DESIGN OPTIMIZATION OF PIXEL SENSORS USING DEVICE SIMULATION FOR CMS TRACKER UPGRADE (PHASE-II)

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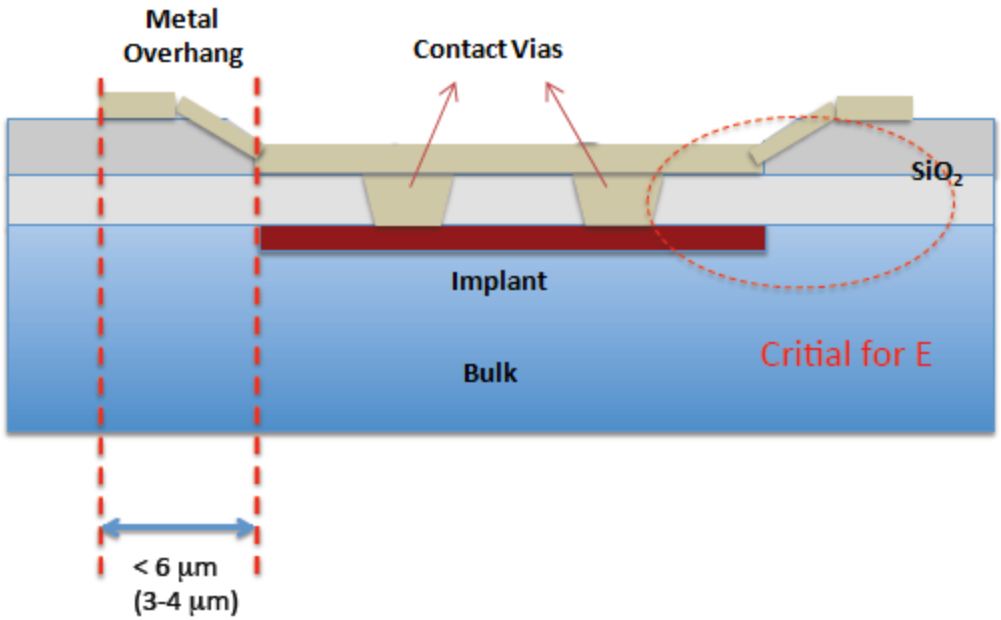
Outline

- 2D Pixel Structure & Simulation Parameters
- Proposed Pixel Geometry Options
- Simulations Performed
- Summary

2D Pixel Structure & Simulation Parameters



Parameters from the Pixel Upgrade Group

- **8 n-in-p Configurations** = 4 Pstop & 4 Pspray :

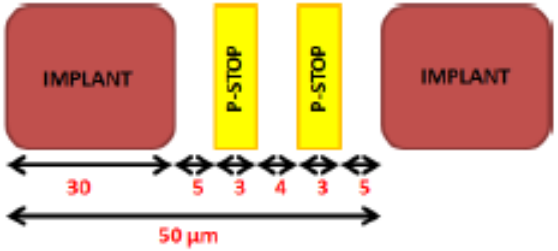
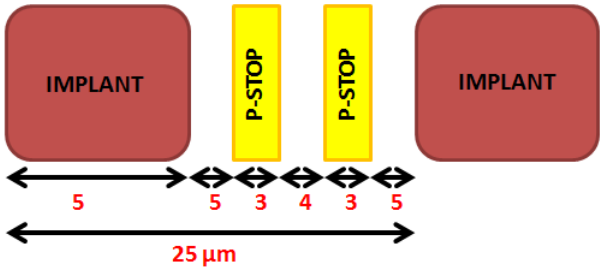
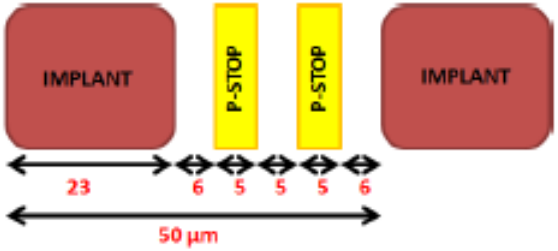
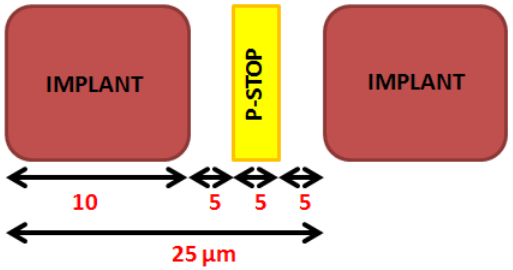
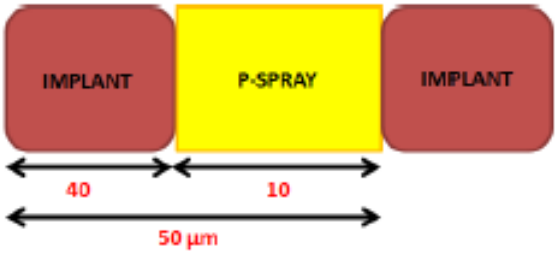
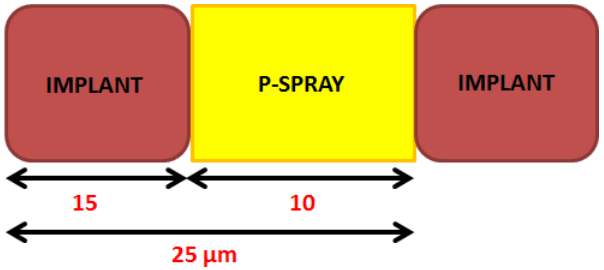
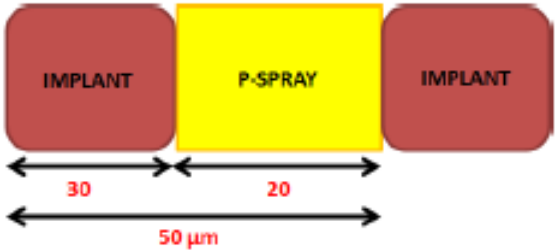
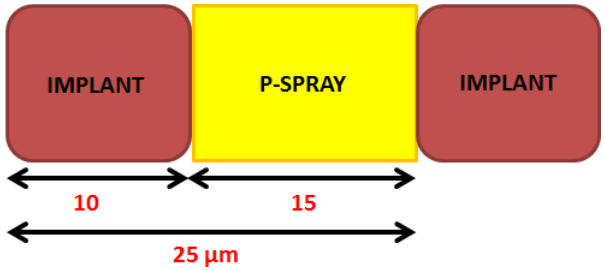
50X50µm^2 Wide, 50X50µm^2 Normal, 25X100µm^2 Wide, 25X100µm^2 Normal

- Alµminµm thickness = 0.55 µm, DC contact through Vias
- Gate SiO_2 thickness = 0.25 µm, Field SiO_2 thickness = 0.70 µm
- Bulk doping concentration N_b = 3e12 cm^{-3}
- Implant doping : conc. N_{im} = 1e19 cm^{-3}, depth D_{im} = 1.5 µm, type = gaussian 0.5 µm
- Temperature = 253 K

Rest Simulation Parameters

- Radiation damage model = 2 bulk traps + QF + 2 Nit traps
- **Fluence cm^{-2}/QF cm^{-2} = 0/1e11, 1e14/1e11, 5e14/1.2e12, 1e15/2e12, 2e15/2e12, 5e15/2e12, 1e16/2e12**

8 Proposed Pixel Geometries

	50µm X 50µm	25µm X 100µm
Pstop Wide		
Pstop Normal		
Pspray Wide		
Pspray Normal		

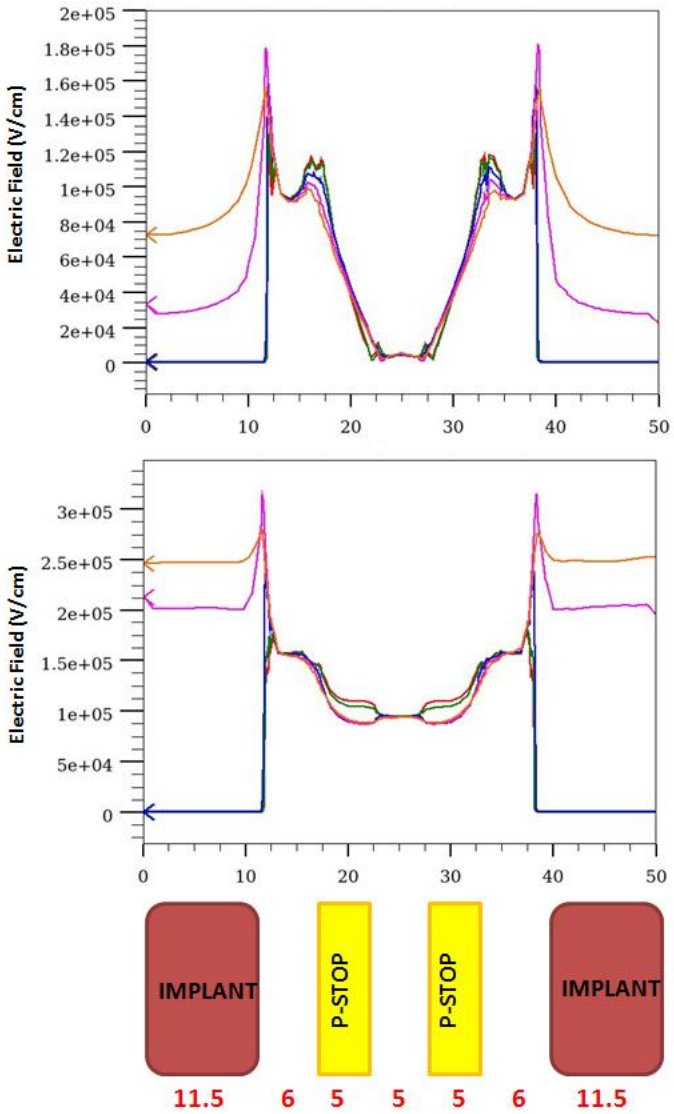
Step-wise Proceeding in Simulations

AIM1 : To identify crucial electric field regions in the device.

AIM2 : Look for the best geometry from the 8 configurations.

AIM3 : Vary depth of detector, pstop-psray depths, and other parameters for the best geometry and look at the variation in the electric field plots.

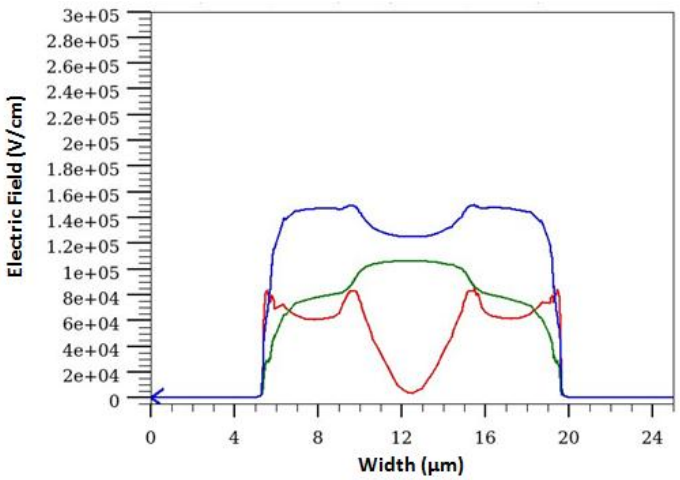
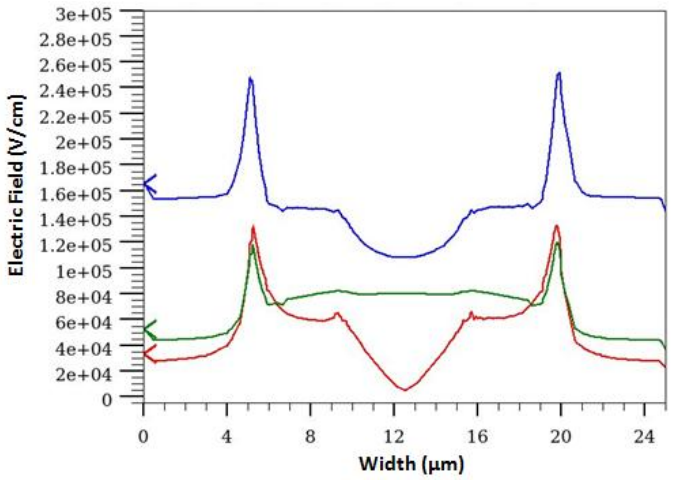
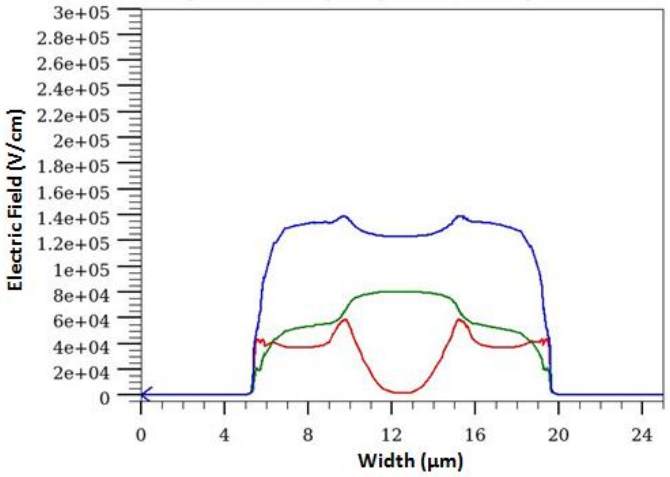
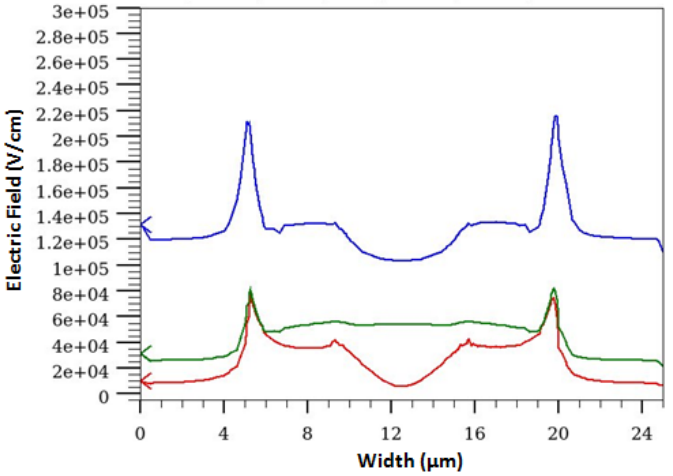
Electric Field Profile @ Different Cutlines

	Fluence	@ 1000V
Pstop Pitch=50µm Conf.=Normal d=200µm N_{pst}=1e16cm^{-3} D_{pst}=1µm MO=4µm	0 1e16	

Cutline @ (below oxide)
- ----- 0.1µm
- ----- 0.2µm
- ----- 0.5µm
- ----- 0.9µm
- ----- 1.2µm

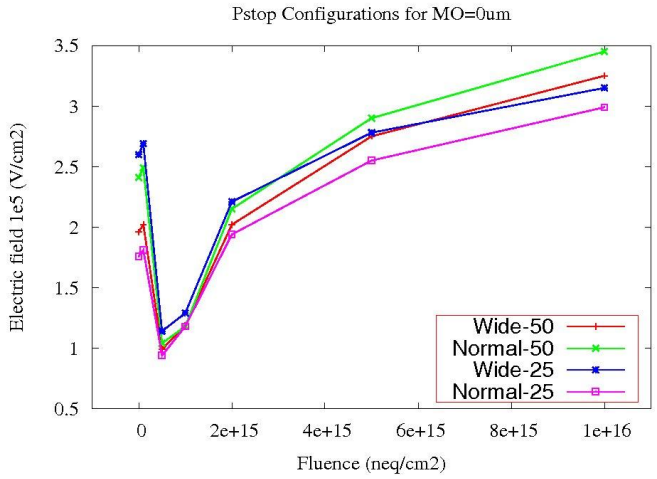
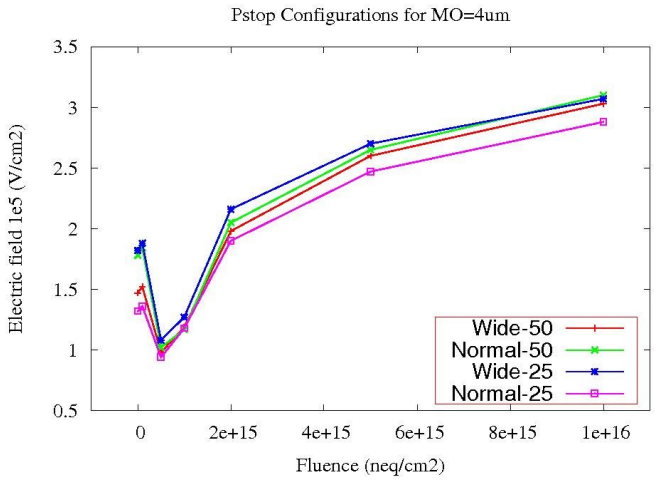
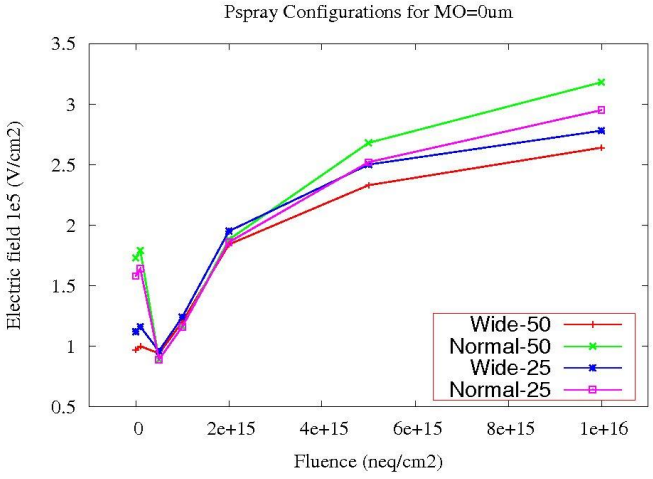
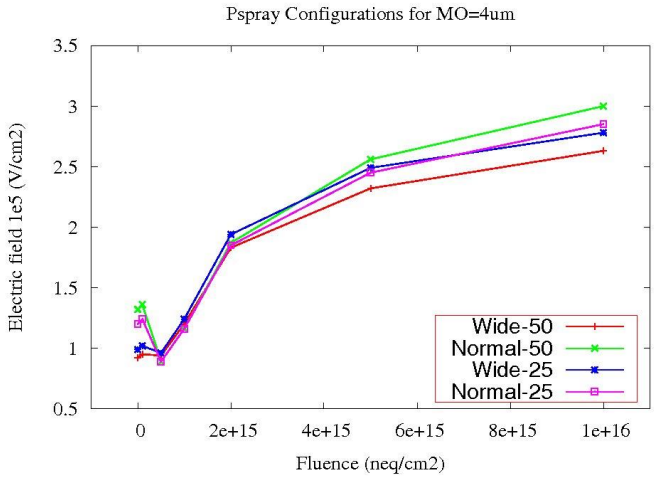
❑ Critical electric field at 0.9µm and at strip curvature, for every fluence!!

Pstop : Pitch=25µm Conf.=Normal d=200µm N_{pst}=1e16cm^{-3} D_{pst}=1µm

MO 4 µm	Cutline @ 0.1 µm	Cutline @ 0.9 µm
@1000 V		
@ 500 V		

✓ **CUTLINE @ 0.9µm, 1000V (n^+ curvature)** for critical electric field region.

Best Configuration : d=200μm $N_{pst-psp}$=1e16-1e15cm^{-3} $D_{pst-psp}$=1μm

Cutline 0.9μm	MO = 0μm	MO = 4μm
Pstop		
Pspray		

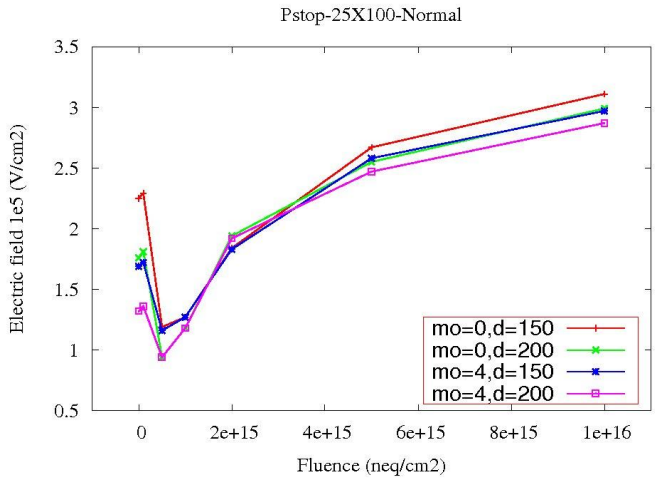
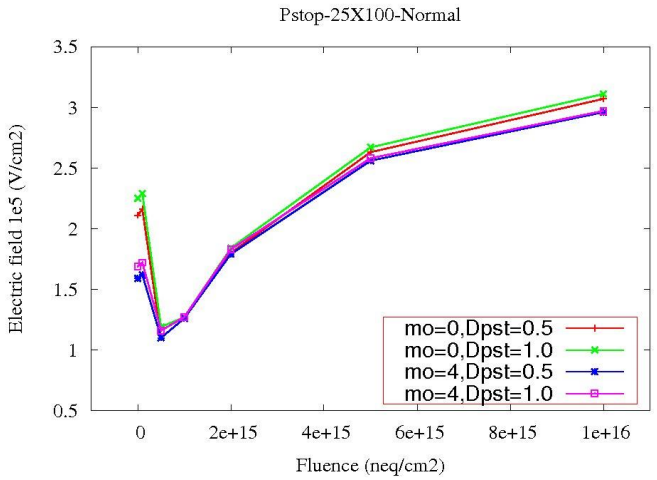
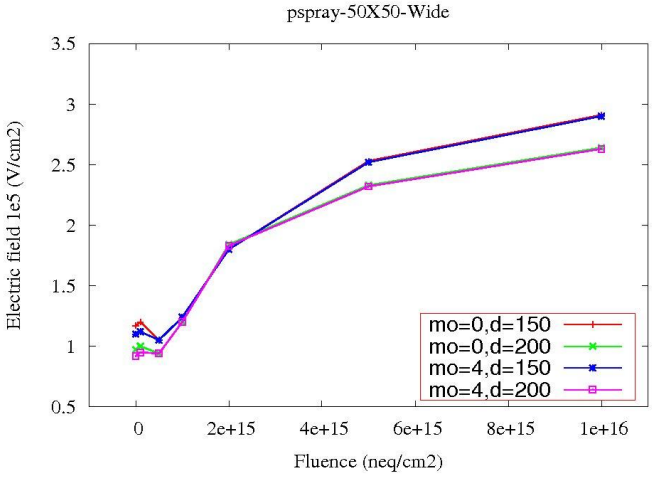
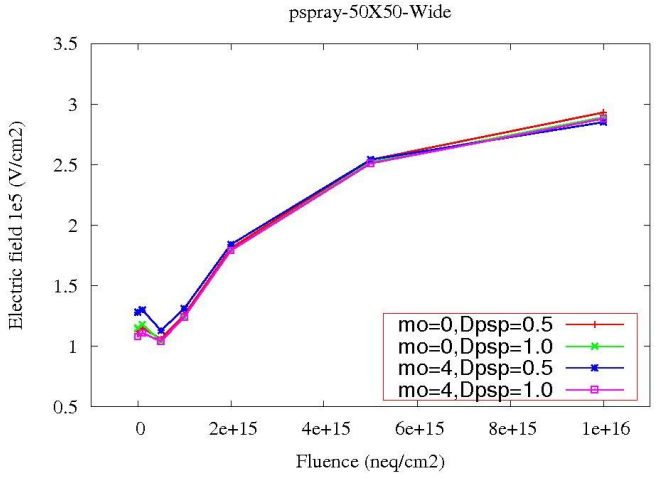
✓ **PSTOP NORMAL 25x100μm2** has the least electric field!

✓ **MO reduces electric filed!**

✓ **PSPRAY WIDE 50x50μm2** has the least electric field!

Effect Of Parameters : $N_{pst-psp}$=1e16-1e15cm^{-3}

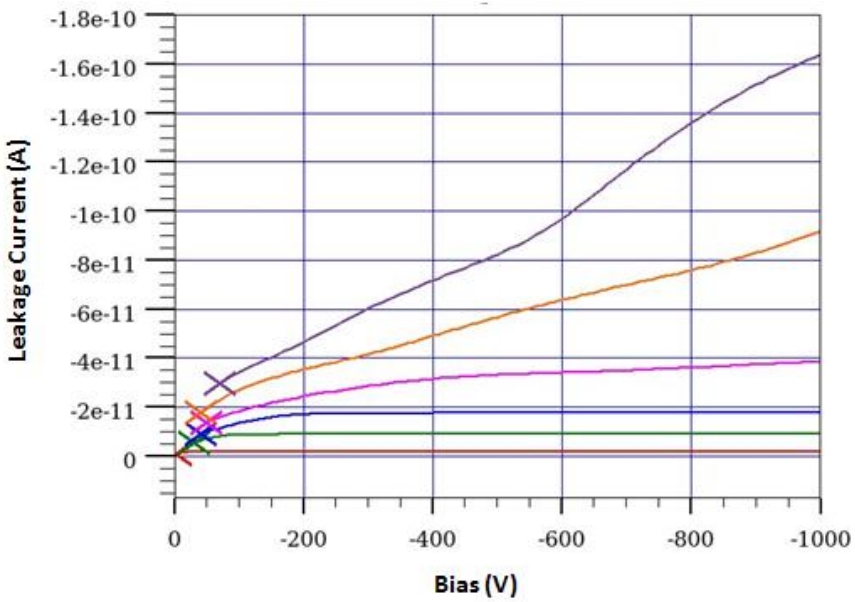
Cutline 0.9µm

	d Effect : $D_{pst-psp}$=1µm	$D_{pst-psp}$ Effect : d=150µm	
Pstop 25 Normal			• Electric field is less for both d & MO increase. • Negligible effect of D_{pst} & MO variation.
Pspray 50 Wide			• Electric field reduces for larger detector depth, but no effect of MO. • No effect of D_{psp} or MO variation.

3 Strip Pixel : IV-CV

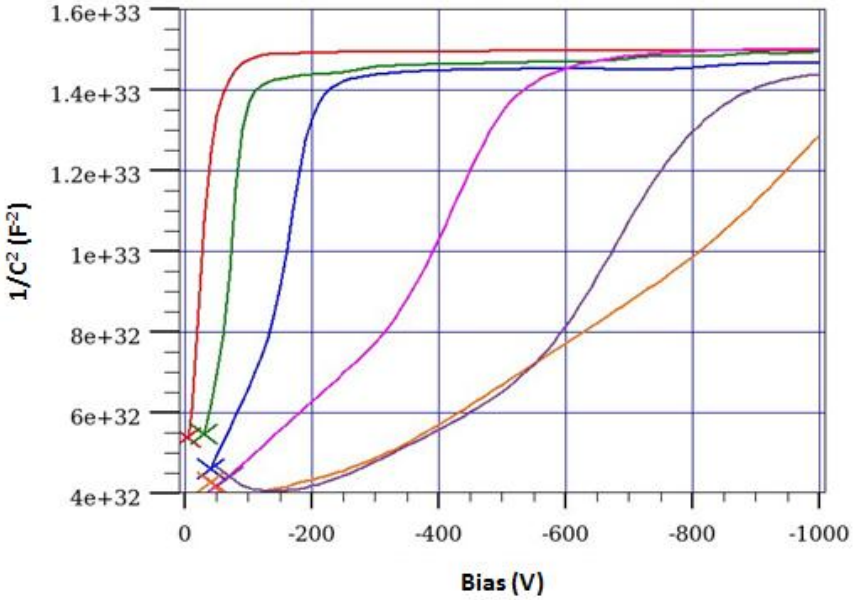
Pstop Pitch=50μm Conf.=Normal d=200μm N_{pst}=1e16cm^{-3} D_{pst}=1μm MO=4μm

IV Characteristics



Fluence cm^{-2}
- 1e14
- 5e14
- 1e15
- 2e15
- 5e15
- 1e16

CV Characteristics



IV Calculation Check For - fluence 2e15cm^{-2} @ 500V full depletion:

$\Delta I = \alpha \Phi V$

$= (8.9 \times 10^{-19}) \times (2 \times 10^{15}) \times (100 \times 10^{-4} \times 200 \times 10^{-4} \times 1 \times 10^{-4})$

$= 3.56 \times 10^{-11}$ A

- Leakage current increase is in proportion to fluence increase.
- Capacitance for 5e15cm^{-2} fluence behaving oddly!!

Summary

❖ Highest electric field is at implant curvature at cutline of 0.9um below oxide.

❖ Metal overhang is effective in reducing the electric fields at high fluence. A metal overhang of 3-4 μm should be fine.

❖ For Pstop, 25X100 μm^2 Normal configuration has the least electric field, whereas for Pspray 50X100 μm^2 Wide configuration has the least electric field.

❖ At high fluence, the detector depth variation from 100 to 200 μm has small effect on the electric field.

❖ Pstop/Pspray depth have negligible effect on the electric fields.

❖ IV is ok. CV behaving oddly for 5e15cm^{-2} fluence.