Study of Low-dose Radiation Resistance of Sidewall Passivation on p-type SCP Devices

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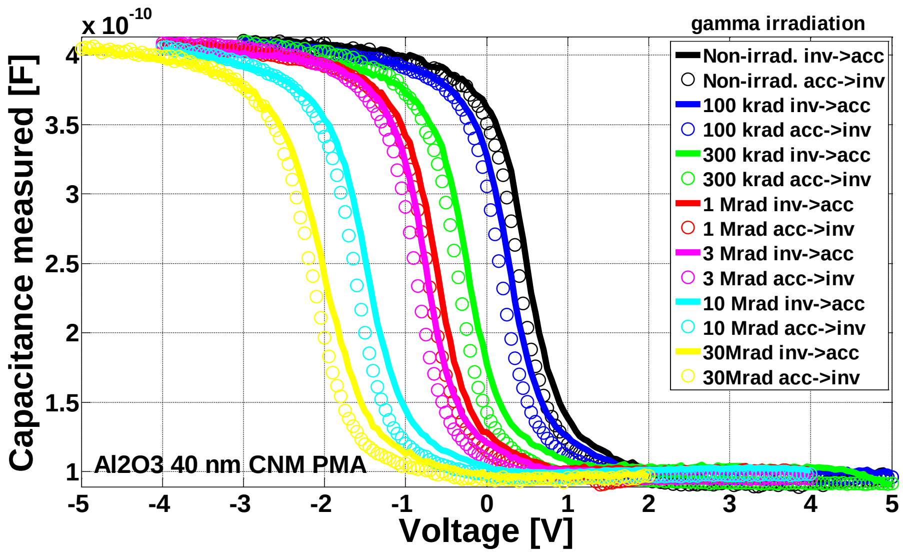
Introduction

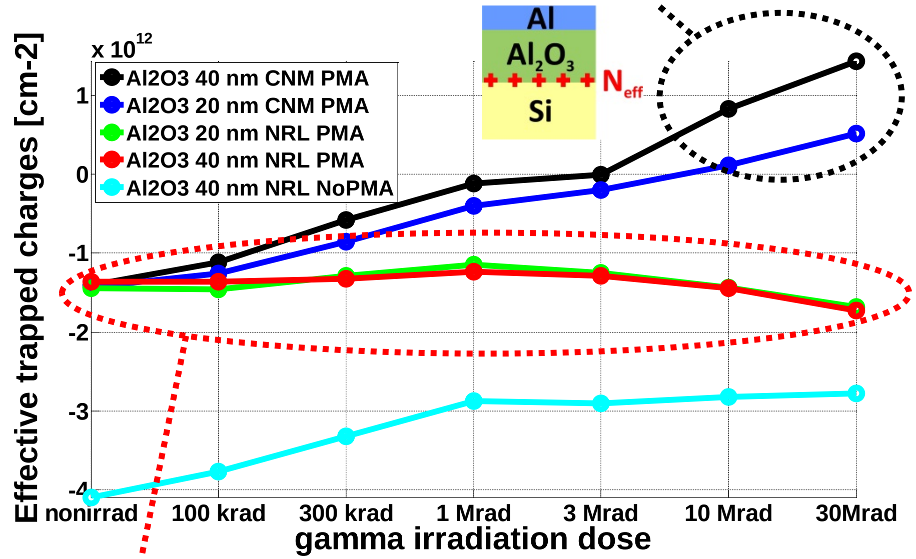
- We have seen that for n-type bulk devices the SCP method works well. In part, this is due to the evolution of (positive) interface charge (between commonly used passivants and silicon) with fluence.
- For p-type bulk devices we have to use alumina (Al_2O_3) that creates a negative interface charge with silicon.
  - We saw ambiguous results for low fluences in the past.
  - We used MOS capacitors with alumina to directly measure the charge development with fluence (G. Pellegrini's report at the last RD50 meeting). {next 2 slides}
- We wanted to apply the lessons learned to the SCP devices.

CV results from Gamma Irradiation

$$N_{eff} = \frac{C_{ox}}{qA}(\phi_{ms} - V_{fb}) \quad \phi_{m\_Al} = 4.25\ eV$$



Positive charge



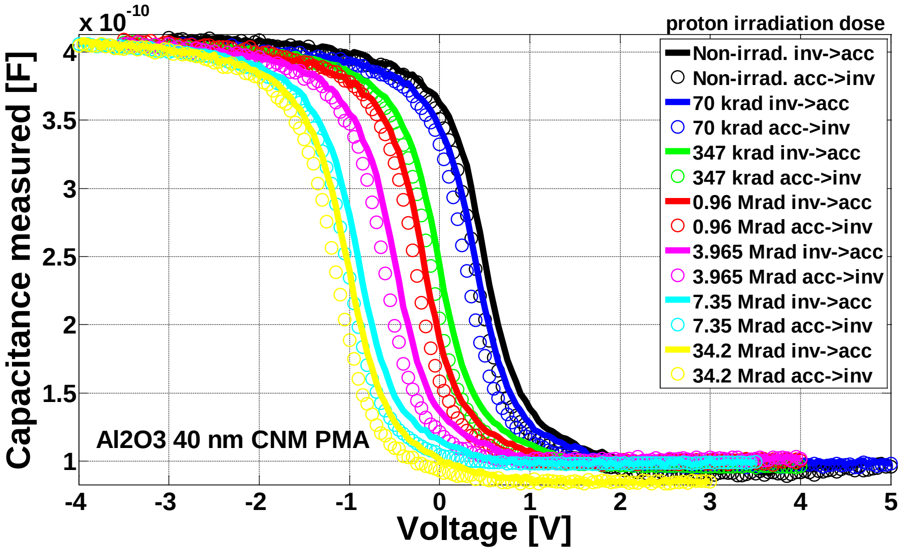
Rad-hard

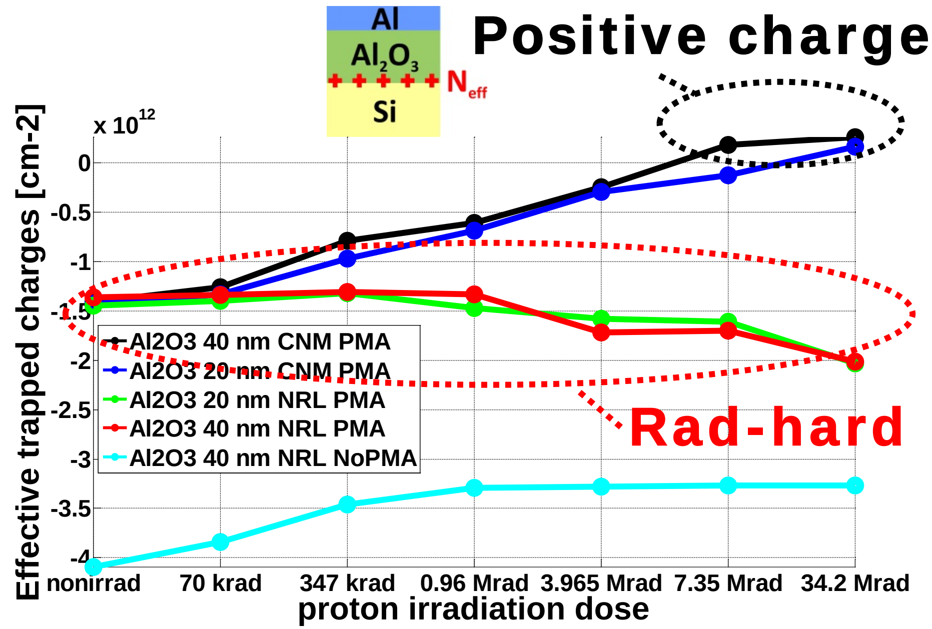
positive charge trapping in process 1 Al_2O_3

gamma-radiation-hardness in process 2 Al_2O_3 with PMA

CV results from Proton Irradiation

$$N_{eff} = \frac{C_{ox}}{qA}\left(\phi_{ms} - V_{fb}\right) \quad \phi_{m\_Al} = 4.25\ eV$$





positive charge trapping in process 1 Al_2O_3

gamma-radiation-hardness in process 2 Al_2O_3 with PMA

SCP processing

- As a follow-up test, we took ATLAS12 strip sensors and applied SCP processing: scribing, cleaving, passivation.
- Extra passivation options were explored, due to the relative ease of post-processing.
- The total of 5 processing option were implemented:
  - Standard passivation option, where the ALD deposition of alumina was done ASAP after cleaving to avoid the native oxide formation in the air.
  - Modified processing, where a wet etch was applied to remove the native oxide before the alumina deposition.
  - "nanostack" of Si Nitride (2-4 nm thick) covered by alumina, to exacerbate the possible native oxide effect (addition of wrong charge).
  - "nanostack" of Si Oxide (2-4 nm thick) covered by alumina, to exacerbate the possible native oxide effect (addition of wrong charge).
  - Si surface with F-type passivation, as an extreme case. This is highly unlikely to work. Based on prior studies, we need H-type.

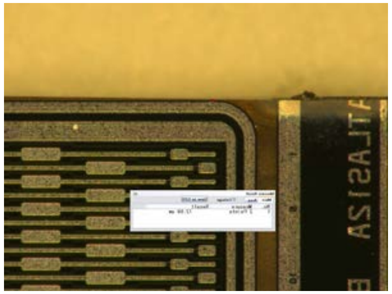
5 sample groups, with 2 devices per group:

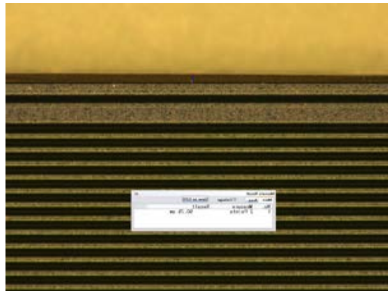
2 Treated with Si-F, 2 Treated with SiNx/Al2O3, 2 Treated with SiOx/Al2O3, 2 “Old” Treatment, 2 “Like-CNM” Treatment

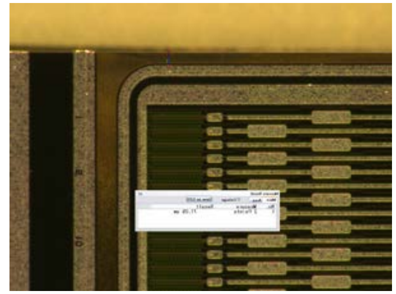
Group	Sample	Distances from GR to edge (corner/middle/corner)
1	Standard Processing Piece 1	57/38/29
1	Standard Processing Piece 2	61/43/38
2	Modified (+wet etch) Processing Piece 1	56/33/24
2	Modified (+wet etch) Processing Piece 2	66/36/24
3	SiNx/Al2O3 Piece 1	71/51/49
3	SiNx/Al2O3 Piece 2	71/72/66
4	SiOx/Al2O3 Piece 1	81/70/53
4	SiOx/Al2O3 Piece 2	96/95/80
5	Si-F Piece 1	71/51/13
5	Si-F Piece 2	74/55/33

Pictures

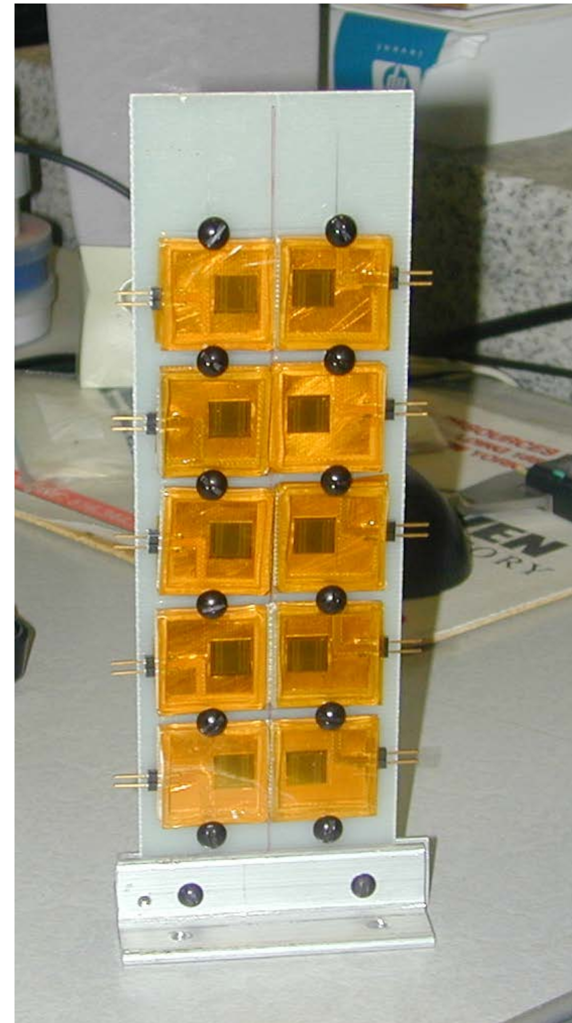
All cuts look very similar, Si-F Piece 1 is shown



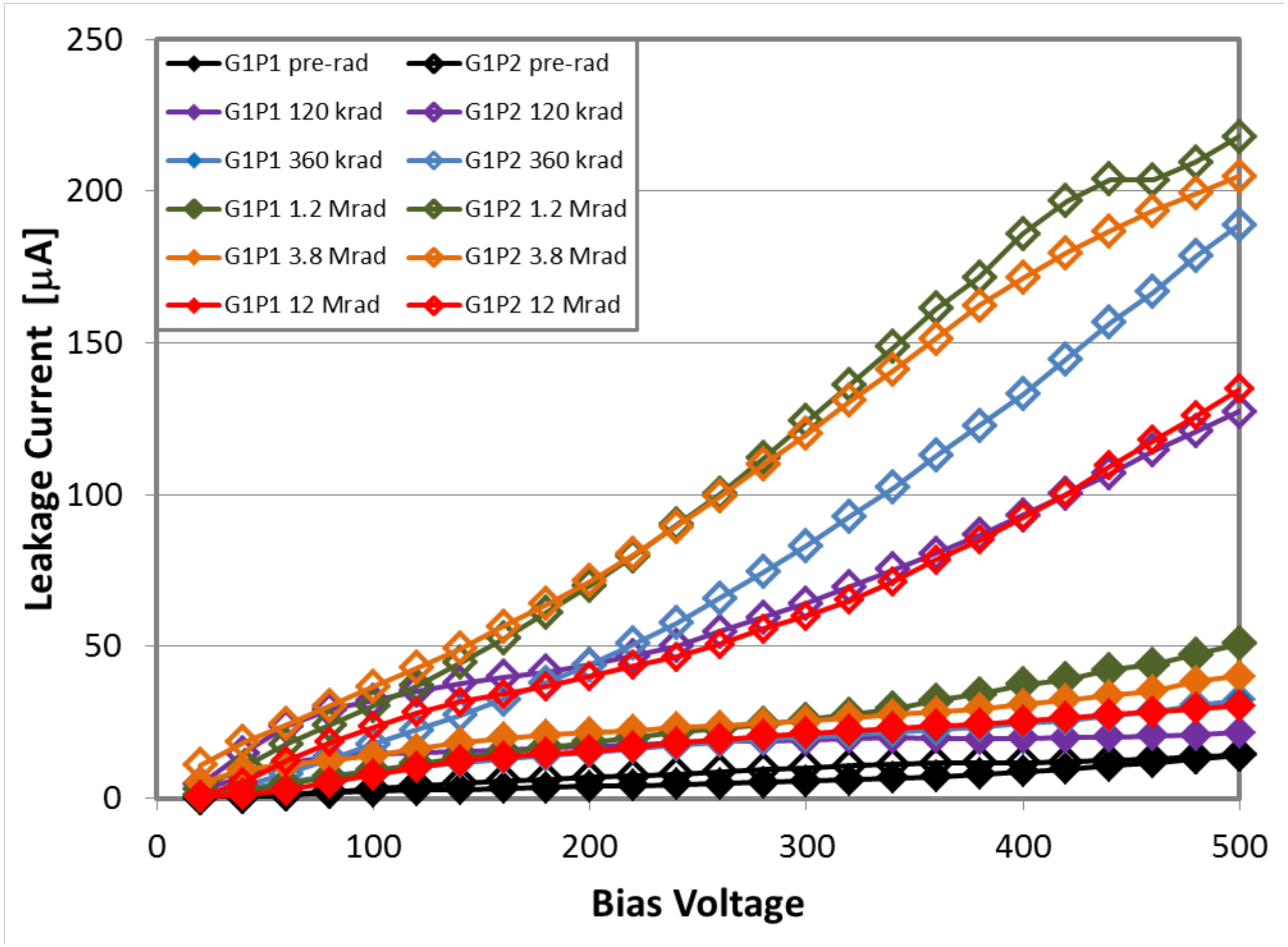




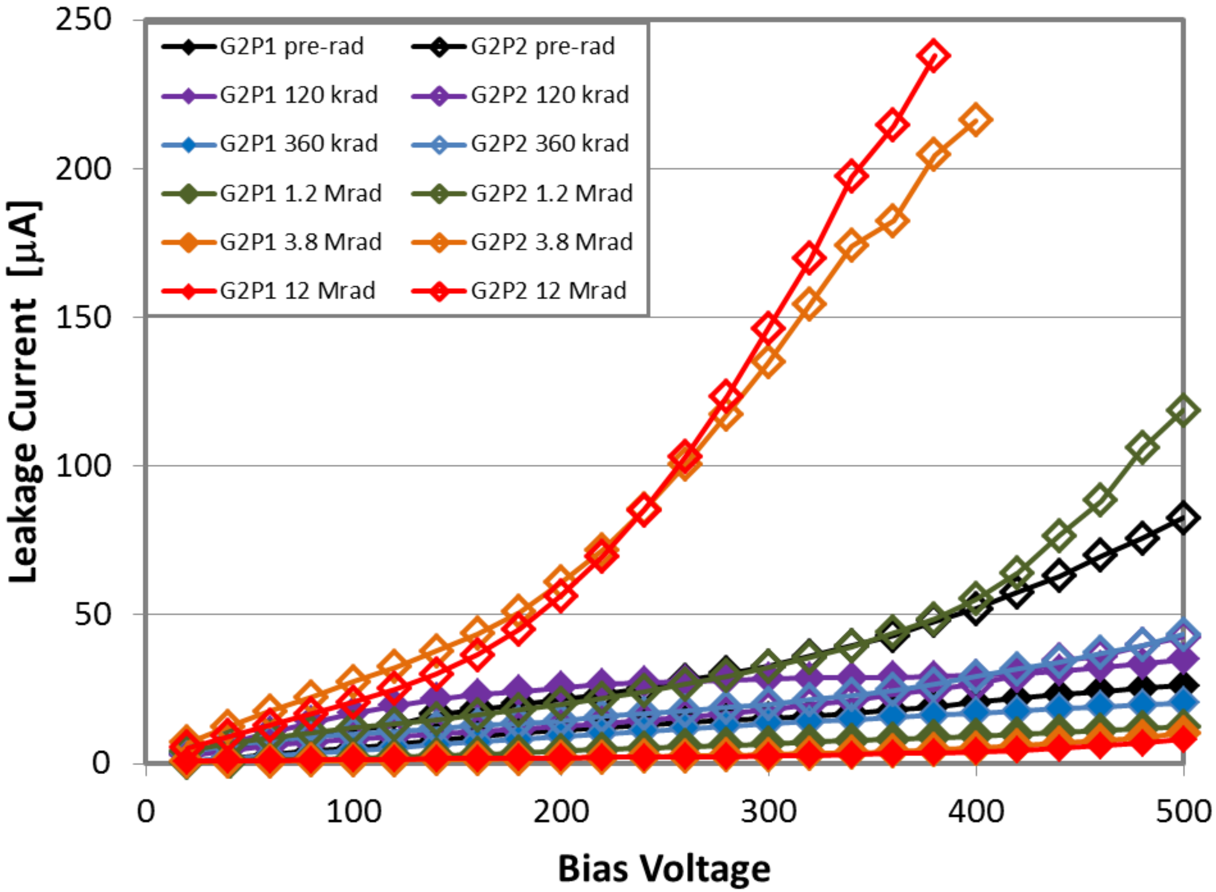
The sensors were irradiated at BNL Co-60 sources with repeated measurements after each dose.



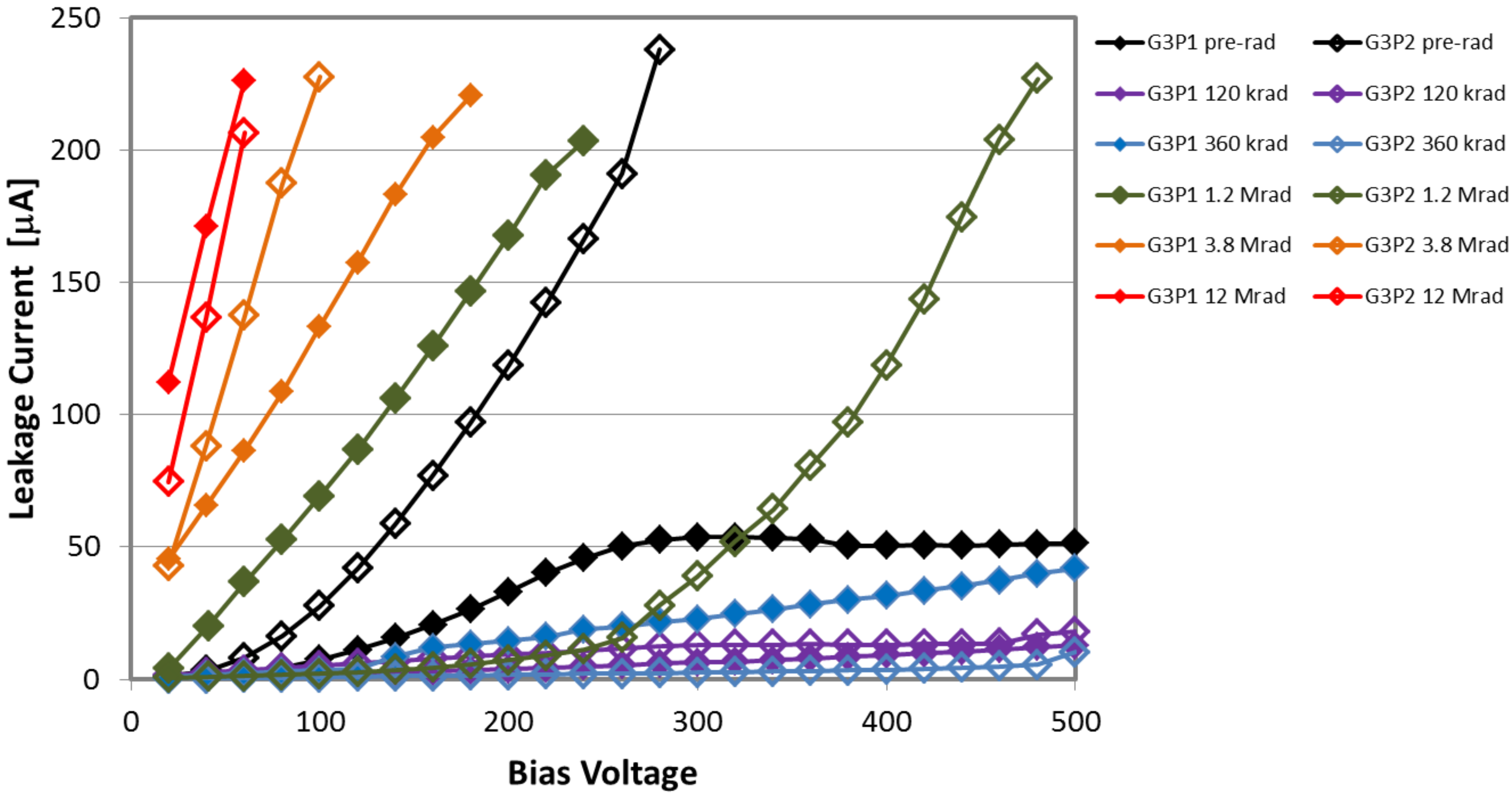
Group 1: “Old processing”



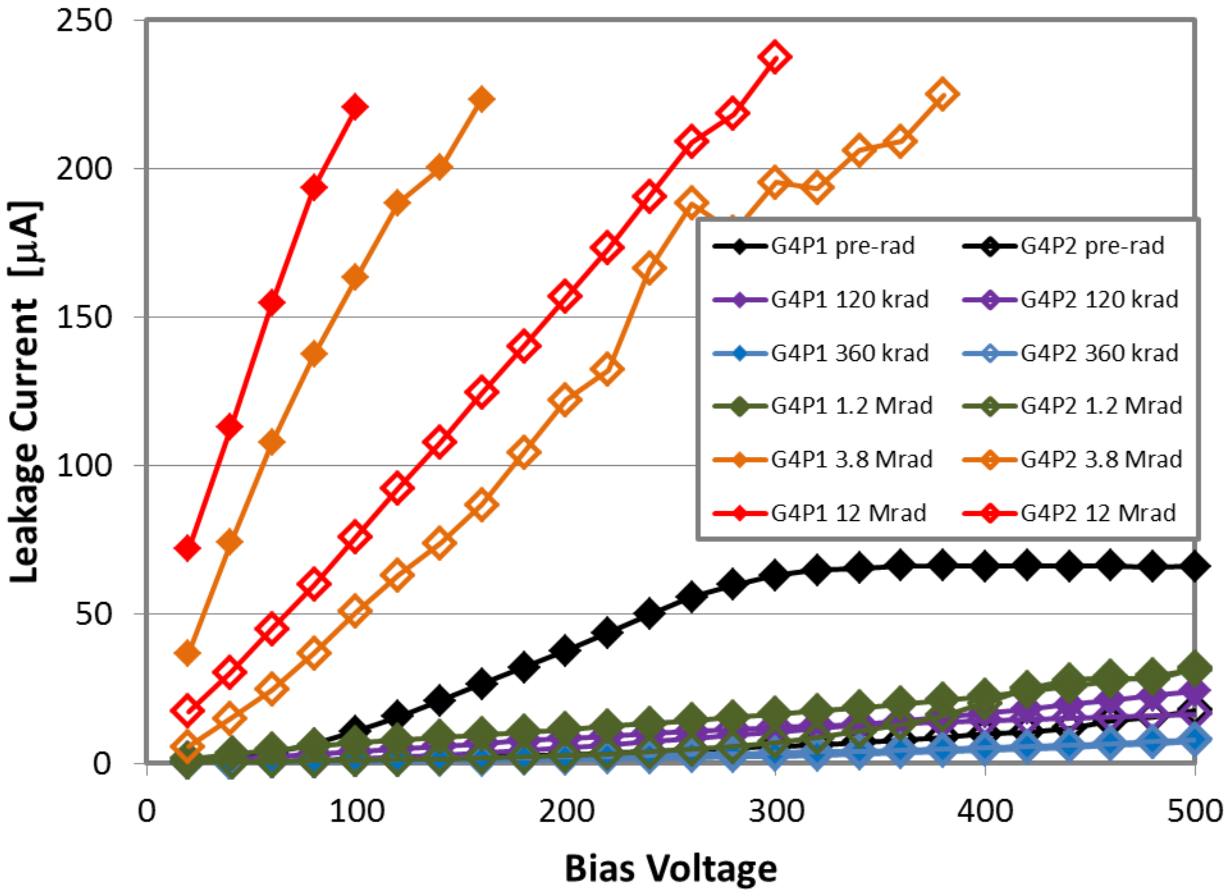
Group 2: “Like CNM”



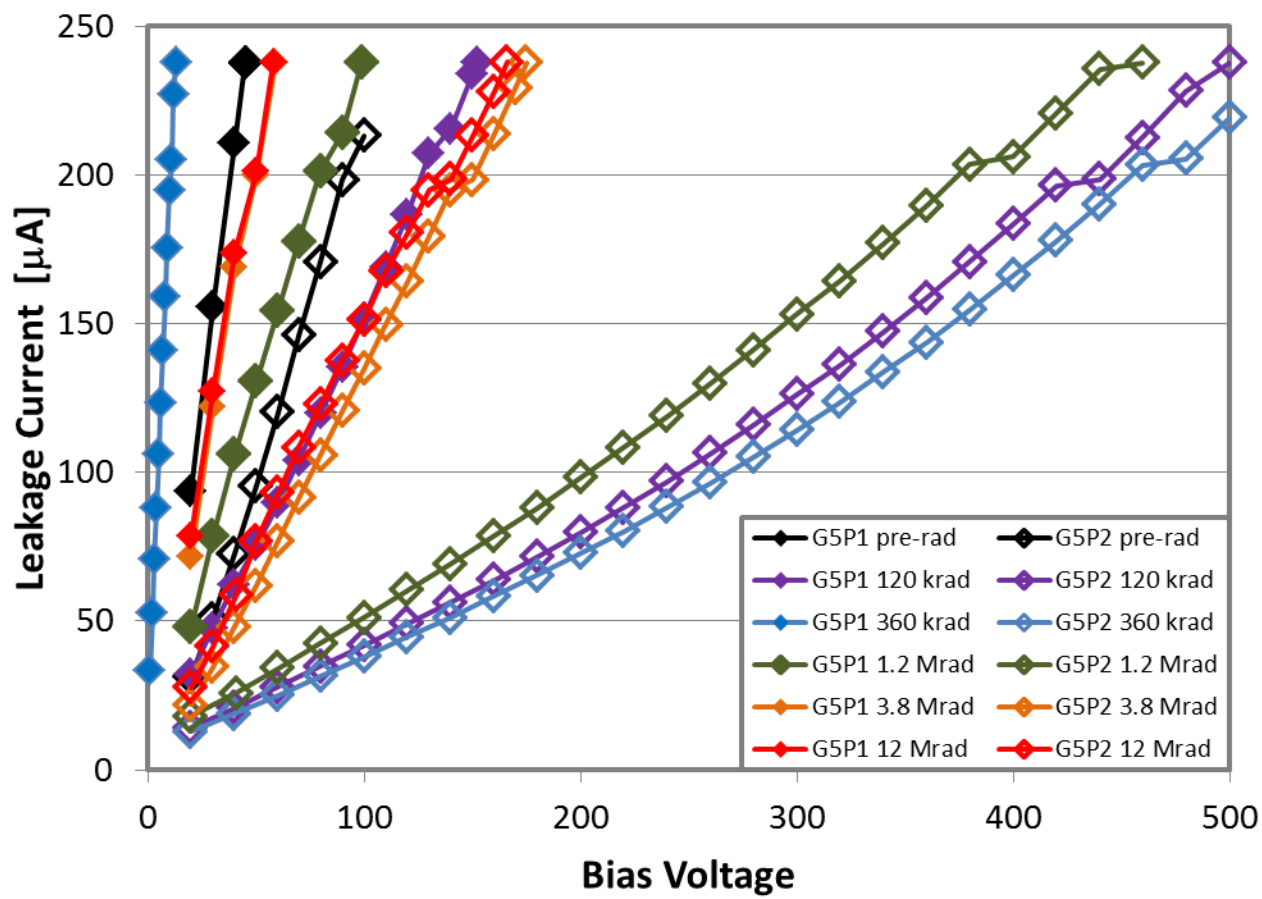
Group 3: SiNx/Al2O3



Group 4: SiOx/Al2O3

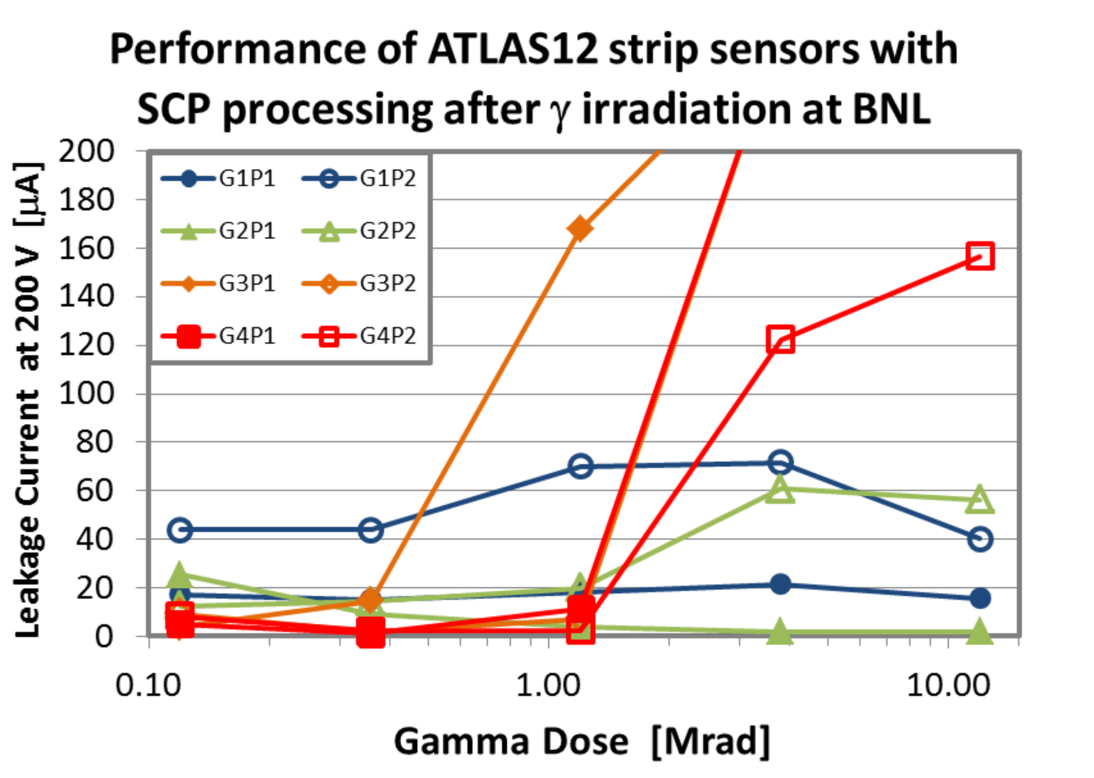


Group 5: Si with F-termination



Current at 200 V as a function of dose

Sensor group	Processing type
Group 1	Standard, with Al2O3
Group 2	Standard+etching, Al2O3
Group 3	SiNx/Al2O3
Group 4	SiOx/Al2O3



Conclusions

- There is a variance in the performance at low doses. However, sensors from group 1 (“old processing”) and group 2 (“like CNM”) clearly have much lower currents than the rest above 1.2 Mrad dose.
- The devices with nitride and oxide layers are not rad-hard.
- The best performing device (with lowest current) at 12 Mrad is from group 2.
- We have confirmed that the modified device processing, which was used in the MOS capacitors study, promises the best performance.

Acknowledgements

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Observation on proton-irradiated SCP p-type planar devices

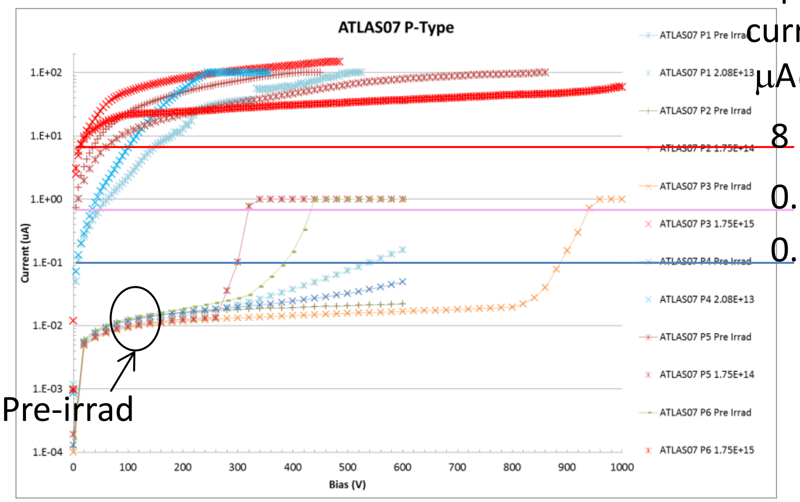
12 SCP p-type strip devices (CIS courtesy A. Macchiolo) irradiated at LANL in 2011 (thanks to S. Seidel):

Results are in-conclusive

- **High fluence devices** (3/3 for 1×10^{16}neq, 3/3 for 1×10^{15}neq) **show expected post-rad leakage current**
- **Low fluence devices** (1/3 for 1×10^{13}neq and 1/3 for 1×10^{14}neq) **show earlier breakdown!**

	Before Irradiation	After Irradiation		
	V(break)	V(break)	Fluence	No
Sensor	at ~10 uA	at ~100 uA		Guard Rings
B1 P5	30	460	10^13	1
B1 P6	290	165	10^13	1
B2 P1	410	80	10^13	3
B1 P8	15	90	10^14	5
B2 P10	310	80	10^14	5
B2 P6	390	100	10^14	1
B2 P8	300	>800	10^15	4
B2 P9	310	335	10^15	5
B2 P11	250	>800	10^15	2
B2 P2	305	390	10^16	1
B2 P3	340	330	10^16	3
B2 P4	380	425	10^16	3

ATLAS07 HPK diodes
2012 CERN SPS
(thanks to G. Casse):



Leakage currents do not scale with fluence

low fluence (< 1×10^{14}): **reduced edge performance**

high fluence (>1×10^{14}): **resistive edge**