State of the art EUV mask blank inspection with a Lasertec M7360 at the SEMATECH MBDC

Patrick Kearney[a], Won-Il Cho[a], Chan-Uk Jeon[a], Eric Gullikson[b], Anwei Jia[c], Tomoya Tamura[c], Atsushi Tajima[c], Hal Kusunose[c]

[a] SEMATECH MBDC, Albany, NY
[b] Lawrence Berkeley Lab, Berkeley, CA
[c] Lasertec Corporation, Yokohama, Japan

Acknowledgement: Abbas Rastegar and Sean Eichenlaub and Pat Gabella.

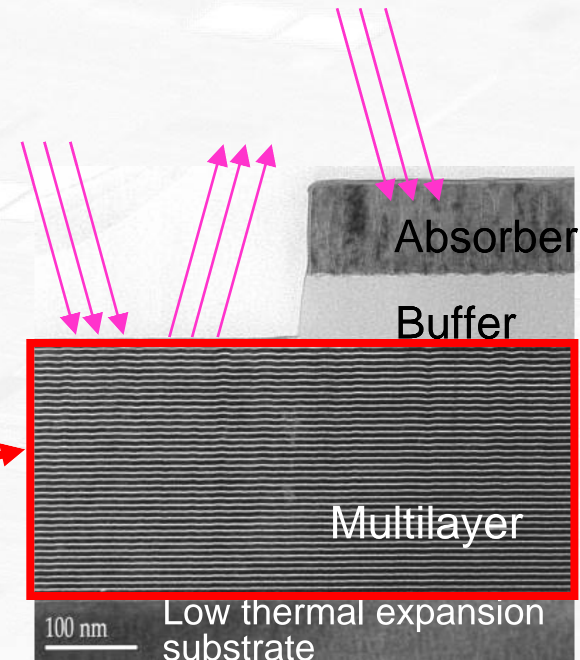
Advanced Materials Research Center, AMRC, International SEMATECH Manufacturing Initiative, and ISMI are servicemarks of SEMATECH, Inc. SEMATECH, the SEMATECH logo, Advanced Technology Development Facility, ATDF, and the ATDF logo are registered servicemarks of SEMATECH, Inc. All other servicemarks and trademarks are the property of their respective owners.

EUV Mask Technology

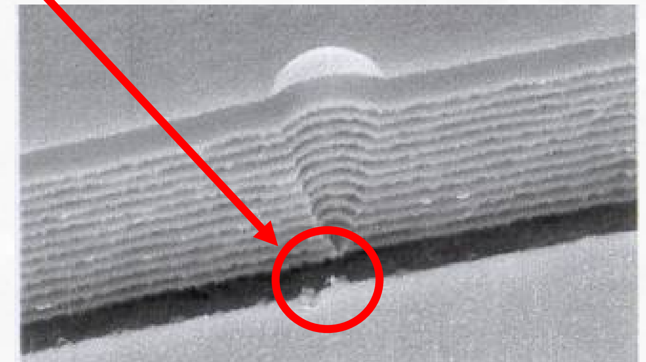
- Masks must be extremely flat and defect free
- Major development effort on EUV mask blanks at SEMATECH North

EUV mask

MBDC Focus



EUV mask construction



Defect in multilayer

TEM courtesy of AMD

SEMATECH
Accelerating the next technology revolution.

SEMATECH Mask Blank Development Center (MBDC) Strategy

- Develop low defect substrates partner with mask blank suppliers to help them improve their substrates and ML coated blanks.
- Advance state of the art mask cleaning partner with cleaning tool vendors to perfect in house cleaning.
- Develop low defect ML coating process/tools partner with tool supplier (Veeco) to develop process and deposition tool for EUVL blank production at the SEMATECH MBDC (Albany NY) facility.

Industry Defect Goals (total mask blank defects)

- Pilot Line defect goal: >**0.01 defect/cm^2 @ 40 nm** (2007).
- Long term (HVM) goal: **0.003 defect/cm^2 @ 25 nm** (2009).

SEMATECH Accelerating the next technology revolution.

MBDC has relied on the Lasertec M1350 inspection tool

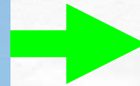
- Received tool in 2003.
- As delivered sensitivity 60nm on QZ, 80nm on ML.
- Upgraded to 54nm on QZ, 70nm on ML.
- Very reliable tool.
- Enabled great progress in:
  - Substrate defects
  - Substrate cleaning
  - Blank defect reduction
- MBDC needs more sensitivity!⇒M7360

M1350 and M7360 are MAGICS tools

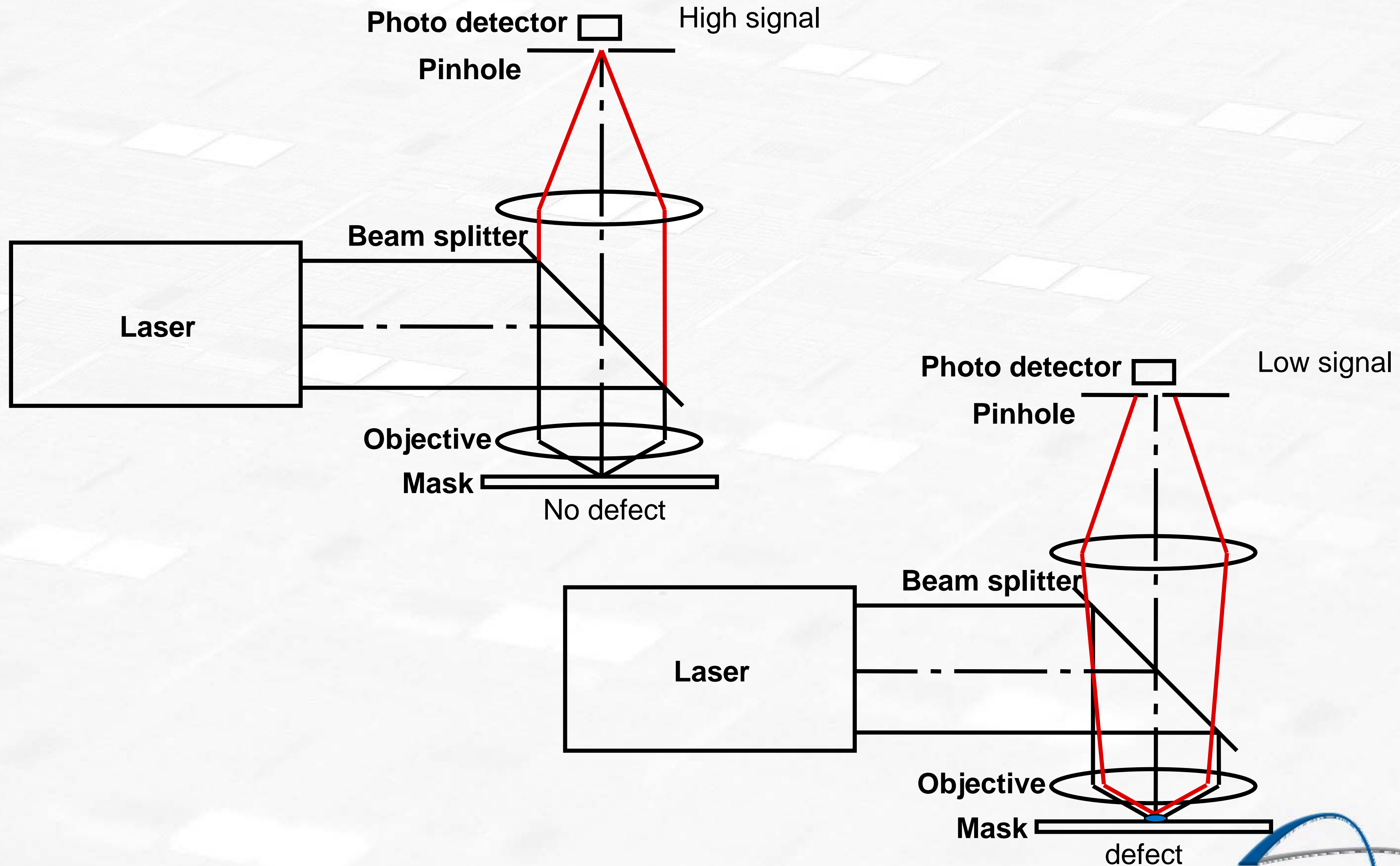
***M**ultiple image*
***A**cquisition for*
***G**iga-bit*
***I**nspection with*
***C**onfocal*
***S**ystem*

M1350 and M7360 Features

Feature	Benefit
1. All-in-one (Inspect & Review)	1. Easy to find cause of defects
2. High Resolution/High Contrast No flare, High sensitivity	2. Can evaluate even small/shallow defect without SEM.
3. Sensitive to phase information	3. Can measure height accurately with 3D-image
4. Windows based GUI Interface	4. Master operation quickly.
5. High Speed	5. Used in both Lab. and production.
6. High Accuracy (Coordinate)	6. Easy-to-coordinate with AFM
7. Marking Function	7. Easy to find defect location by AFM



Confocal Laser Microscope Optics on the M1350 and M7360 are very sensitive to surface defects



M7360 is a 30nm mask blank inspection tool resulting from a JDA between Lasertec and SEMATECH

The M7360 is a MAGICS tool operating at 266nm wavelength.

Specifications:

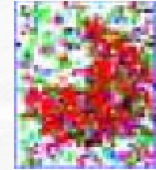
- 30nm PSL sensitivity on blank substrates (transparent)
- 30nm PSL sensitivity on ML coated mask blanks
- 60 minutes per mask scan time
- Clean handling from both MRP and RSP (multiple reticle pod and reticle SMIF pod)

M7360 was accepted September 22, 2006

M7360 in the MBDC cleanroom.

PSL spheres are not stable under 266nm scanning in the tool so we use SED

One quadrant of a 50nm PSL spot is removed by scanning



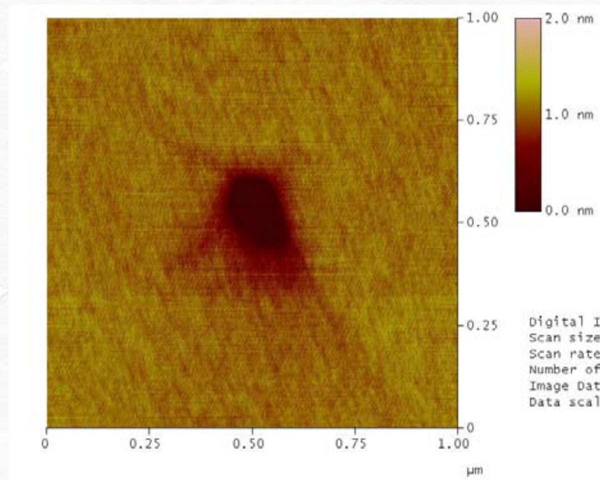
- A new sensitivity standard is needed.
- For this talk I will use native and programmed defects to calibrate the tool.
- Defect size is measured by AFM.
- AFM data converted into a single number for each defect, Spherical equivalent volume (SED), the diameter of the sphere with the same volume as the defect.

M7360 can see 40nm PSL equivalent defects on ML

Find small defects with M1350
 (scan into the noise)

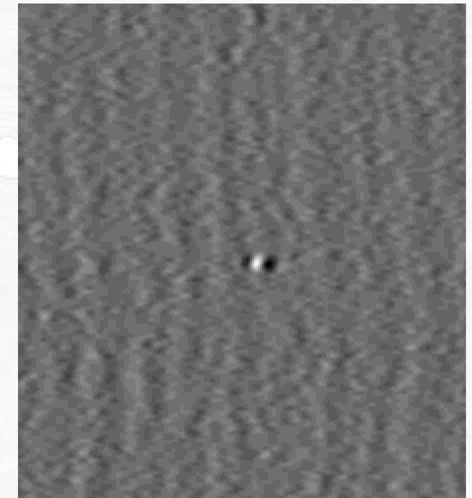
M1350 seen in 1 of 10 scans in pixel 1

Determine defect size with AFM



4.1 nm deep pit
57nm FWHM
(28nm SED)

Scan on M7360
Determine contrast, pixel and capture efficiency



100% CE, Pixel 4
2.6% contrast

For this defect the measured M7360 contrast of 2.6% agrees well with simulations of 2.5%.

This is a 40nm PSL equivalent defect. (40nm PSL has 2.55% simulated contrast)

Accelerating the next technology revolution.

Programmed QZ bumps on QZ demonstrate the M7360 is much more sensitive than the M1350

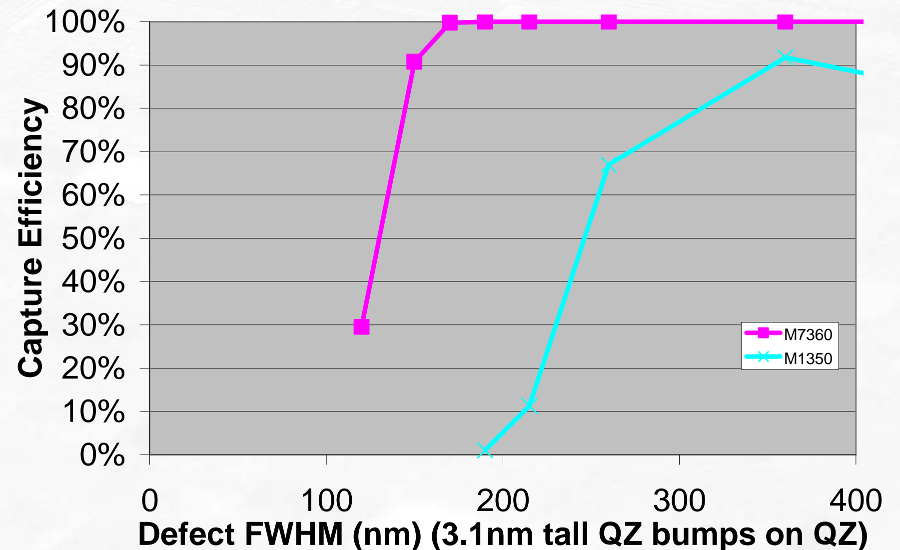
M1350

M7360

75 80 95 120 150 170 190 215 260 360 515 770 1010

Increasing FWHM →

All programmed defects are 3.1nm tall QZ bumps with varying widths on QZ



Lasertec

SEMATECH

Accelerating the next technology revolution.

Characterization of QZ sensitivity with native defects

- 2 of our highest quality QZ plates were inspected on the M7360, of the defects found 56 were selected for AFM analysis.
- The surface profile of each defect was measured with AFM.
- The AFM data was converted to SED for each defect.
- AFM showed the defects were 33 pits and 23 bumps (particles).
- Plot of the data follows

SEMATECH Accelerating the next technology revolution.

Pre-Beta M7360 reliably measures to ~30nm SED and has some detection down to below 20nm SED

SED (nm)

60
55
50
45
40
35
30
25
20
15
10
5
0

0 1 2 3 4 5 6 7 8 9 10

7360 Pixel Size

particles
pits
Linear (All)

For comparison the M1350 sees reliably to ~55nm SED
And has some detection down to ~35nm SED.
The smallest printable ML bump defect is ~14 nm SED.

Lasertec

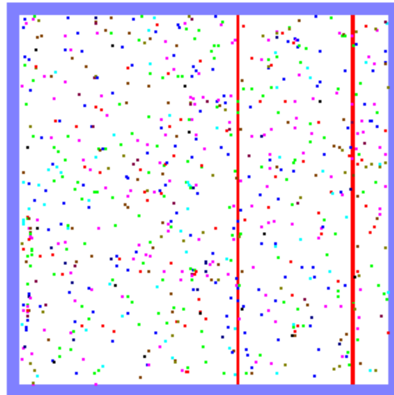
M7360 sees ~3-7X the defects seen by the M1350

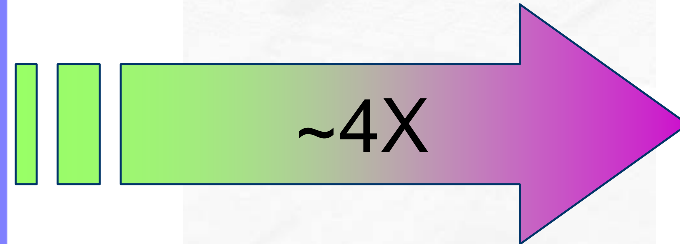
M1350 scan of ML

11/02/05 02:58

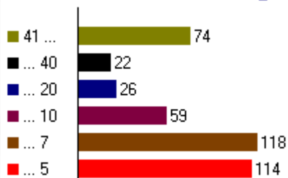
[Sample Information]

Sample ID : 142MM
Lot ID :
Cassette/Slot No. : 2 - 1
WFD File : D:\DEF001A\142mm.wfd
Work Folder : Step 900
LDF File : Lot_541PUQ48_Step_051102021328.ldf [Count = 1038]
Sample Size : 152 mm
Comment :





Pixel Histogram



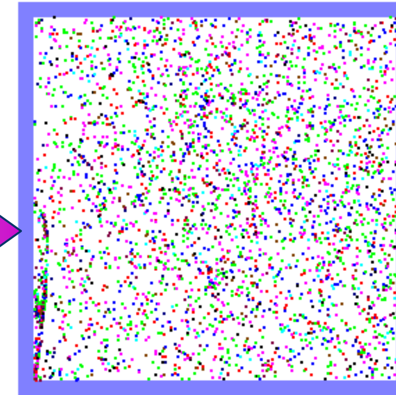
(Pixels) Total = 1038

M7360 scan same sample

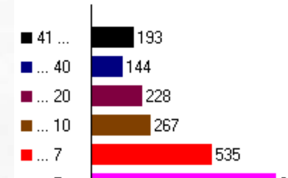
01/19/06 11:47

[Sample Information]

Sample ID :
Lot ID :
Cassette/Slot No. : 1 - 4
WFD File : D:\Data\Mask-140mm.wfd
Work Folder : 5Y1PUQ48
LDF File : 000014.ldf [Count = 4352]
Sample Size : 152 mm
Comment :



Pixel Histogram



(Pixels) Total = 4352

Much bigger defect signal to drive down!

Lasertec

Accelerating the next technology revolution.

Conclusion

- The M7360 is installed and operational at Pre-Beta sensitivity.
  - Currently much more sensitive than the M1350.
  - Current sensitivity for reliable adder calculations is ~ 30nm SED on QZ (already meets Final-Beta 30 nm PSL sensitivity).
  - Current sensitivity for detecting particles is below 20 nm SED on QZ.
  - We estimate this will result in seeing 3-7x the number of defects seen on the M1350.
- Final-beta tool upgrades should yield even more sensitivity in 2007.
  - 30nm PSL equivalent on ML (18nm SED).