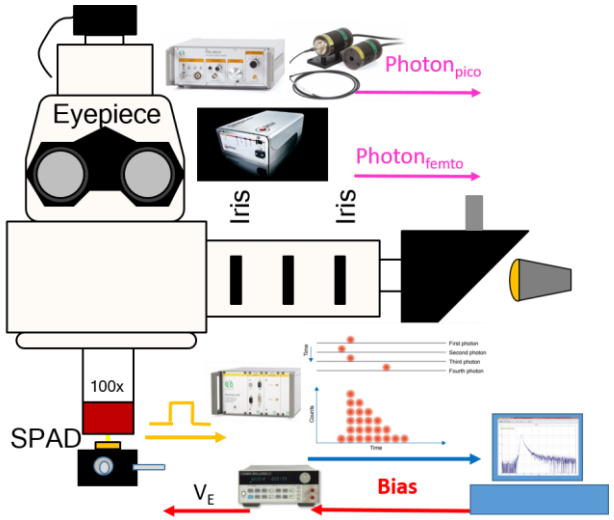
In NCTU (Gain) :

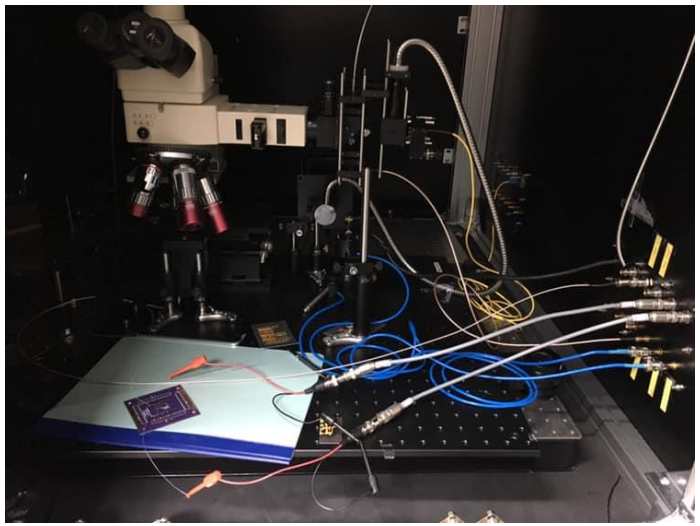
- Picosecond laser
  - PDL 800D
  - LDH D-C-640
- TCSPC
  - Picoharp 300
- Femtosecond laser
  - Toptica FemtoFErb 780
- Pusle Picker

In NCU (IV & CV):

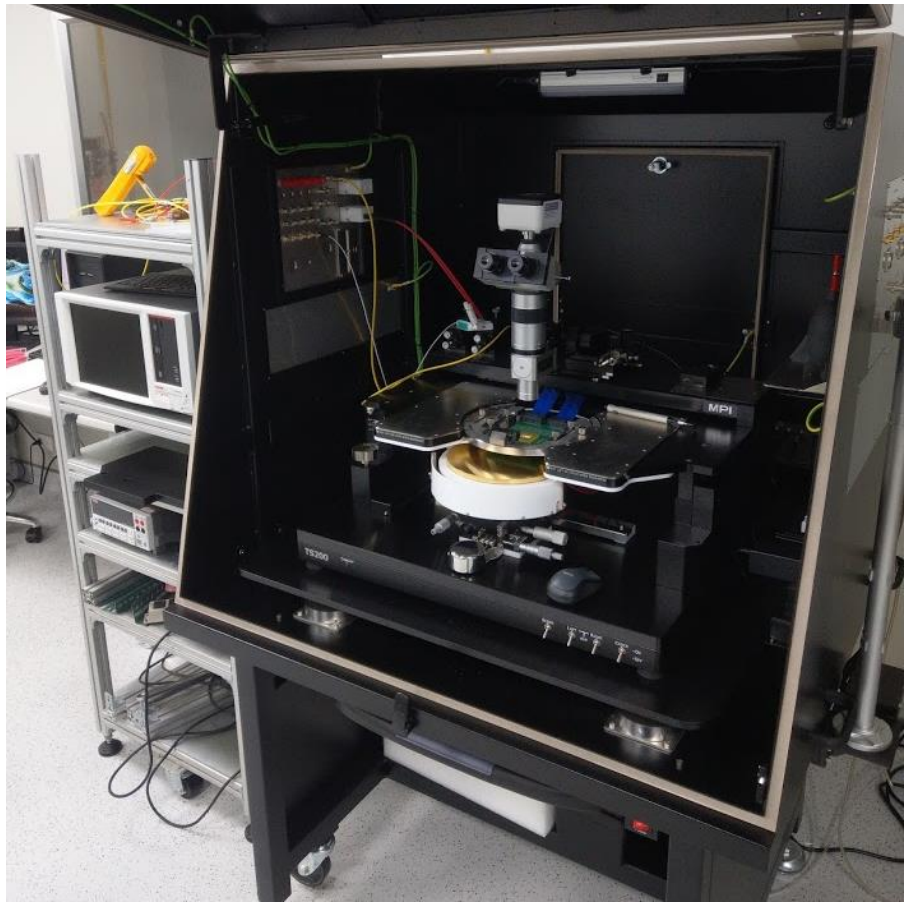
- Class 10,000 Clear Room
- Source meter
  - Keithley 4200 / 2410 / 2470
- Current meter
  - Keithley 6514
- Capacitor meter
  - Keithley 4200

Integrated Auto Optical measurement System in NCTU





Probe station measurement System in NCU



By Prof. Jau-Yang Wu

Summary

- We had designed the different structures LGAD testing key in 6 inch wafer to study the breakdown voltage.
- The LGAD manufacture was running in TSRI. We can get more information from TSRI to verify our simulation.
- We can do the TCAD simulation about the real process flow and electric characteristic.
- Some structures was simulated to get the expected result. Also simulated the gain by set the laser to imitate experiment method.
- After manufacture is done, we will go to measure the IV, CV and gain. In the other hand, will also chose 1-2 wafer to measure the doping profile to verify simulation.