

EFUG2005



Triple Beam for TEM Sample Preparation

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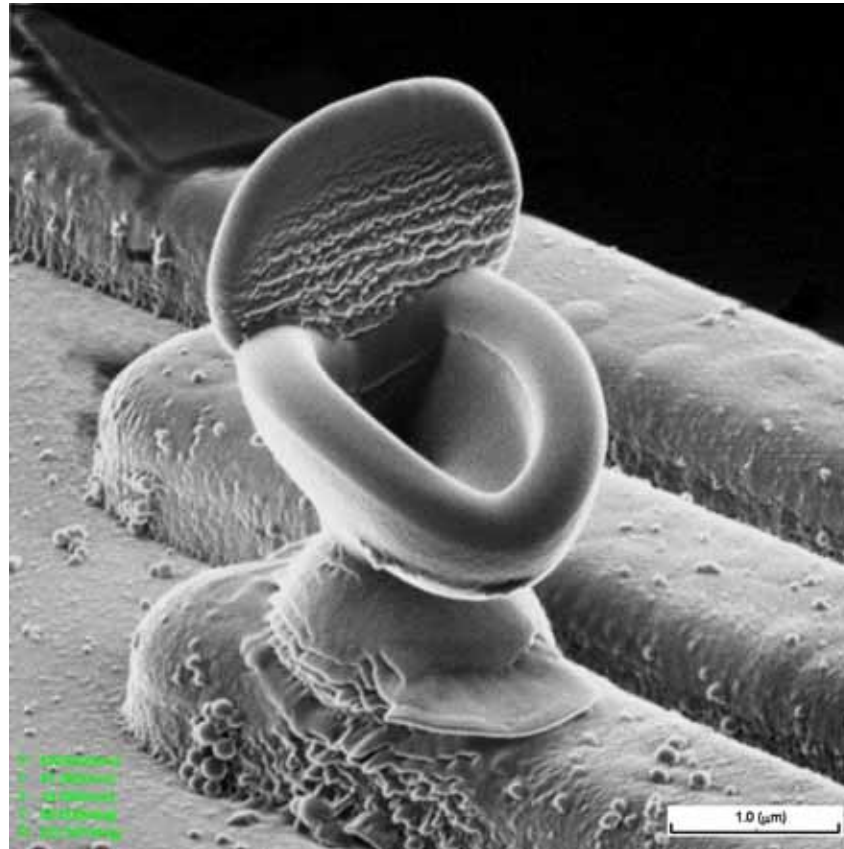
SII NanoTechnology Inc.

Dec. 1st, 2005



- 1984 Mask Repair
- 1986 Single Beam FIB
- 1990 Double Beam
- 2005 Triple Beam





Toilet in the “Nano World”

Carbon deposition using Phenanthrene gas

SII NanoTechnology Inc.
is not only making "Toilet"
but also making TEM samples
by FIB!

Purpose of this Research and Development
Concept of Triple Beam
Evaluation of the First Machine
Conclusion

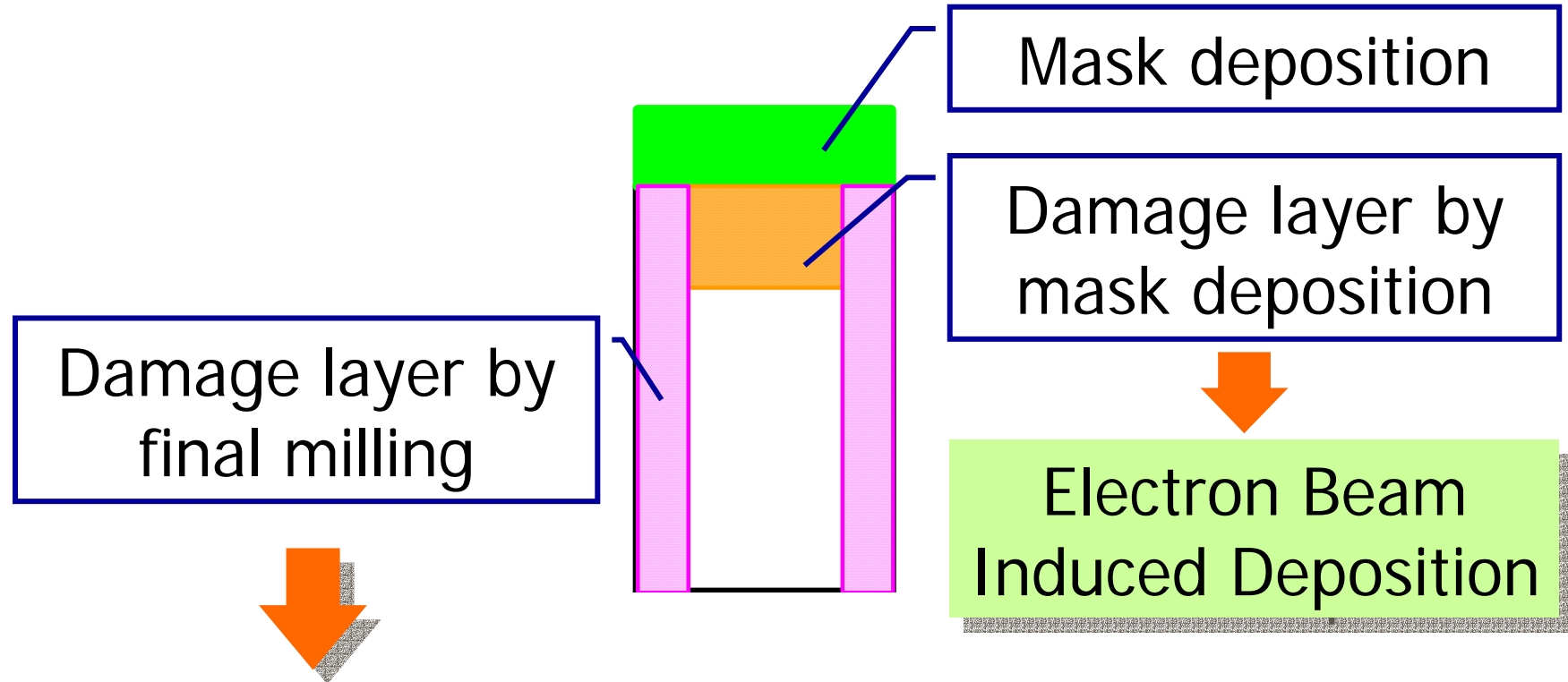
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Purpose



One of Current Issues
Damage at walls of lamellas

One of Solutions for Reduce Damage

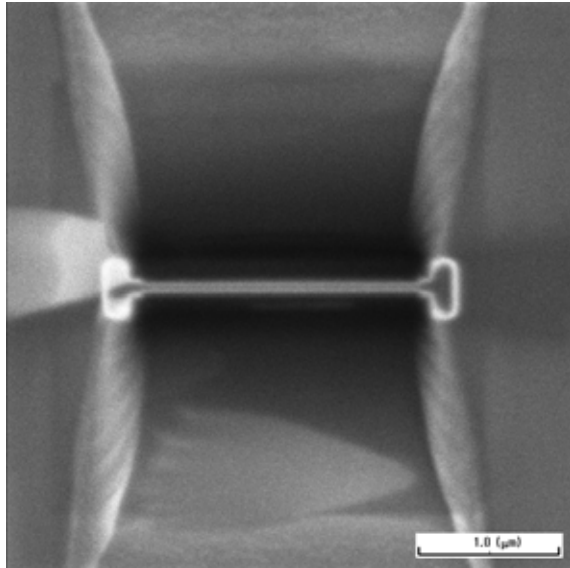


Low Acceleration Voltage Ga Ion Beam

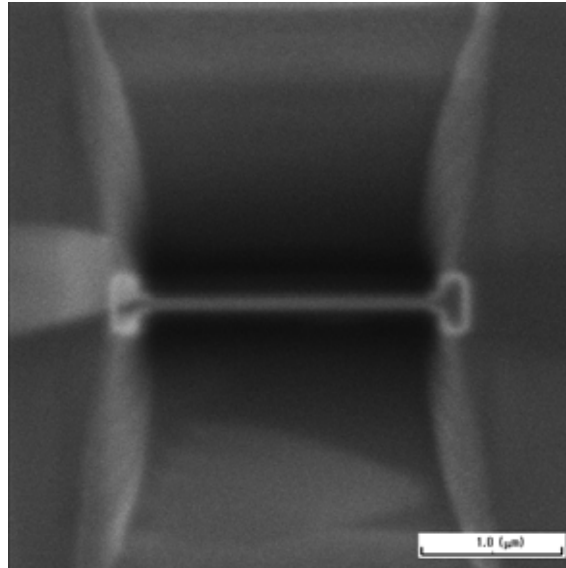
Low V_{ACC} FIB



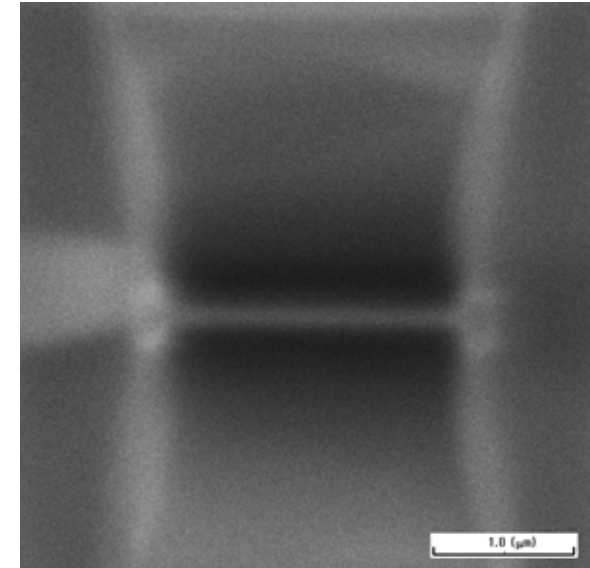
3kV



2kV



1kV



Scanning Ion Microscope Images
By Final Milling Ion Beam Current 40pA
SMI3000-Series

Thickness of Lamella: approximately 200nm

Mechanical Damage was reduced
by Low V_{ACC} Ga Ion Beam



Chemical Damage?



Low Energy Inactive Gas Ion Beam

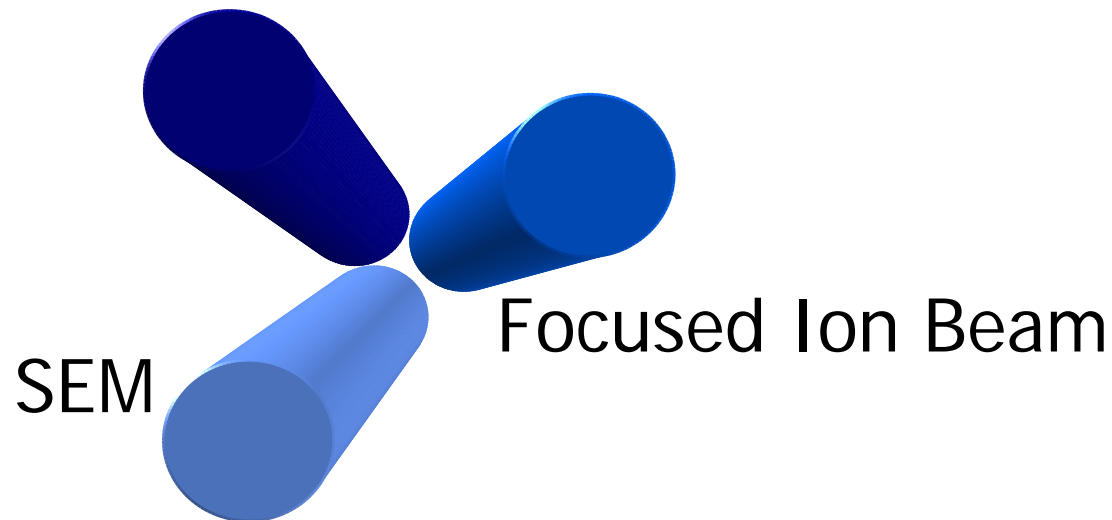
How to Operate Low Energy Inactive Gas Ion Beam?

- To Realize High Precision Processing
 - Irradiation Point
 - Incidence Angle
 - End Point Recognition
 - Reduce Re-deposition
 - etc.



Solution for Damage-Reduce
TEM Sample Preparation
is
Triple Beam !

Inactive Gas Ion Beam



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Role

FIB: Making the lamella

Ar: Finishing the lamella

SEM: Monitoring the sample state

Advantages

Sureness

Ga free finishing or reduce effect of Ga

Easy operation

Cross Three Beams at One Point of the Specimen Surface*

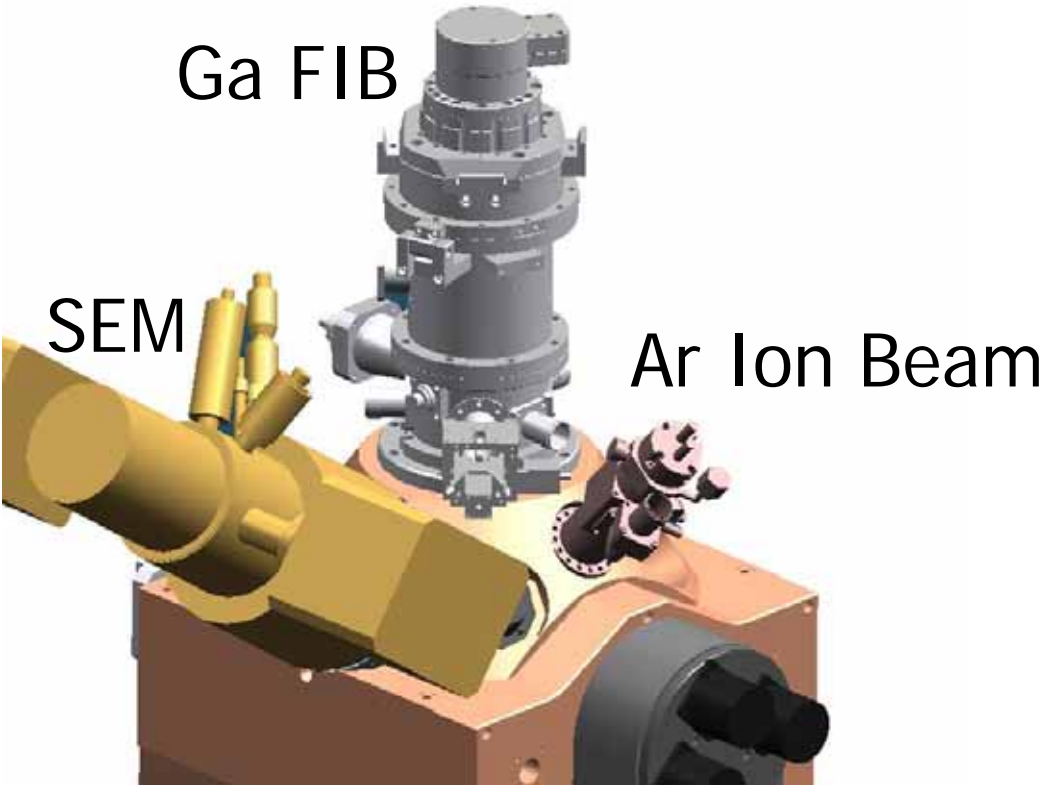
Decide Ar Beam Incidence Angle by Stage Operation

Set the Sample at the Beam Coincidence Point by SEM Observation

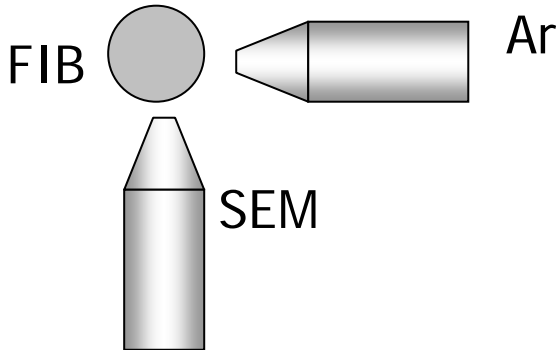
Use Optimized Grids for this Process to Reduce Re-deposition

*Combination of FIB and Inactive Gas Ion Beam: USP5,574,280

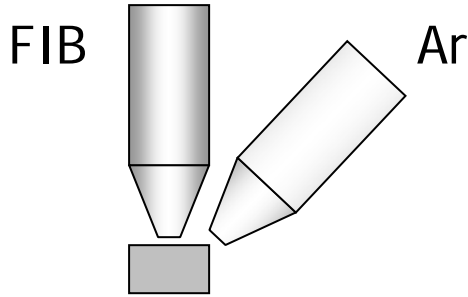
Column Alignment



Top View



Side View



SMI3050TB

Performance of Ar Ion Beam

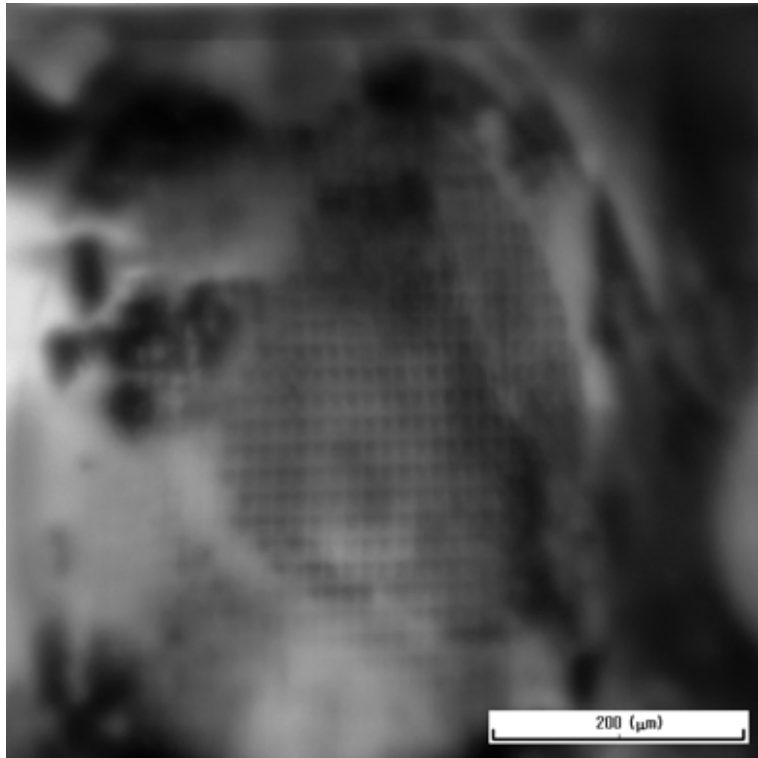


Acceleration Voltage:	1.0kV
Max Beam Current:	10nA
Max Etching rate:	>5nm/min

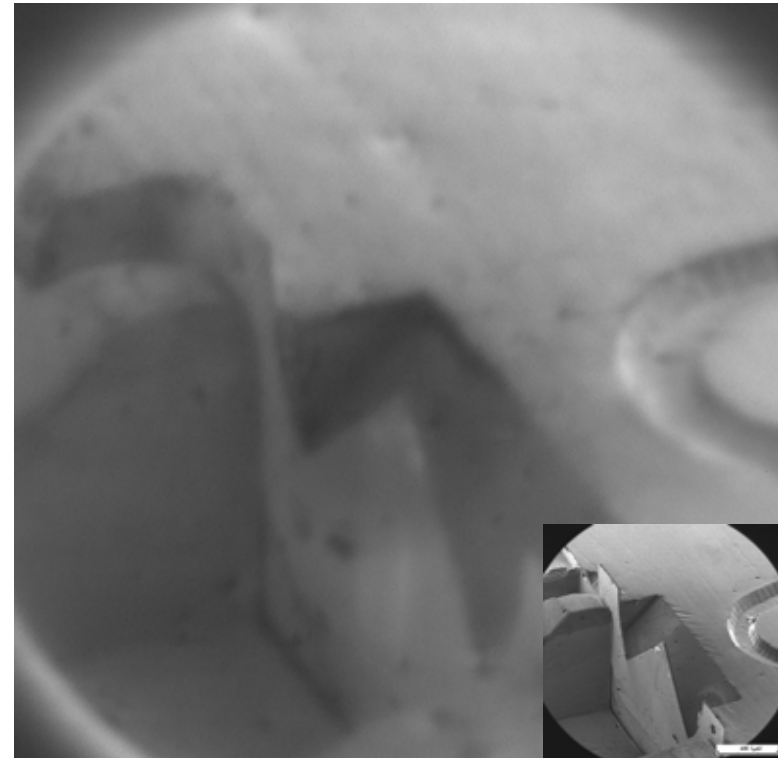
Scanning Ar Ion Beam Images



300 Mesh



Optimized Grid

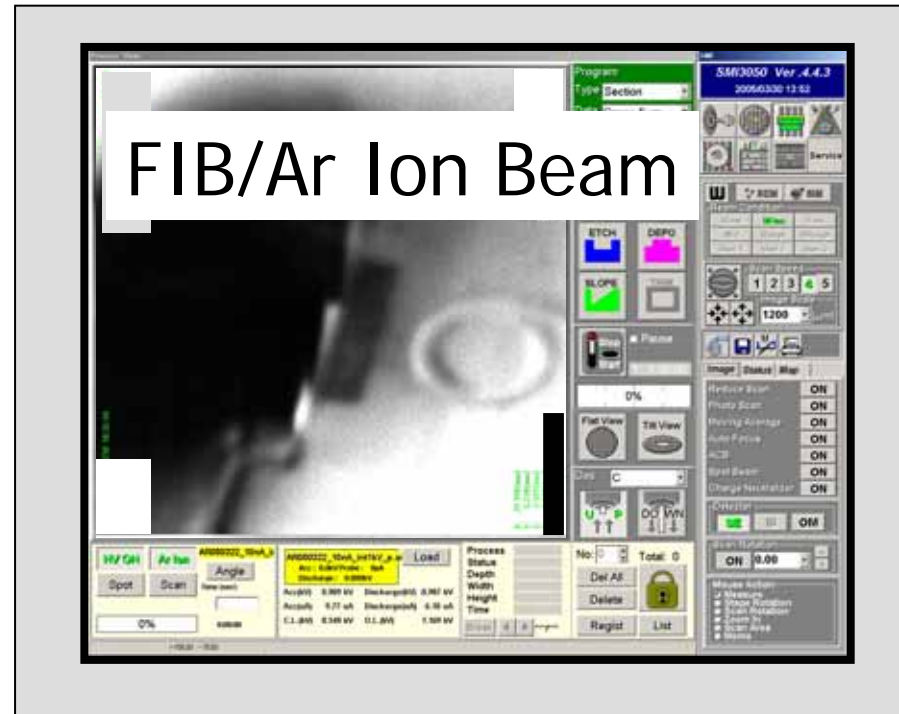


Adjust Beam Irradiation Point

Double Display



- High Resolution Observation
- Process Monitor
- Adjust Sample Position for Ar Ion Beam Process



- FIB Processing
- FIB Observation
- Ar Ion Beam Processing
- Scanning Ar Ion Beam Image

Incident Angle Adjustment



The screenshot displays the SEM software interface with a central 'Process View' window showing a grayscale image of a sample. A smaller 'Ar Angle' dialog box is overlaid on the image, and a larger, detailed 'Ar Angle' dialog box is shown to the right, connected by a black arrow. The larger dialog box has two tabs: 'Auto' and 'Manual'. The 'Manual' tab is selected, showing the following settings:

- Ar Angle (deg): 10.00
- Observe Both Side
- Observation Mode: Frontside Backside
- Delta Rotation: 165.106
- Delta Tilt: 0.000
- SEM Angle: -52.338
- SEM Side: Back
- Go button

Below the 'Go' button is the 'Home Position' section:

- Rotation: 0.000
- Tilt: 0.000
- Reg. Home button
- Go Home button

The background interface includes a 'Program' section with 'Type Section' and 'Data Cross Num' dropdowns, 'Process' mode selection (Flat, Vector, MP, 3D), and various process buttons like ETCH, DEPO, SLOPE, and TRIM. A 'Stop/Start' control and a '0%' progress indicator are also visible. At the bottom, there are 'HV ON', 'Ar Ion', and 'Angle' buttons, along with a status bar showing 'AR050322_10nA' and various parameters like Acc(kV), Discharge(kV), Acc(uA), Discharge(uA), C.L.(kV), and O.L.(kV).

Processing



Process View

Program: Section
Data: Cross_5um

SII SMI3050 Ver.4.4.3
2005/03/30 13:52

Ar Ion Beam Controller

AR050322_10nA_i

HV ON Ar Ion Angle
Spot Scan Time (sec)
0
0% 0:00:00

AR050322_10nA_i
Load
Process Status
Depth
Width
Height
Time
No: 0 Total: 0
Del All
Delete
Register List

Acc(V) 0.909 kV Discharge(V) 0.907 kV
Acc(uA) 9.77 uA Discharge(uA) 6.10 uA
C.L.(V) 0.510 kV O.L.(kV) 1.169 kV

Auto Focus: ON
ACB: ON
Spot Beam: ON
Charge Neutralizer: ON
Detector: SE SI OM
Scan Rotation: ON 0.00
Mouse Action: Measure, Stage Rotation, Scan Rotation, Zoom In, Scan Area, Memo

300 (µm)

Gas: C

DO WN

Outline



Purpose of this Research and Development

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Evaluation of the First Machine

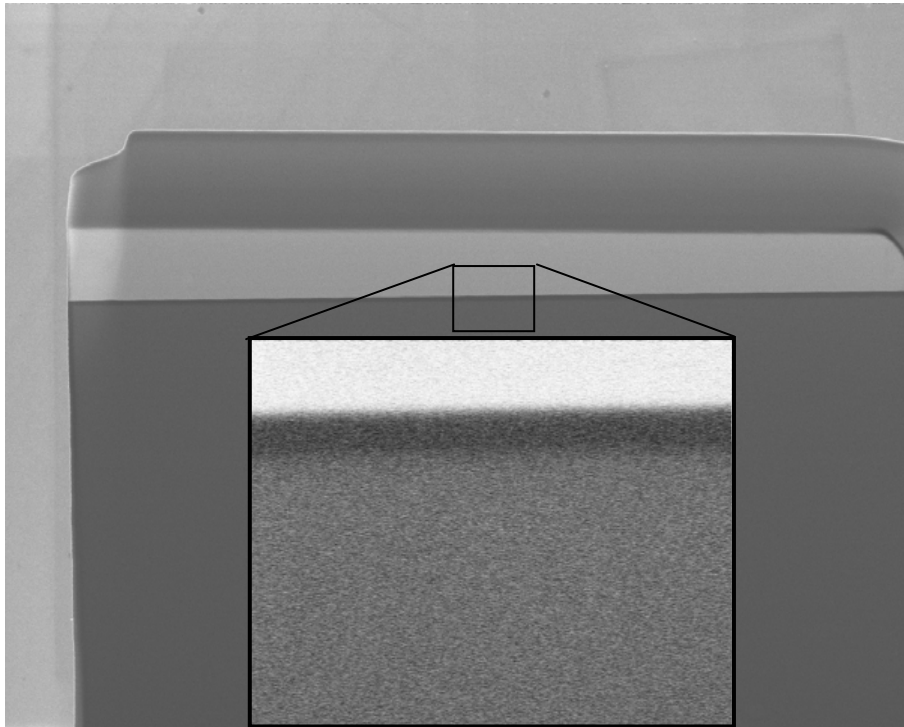
Conclusion

Damage Evaluation by STEM



Ga-FIB

VACC=30kV

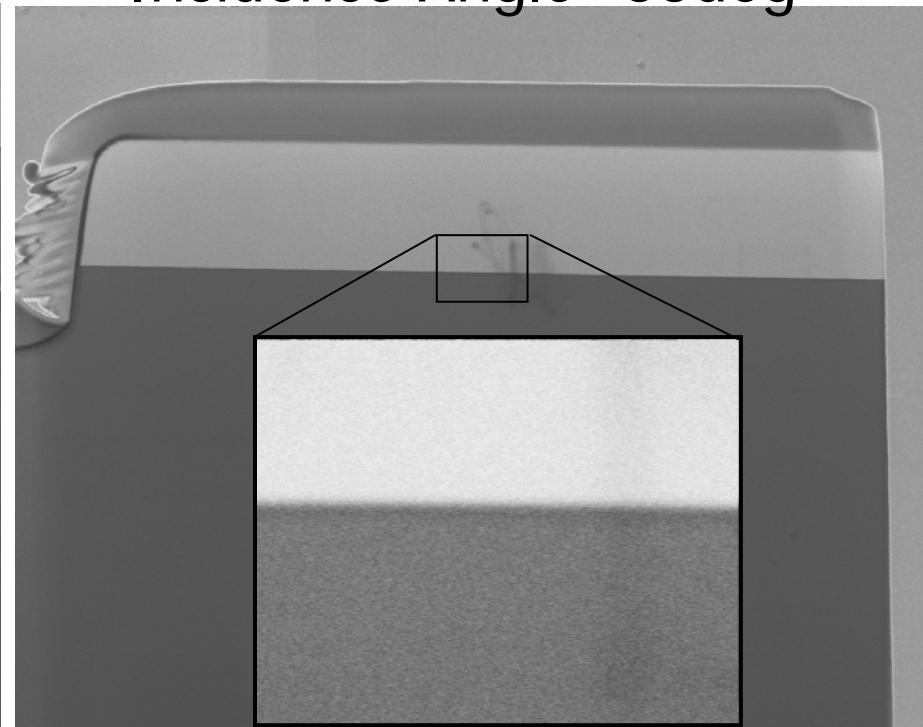


Damage Thickness: 2~30nm

Ar Ion Beam

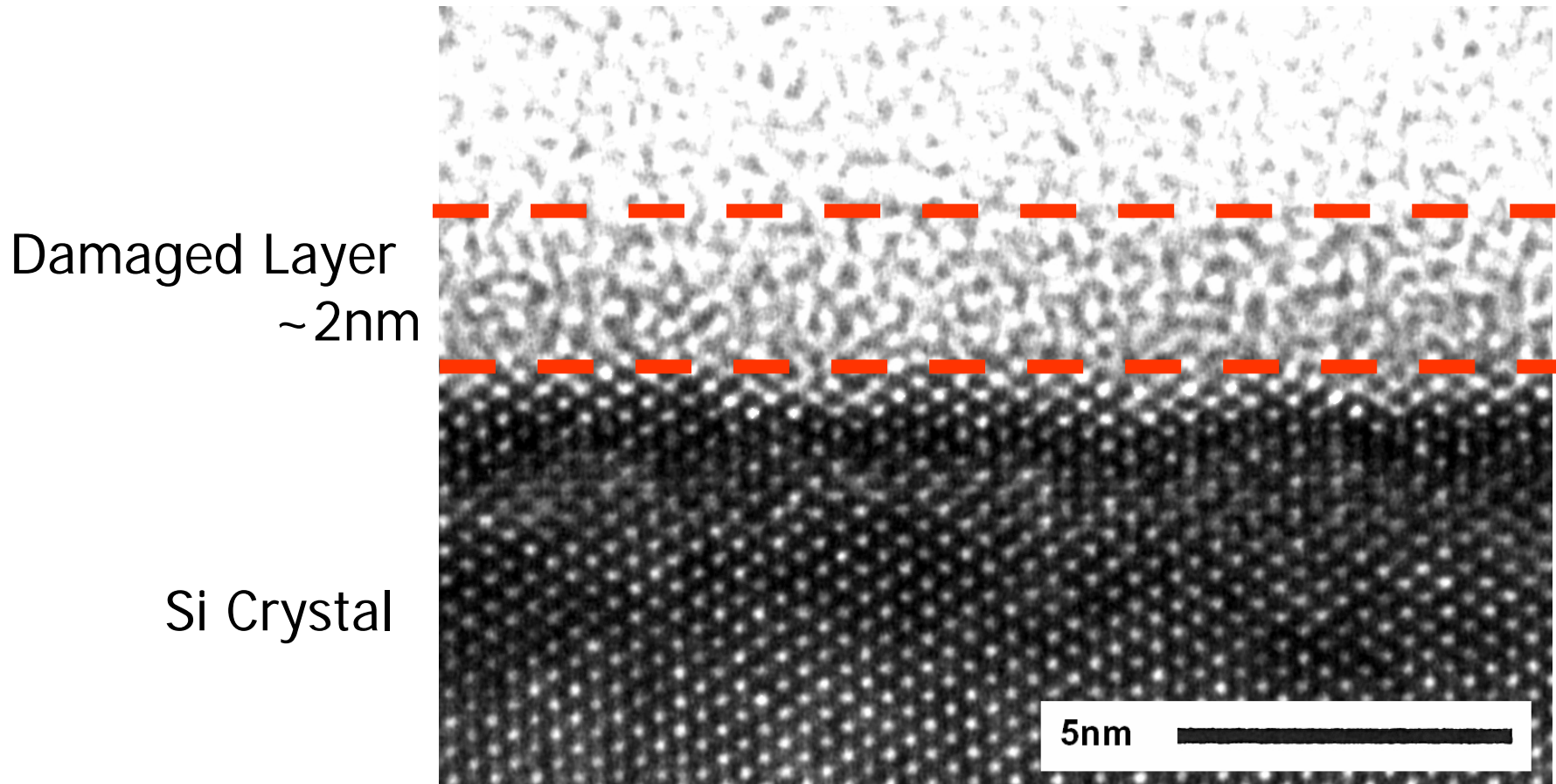
VACC=1kV

Incidence Angle=55deg



Damage Thickness: a few nm

Damage Evaluation by TEM



Ar Ion Beam: $V_{ACC}=1\text{kV}$, Incidence Angle=20deg.

Outline



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Specification



SMI3050TB

FIB

Resolution	4nm@30kV
V _{ACC}	5 ~ 30kV
	1kV Available

Ar Ion Beam

V _{ACC}	1kV
Max Current	10nA

SEM

Resolution	5nm@1kV
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Purpose of Triple Beam

Design Concept of Triple Beam

Low Energy Ion Beam Final Milling with Real Time Observation by SEM

Two Options, Ga Ion or Inactive Gas Ion

Operation, Control Incidence Angle

Evaluation Results of Final Milling by Low Energy Ion Beam

Merci!

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