Silicon Sensor R & D

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on behalf of Korean MPC-EX group

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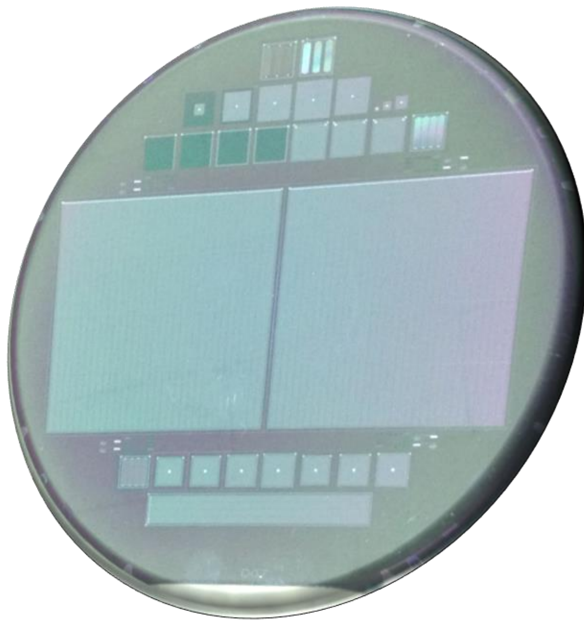
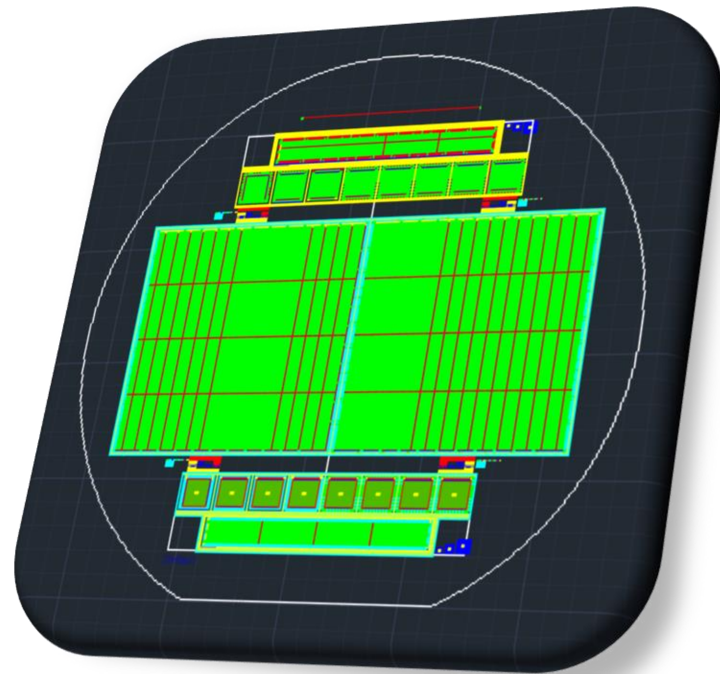
Introduction to Minipad sensor

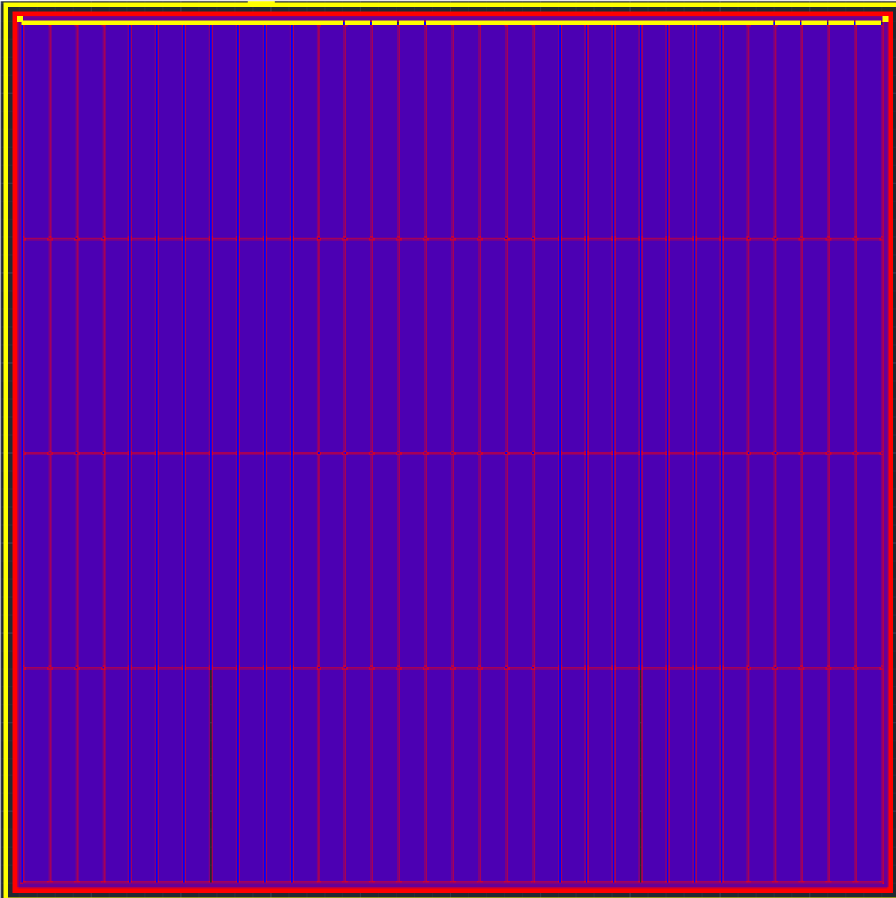
Minipad sensor

We performed R&D's of the silicon minipad sensor for PHENIX MPC-Ex upgrade. R&D has evolved into main production.



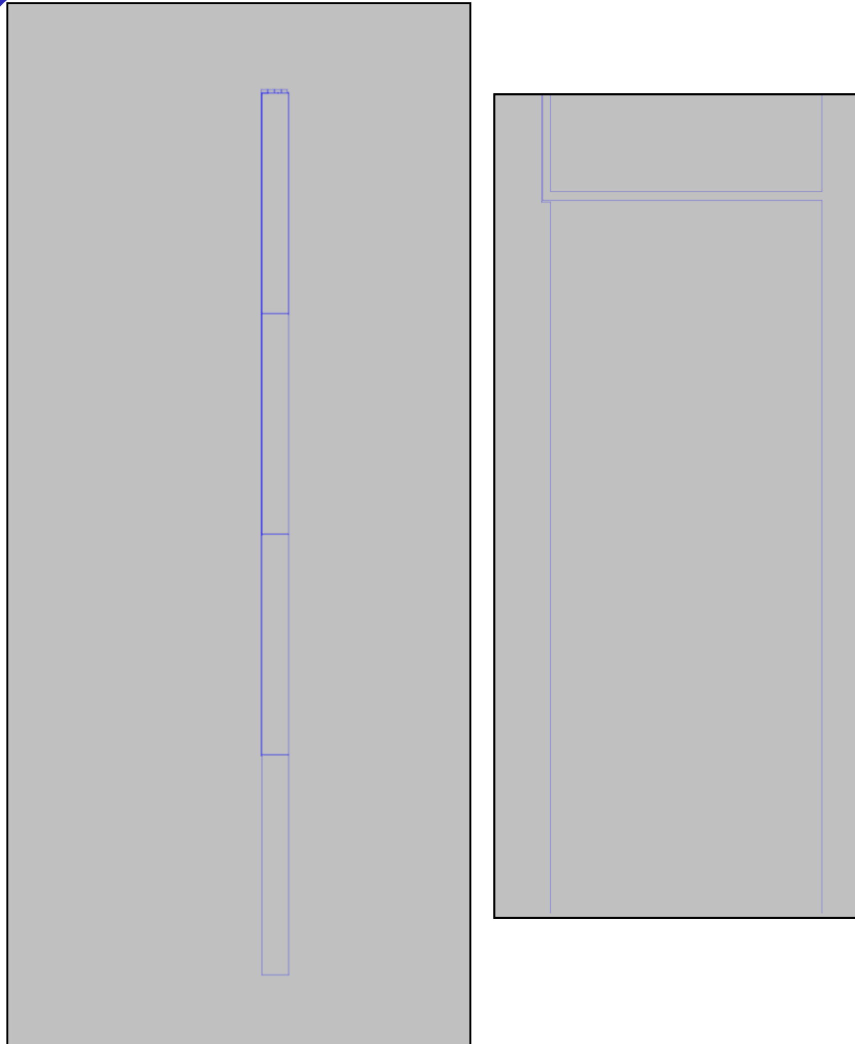


Minipad sensor



The “minipad” sensor has 128 miniature pads covering 6 (cm) x 6 (cm) of silicon surface, and operates under full depletion.

Minipad geometry



Areal coverage of a pad is 1.8(mm) x 15(mm).

4 pads for a column,

32 columns in total.

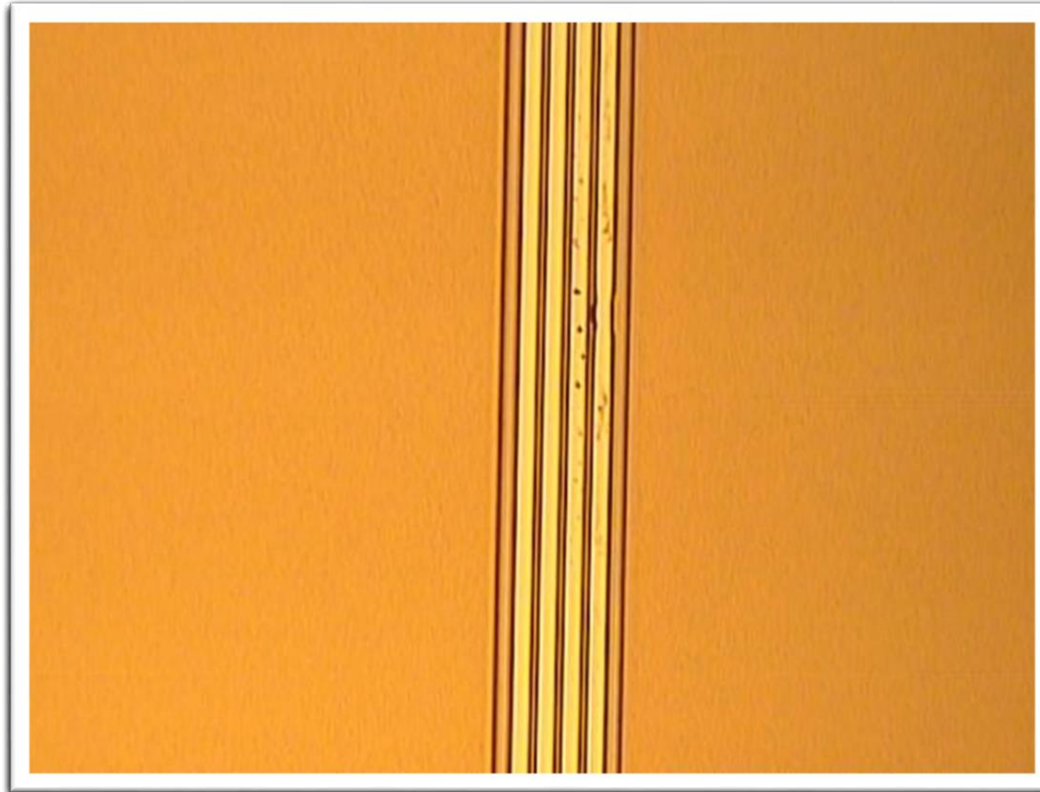
Particles passing a pad generate electric signals transported to bonding pad through metal trace.

Signals reaching bonding pad are digitized by SVX4.

Baseline Minipad sensor design

Development

Metal trace spacing



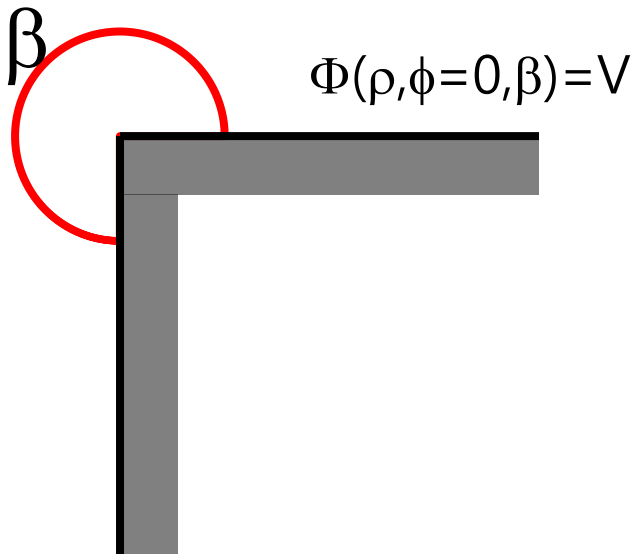
Shorts between metal traces frequently occurred.

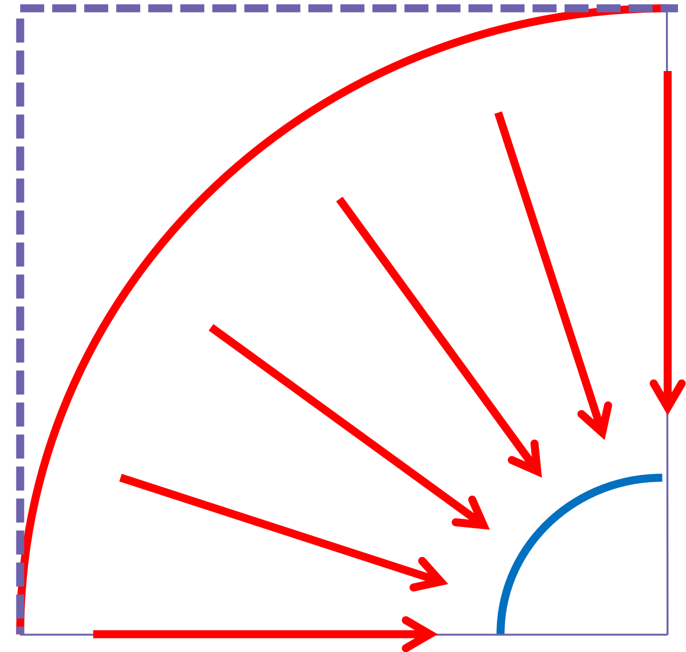
We increased distance between metal traces to overcome defects created in lithography.

$10\mu m \rightarrow 20\mu m$

Reduction of local electric field and current

1. Pattern edge rounding

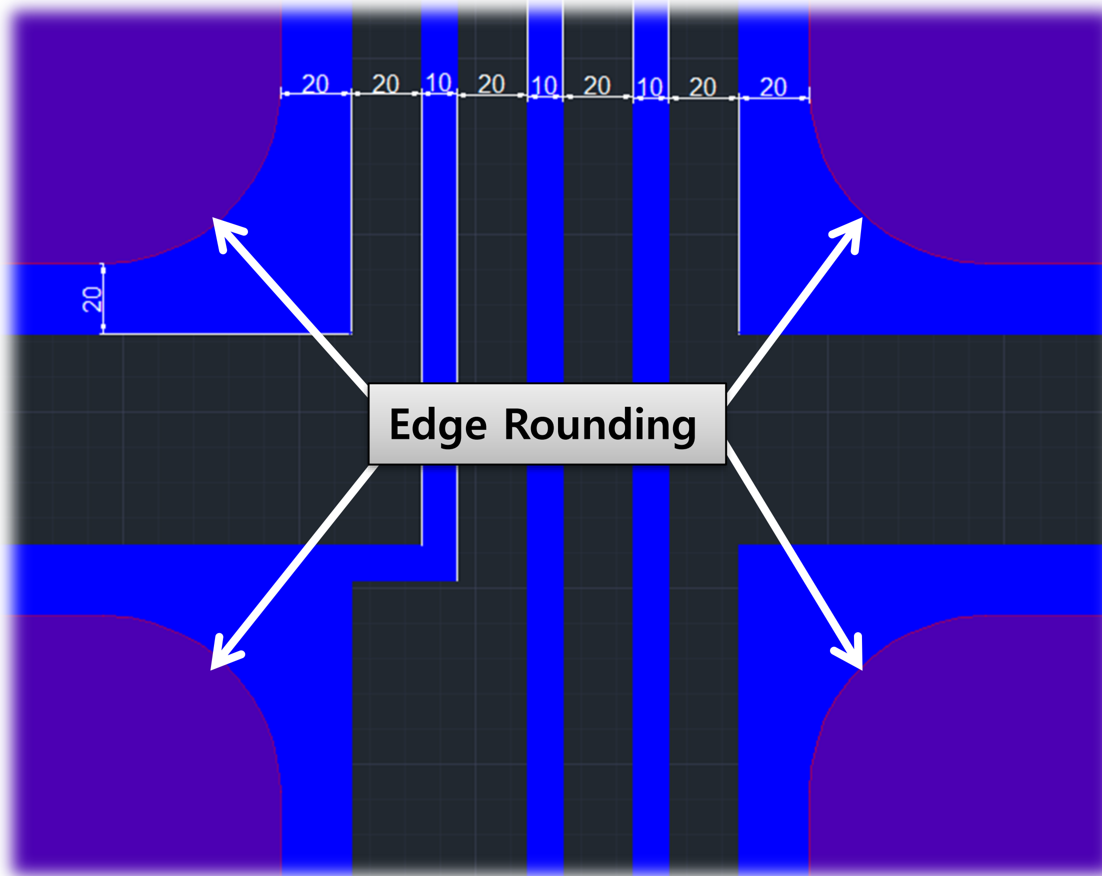




$$\Phi(\rho,\phi) = V + \sum_{\nu=1}^{\infty} \Phi_\nu \rho^\nu \sin\left(\frac{\nu\pi}{\beta}\phi\right)$$

Reduction of local electric field and current

1. Pattern edge rounding



Reduction of electric field

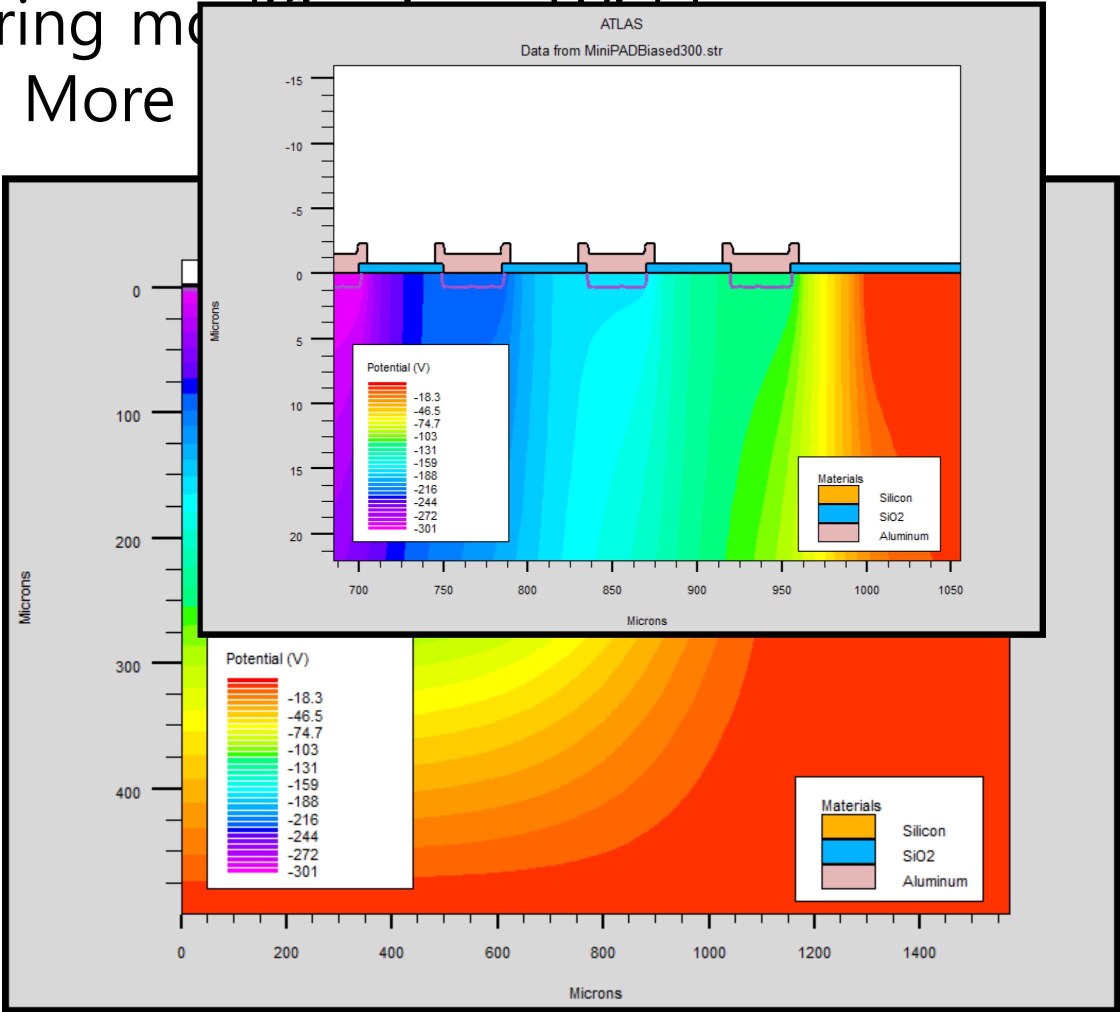
1. Metals covering beyond p+ pattern edges.

2. Rounding of p+ pattern edges.

Reduction of local electric field and current

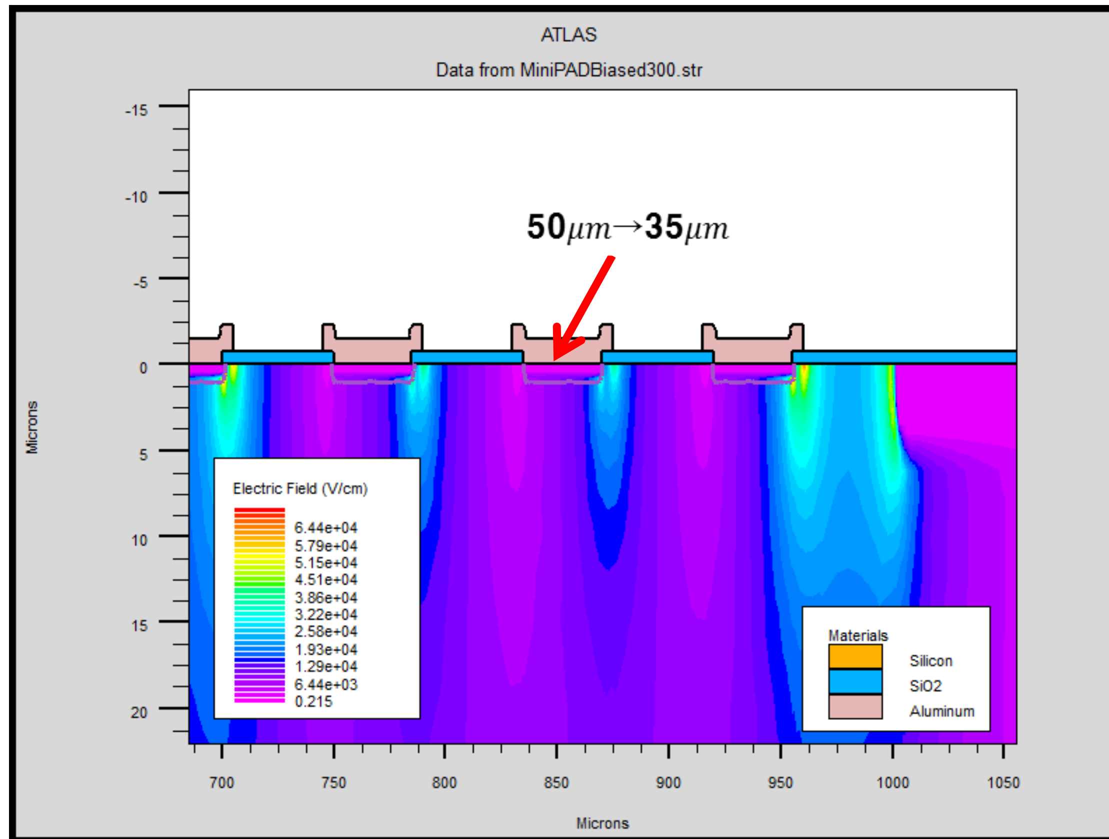
2. Guardring m

→ More



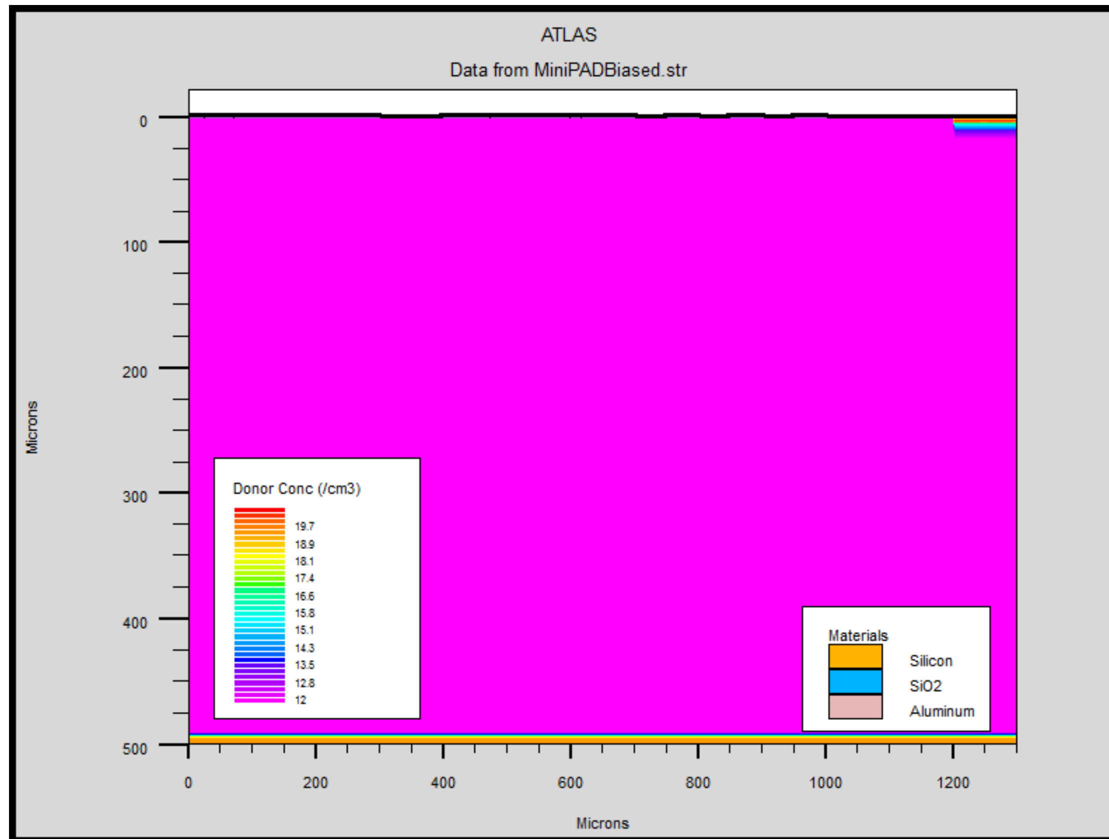
Reduction of local electric field and current

2. Guardring modification : Width



Reduction of local electric field and current

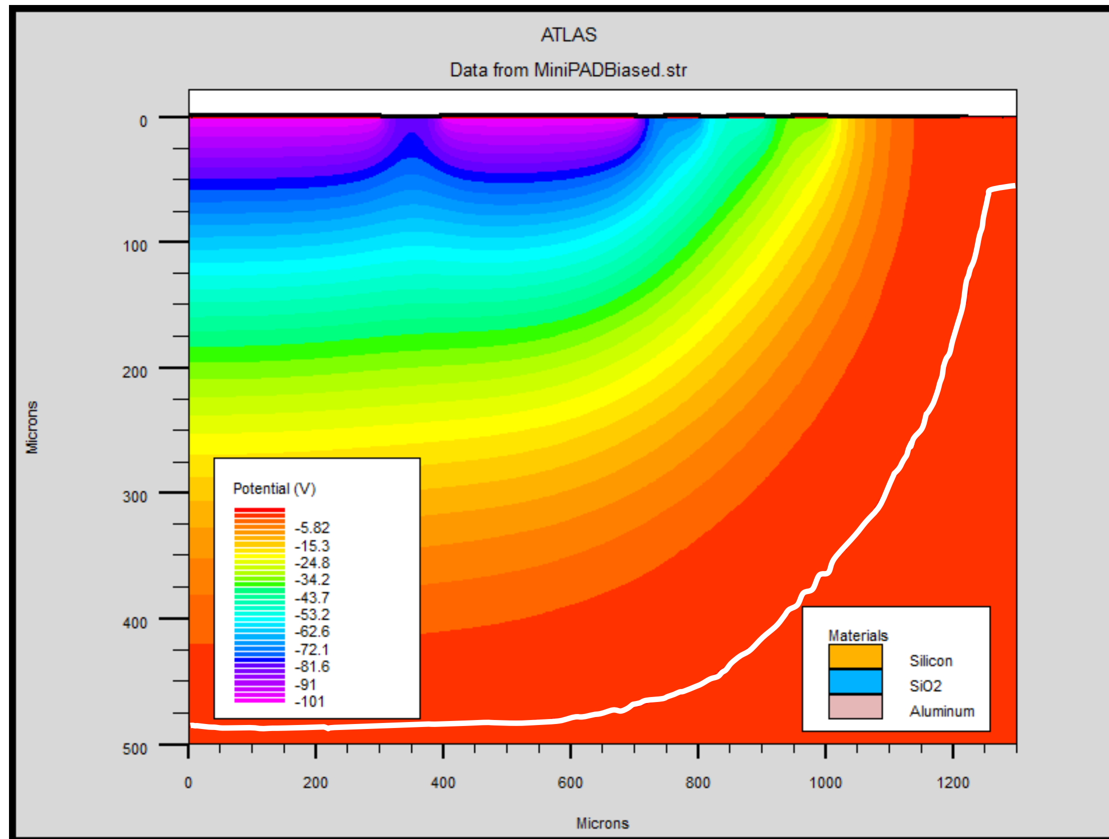
3. Channel stop : Termination of E-field



<Doping profile>

Reduction of local electric field and current

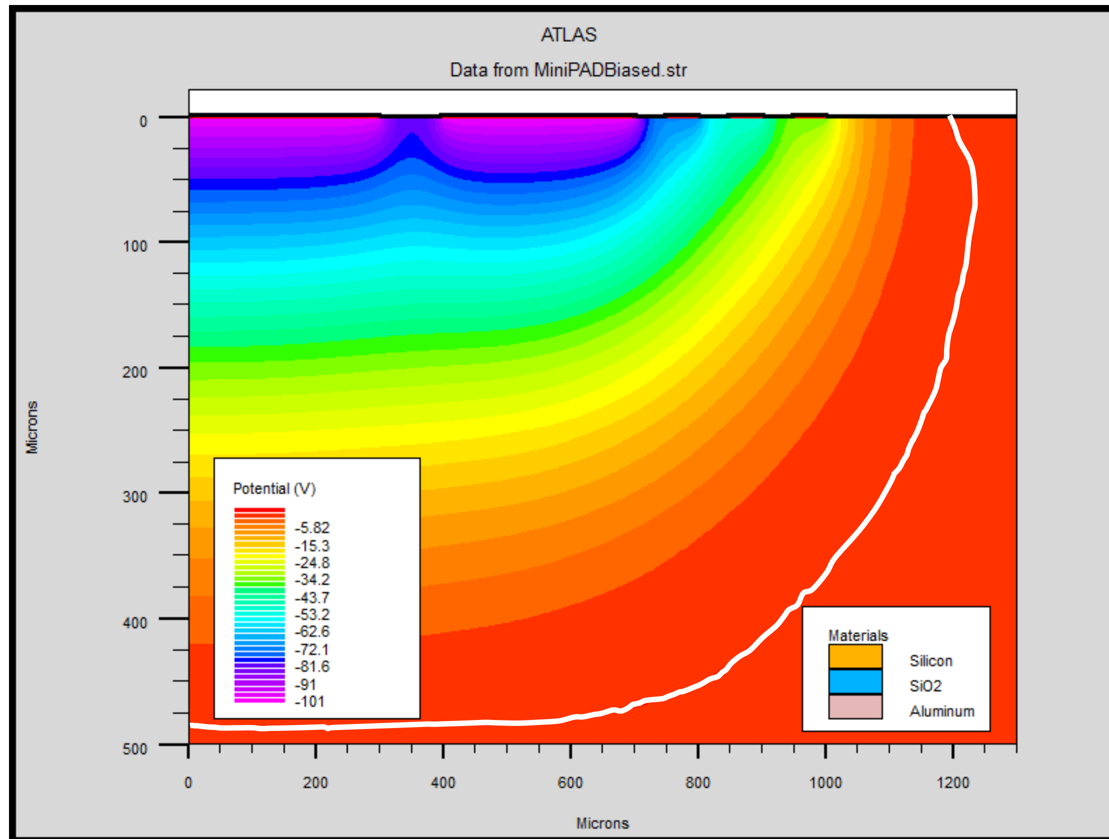
3. Channel stop



<P+ dicing line>

Reduction of local electric field and current

3. Channel stop

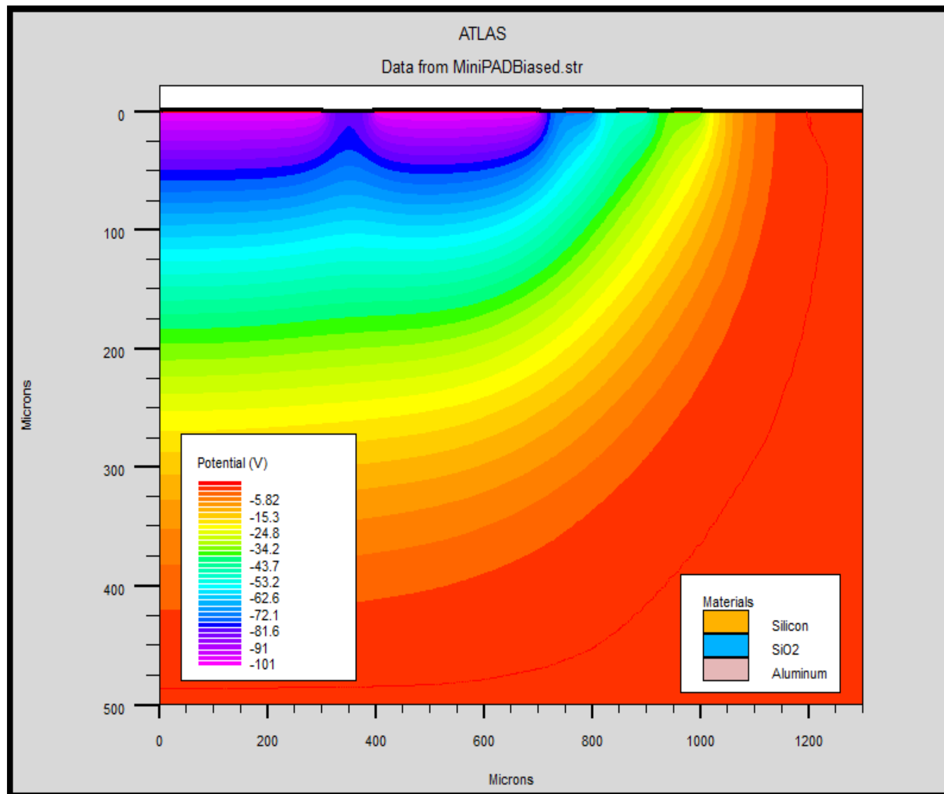


<N+ channel stop>

Research

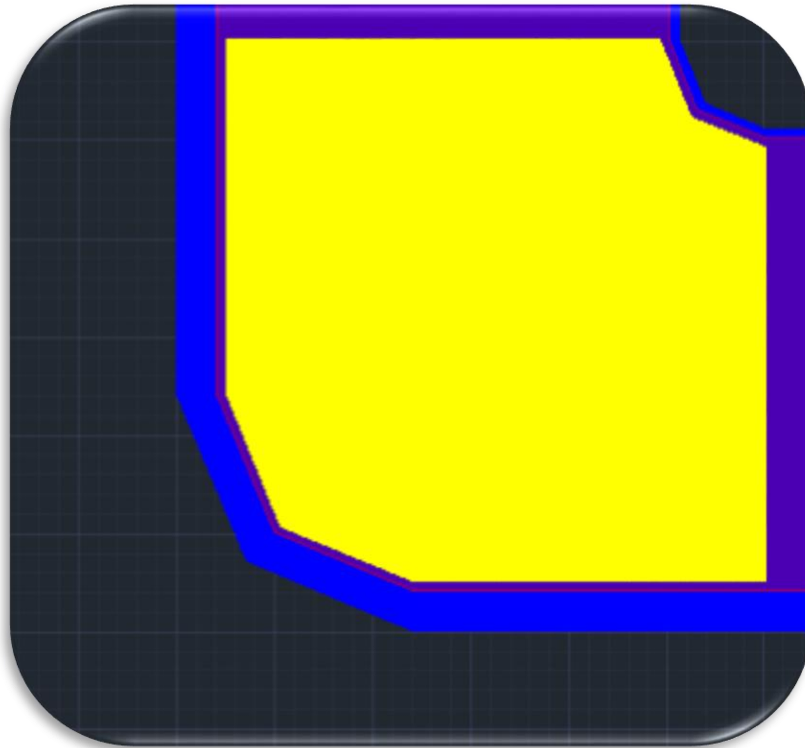
Guardring, leakage current

1. Stop surface current from the edge.
2. Gradual field degradation.

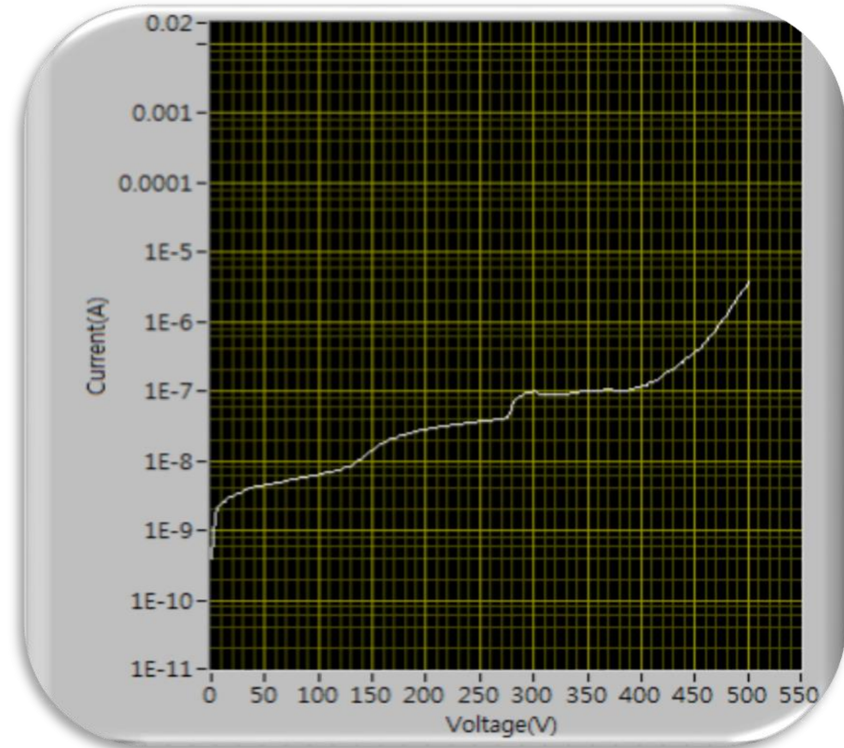


<Guardring arrangement>

Guardring (main guardring only)



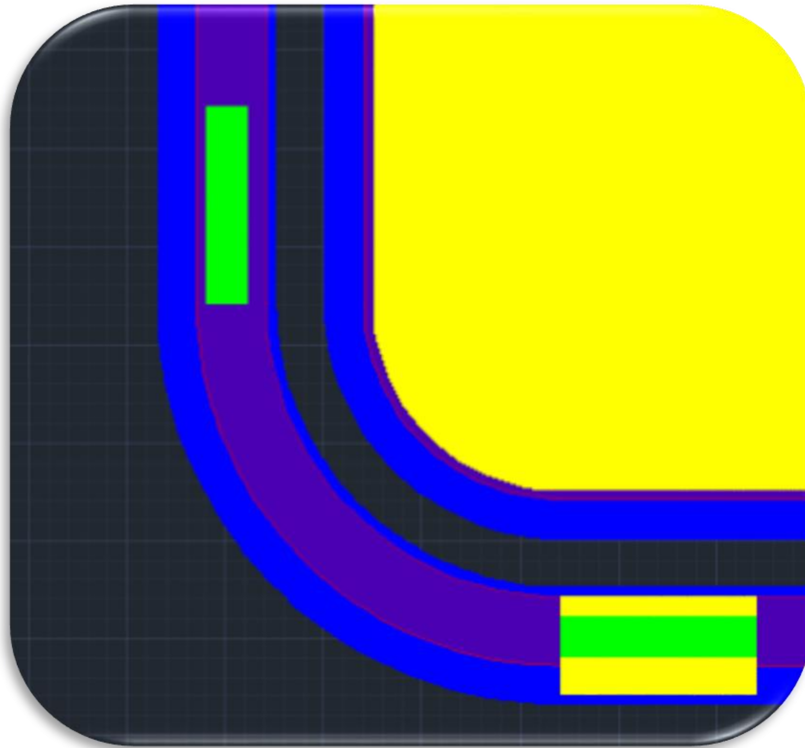
J04 Test Pattern (One guardring)



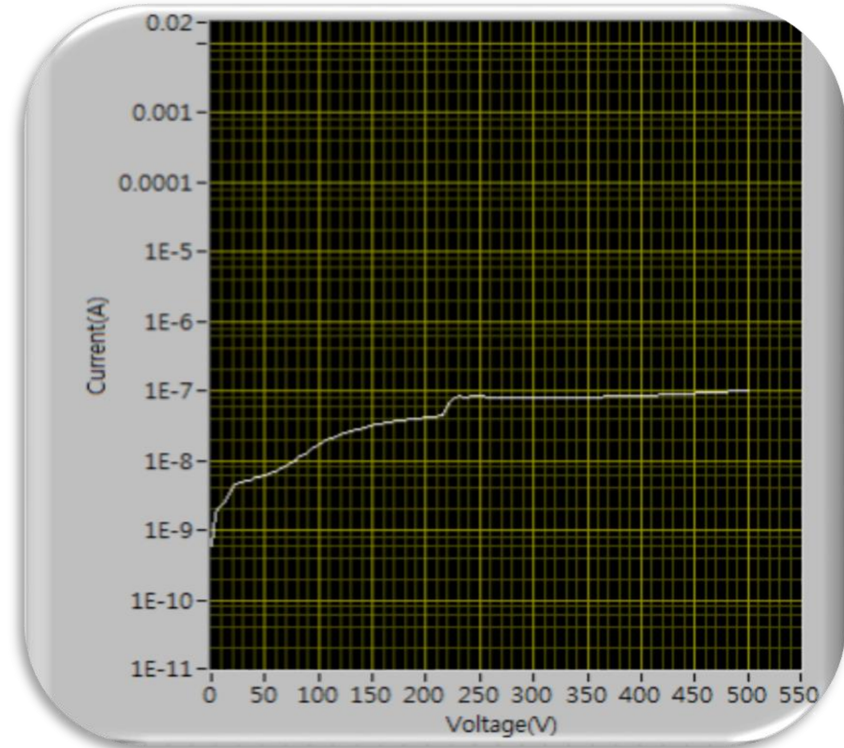
Guardring leakage current

- P+
- Metal

Guardring (main + 1 tertiary guardring)



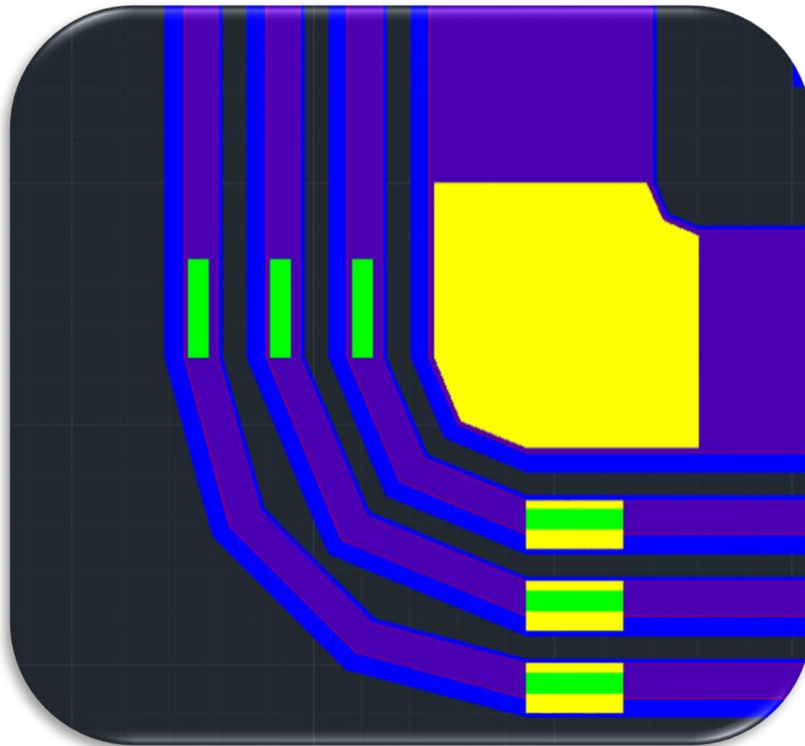
J04 Test Pattern (Two guardring)



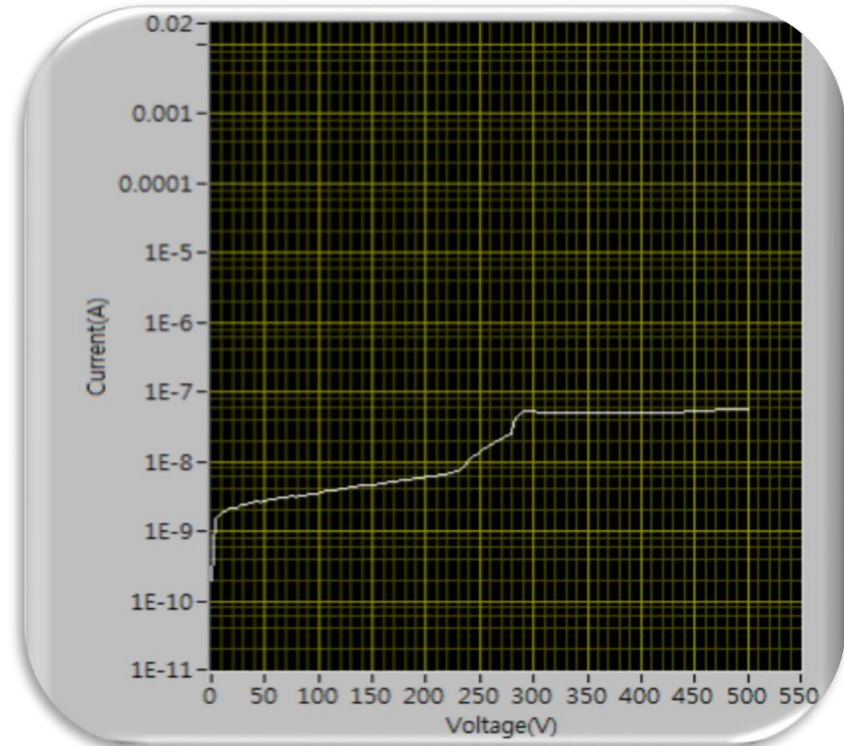
Guardring leakage current

- P+
- Metal

Guardring (main + 3 tertiary guardring)



J04 Test Pattern (Four guardring)

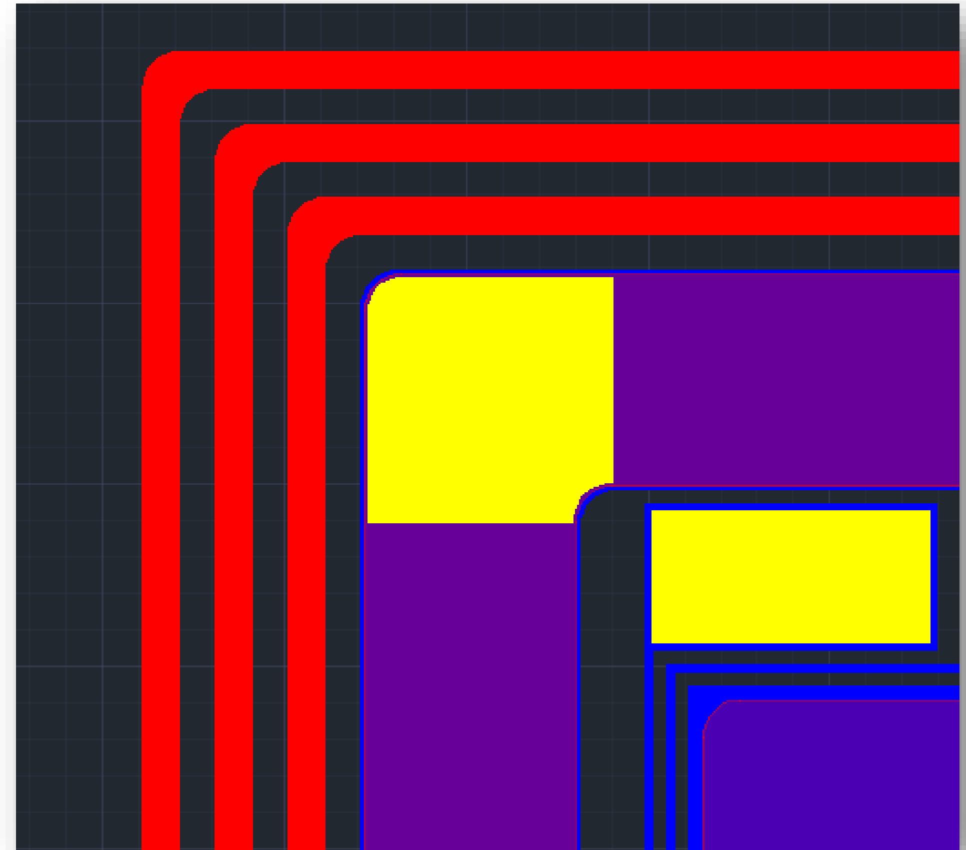


Guardring leakage current

- P+
- Metal

Thickness of Overhang

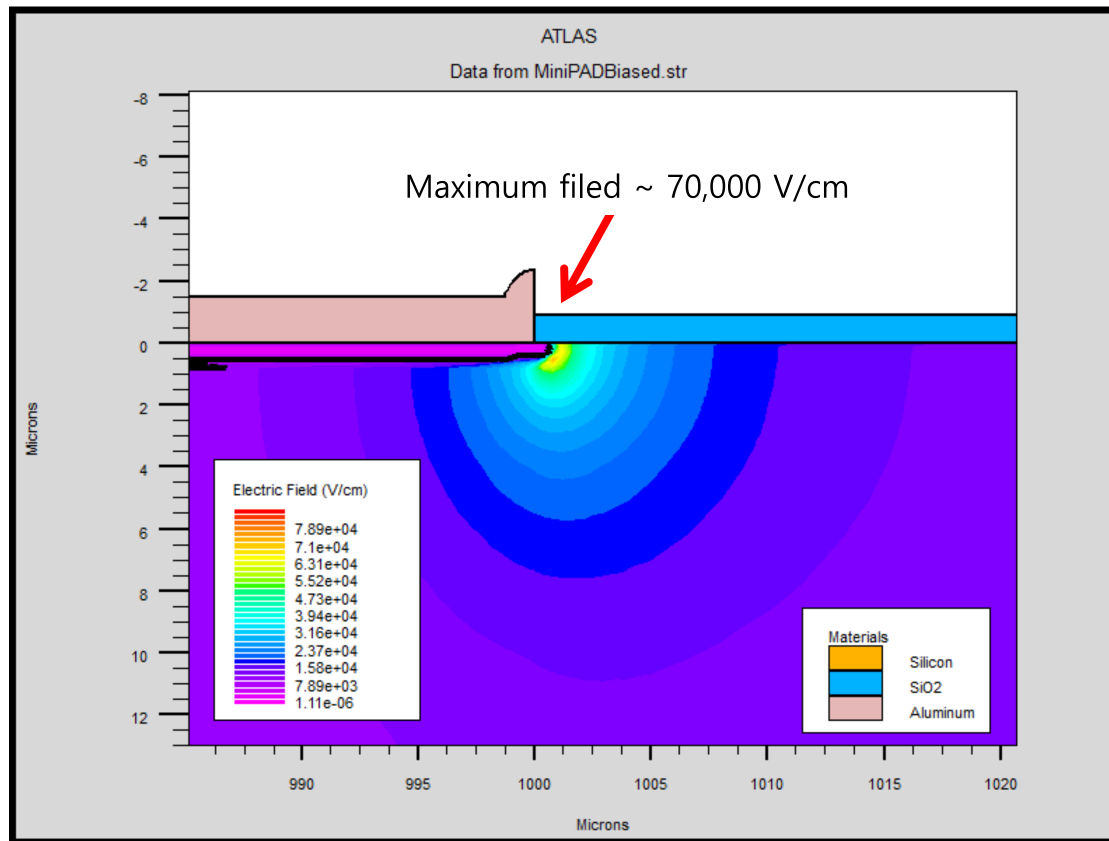
We added metal over tertiary guardrings. Metal over tertiary guardring reduces maximum local field.



<Guardring Structure>

Thickness of Overhang

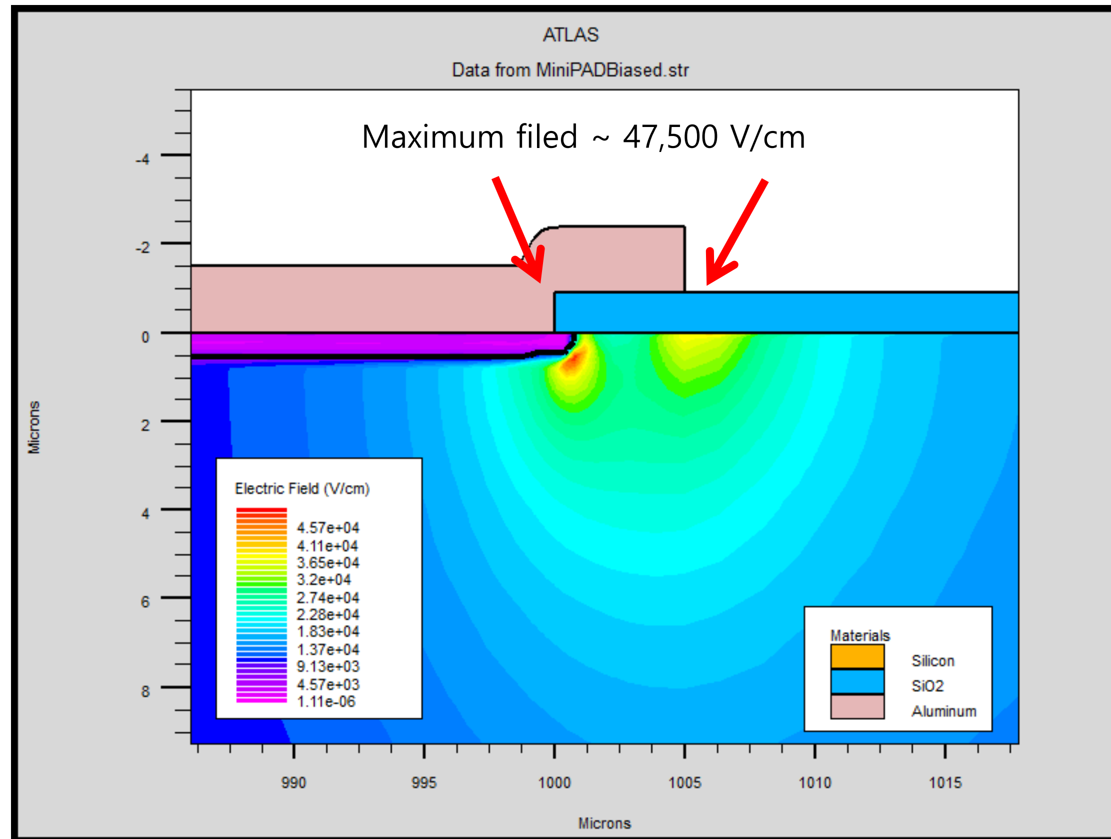
Metal over tertiary guardring



<Without extension>

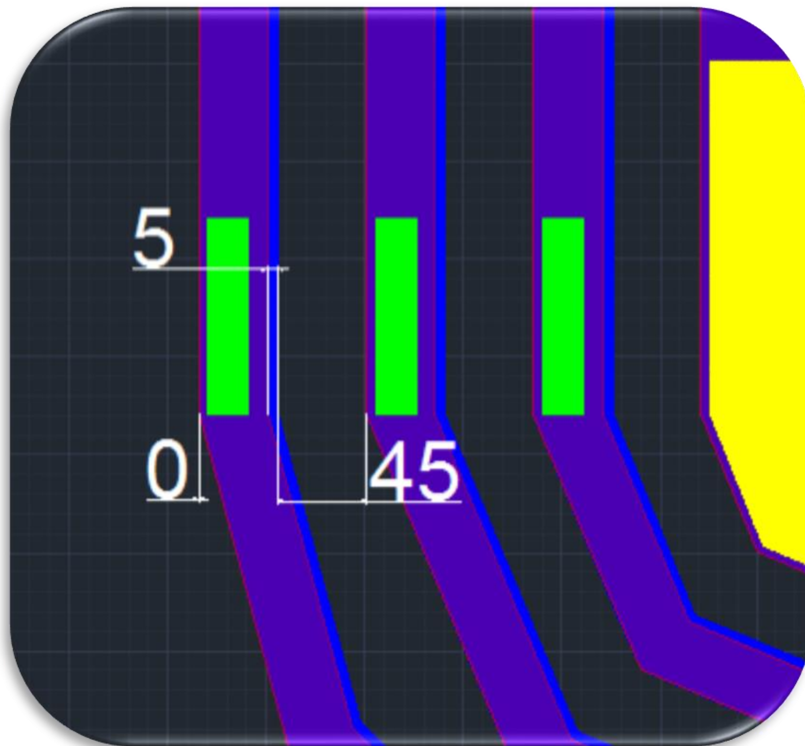
Thickness of Overhang

Metal over tertiary guardring

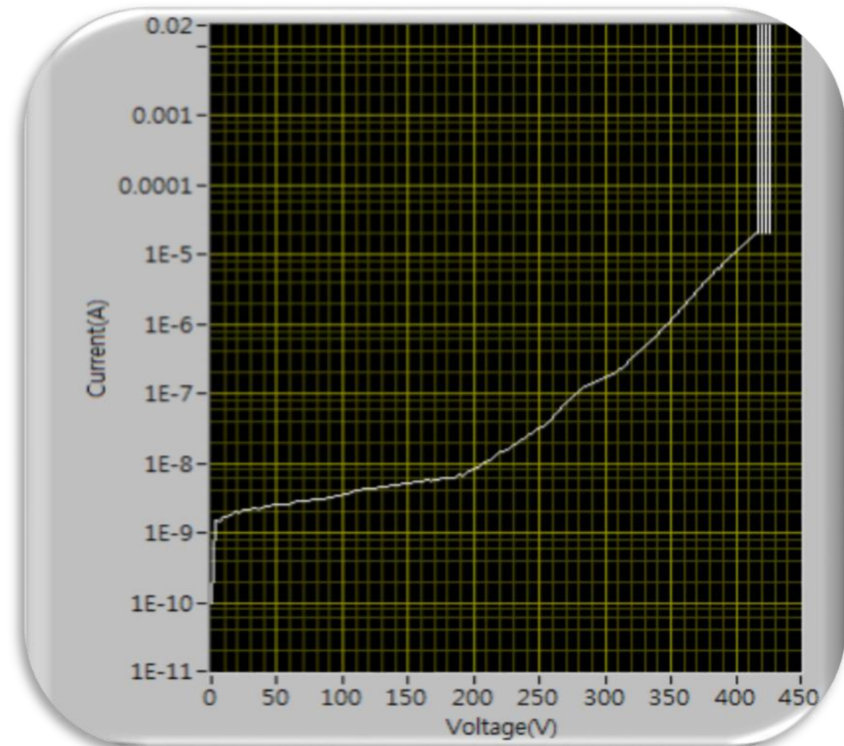


<Metal extended over P+ pattern>

Thickness of Overhang



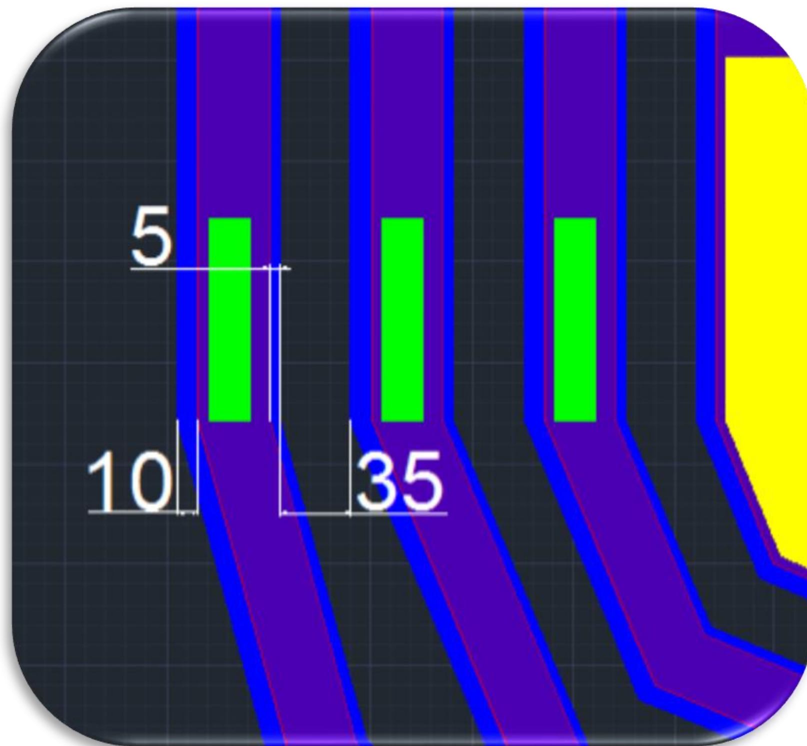
J04 Test Pattern ($0\mu m$ Overhang)



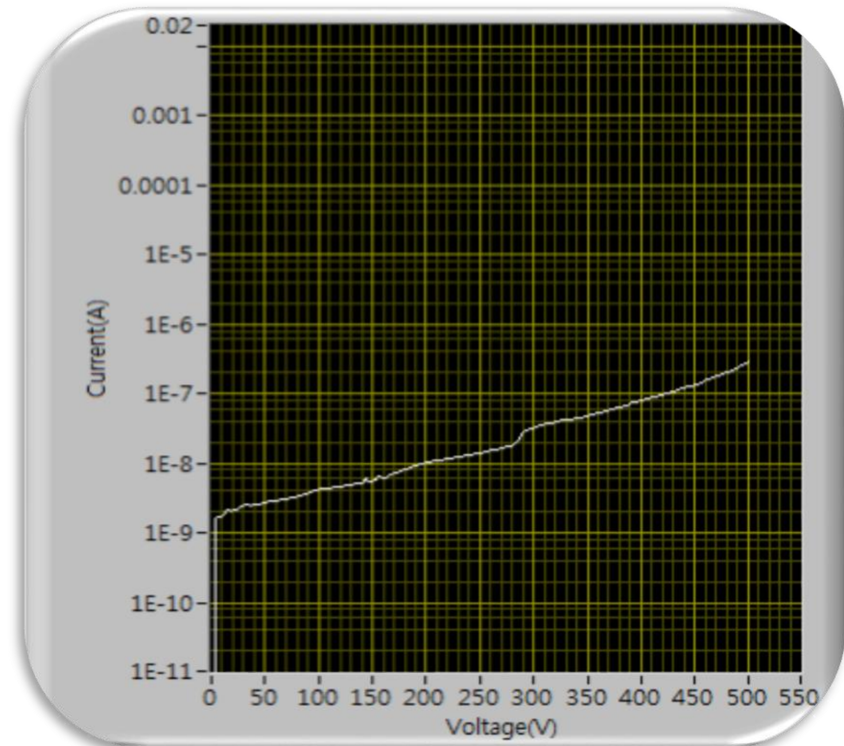
Guardring leakage current

- P+
- Metal

Thickness of Overhang



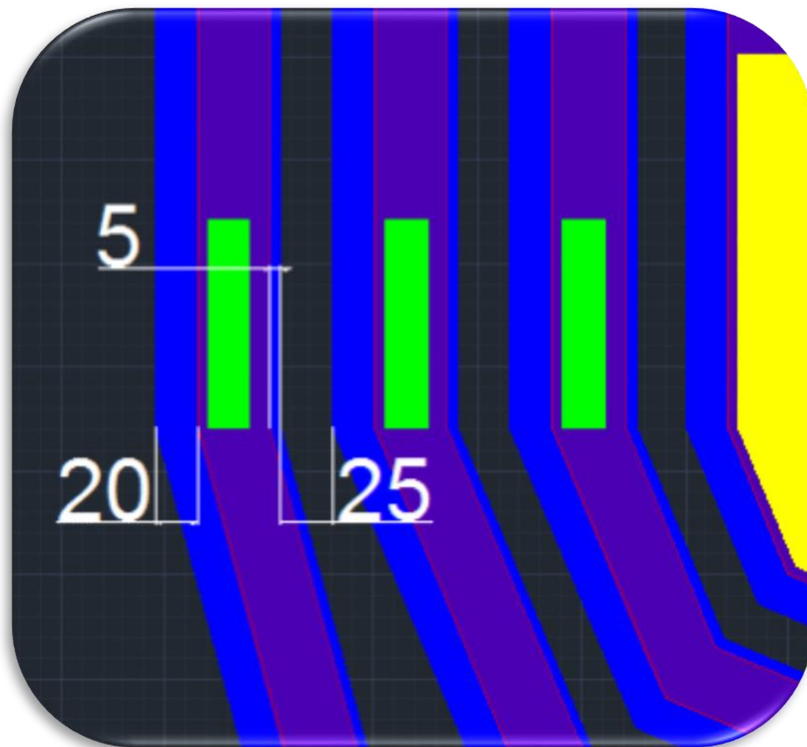
J04 Test Pattern ($10\mu m$ Overhang)



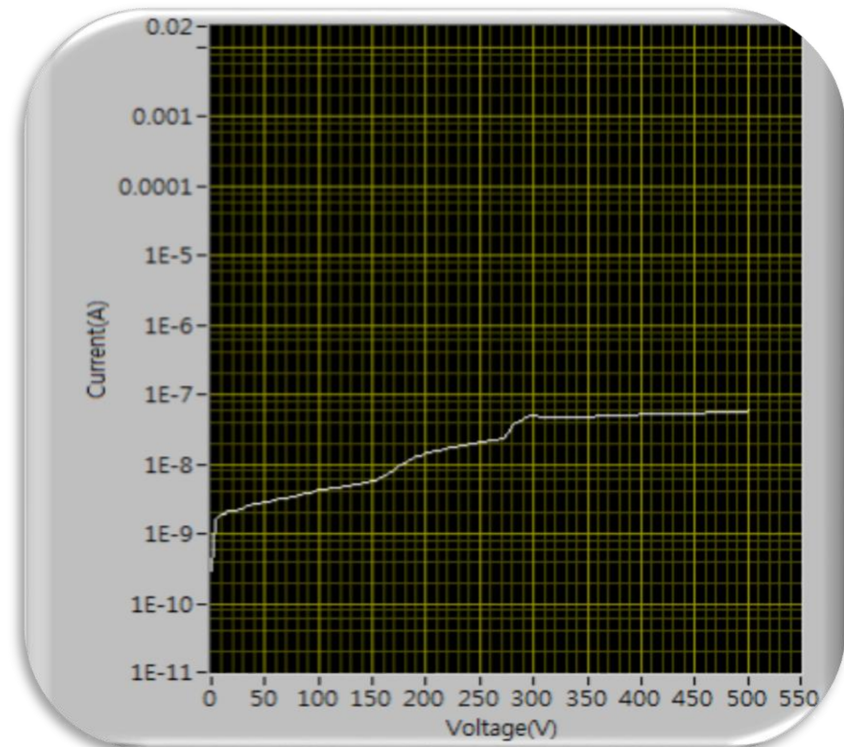
Guardring leakage current

- P+
- Metal

Thickness of Overhang



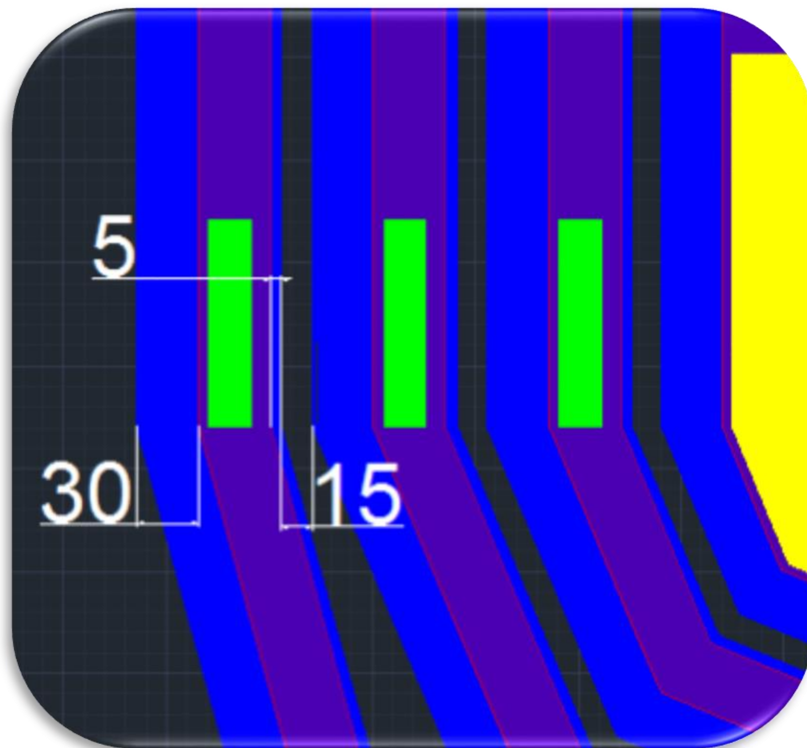
J04 Test Pattern ($20\mu m$ Overhang)



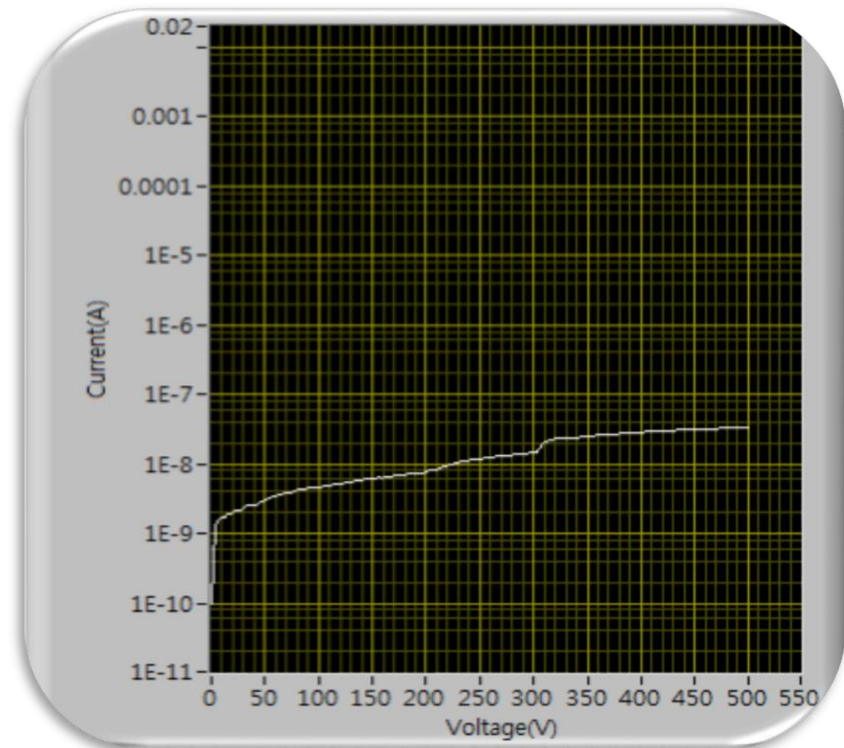
Guardring leakage current

- P+
- Metal

Thickness of Overhang



J04 Test Pattern ($30\mu m$ Overhang)



Guardring leakage current

- P+
- Metal

Summary & Prospect

Summary & Prospect

We

1) adjusted spacing between metal traces to avoid defects in metal etching process

2) improved guardring design to regulate electric field strength and reduce local current density

3) and studied channel stop to remove uncertainty in oxide trap charge and suppress defects created by dicing.

Development evolved into main production. Main production started by the end of September.

Acknowledgement

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Current presentation is based on the collaborative work with BNL and Iowa state university, Ames.