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a ceradyne company

The Cluster Implant *Source*

ClusterBoron technology for <10nm junctions

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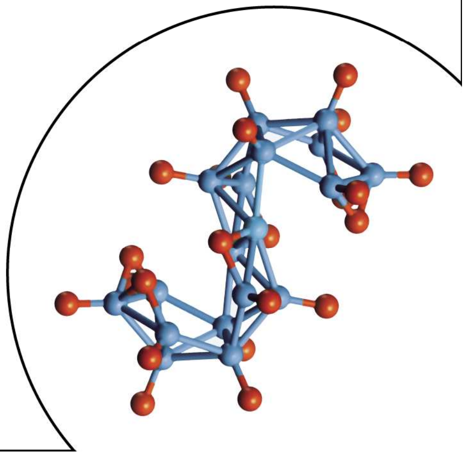
Semicon West '09 WCJUG



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Challenges for 10nm junctions

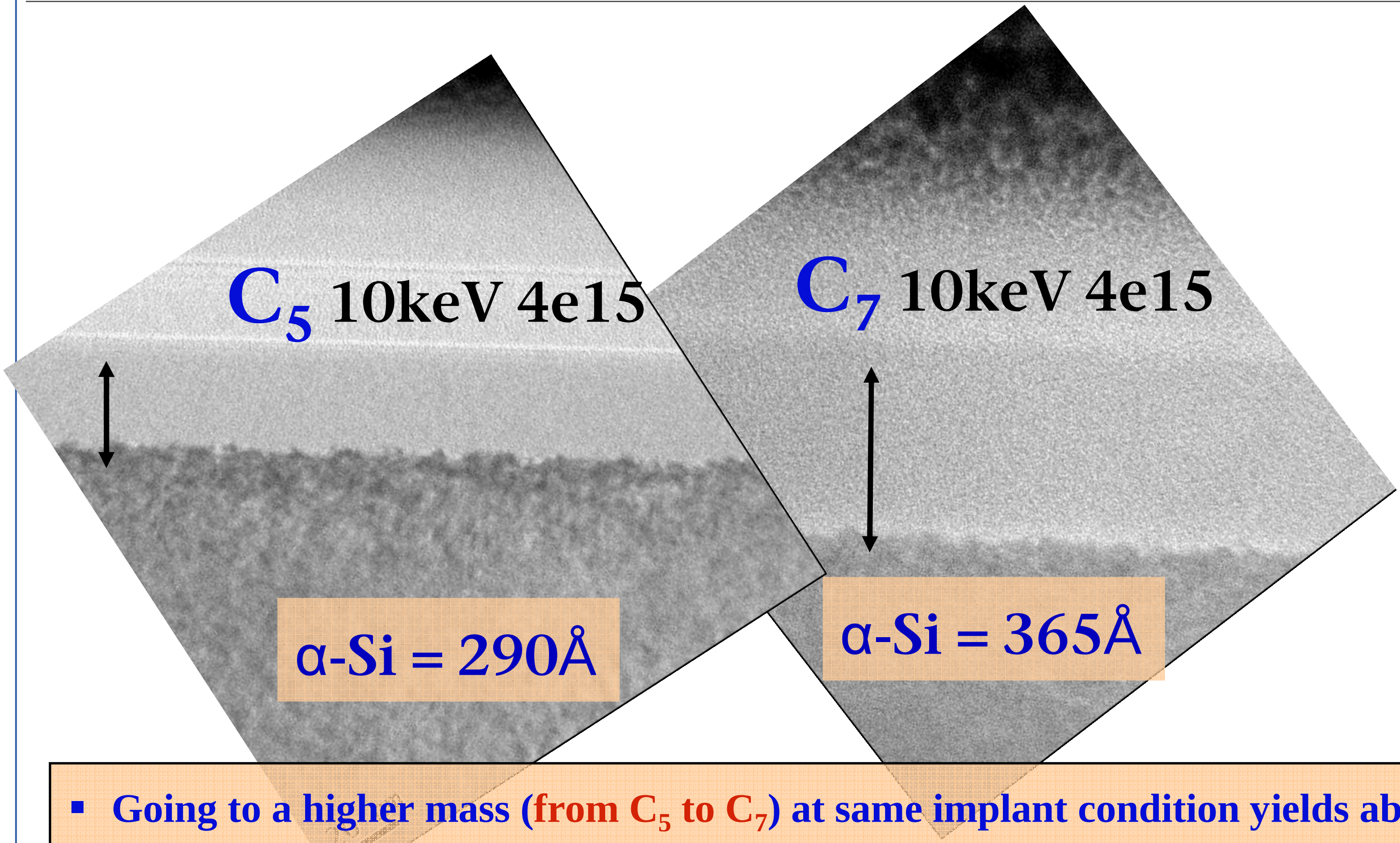
- Boron implant, 250-300eV
  - Channeling
  - Energy Contamination
  - Amorphization
- Diffusion during annealing
- Dopant Activation and sheet resistance
- Characterization
- Process Integration

ClusterBoron Dimer Technology

- ClusterIon source with ClusterBoron ($B_{18}H_{22}$) feed material produces ClusterBoron-Dimer ($B_{36}H_x$) ion beam
- Dimer production by ion source is less than the B18 primary beam, but transport conditions produce dose rate advantage for the dimer at low energy (<400eV)
- B36 Process Evaluation
    - Amorphization
    - Depth Profile
    - Activation

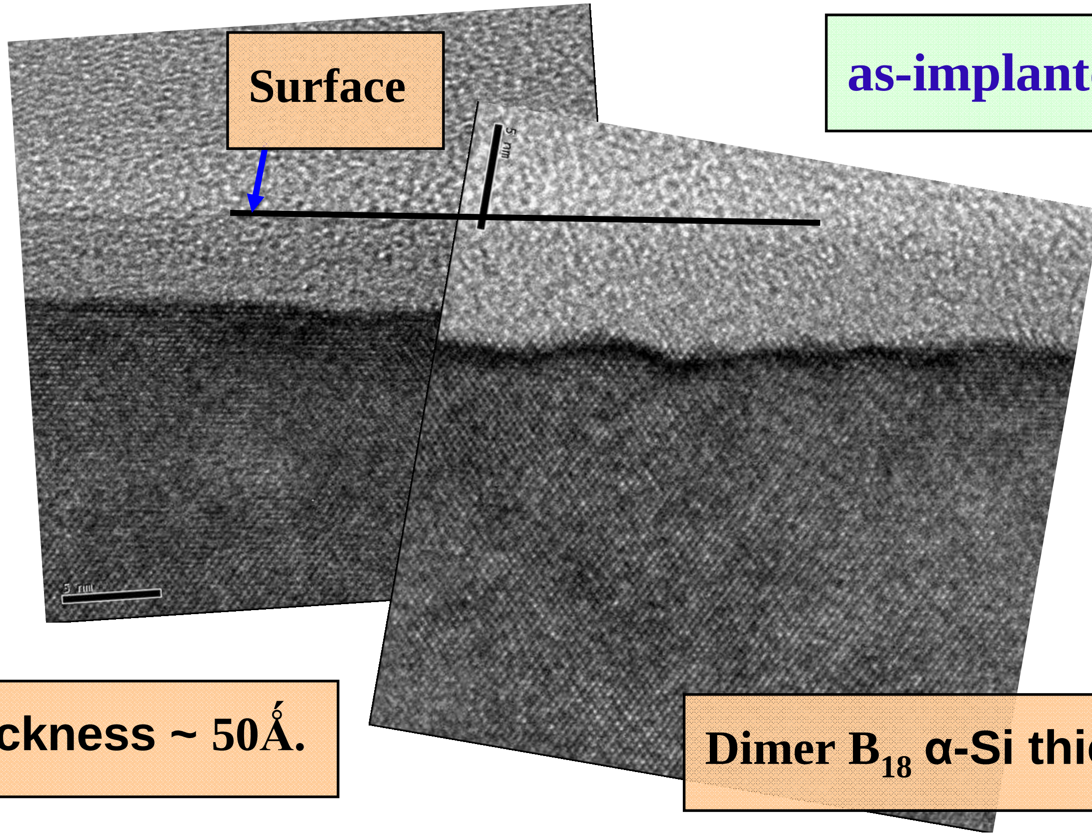
Self-amorphization

ClusterCarbon Self-amorphization - C_5H_5 vs C_7H_7



- **Going to a higher mass (from C_5 to C_7) at same implant condition yields about 25% increase in α-Si layer thickness**

$B_{18}H_{22}$ and Dimer $B_{18}H_{22}$ ($B_{36}H_x$) 300eV@1e15



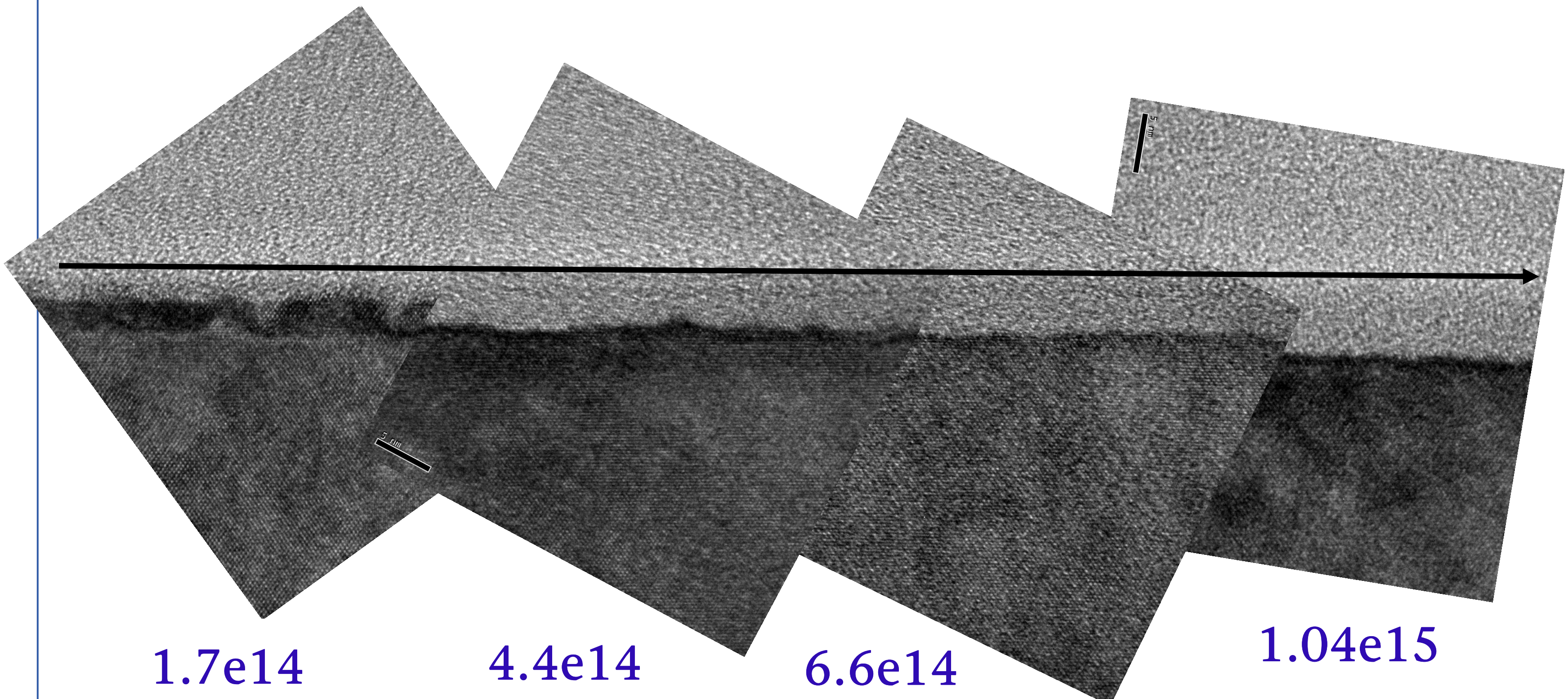
as-implanted

B_{18} α-Si thickness ~ 50Å.

Dimer B_{18} α-Si thickness ~ 63Å.

- **Thicker amorphous layer leaves less Si interstitials for residual EOR defect formation and also less TED. All leads to higher dopant activation.**

$B_{36}H_x$ XTEM (500KX)
300eV Dose Sequence

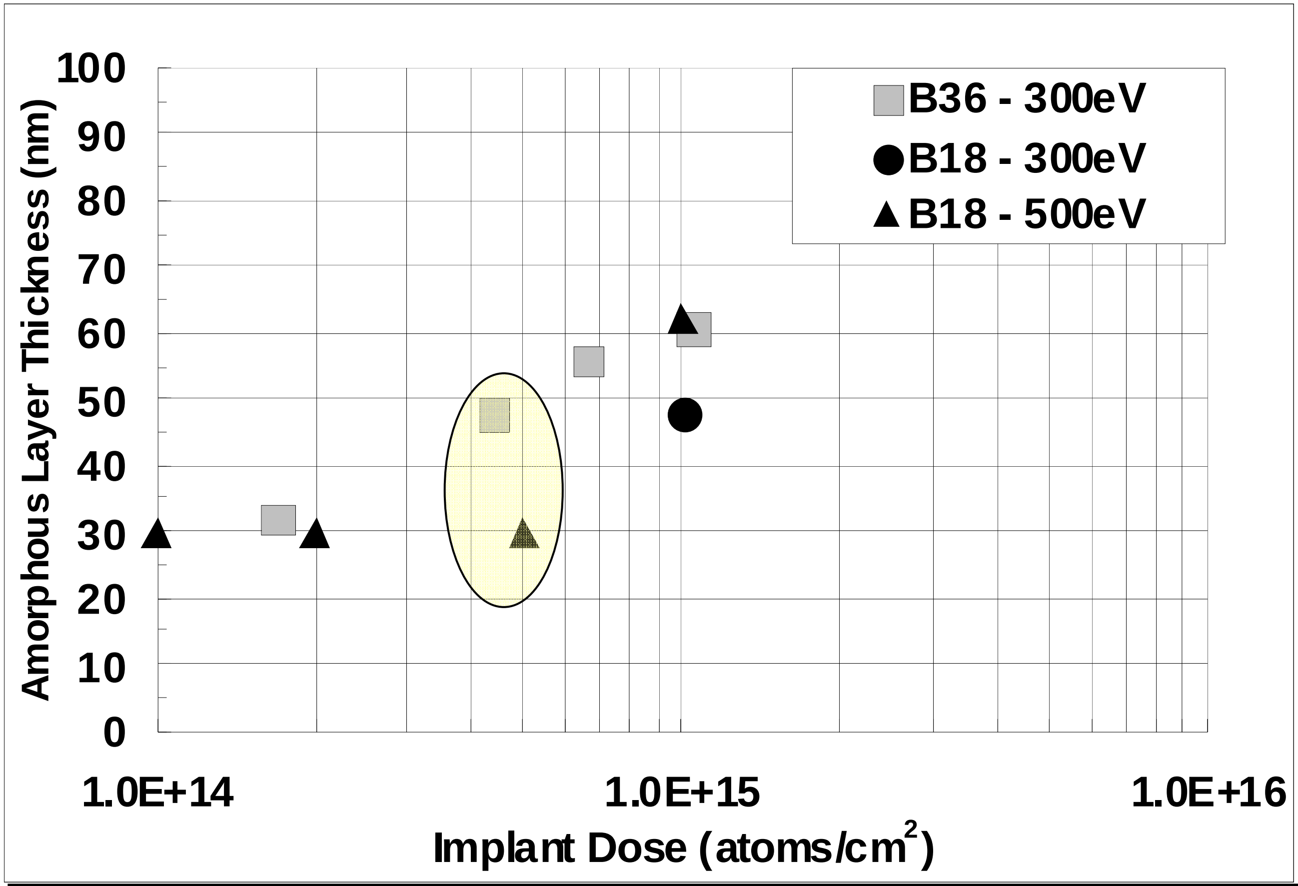


1.7e14	4.4e14	6.6e14	1.04e15
30Ǻ	48Ǻ	56Ǻ	63Ǻ

- **Lower dose threshold for amorphization.`**

XTEM

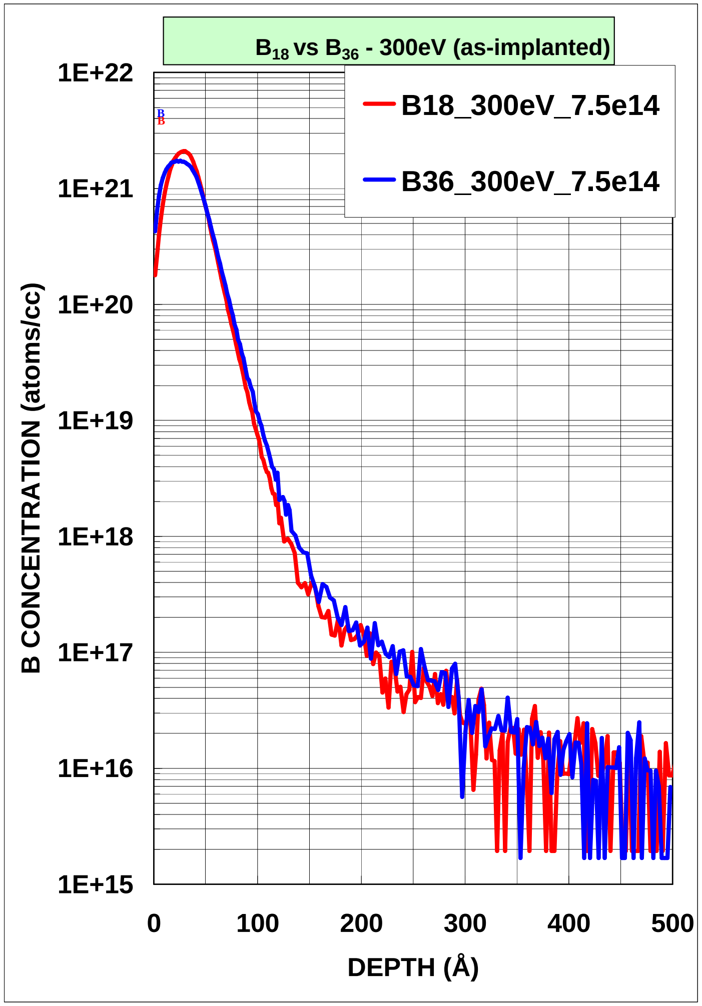
$B_{18}H_{22}$ and $B_{36}H_x$ – 300eV@1e15



Amorphization threshold is lower with B_{36} compared to B_{18} even for $E_{B36} < E_{B18}$

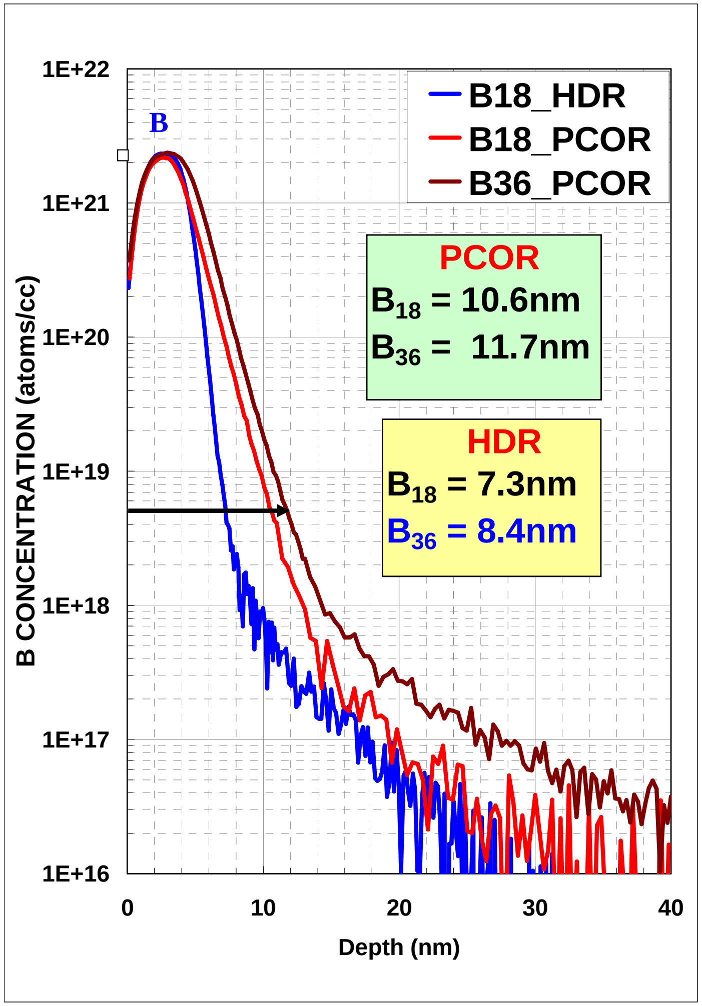
SIMS Profiles (Xj)

B_{18} vs B_{36} – 300eV @ 7.5e14 atoms/cm^2



SIMS profile for B_{36} is slightly deeper than B_{18}. At a boron concentration of 5e18 atoms/cm^3, the difference in Xj between B_{18} and B_{36} is around 5Å.

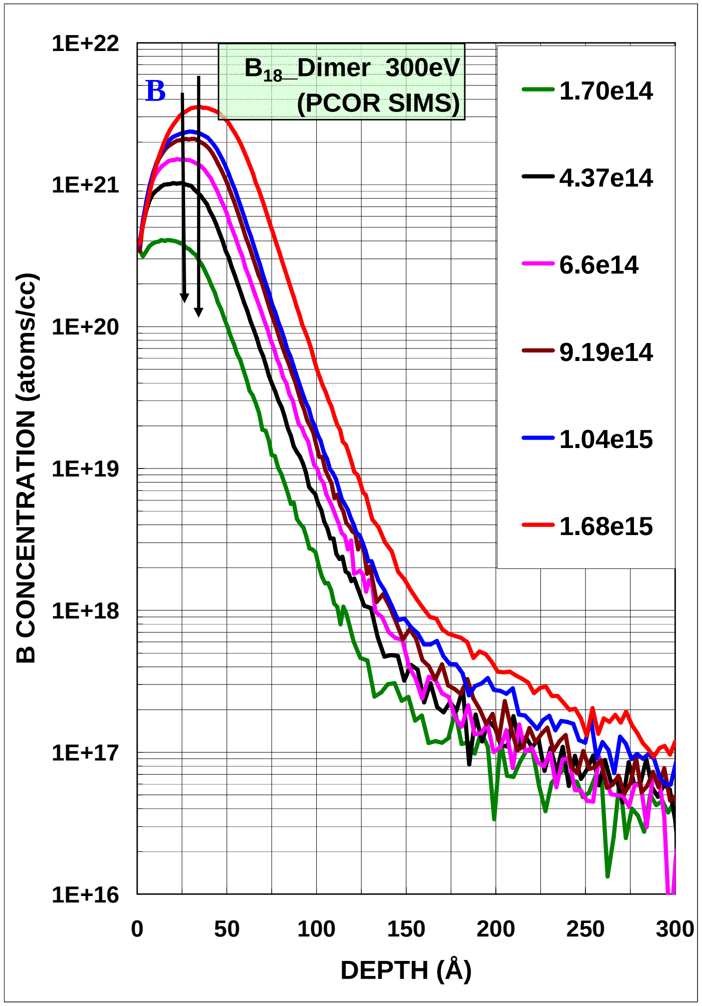
$B_{18}H_{22}$ & $B_{36}H_x$ @ 300eV _1e15
HDR & PCOR protocol



SIMS profile for HDR protocol is shallower than PCOR protocol.

At concentration of 1e18, the difference in Xj is about 4nm.

$B_{36}H_x$ at 300eV – Dose Sequence SIMS Profile PCOR



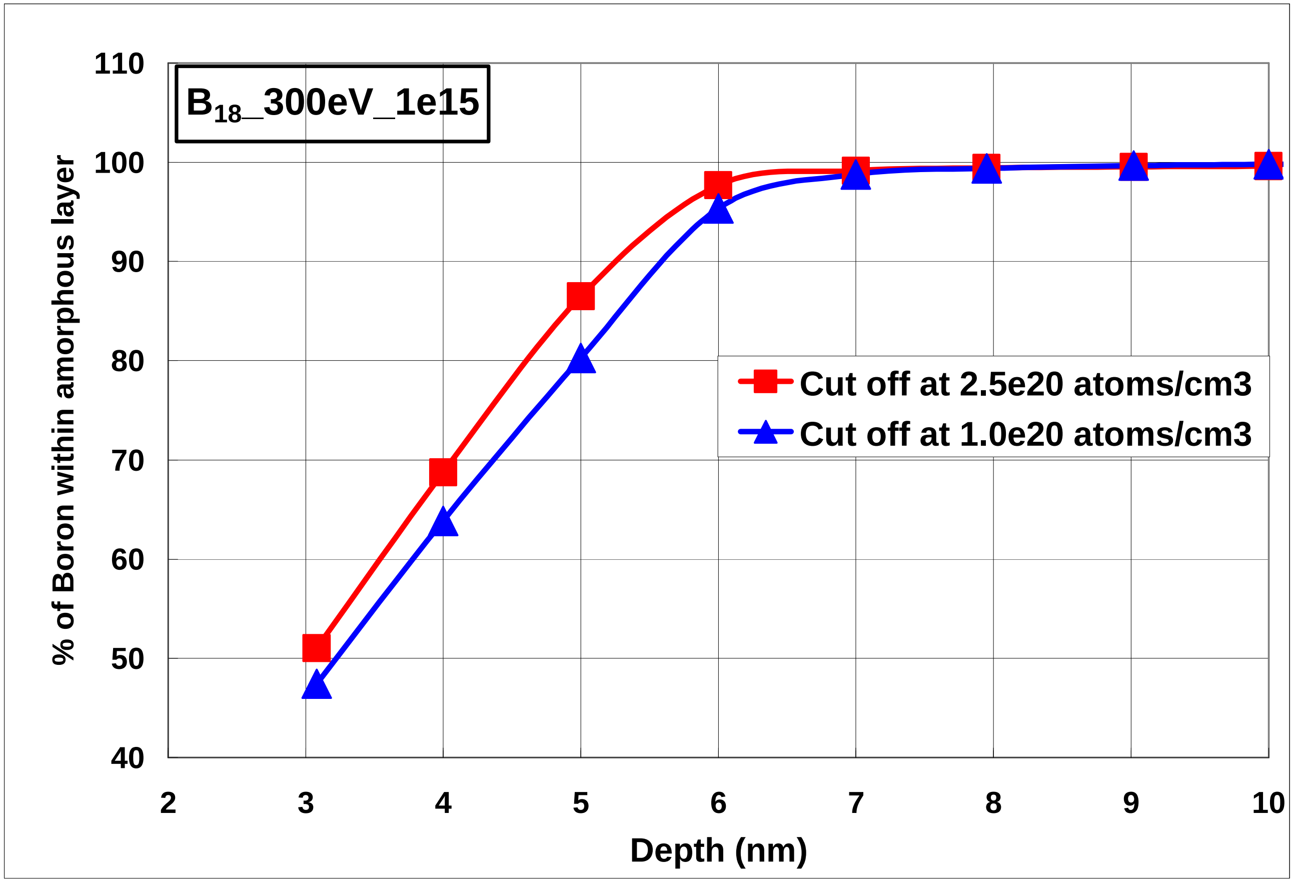
For 300eV dimer B_{36} implant, beyond 7e14 dose, the Rp shifts deeper.

Xj ranges from 8nm to 12.5nm for dose range from 2e14 to 2e15 atoms/cm^2

Clearing the way Effect :

- **V.I.Shulga and P.Sigmond , Nucl. Instr. and Meth B, Vol. 47, p.236, (1990).**
- **Matsuo et al MRS (1998)p.17 (at cluster size > 10, Rp is larger than monomer)**

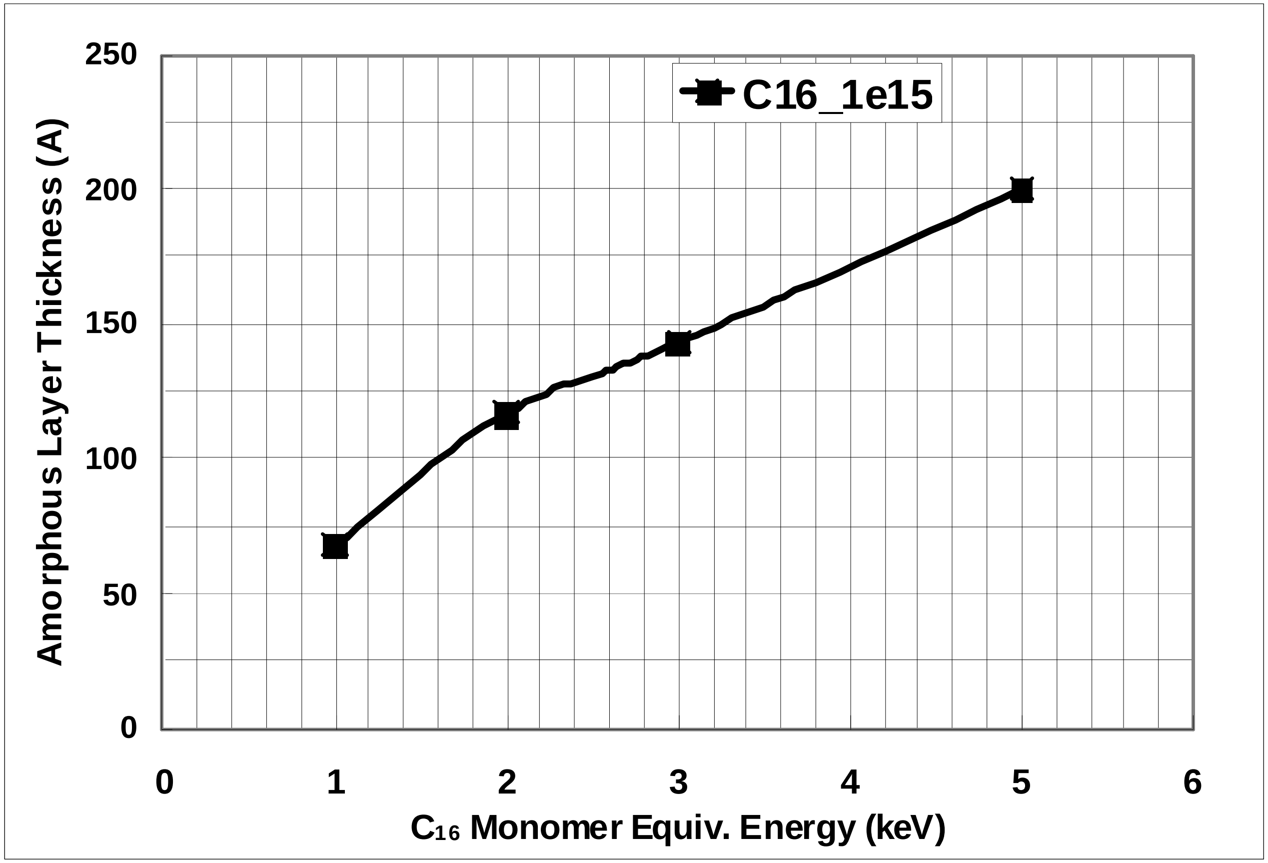
Percentage of implanted Boron within α-Si layer : B_{18}- 300eV @ 1e15



About 30% more boron is present in the α-Si for a difference of 20Å thickness in α-Si (40Å and 60Å).

C_{16} co-implant @ 1e15 atoms/cm^2

α-Si thickness



Provides a guidance to chose an energy and dose to obtain a given α-Si thickness

Retained dose vs. screen/native oxide

- Simulation via Marlowe
  - From Krull, et al, IIT 1998

Oxide (A)	1000eV	500eV	250eV
10	0.91	0.80	0.66
20	0.82	0.62	0.31
30	0.68	0.38	0.09

Millisecond anneal (Flash and Laser)

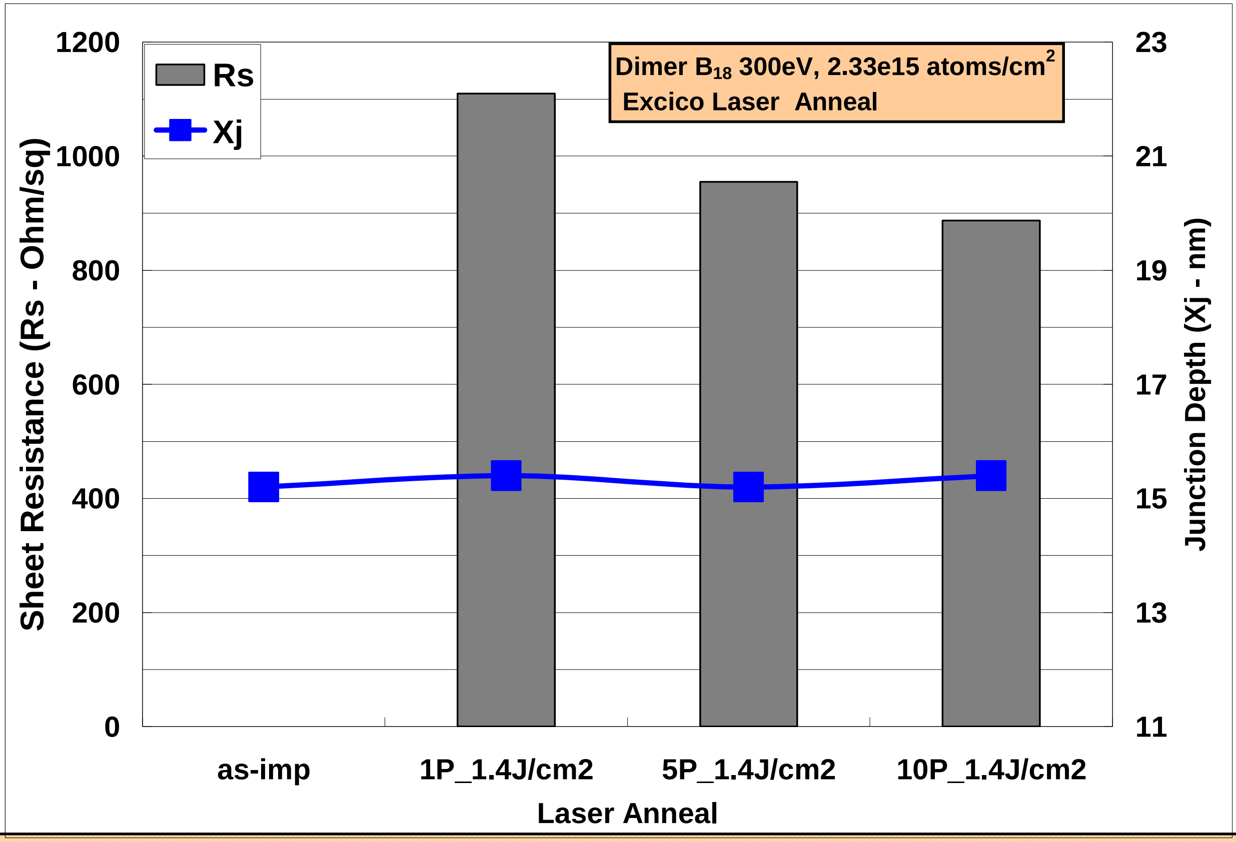
Rs and Xj Results

$B_{36}H_x$ – 300eV, 2.3e15 atoms/cm^2

Dimer $B_{18}H_{22}$ - 300eV, 2.33e15 atoms/cm^2 Excico Laser Anneal			
Sample	Rs (Ohm/sq)	Xj at 5e18 (PCOR) (nm)	SIMS dose (atoms/cm^2)
as-imp	x	15.2	2.33E+15
1P_1.4J/cm^2	1110	15.4	2.31E+15
5P_1.4J/cm^2	955	15.2	2.30E+15
10P_1.4J/cm^2	887	15.4	2.29E+15

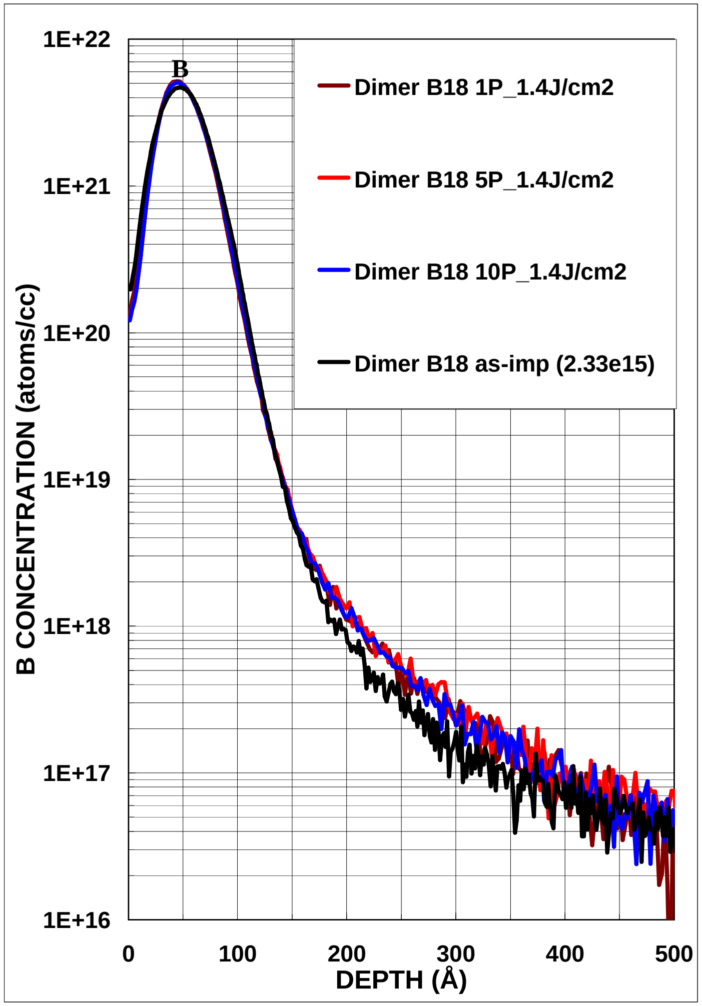
Good Rs number is obtained for a laser energy density for 10P 1.4 J/cm^2. Practically there is no change in Xj values. Higher number of pulses increases boron activation.

Rs & Xj Results : $B_{36}H_x$ – 300eV, 2.33e15 atoms/cm^2 Excico Laser Anneal



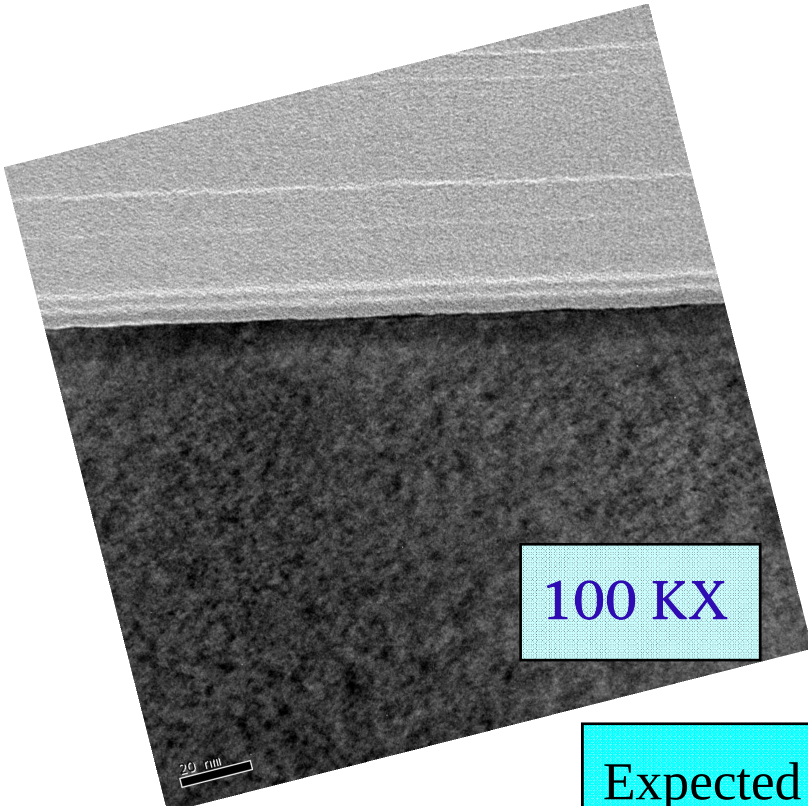
No change in Xj for various # of laser pulses at a laser energy density of 1.4J/cm^2. But Rs lower by about 20% for 10 pulse case.

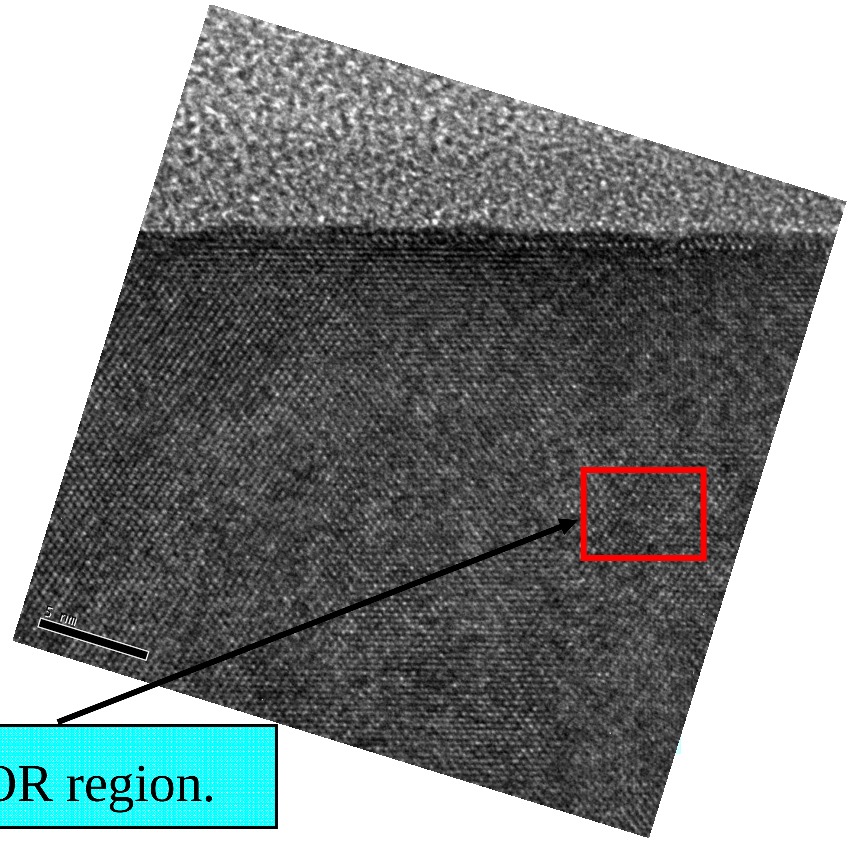
$B_{36}H_x$ – 300eV, 2.33e15 atoms/cm^2
Excico Laser Anneal



Practically no change in Xj after anneal at 5e18 atoms/cm^3.

$B_{36}H_x$ – 300eV, 2.33e15 atoms/cm^2
Excico Laser Anneal

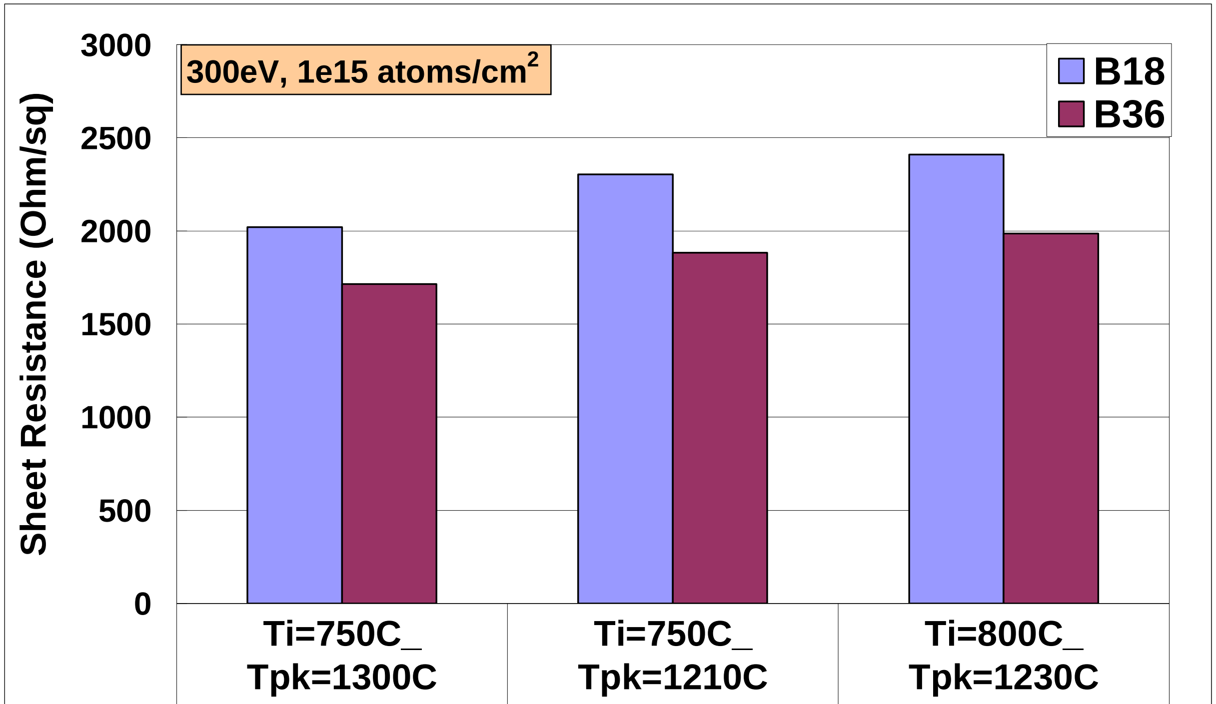




No obvious extended defects observed even with high boron dose.

B_{36} vs B_{18} – 300eV, 1.0e15 atoms/cm^2

Flash Anneal

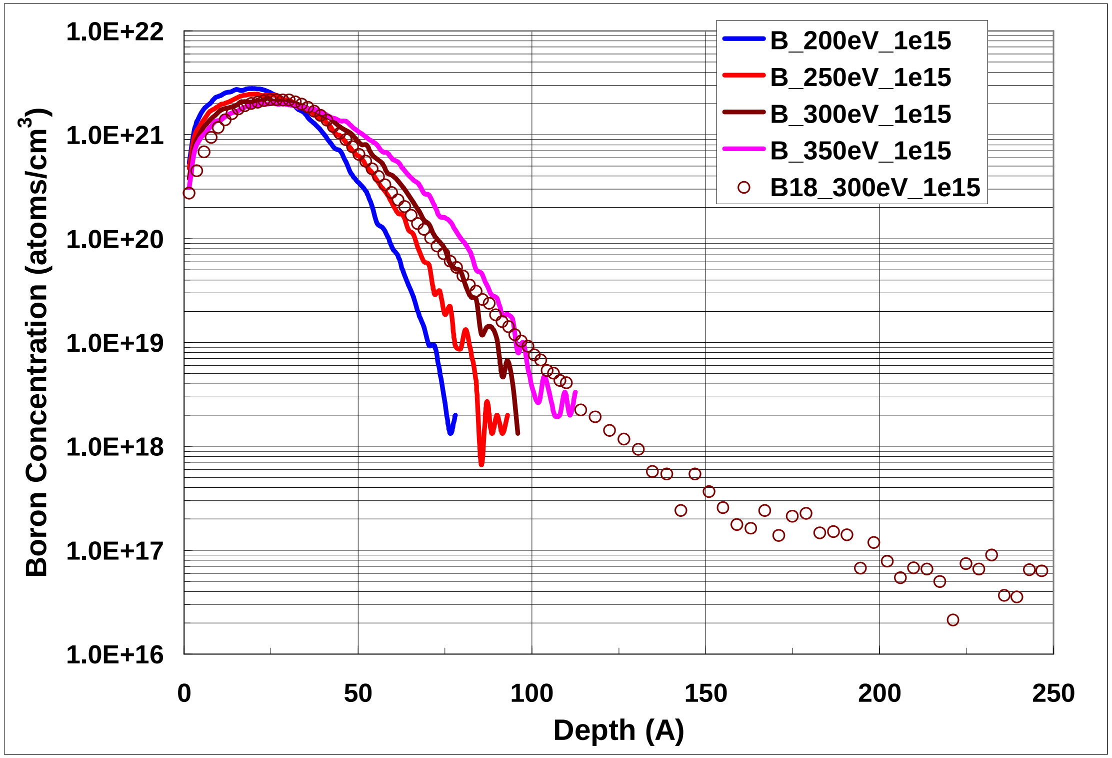


	Ti=750C_ Tpk=1300C	Ti=750C_ Tpk=1210C	Ti=800C_ Tpk=1230C
B18	2019	2302	2409
B36	1714	1883	1986

B_{36} is better than B_{18} by 15 – 20%. Possible explanation could be due to the higher amorphous layer thickness from B_{36} implant.

SRIM simulation Boron

Xj below 10nm



By choosing the right dose and energy Xj less than 10nm could be easily realized either with B_{18} or Dimer B_{18}.

Summary

- ClusterBoron (especially heavier B_{36} species) is a good candidate for very ultra-low energy implants beyond 32nm technology nodes.
    - Shallow and abrupt junctions
    - Low Rs and contact resistance with no crystal regrowth defects
    - Throughput advantage at low energies with added process advantage
- B_{18} and B_{36} are good candidates where junctions less than 10nm are required.

Acknowledgments

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