**Effects of pellicle wrinkles on EUV reflectivity and local critical dimension**

Seung Chan Moon, Dong Gi Lee, Young Woong Kim, Jin Hyuk Choi and Jinho Ahn

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**INTRODUCTION**

- **Impact of pellicle wrinkles on EUV reflectivity (EUVR)**

  - EUV pellicle has been researched to prevent yield reduction due to particles generated during the EUV lithography.
  - EUV light reflected from the pellicle causes local CD variation due to overexposed edges and corners of the field.
  - EUVR of pellicle is restricted under 0.04% to guarantee CD, but the pellicle wrinkles can induce increase of EUVR.
  - We experimentally demonstrate the impact of wrinkles on mask imaging performance such as image contrast & CD variation.

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**METHODS**

- **Measurement of the pelliclized mask with EUV ptychography microscope**

  - EUV ptychography microscope was used to capture both reflected light from the pellicle and diffraction patterns of 200 nm C/H mask, separately.

  ![Fig. 3 EUV ptychography microscope and its specification](image)

  - Table: EUV ptychography microscope specifications

<table>
<thead>
<tr>
<th>NA (°mask)</th>
<th>Resolution</th>
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<tr>
<td>0.125</td>
<td>54 nm</td>
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  - EUV generation module
    - Bandwidth: 0.048
    - Pulse width: 50 fs
    - Power: 15 mW
    - Pulse Energy: 4.0 mJ

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![Fig. 4 Schematic representation of EUVR measurement setup and synthesis of the diffraction pattern and EUVR](image)

- EUV pellicle was designed to have a rather high EUVR of 0.61% at wrinkle free zone to exaggerate the effect of wrinkles.
- Reflected light and C/H diffraction pattern were synthesized to generate the diffraction pattern of pelliclized mask.
### EFFECTS OF PELLCLE WRINKLES ON EURO MIRROR INTENSITY IMPROVEMENT (EUVR)

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#### METHODS

**1. Object image reconstruction with ptychography**

- The diffraction pattern can be represented with the Fourier transform of a function defined by the convolution of probe function and object function.

![Convolution of probe and object function](image)

**Fig. 5.** Convolution of probe and object function

- Ptychography is a computational method based on iterative algorithm to reconstruct the object image of a specimen from a series of diffraction patterns.

![Schematic process of ptychography](image)

**Fig. 6.** Schematic process of ptychography

- Regularized ptychographical iterative engine (rPIE) moderately adjusts the imbalance of probe intensity by adding a regularization term to the update function.

**RESULT & DISCUSSION**

**2. Amplifying and position shifting of reflected light due to pellicle wrinkles**

- EUVR was amplified to 0.82% (c) and 2.43% (b) without position shift at the Fourier domain due to focusing effect resulting from the concaved shape of wrinkles.

![Measured EUVR of pellicle from a wrinkle free zone](image)

**Fig. 7.** Measured EUVR of pellicle from a wrinkle free zone (a) and two different wrinkled zones (b) and (c)

- EUVR (0.61% at wrinkle free zone) were measured to be 0.82% (c) and 2.43% (b) at two different wrinkled zones.

- EUVR was amplified to 2.43% (b) without position shift at the Fourier domain due to focusing effect resulting from the concaved shape of wrinkles.

**Fig. 8.** (a) Position shift of the reflected light at the Fourier domain due to wrinkle, (b), (c) Optical path length difference (OPD) between flat and slope of wrinkled zone in thin film

- EUVR was amplified to 0.82% (c) with position shift at the Fourier domain due to OPD in thin-film resulting from the reflection at wrinkle slope.

![Schematic process of ptychography](image)
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**RESULT & DISCUSSION**

- **Effect of reflected light from pellicle wrinkles on aerial image**

  - The EUV mask images were reconstructed with rPIE from the synthesized diffraction patterns
  
    ✓ C/H diffraction pattern 9(a) was synthesized with the reflected light 7(b) and 7(c)
  
    ▪ The image contrast of 9(a) was 78%, but it decreased to 73% 9(b) and 76% 9(c), as the reflected light from the pellicle was synthesized around the 0th and 1st order of the C/H mask diffraction pattern, respectively
  
    ▪ 6 nm of ΔCD was observed due to additional reflected light around the 1st order diffraction pattern which has spatial frequency, and 3 nm of ΔCD was observed due to additional reflected light around the 0th order diffraction pattern working as background

  **CONCLUSION & FUTURE WORK**

  - EUVR can be amplified due to the morphology of the wrinkle, and it can be critical as focusing effect occurred at the concaved area
  
    ▪ Reflected light from the pellicle wrinkles has a random position at the Fourier domain due to fluctuating surface of the wrinkles, and it affects imaging performance differently depending on its position
  
    ▪ Reflected light around the 0th order diffraction pattern working as background noise causes image contrast loss, whereas the reflected light around the 1st order diffraction pattern has more influence on CD variation due to spatial frequency
  
    ▪ In this study, the reflected light from the pellicle wrinkle results in 5% of image contrast reduction and 6 nm of local CD variation
  
    ▪ Although the pellicle satisfies the reflectivity requirements, we also need to quantify the limit of wrinkles during EUV lithography in order to guarantee EUV reticle CD size

**REFERENCES**