Slim Edges from Cleaving and ALD Sidewall Passivation

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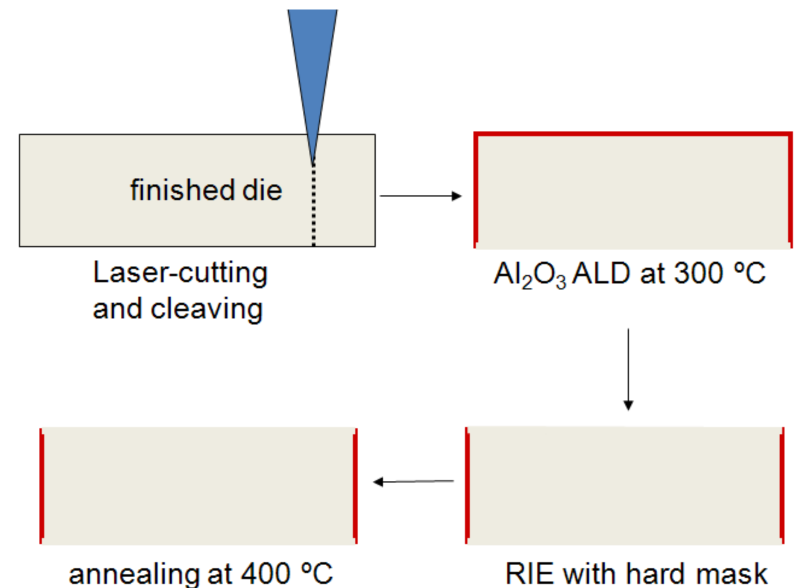
Slim Edges Development at UCSC - NRL

- **The objectives are**:
  - To develop a method for slim edges with p- and n-bulk sensors.
  - To alleviate the HV-on-top feature with n-on-p sensors.
- **The method is**:
  - To laser-scribe and cleave the sensors.
  - To deposit a passivation layer on the sidewall with Atomic Layer Deposition ALD
  - For p-bulk Al_2O_3 has the proper (negative) interface charge
  - For n-bulk SiO2 has the proper (positive) interface charge

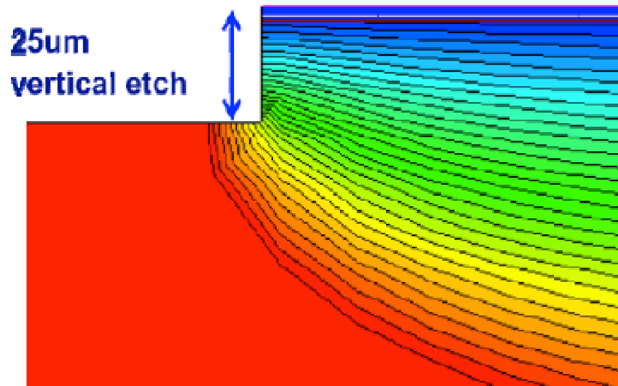
Complete background talk by Marc Christophersen at the 2011 Trento meeting

- So far worked with diodes from ATLAS07 batch from HPK and strip sensors made by HPK (GLAST) and HLL.
- Processed the total of 5 diodes and ~25 strip sensors.
- Next is to investigate radiation effects.

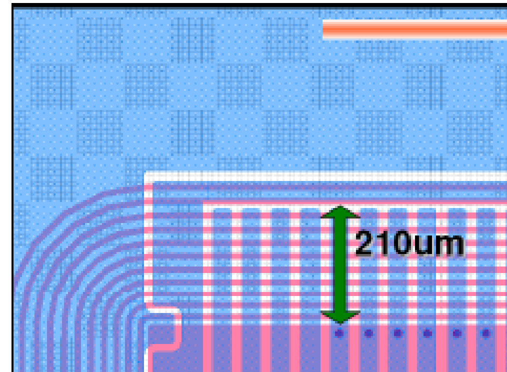
Post-fab Treatment Sequence



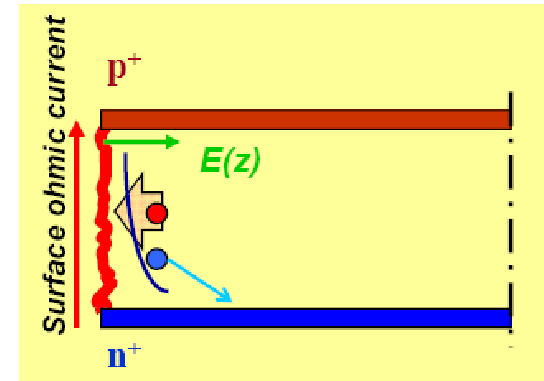
Last Frontier in Si Detectors: Slim Edges?



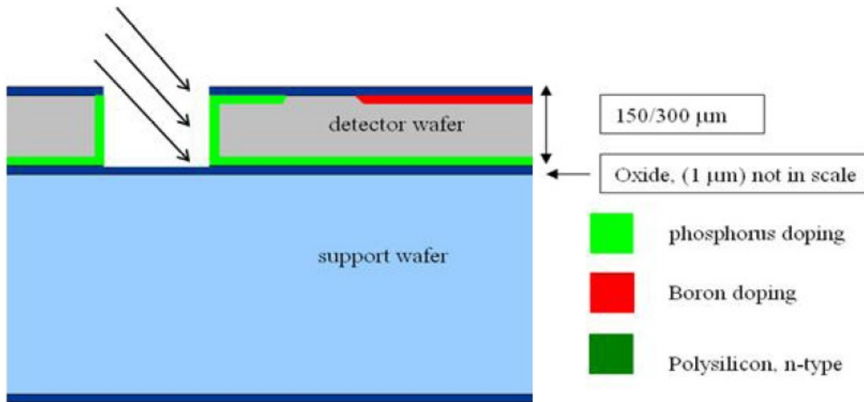
J. D. Segal, et al., NSS 2010



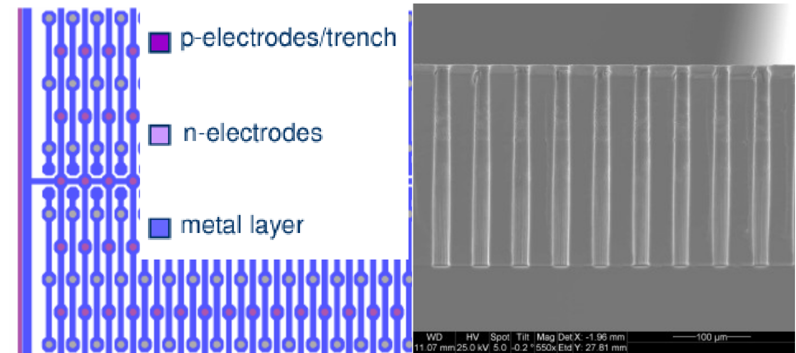
A. Rummler et al., 2010



E. Verbitskaya et al., 13 RD 50 workshop, 2008



J. Kalliopuska, NSS 2010



T.-E. Hansen et al., 2009

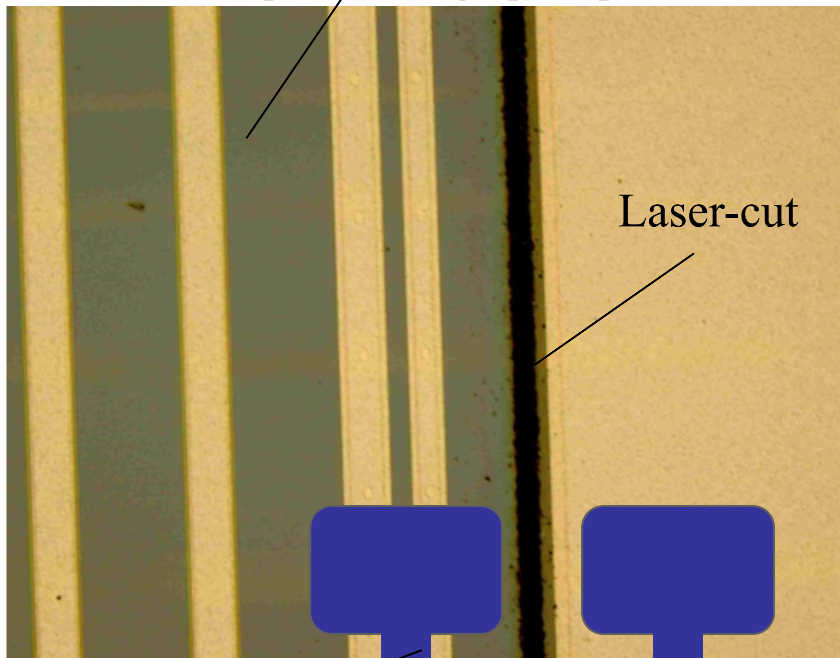
Goal of our research:

- **slim edges through post-processing of fabricated devices on die level: cheap, simple and reliable**
- **slim edges on p- and n-type devices**

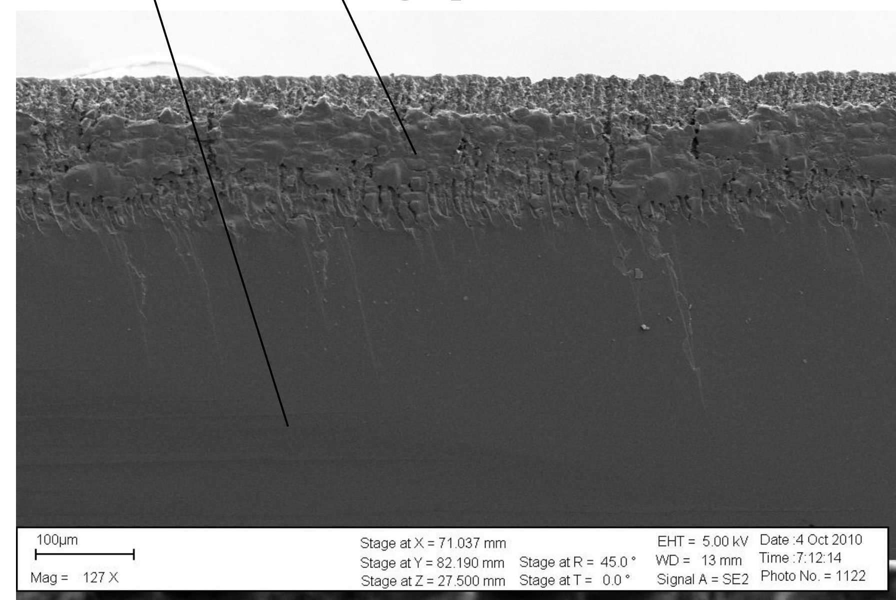
Laser-Scribing and Cleaving

- used finished dies (post-processing)
- laser scribing from top side→ laser-damage
- cleaving → no damage

Optical micrograph, top-view

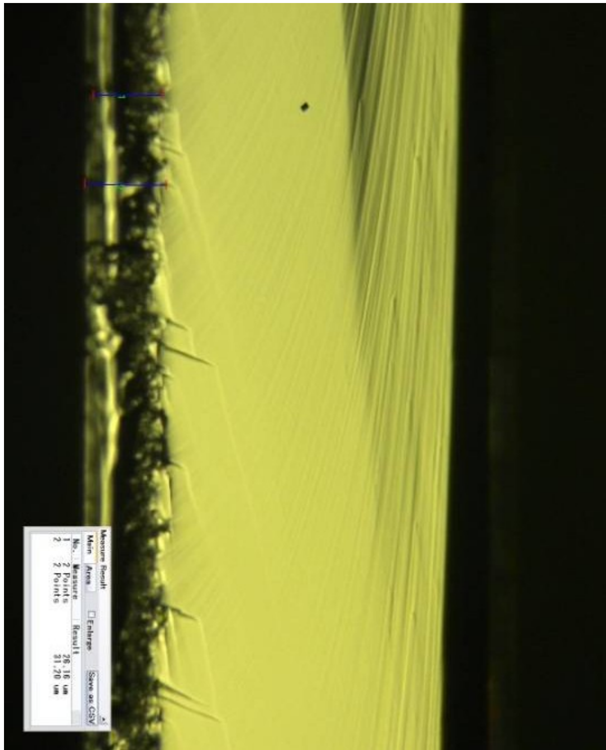


SEM micrograph, cross-section

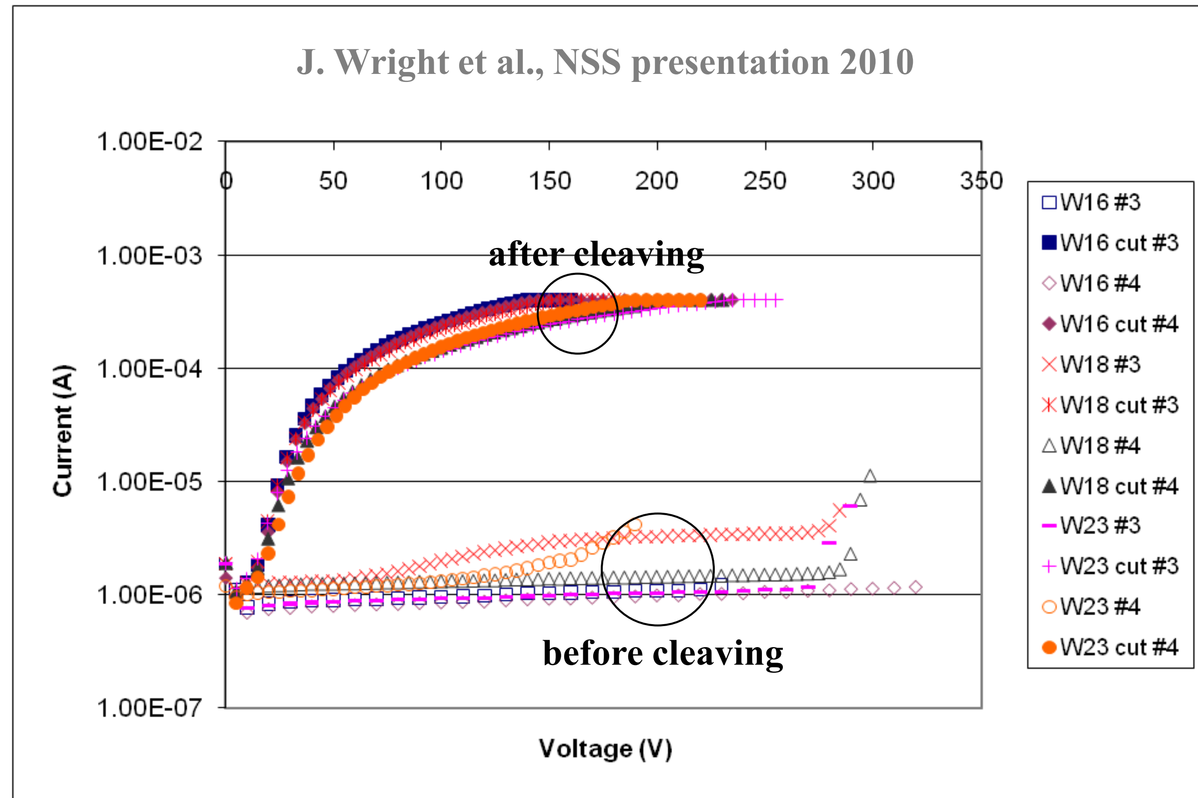


Laser-scribing done at U.S. Naval Research Laboratory using an Oxford Laser Instruments E-Series tool. Breaking done by hand using tweezers, but can be done fully automatic, need to develop procedures.

P-Type Sensor – NSS 2010 Presentation



Optical micrograph, cross-section



- Some of the sensors showed a relatively early breakdown voltages of 200/300 V before the procedure.
- Processed sensors show a uniform early breakdown at ~20 V.
- We also tested Micron and HPK p-type sensors.

ALD Alumina Passivation for P-Type Silicon

alumina layer passivation
(distance to guard 29 μm)

Reference
(un-cut device with guard ring)

Current [A]

1e-10

0 20 40 60 80 100 120 140 160

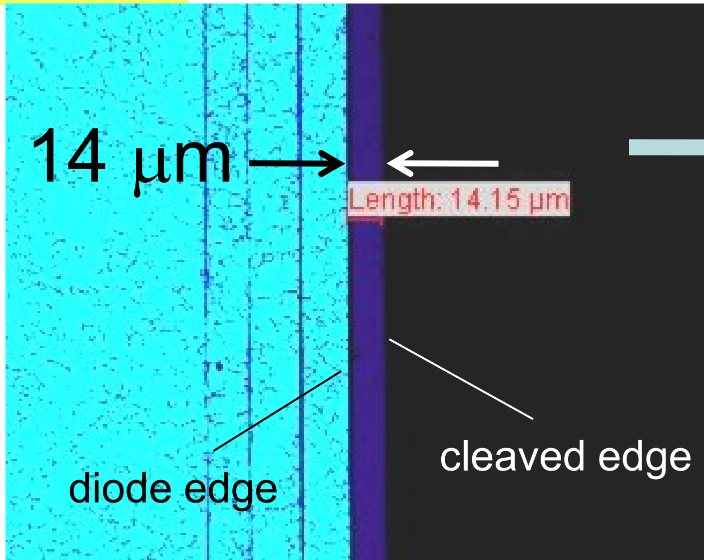
Bias [V]

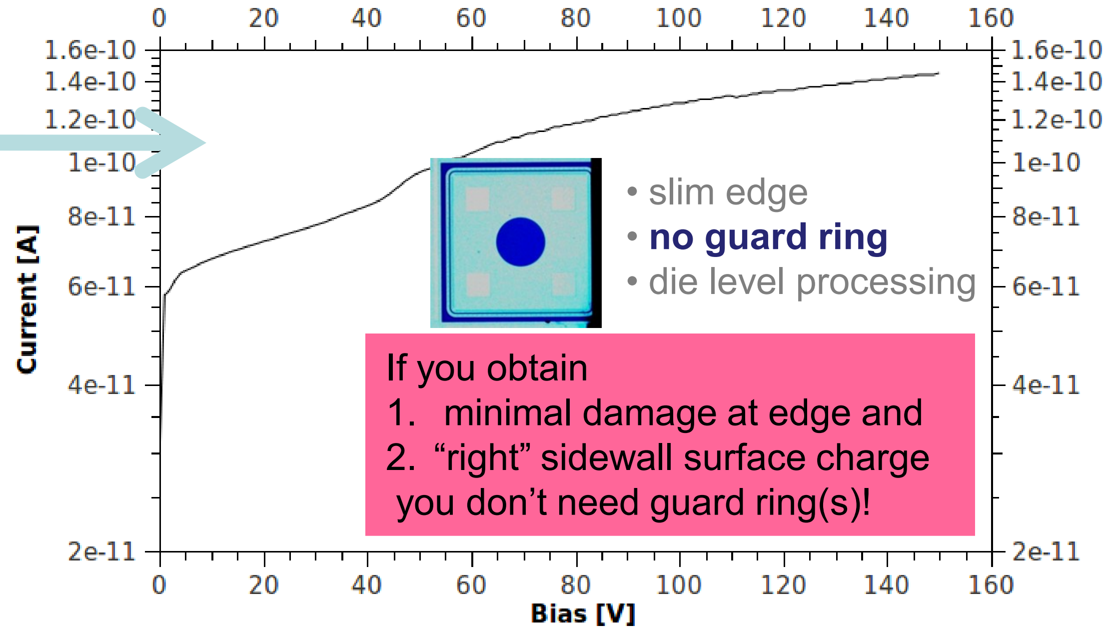
Leakage for sample with Al_2O_3 passivation comparable to un-cut device with full guard ring structure.

Device I (HPK)

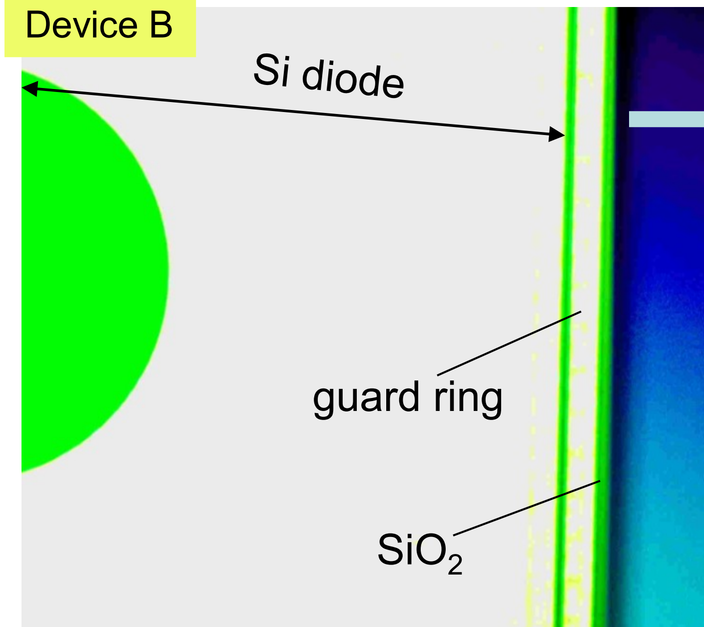
Examples of Processed Devices

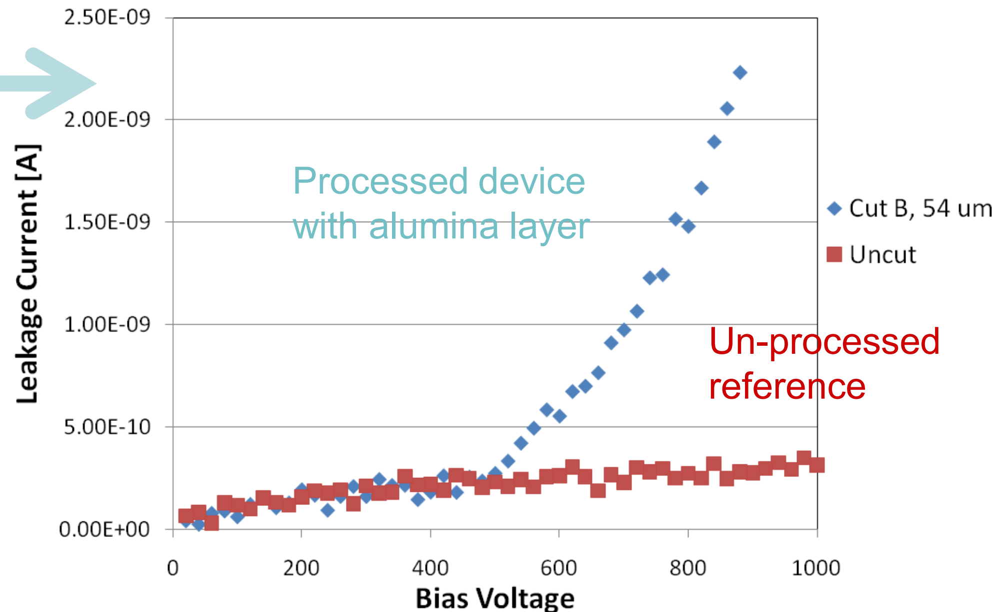
Device A





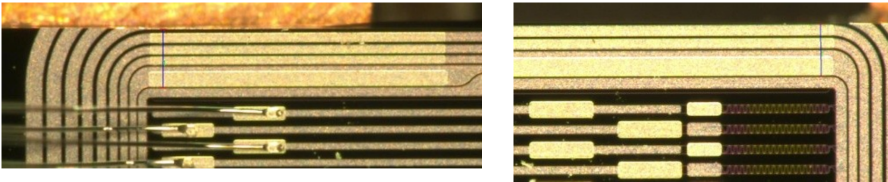
Device B

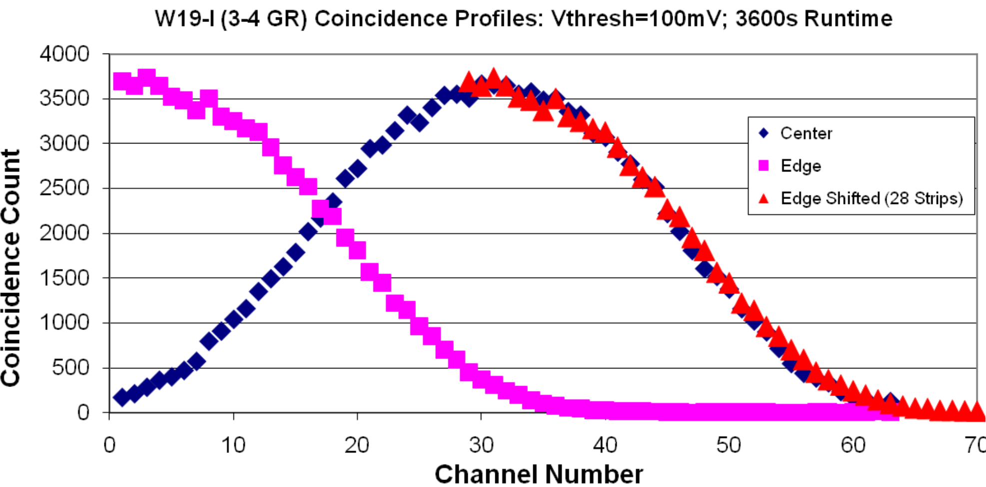




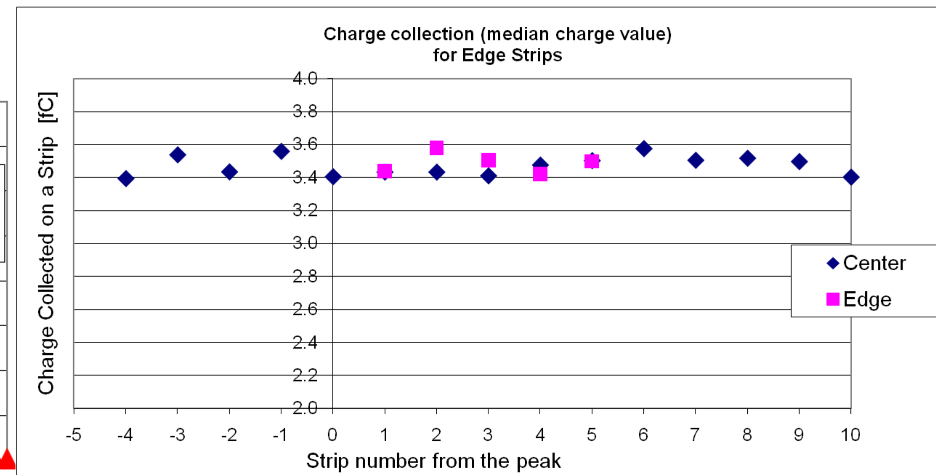
Need Low current AND Charge Collection

- Processed HLL strip sensors courtesy A. Macciolo. They are easy to cleave due to margins available.
- V(depl) = 65 V. V(break) = 400 V. Edge distance from bias ring = 200-270 um.
- Moved around electron beam from Sr-90 source to find a possible variation of charge collection efficiency and the total charge on the edge strips.





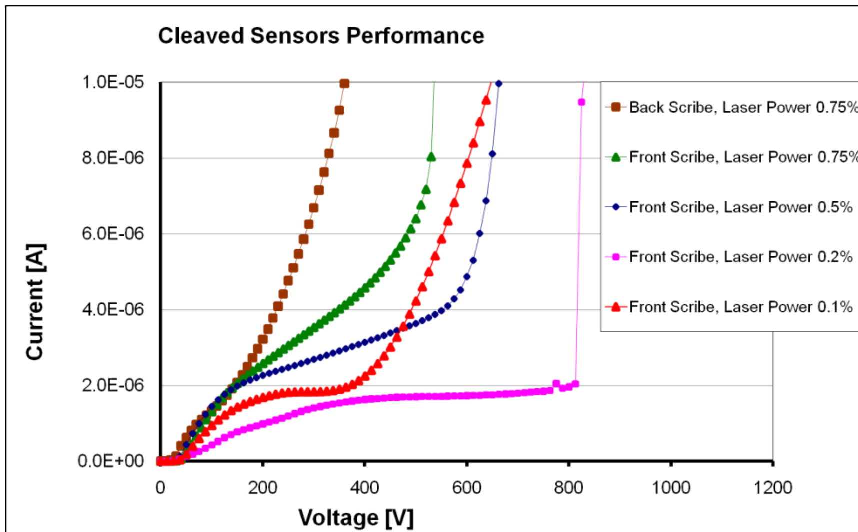
Beam Profiles

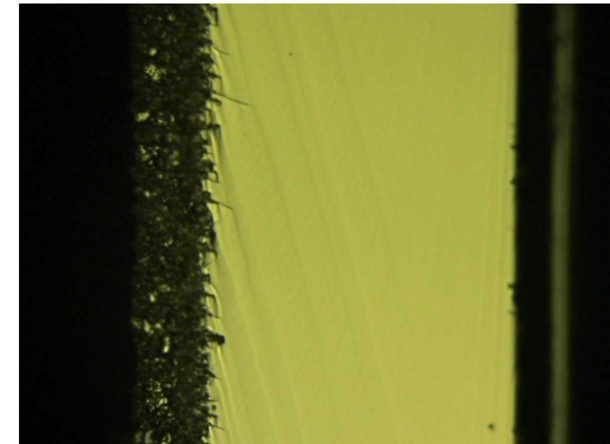


Collected Median Charge on Strips

N-bulk sensors

- Processing of n-bulk sensors is easier, since formation of SiO_2 passivates the sidewall. Prototyped with p-on-n HPK sensors from GLAST/Fermi production.



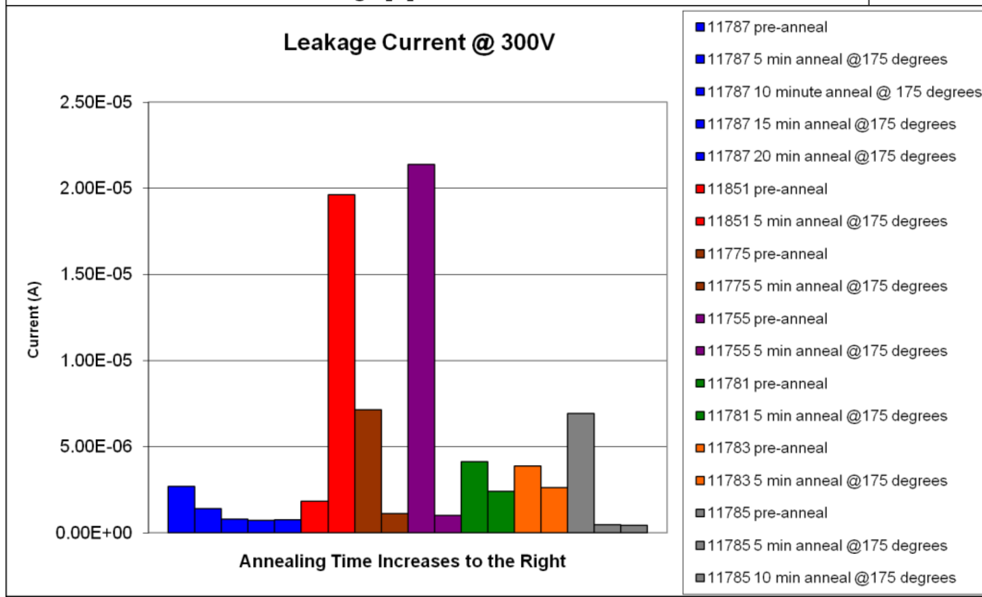


Edge illumination

scribe at 100 um from the guard ring.

front-side scribe seems to be preferential to back-side one.

lower laser power is preferential.

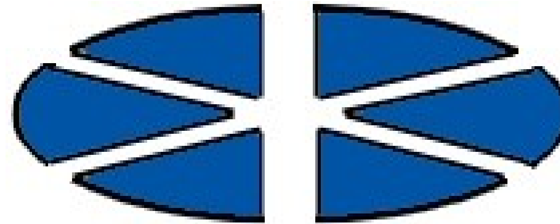


These sensors were breaking down at relatively high voltages, 100s of volts. Performance improves with high-temperature exposure which facilitates formation of SiO_2 on the sidewall surface.

Production Requirements

- Have to have <100> lattice orientation. Then the cleaving can be done along orthogonal axes in the wafer plane, and the sidewalls are vertical.
- Have to have a good alignment between the lattice and the masks.
- At the current stage, the cleaving is done by hand. It would be helpful to have sufficient margins around the sensor envelopes to facilitate that. W >> thickness, e.g. 2 mm for 300 um thick sensors.

Cleaving of <100> wafer



Cleaving of <111> wafer

Propose RD50 Common Project:

1) Use existing finished wafers (preferred un-diced) of any manufacturer
2) Post-processing (cleaving and ALD) both on pixel and strip sensors.
3) An example in the pixel area is the creation of active edges on the double-sided 3D sensors eliminating the costly support wafer technology.
4) For large-scale strip sensors investigate the extend to which corners present difficulties and whether they need special attention.
5) i-V and charge collection measurement pre- and post-rad
6) For post-processed samples “close the loop”:

   a. Provide SEM images of the cleaving and ALD deposits
   b. Determine the charge density profile on the edges after ALD deposition
   c. Provide SILVACO simulations of the field profile at the sensor edge
   d. Compare charge collection info with the field profile

7) For full-size strip sensors (> 5 cm): Second year

   a. Procure sensors of both n-and p-type and develop reliable cleaving technique and distances.
   b. After ALD treatment and testing, assemble into “staves” and establish the minimum distance between sensors and their active areas.