SCREEN Thermal Products

July 16, 2015

NCCAVS Junction Technology Group

Semicon West

San Francisco, CA

SCREEN Semiconductor Solutions Co., Ltd.

Agenda

- **Thermal Products Overview**
- **Laser Anneal**
- **Presentation – “*Formation of Ge n+/p junction shallower than 20 nm and diffusion control using Flash Lamp Annealing (FLA)*”**

Providing leading-edge technology and total solution from Kyoto to the World!

Company Name: SCREEN Semiconductor Solutions Co., Ltd.
Head Quarter: Kyoto, Japan
President: Tadahiro Suhara

Product Line-up

Semiconductor Equipment Solutions from SCREEN

Track Coat/Develop

SOKUDO DUO DT-3000

Market Share No.1
Wet Clean Single

AQUASPIN SU-3200

Metrology

RE/VM series

Market Share No.1
Wet Clean Batch

F-WET FC-3100

Market Share No.1
Scrubber Clean

AQUASPIN

Laser Anneal

LT-3100

Flash Anneal

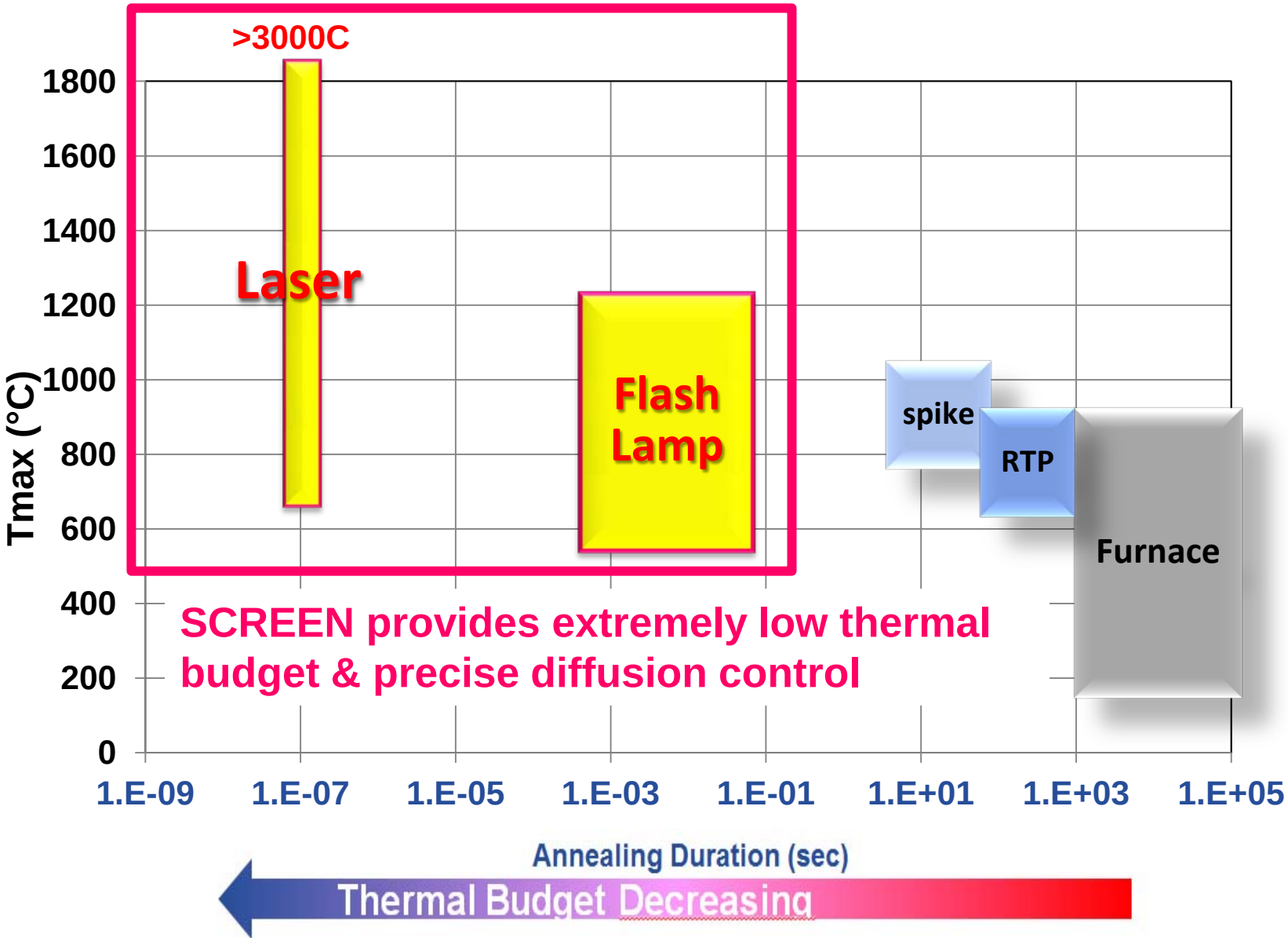
LA-3000F

Source: Gartner, April 2015

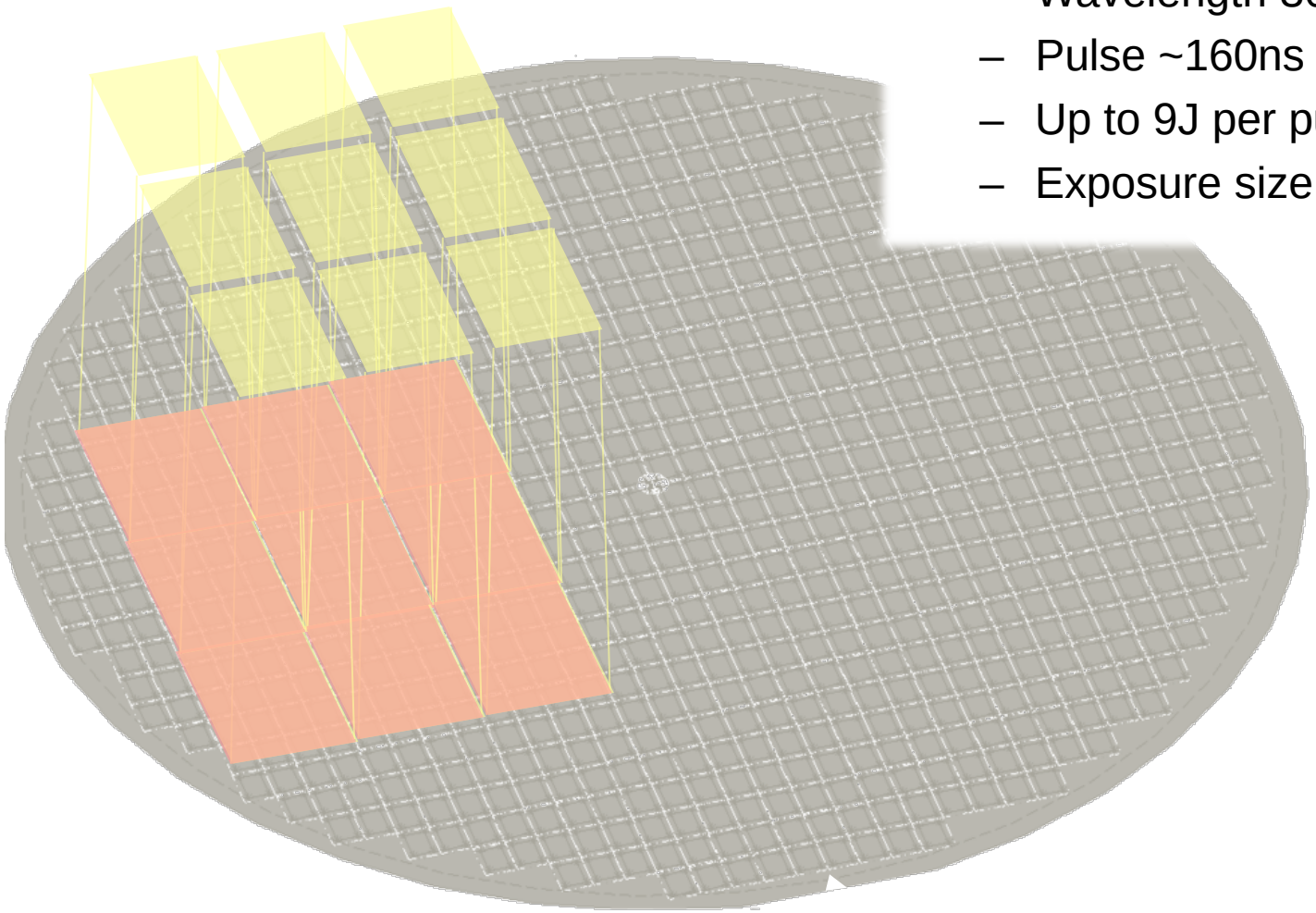
Uniquely Positioned for Advanced Thermal Processing

- **SCREEN is an established supplier of thermal processing equipment**
  - Halogen lamp based system for RTA at 150 & 200mm
  - Flash lamp with Halogen assist heating for advanced millisecond thermal processing at 300mm and beyond
- **Expand offering with 2014 acquisition of Laser Anneal supplier.**
  - New company “LASSE (Laser Systems & Solutions of Europe)” as SCREEN’s subsidiary
  - Excimer Laser based system
  - High energy density with short pulse duration → Low thermal budget
- **Combined SCREEN offers a unique portfolio of advanced thermal processing platforms to the semiconductor industry**

Thermal Annealing Technology Portfolio



LT Product – Step and Repeat Process



- **LT-3x00 process**
  - Wavelength 308nm
  - Pulse ~160ns
  - Up to 9J per pulse
  - Exposure size: 10*10 to 26*33mm²

Global Reach

- **PTC near Kyoto & Demo Lab near Paris**
- **Harnessing full capability of SCREEN Products**

Flash Lamp Annealing System
LA-3000-F

φ300mm

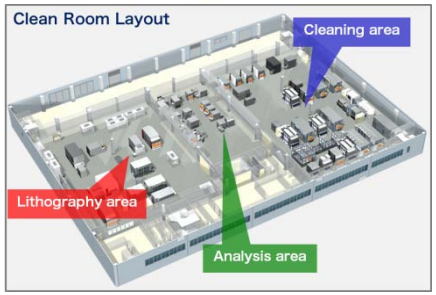
Laser anneal
LT-3000/3100

LASSE (near Paris)

Flash Lamp anneal LA-3000
Laser anneal LT-3000

Laser Annealing System
LT-3000

φ300mm



SCREEN Process Technology Center (near Kyoto)

Formation of Ge n+/p junction shallower than 20 nm and diffusion control using Flash Lamp Annealing (FLA)

H. Kawarazaki, H. Tanimura, Y. Ono, T. Yamada,
S. Kato, T. Aoyama, and I. Kobayashi

SCREEN Semiconductor Solutions Co., Ltd.

Outline

1. **Introduction**
2. **Experimental methods**
3. **Results**
   A) Shallow junction formation
   B) High-precision diffusion control
4. **Conclusions**

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1. Introduction

2. Experimental methods

3. Results

A) Shallow junction formation

B) High-precision diffusion control

4. Conclusions

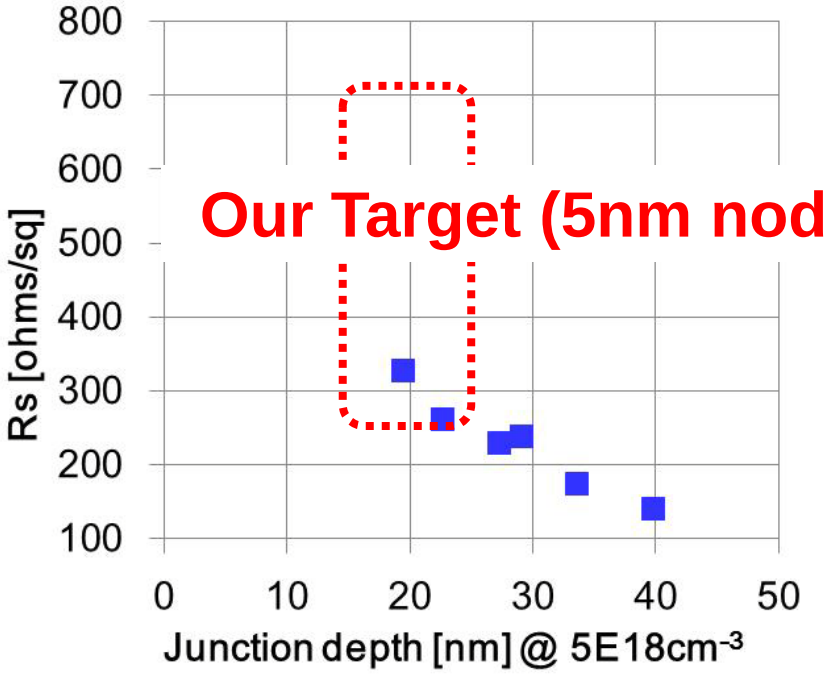
Introduction

Recently, the development of Ge devices has been pursued.

However, there are few reports on n+/p junctions.

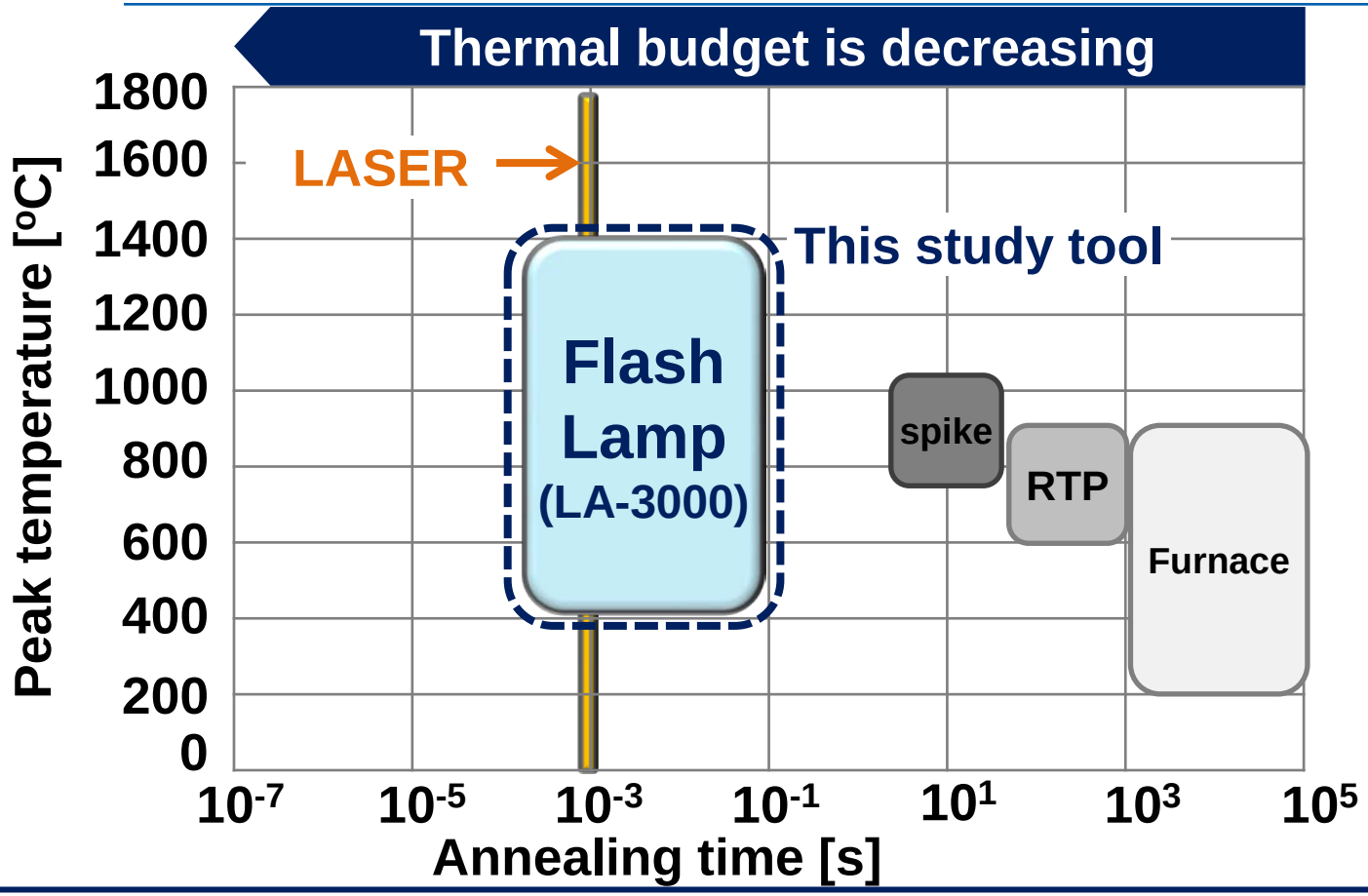
Behind this background…

- **Very little research on doping technology**
- **N-type dopants diffuse much faster than p-type in Ge**
- **Difficult to get high activation in Ge**



M. J. H. van Dal, B. Duriez, G. Vellianitis, G. Doornbos, R. Oxland, M. Holland, A. Afzalian, Y. C. See, M. Passlack and C. H. Diaz, IEDM 2014, pp235-238

Trend of annealing and FLA

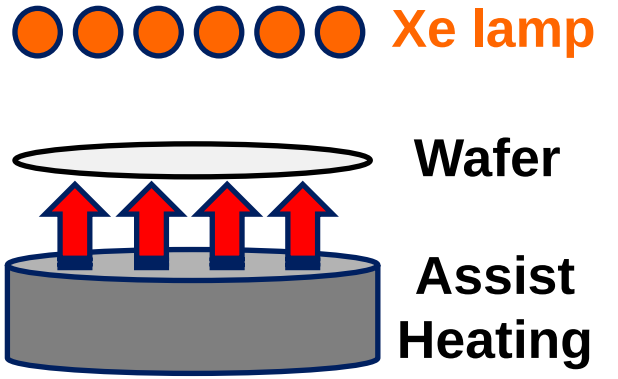


Though short time annealing is needed to form shallow junctions, it makes difficult to control dopant diffusion.

So we used FLA in this study, because It has a **wide range** of annealing time.

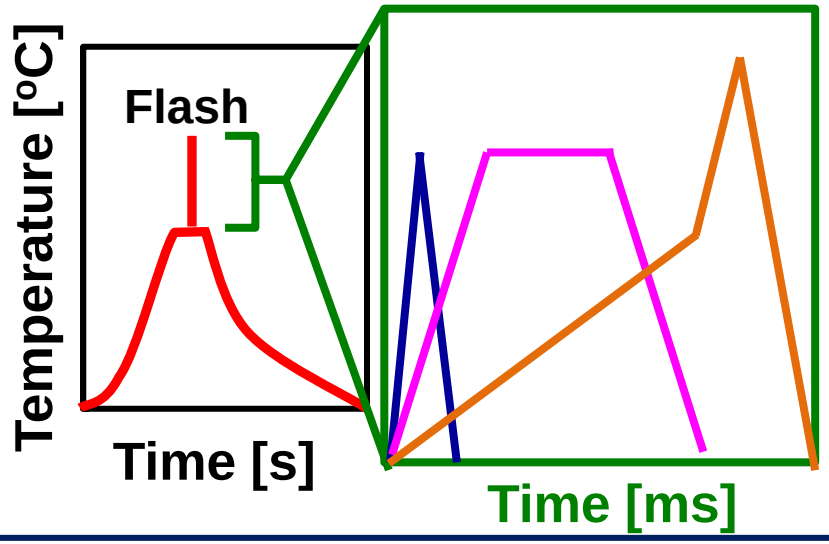
Introduction of FLA and presentation theme

FLA system



(Halogen lamp / Heater)

Temperature profile



S. kato et al VLSI tech. p71(2010)

T. Onizawa et al VLSI tech. p162(2009)

***FLA: LA-3000**

FLA feature

- **High accuracy annealing in millisecond order**

Today, we present

- **The formation of shallow n+/p junctions in Ge**
- **High-precision diffusion control**

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1. Introduction
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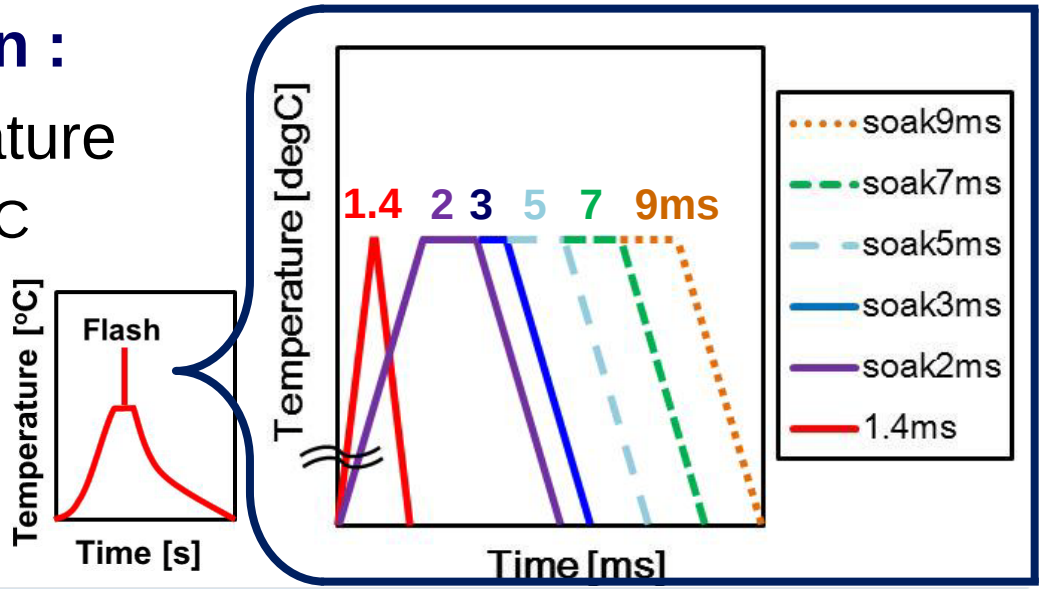
Experimental methods

- **Substrate : P type Ge wafer**
- **Implantation :**

No.	PAI	Dopant	Energy [keV]	Dose [atoms/cm2]
1	Ge	P	2	$1x10^{15}$
2	-	P	2	$1x10^{15}$
3	Ge	As	5	$1x10^{15}$
4	-	As	5	$1x10^{15}$

- **Anneal condition :**
  - Peak Temperature
    - 610~900 degC
  - Flash pulse
    - 1.4 ms
    - Soak 2~9 ms



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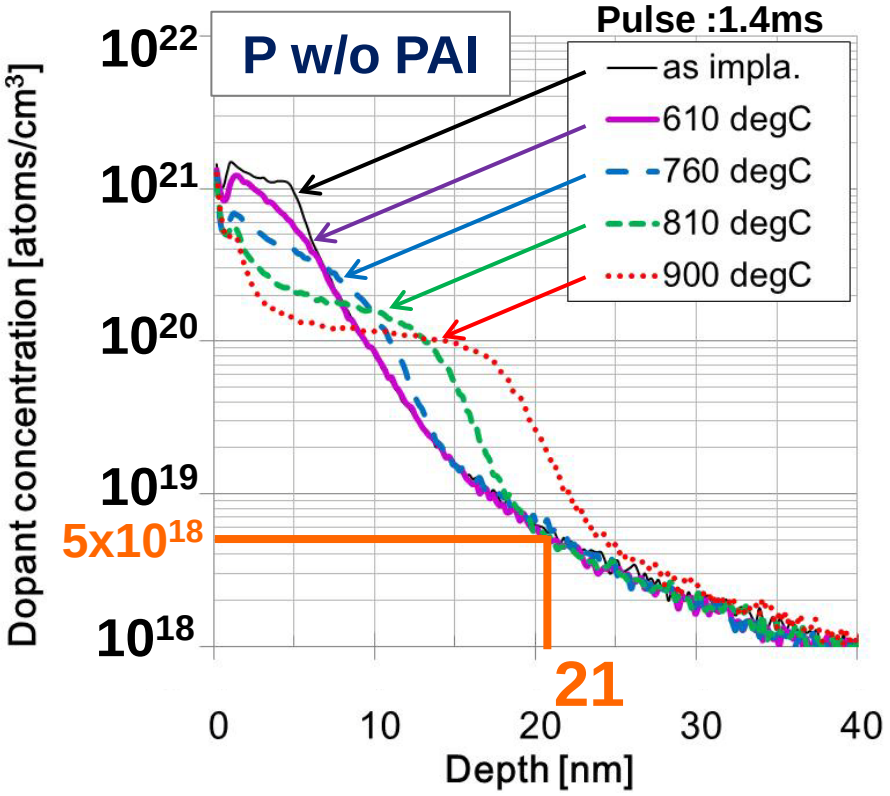
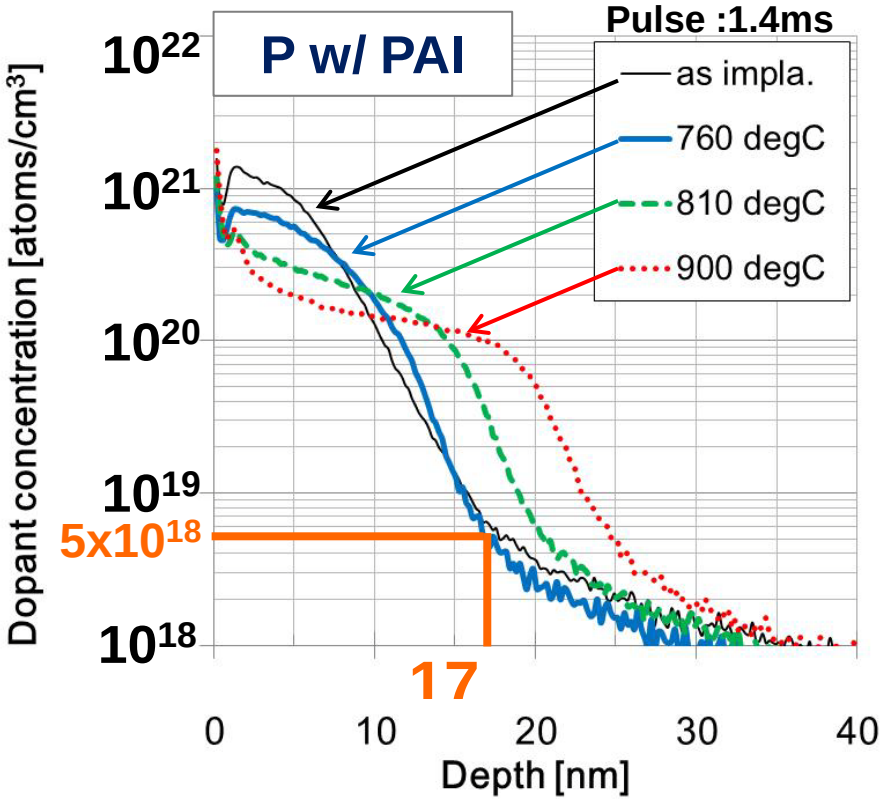
SIMS profiles of P for various Tp

Tp: peak temperature

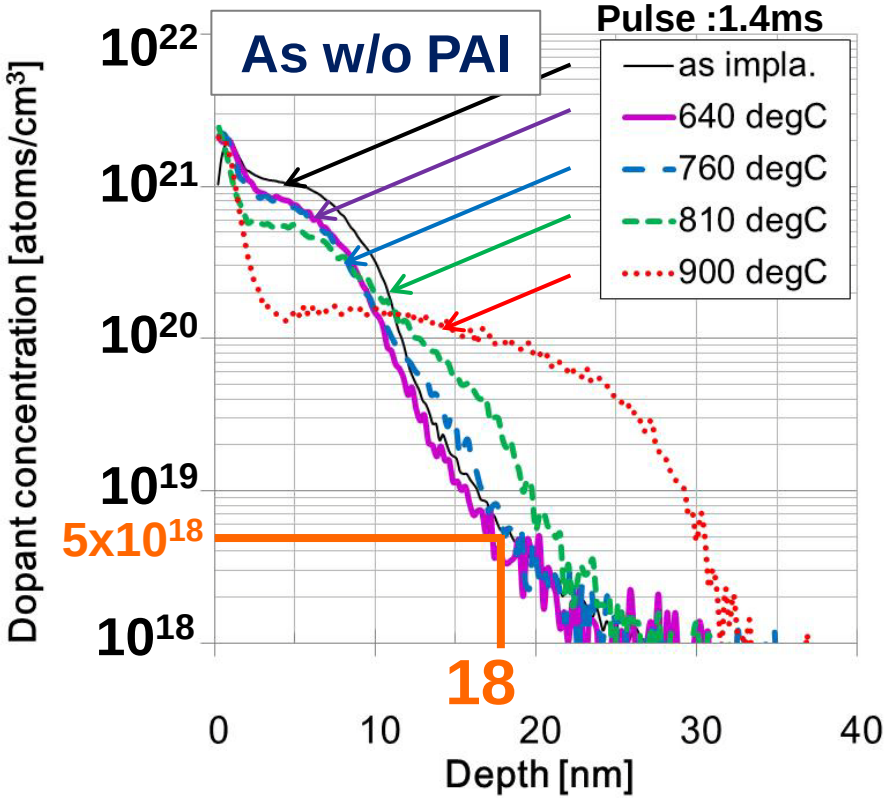


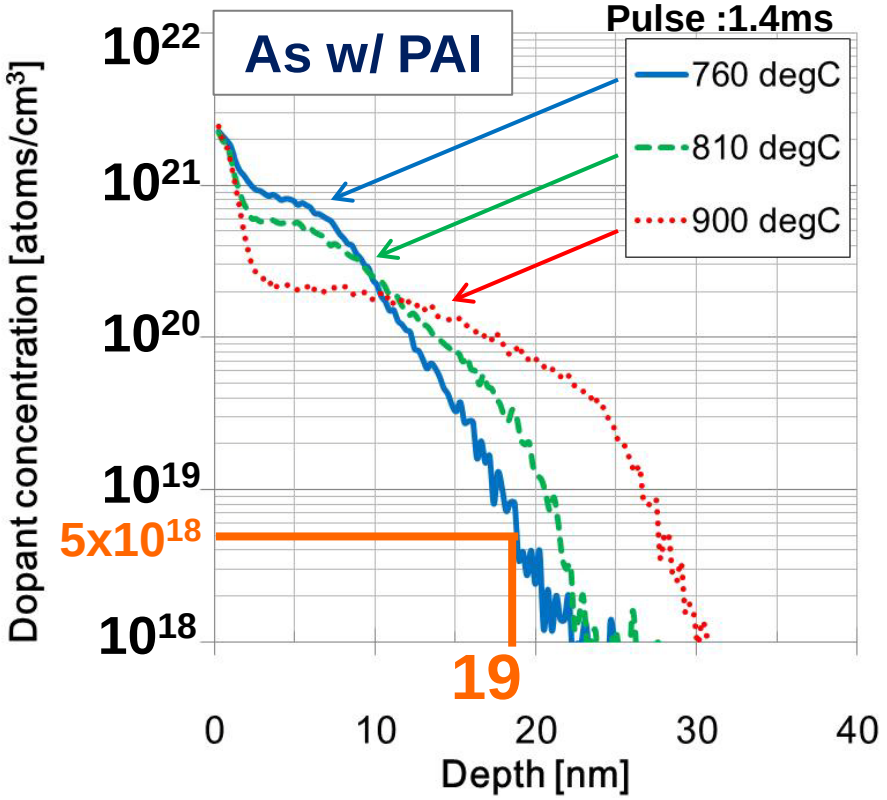


- FLA can form shallow junction in Ge.
- PAI layer suppresses the channeling effect during ion implantation.

SIMS profiles of As for various Tp

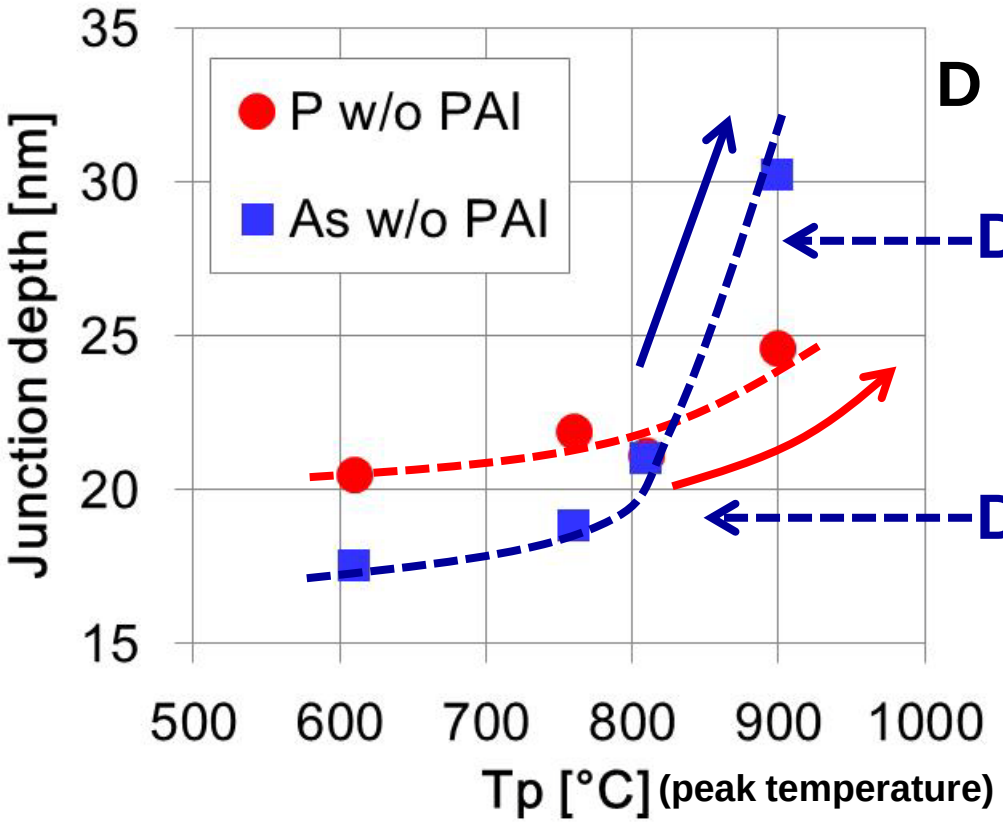
Tp: peak temperature





♦ **FLA can also form shallow junction in As.**

High diffusivity of As in high temperature



D : Diffusivity

D ≒ Di

i : intrinsic

D ≒ De(n/ni)^2

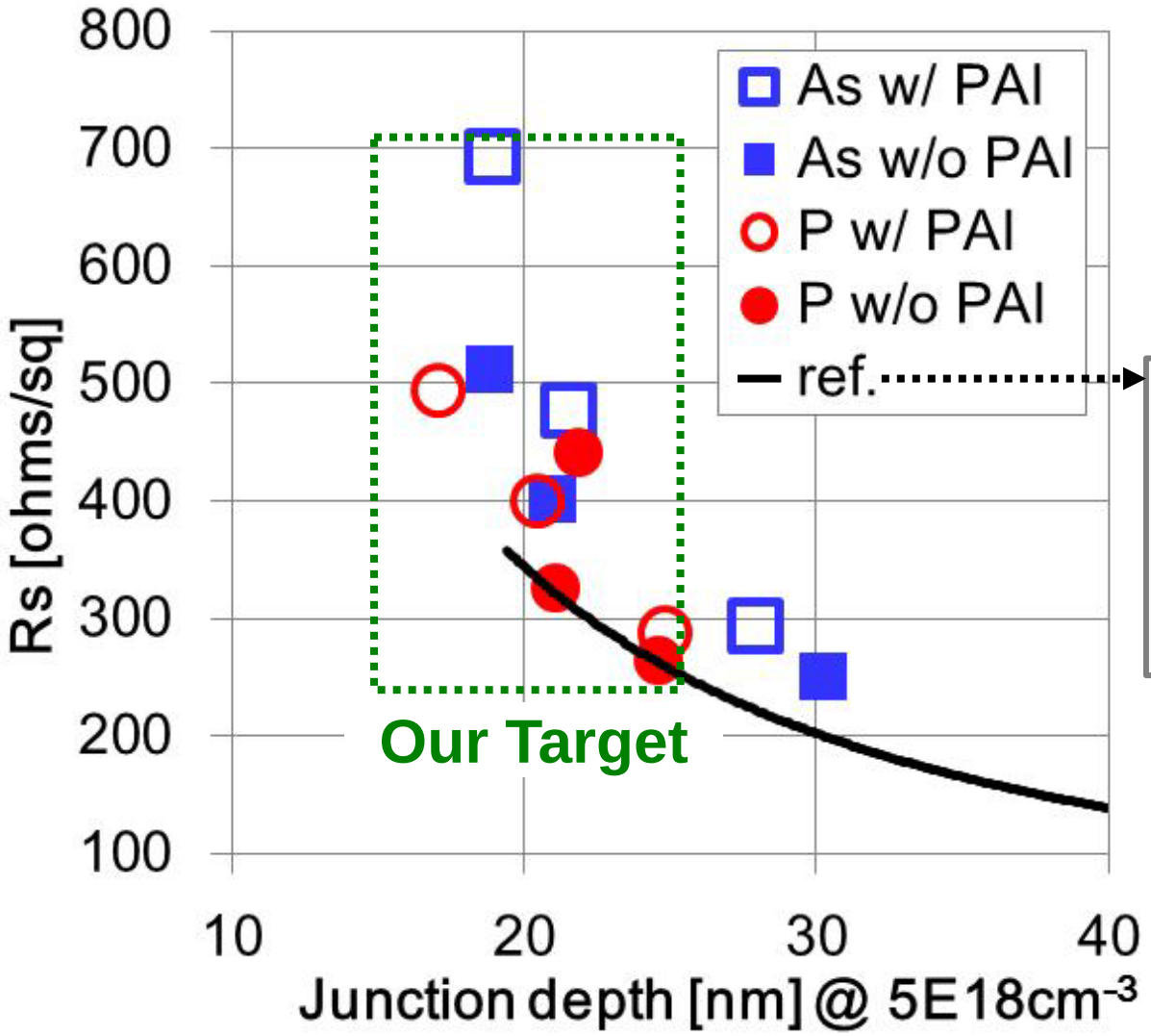
e : extrinsic

n : concentration

**** Junction depth defined as being at a concentration of 5x10^{18} atoms/cm^3**

- **As diffuses well in higher temperature.**
- **FLA can control the junction depth.**

Shallow junction and high activation



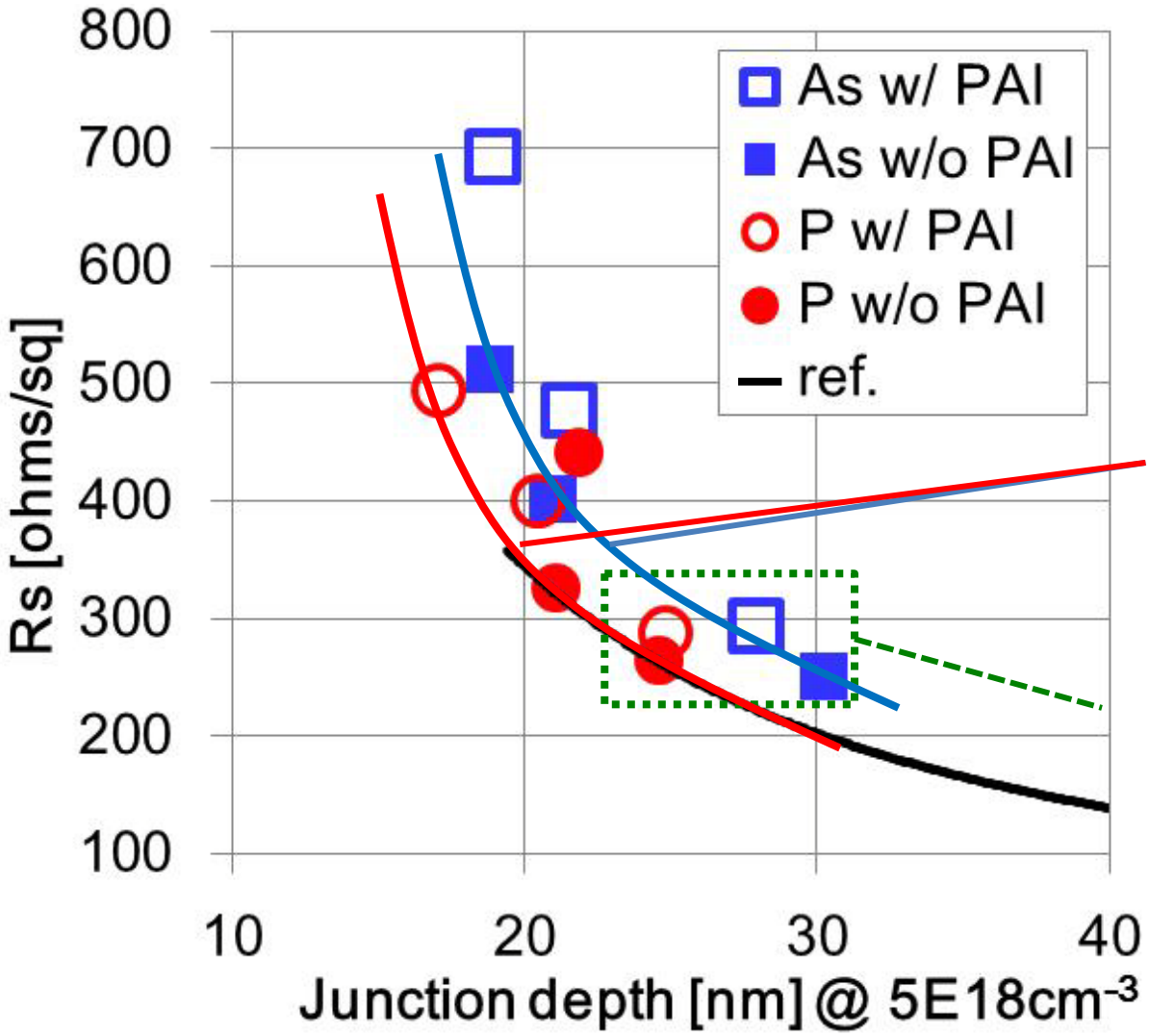
Low resistivity as well as shallow junction depths is also important for device applications.

M. J. H. van Dal, B. Duriez, G. Vellianitis, G. Doornbos, R. Oxland, M. Holland, A. Afzalian, Y. C. See, M. Passlack and C. H. Diaz, IEDM 2014, pp235-238

*** All the sheet resistances were measured by micro-RSP**

♦ FLA can form high activated junctions.

Comparison of As and P, PAI effect

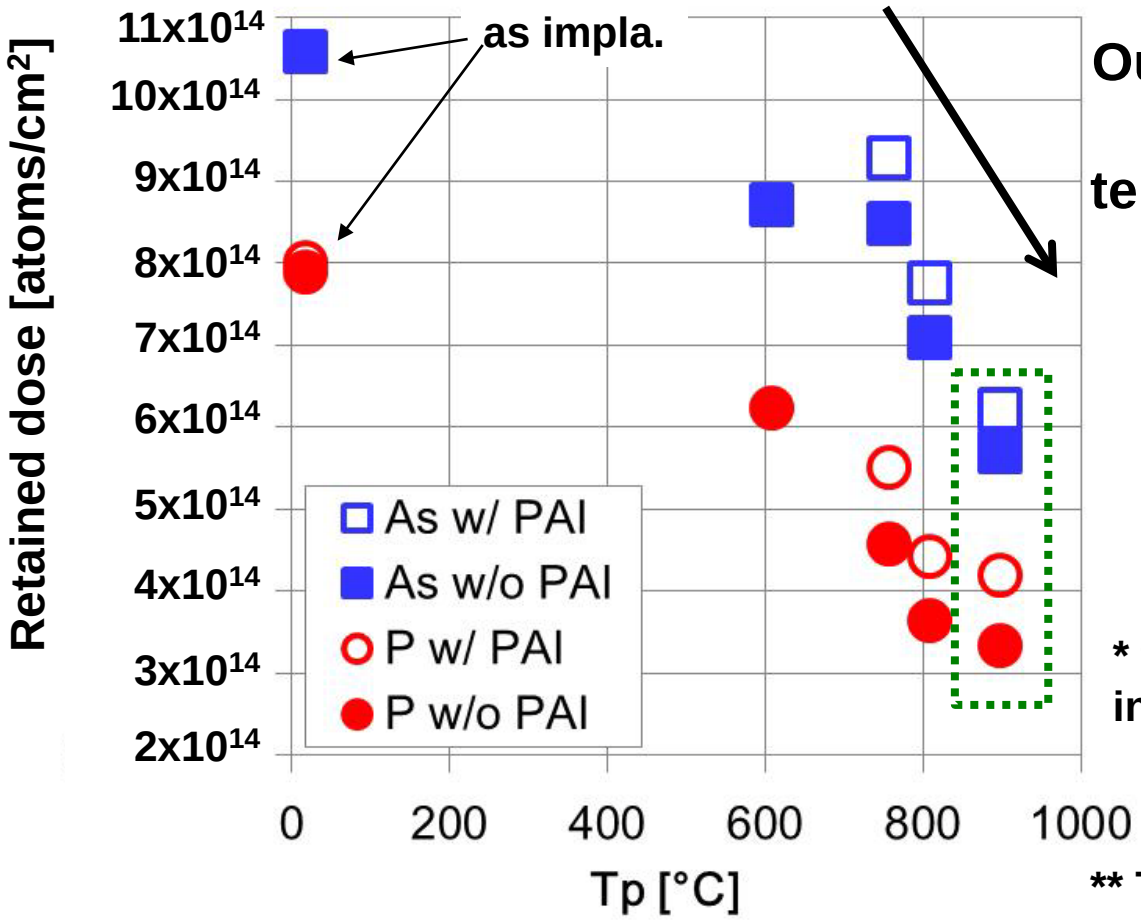


Xj :
P < As

Rs :
w/o PAI < w/ PAI

♦ **We analyzed retained dose and XTEM.**

Retained dose vs annealing temperature



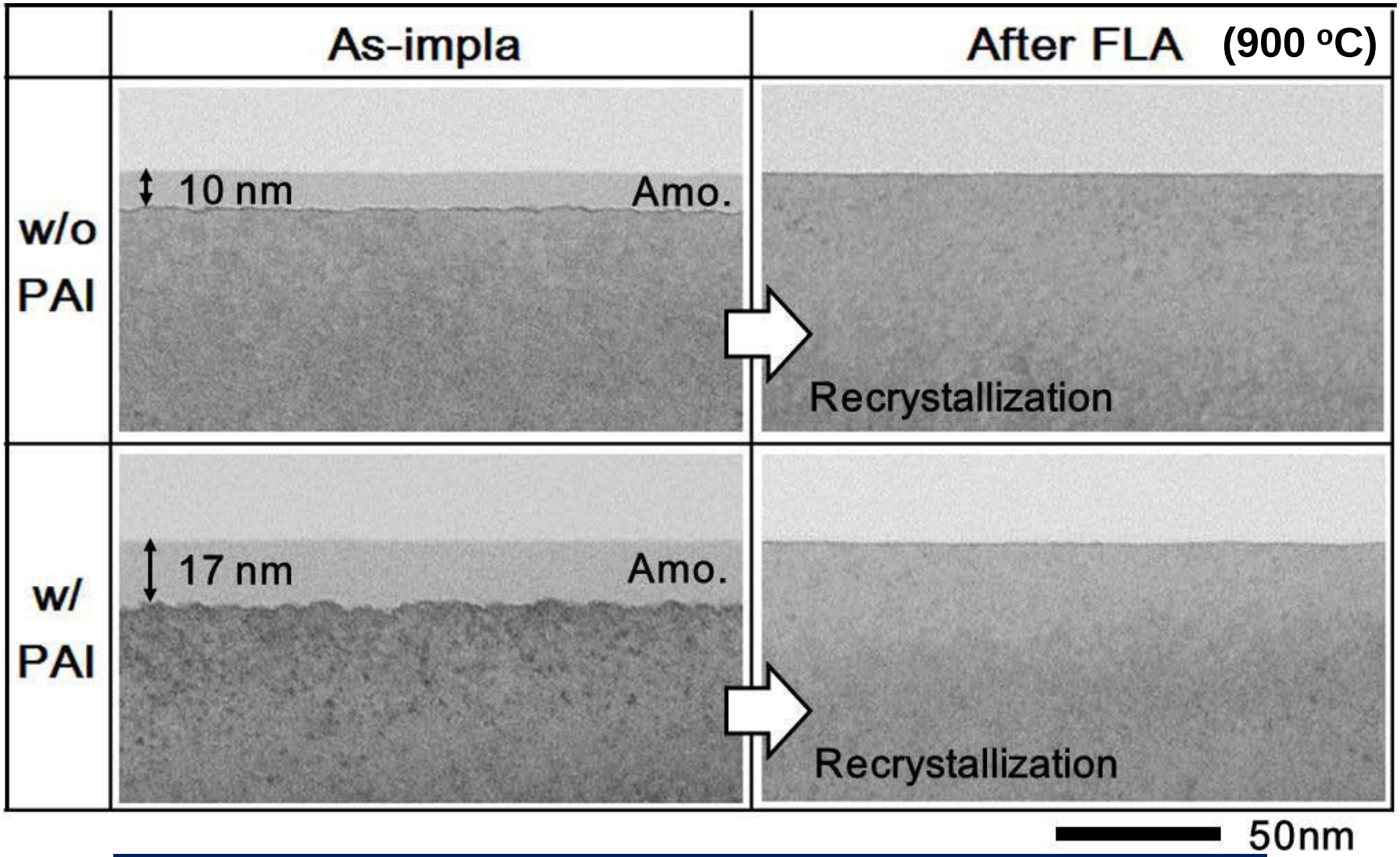
Out-diffusion becomes prominent as peak temperature increases.

*** the doping concentration integrated from 0 to 50 nm.**

**** Tp : peak temperature**

- **PAI suppress the out-diffusion, so we expect further improvements.**

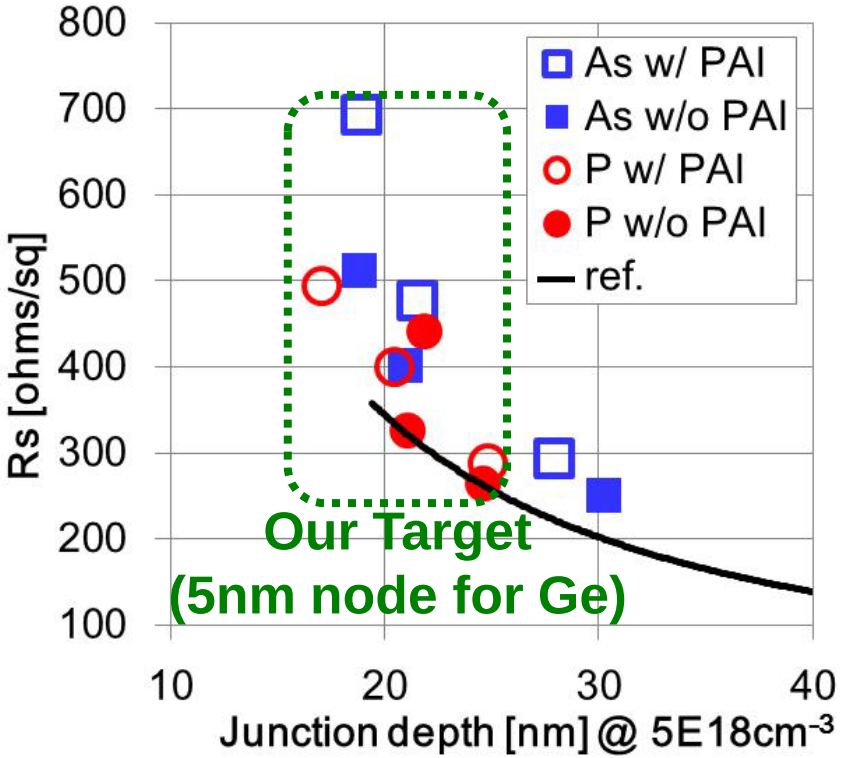
Damage free junction using FLA



♦ **FLA can form damage free junctions.**

Summary of this section

- **FLA can form excellent n+/p-Ge junctions**
  - shallow junction depths
  - low sheet resistivity
  - no residual defects



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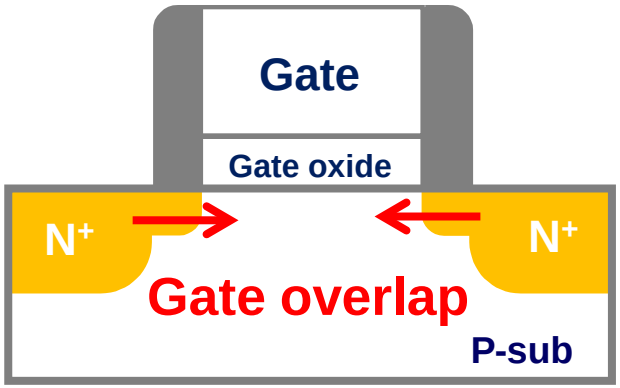
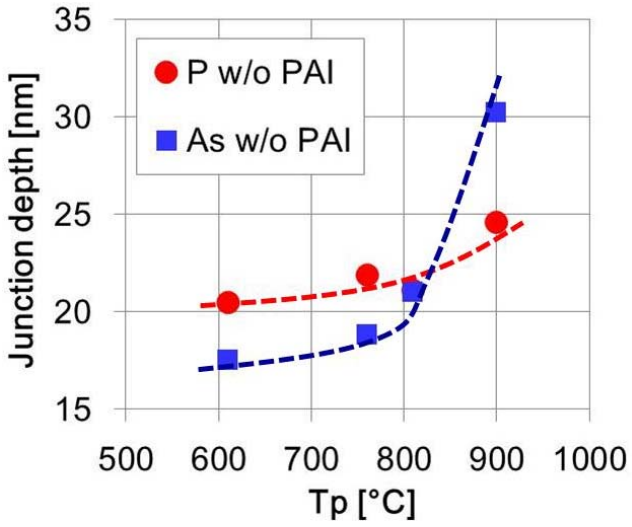
Precise diffusion control



Diffusion control is important.

Gate overlap is one of the most crucial factors in device performance.



We have already demonstrated the diffusion control by changing Tp.

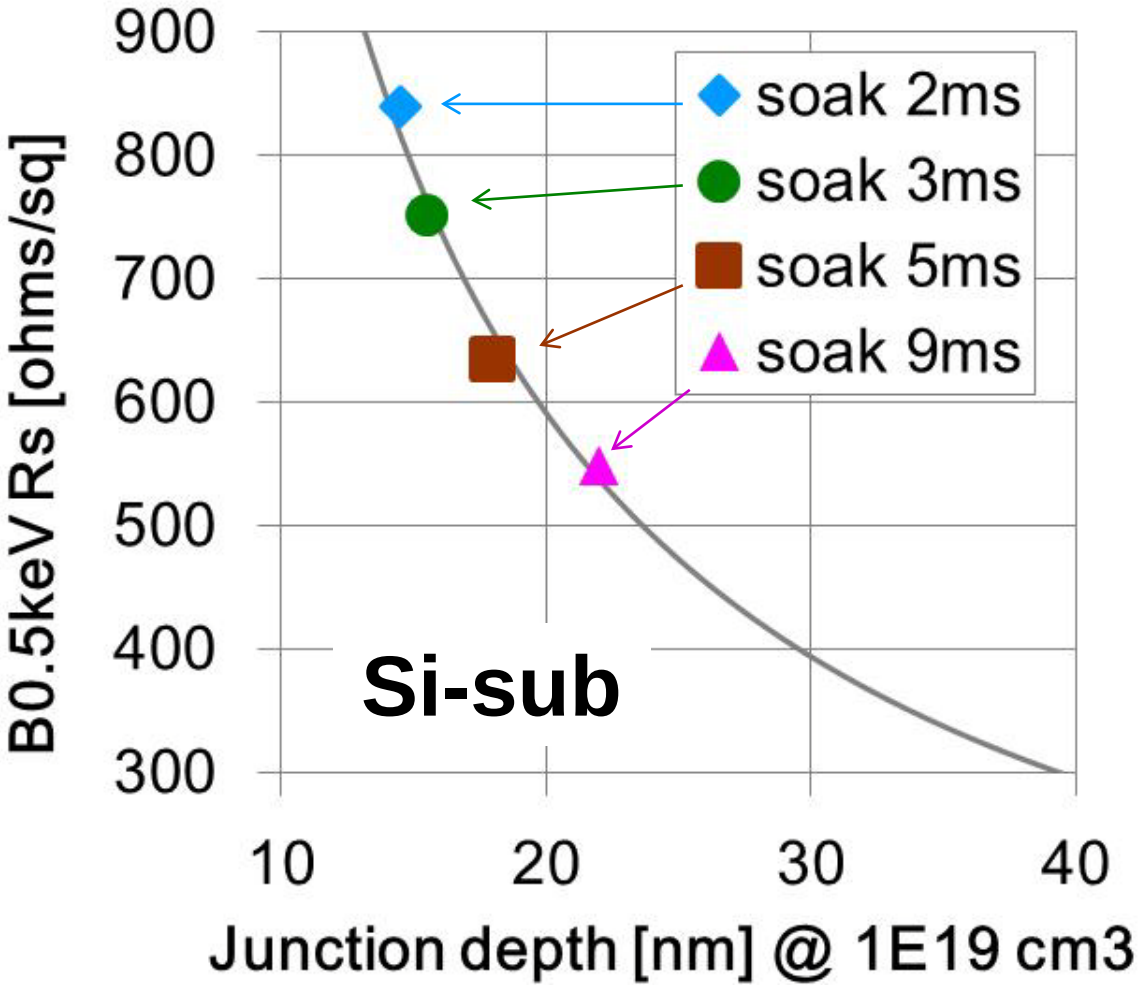
Tp : peak temperature

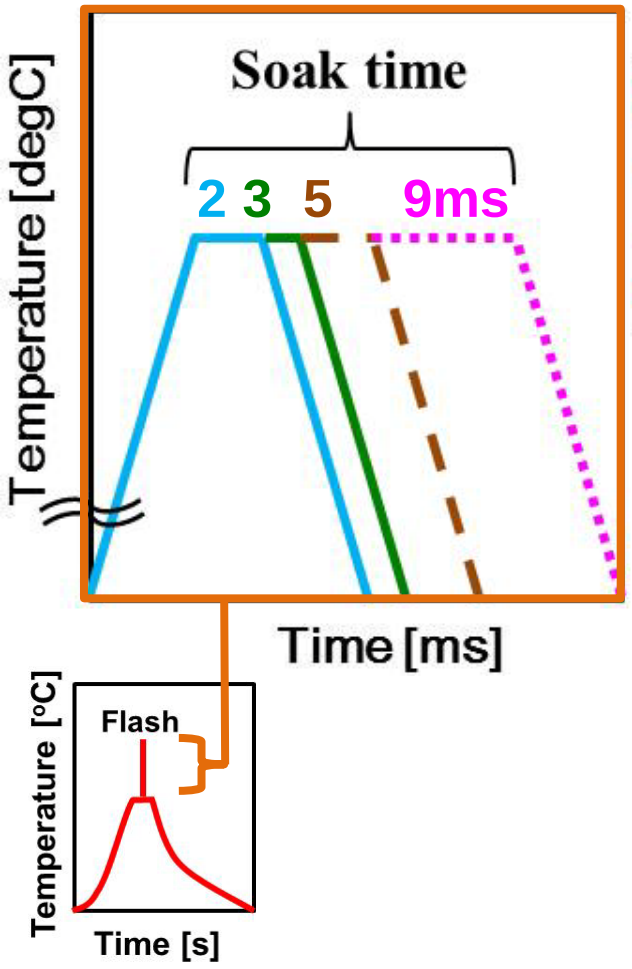
However Tp is often limited by other fabrication factors.

Ex. (1) relaxation of the local stress
(2) other process condition

Practical way is needed alternative to only Tp controling.

Diffusion control by changing flash pulse

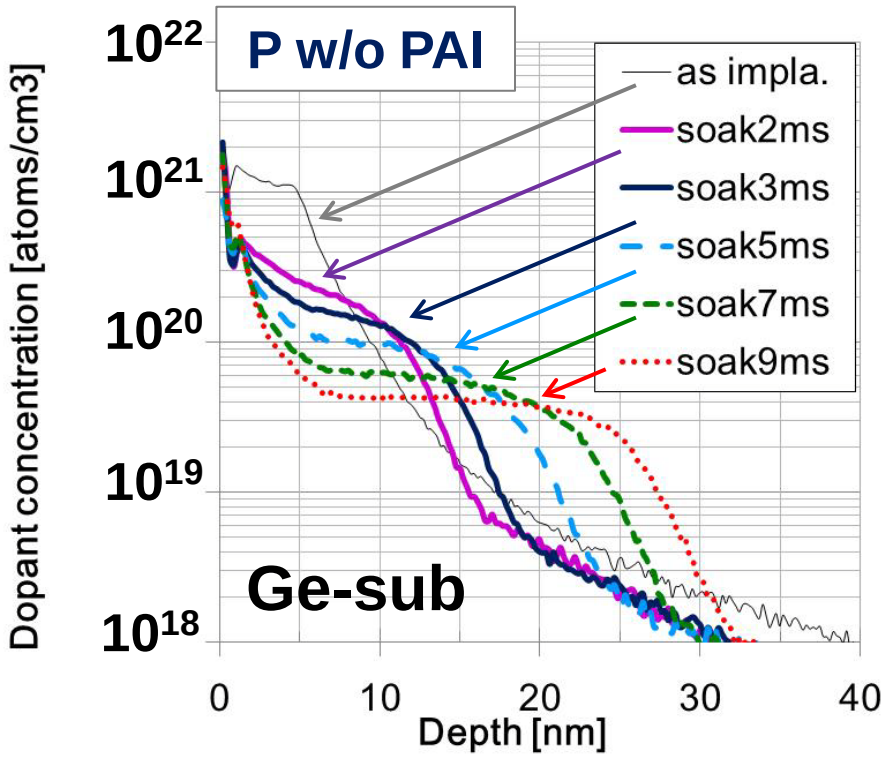


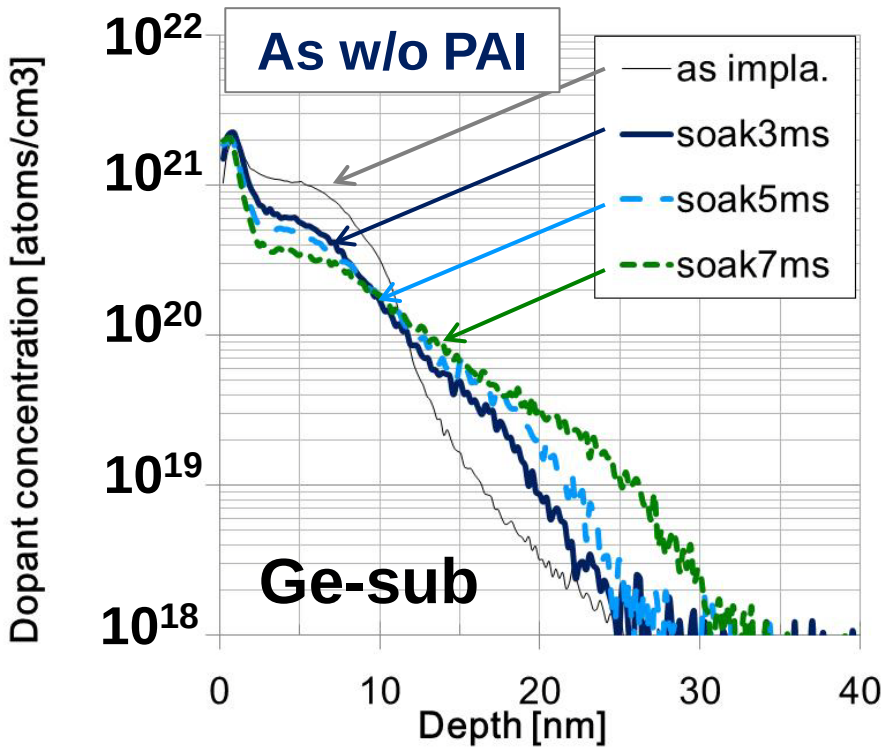


♦ **We propose diffusion control by flash pulse.**

⇒ **We applied for Ge-sub.**

SIMS profiles (soak pulse length change)



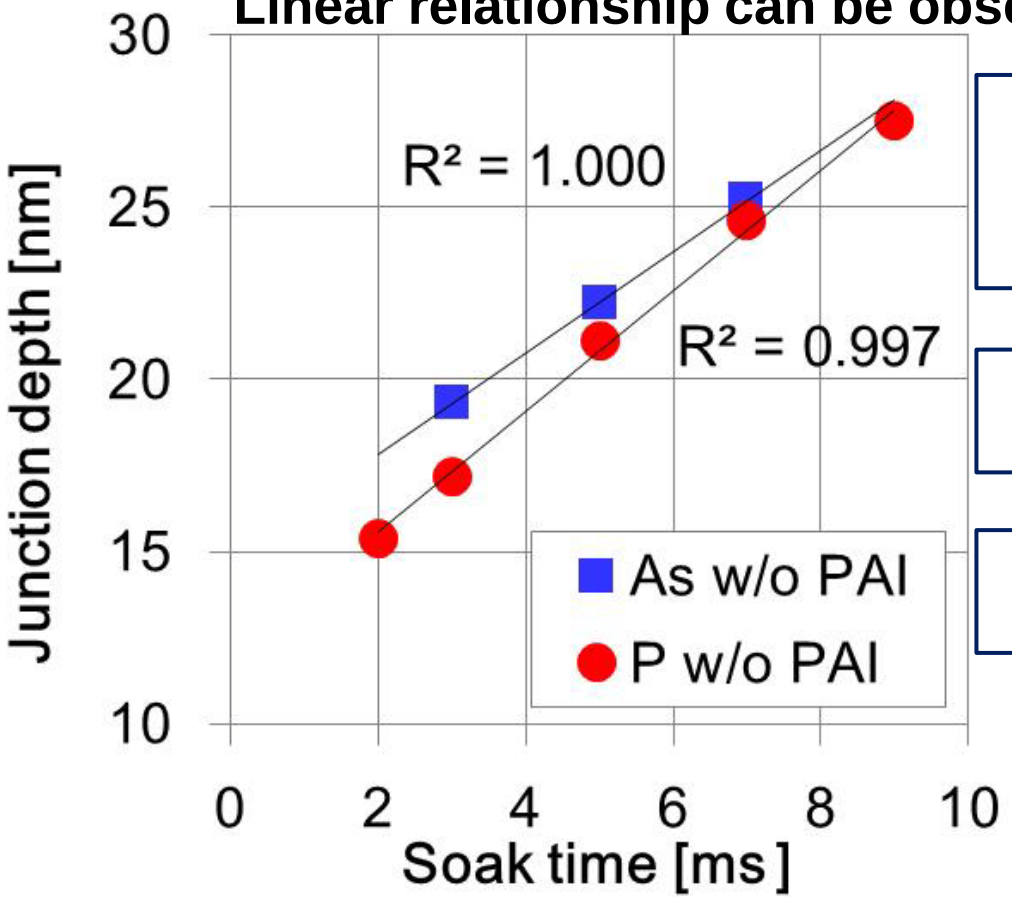


- **FLA can also control dopant diffusion in Ge by changing the millisecond soak time.**

⇒ **We checked diffusion controllability.**

Diffusion controllability

Linear relationship can be observed



FLA can control the diffusion by approximately 1nm per 1ms in P sample.

FLA system control of the soak time is of the order of 100usec

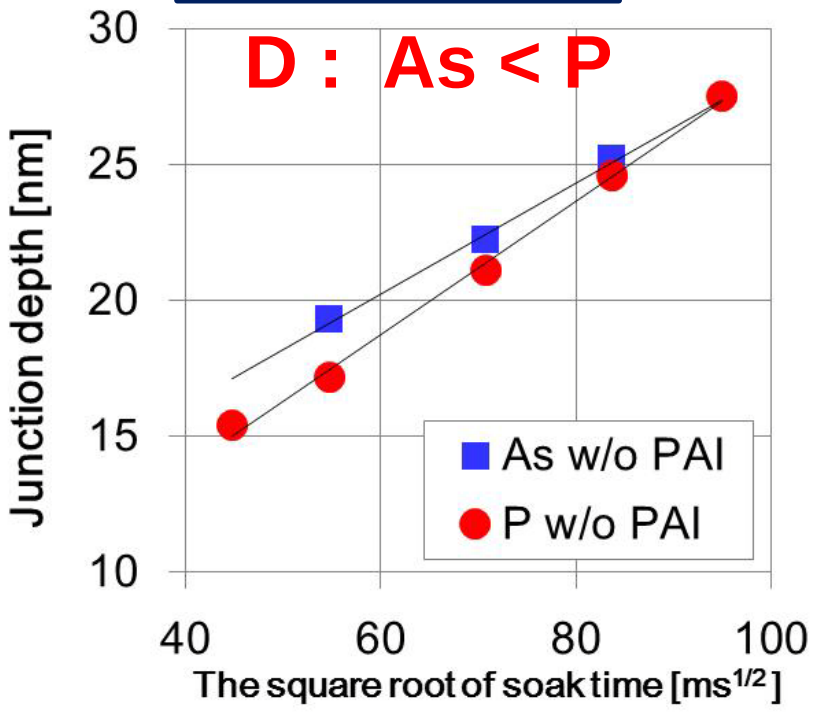
FLA may be able to control the diffusion to the order of 1ang.

***junction depth defined as being at a concentration of $1x10^{19}$ atoms/cm3**

♦ Great accuracy of diffusion control.

Dopant characteristic

This study



Reference data

ρ_c : As < P

Doping species	Ni	ρ_c ($\Omega \cdot cm^2$)	R_{sc} (Ω/sq)	R_{me} (Ω/sq)
P	thin	5.0e-6	148	8.5
P	thick	8.8e-5	133	3.5
As	thin	1.1e-7	95	8.5
As	thick	1.9e-7	93	3.5
B	thin	5.4e-7	38	9

M.J.H. van Dal et al., IEDM 2014, pp235-238

- **We propose to use P and As separately**
  - P for gate overlap control
  - As for contact barrier lowering

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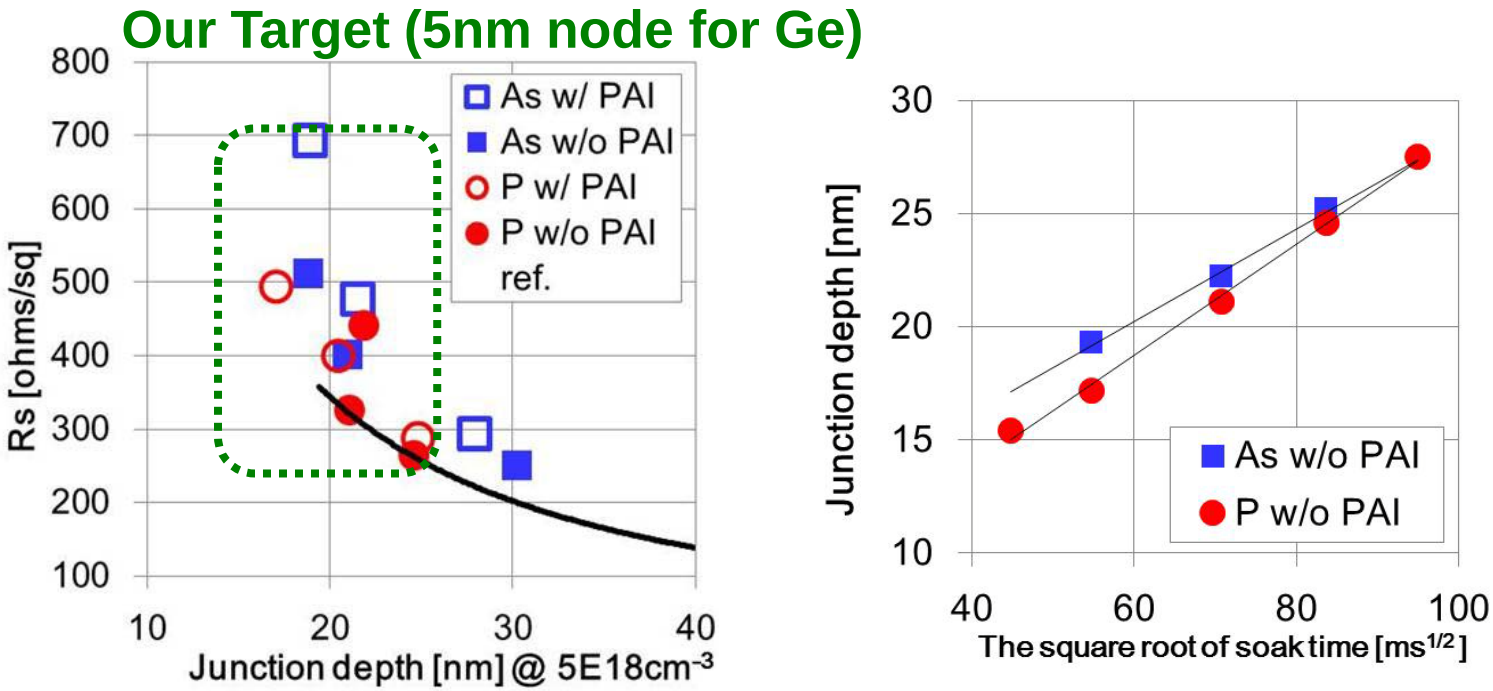
Conclusions

- **FLA can form high activated and diffusion less junctions in Ge.**
- **FLA has excellent controllability of the dopant diffusion.**



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