Cluster Ion Implantation for Process Application
ー Carbon Cluster co-Implantationー

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Outline

1. Introduction & Motivation
2. Experimental
   2-1. Basic Condition
   2-2. Practical Condition
3. Results and Discussion
4. Conclusion

1. Introduction: Cluster Ion Implantation

- Efficient Low Energy Beam Transportation
- Effective High Current Implantation

Application

Self-amorphization, Less EORD, High Activation

SDE, SD

Low Divergence & Low Incident Angle Variation

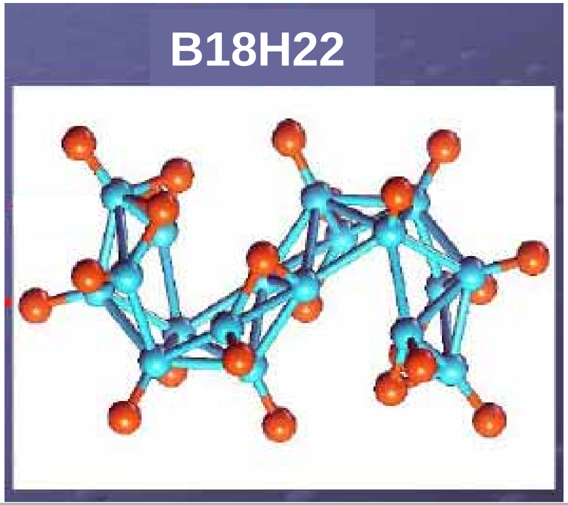
Deep Contact

Halo

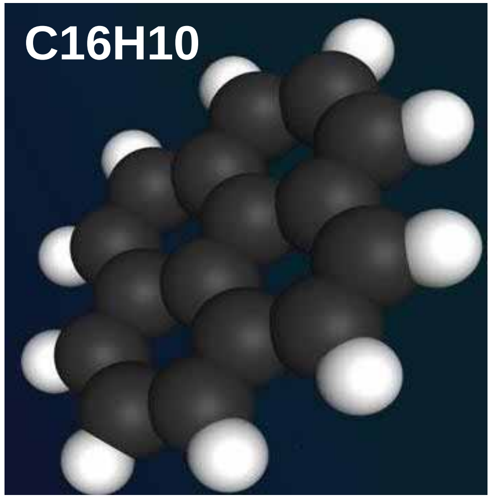
High Productivity

DPG

Octadecaborane

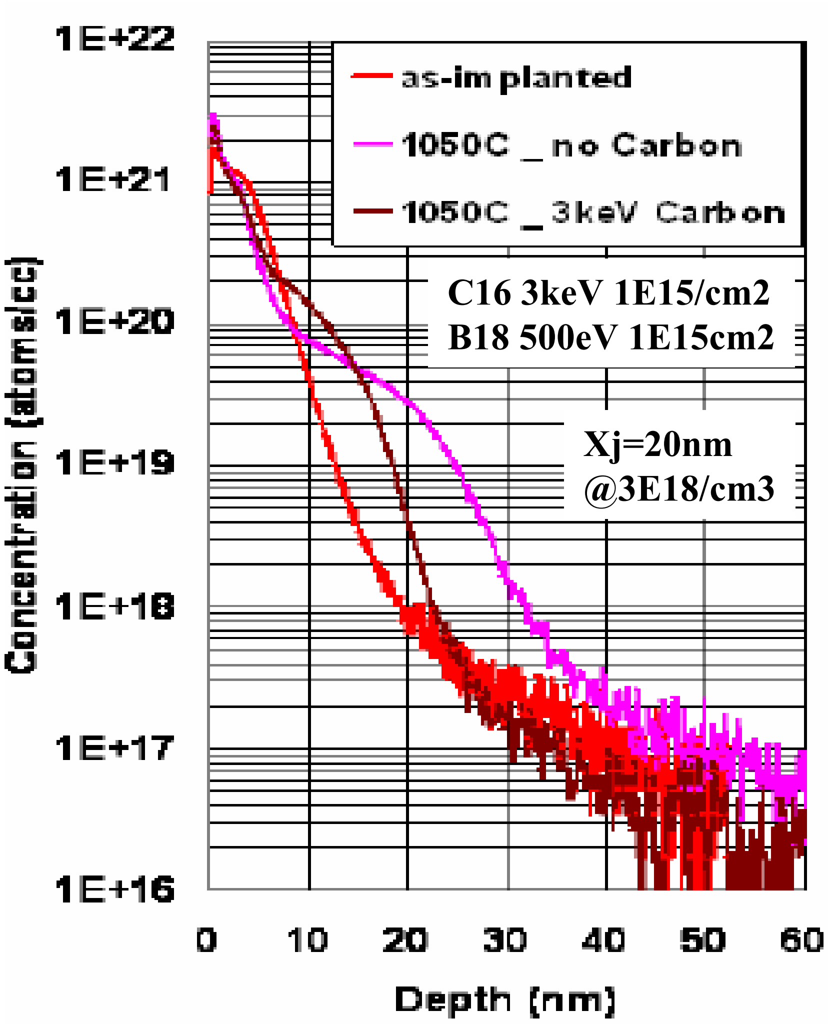


pyren



Carbon Cluster co-Implantation for PMOS

NISSIN ION EQUIPMENT CO.,LTD. Cluster CLARIS



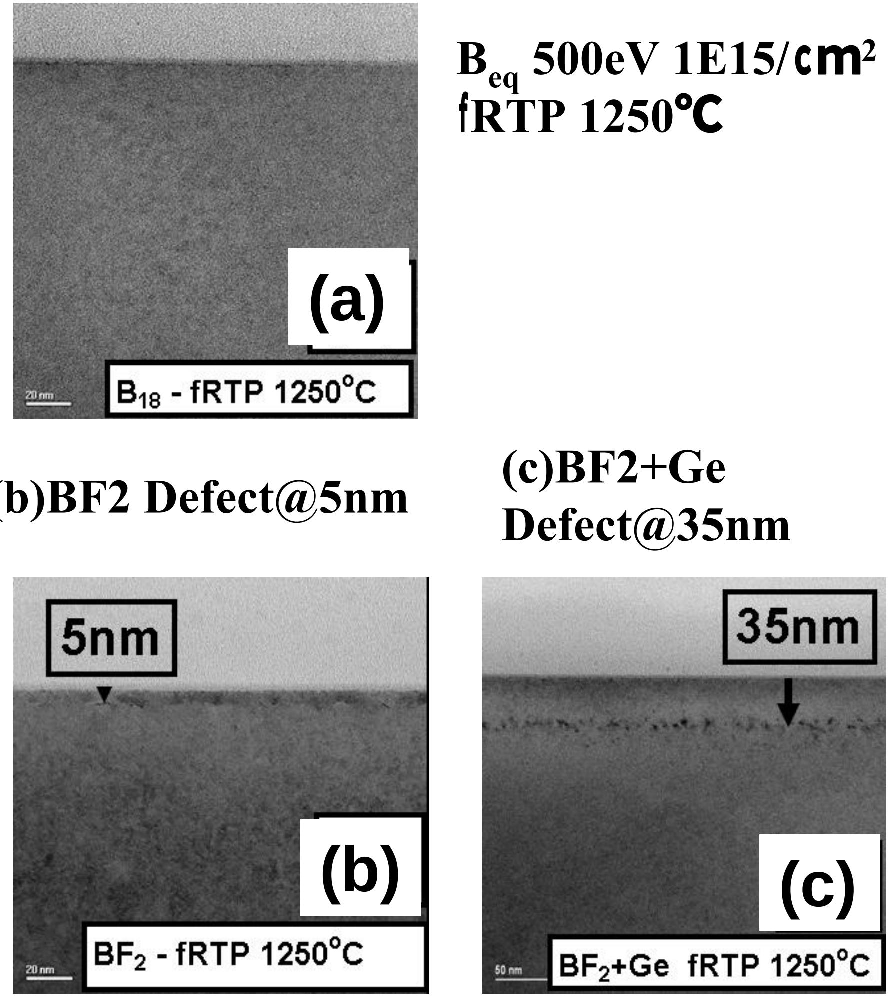
K.Sekar et.al, RTP2006
SemEquip. Inc.

(a)B18 Defect free

B_{eq} 500eV 1E15/cm²
fRTP 1250℃

(b)BF2 Defect@5nm

(c)BF2+Ge Defect@35nm



Single Carbon co-Impla. for NMOS

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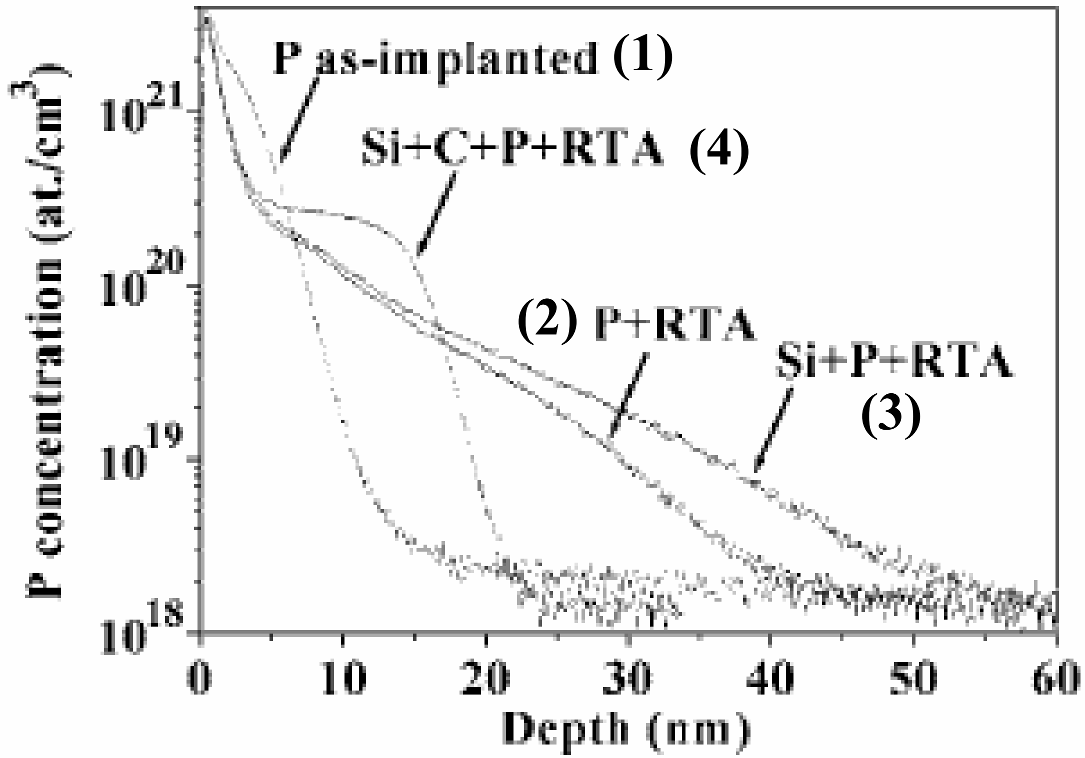
Cluster CLARIS

B.J.Pawlak et.al, Appl.Phy.Letter,**89**, 062102(2006)

Philips Res. Europe

Ion	Si	C	P	SRTA	Comment
Energy	50keV	6keV	1keV	T=1050 ℃	
Dose	1E15/cm2	1E15/cm2	7E14/cm2		
1			○		as I/I
2			○	○	TED
3	○		○	○	>TED
4	○	○	○	○	Box Profile

Si-PAI+ Single C suppresses P-TED



Single Carbon co-Impla. for NMOS; Si+C+P+RTA

B.J.Pawlak et.al, Appl.Phy.Letter,**89**, 062102(2006)

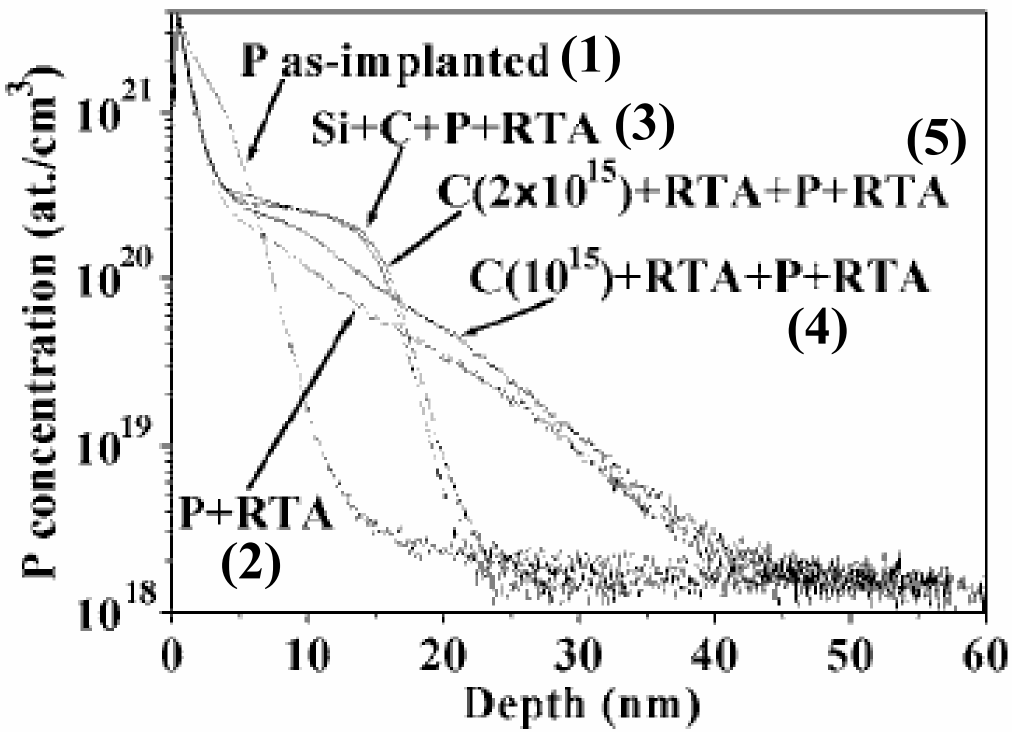
Philips Res. Europe

Ion	Si	C	SRTA	P	SRTA	Rs	Comment
Energy	50keV	6keV	1030 ℃	1keV	1050 ℃	(Ω/sq)	
Dose	1E15/cm2	(/cm2)		7E14/cm2			
1				○			as I/I
2				○	○		TED
3	○	1.E+15		○	○	326	Box Profile
4		1.E+15	○	○	○		>TED
5		2.E+15	○	○	○	374	Box Profile

No-PAI+C2E15+RTA suppresses P-TED, but higher Rs.

⇒ PAI+C1E15 is best solution.

Substitutional C exchanges i-Si, then sup. P-TED



2. Experiment(1): Cluster Carbon co-Implantation for NMOS

Conception : Si/Ge + C ⇒ C7 PAI & Co-Implantation
Intention : Low Rs･Xj & low leak current and high productivity

As/P Dose (/cm2)	C7 10keV Dose (/cm2)	Xj(nm) @5E18/cm3	Rs (Ω/sq)	Rs･Xj (Ω/sq･nm)
As 45keV 3E15	0	99.4	77.3	7687
P 15keV 3E15	0	129	60.6	7816
	5.0E+14	108	65.8	7109
	1.0E+15	89.5	71.4	6394
	2.0E+15	72.8	84.7	6169
	3.0E+15	66.6	99.0	6596

RTA 950 ℃ 10sec

Cluster Carbon co-Implantation for NMOS

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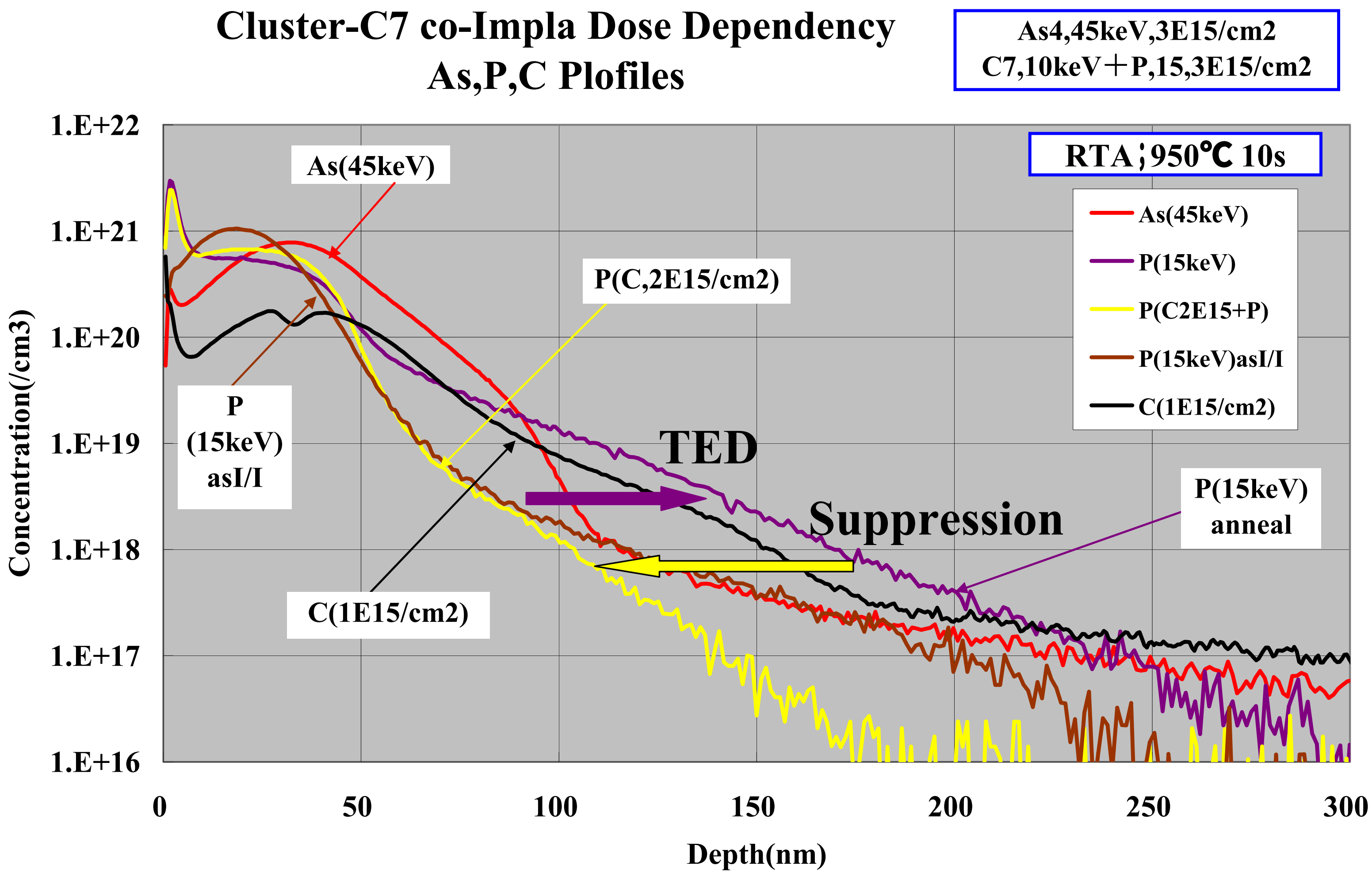
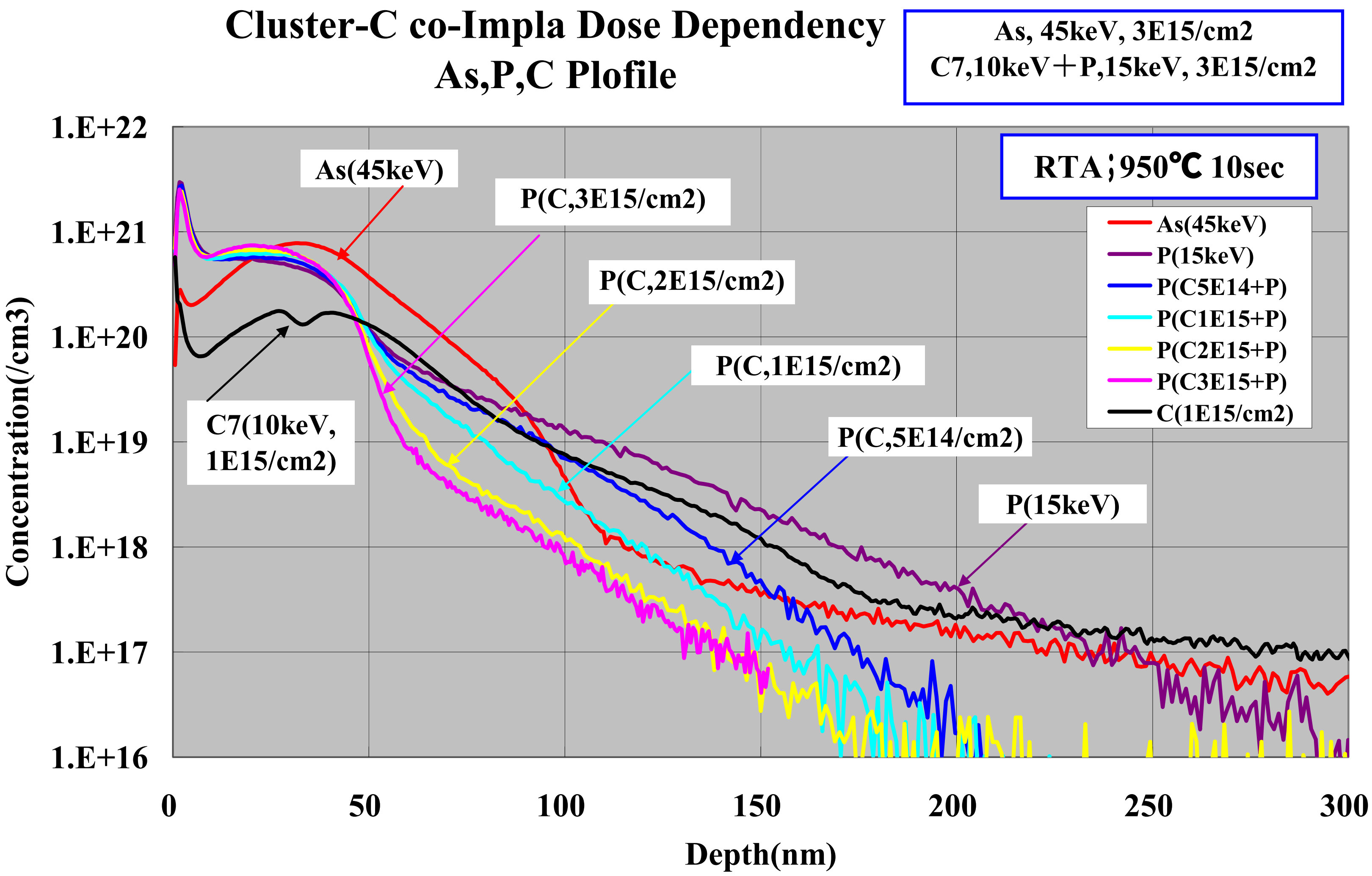
Si PAI+C⇒C7 co-Implantation



Si PAI+C⇒C7, P TED is suppressed.

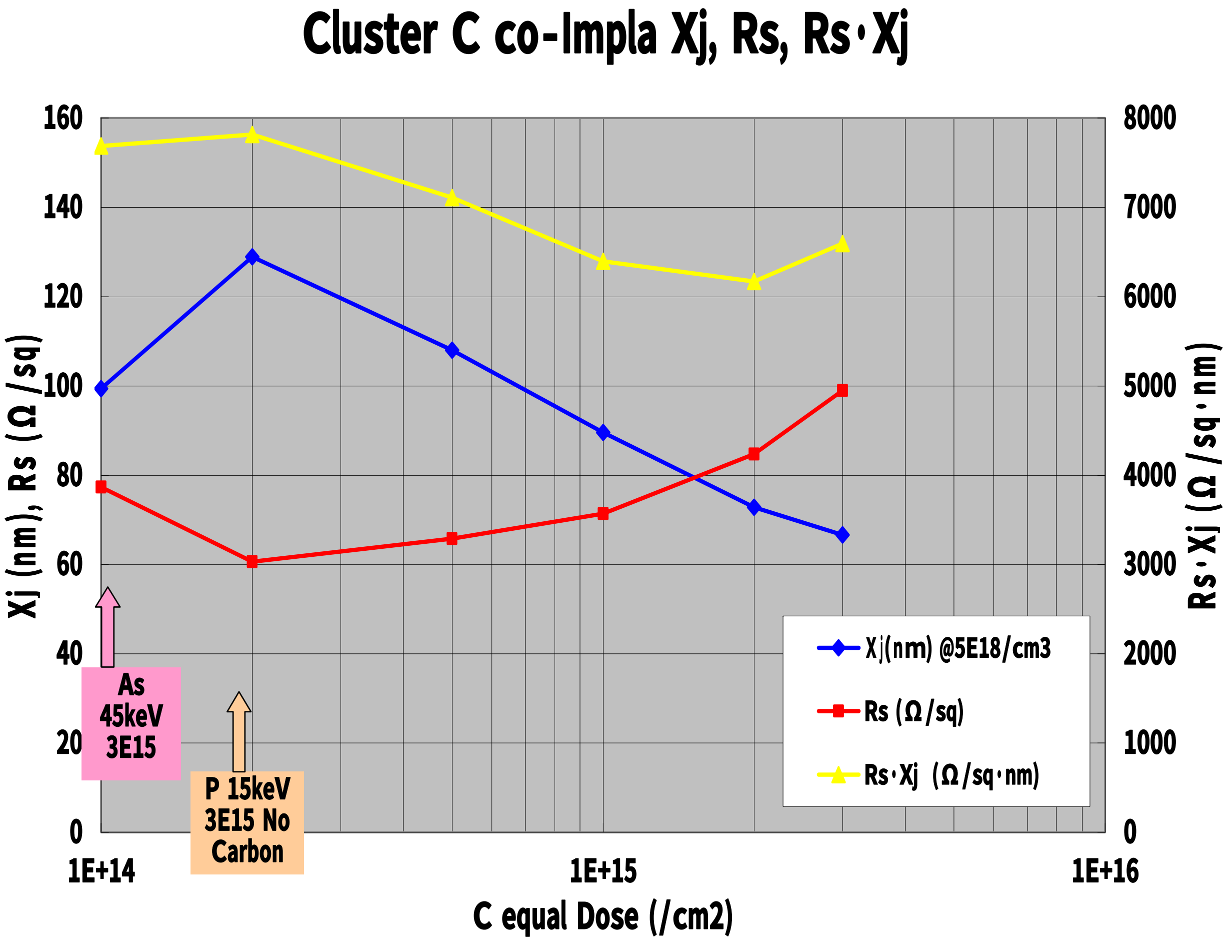
Carbon Cluster co-Implantation for NMOS



Si PAI+C⇒C7, P TED is suppressed.

Rs x Xj , C7 co-Implant; Dose Dependency.

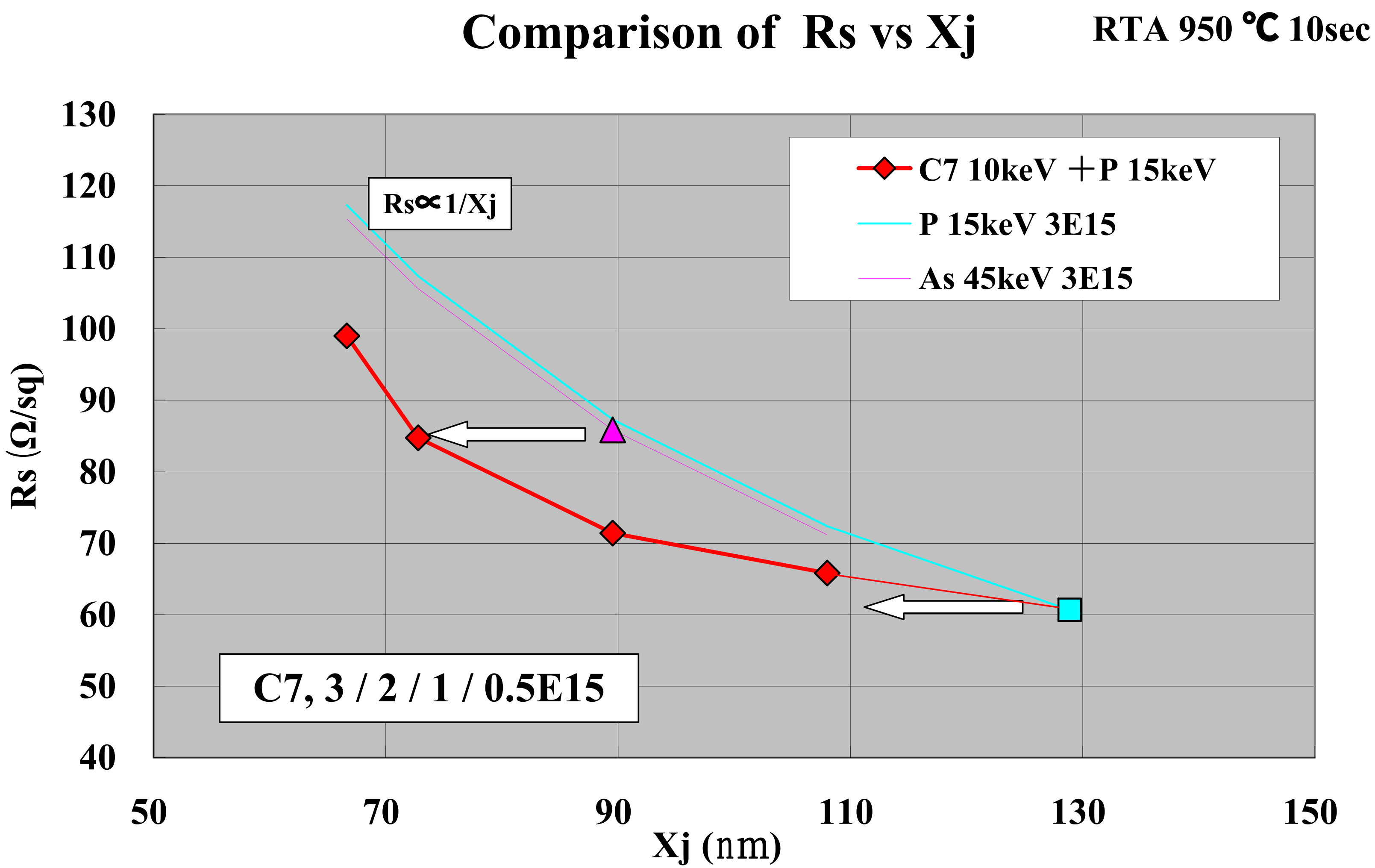
C7 10keV 0.5-3E15/cm2 + P 15keV 3E15/cm2, RTA 950 ℃ 10sec



Reference：
As,45keV,
3E15

P TED is suppressed by C7+P. Rs×Xj is improved better than As implant.

Comparison of Rs - Xj ; As・P vs. C7＋P



C7 co-Impla makes smaller Rs × Xj without Ge PAI

2. Experiment(2) Application for Device Condition

C7 Dose Dependency Condition & Result
As+P Double Implantation

Ion	C7H7	As4	P4	RTA 950℃	Rs(Ω/sq)	Xj(nm) @P3E18	Xj(nm) @As3E18	Rs・Xj (Ωnm) @P3E18	Comment
Energy	10keV	5keV	3keV						
Dose	(/cm2)	1E15/cm2	5E14/cm2						
1	–	○	○	–	592000	18	–	1.08E+07	as I/I
2	–	○	○	○	215	48	31	10208	TED
3	5.E+14	○	○	○	234	48	–	11145	=TED
4	1.E+15	○	○	○	248	34	27	8503	<TED
5	2.E+15	○	○	○	280	26	–	7156	Box Profile
6	3.E+15	○	○	○	312	25	–	7685	Box Plofile

(Acc. Voltage for C7;76kV, As4;20kV, P4;12kV)

C7 Dose Dependency, co-Implant SIMS

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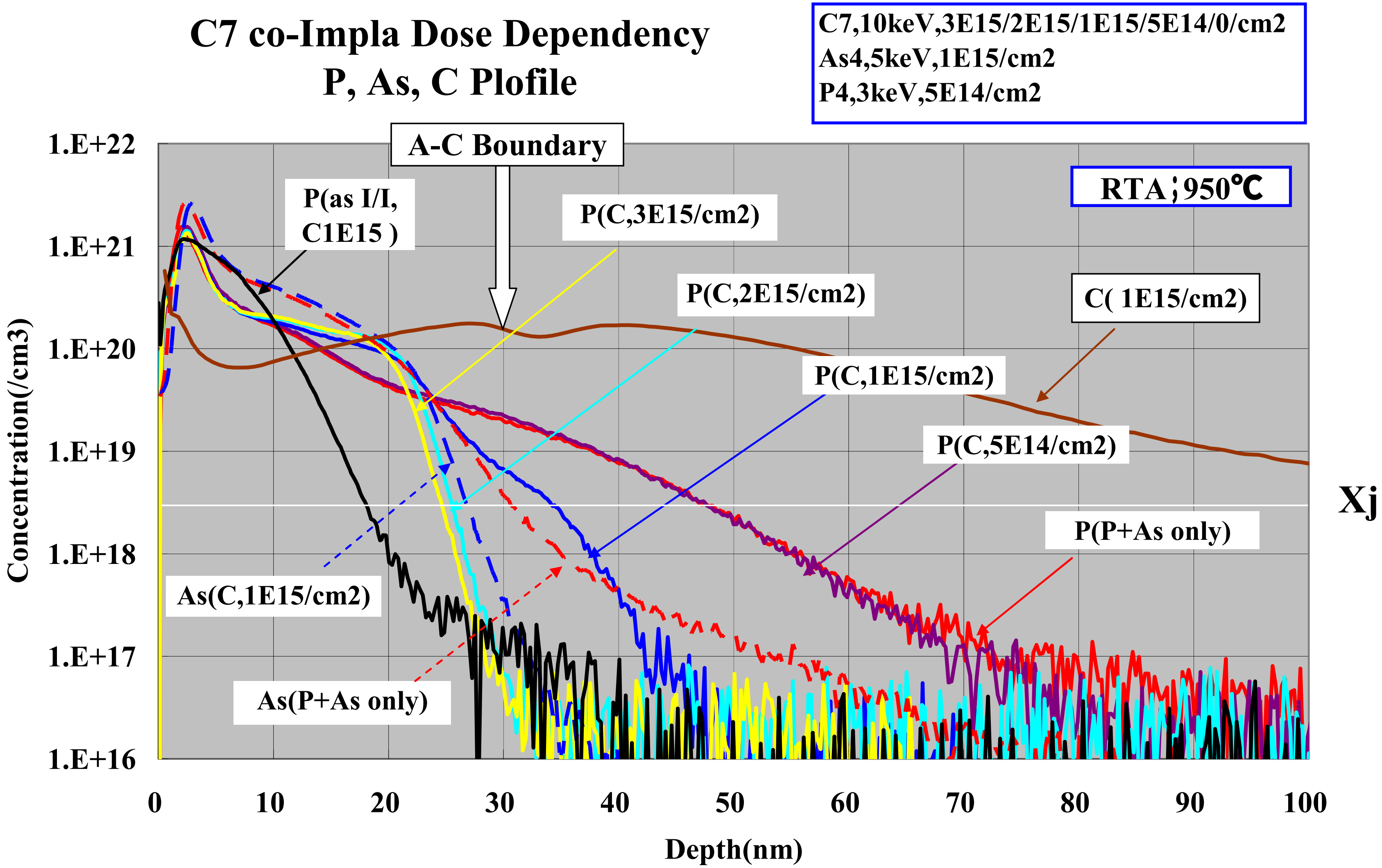

C7 Dose Dependency, co-Implant SIMS

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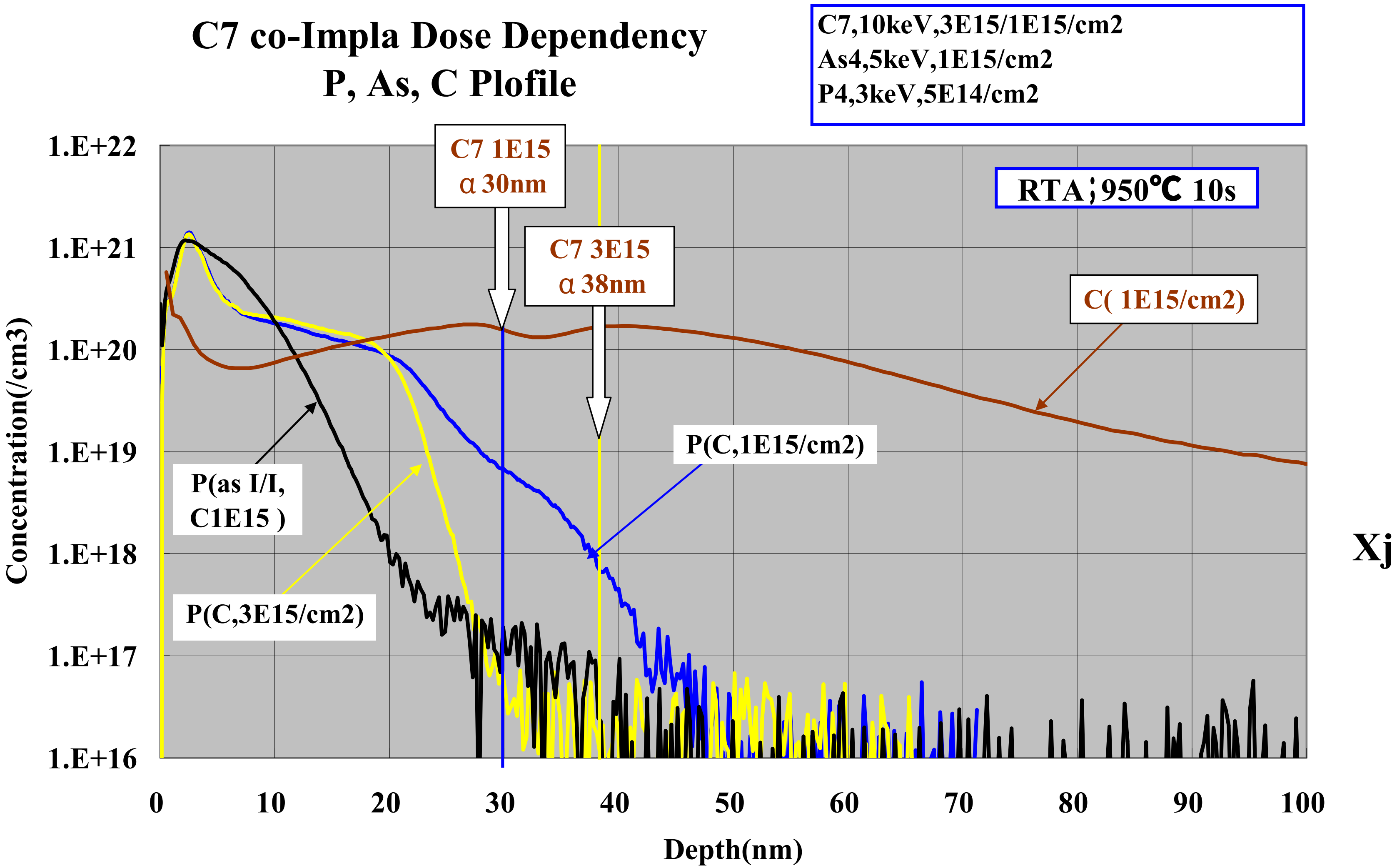
Cluster CLARIS



To make a boxlike profile, carbon α layer should cover the P EORD area.

C7 Dose Dependency, Rs & Xj

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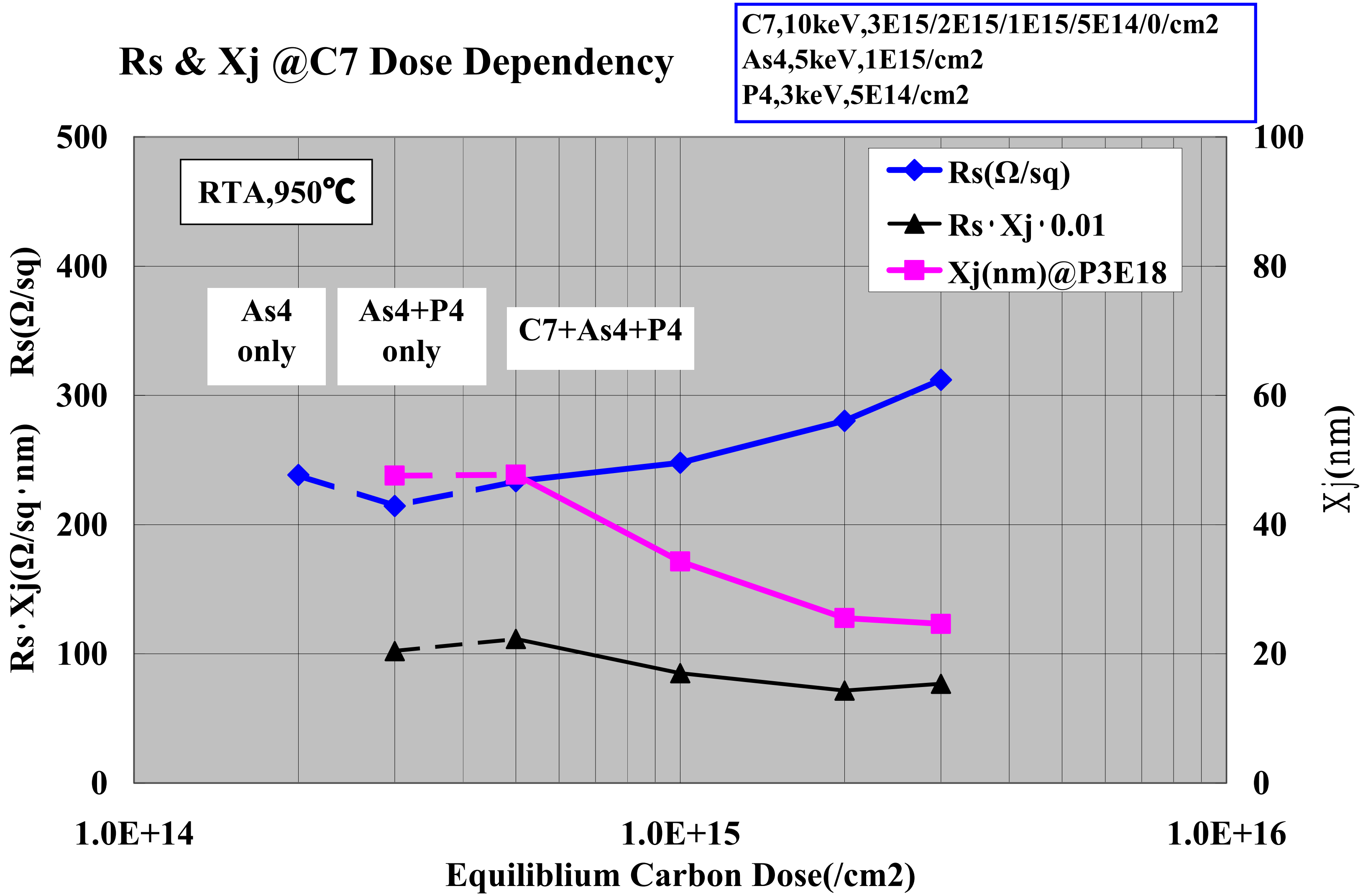
Cluster CLARIS



C7 Dose Dependency, Rs & Xj

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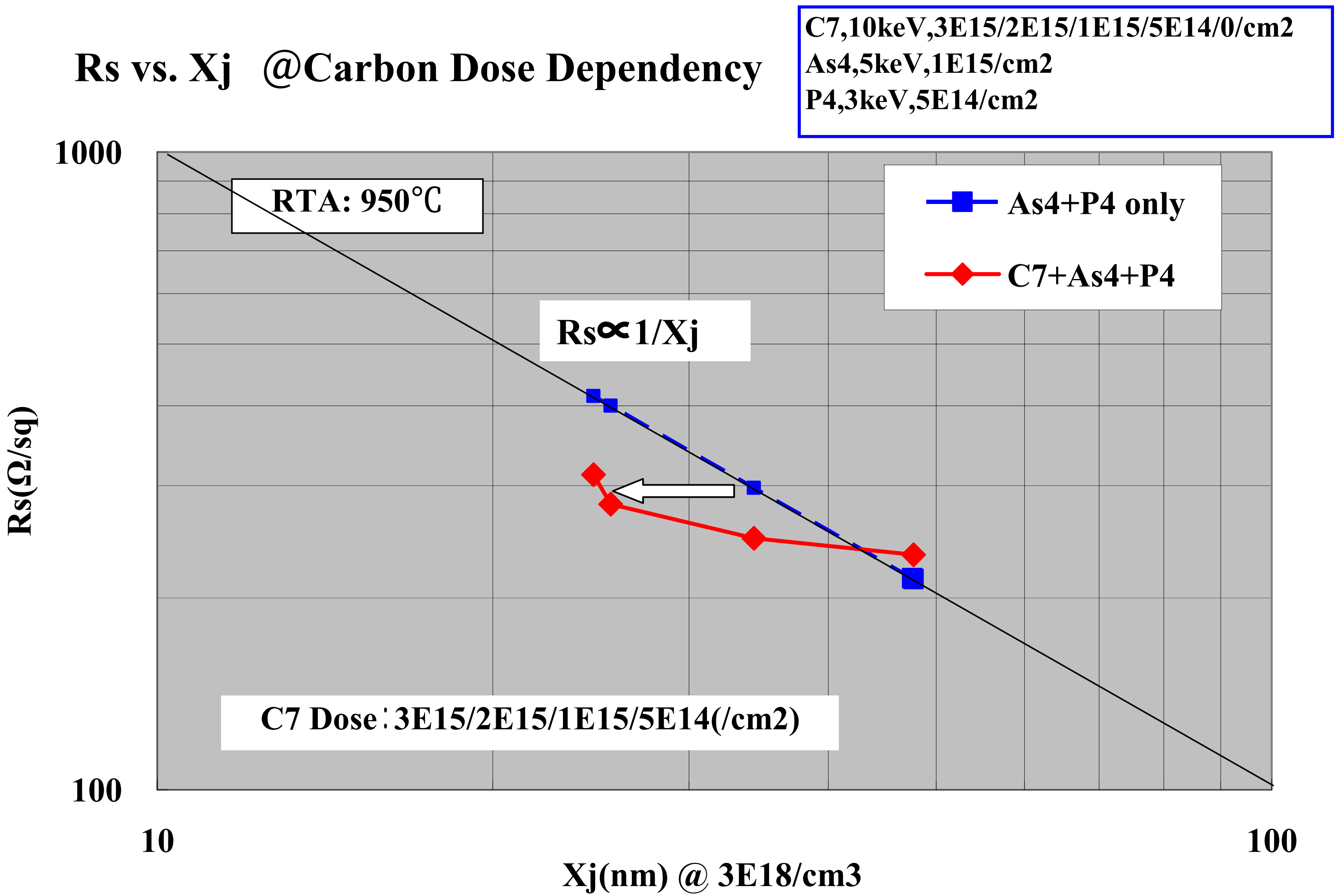
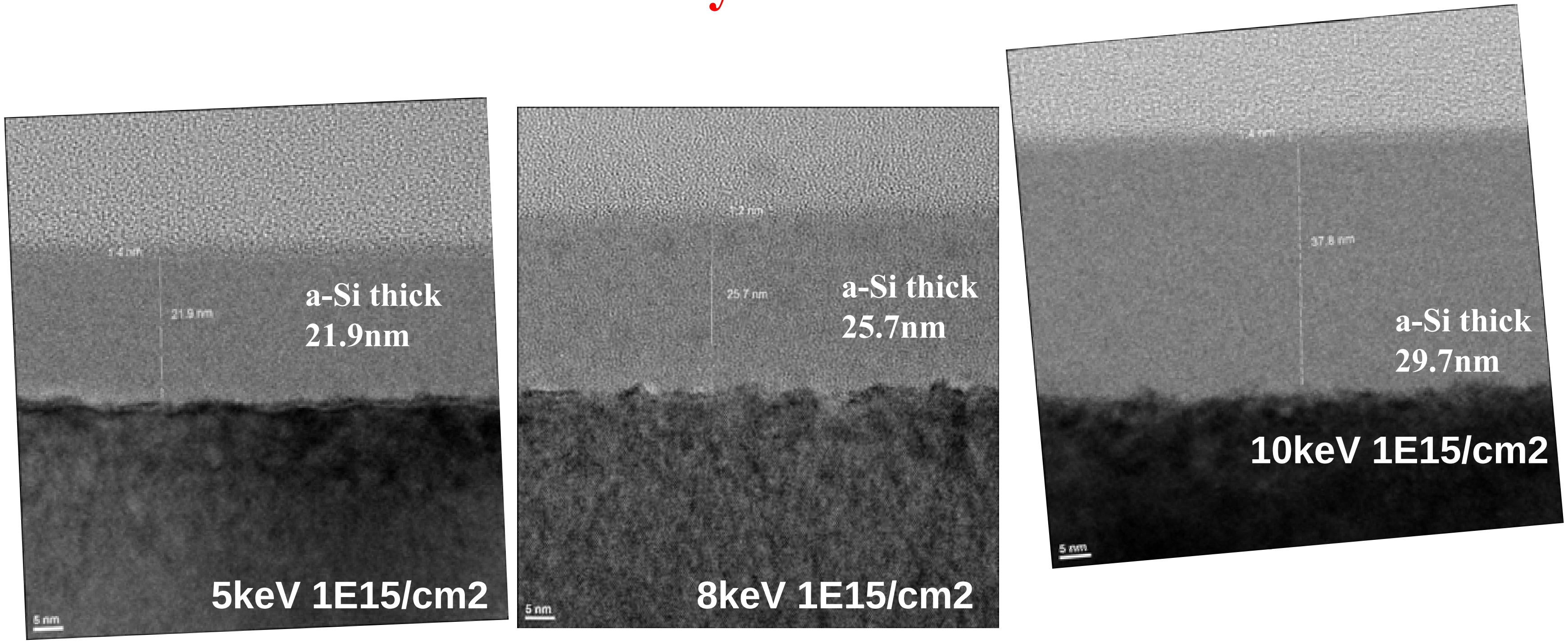
Cluster CLARIS



3. Results Evaluation and Discussion

C7 Cluster Implantation ; Amorphous Layer Thickness TEM

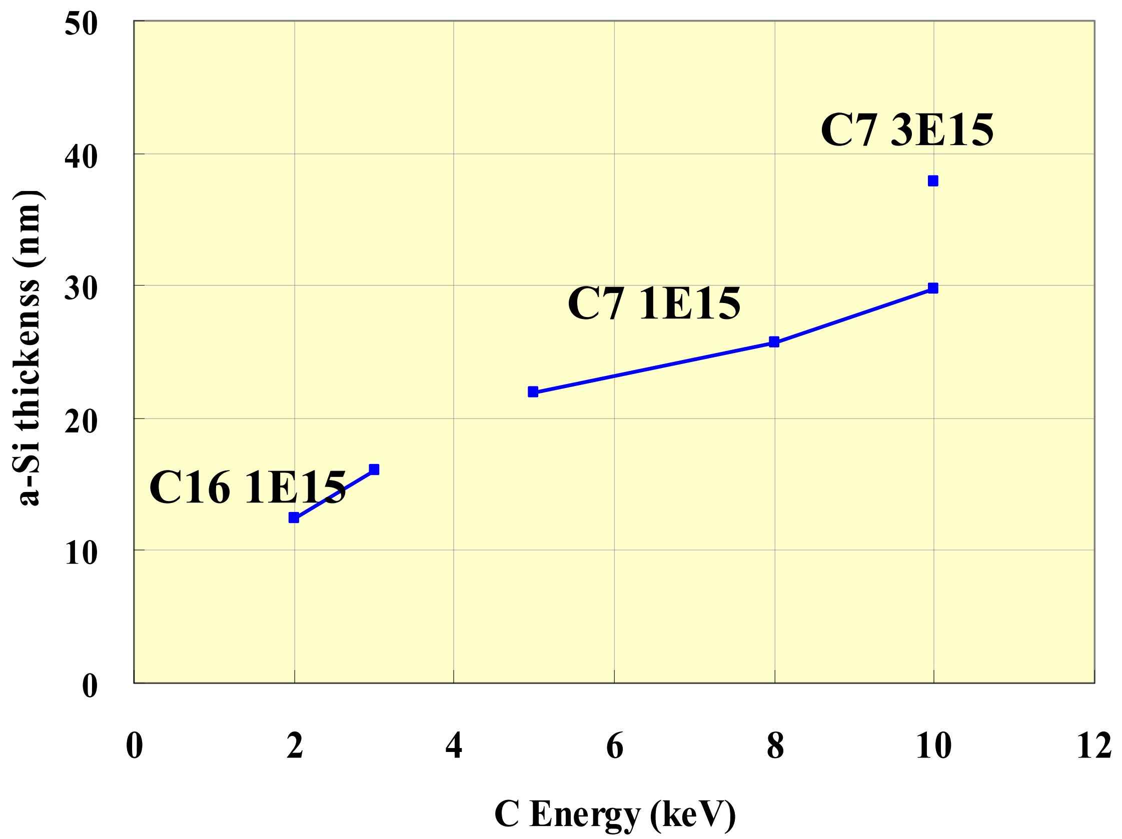
TEM of α-Layer Thickness



Amorphous layer thickness increases with bean energy.

Cluster C7/C16 Impla, α-Layer Thickness

C7 Implantation, Amorphous Layer Thickness

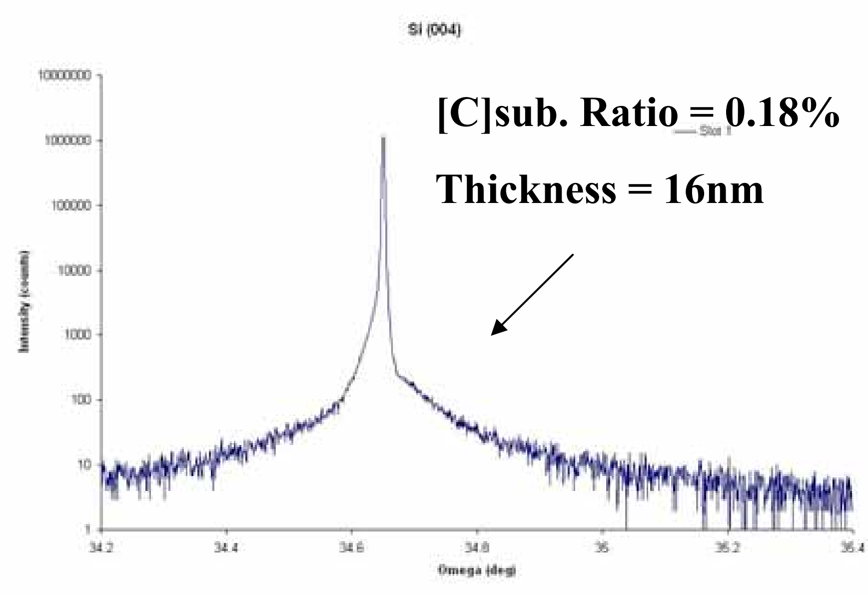


- Amorphous Thickness depend on the Energy and the Dose.
- Amorphous Thickness affects the sheet resistivity, Rs.

Comparison C7 vs Single C co-Implant.

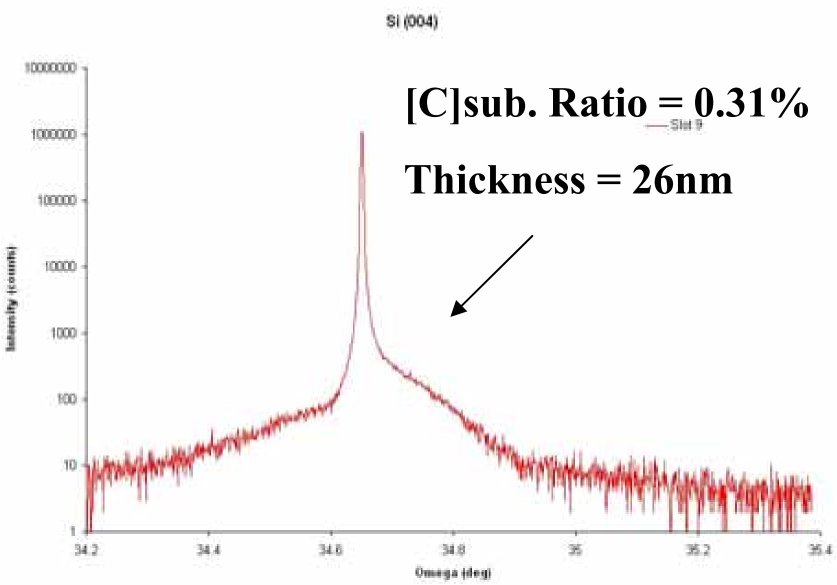
HR-XRD Measurement

C_{mono} 10keV 1E15 /cm^2



Dopant Substitutional Ratio=14%

C7 10keV 1E15 /cm^2



Dopant Substitutional Ratio=40%

Cluster Carbon makes higher dopant substitutional ratio.

Comparison C7 vs Single C co-Implant.

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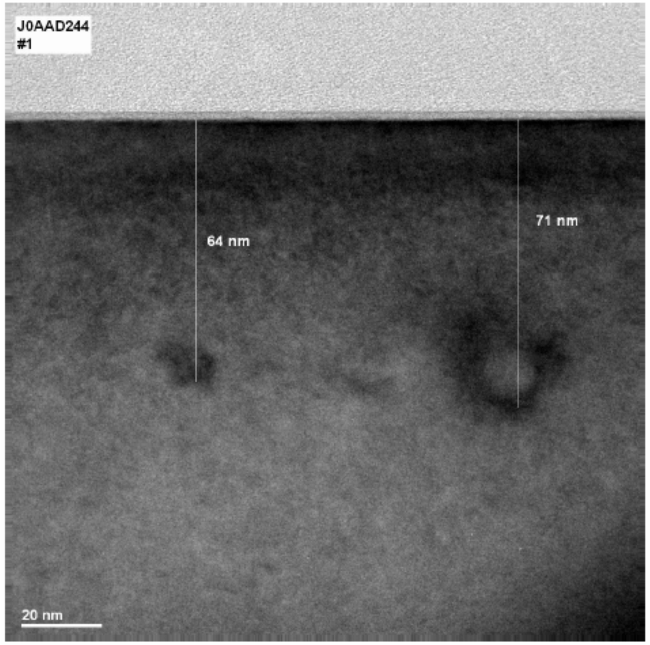
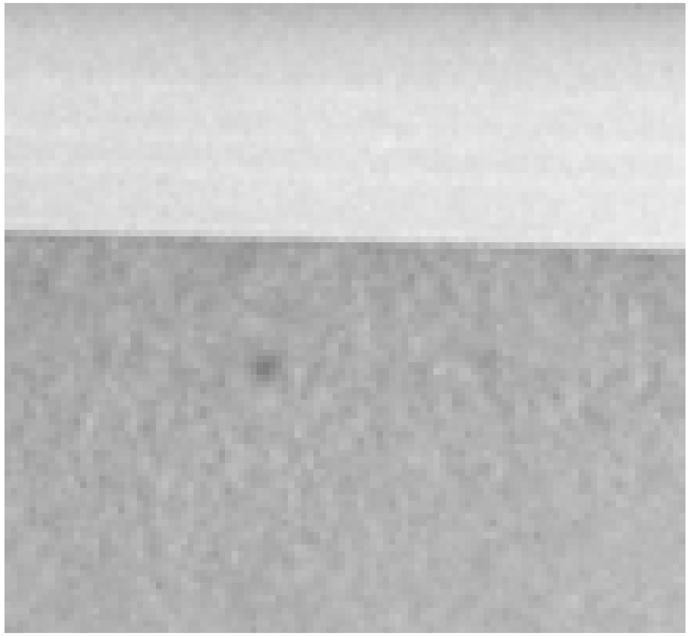
XTEM Measurement after RTA 950℃ 10s

C_{mono} 10keV 1E15 /cm²



C7 10keV 1E15 /cm²



Single Carbon Implantation shows some residual defect after RTA

4. Conclusion

1. **For NMOS shallow junction formation, As can be changed to Carbon Cluster co-implantation C7 ＋P4, which suppress TED and makes box like profile.**

2. **For suppress P TED, the control of implantation condition is important.**

3. **Comparing to the single Carbon co-Implantation, Carbon Cluster co-Implantation is superior with suppression efficiency, and good re-crystallization.**

4. **Cluster ion implantation is a candidate to serve a low cost process for beyond 32nm node Tr.**

Thank You for Your Attention !

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