Development of Coherent EUV Scattering Microscope

J. Kishimoto, T. Watanabe, and H. Kinoshita,
Dong gun Lee*, Seong-Sue Kim*, and Han-Ku Cho*

Laboratory of Science and Technology for Industry,
University of Hyogo, Japan

*Samsung Electronics Co., Ltd., Korea

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Outline

1. Background of development
2. Experimental setup of CSM
3. Experimental result
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Background

We have developed the EUV microscope as the inspection tool of EUVL masks, and succeeded to observe a large number of patterns.

But, it reaches the resolution limit of optical systems.

I considered the development of the inspection method without optical systems was necessary.

Development of coherent EUV scattering microscope (CSM)
Evaluation method for mask

Visible ~ DUV Microscopy
800 nm ~ 150 nm
10 nm ~ 1 Å
Diffraction Microscopy
Scatterometry (OCD)
X-Ray Scattering Microscopy

Low cost
High throughput
High accuracy

EUV Scattering Microscopy

The coherent EUV scattering microscope
Overview of CSM

**Coherent EUV scattering microscope (CSM)**
Radiation light is changed to the coherent light by pinhole, and irradiates the EUV mask via Mo/Si multilayer mirrors. CSM detects diffraction image from the EUV mask using X-ray CCD camera.

- **EUV beam from synchrotron**
  - Incident angle: 6 deg. (Reflection)
  - Wavelength: 13.4 nm
  - Band width: 0.3 nm (FWHM)
  - Field of view: 5μmφ~20μmφ
  - **Minimum resolution: 55 nm**
  - Visible shadowing image
  - X-Y stages for 6”mask
  - 6”mask load-lock chamber
Obtained patterns by CSM (1)

Visible shadow image

Visible shadow image of the mask pattern obtained with a 4-mm diameter aperture and a thin glass window to reduce the EUV beams

Diffraction pattern of contact patterns

Field spectrum obtained from 120-nm contact patterns.

The desired location can be observed easily.
Obtained patterns by CSM (2)

We can also observe the defect pattern on the mask using obtained diffraction patterns.
Obtained patterns by CSM (3)

Pitch 1000nm
Space 300nm
Concept of iterative algorithm

|Amplitude| of field spectrum
\[ g(K) = |g(K)| \exp(i\phi(K)) \]

\[ g'(K) = |f(K)| \exp(i\phi(K)) \]

※|f(K)|: Actual obtained experiment data

Mask image
\[ \rho(r) \]

Image plane constraint
\[ \rho'(r) \]

FFT

FFT\(^{-1}\)
Reconstructed DRAM patterns

120nm L&S

132nm Active

120nm Contact
EUV microscope vs. CSM

(1 μm pitch EUV mask pattern)

Field spectrum from CSM

Image from EUVM

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6”mask CD uniformity measurements

There is a big difference between measured results of CSM and CD-SEM.
(CSM: about 140nm CD-SEM: about 100nm)

Because of the linearity, the high reliability of CSM is confirmed. Therefore without using CD-SEM, it’s possible to measure CD.
Measurement principle

When the inclination of the sidewall of the absorber pattern is loose, it seems the measured value of CSM is more reliable.
Summary and future work

Summary

• By iterative algorithm, periodic structure patterns of semiconductor device were reconstructed.
• The resolution by the current state is 55nm on EUV mask.
• As a result of CD uniformity measurements, a result like SEM of the mainstream equipment is obtained. CSM obtained the high reliability of measurement.

Future work

• Reduce the noise, and improve the iterative algorithm.
• Improve the calculation speed by introducing a super computer.
• Try the observation of non-periodic structures as well as the observation of periodic structures.