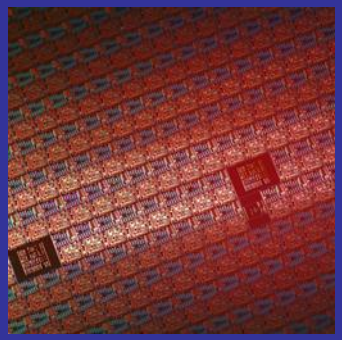
Accelerating the next technology revolution

EUVL Mask Blank Defect Inspection Capability Improvement and its Application at SEMATECH

Andy Ma, Ranganath Teki, Arun John,
Jenah Harris-Jones, Frank Goodwin,
Tomoya Tamura*, Anwei Jia*, Sato Yuta*

SEMATECH
* Lasertec Corporation



Outline

- Introduction
- Mask blank inspection tools at SEMATECH
- Current status of the Lasertec M7360 and its applications
  - Defect inspection sensitivity on PDM
  - Defect inspection sensitivity on SiO_2 particle masks
- EUV mask blank inspection tool capability assessment (16 nm HP)
- Future plans
- Summary

Introduction

- Defect-free EUV mask blanks remain one of the greatest challenges for the commercialization of EUVL
- Defect inspection capability is essential for defect-free mask blank development
  - 20 nm sensitivity is required for the 16 nm hp node

- The M7360 inspection tool is critical to SEMATECH for
  - Provide incoming Qz inspection for defect reduction at the supplier site
  - Perform post- ML deposition blank inspection for the ML defect reduction program at SEMATECH
  - Support Qz and ML mask blank cleaning process development
  - Improve effectiveness of defect failure analysis to classify and mark specific defects for defect composition analysis (AFM, EDX, TEM..)

Inspection Tool Set at SEMATECH: Lasertec

M1350 (1G)

M7360 (2G)

	M1350	M7360
Laser Wavelength	488 nm	266nm
Inspection Power	200 mW on QZ 120 mW on ML	600mW on QZ 170mW on ML
Detection system	Single detector system	Dual detector system
Scan speed	20 minutes on QZ, 45 minutes on ML- dense scan mode	90 minutes on both QZ and ML
Inspection capability	QZ: 65nm ML: 73nm	QZ: 35nm ML: 40nm

M7360 Inspection Capability Improved Through Several PMs (2010- 2012)- I

- Obtained good inspection performance on the M7360 after several major PMs, software upgraded, and temperature enclosure improvement.
  - Inspection sensitivity improvement
    - Qz: 45 nm to 35 nm
    - ML: 50 nm to 40 nm
  - Tool uptime increased from <60% to > 95%.
  - Temperature uniformity improvement on the M7360's "Thermal chamber " which reduced FSE intervention to adjust beam position and beam profile from every 1-2 days → 5-7 days → every monthly PM.
- Software upgraded:
  - Installed low power calibration: Reduced inspection variation and minimized ML damage during defect review.
  - Installed auto-focus calibration position editor: User-friendly way to change auto focus position and focus off-set to optimize inspection sensitivity.
  - Improved mask stage tilt control: Optimized mask tilt stage control to improve inspection sensitivity uniformity.

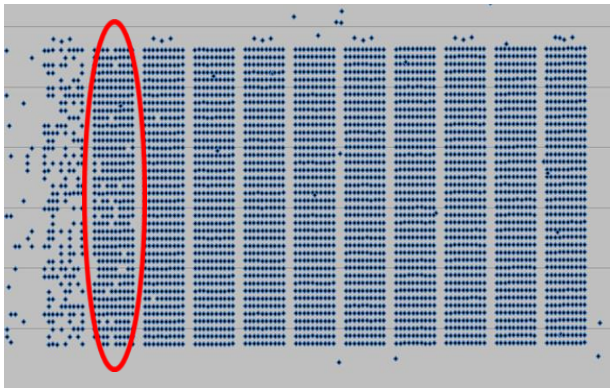
M7360 Inspection Capability Improved Through several PMs (2010- 2012)- **II**

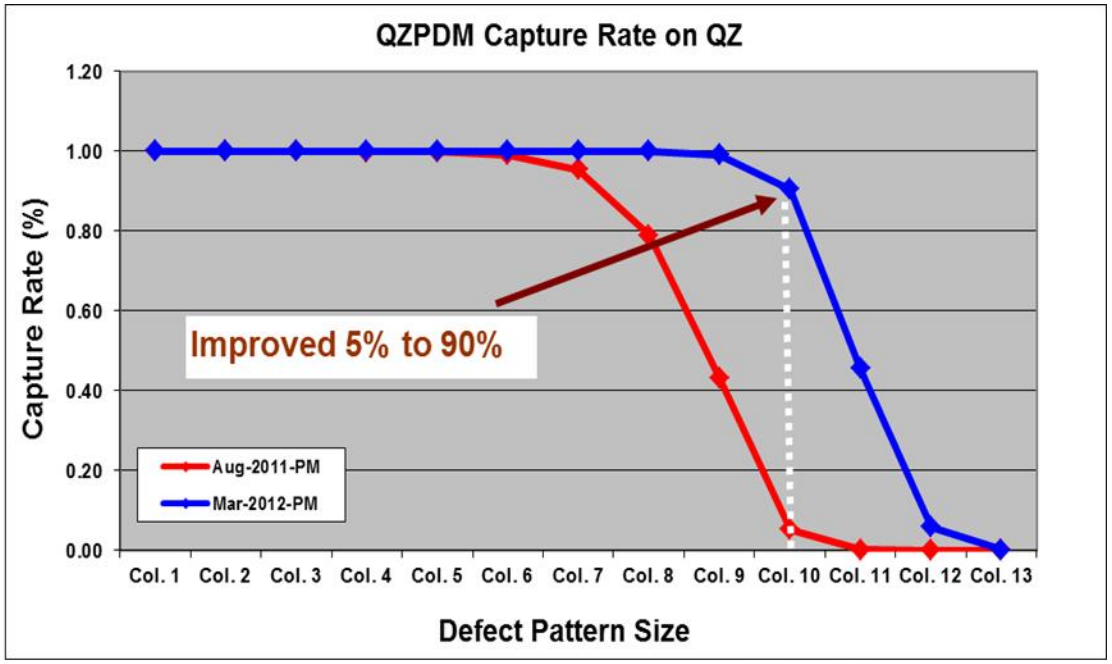
- Hardware upgraded
  - Installed Purge system to reduce/ minimize optics contamination from environment.
  - Installed new capability to allow FSE to adjust and optimize the beam profile during PMs.
- Thermal chamber environment improvement:
  - Improved temperature uniformity for temperature enclosure from +/- 0.5^{o} C to +/- 0.1^{o} C through:
    - Added additional cooling control units
    - Increased 30% of air flow inside the thermal chamber
    - Balance the air flow and circulation by installing air fans under the floor.
  - Increased frequency of “chemical filters” replacement
    - Replaced M7360 cleanroom chemical air filter from yearly to every 6 months.
    - Replaced system of “chemical filters set” from every 5 years to every 3 years to reduce optics contamination from “thermal chamber” environment.

M7360 Inspection Sensitivity Improvement on QZPDM (Improved 5% to 90% on defect size col.#10; 105nm of FWHM, 3.1 nm of height; ~ 33 nm of SiO2)

#10 (5%)- Aug-2011 PM

#10 (90%)- Mar- 2012 PM

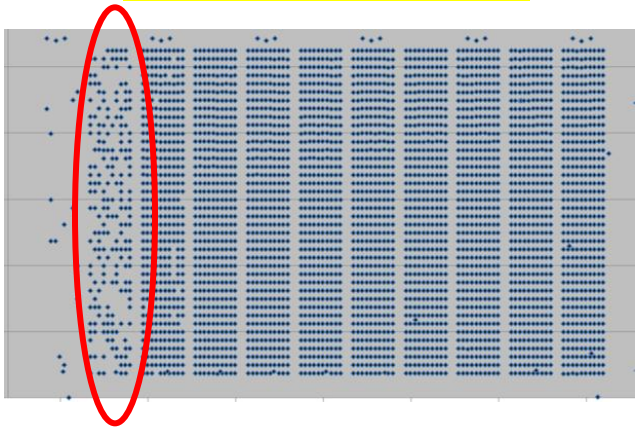




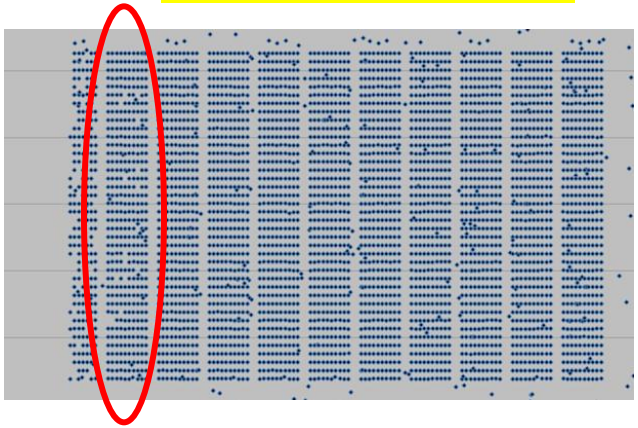
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Defect width (nm FWHM)	210	200	190	180	170	160	150	140	120	105	95	85	75
Defect height (nm)	3.1												

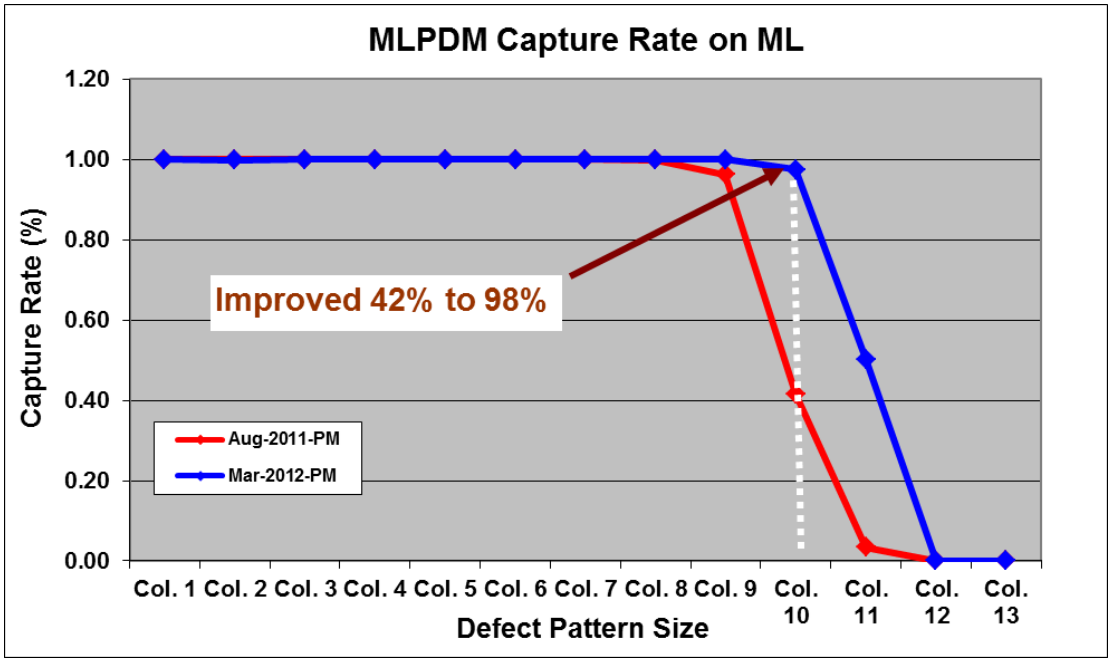
M7360 Inspection Sensitivity Improvement on MLPDM (Improved 42% to 98% on defect size col. #10: 70nm of FWHM, 2.2 nm of height; ~ 38 nm of SiO2)

#10 (42%)- Aug-2011 PM



#10 (98%)- Mar- 2012 PM

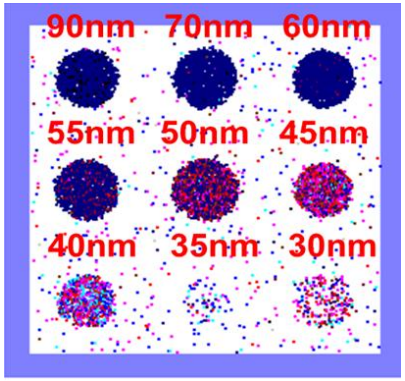




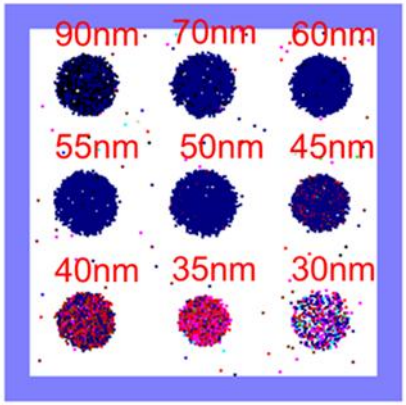
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Defect width (nm FWHM)	200	180	160	150	140	120	105	95	85	70	65	58	55
Defect height (nm)	2.9	2.9	2.9	2.9	2.8	2.7	2.6	2.6	2.5	2.2	1.6	1.3	0.4

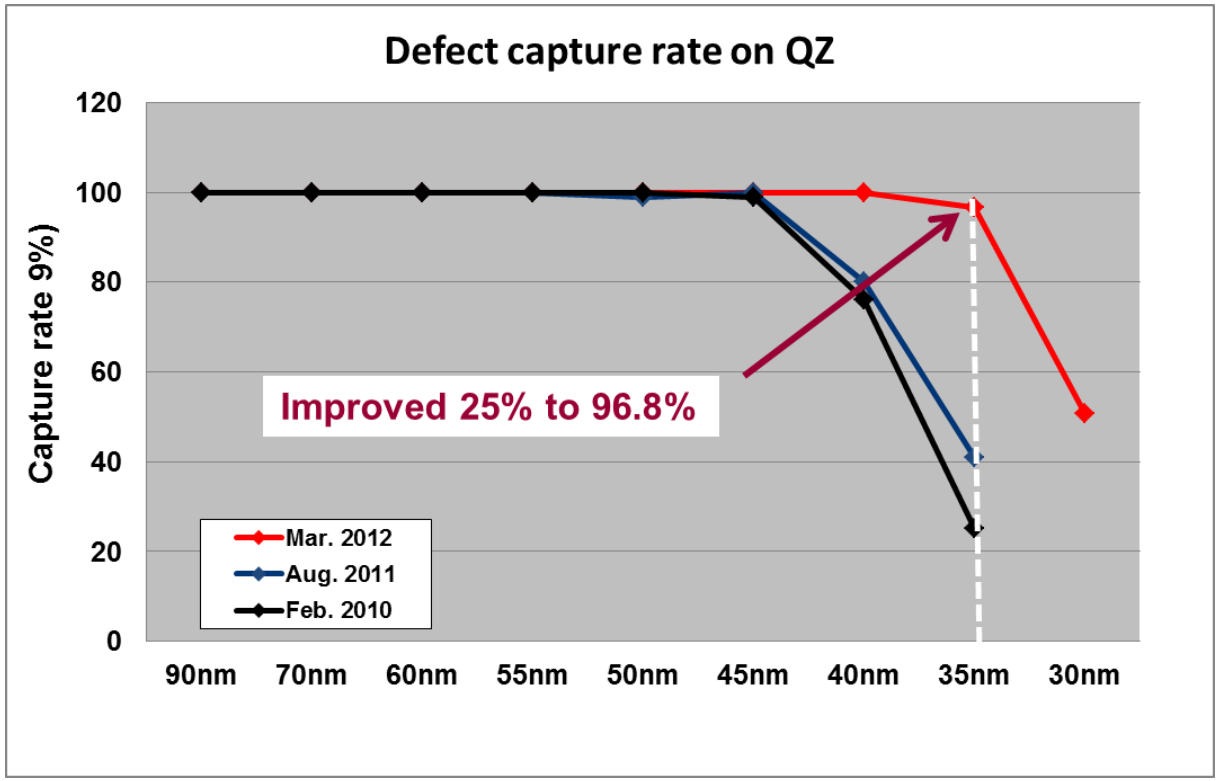
35 nm Inspection Capability Achieved on Quartz Inspection (Improved 25% to 96.8%)

FEB 2010 PM



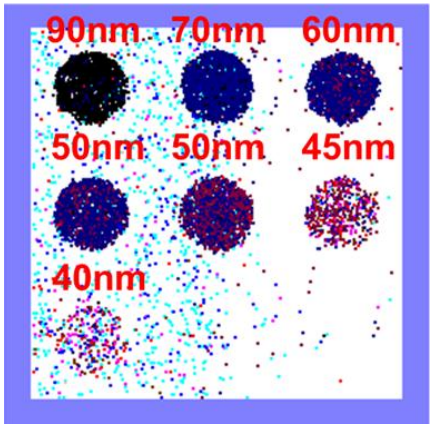
Mar-2012 PM



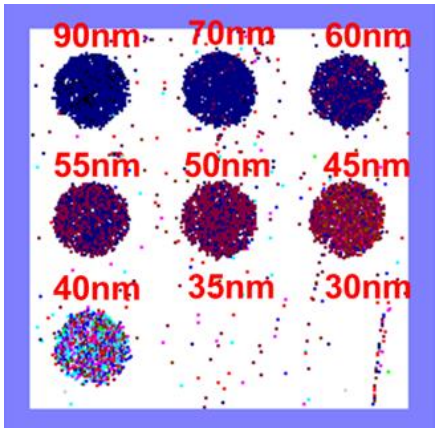


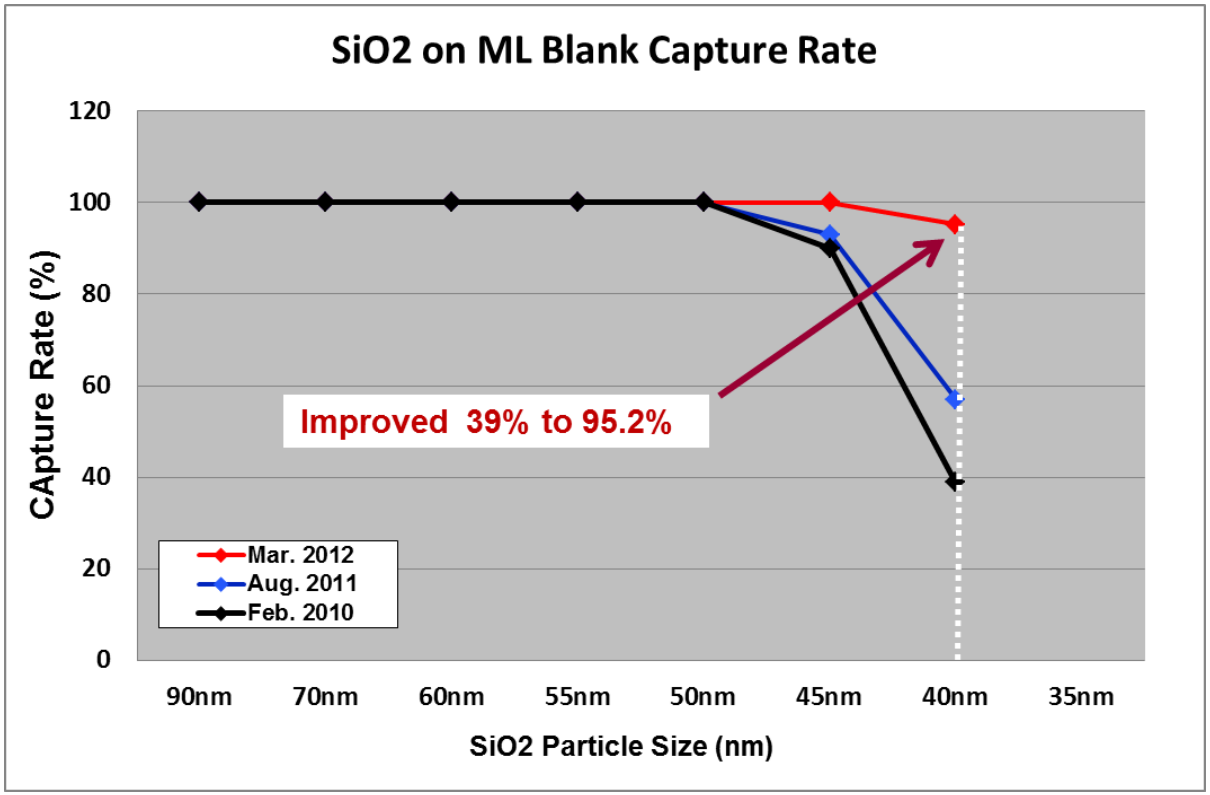
40 nm of Inspection Capability Achieved on ML Blank Inspection (Improved 39% to 95.2%)

Feb. 2010 PM

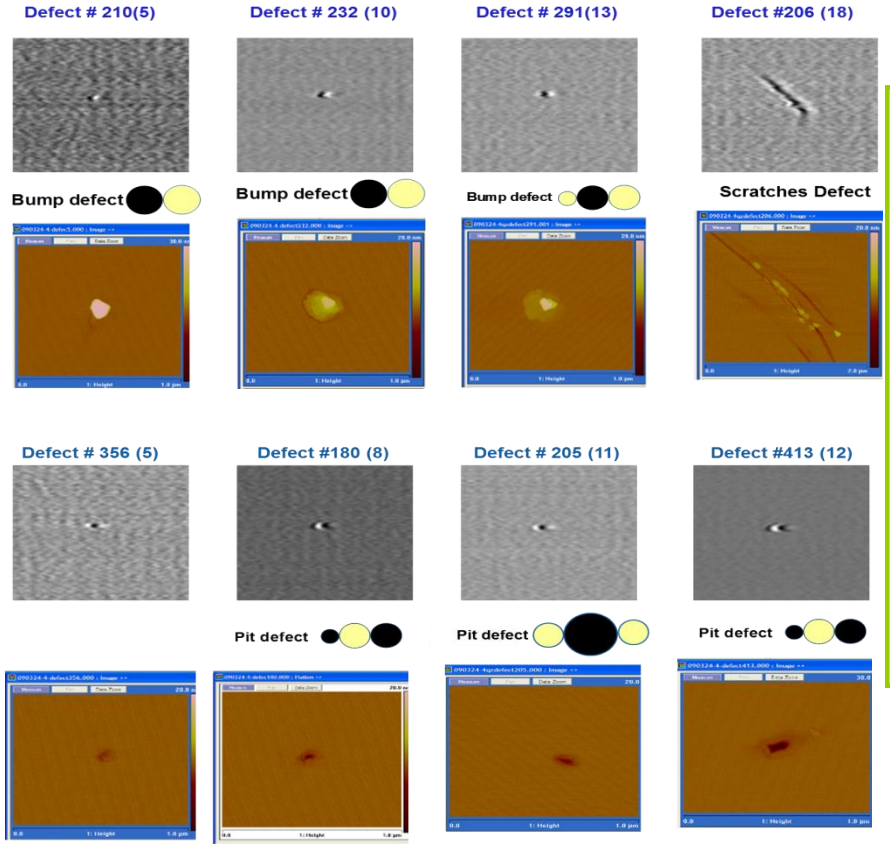


Mar-2012 PM

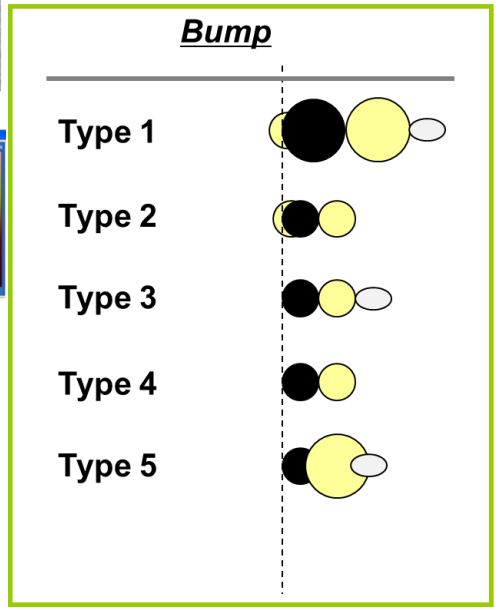


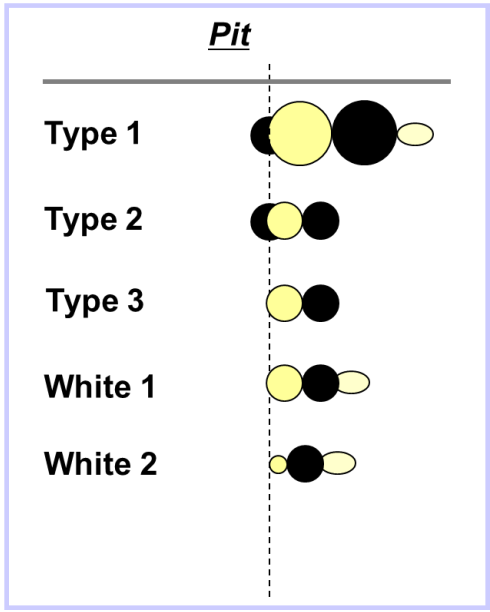


QZ Substrate Defects Classification on the M7360



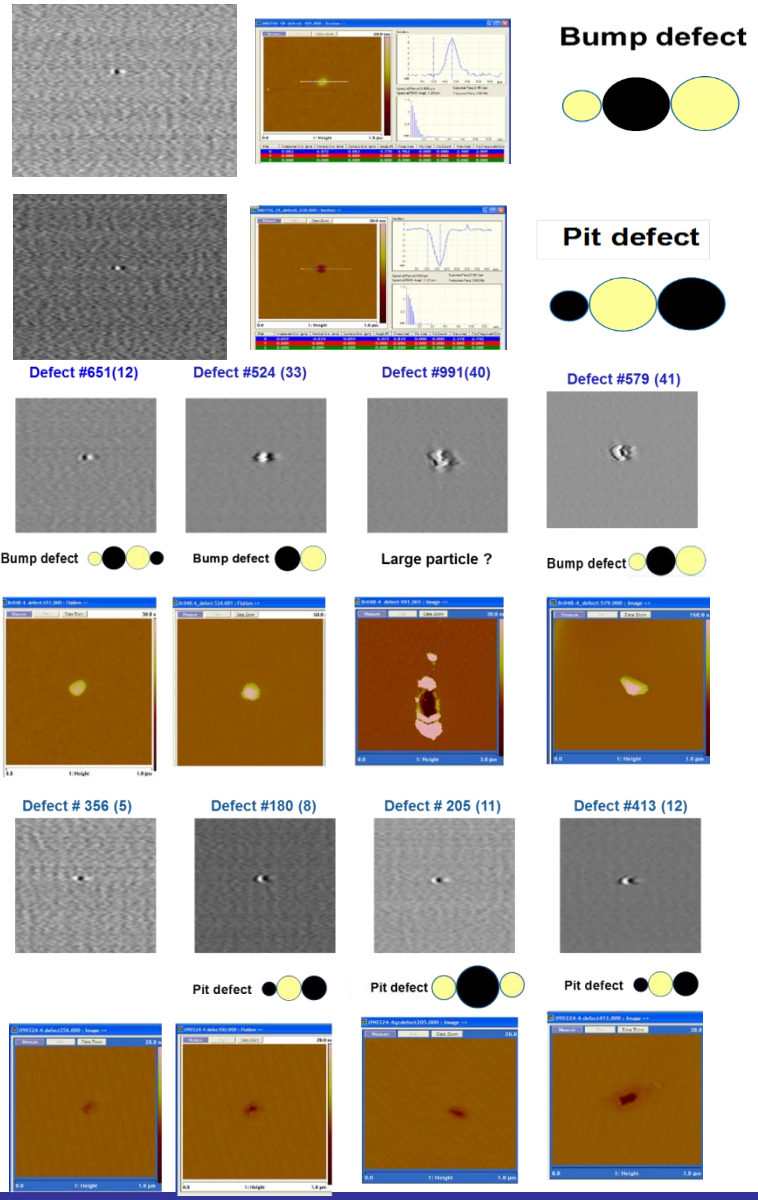
Qz Natural Defect Image Pattern





Auto defect classification: ~80 - 85% accuracy
Manual defect classification: > 95% accuracy

ML Blank Defect Classification on the M7360

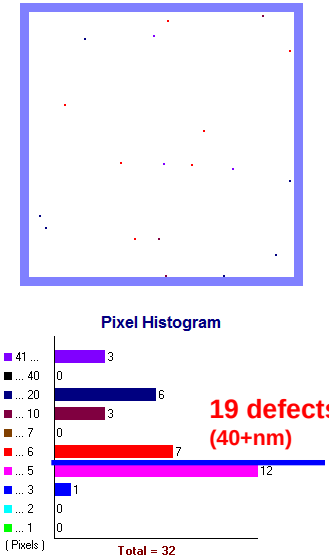
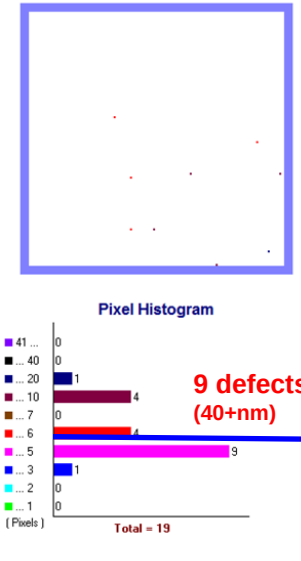
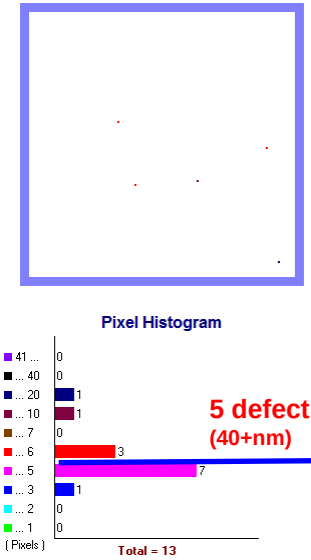
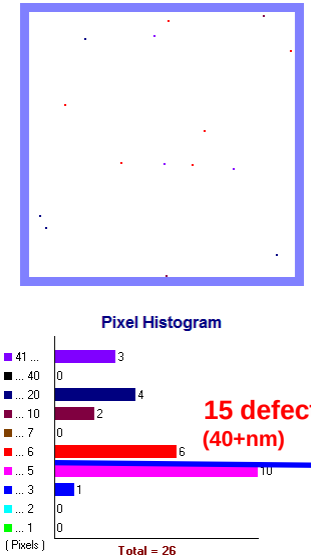
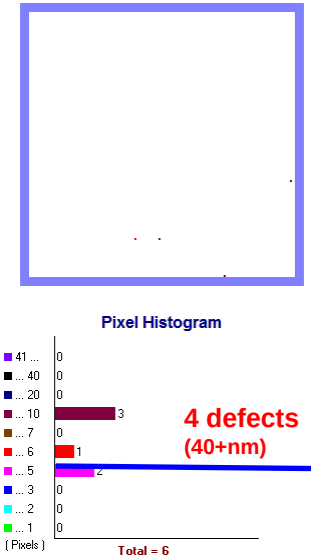


ML Natural Defect Image Pattern

Bump	*Pit*
Type 1	Type 1
Type 2	Type 2
Type 3	Type 3
Type 4	Type 4
Type 5	Type 5
Type 6	Type 6
Type 7	Dark 1

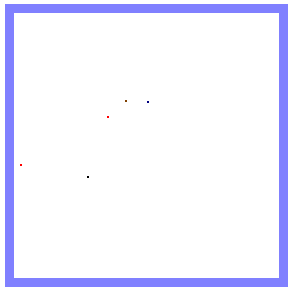
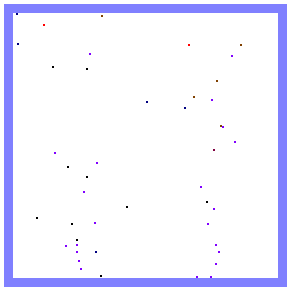
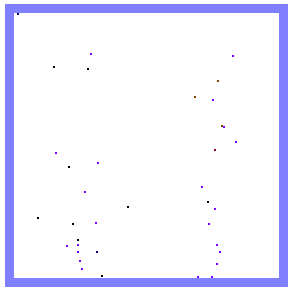
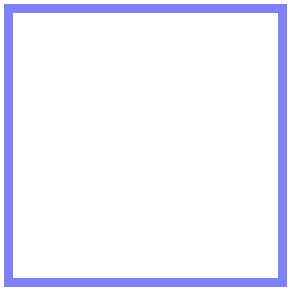
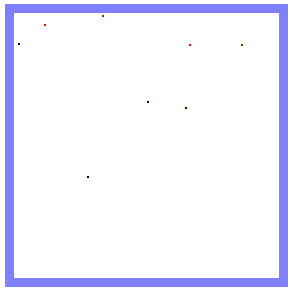
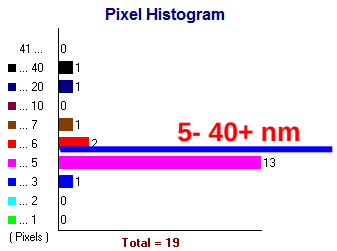
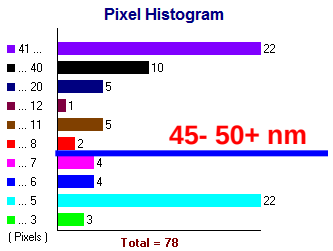
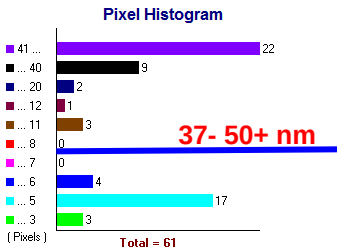
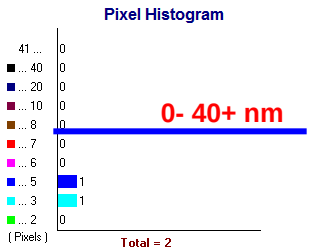
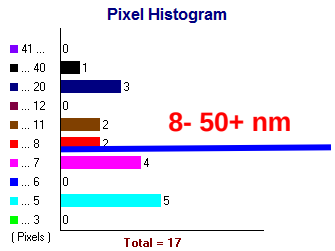
Auto defect classification: ~80- 85% accuracy
Manual defect classification: > 95% accuracy

Support Qz Substrates Cleaning Process Development (Plate ID# DRT1203014)

Pre- clean	Post clean	Add (added defects)	Sub (removed defects)	And (common defects)
				
Pre- clean defects - 15 particle - 2 pit - 2 scratch	Post- clean defects: 9 - 2 particle - 5 pit - 2 scratch	Cleaning added defects - 2 pit - 3 particle	Cleaning removed defects - 15 particle	Common defects: 4 - 2 pit - 2 scratch

QZ Cleaning process: Removed 15 particles , added 3 particles, and added 2 pits.

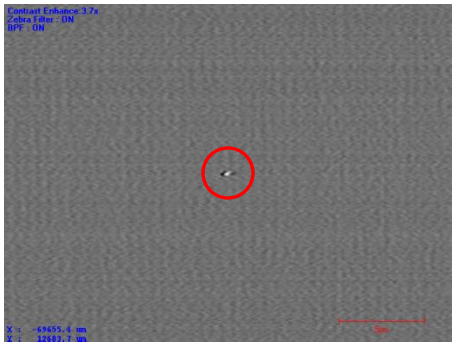
Support ML Deposition Process Development (Plate ID# DRT1203019)

Pre- deposition	Post deposition	Add – Deposition Added defects	Sub- decorated defects	And -common defects
				
				
Substrate defect: 5 3- particle 1- pit 1- scratch	ML defect: 45 43- particle 1- pit 1- scratch	Deposition added defect: 37 37- particle	All substrate 40+nm Defects were detected after ML Dep.	Common defects: 8 6- particle 1- pit 1- scratch

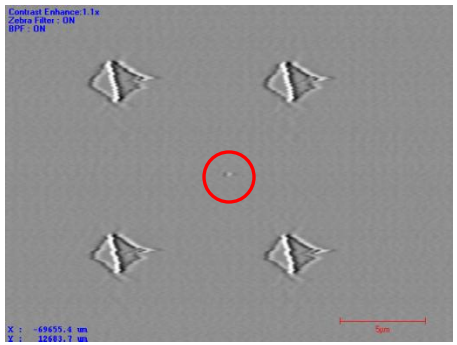
ML deposition process: Introduced 37 particle defects, and all 40+nm of substrates defects are becoming detectable defects @ 50+nm.

M7360 has Punchmarking Capability to Help Locate Defects for FA

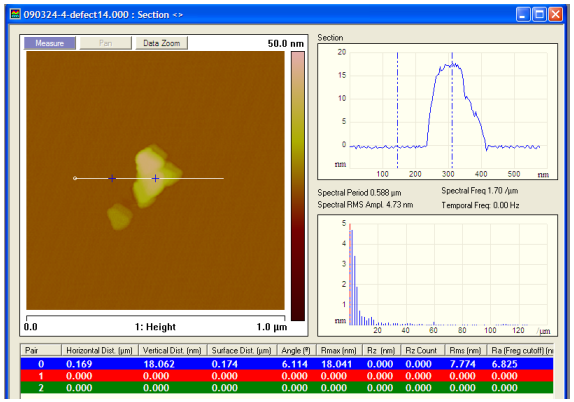
Def # 9 – bump defect



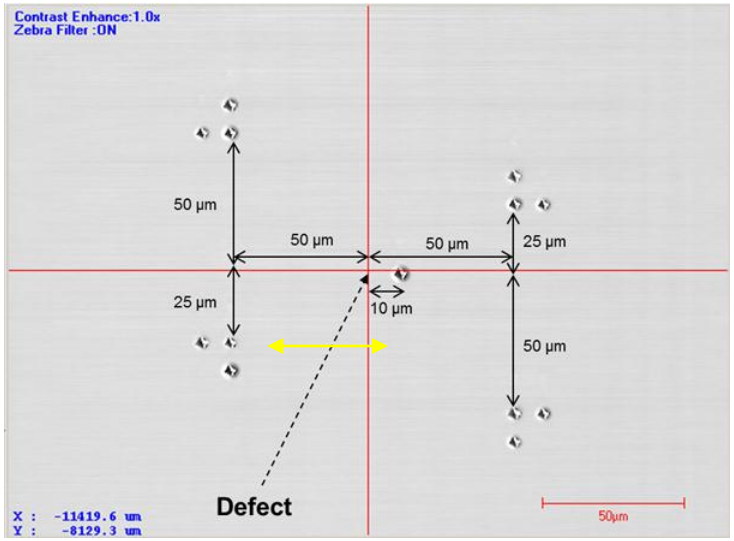
Def # 9 – punch marking



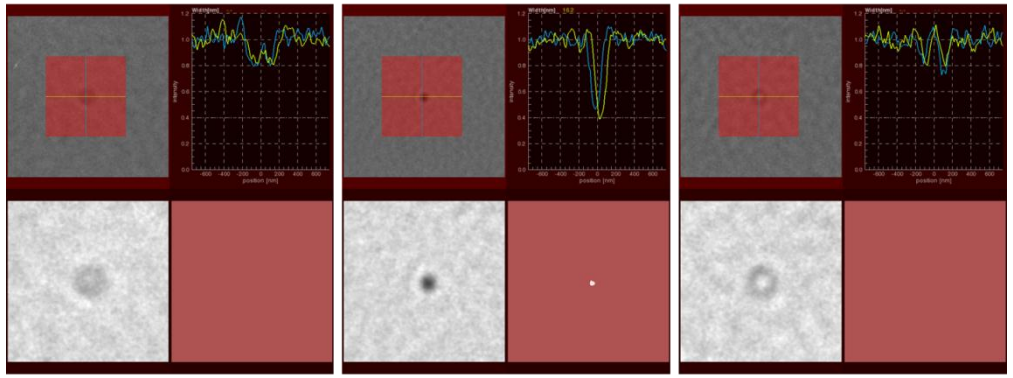
Def # 9 – AFM image



Punchmarking for AIT image review



Defect # 115, pit



F= 200 nm F=000 nm F=-200 nm

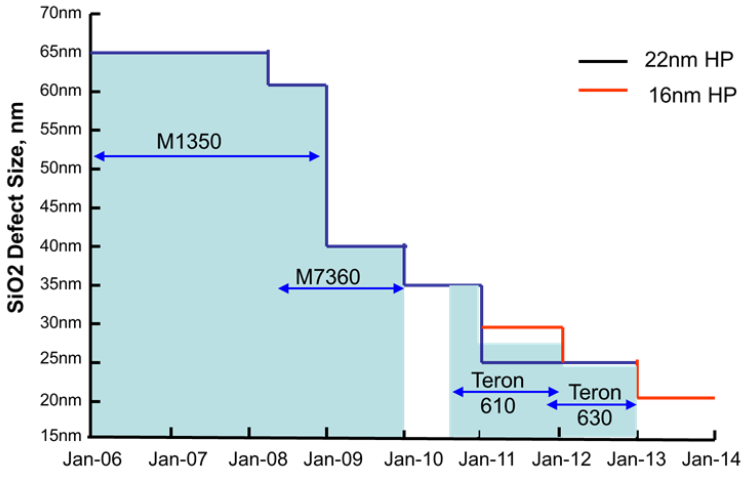
EUV Mask Blank Inspection Tool Capability Assessment (16nm HP)

Year (2 years ahead) (HP node)	Spec	2009 (32 nm)	2010 (32nm)	2011 (22nm)	2012 (22nm)	2013 (16nm)	2014 (16nm)
Mask Substrate Defect cut-off size	20 nm	40	35	25	25	20	20
M7360 Inspection capability (ISMT)		55	45	40	35	30	30
Alternative inspection tool (193 nm)				25	25	20	20
Multiliers Defect cut-off size	20 nm	45	35	25	25	20	20
M7360 Inspection capability (ISMT)		60	50	45	40	35	
Alternative inspection tool (193 nm)				25	25	20	20

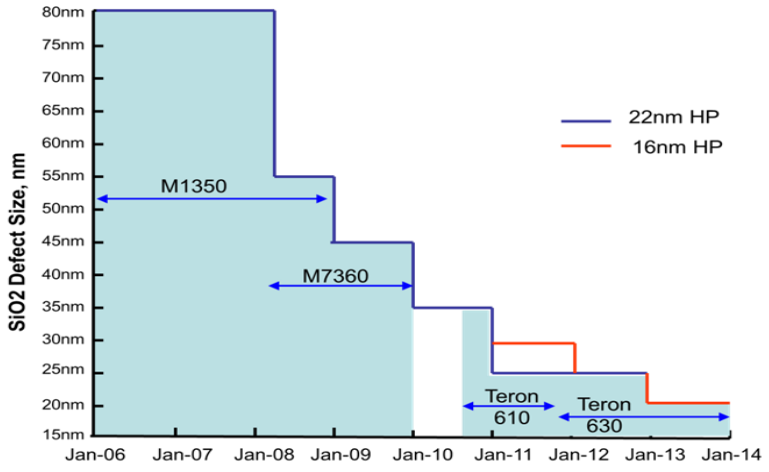
: Current Capability

: Process Improvement

Substrate Inspection Tool Capability / Roadmap from one IDM



ML Blank Inspection Tool Capability / Roadmap from one IDM



Future Plan

- Perform EUV mask blank inspection tool benchmarking
  - KLA (Teron 61X & 63X)
  - Actinic blank inspection tool (EIDEC Lasertec tool)
- Work with Lasertec to reduce the stage speed from 0.6 to 0.5 or even 0.4 to improve sensitivity on both Qz and ML blanks: 30 nm on Qz and 35 nm on ML blanks.
  - Improve surface roughness (0.08 nm → < 0.05 nm, rms, λ: 100 nm to 1 μm) on ML blanks.
    - A more aggressive setting can be used on the slice level and a spatial filter on smoother ML blanks.

Summary

- SEMATECH M7360 inspection sensitivity has been improved on QZ from 45 nm → 35 nm (SiO_2 particle size), and on ML from 50 nm →40 nm (SiO_2 particle size).
- M7360 inspection tool has capability to support development of QZ substrate cleaning process and ML deposition process to achieve the goal of defect-free pilot line of EUVL ML blanks.
- M7360 defect punchmarking capability is essential for FA defect analysis and supporting AIT image review.
- A next generation Qz and ML blank inspection tool and lower cost ownership are needed to bridge the gap for 20 nm inspection capability requirement for ML blank manufacturing in 2014-2015.

Acknowledgements

- Hoya Corporation for providing the Qz and ML programmed defect masks
- Prof. David Pui and Kyoungtae Kim, University of Minnesota for the SiO_2 sphere particles deposition

Thank you for your attention