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New Test Vehicle with a Variety of Programmed ML Defects for EUV Blanks Inspection

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Outline

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- Background
- Motivation
- Experiment
- Results
- Summary
- References

Background

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- Recently EUV mask yield and defect inspection are strongly focused in the industry.

Technical Issue on EUV Lithography					
Rank	2007	2008	2009	2010	2011
1	**Source**	**Source**	**Mask**	**Mask**	**Source**
2	**Resist**	**Mask**	**Source**	**Source**	**Mask**
3	**Mask**	**Resist**	**Resist**	**Resist**	**Resist**

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- Multilayer defect is one of the key issue that EUV mask/blank industry has to overcome. However, there are some difficulties.
- Target defect size is ~1nm height level according to several researches.
  - Big challenges for defect inspection
- Curious results have been reported that defect printability and detectability of rectangle shape defects (programmed defect) and natural defects are very different.

Motivation

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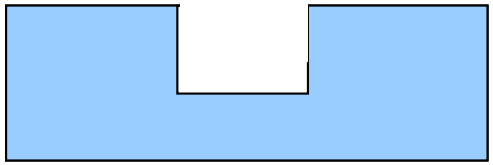
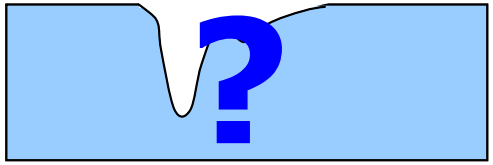
- Need to consider how to obtain appropriate test blanks with programmed ML defects for future tool evaluation and qualification.



Programmed defect
(rectangle shape)



Natural

  - How can targeted 1nm order defects be fabricated with high accuracy?
  - How can 'Natural-like' programmed defects be fabricated?
  - Rectangle shape defects may not be appropriate to reproduce real situation of 'Natural' defects.

✓**Propose new programmed ML defect fabrication method and verify the effectiveness of the method.**

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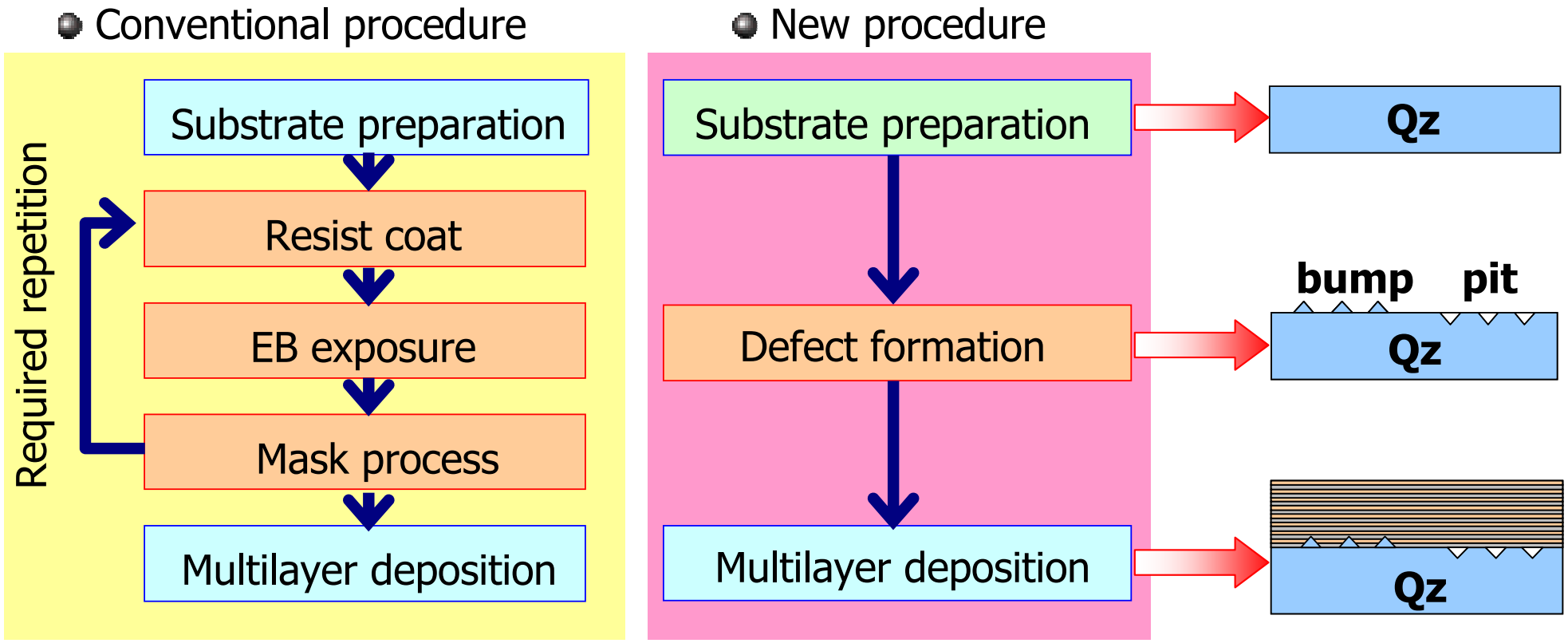
Programmed defect blank fabrication procedure



- **Conventional procedure** : Need to repeat defect formation process to fabricate all designed defect height.
- **New procedure** : **Simple & flexible defect fabrication process**

✓**Programmed defect blank was fabricated with proposed new fabrication procedure.**

Defect Types

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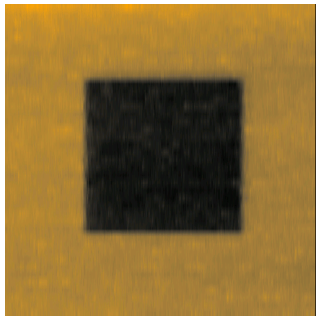
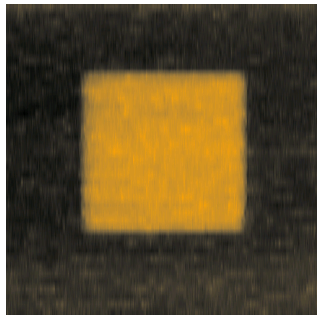
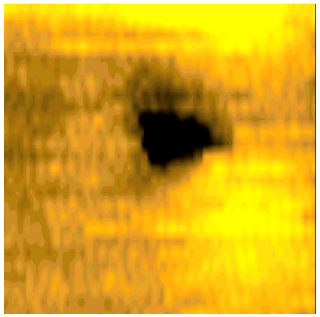
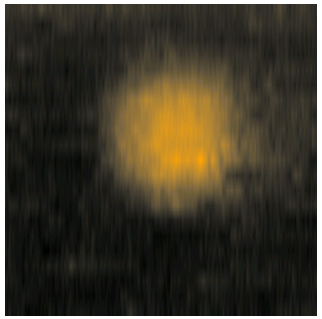
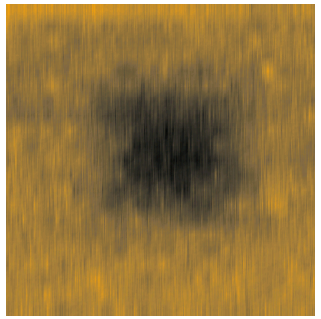
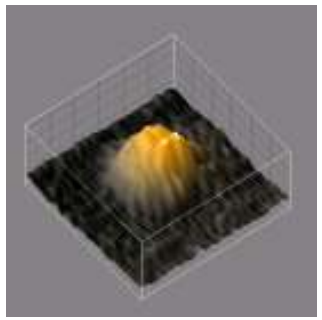
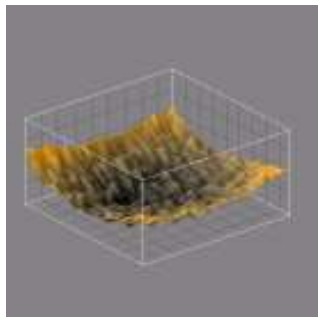
- **Both rectangle shape defects and natural-like defects were fabricated by new method.**

Defect Type	Rectangle Pit	Rectanble Bump	Natural-like Pit	Smooth-edge Bump	Smooth-edge Pit
2D Image					
3D Image					

✓ **Attempted to reproduce rectangle shape defects similar to the defects which conventional method fabricates.**

✓ **Natural-like and smooth-edge defects are supposed to be similar to a shape of real substrate defects.**

Defect Size Measurement Result

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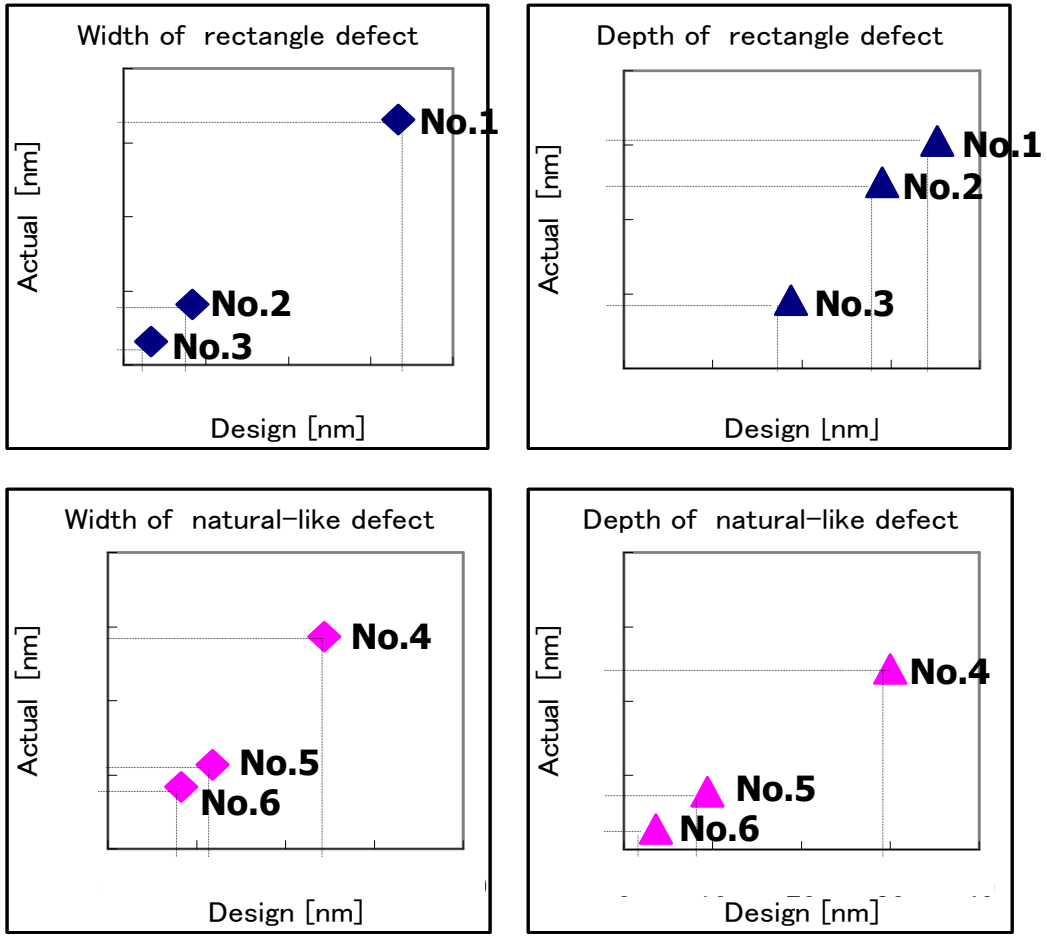
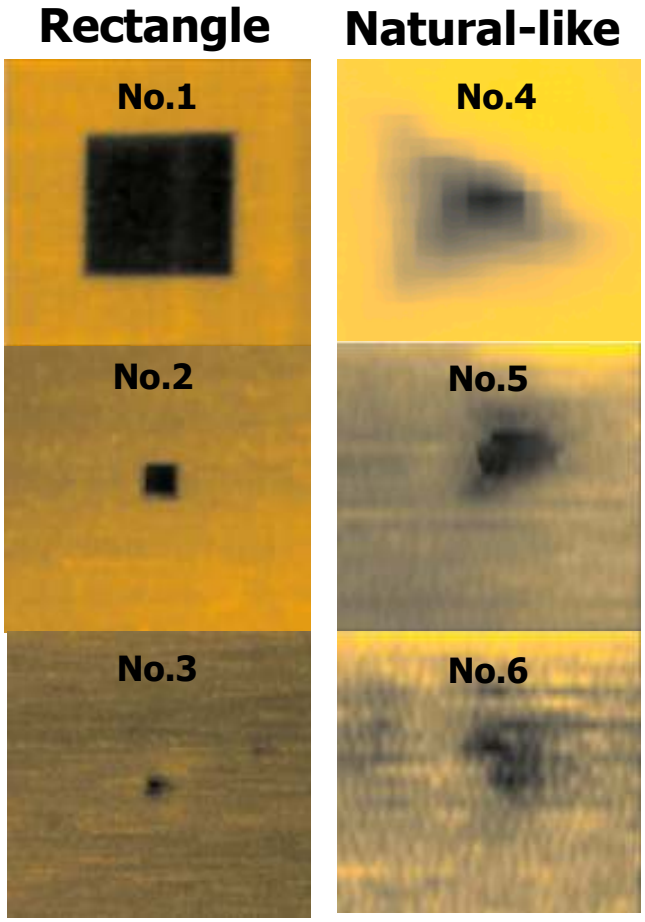
Programmed defect size between design and measured.



AFM image



- **Confirmed linear relation between design and measured size.**

✓**Source of the ML defects were successfully fabricated.**

✓**Confirmed fabricated defect sizes were well controlled by the new method as expected.**

Defect Printability Simulation

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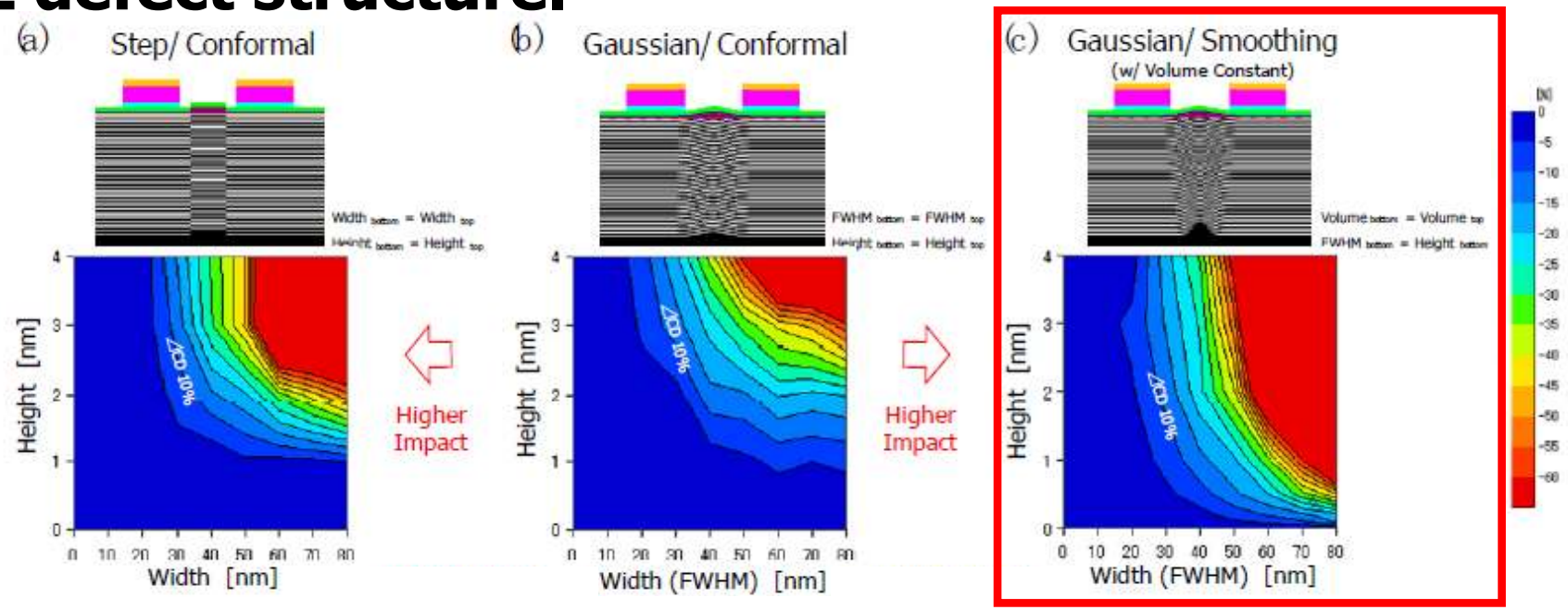
- **Selete reported printability of ML defects depends on ML defect structure.**



*Source SELETE at SPIE2011

- ✓Generally small size of ML defects have been focused on ML defect printability study.
- ✓Wide defect below 1nm height can be critical on some defect structure model.
  - ➢Light up shallow and complicated defect structures.

New Defect Types

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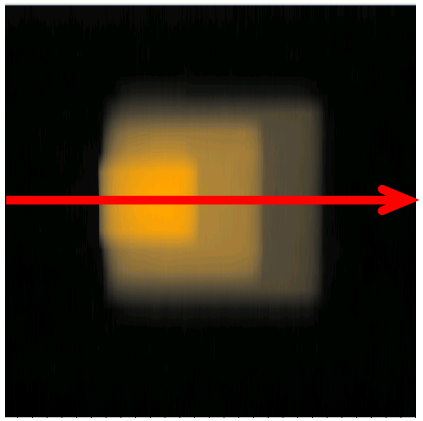
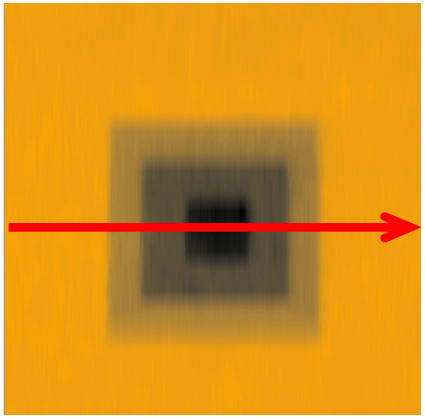
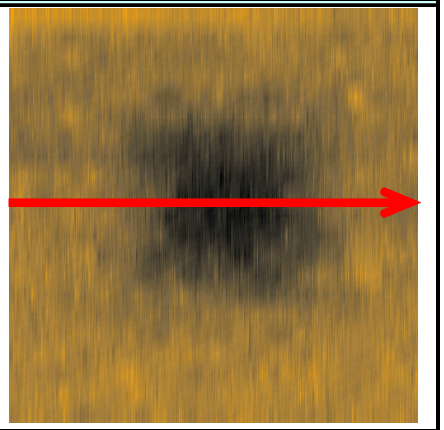
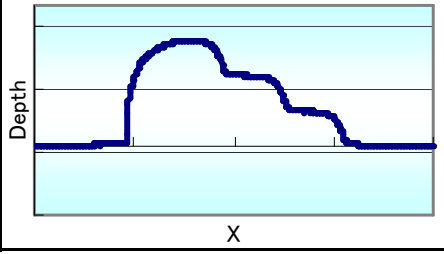
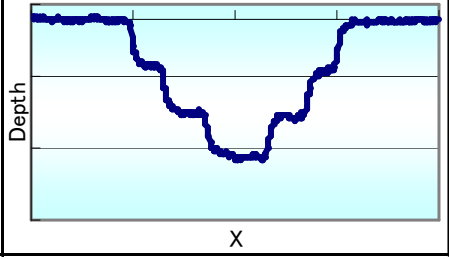
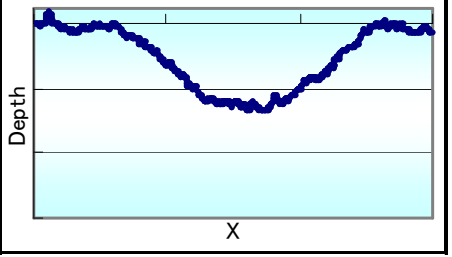
- **Tested to fabricate other types of defect shapes to confirm flexibility of the new procedure.**

Defect Type	Multi Step		Smooth-edge
	Bump	Pit	Pit
2D Image			
Cross Section			

✓**Confirmed very unique defect shapes were fabricated by application of the new defect fabrication method.**

✓**Expected to be capable to reproduce real defect situation.**

ML Defect Shape Transition

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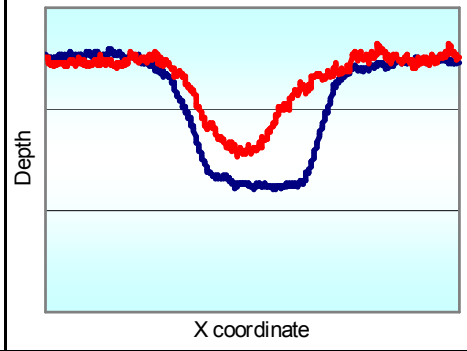
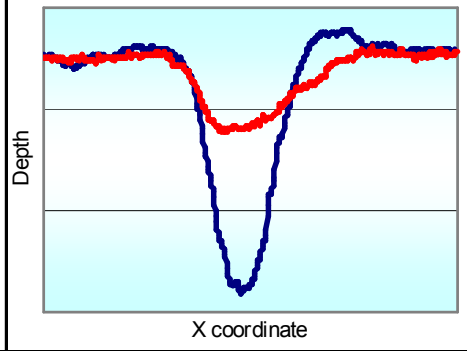
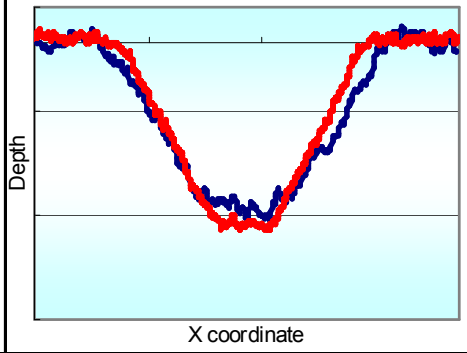
- **Compared defect shape before and after ML deposition of fabricated defects.**

Defect Type	Rectangle Pit		Natural-like Pit		Smooth-edge Pit	
2D Image	Bottom	Top	Bottom	Top	Bottom	Top
Cross Section						
Deposition Model	**Semi-smoothing**		**Smoothing**		**Conformal**	

✓**Defect shape transition model is very complicating.**

✓**Difficult to predict how ML defect shape grows from the bottom to the top of Multilayer.**

Conventional Method vs New Method

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- **Compared test blank manufacturability between conventional and new method.**

Items		Conventional Method	New Method
Manufacturability	Defect height control		
	Defect quantity		
	Defect type		
	Process complexity		

 : Excellent  : Good  : Unsuited

- **Conventional**
  - **Easy to fabricate many same height defects.**
  - **Long and complex defect formation process**
  - **Only rectangle shape defects**
- **New Method**
  - **Can fabricate many types and sizes.**
  - **Simple defect formation process**
  - **Not good to duplicate exact same defect a lot.**

Conventional Method vs New Method

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■ Suitability for purpose of test blank usage

Items		Conventional Method	New Method
Purpose of use	Quantification		
	Tool control		
	Algorithm development & optimization		
	Defect review function development		

 : Excellent  : Good

◆ **Conventional**

- **Easy to quantify defects due to its' rectangle shape.**
- **Rectangle shape defects are totally different from Natural defect shape.**

◆ **New Method**

- **Natural-like defects can reproduce similar situation as real defects.**
- **May not be easy to quantify some defect types due to its' complex shape.**

Summary

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- Source of defects were fabricated on substrate by newly developed methods.
- Attempted to fabricate very unique shape defects.
  - ✓ Succeeded to fabricate very shallow defects with 0.1nm depth.
  - ✓ Showed flexibility of defect source fabrication.
- Confirmed different defect structure models were reproduced on the fabricated test blank.
  - ✓ Supposed defect structure model is very complicating.
- New programmed defect fabrication method showed good effectiveness to provide proper test vehicle.
  - ✓ Further evaluation for inspection and printability test with the fabricated vehicle will be expected.
- The defect fabrication technique is expected to be useful for future tool development.

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