PAI & Halo ion effects on junction activation and leakage

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presented at IIT10

Process Mix: 4 PAIs, 2 Halos, 0.2 keV B

PAI:

Xe: 5, 14 keV

*B_{36}: 4, 20 keV

*In: 5, 14 keV

Ge: 3, 10 keV

*Note: p-type dopant

Halo:

20 keV As

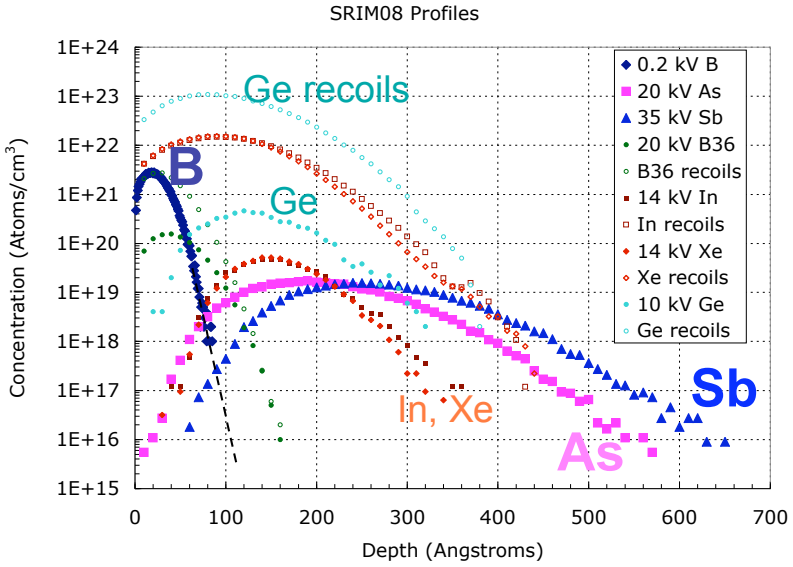
35 keV Sb

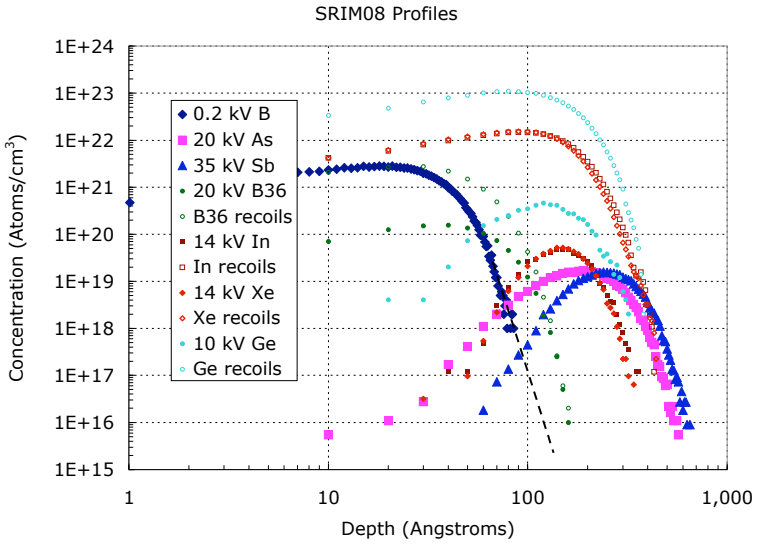
Junction:

0.2 keV B, 1e15

GAI-Implant				Extension Implant			Halo Implant			Annealing
ion	Energy	Ion Dose	Atom Dose	ion	Energy	Boron Dose	ion	Energy	Boron Dose	LSA
Xe	14.0 keV	-	5.0E+13 /cm2	B	0.2 keV	1.0E+15 /cm2	none			5 stripes
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
	5.0 keV	-	5.0E+13 /cm2				none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
B36Hx	20.0 keV	2.78E+12 /cm2	5.0E+13 /cm2				none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
	4.0 keV	2.78E+13 /cm2	1.0E+15 /cm2				none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
In	14.0 keV		5.0E+13 /cm2				none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
	5.0 keV		5.0E+13 /cm2				none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
Ge	10.0 keV		5.0E+14 /cm2				none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
	3.0 keV		5.0E+14 /cm2				none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	
none							none			
							As	20.0 keV	3.0E+13 /cm2	
							Sb	35.0 keV	3.0E+13 /cm2	

SRIM Profiles

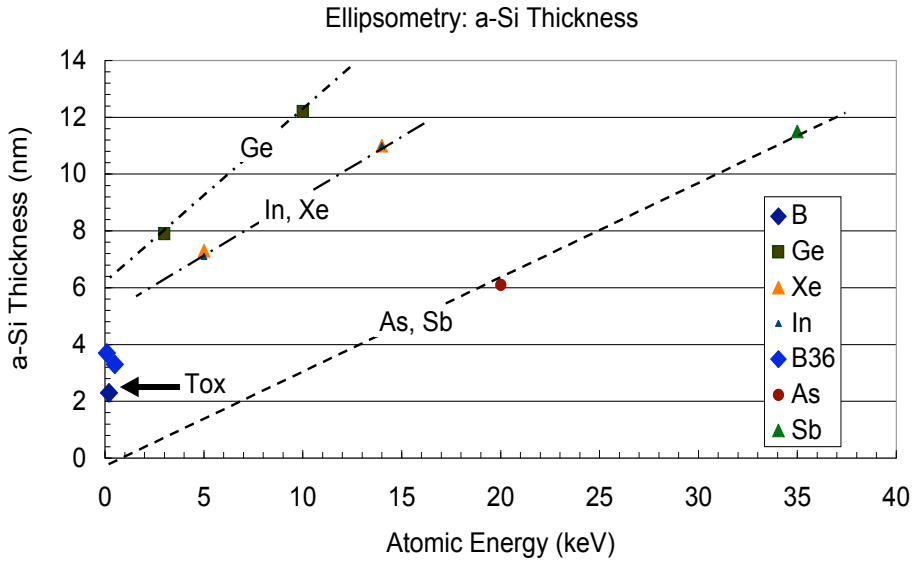


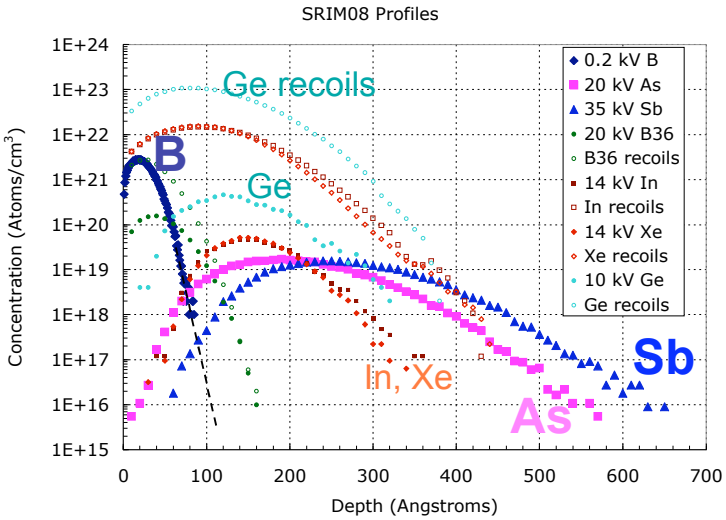


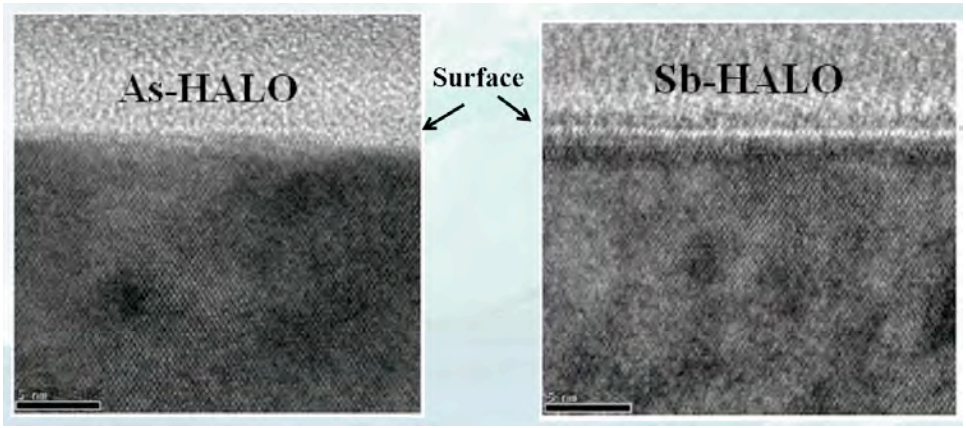
a-Si Layers

Ellipsometry finds only “thin” a-Si layers.

TEM sees no a-Si in the As and Sb halos.
(Halo dose = 3e13 atoms/cm^2)







Laser Anneals

Laser Anneals:

Ultratech LSA

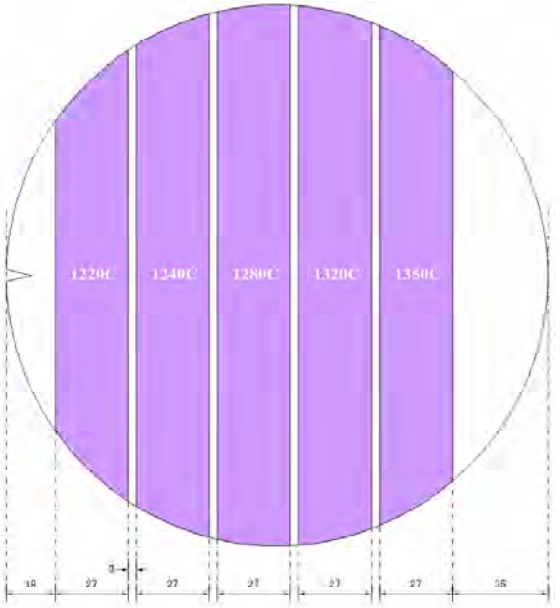
1220 C

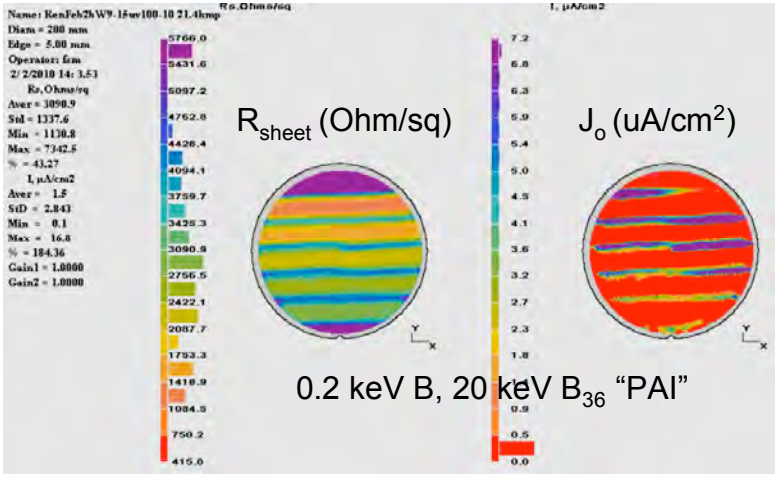
1240 C

1280 C

1320 C

1350 C





Halos, lasers & leakage
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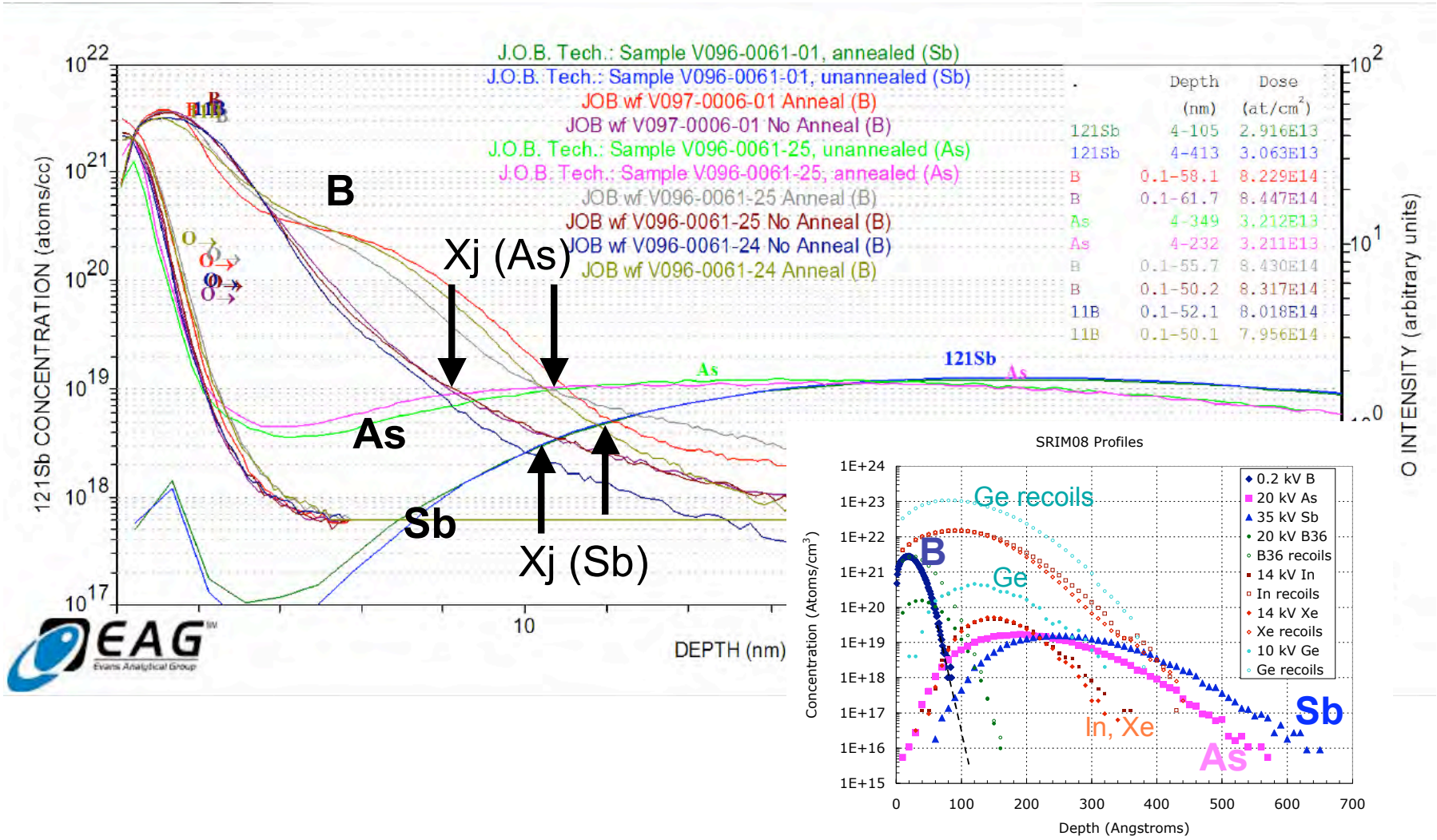
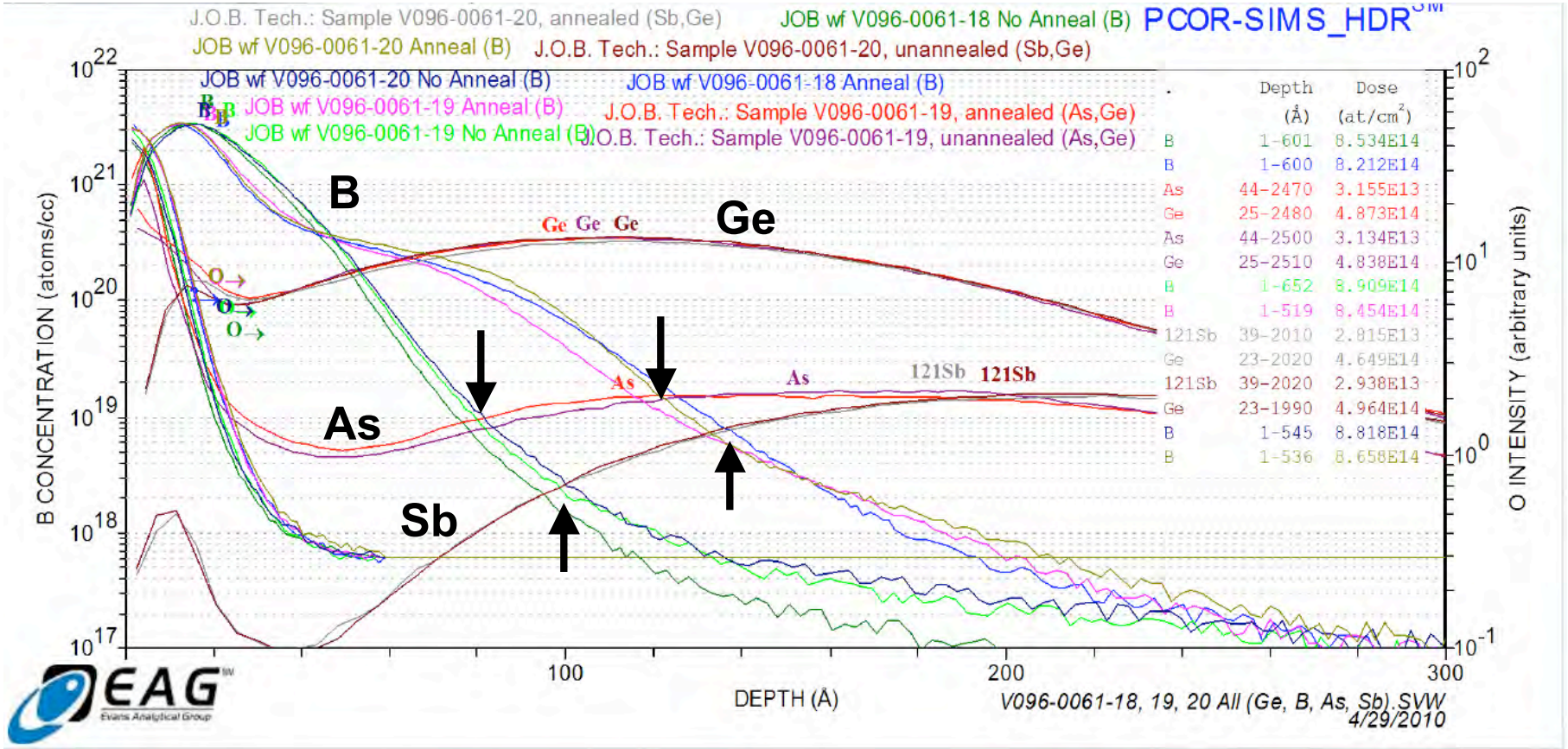
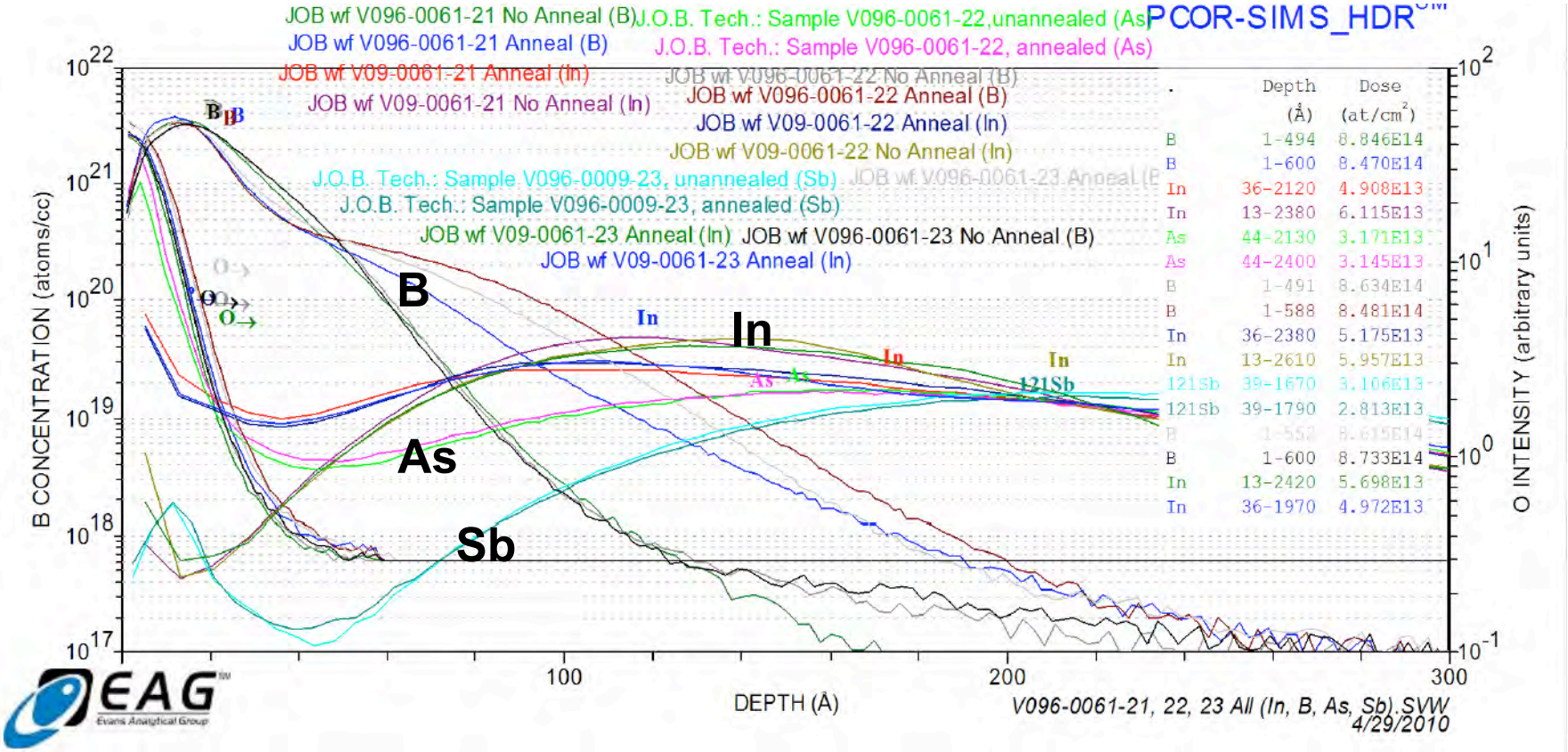
SIMS: 0.2 keV B and Halos



SIMS: 10 keV Ge, 0.2 keV B & Halos



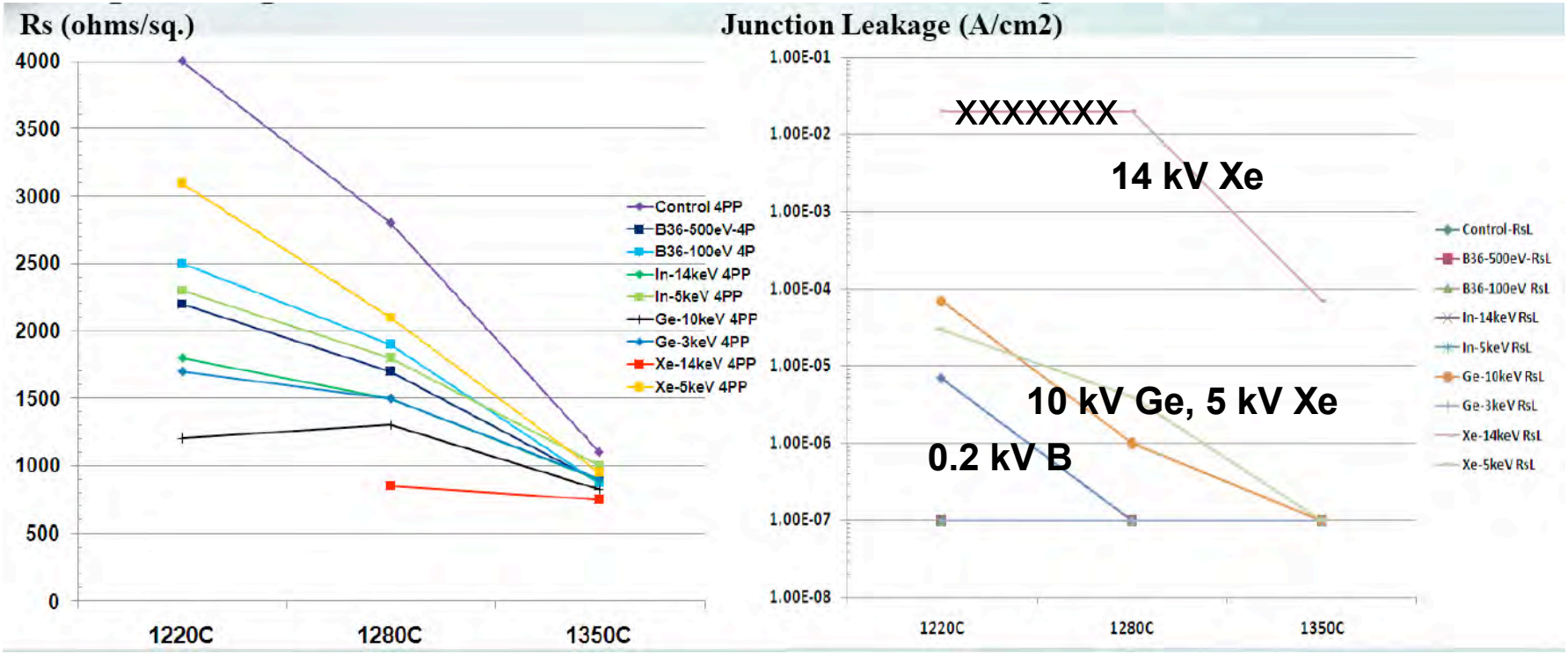
SIMS: 14 keV In, 0.2 keV B & Halos



Note: In levels higher than As or Sb for <20 nm. Counter-doping?

Activation & Leakage (no Halo)

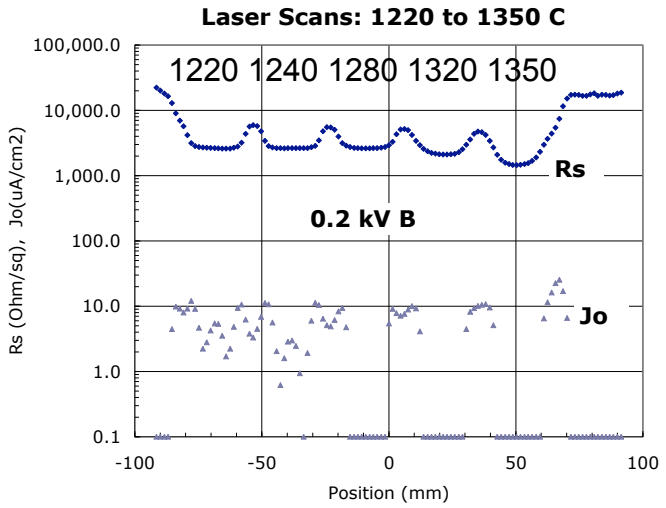
Different PAI ions give very different Rs and leakage



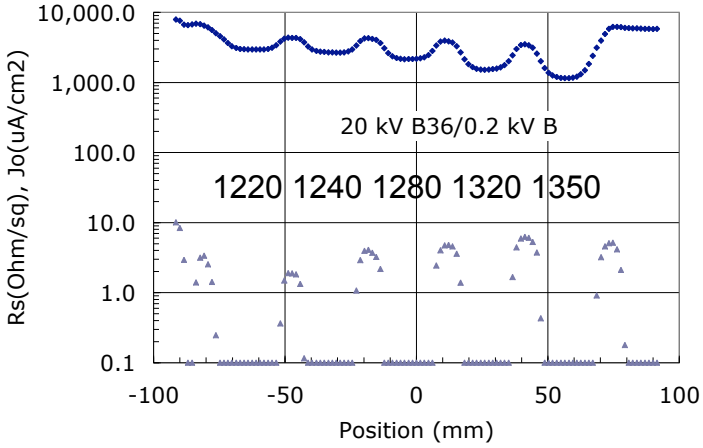
"control" = 0.2 keV B with no PAI & no halo

RsL Line Scans: Rs & Jo
0.2 keV B (and 20 kV B_{36}): no Halo

0.2 keV B implants need laser temps >1240 C to get to minimal leakage.



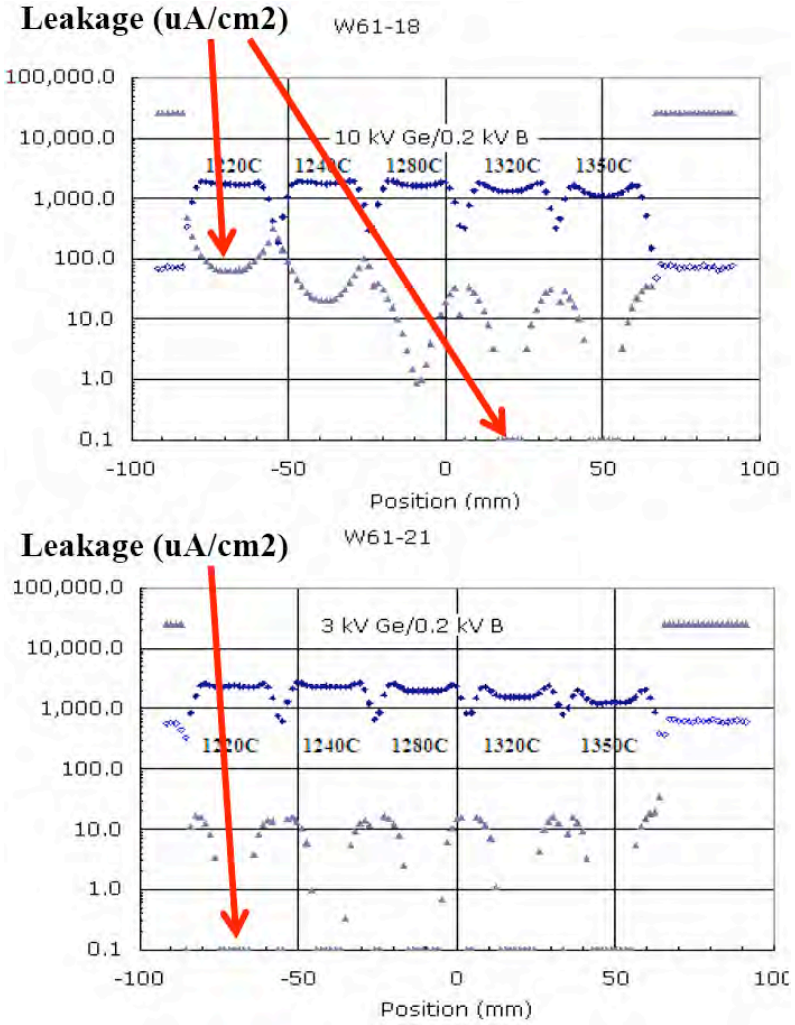
Addition of B_{36} "PAI" to the 0.2 keV B greatly improves leakage for lower laser temps.



RsL Line Scans: Rs & Jo
0.2 keV B (and Ge PAI): no Halo

Deep (10 kV) Ge PAI has higher leakage than shallow (3 keV) Ge.

Width of “low leakage” stripes are much thinner than good activation (Rs), implying intra-scan anneal temperature variations.

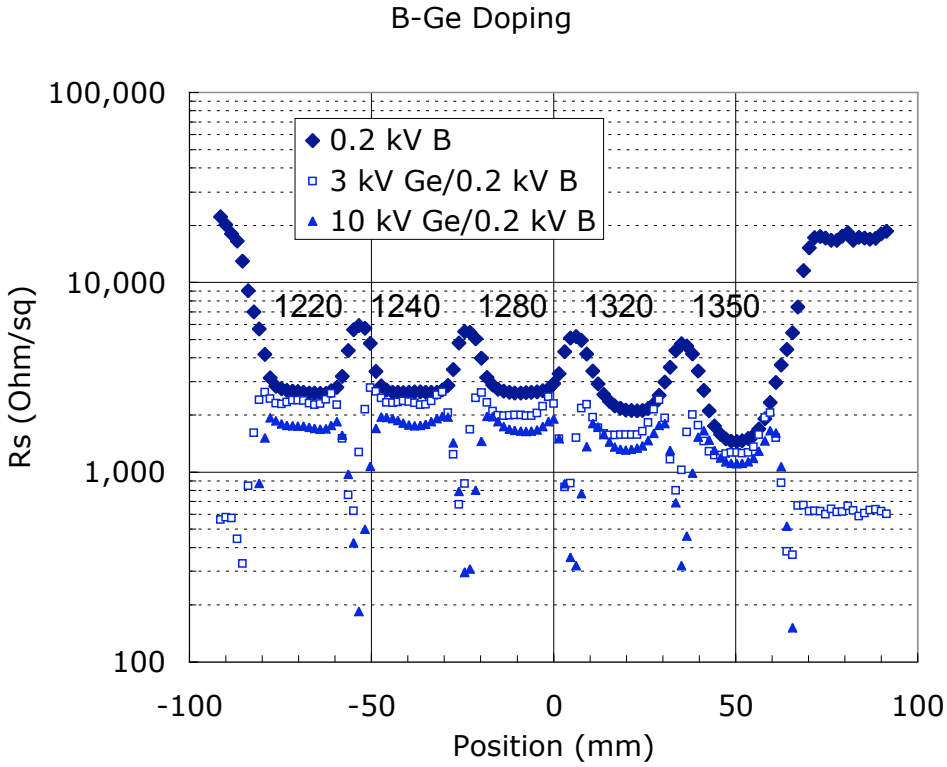


RsL Line Scans: Rs & Jo
0.2 keV B (and Ge PAI): no Halo
B activation

Deeper Ge PAI lowers B junction Rs (at the cost of higher leakage current).

Implication:

Deeper a-Si layer results in higher B dopant activation.



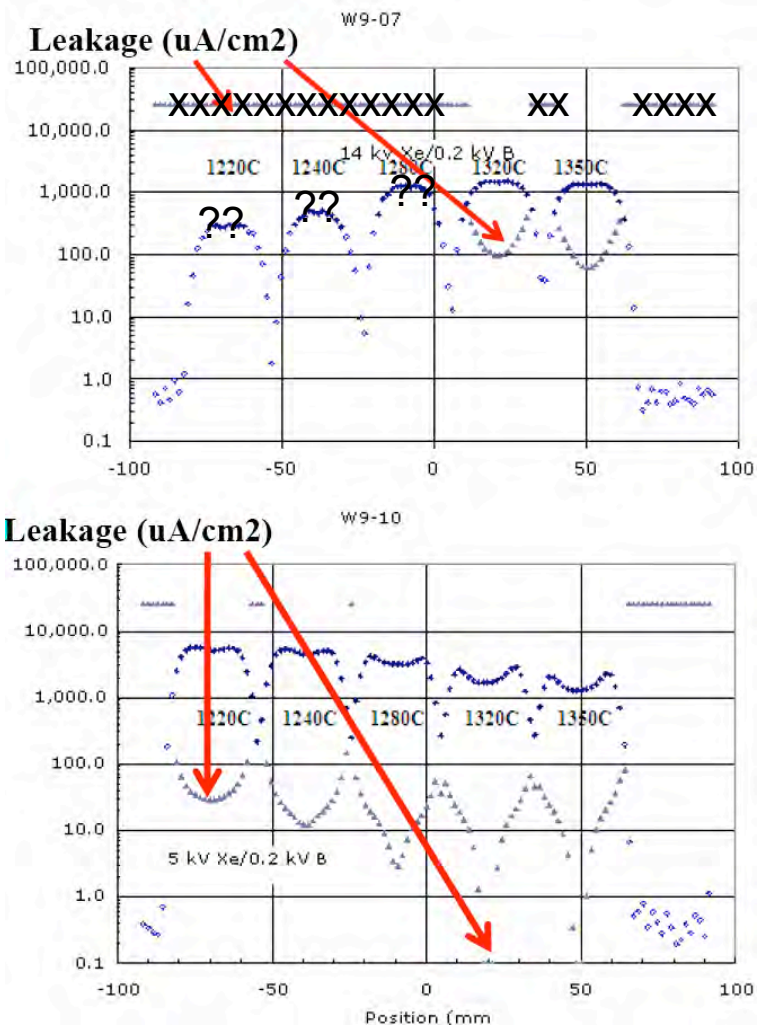
RsL Line Scans: Rs & Jo
0.2 keV B (and Xe PAI): no Halo

Xe PAI has much higher leakage and poorer dopant activation than Ge.

Deep (14 kV) Xe worse than shallow (5 kV) Xe PAI.

Note:

JPV values are very low when Jo is >2e-2 A/cm^2 (>2e4 uA/cm^2) so Rs values are questionable.

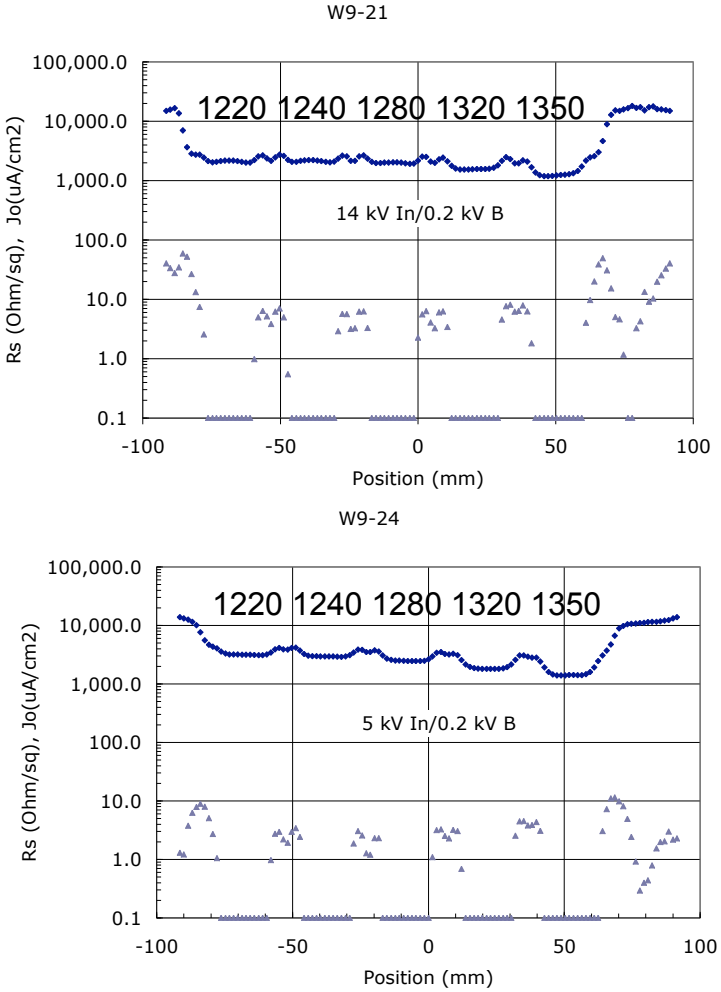


RsL Line Scans: Rs & Jo
0.2 keV B (and In PAI): no Halo

Leakage for ^{115}In "PAI" much lower than ^{131}Xe or ^{73}Ge.

Possible effect of In PAI increasing p-doped Xj to deeper than main residual damage ??

Active In decreases R_{sheet} at higher temps (see next slide).



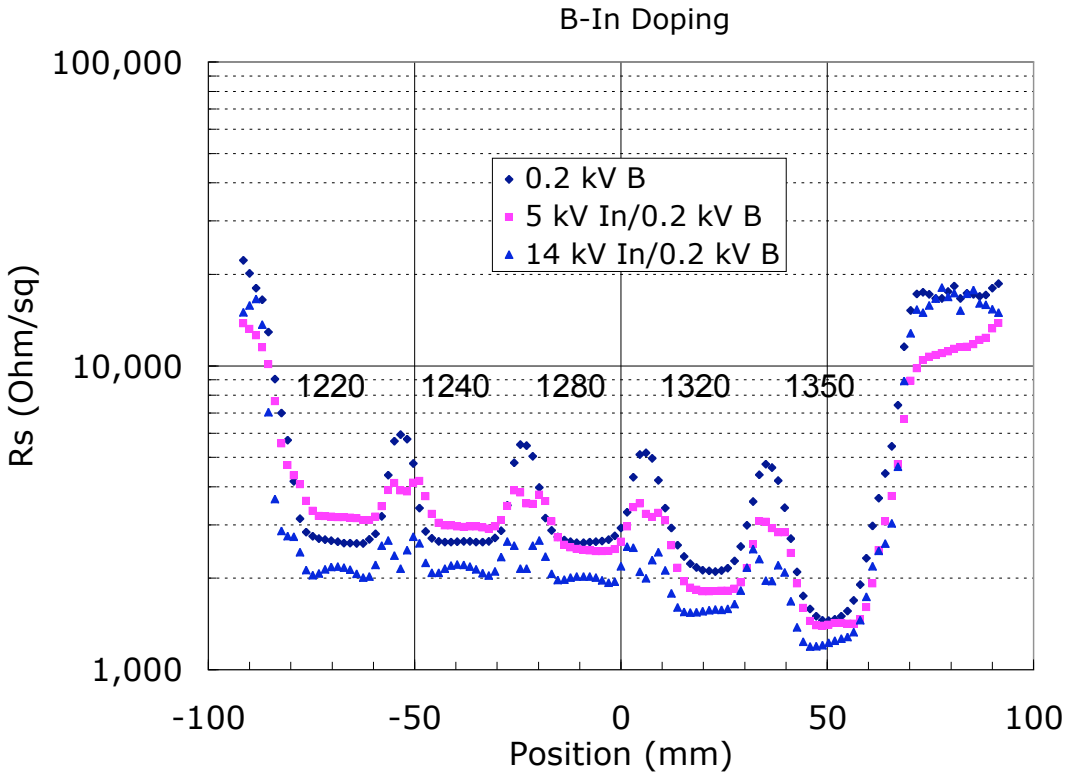
RsL Line Scans: Rs & Jo
0.2 keV B (and In PAI): no Halo

At >1280 C, In “PAI” results in lower R_{sheet}.

An activation increase or an Xj shift?

For lower (<1280 C) temps, 5 keV In raises the R_{sheet} above the 0.2 keV B alone.

Implication: Higher temps needed to fully activate In.

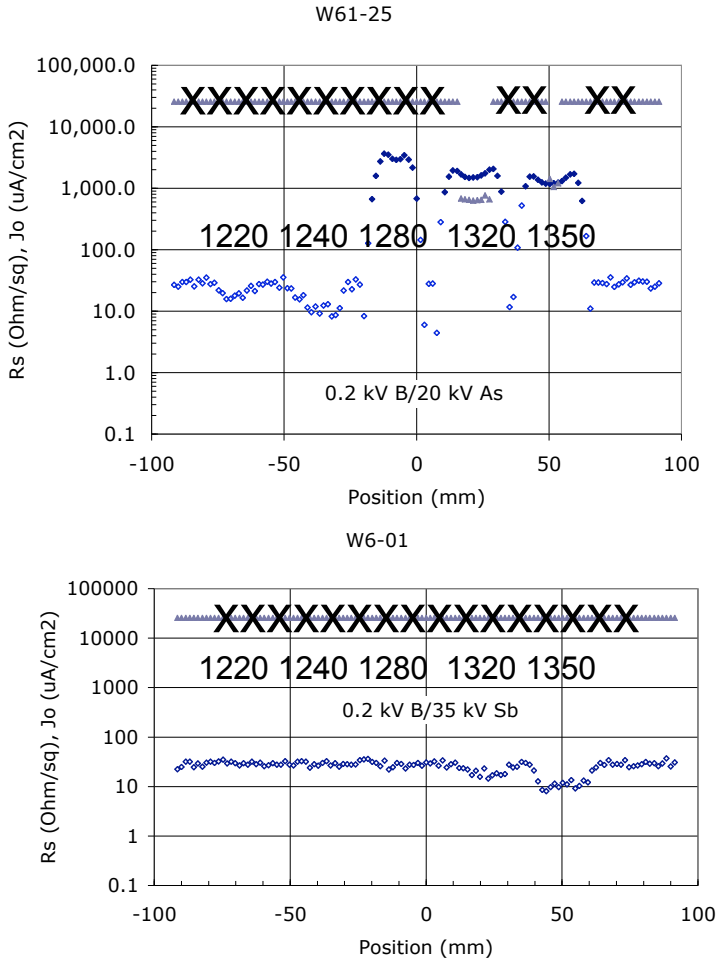


RsL Line Scans: Rs & Jo
0.2 keV B (no PAI): As or Sb Halo

Addition of of halo profiles strongly increases carrier recombination and tunneling leakage currents.

As halo activation and leakage better than Sb, but only at >1280 C.

"Modest" leakage (≈1e-3 A/cm^2) only seen in the *middle* of the 1320 and 1350 C scans for As halo.



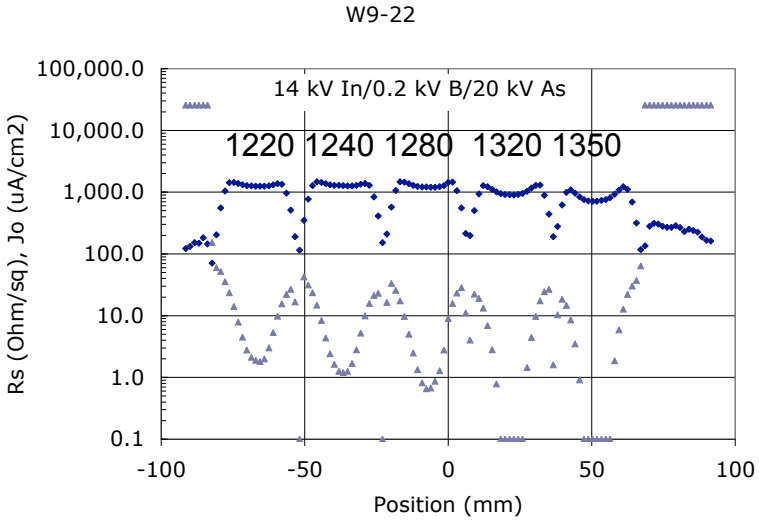
RsL Line Scans: Rs & Jo
0.2 keV B (14 keV In PAI): As or Sb Halo

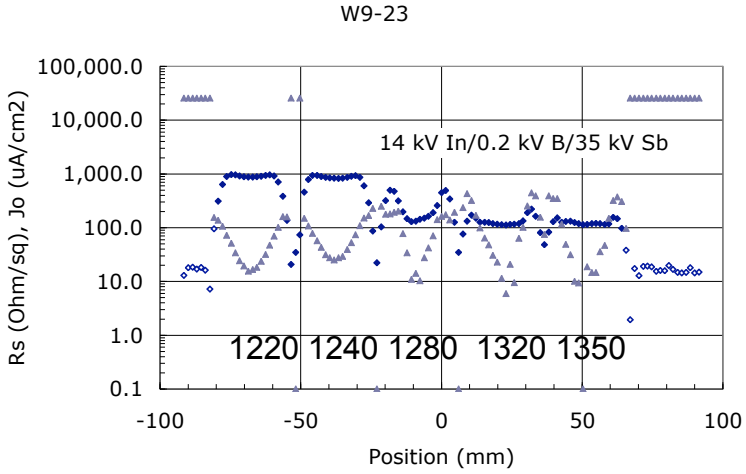
Deep 14 keV In “PAI” results in lower leakage currents for for the As and Sb halos.

Implication:

Active In counter-dopes the upper portions of the halo profiles, increasing depletion layer thickness and lowering recombination and tunneling currents.

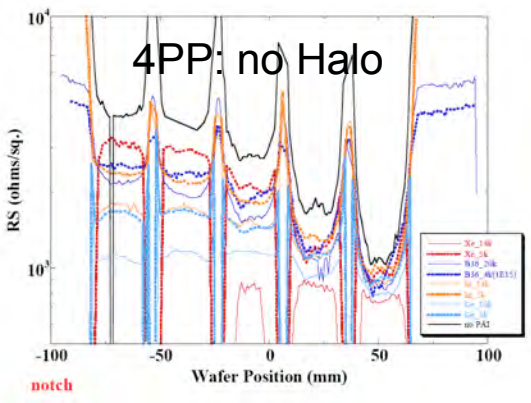
Also possible deeper junction Xj.

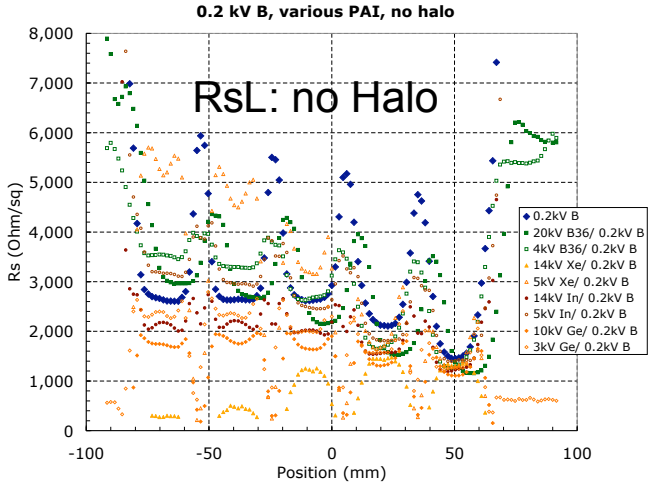




Sheet Resistance

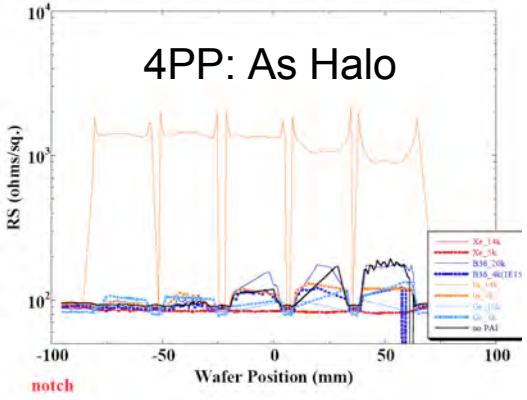
No Halo:
RsL generally lower values than 4PP.

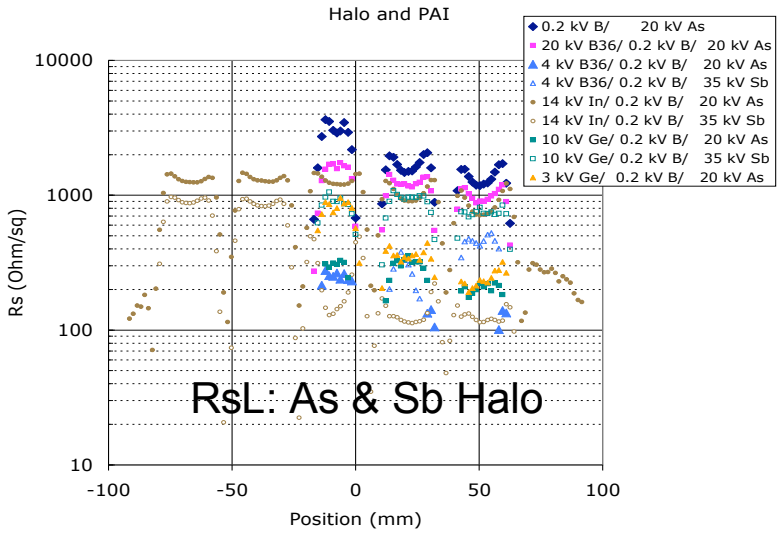




As or Sb Halo:
4PP values all too low (due to substrate leakage).

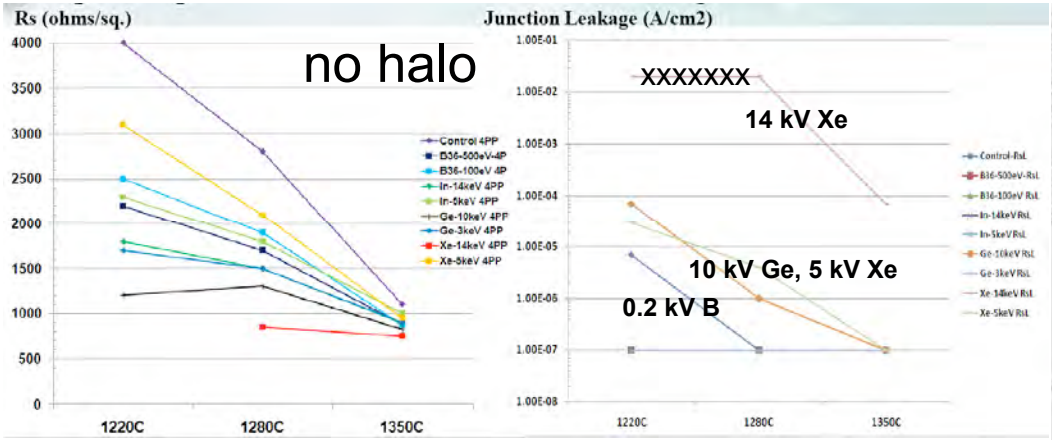
For deep In PAI, 4PP values valid (modest leakage).

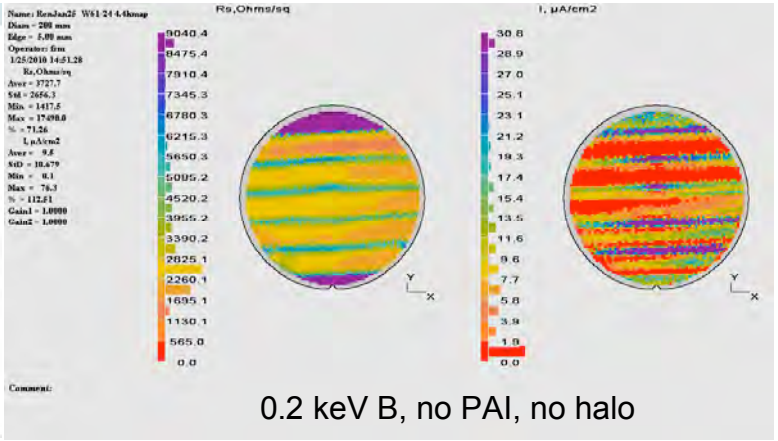




PAI & Halo ion effects on junction activation and leakage: Summary

1. The specific ions used for PAI and halo implants greatly influence Rs and leakage values. It is not just “damage”.
2. Halo profiles greatly increase leakage levels and increase effect of residual damage from PAI implants. (Not news).
3. “PAI” with p-type ions (B_{36}, In) reduce Boron junction leakage currents, especially for halo profiles. Counter-doping?
4. Significant amount of intra-scan temperature variations.





0.2 keV B, no PAI, no halo