

3rd presentation''

Fabrication & Measurement for

Smart & Small Structures (Triple S)

MINA: C S Kim and J B Park

Design for Manufacturing

Contents

- Patent & Any research
- Previous work
 - Material & Detail design
 - Parameter for design of experiment (DOE)
 - Design of experiment
- Fabrication
 - Programming the ion beam control
 - Beam overlapping & No. of slice is determined
 - Ion beam condition
 - Dwell time and count (slice) No. is determined
 - Microscale fabrication & Measurement
 - Trouble shooting of microscale fabrication
 - Nanoscale fabrication & measurement
 - Examples of evaluation
- Schedule board

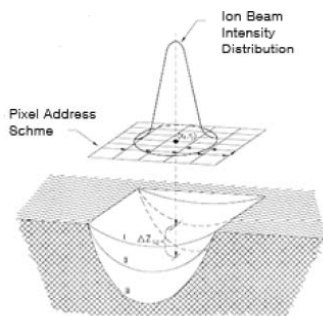
Project plan

- Mission statement & Brain storming
- Conceptual design
- Pre-study
 - Python
 - Design of Experiment
- Detail design
 - Beam current, Dimension, and so on
- **Fabrication & Measurement**
 - **Microscale structure**
 - **Nanoscale structure**
- **Analysis**
 - **Relative parameter extraction**
- Evaluation
- Documentation

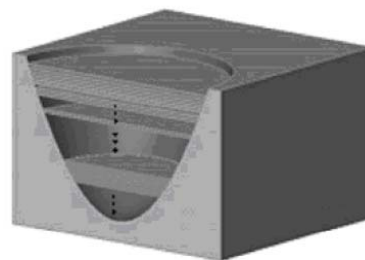
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Patent & Research Investigation

- V or Curved shapes
 - No Patent
 - Research from any journals



Pixel Dwell Time Control



Discrete Slice Control

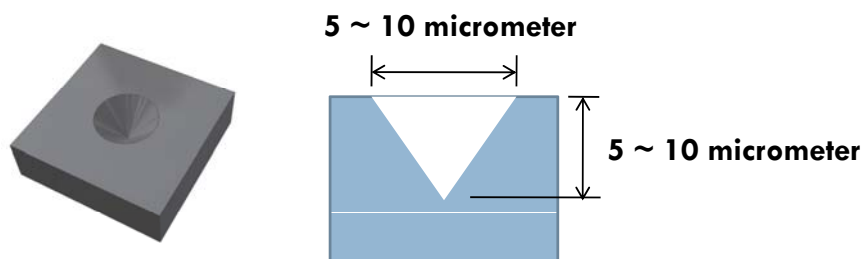
What We Are!!

Continuous Slice Control

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Material Selection

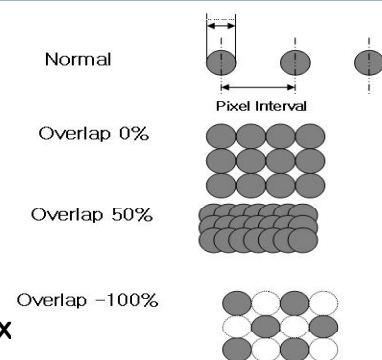
- Silicon substrate
 - Easy to get
 - Good surface roughness for evaluation
- Machining shape
 - Circular & Rectangle trendches
 - V-groove



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Processing Parameter

- Processing parameter
 - Ion dose → **Slice No.**
 - How many ions are injected
 - Dwell time
 - How long ion beams are stay in one pix
 - It deals with the scan speed
 - Beam overlapping
 - How much the area of the ion beam overlaps
 - Related with field of view
 - Field of view
 - Processing screen size (influence on pixel size)



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Suggested Design of Experiment (DOE)

□ 4 factor 3 level

	Ion dose (A) : Slice (Count) No.	Dwell time (B)	Beam overlap (C)	No. of slice (D)
1	Undetermined	0.5	-50	10
2		1	0	20
3		2	50	30

$L_9(3^4)$ Orthogonal array

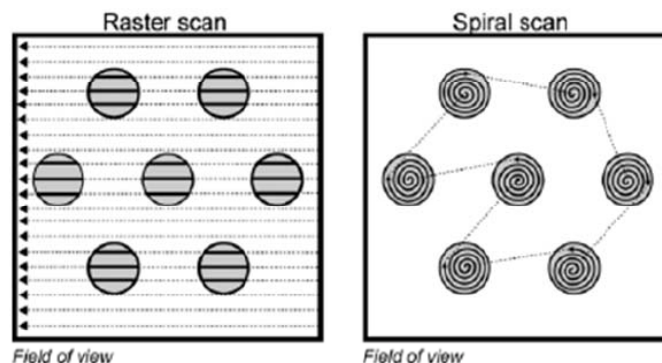
No	Factor				Result			
	A	B	C	D	Sputter Yield	Feature definition	Side wall angle	Radius of curvature
1	1	1	1	1				
2	1	2	2	2				
3	1	3	3	3				
4	2	3	2	3				
5	2	1	3	1				
6	2	2	1	2				
7	3	1	3	2				
8	3	2	1	3				
9	3	3	2	1				

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Programming the Fabrication

□ Vector Scan Method

- Pixel by Pixel Control
- Specifically the spiral scan schematics used
- Merged process
- Beam overlapping and No. of Slice can be determined



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Experimental Condition for DOE: Microscale

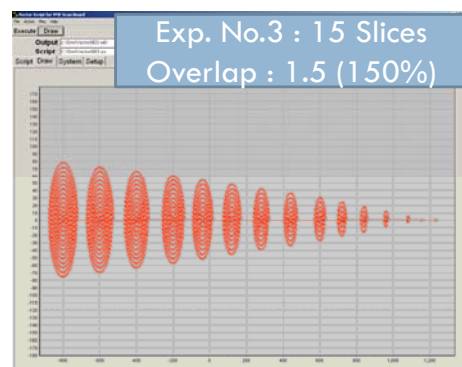
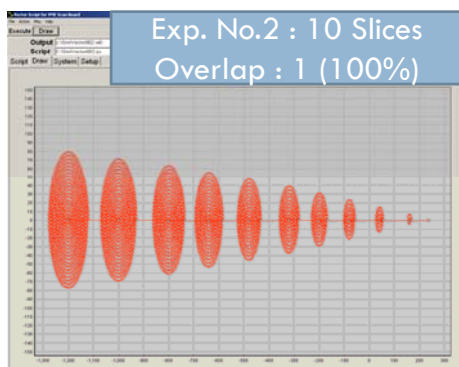
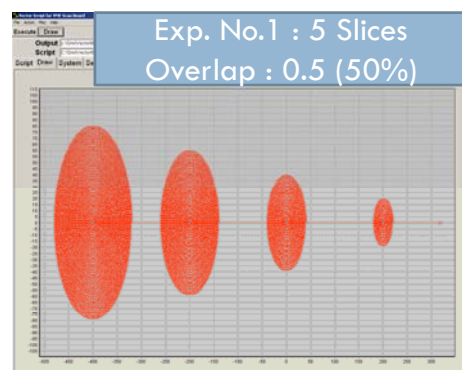
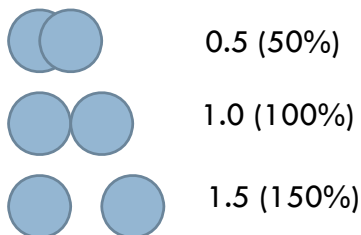
	Count (A)	Dwell time (B)	Overlap (C)	No. of slice (D)
1	4000	0.5	0.5	5
2	5000	1	1	10
3	6000	2	1.5	15

Factor					
No.	A	B	C	D	Fab. Time
1	1 (4000)	1 (0.5)	1 (0.5)	1 (5)	23
2	1 (4000)	2 (1)	2 (1)	2 (10)	19
3	1 (4000)	3 (2)	3 (1.5)	3 (15)	22
4	2 (5000)	3 (2)	2 (1)	3 (15)	62
5	2 (5000)	1 (0.5)	3 (1.5)	1 (5)	3
6	2 (5000)	2 (1)	1 (0.5)	2 (10)	96
7	3 (6000)	1 (0.5)	3 (1.5)	2 (10)	8
8	3 (6000)	2 (1)	1 (0.5)	3 (15)	149
9	3 (6000)	3 (2)	2 (1)	1 (5)	28

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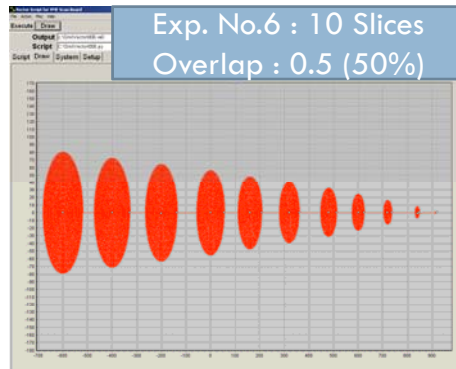
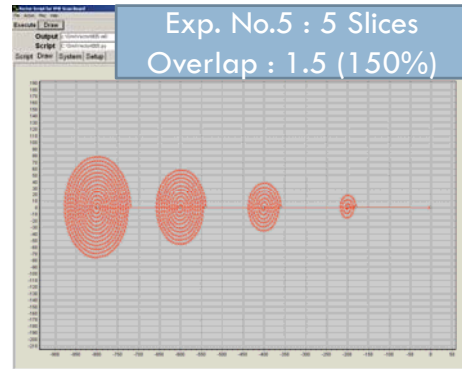
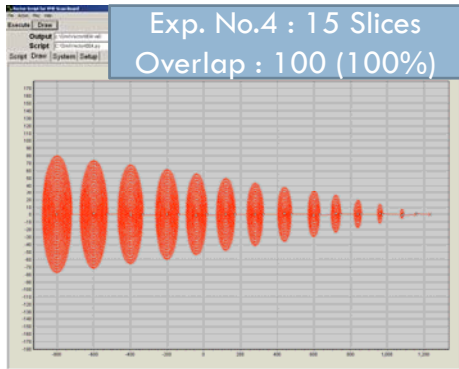
Fabrication Procedure: Vector Program

Beam Overlap Schematics



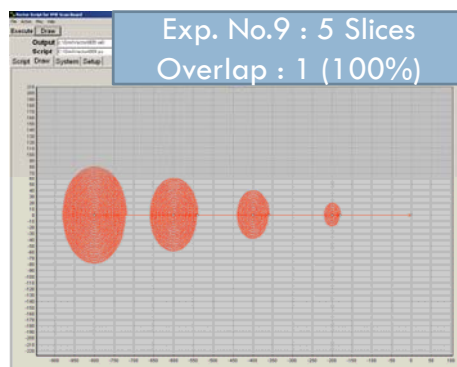
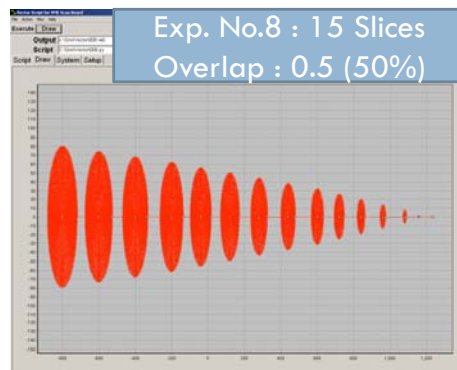
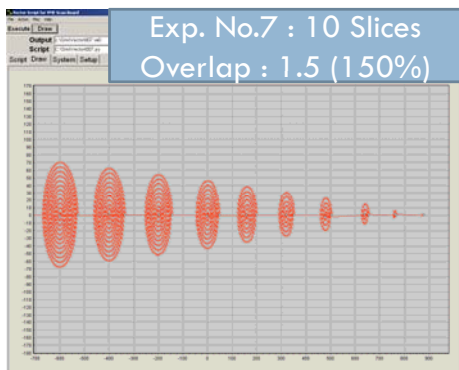
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Fabrication Procedure: Vector Program



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Fabrication Procedure: Vector Program



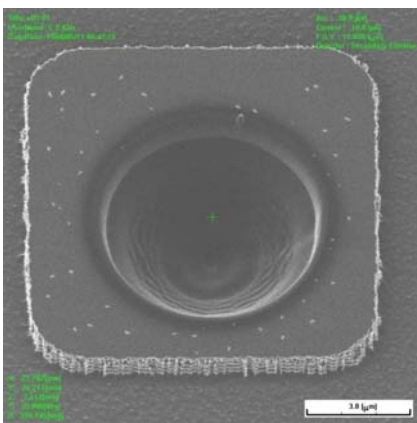
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Experimental Condition

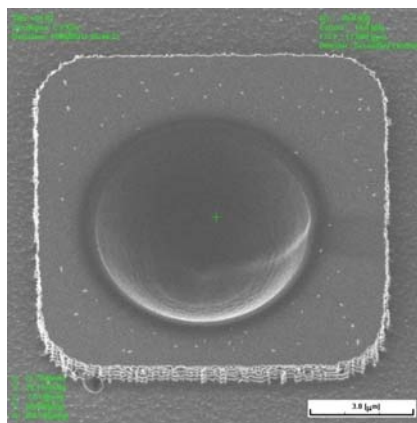
Parameter	Condition	
Field of View (μm)	120	24
Pixel Size (nm)	150	30
Defined Area (μm^2)	6 μm in diameter	1.2 μm in diameter
Ion Energy (KeV)	30	
Ion Dose (ions/ cm^2)	Cannot be determined (related to slice No.)	
Spot Size (nm)	150	30
Probe Current (pA)	6640	91.309
Current Density (A/ cm^2)	368.011	12.924
Dwell Time (μs)	Variation 0.5, 1, 2	
Beam Overlap (%)	Variation -50, 0, 50	
Refresh Time (ms)	0	0
Slice (count) Number	Each (4000, 5000, 6000)	Total (4000, 5000, 6000)

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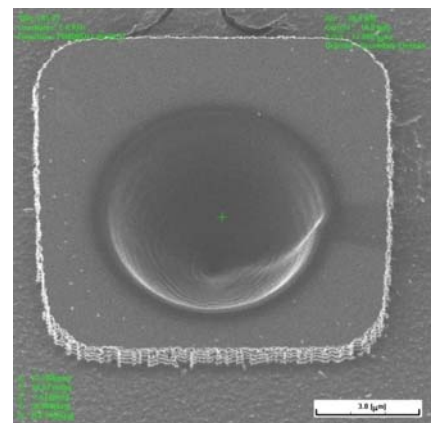
Microscale Fabrication Set 1



Exp. No. 1



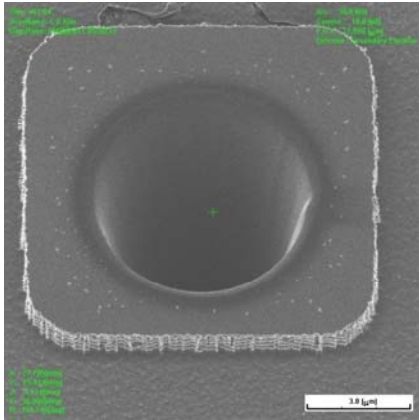
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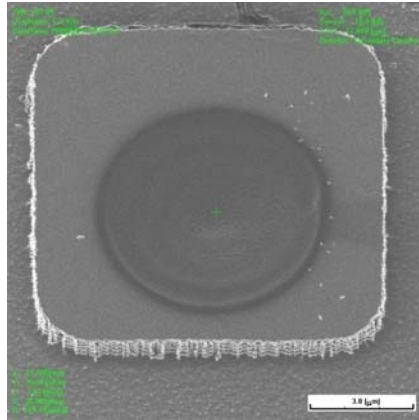
Exp. No. 3

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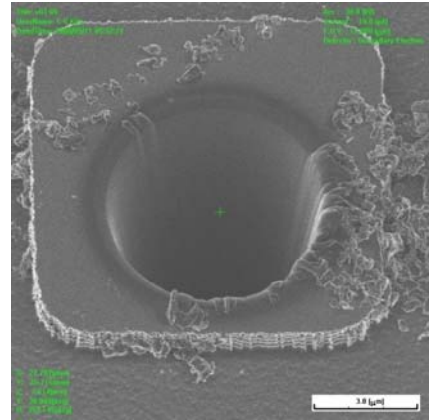
Microscale Fabrication Set 1



Exp. No. 4

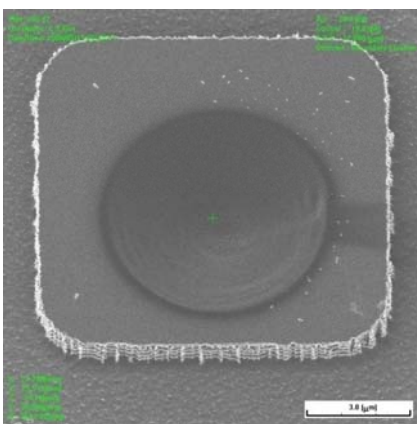


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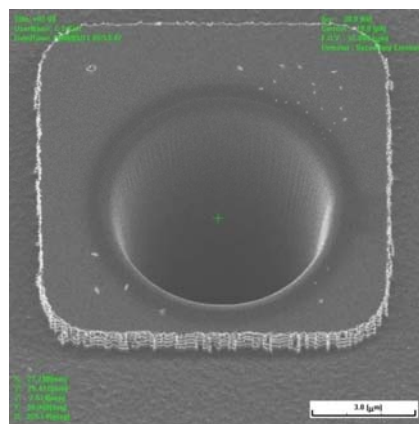


Exp. No. 6

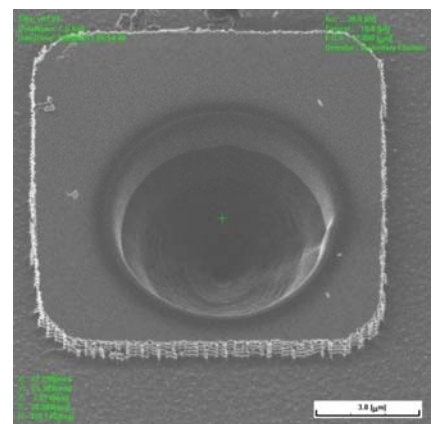
Microscale Fabrication Set 1



Exp. No. 7

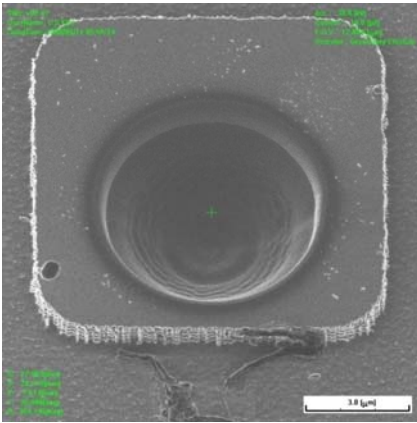


Exp. No. 8

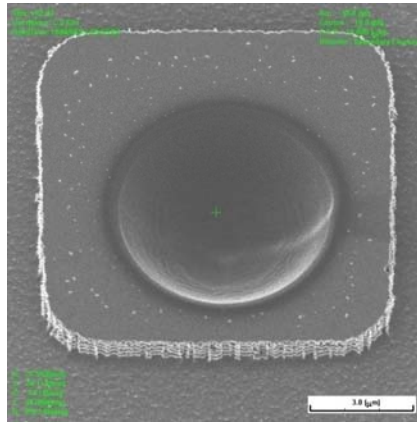


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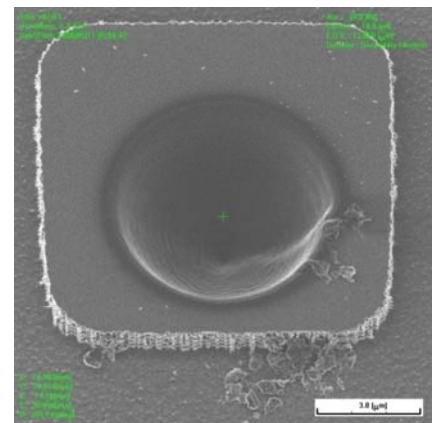
Microscale Fabrication Set 2



Exp. No. 1



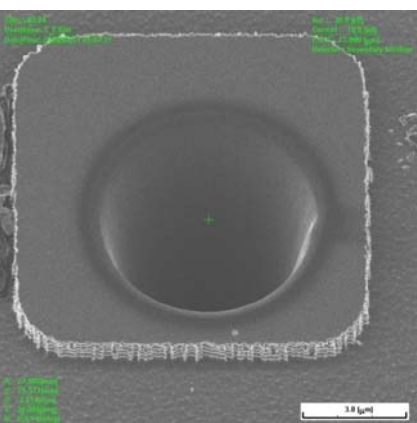
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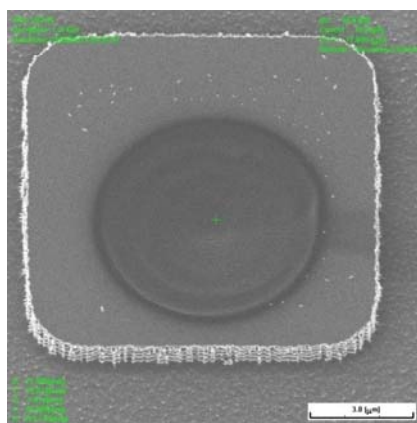
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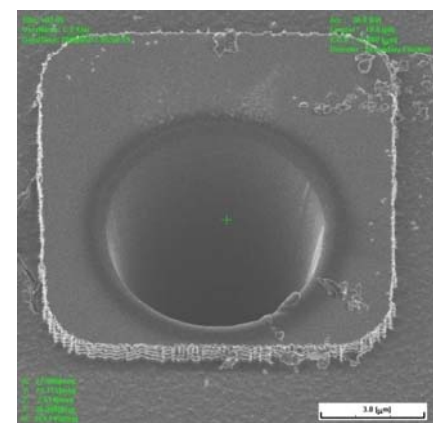
Microscale Fabrication Set 2



Exp. No. 4



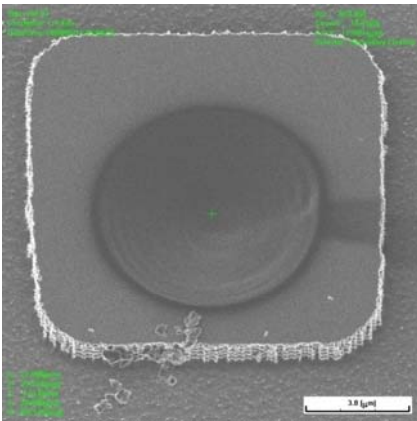
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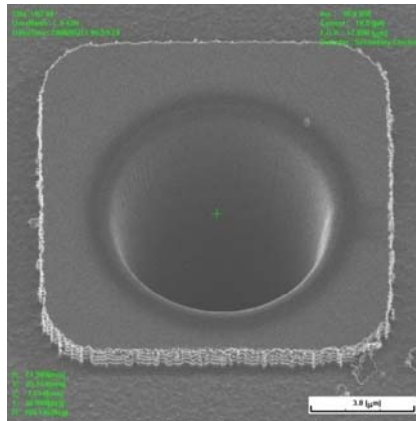
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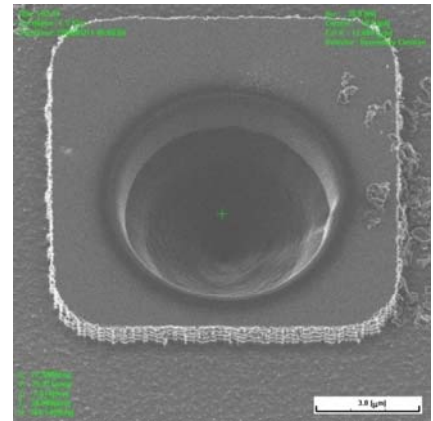
Microscale Fabrication Set 2



Exp. No. 7



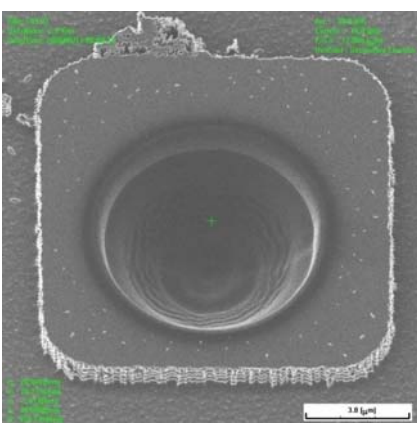
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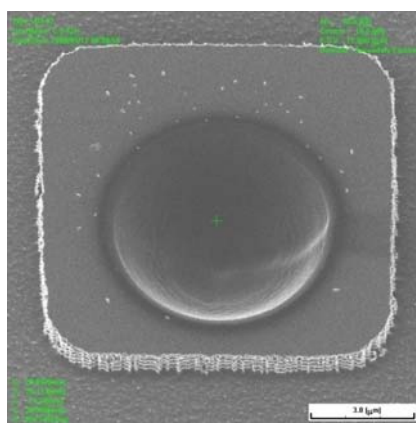
Exp. No. 9

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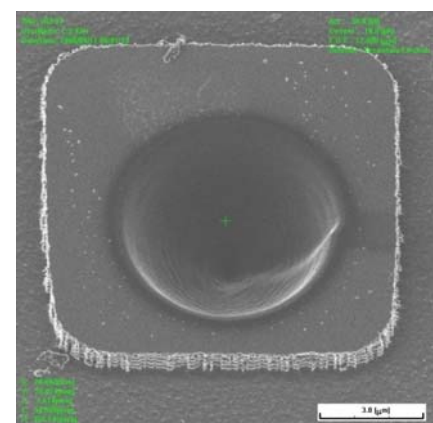
Microscale Fabrication Set 3



Exp. No. 1



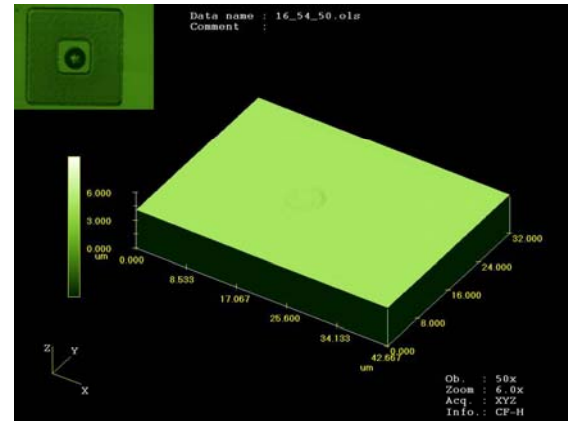
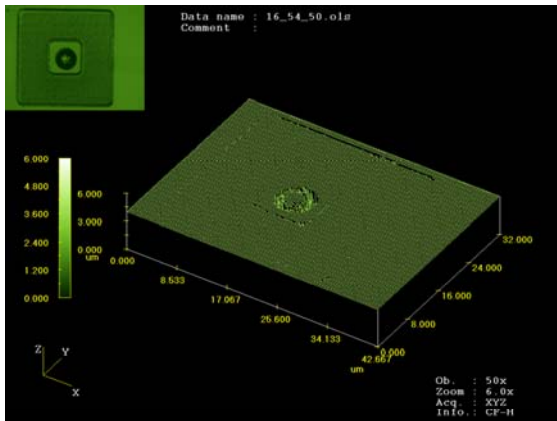
Exp. No. 2



Exp. No. 3

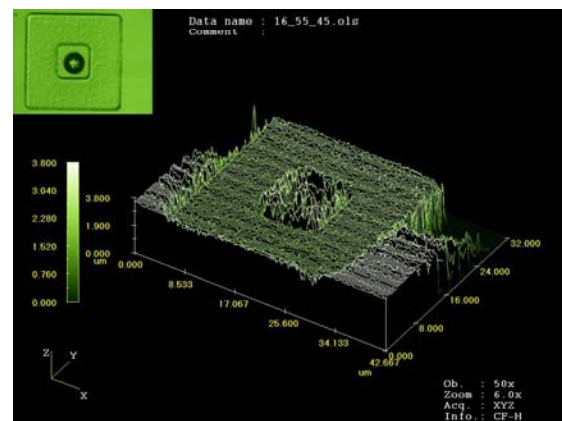
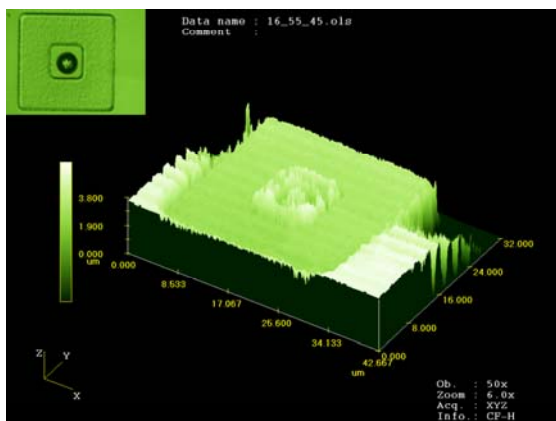
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Measurement with Confocal Microscope 1



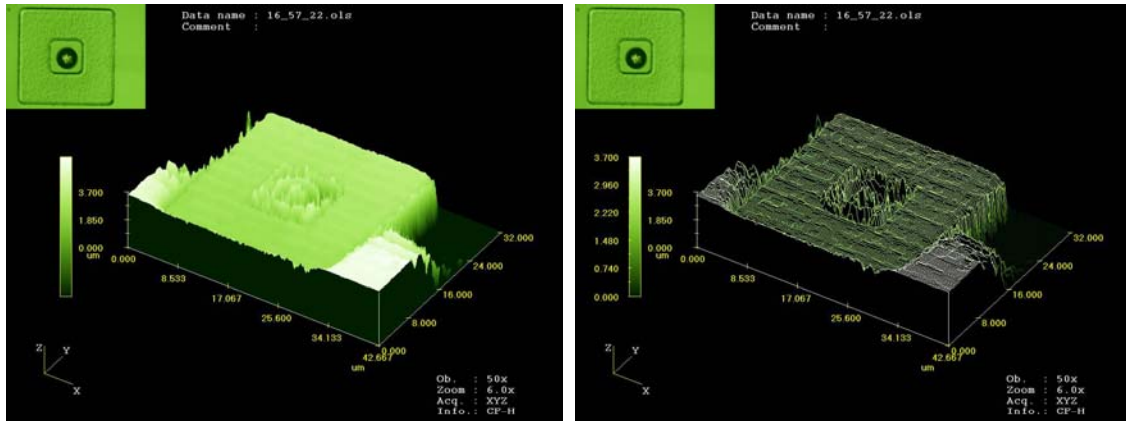
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Measurement with Confocal Microscope 2



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Measurement with Confocal Microscope 3

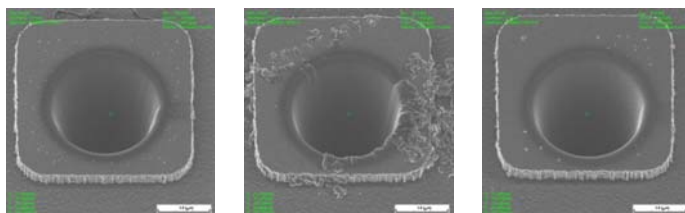


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Results: Microscale Fabrication

□ Fabrication

- Circular cone of 6,000 nm in diameter (3 sets)
- **Exp. No. 4,6 and 8: Too deep fabrication**



□ Measurement

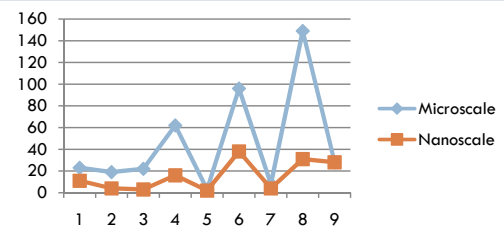
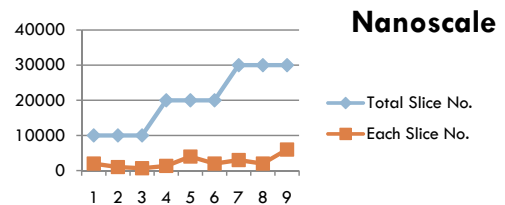
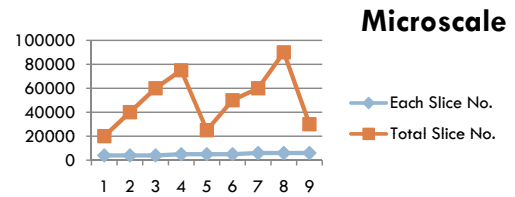
- 3-D construction with confocal microscope
- **Observation failed**

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Trouble Shooting

□ Fabrication was done finely, but **Problems!!A**

No. of Slice	Microscale		Nanoscale	
	Each Count	Total Count	Total Count	Each Count
5	4000	20000	10000	2000
10	4000	40000	10000	1000
15	4000	60000	10000	666.6666667
15	5000	75000	20000	1333.3333333
5	5000	25000	20000	4000
10	5000	50000	20000	2000
10	6000	60000	30000	3000
15	6000	90000	30000	2000
5	6000	30000	30000	6000



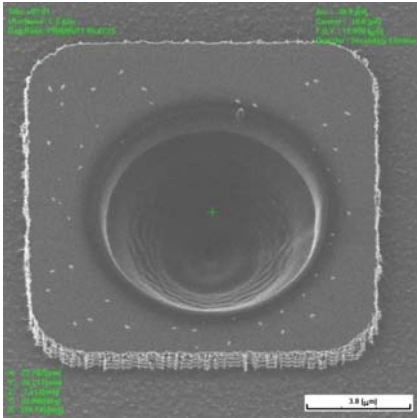
Comparison of Fab. Time

Experimental Condition for DOE: Nanoscale

	Total Count (A)	Dwell time (B)	Overlap (C)	No. of slice (D)
1	10000	0.5	0.5	5
2	20000	1	1	10
3	30000	2	1.5	15

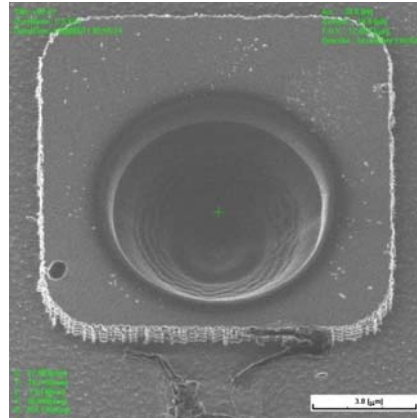
No.	Factor				Fab. Time
	A	B	C	D	
1	1 (10000)-2000	1 (0.5)	1 (0.5)	1 (5)	11
2	1 (10000)-1000	2 (1)	2 (1)	2 (10)	4
3	1 (10000)-667	3 (2)	3 (1.5)	3 (15)	3
4	2 (20000)-1333	3 (2)	2 (1)	3 (15)	16
5	2 (20000)-4000	1 (0.5)	3 (1.5)	1 (5)	2
6	2 (20000)-2000	2 (1)	1 (0.5)	2 (10)	38
7	3 (30000)-3000	1 (0.5)	3 (1.5)	2 (10)	4
8	3 (30000)-2000	2 (1)	1 (0.5)	3 (15)	31
9	3 (30000)-6000	3 (2)	2 (1)	1 (5)	28

Comparison of Each Sets: Sample No. 1



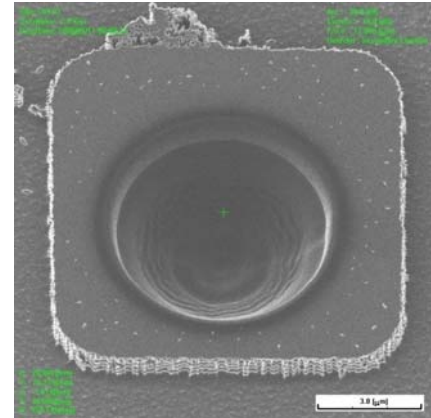
Exp. No. 1

Set 1



Exp. No. 1

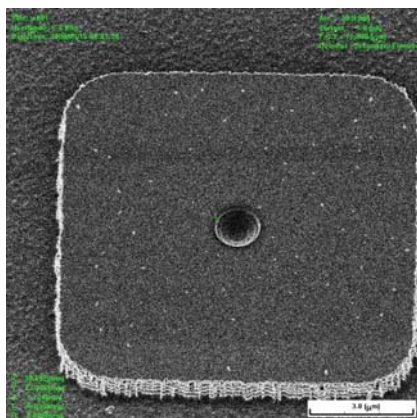
Set 2



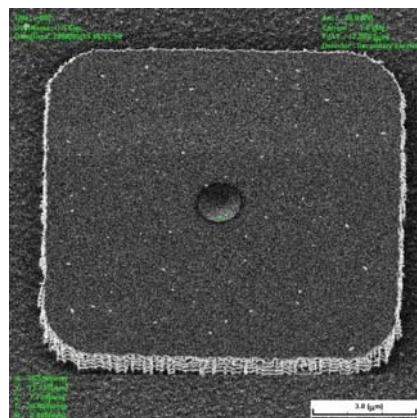
Exp. No. 1

Set 3

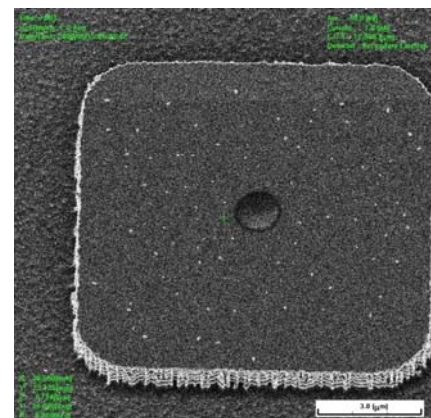
Microscale Fabrication



Exp. No. 1

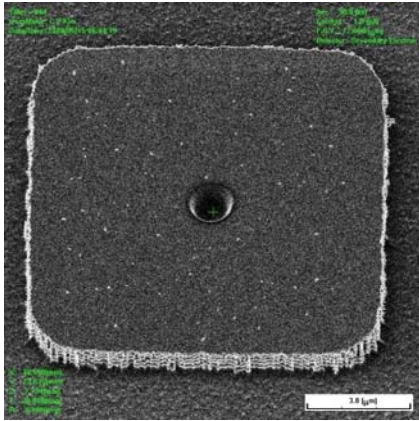


Exp. No. 2

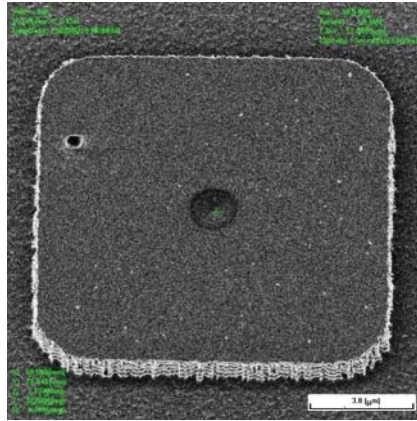


Exp. No. 3

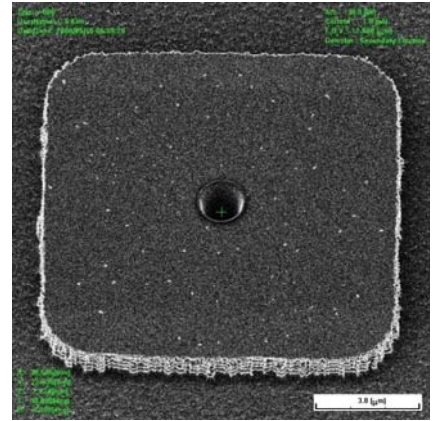
Microscale Fabrication



Exp. No. 4

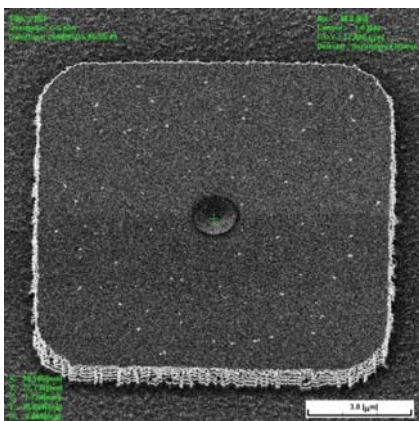


Exp. No. 5

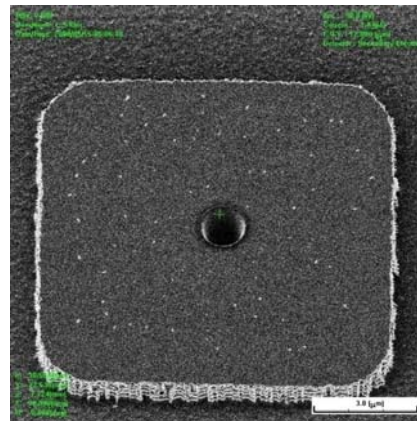


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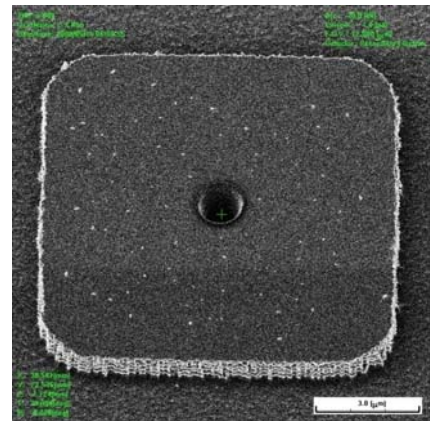
Microscale Fabrication



Exp. No. 7

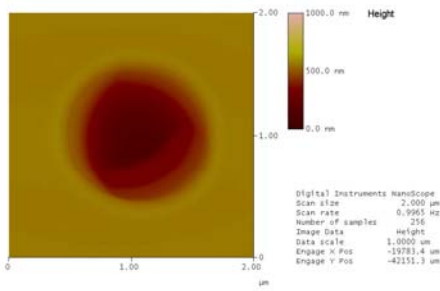


Exp. No. 8

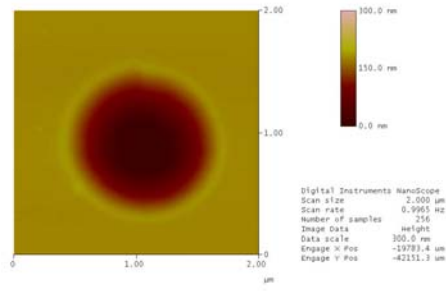


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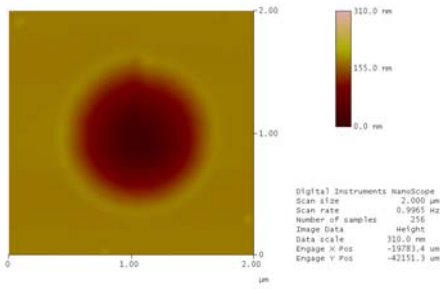
AFM Measurement Sample 1-4



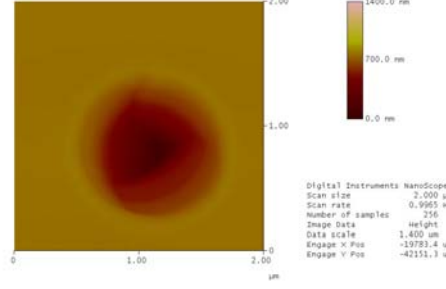
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080516.002-1



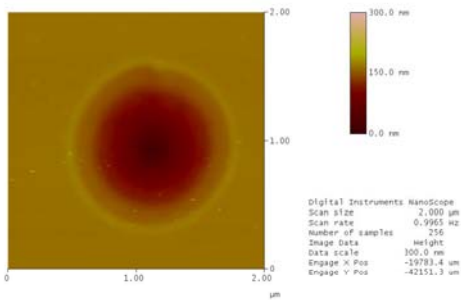
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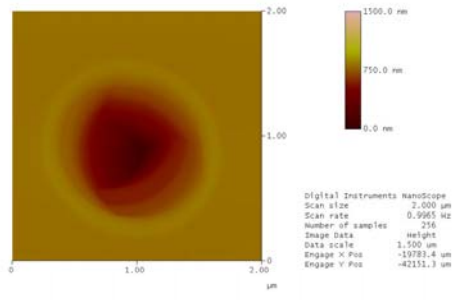
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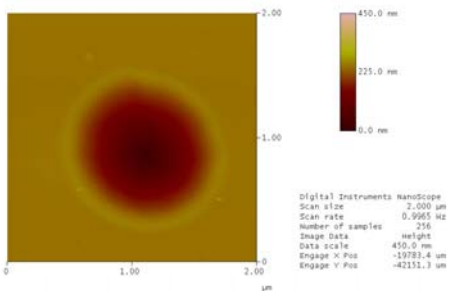
AFM Measurement Sample 5-8



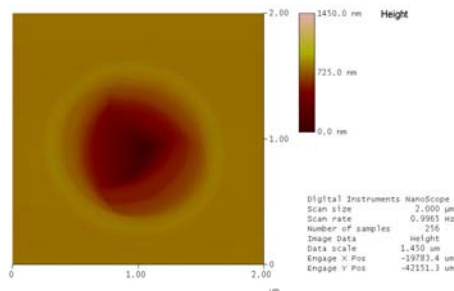
080516.005-1



080516.006-1



080516.007-1



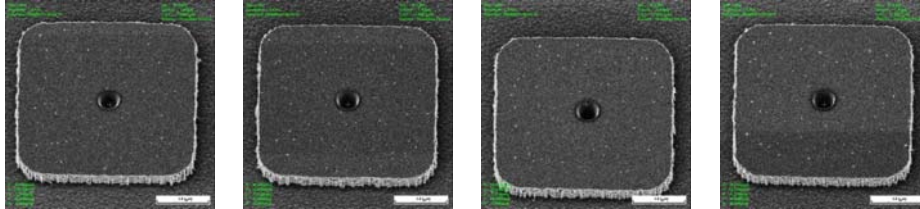
080516.008-1

School of Mechanical & Aerospace Engineering Seoul National University

Results: Nanoscale Fabrication

□ Fabrication

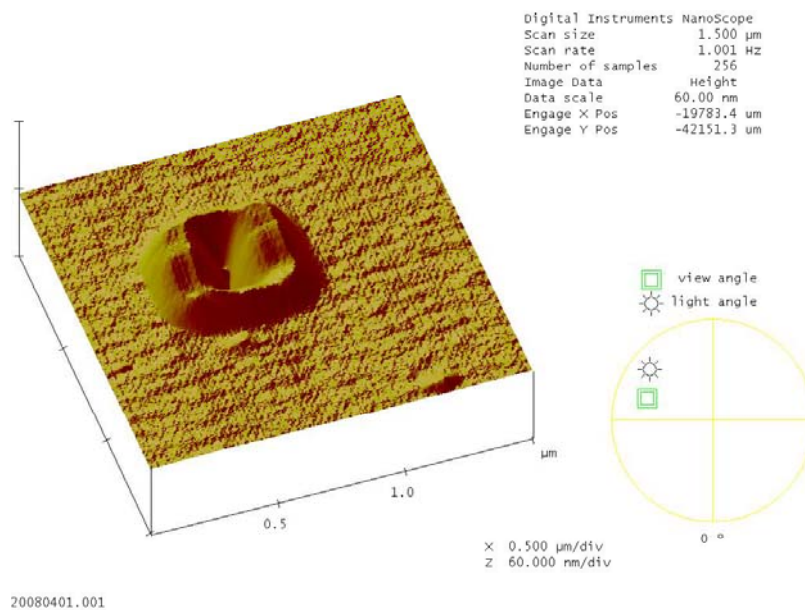
- Circular cone of 1,200 nm in diameter (1 sets)
- **Exp. No. 4,6, 8 and 9: seem like deeper than others**



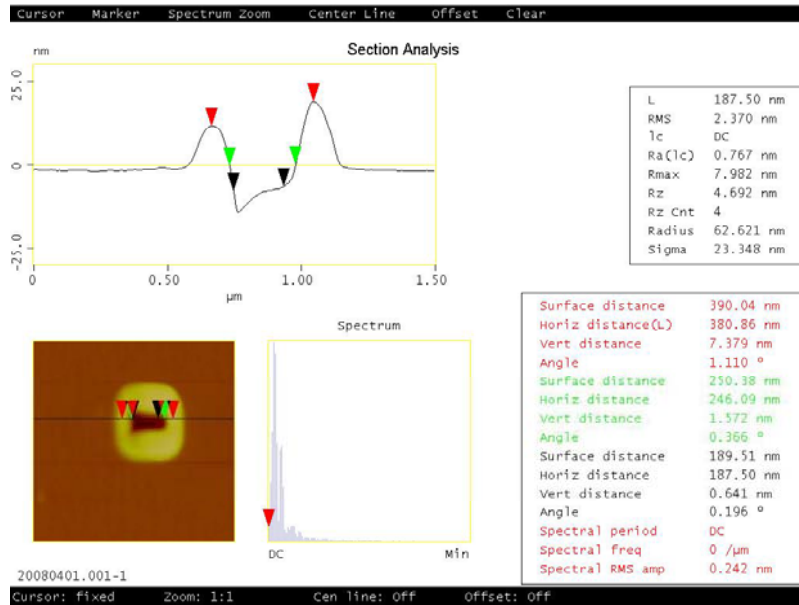
□ Measurement

- 3-D construction with AFM measurement
- 8 of 9 samples were observed, 1 sample left

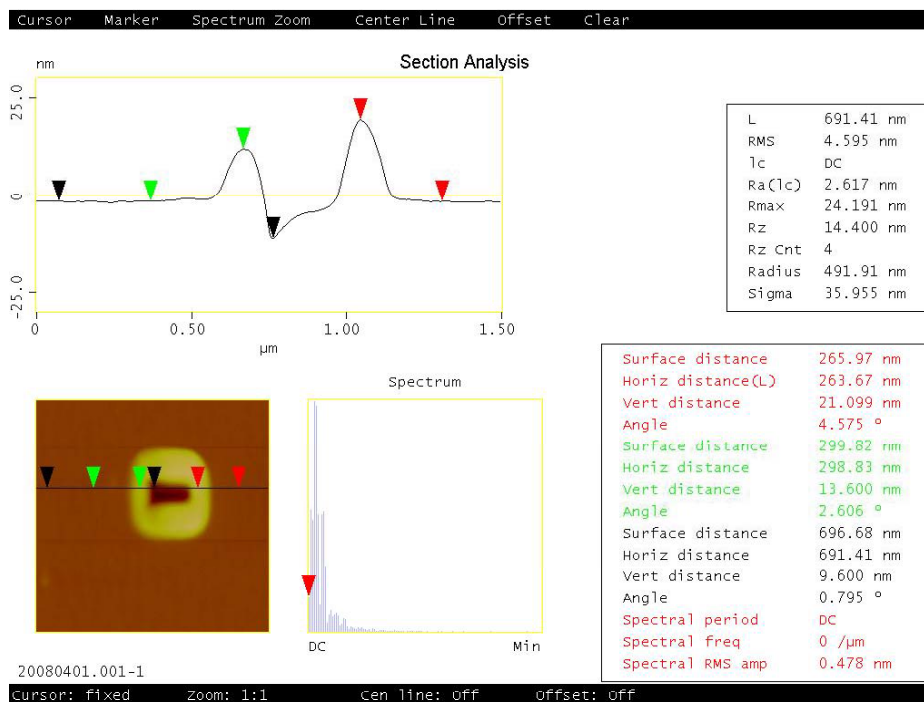
Evaluation Example: 3-D View



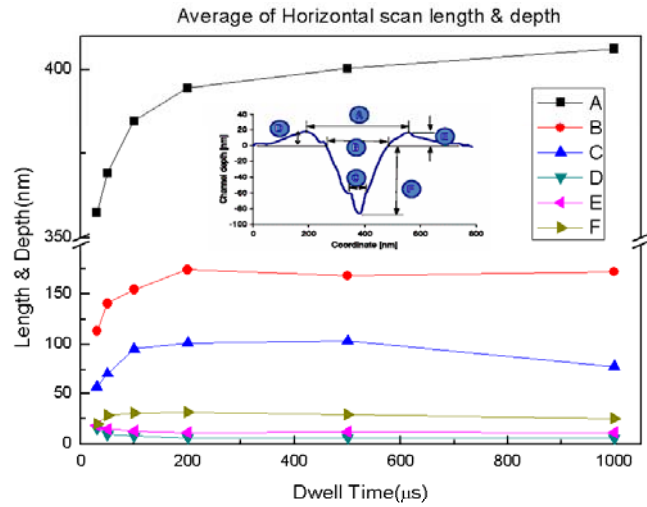
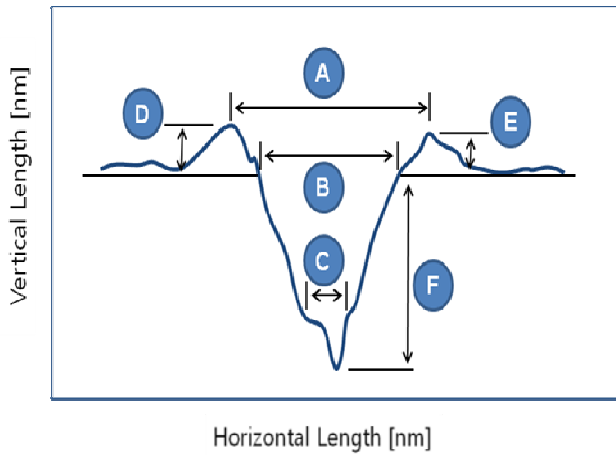
Evaluation Example: Cross-section



Evaluation Example: Cross-section



Evaluation Example: Evaluation



Schedule boards

Plan		Week (20 March 2008 ~ Mid June 2008)														
		1	2	3	4	5	6	7	8	9	10	11	12	13		
Mission statement and Brain storming		█														
Conceptual Design			█	█	█											
Pre-study	Python		█	█	█	█										
	Design of Experiment		█	█	█	█										
Detail design	Parameter				█	█	█									
	Material				█	█	█									
	Shape				█	█	█									
Fabrication								█	█	█						
Analysis								█	█	█						
Evaluation								█	█	█						
Documentation														█	█	

Thanks
Any Questions??