Accelerating the next technology revolution

# Fiducial Mark for Defect Mitigation Technology

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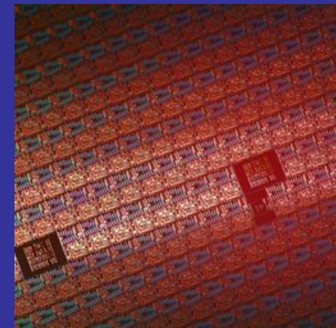

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# Executive Summary

- **Objective and approach:**
  - Fiducial mark as defect mitigation strategy to “salvage” EUV blanks with a few defects to save cost and availability.
  - Use current tool infrastructures to reduce cost of implementation.
- **What are included in SEMI Standardization:**
  - Mark locations & Mark design
  - Mark readability including blank inspection tools,ebeam writers, and defect review tools.
- **What are NOT included:**
  - Methods to make marks
  - Mark depth, as long as meeting readability requirement.
- **Taskforce Members:** Intel, Samsung, GF, UMC, KLA, Lasertec, AGC, ASML, NuFlare, SEMATECH
- **Taskforce Key Deliverables and Schedule:** SEMI blue ballot – Q4, 09, Yellow ballot – Q1, 10.

# The Requirement of Fiducial Mark

- Reserved area for fiducial mark on the blankmask
  – Fiducial marks should be rotationally symmetric to allow blank rotation (90 or 180 degree rotations only).
  – The region should not be used by other tools.
- Mark contrast
  – The mark should be readable and usable for alignment by blank inspection and ebeam writing tool.
- The dimension of fiducial mark
  – The mark size and fidelity should provide accurate position signal.

# How to Use Defect Information?

Defect image | Mask layout | Overlapped image

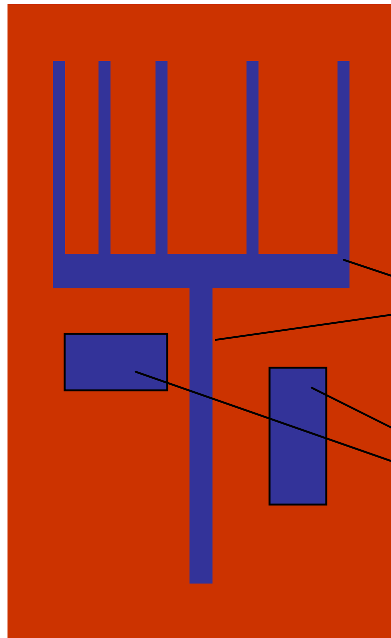
Rotation

Shift

Mask writing strategy

- Fiducial marks help to realize "defect free" EUV blanks and thus lower the cost of EUVL.
- Pattern shift and blank rotation are allowed to hide one or more ML defects under the absorber patterns.
- ML defects that are completely under the absorber will not print on the wafer.

# Defect Mitigation Technology using Fiducial Mark



Zone 1 : Critical smallest CD

Zone 2 : Less critical large CD

Zone 3 : Large dummy or pad, CD is not important

Mask Layout

- Zone2 or 3 will be first sort for fiducial mark application

# SEMI Fiducial Mark Draft Ballot

## SEMI DOCUMENT XXXX- DRAFT- October 6, 2009
## SPECIFICATION OF FIDUCIAL MARKS FOR EUVL MASK BLANKS

### 1 Purpose

This standard specifies key requirements of mask fiducial marks that can be used as a coordinate system for referencing defect locations on EUV blanks.

### 2 Scope

2.1 This standard is intended to set an appropriate level of technical specifications of mask fiducial marks, such as their loactions, shapes, sizes, line dimensions, limits of variation, and readibility by mask metrology and pattern write tools.

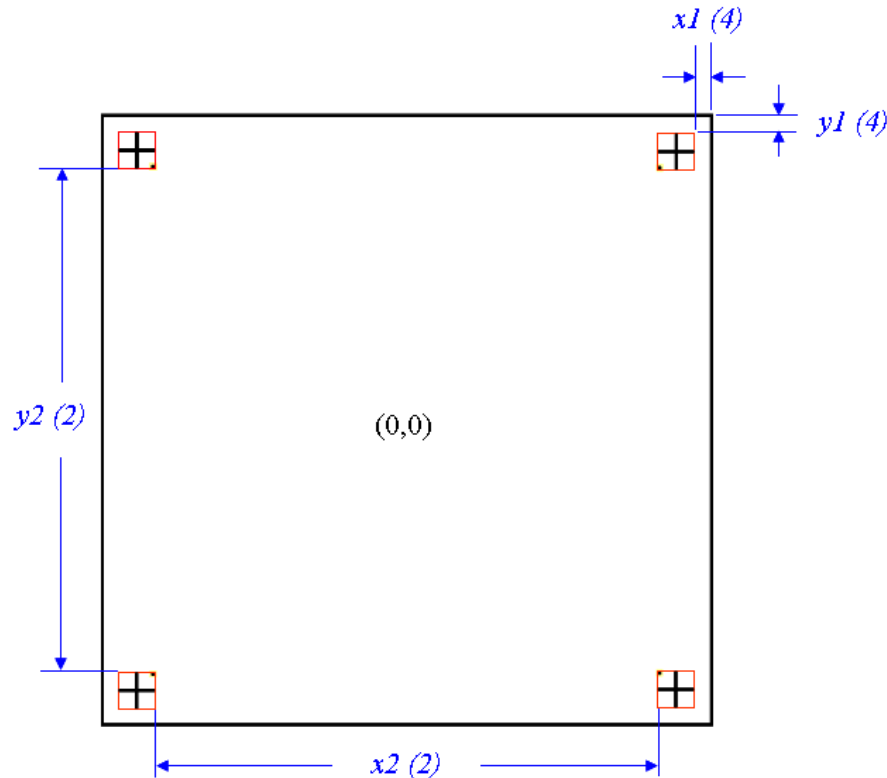
2.2 To allow innovation, this standard does not specify techniques to be used, or how the fiducial marks are generated.

**NOTICE:** This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

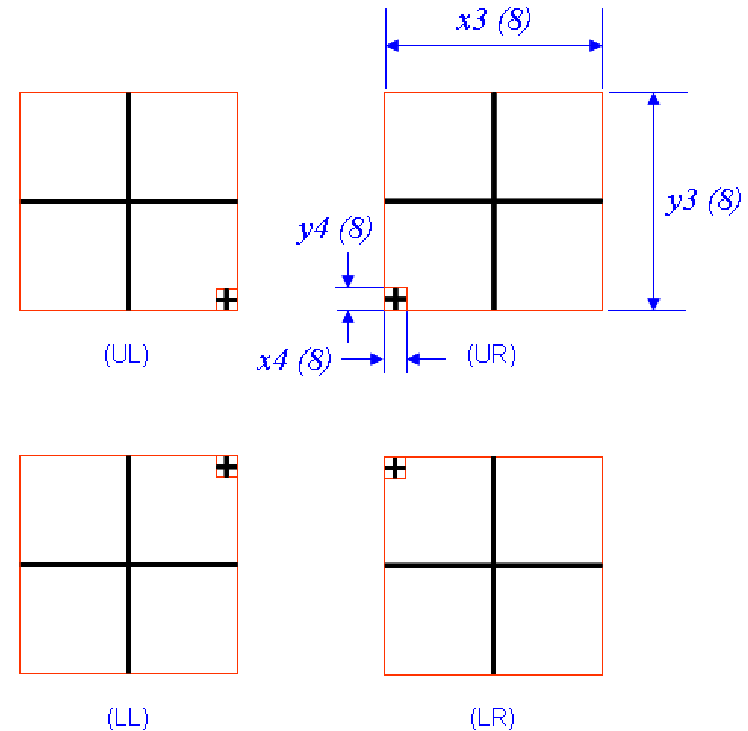
### 3 Referenced Standards and Documents

3.1 *SEMI Standards*

# Fiducial Mark Layout (Draft)




Fiducial mark layout on an EUV mask blank (not to scale). One mark is placed at each corner.

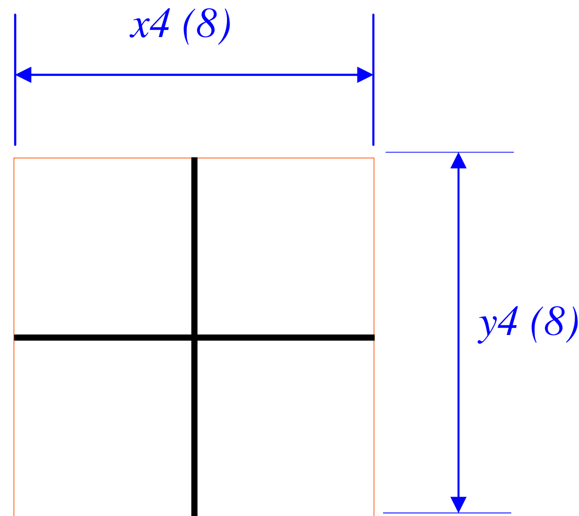



Layout of coarse and fine marks for all the four fiducial marks (not to scale). (Red lines are guide to eyes)

# Draft FM Specifications

| Symbol Used | Figure | Value (mm unless specified) | Tolerance (mm unless specified) | Reference Measured From | Feature Measured To |
|---|---|---|---|---|---|
| x1 | 1 | **5.0** | **Minimal** | Nearest edge of mask blank | Outmost line end of coarse mark |
| x2 | 1 | 135.000 | ±0.010 | Inmost line ends of the fine and/or coarse marks on the left | Inmost line ends of the fine and/or coarse marks on the right |
| x3 | 2 | 3.000 | ±0.010 | Left end of coarse mark | Right end of coarse mark |
| x4 | 2 | 0.100 | ±0.010 | Left end of fine mark | Right end of fine mark |
| y1 | 1 | **5.0** | **Minimal** | Nearest edge of mask blank | Outmost line end of coarse mark |
| y2 | 1 | 135.000 | ±0.010 | Inmost line ends of the fine and/or coarse marks on the bottom | Inmost line ends of the fine and/or coarse marks on the top |
| y3 | 2 | 3.000 | ±0.010 | Left end of coarse mark | Right end of coarse mark |
| y4 | 2 | 0.100 | ±0.010 | Lower end of fine mark | Upper end of fine mark |
| CD (for both coarse and fine marks) | | 4.0 um | 0.1 um | CD is defined as line width of both the fine and coarse marks. | |
| LER (3σ on each side) | | 10.0 nm | Maximal | 3σ on each side | |

## Other Fiducial Mark Design Options: #1



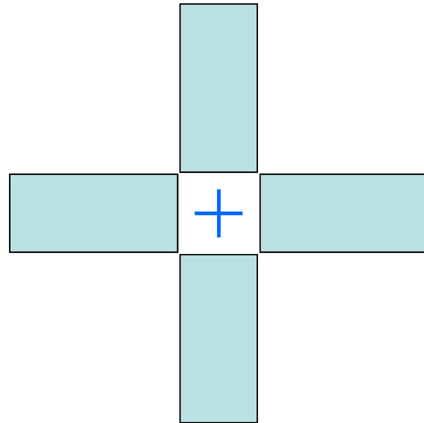

Suggested by E-beam writing supplier. Overall, it may be the best option.

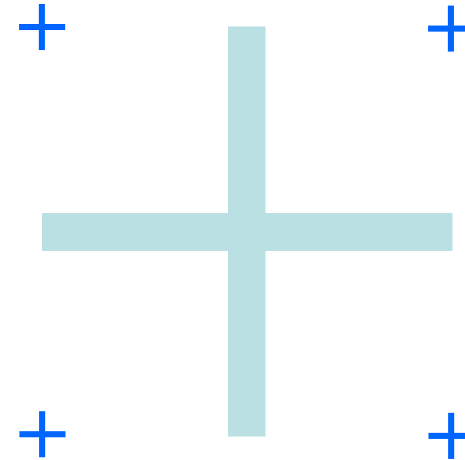
**Option #1.** Increase the line length of coarse mark (x4/y4) to 4mm (from 3), and eliminate fine marks. (Red lines are guide to eyes)

**The good: Simplicity. Symmetric**

**The Bad: The maximum central area (x2/y2) would be reduced to ~133nm (from ~135mm).**

## Other Fiducial Mark Design Options: #2, #3





**Option #2.** Aligned up fine and course marks to they are centered at the same location.

**Option #3.** Place one fine mark at each corner of the coarse mark.

**The good: All the four fiducial marks (coarse + fine) will be identical/and symmetric.**

**The Bad: Complex.**

# Defect Coverage Accuracy

| DRAM Half pitch | 11 | 16 | 23 | 32 | 45 | 65 | 90 | 130 |
|---|---|---|---|---|---|---|---|---|
| Mask CD (4x) | 44 | 64 | 92 | 128 | 180 | 260 | 360 | 520 |
| Mask uniformity (3 sigma) | 1.3 | 1.8 | 2.6 | 3.7 | 5.2 | 7.3 | 10.2 | 14.7 |
| Mask MTT (+/- Range) | 0.9 | 1.3 | 1.8 | 2.6 | 3.6 | 5.2 | 7.2 | 10.4 |
| | | | | | | | | |
| Inspection tool sensitivity | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| E-beam alignment accuracy to fiducial mark | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| E-beam stage accuracy (sigma) | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| Max space for defect to move considering mask error | 34.7 | 50.6 | 72.7 | 101.0 | 142.1 | 205.4 | 284.5 | 410.9 |
| Max space for defect to move without considering mask error | 44 | 64 | 92 | 128 | 180 | 260 | 360 | 520 |

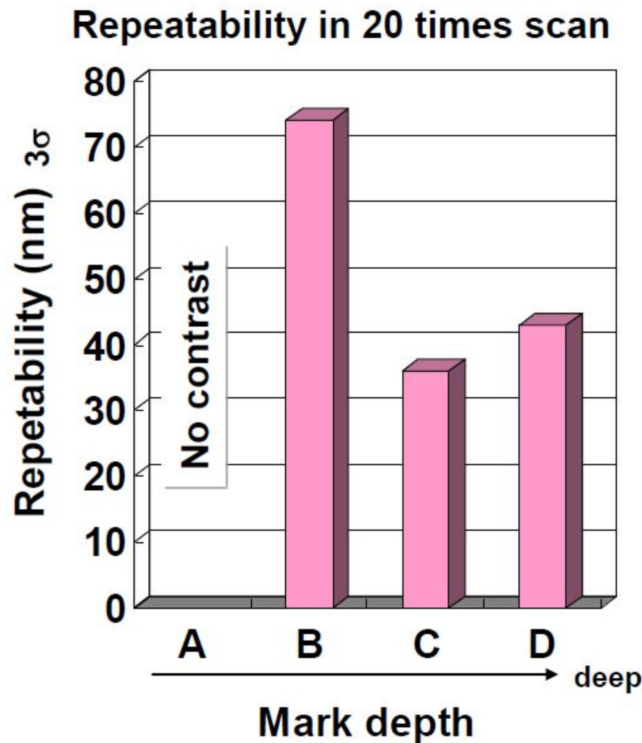
| Required inspection tool accuracy (3sigma) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***with mask error*** | **-** | ***17.5*** | ***49.1*** | ***82.3*** | ***128.1*** | ***197.6*** | ***283.4*** | ***420.4*** |
| ***without mask error*** | **-** | ***22.5*** | ***54.0*** | ***88.7*** | ***136.9*** | ***209.8*** | ***300.3*** | ***444.7*** |

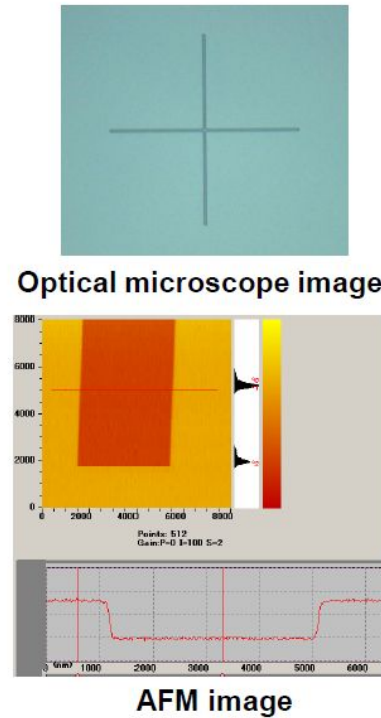
$$\sigma^2(A) = \sigma^2(B) + \sigma^2(C) + \sigma^2(D)$$

A : Max space for defect to move under absorber
B : Defect location measurement error (include both stage accuracy and repeatability)
C : Ebeam alignment accuracy to fiducial mark
D : Ebeam stage accuracy

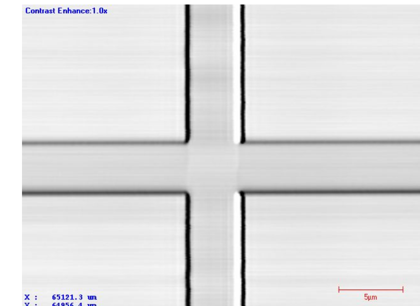
# Demonstration of Fiducial Mark by Blank Company

## Initial results in EB scan




Intel Lasertec M1350 image of ML fiducial mark



- Optimum depth for mark was decided from actual EB scan evaluation
- Repeatability would be improved by optimization of EB writing process

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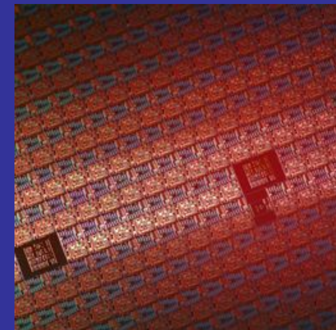
# Backup



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# Proposed Roadmap for Fiducial Mark Standardization

| 2008 | | | | 2009 | | | | 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |

Industry FM workgroup

Workshop

TFOF / TF Kickoff @SEMICON West

Fiducial strategy
- Layer
- Implementation

Demonstrated methods

Blue ballot

Yellow ballot

# Tentative Plan

- Request to SEMI NA Micro Patterning Committee in its 2/28/09 (2010?) meeting, for Cycle 6 yellow (Blue?) ballot voting (9/14-10/14/09).
- Draft blue ballot review by TF, at SEMICON West (July, 2009)
- Yellow (Blue?) ballot submission on 8/31/09
- In the meantime, develop/demonstrate marking methods.

# The Purpose of Fiducial Mark

- Fiducial marks are mainly for ML defect mitigation technology which allows to utilize a mask blank with limited defects.
- Implementation of ML defect mitigation scheme can reduce blank cost by increasing blank yield.

# Example of ML Defect Coverage via Absorber Pattern

**Case 1**
Absorber pattern 1μm L/S (4x)

ML def size ~1.5μmx1.5μm

Shift mask pattern to cover ML def

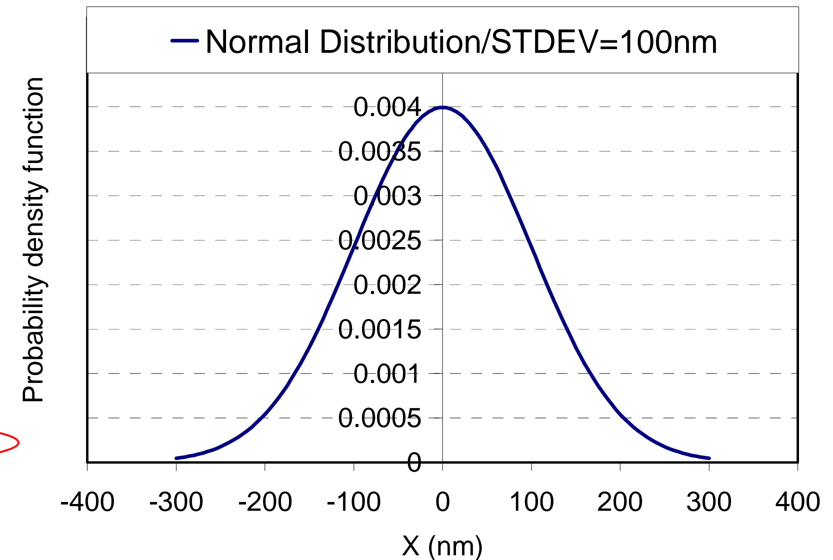
Results: in order to measure y-error, we cut the line such that a 1μm$^2$ absorber pad is aligned to the ML defect

**Case 2:**
5μmx5μm contacts mimics absorber

- The experiment used ML indentation as the first set fiducial mark and first layer e-beam patterned fiducial mark as the final fiducial mark.

# Small Defect Position and Alignment Error Allows Small Absorber Area

| For defect coverage position Normal Distribution with standard deviation σ (A) | |
|---|---|
| Absorber pad (square) size | Probability of covering a defect when its average position is at the pad center |
| Defect size+1σ(A) | 38% |
| Defect size+2σ(A) | 68% |
| Defect size+4σ(A) | 95% |
| Defect size+6σ(A) | 99.7% |




$$\sigma^2(A) = \sigma^2(B) + \sigma^2(C) + \sigma^2(D)$$

- Reducing σ(B), σ(C), and σ(D) will allow the use of small absorber pad

# Fiducial Mark TF activity/plan

- **The core team meets on as-needed base, currently focusing on ballot editing.**
  - Next meeting slated for 10/??  Everyone is welcome to attend.
- **Targeted to submit informational (Blue) ballot in November, 2009.**
- **Targeted to submit Letter (Yellow) ballot in March 2010.**
- **Final standard approval targeted for Summer 2010.**