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F-2005-PDN-0000360-R2

$B_{10}H_{14}$ Implantation for 45nm Node USJ Doping

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Nissin Ion Equipment Co., Ltd.,

Outline

I Introduction

II Equipment Development

beam current of present configuration

III Implantation Characteristics

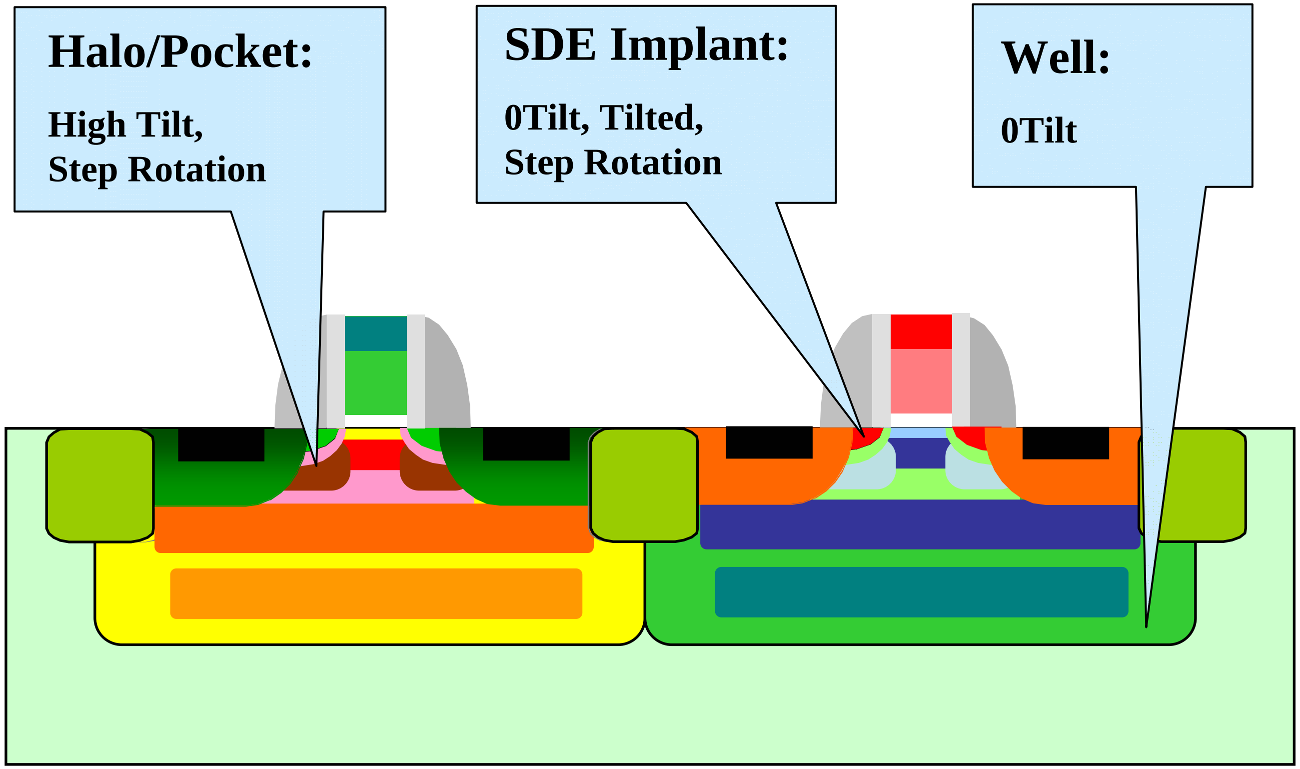
3keV equivalent energy implantation

500eV equivalent energy implantation

IV Summary

Requirement for 45nm node I/I

Tilt Angle（0，30，45deg) & Step Rotation (1，2，4，8，12 step）



Accurate Dose, Precise Control of Beam Angle & Size

Low Energy Implantation Technologies

		Advantage	Task
1	**I/I System with Decel. Mode**	Traditional System	Energy Contamination?
2	**Molecular (Cluster) Ion Implantation**	Low Space Charge Effect. Good angle control.	Cross contamination? Statistical Fluctuation?
3	**Plasma Immersion Ion implantation**	Ultra Low Energy	Angle Control? Non-Mass Analysis?
4	**Gas Cluster Ion Doping**	Ultra Low Energy	Dose Control?

There are many candidates !

I. Introduction

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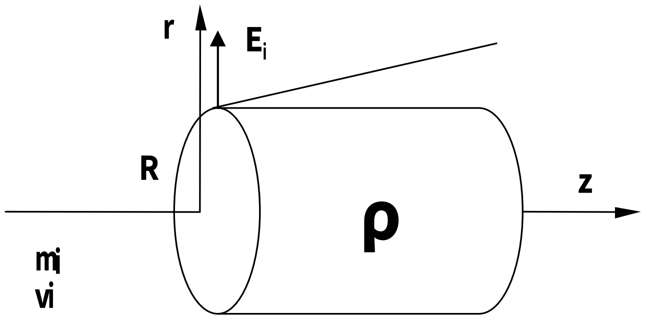
Space Charge Effect at Ultra Low Energy



ρ :space charge density

from Gauss' law

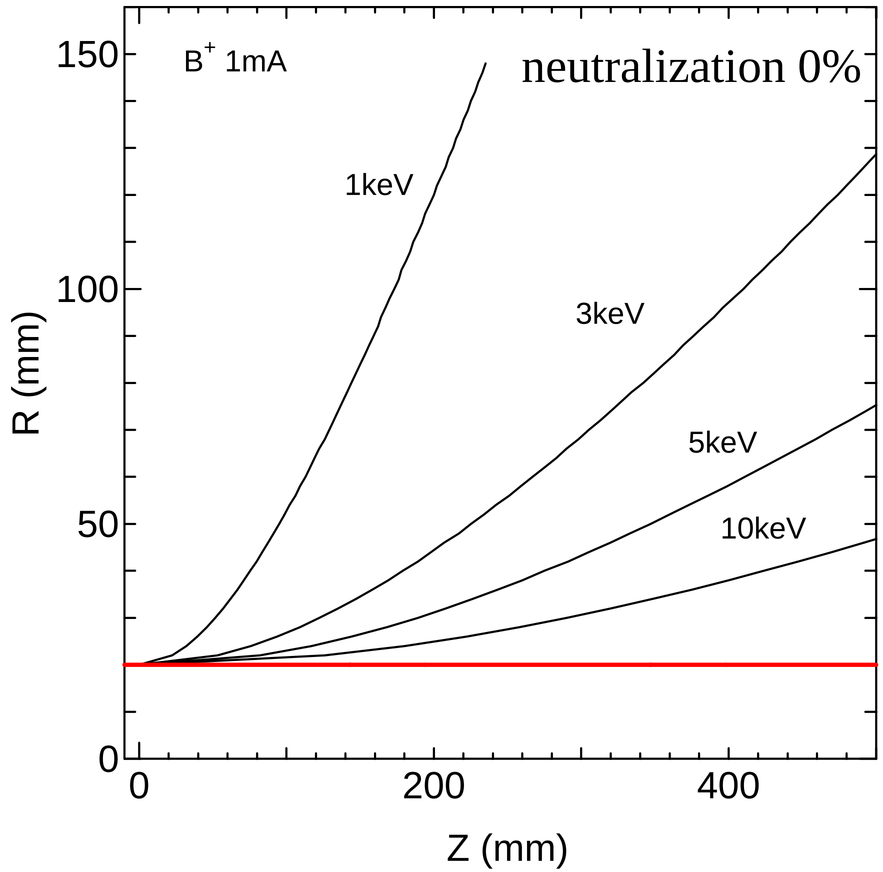
$$\iint_a (\varepsilon_0 \mathbf{E}, d\mathbf{a}) = \iiint_v \rho \, dv$$

$$2\pi r \varepsilon_0 E_r = \pi R^2 \rho$$

$$\rho = \frac{I_i}{\pi R^2 v_i}$$ Neutralization:0**%**

$$z = 2\frac{R}{K}\int_0^{\sqrt{\ln(R/r)}} e^{u^2} du$$

$$K^2 \equiv \frac{I_i}{(2V)^{3/2}} \frac{1}{\pi\varepsilon_0}\left(\frac{m_i}{e}\right)^{\frac{1}{2}}$$



Beam will be blown-up with decreasing energy

Beam diverges easily and is difficult to transport.

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Molecular ; Decaborane ($B_{10}H_x^+$) Ion Implantation

1/10 times lower beam current (*J*), 10 times higher energy (*V*)
can be applied with the equivalent boron monomer implantation

Space charge force *S* $\propto J\sqrt{\dfrac{M}{eV^3}}$

For example

$B_{10}H_x^+$: 5keV: 100µA
(Equivalent B^+: 0.5keV: 1000µA) = B^+: 0.5keV: 10µA

↓

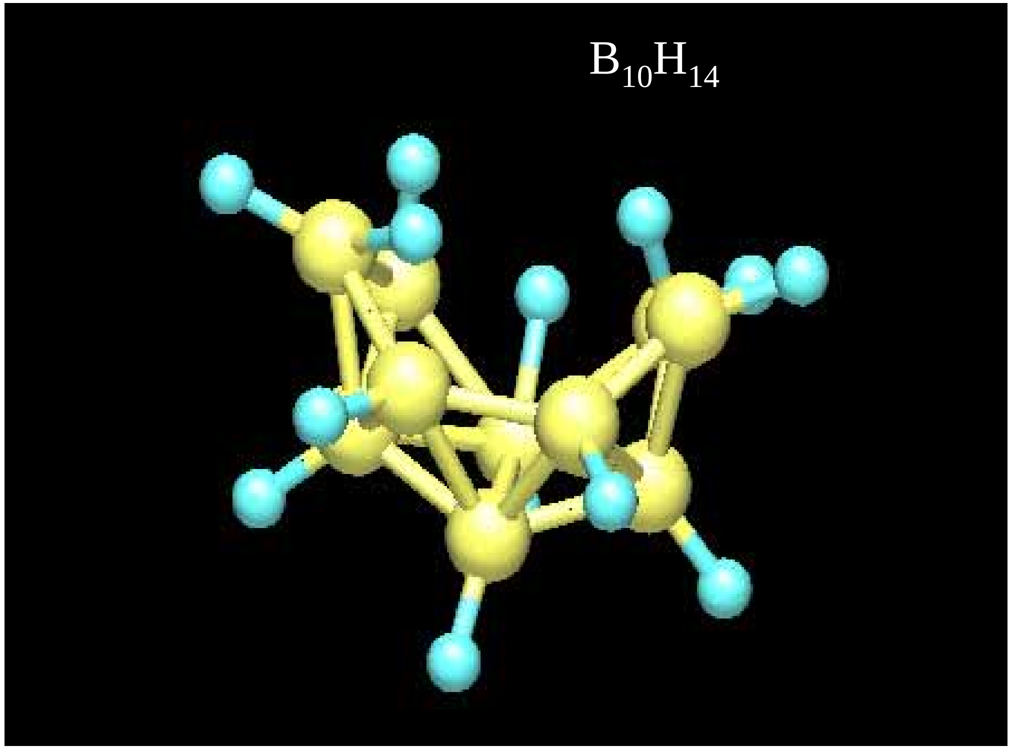
1/100 times smaller space charge force

Small beam divergence, easy to control the beam angle for across the wafer.

I. Introduction

Decaborane characteristics

Material properties



Solid @ Room temperature

Melting point: 99.6°C

Boiling point: 213°C

Vapour pressure: 6.7Pa @ 25°C

Ionization Potential: 9.56eV

Toxic vapor

I. Introduction

Decaborane characteristics

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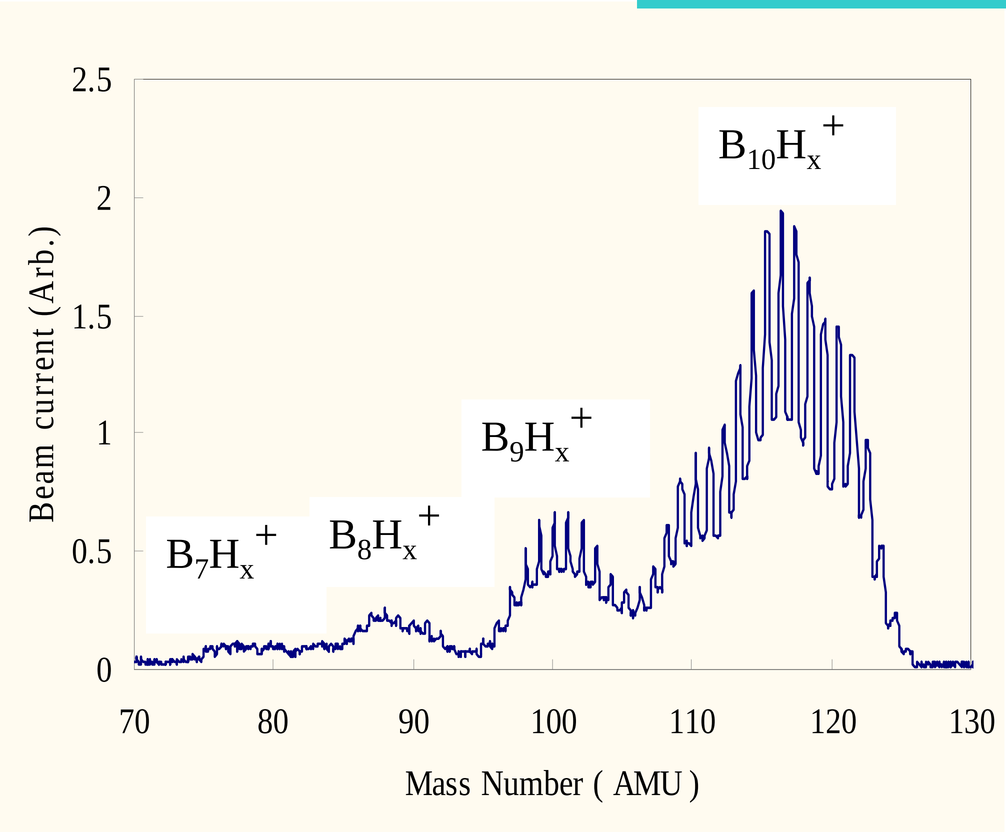
Typical mass spectrum



Many neighboring peaks

- ***the number of attached hydrogens**
- ***the number of boron isotope ^{11}B, ^{10}B**

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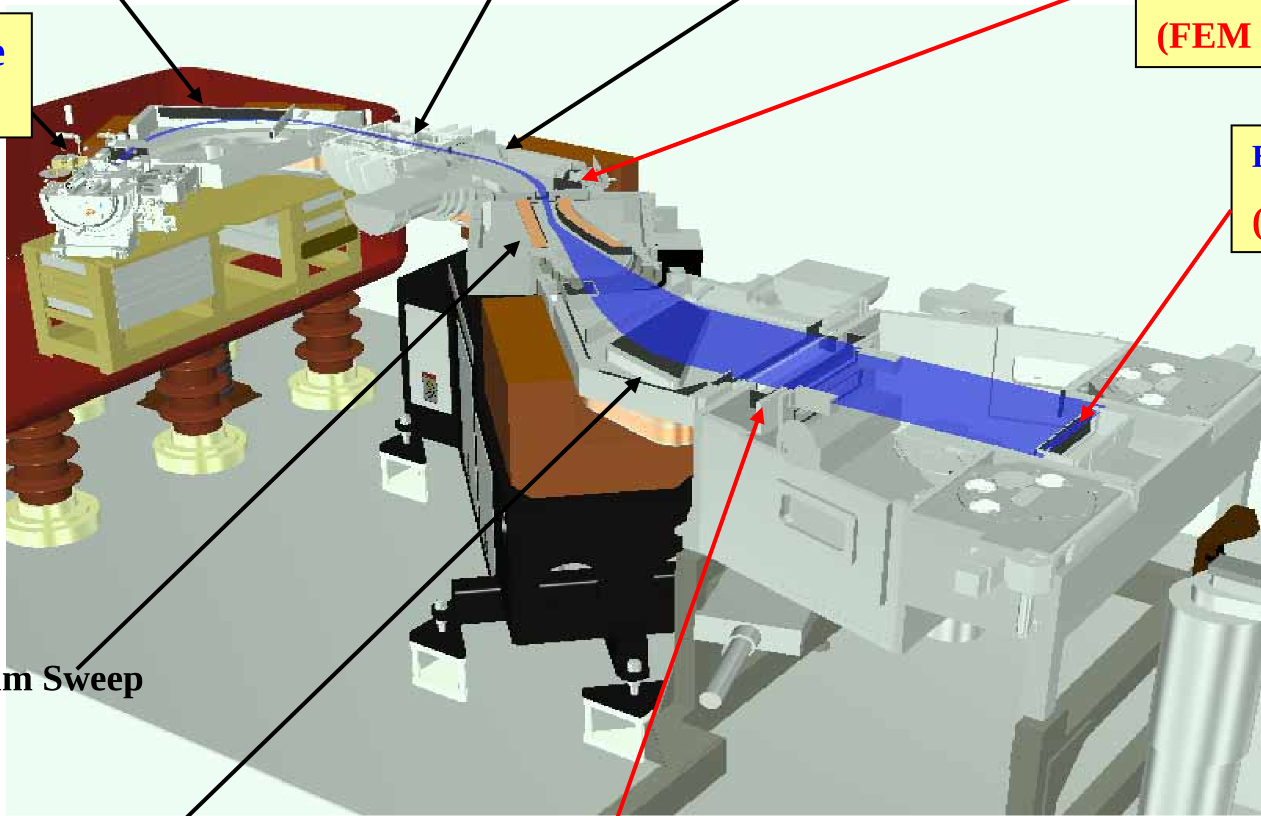
II. Equipment development

Overview of EXCEED2300H Beam Line

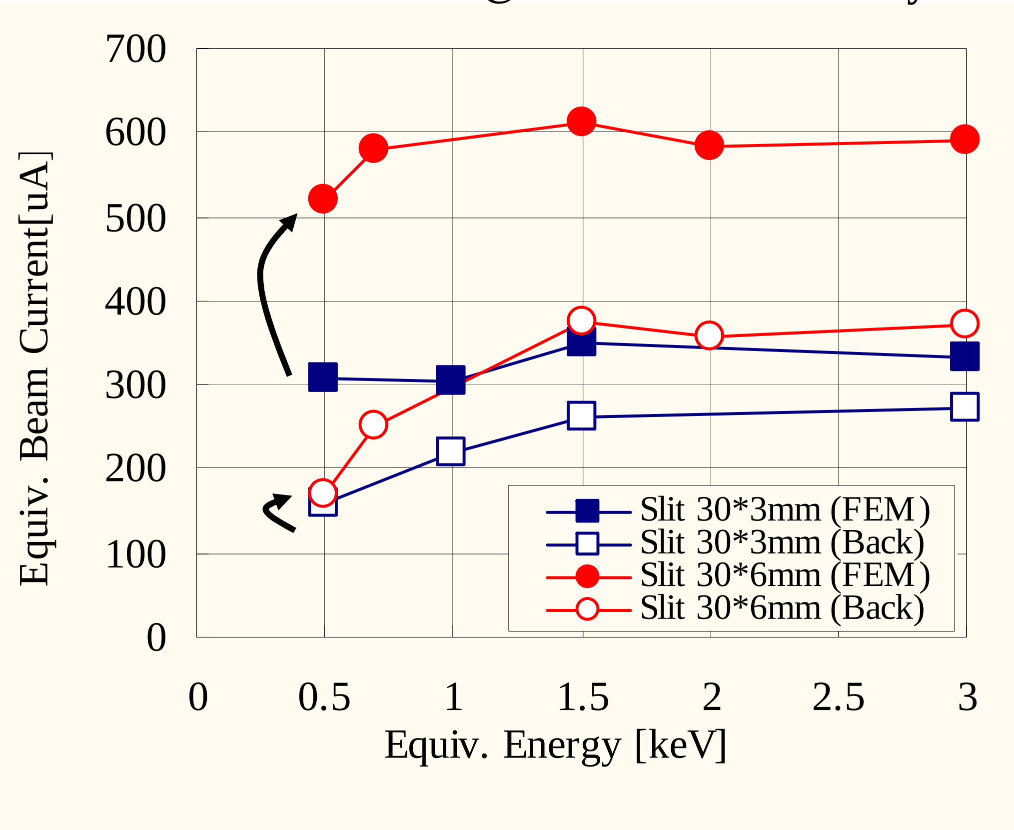


II. Equipment development

Improve beam current I ;Larger ion source slit size

Ion Source slit size 30*3mm⇒30*6mm

Beam current @ FEM & Back faraday



Beam current @ FEM faraday 300uA⇒520uA ->almost doubly improved

Larger slit size increases FEM Faraday beam current. But Back Faraday beam current not so much.

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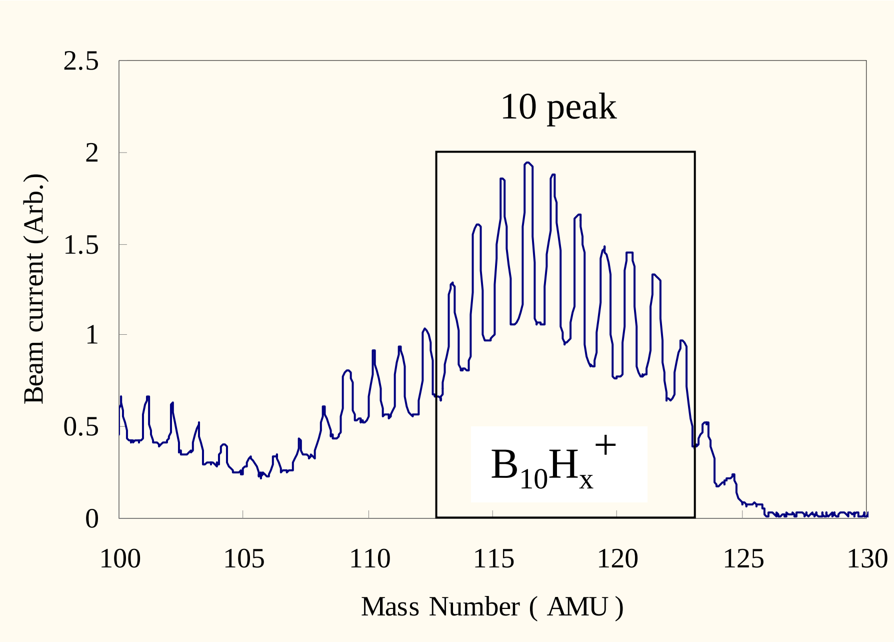
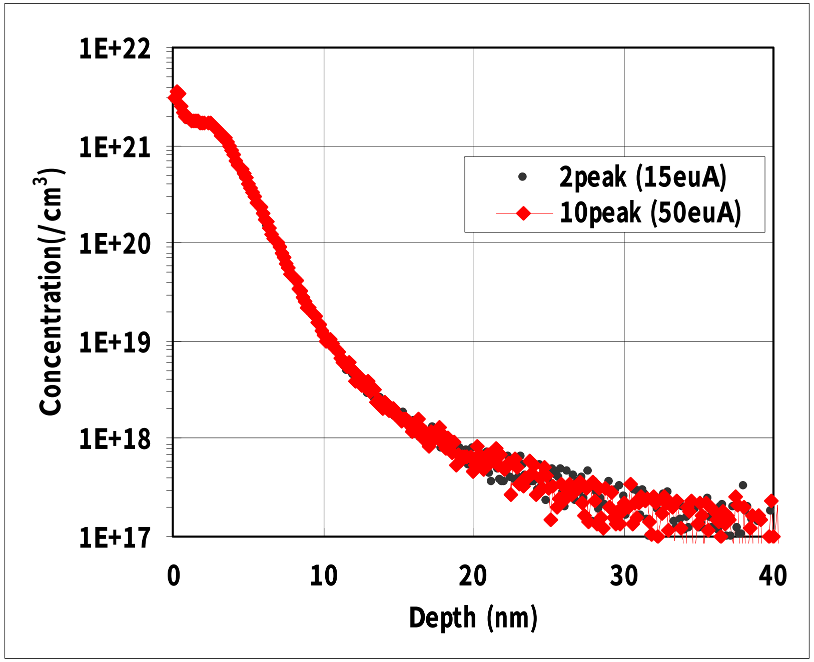
Improve beam current II;multi peak acceleration



By widening the mass resolving slit , i.e. 10 peaks can be introduced to the beam line

Beam current increases.

Comparison of SIMS
(as-implanted, 500eV equivalent, 1E15/cm²)



*Profiles of SIMS are completely the same.

Multi peak acceleration is acceptable but cross-contamination is a future problem.

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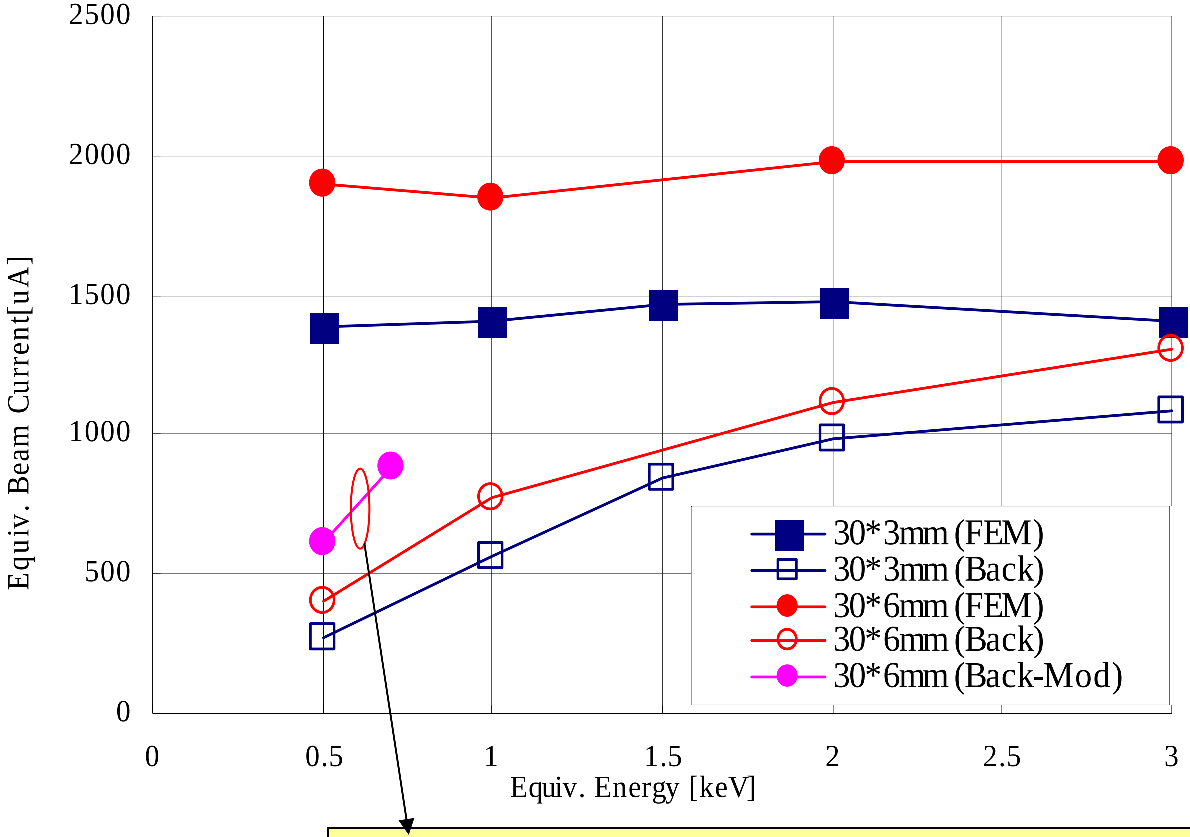
Improve beam current III;Wide slit+multi peak acceleration

Beam current (10 peak input)



1900uA@500eV (FEM)

620uA@500eV

(Back Faraday)

Focusing element is added in the beam line.
It means beam optics should be optimizing.

II. Equipment development

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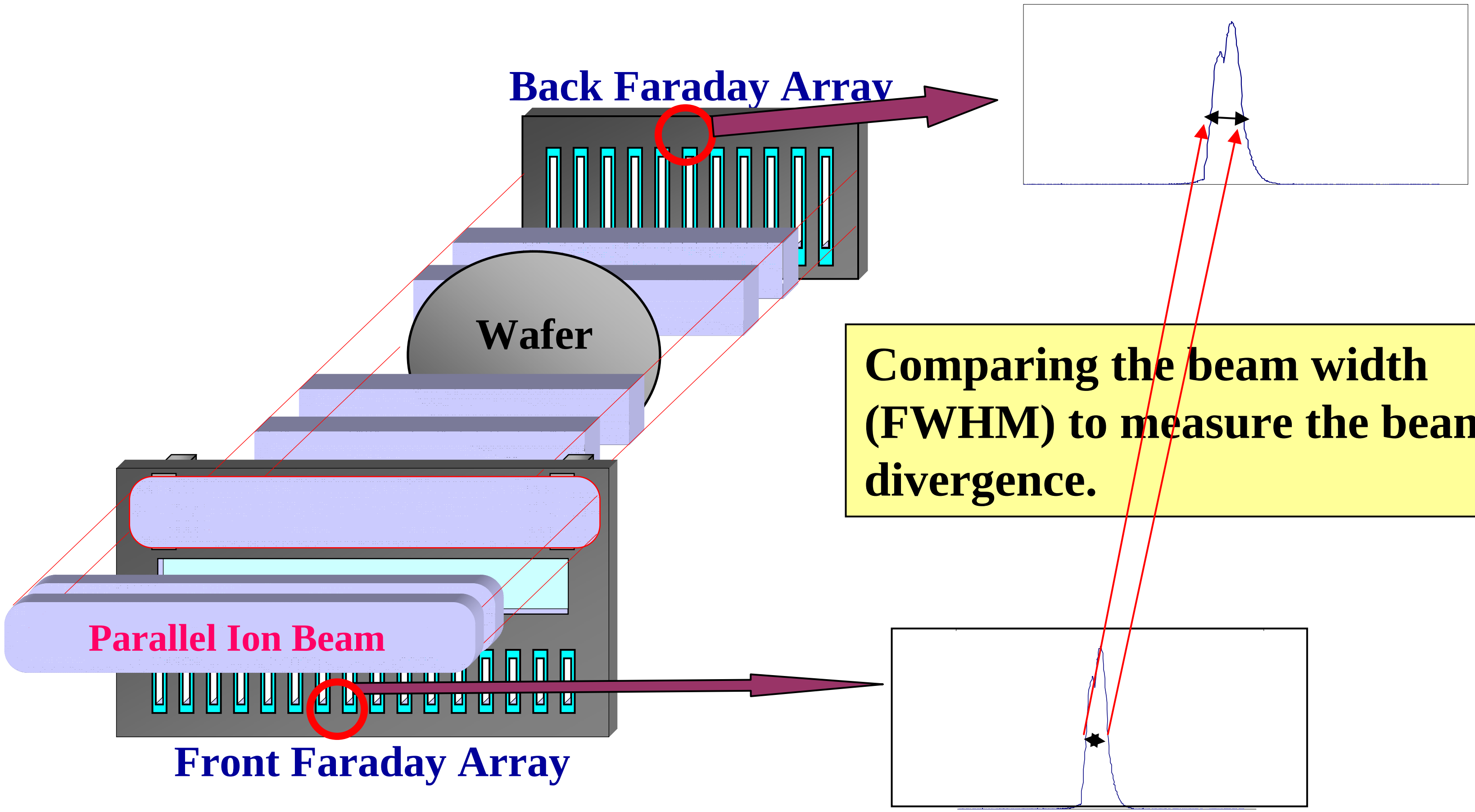
Beam divergence measurement



Comparing the beam width (FWHM) to measure the beam divergence.

II. Equipment development

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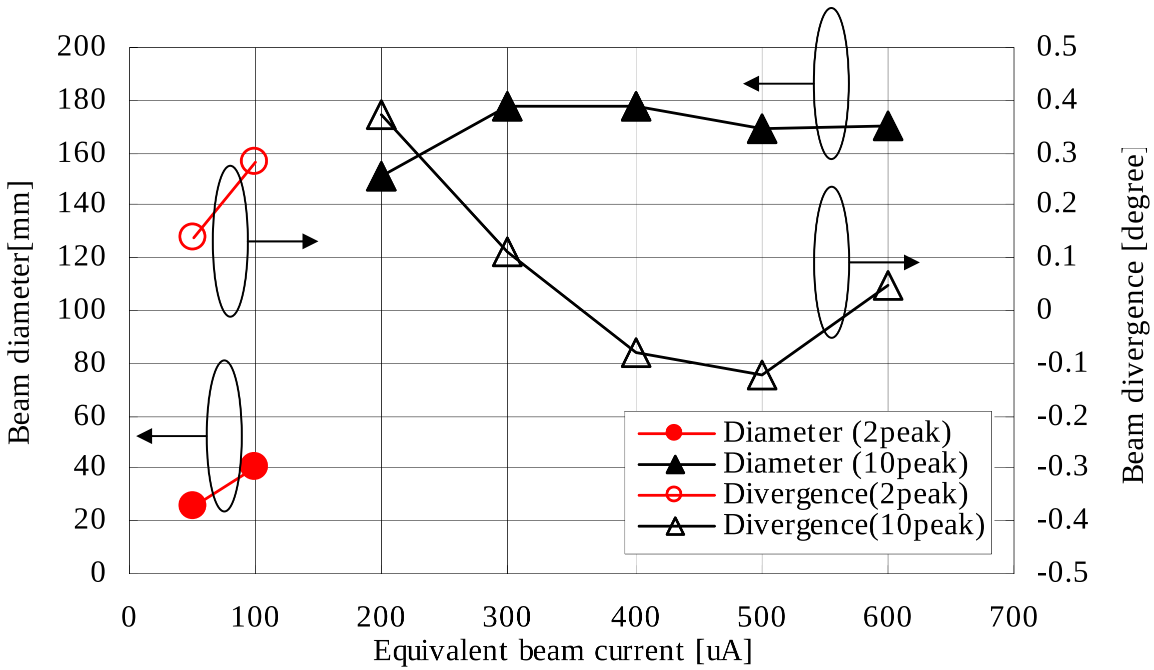
Beam divergence measurement

Beam diameter and divergence at a wafer (equivalent energy 500 eV)



The diameter of 10peak is 6 times as large as that of 2 peak.

The divergences are less than 0.4deg in both cases.

The parallelism is less than 0.5deg in both cases.

In 2peak case and 10peak case, the beam divergence is both less than 0.4deg.

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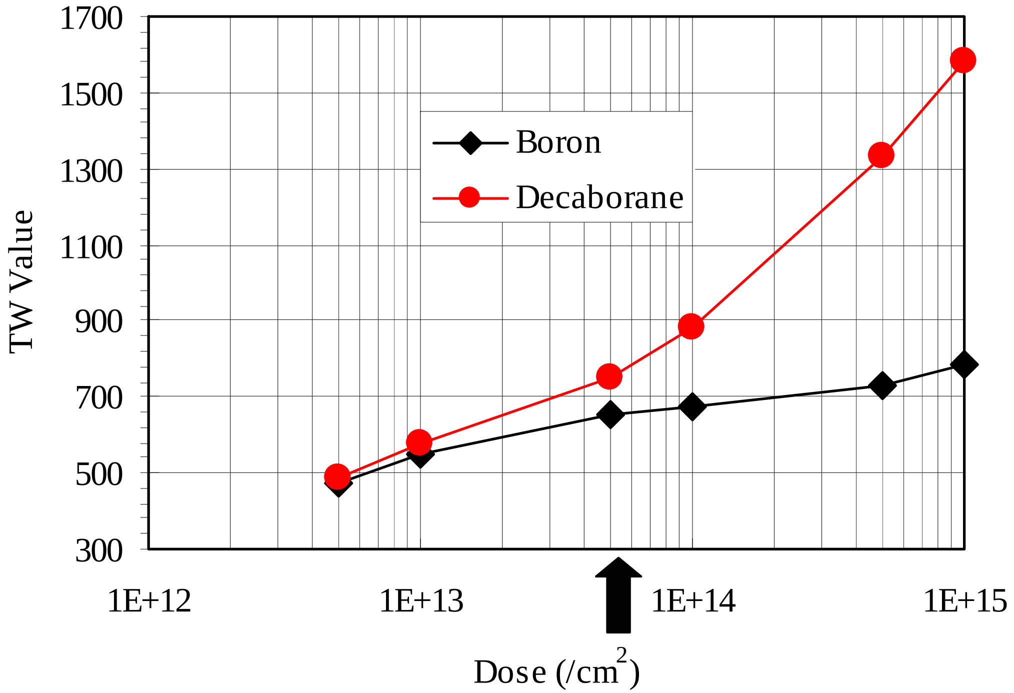
III. Implantation Characteristics

3keV equivalent energy implantation

TW value comparison



At lower dose condition, both TW values are almost same, but at higher dose condition, TW of decaborane is relatively high.

At decaborane higher dose, the crystalline damage is increased.

III. Implantation Characteristics

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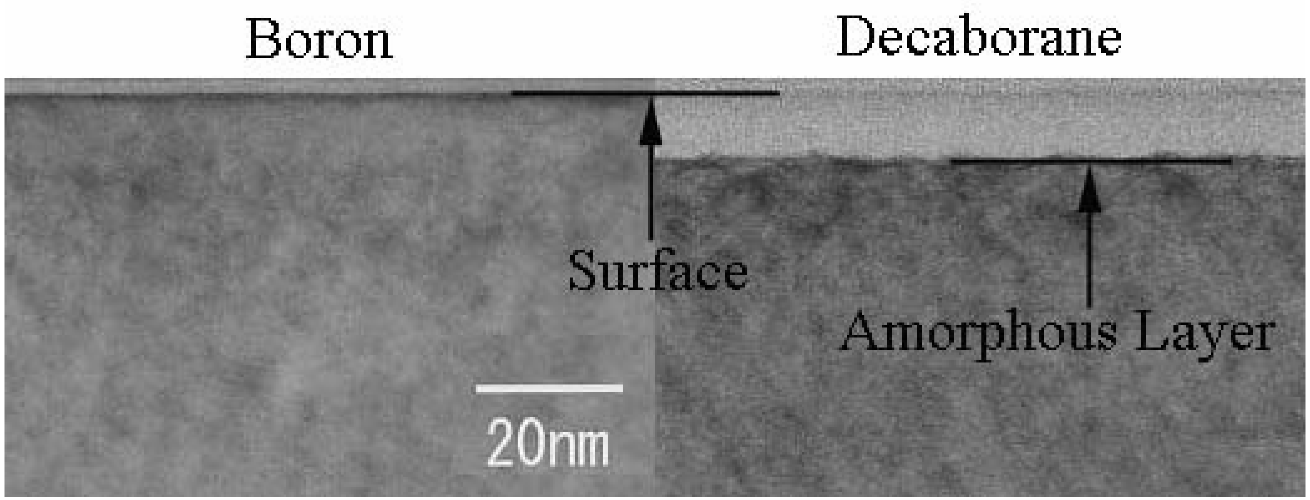
3keV equivalent energy implantation

TEM images comparison (as-implanted, Dose rate: 1E15/cm^2)



Amorphous layer by decaborane implantation is observed. Thickness of a amorphous layer is 9nm, which corresponds to the Rp of decaborane.

III. Implantation Characteristics

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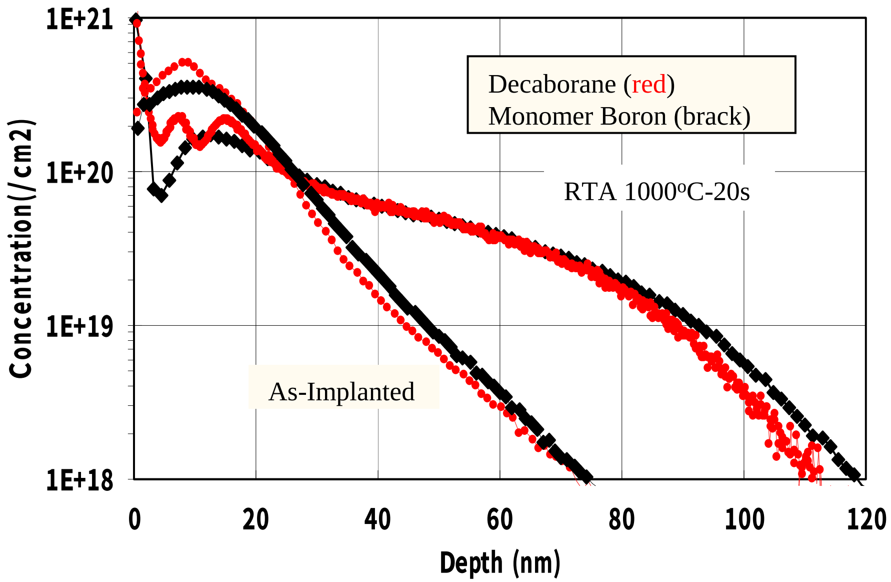
3keV equivalent energy implantation

SIMS profile comparison (Dose rate: 1E15/cm^2)



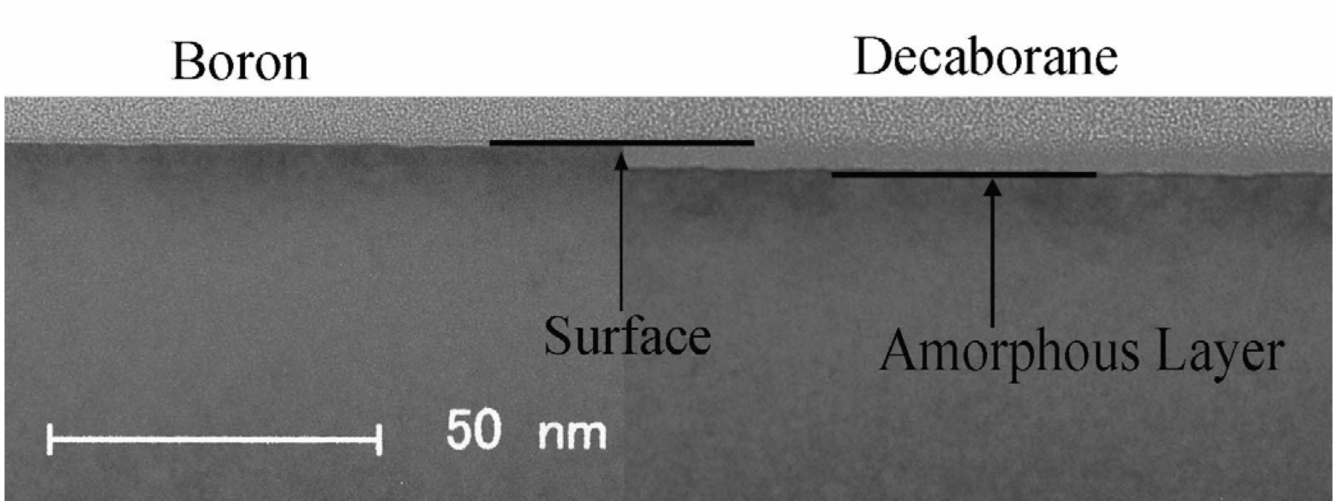
As-implantation, both profiles are not so much different with Rp 9 - 10nm.
After-anneal, the profile of decaborane is divided at around Rp.

Anneal ; RTP1000 °C

For decaborane annealing, boron diffuses with different speed in the amorphous layer and crystalline layer.

500eV equivalent energy implantation (as-implanted)

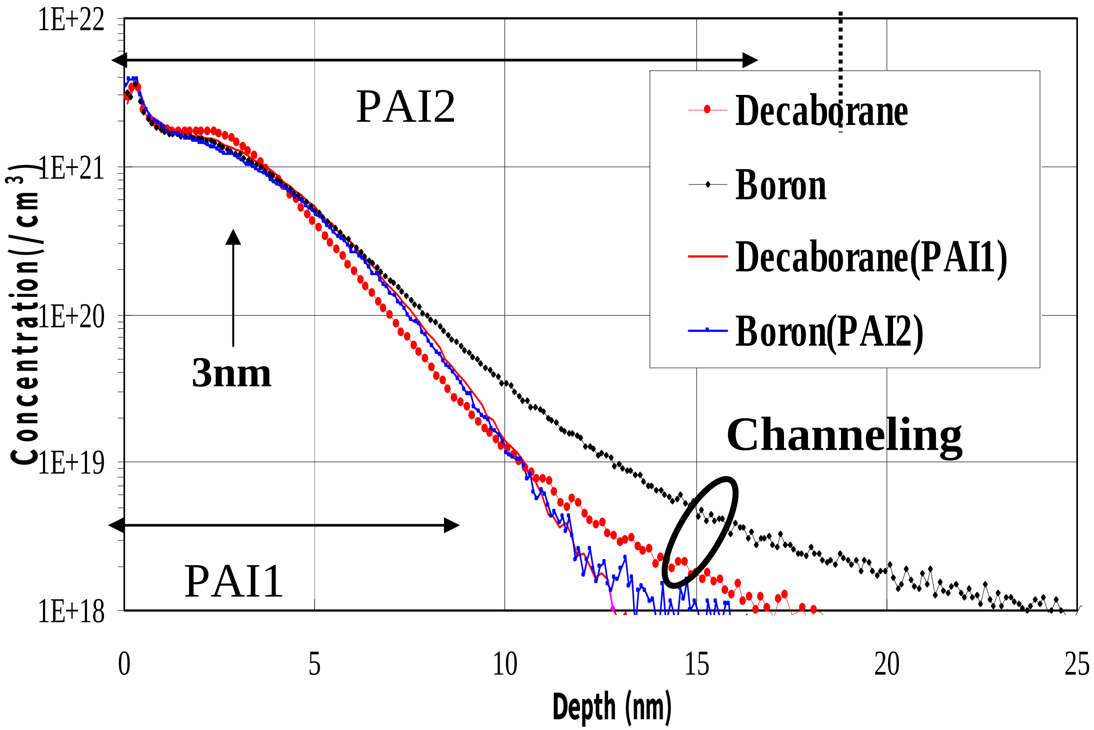
TEM images comparison (as-implanted, Dose rate: 1E15/cm2)



Thin amorphous layer (3 nm) is observed.

500eV equivalent energy implantation (as-implanted)

As-implantation SIMS comparison (Dose rate: 1E15/cm^2)



Without PAI

Decaborane tail is Shallower and Steeper

With Ge-PAI

Both almost same up to 13nm

III. Implantation Characteristics

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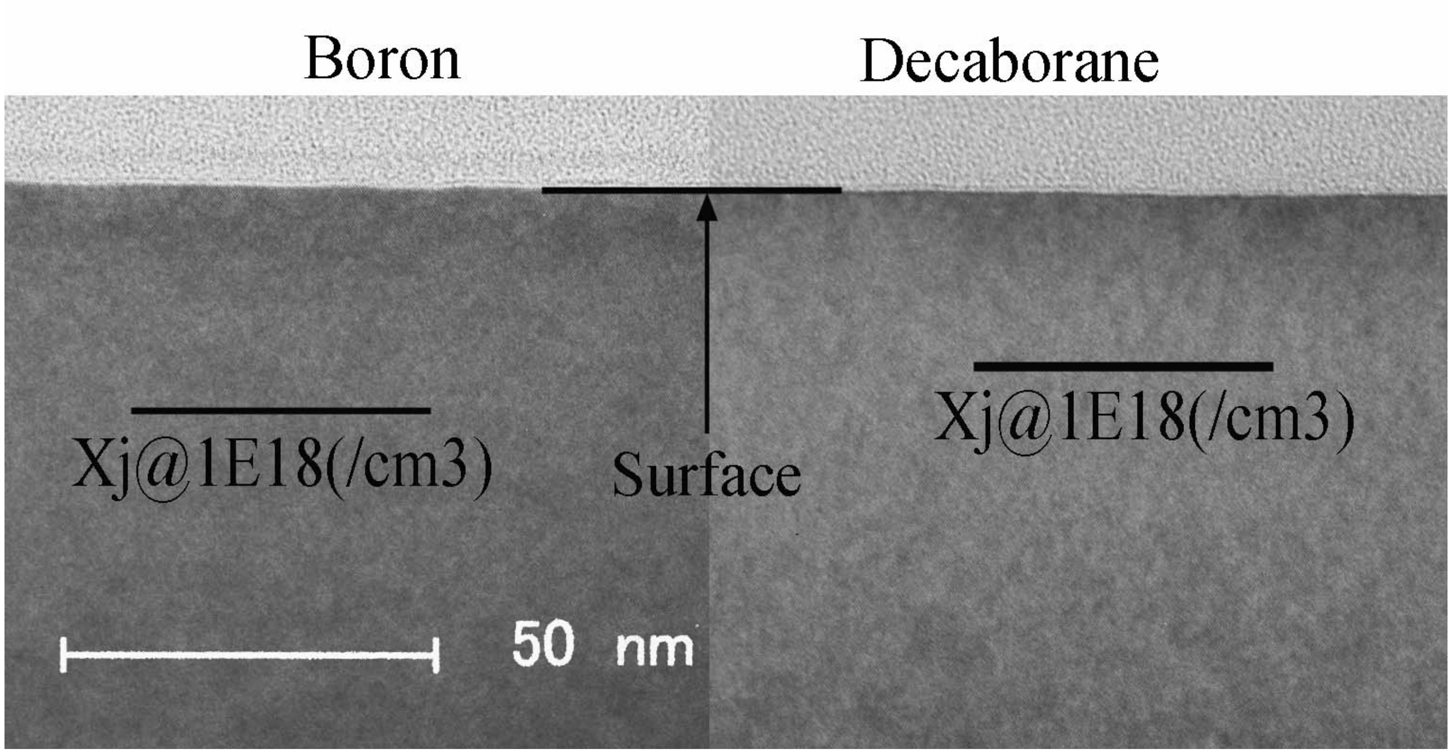
500eV equivalent energy implantation (after annealing)

TEM image comparison after RTA

RTA 1000 ^{o}C, Dose: 1E15/cm2



No significant residual defects are observed.

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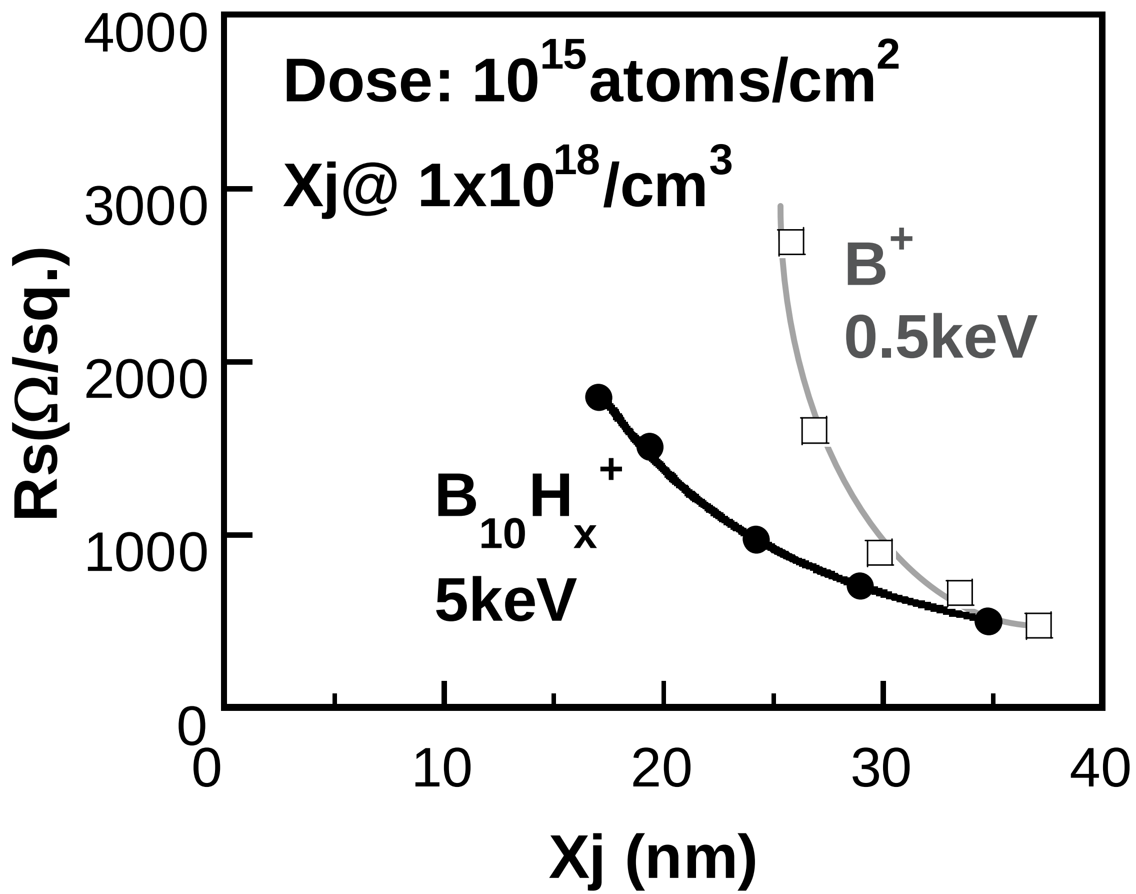
500eV equivalent energy implantation (after annealing)

Rs VS Xj

RTA Temp. 900 - 1050 ºC



Decaborane ->
Shallower Xj with same Rs
Low Rs with same Xj

Better activation!

IV. Summary

Ion source and beam line development

1. Wide source slit and 10-peak acceleration makes improve beam current with 1900uA @FEM and 600uA @Back Faraday.
2. The beam divergence of less than 0.4deg is achieved.

Implantation characteristics

3. For Decaborane implantation amorphous layer is formed at higher dose.
4. Amorphous layer suppresses the channeling and changing the anneal process to improve the activation.

Decaborane implantation is a promising process for beyond 45nm USJ doping.

<Acknowledgment>

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Thank you for your attention!