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The Cluster Implant *Source*

USJ with ClusterBoron and ClusterCarbon co-implants

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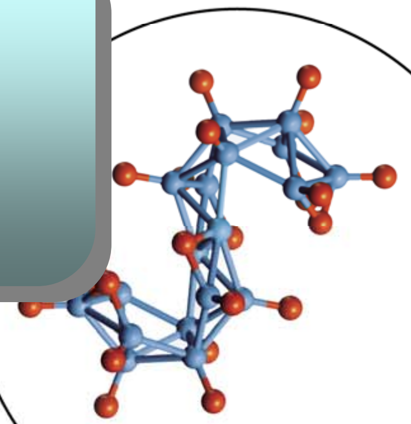

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Scheme : -

- Cluster Species for USJ applications (B_{18}, B_{36}, C_{16})
- Self-amorphization with ultra low energies (500eV and below) and impact on activation
- Cluster ion (C_{16}) as PAI & co-implant.
- Xj < 10nm and abrupt dopant profiles using Cluster species implants.
- B_{18} and B_{36} comparison with and without co-implant using millisecond and spike anneals.
- Results to support all the above statements.

Experiment

Implant Species

1) $B_{18}H_{22}$ (B_{18})

2) $[B_{18}H_{22}]_2$ (B_{36})

3) $C_{16}H_{10}$ (C_{16})

Implant Energy and Dose

1) 200eV, 300eV, 500eV

2) 5e14 - 1e15 atoms/cm^2

3) $C_{16}H_{10}$ - 3keV, 1e15 atoms/cm^2

Anneal

1) Impulse spike anneal (iRTP)

2) Flash Anneal (Mattson) (fRTP)

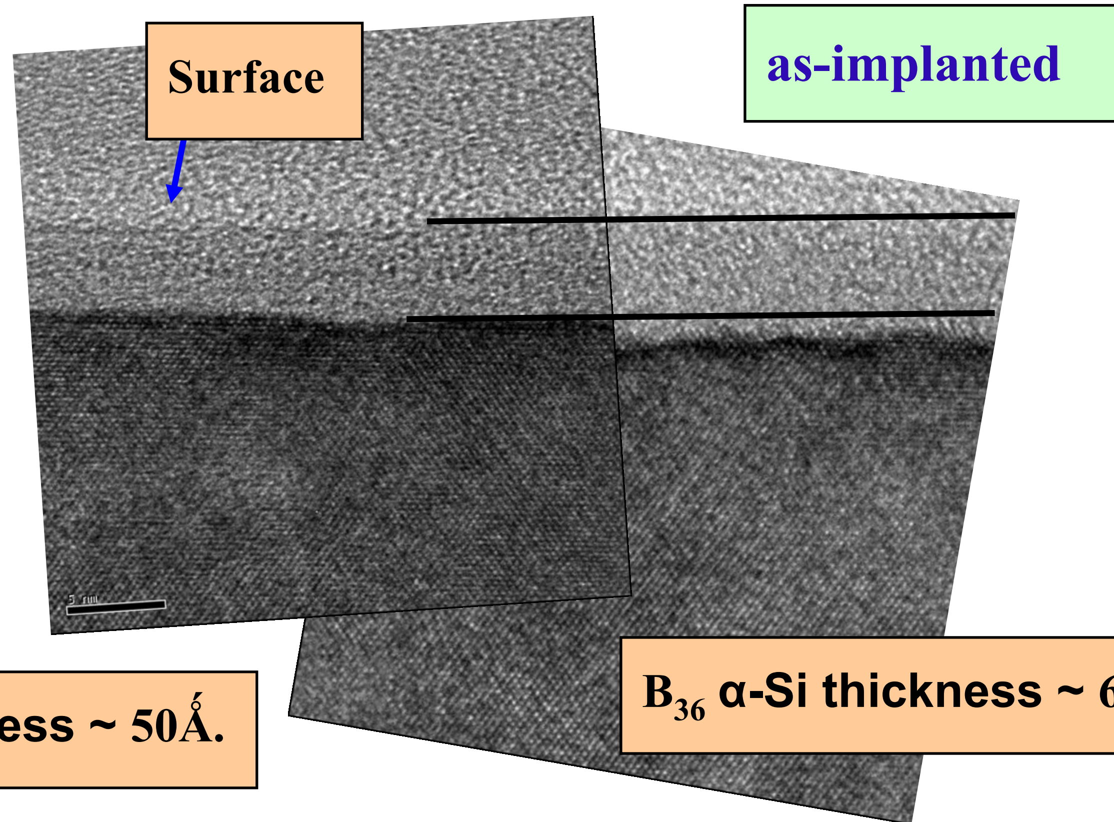
Metrology

1) Rs

2) SIMS

3) XTEM etc…

Self-amorphization - B_{18} vs B_{36}
300eV@1e15

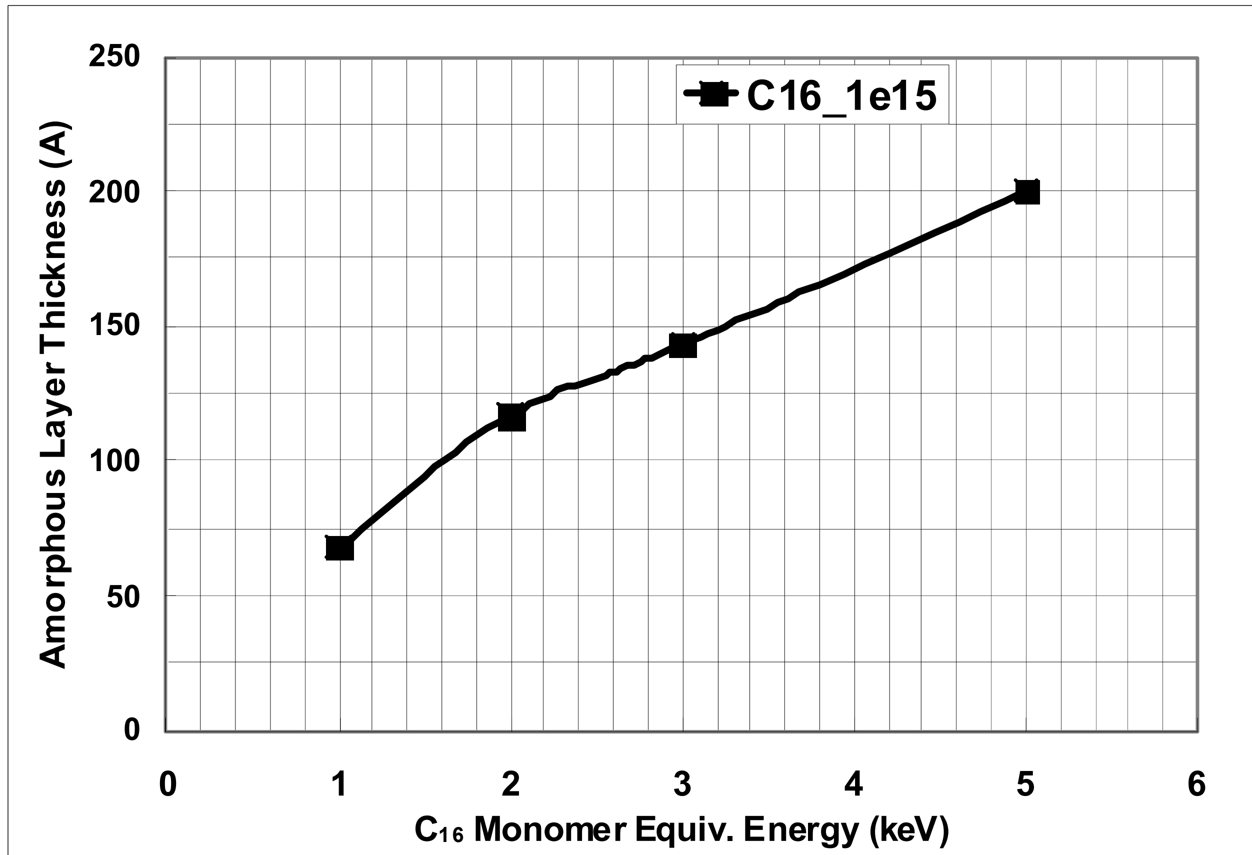


B_{18} α-Si thickness ~ 50Å.

B_{36} α-Si thickness ~ 63Å.

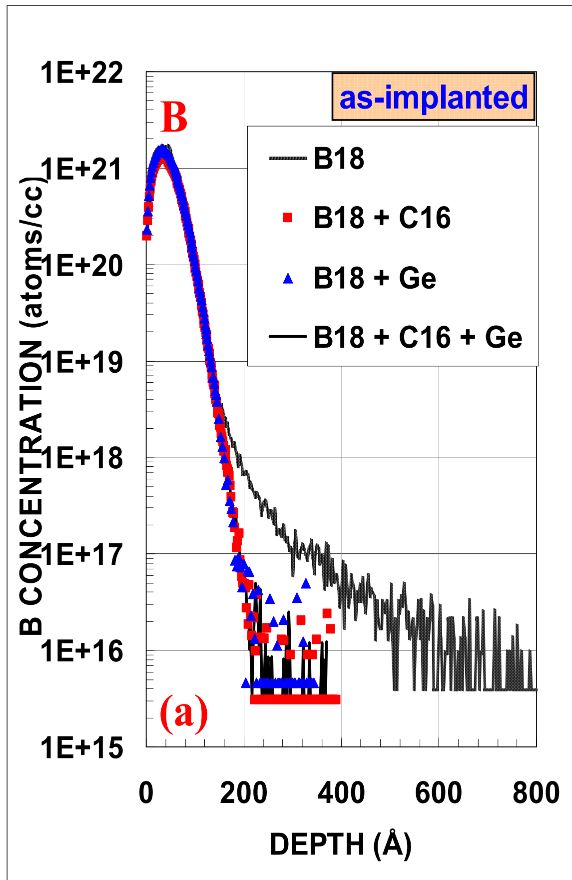
- Thicker amorphous layer leaves less Si interstitials for residual EOR defect formation and also less TED. All leads to higher dopant activation.

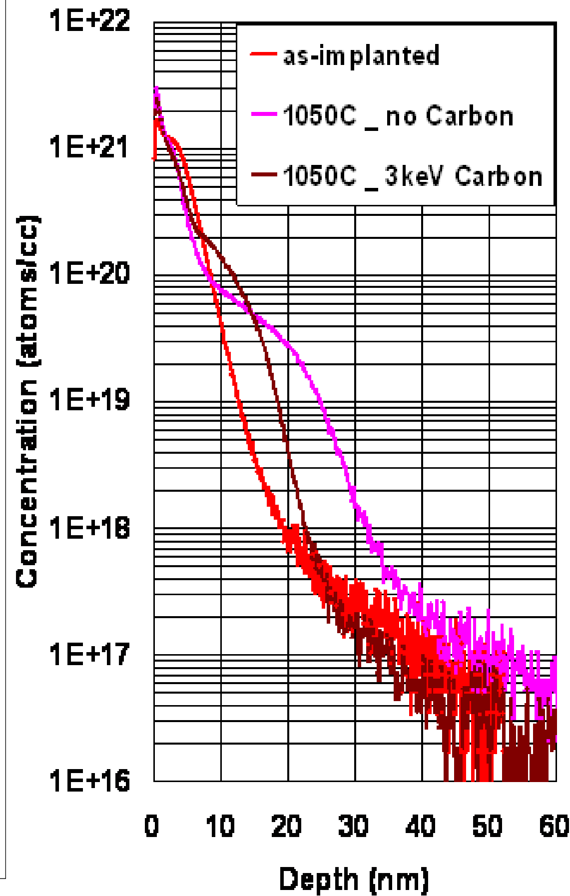
C_{16} co-implant @ 1e15 atoms/cm^2
α-Si thickness



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

$B_{18}H_{22}$ with $C_{16}H_{10}$
PAI & Co-implant to reduce diffusion



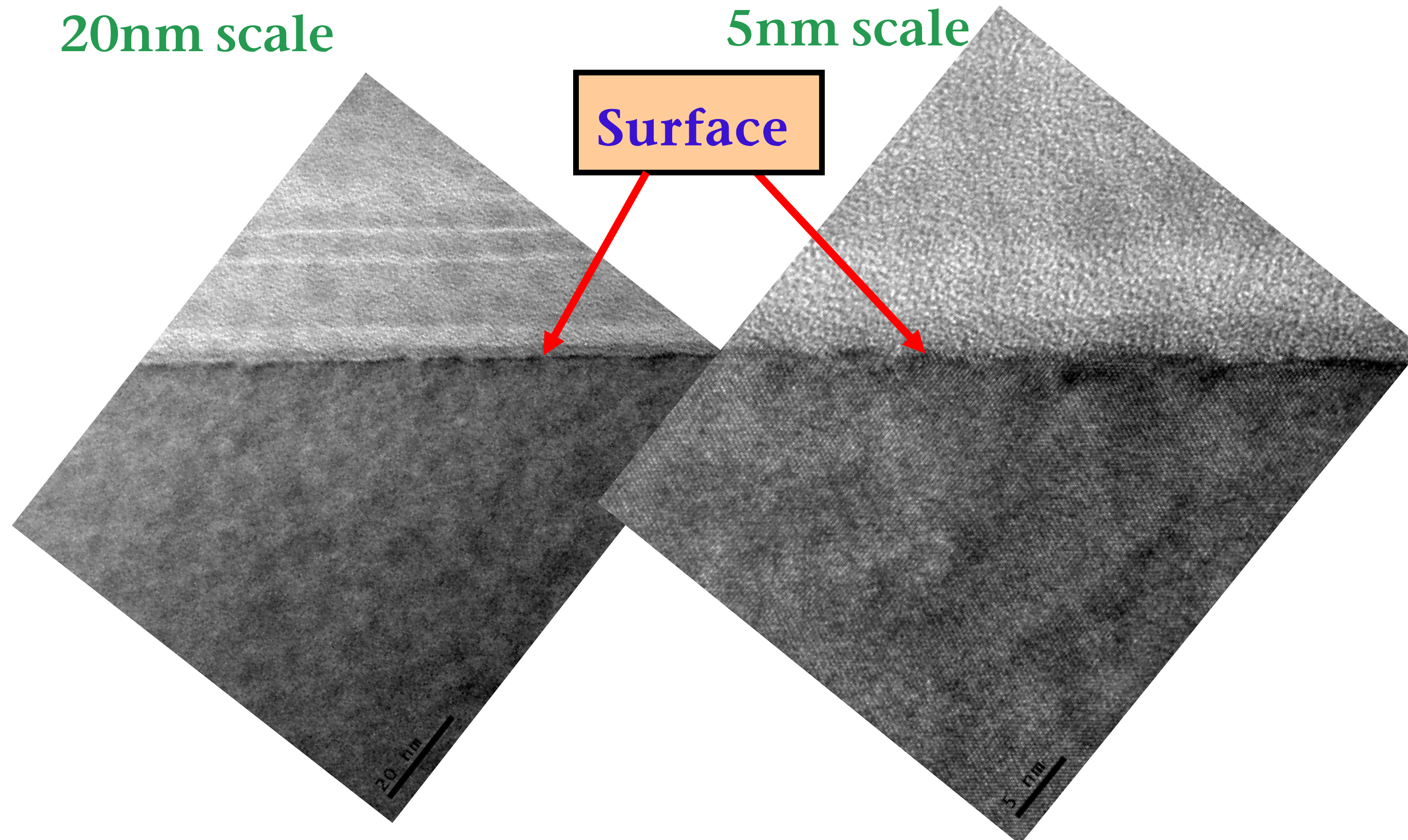


CARBON co-implant provides the following:

- Shallower junction
- Higher solid solubility
- Improved junction abruptness

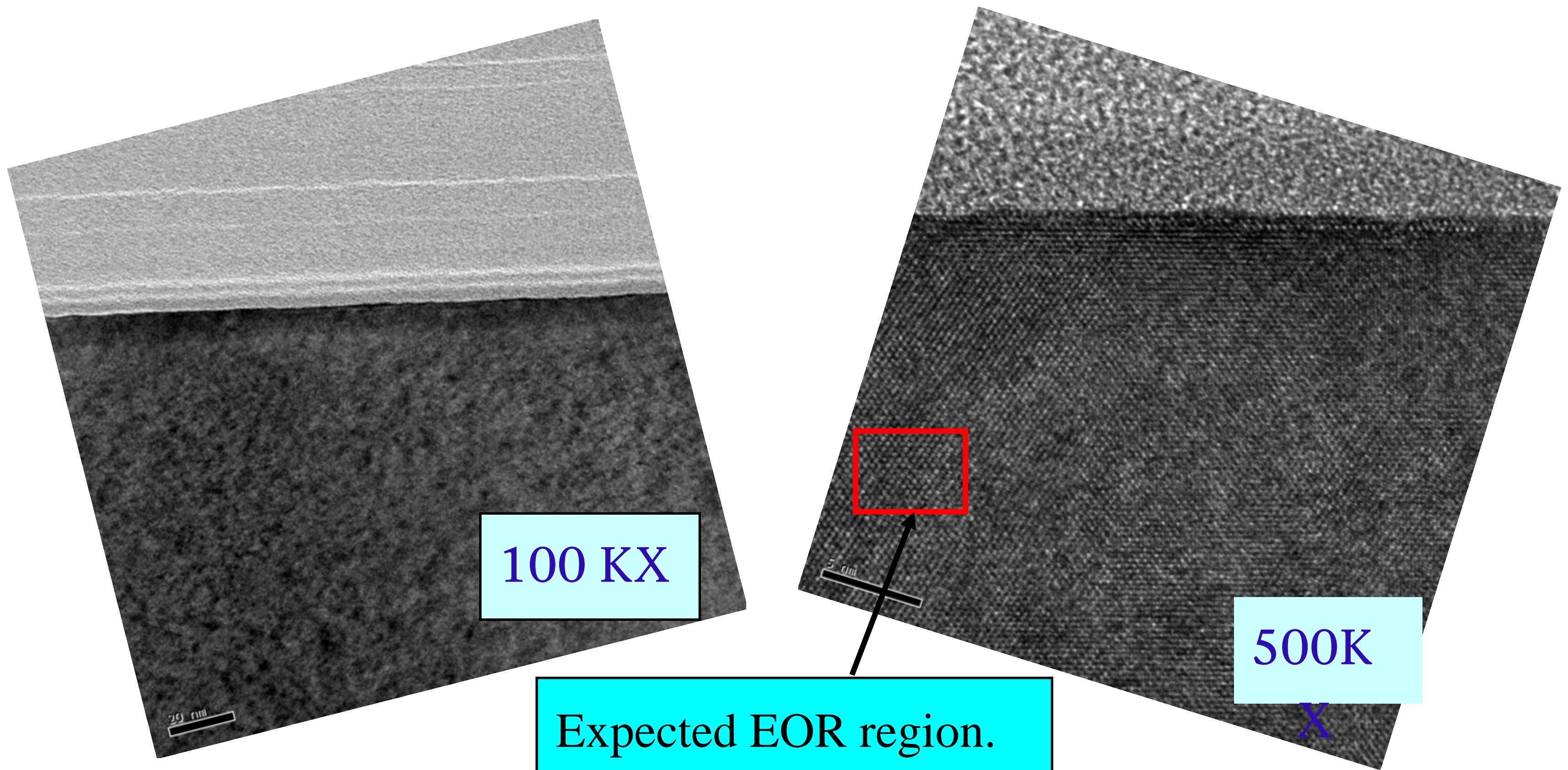
(Cluster Boron 500eV, 1e15 – Spike anneal 1050°C with and without Carbon)

X-TEM C_{16} (3keV) + B_{18} (0.5keV) @1e15 atoms/cm^2
950°C , 5 sec – annealed NO EOR DAMAGE



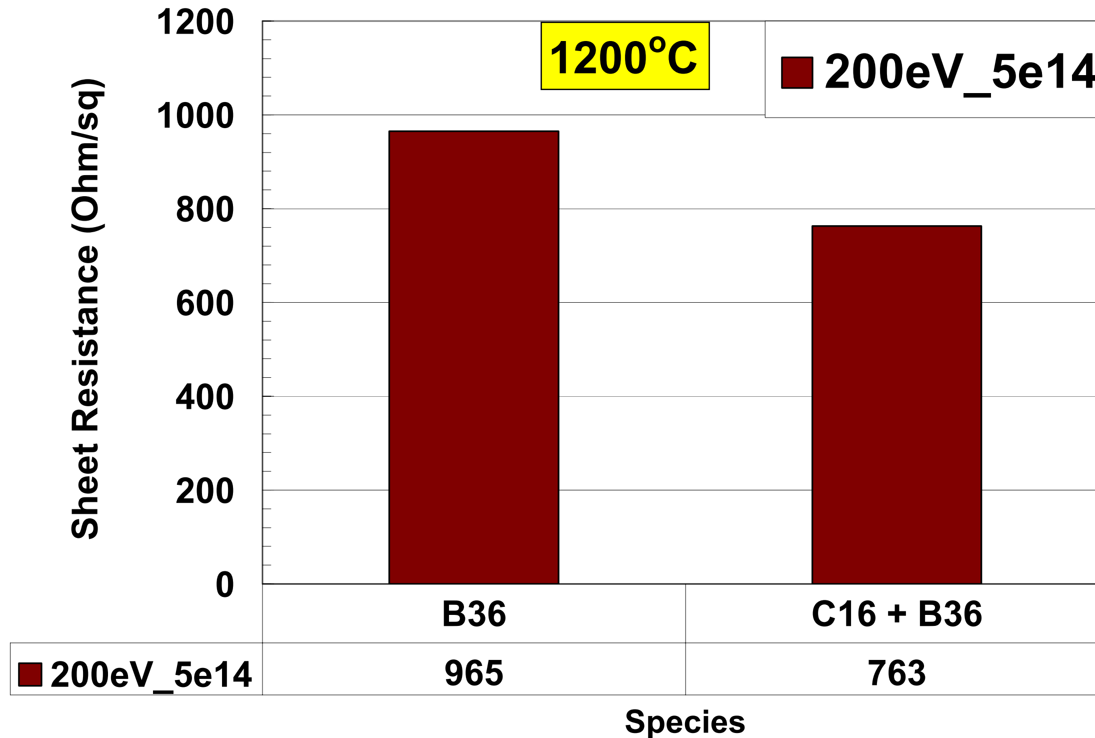
- No EOR damage is seen with TEM for 950°C 5 sec anneal

$B_{36}H_x$ – 300eV, 2.33e15 atoms/cm^2 – No EOR defect millisecond Anneal



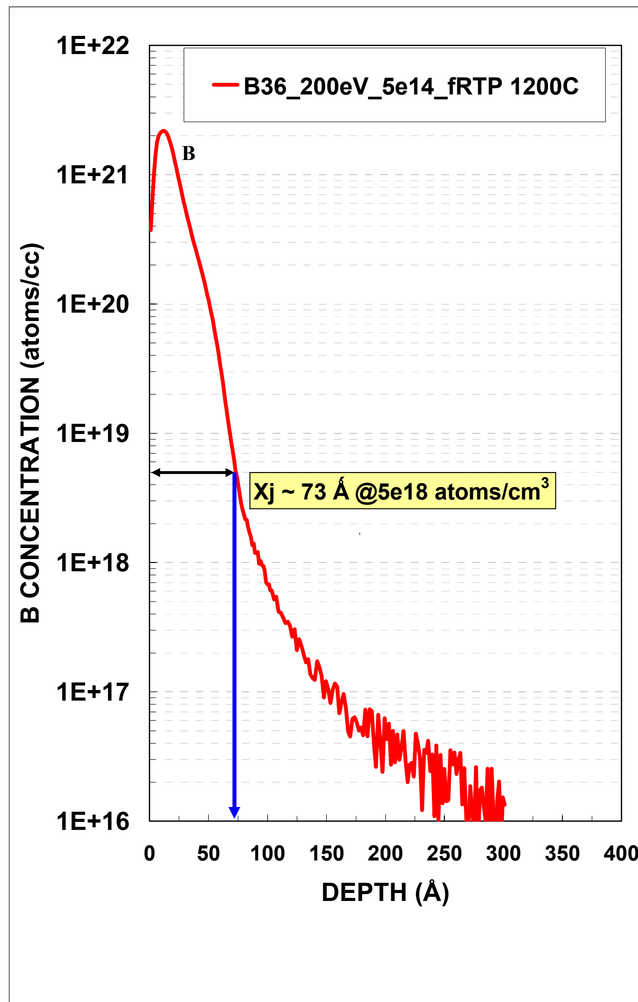
No obvious extended defects observed even with high boron dose.

B_{36} vs $C_{16} + B_{36}$ – 200eV, C_{16}_3keV
Flash Anneal co-implant effect



Using B_{36} or C_{16}+B_{36} one can get to low sheet resistance with millisecond anneal with Xj < 10nm

B_{36} – 200eV, C_{16}_3keV
Flash Anneal SIMS - Xj



Using B_{36} only without any PAI

Xj ~ 7.3 nm.

Rs ~ 965 Ohm/sq

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Rs, Xj, Abruptness comparison : B_{18} vs B_{36}

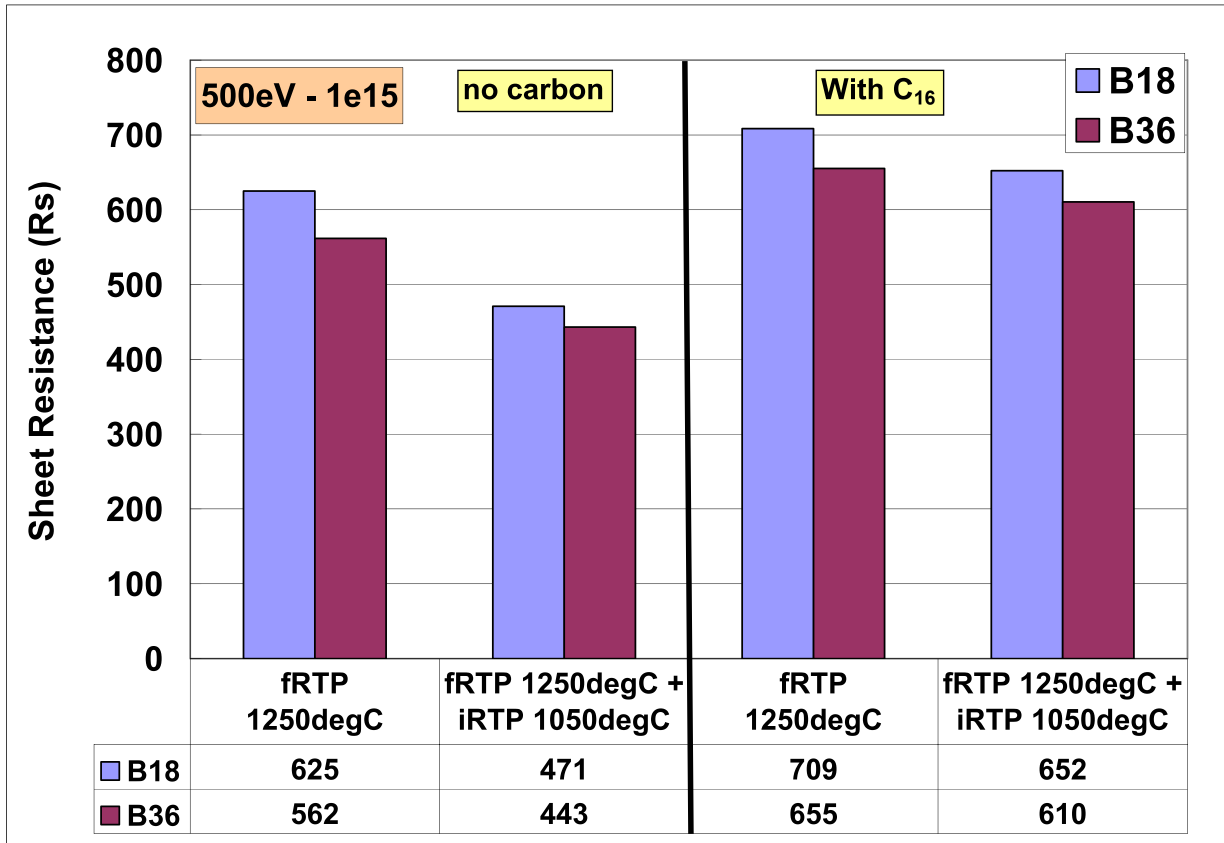
300eV, 9e14 (atoms/cm^2)		
Species	B_{18}	B_{36}
Rs (Ω/sq)	1228	815
Xj (nm)	9.1	9.8
Abruptness (nm/decade)	2.1	1.7

Rs, Xj, Abruptness comparison : B_{18} vs B_{36}

B_{18} / B_{36} - 500eV, 1e15 (atoms/cm^2) C_{16} - 3keV, 1e15 (atoms/cm^2)								
Anneal	fRTP 1250°C				fRTP 1250°C + iRTP 1050°C			
Species	B_{18}	B_{36}	$B_{18} + C_{16}$	$B_{36} + C_{16}$	B_{18}	B_{36}	$B_{18} + C_{16}$	$B_{36} + C_{16}$
Rs (Ohm/sq)	625	562	709	655	471	443	652	610
Xj (nm)	16.1	16.0	15.6	16.2	28.1	27.7	19.1	20.0
Abruptness (nm/decade)	4.2	4.2	3.4	3.5	12.5	12.5	4.3	4.7

Sheet Resistance (Rs) with and without Co-implant

B_{18} vs B_{36} – 500eV, C_{16}_3keV@ 1e15 atoms/cm^2

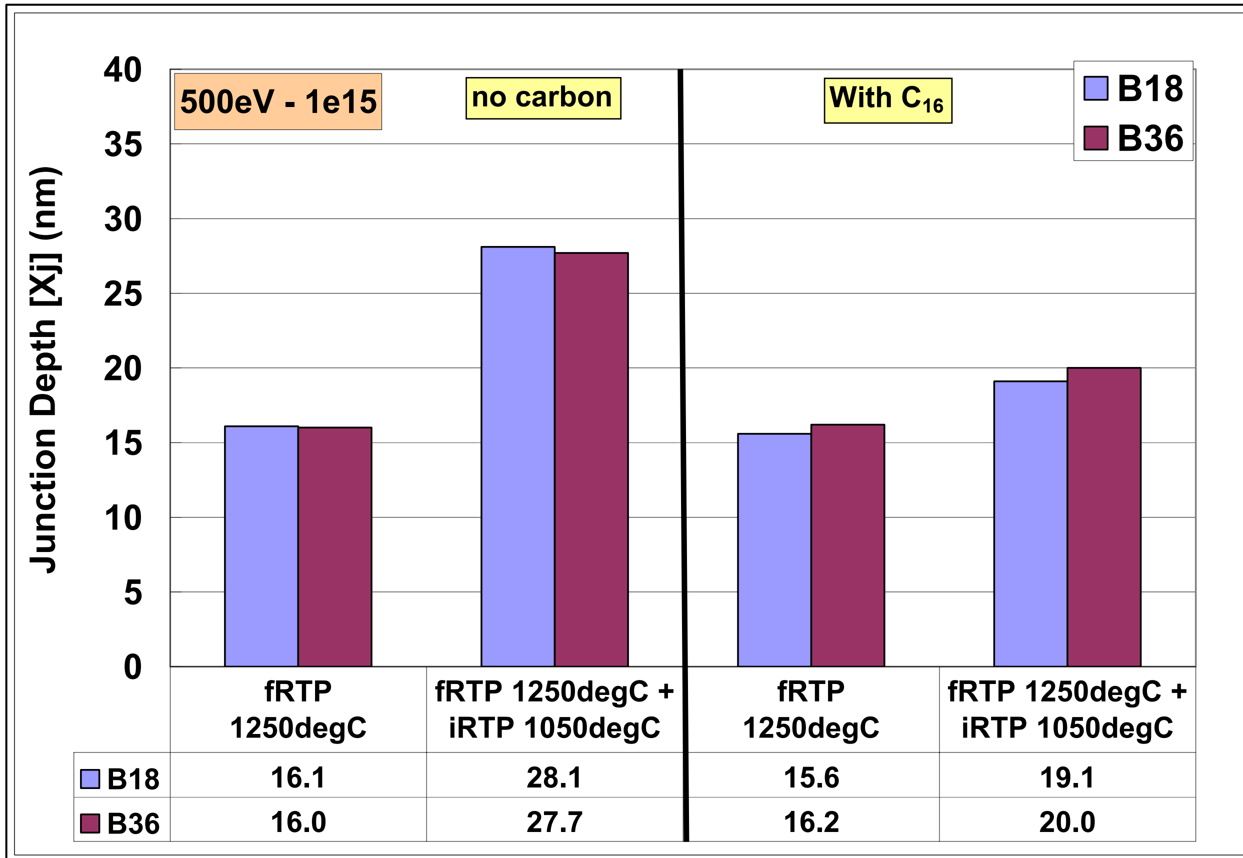


	fRTP 1250degC	fRTP 1250degC + iRTP 1050degC	fRTP 1250degC	fRTP 1250degC + iRTP 1050degC
B18	625	471	709	652
B36	562	443	655	610

- Rs with B_{36} is lower than B_{18} by about 6 – 10%
- 10% lower Rs for B_{36} with fRTP only anneal when compared to B_{18}.

Junction Depth (Xj) with and without Co-implant

B_{18} vs B_{36} – 500eV, C_{16}_3keV@ 1e15 atoms/cm^2

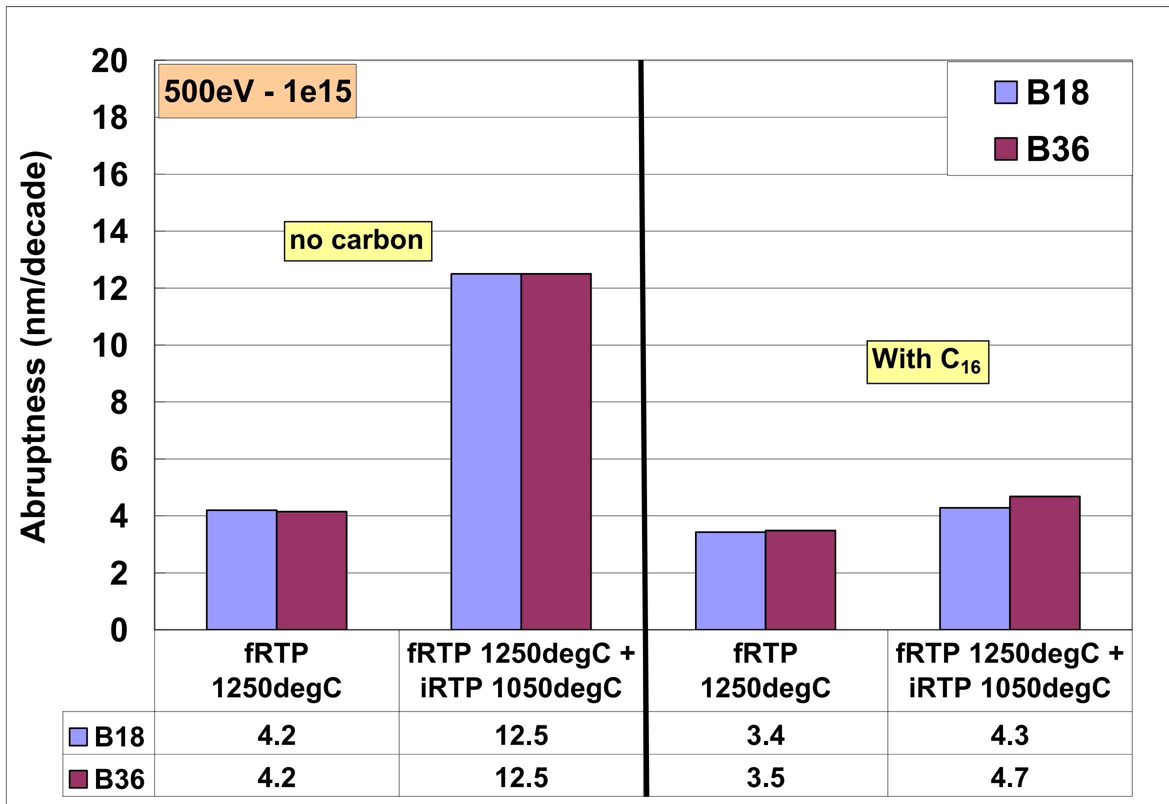


	fRTP 1250degC	fRTP 1250degC + iRTP 1050degC	fRTP 1250degC	fRTP 1250degC + iRTP 1050degC
B18	16.1	28.1	15.6	19.1
B36	16.0	27.7	16.2	20.0

- C_{16} co-implant is highly effective for spike anneal scenario in the form of lower Xj.
- 30% reduction in Xj, in the case of spike anneal.

Abruptness with and without Co-implant

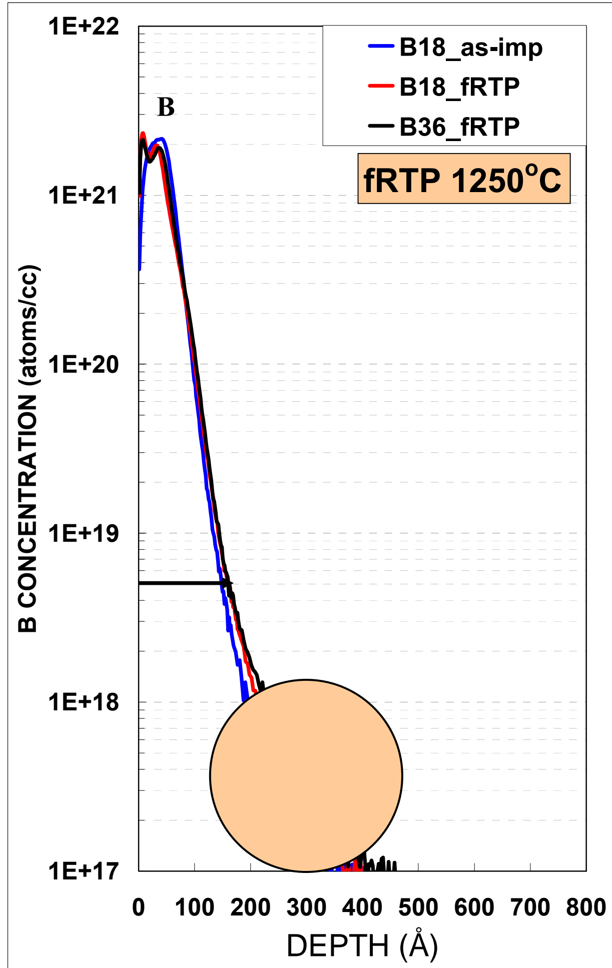
B_{18} vs B_{36} – 500eV, C_{16}_3keV@ 1e15 atoms/cm^2

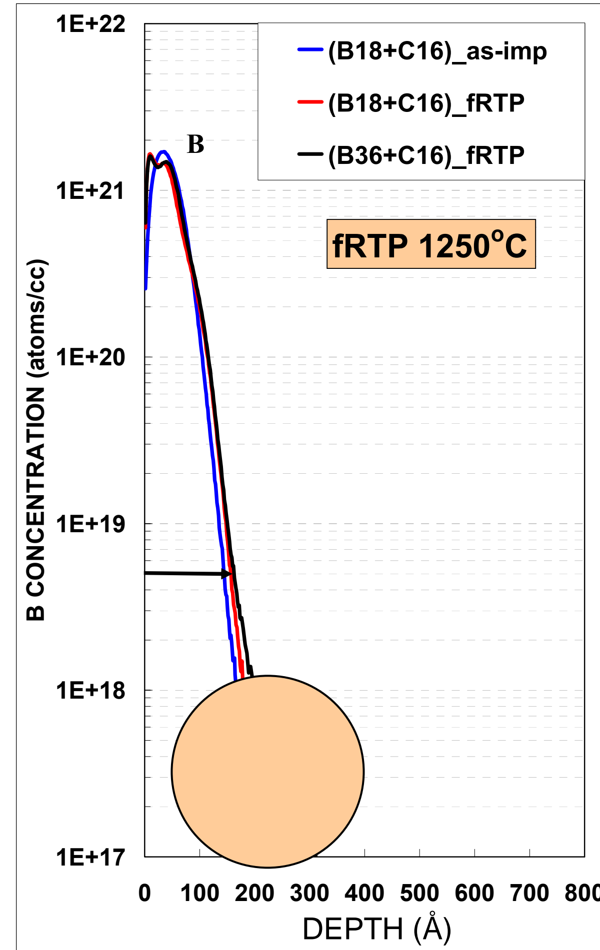


➢ Abruptness is similar between B18 and B36. Abruptness is large only for the spike anneal case without C_{16} co-implant . This is due to the diffusion of boron.

SIMS Profile - fRTP

B_{18} vs B_{36} – 500eV, C_{16}_3keV@ 1e15 atoms/cm^2





- With fRTP, the profiles are very similar except for the abruptness below 1e18 conc.

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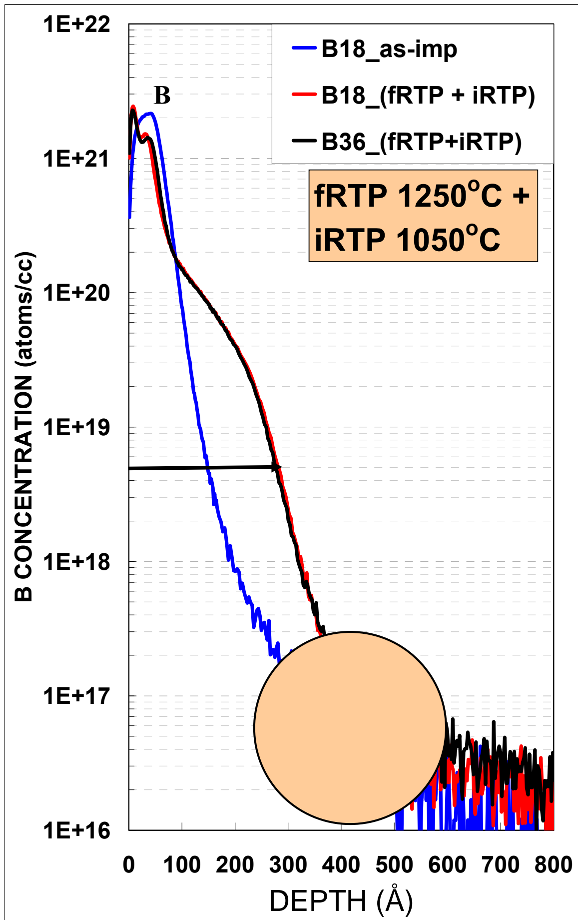
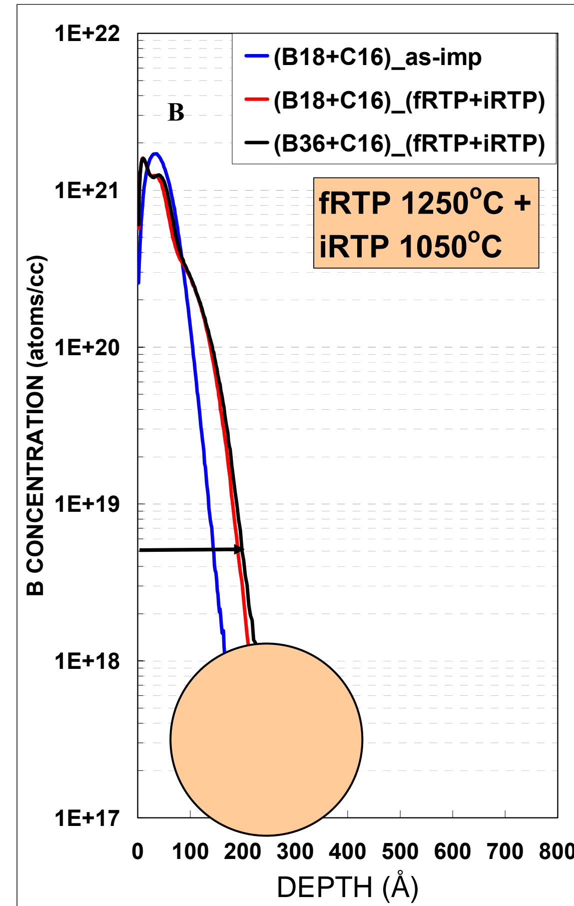
SIMS Profile – (fRTP + iRTP)

B_{18} vs B_{36} – 500eV, C_{16}_3keV@ 1e15 atoms/cm^2





➢ Under (fRTP+iRTP) anneal, C_{16} is very effective in trapping Si interstitials and thus reduced Xj.

Summary

- Heavier cluster ion (B_{36}) shows roughly 30% higher amorphous layer thickness when compared to B_{18} for low energies (300eV)
  - better activation, no EOR defect after MSA anneal.
- Junction depth at 5e18 atoms/cm^3 is less than 8nm for achievable with B_{36}
- At higher energy (500eV), B_{18} and B_{36} behave very similar, other than the 10% lower Rs with B_{36} implant.
- The effect of C_{16} co-implant is similar for both B_{18} and B_{36}.
- Depending on the process or productivity requirement, either B_{18} or B_{36} could be utilized.

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