Development of EUV-ptychography microscope: EUV Scanning Lensless Imaging (ESLI)

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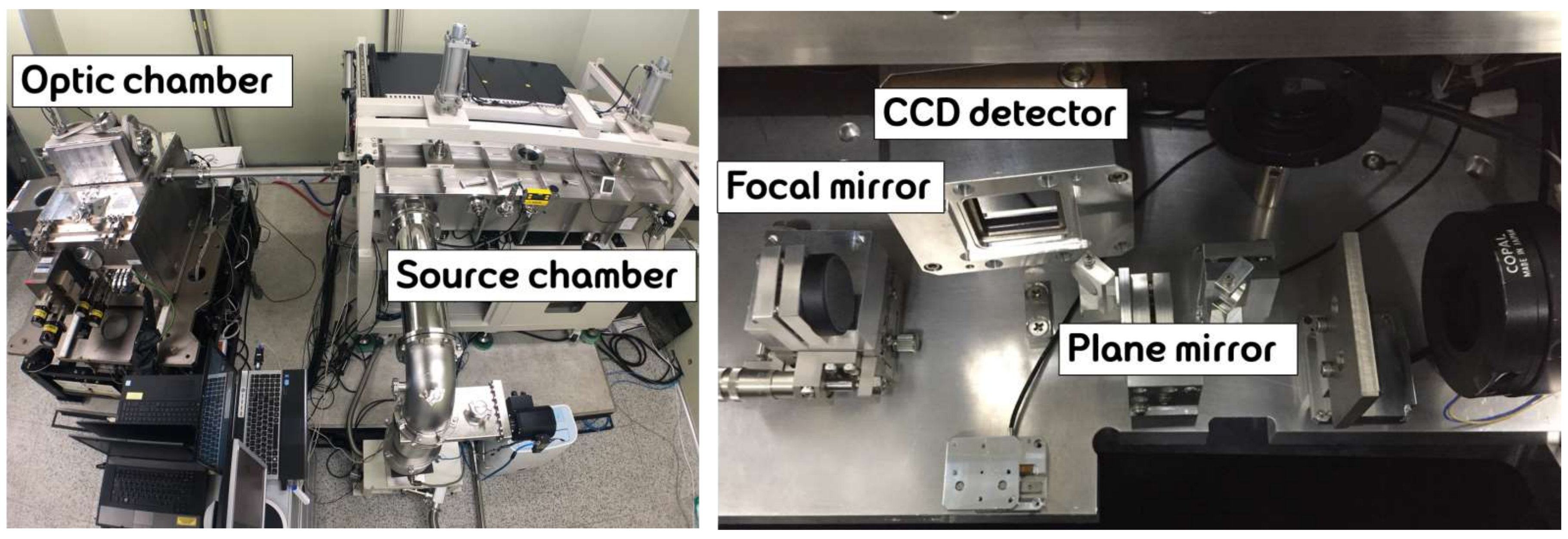
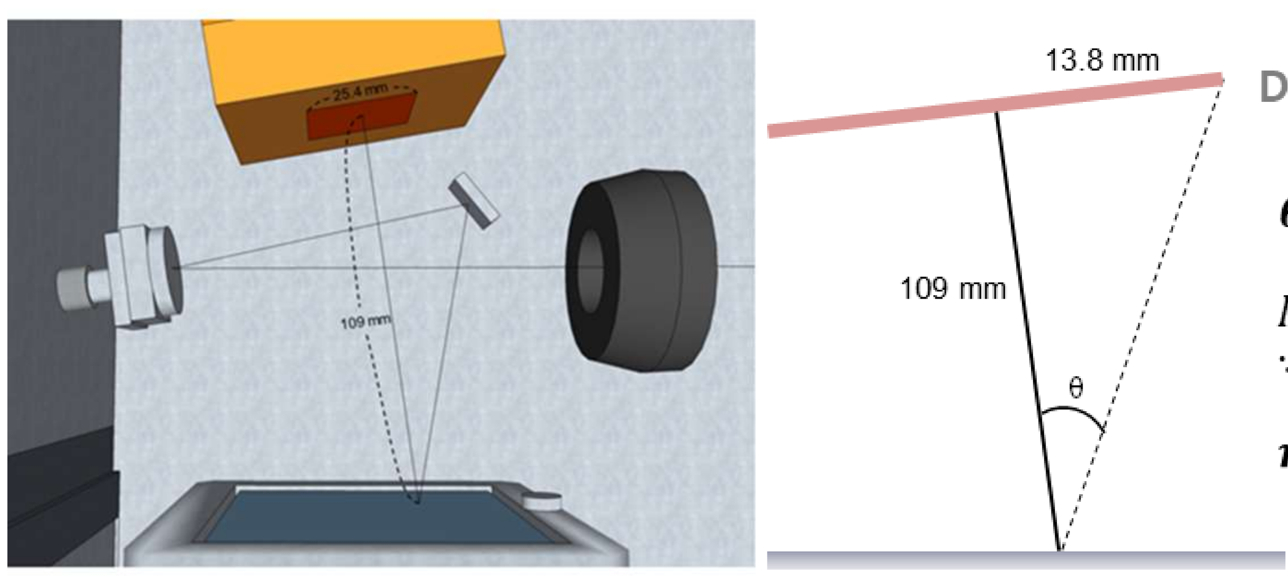
INTRODUCTION

❑ EUV Scanning Lensless Imaging (ESLI)



< EUV Scanning Lensless Imaging (ESLI) >

- Actinic inspection tool using high-order harmonic generation (HHG) source and ptychography



$$\theta = \tan^{-1}\frac{13.6}{109} = 7.11°$$

$$NA(@reticle) == 0.1256$$

$$\because NA = n \cdot sin\theta$$

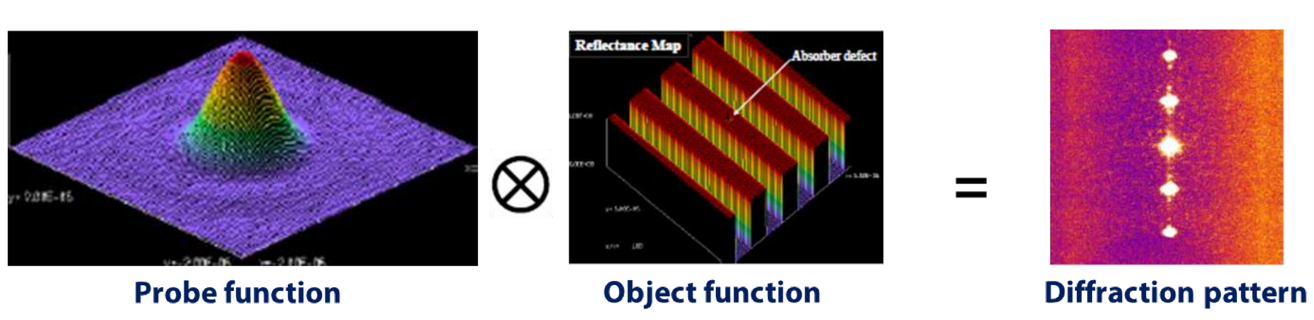
$$r \approx \frac{\lambda}{2NA} = 53.74\ nm$$

< Numerical aperture of ESLI >

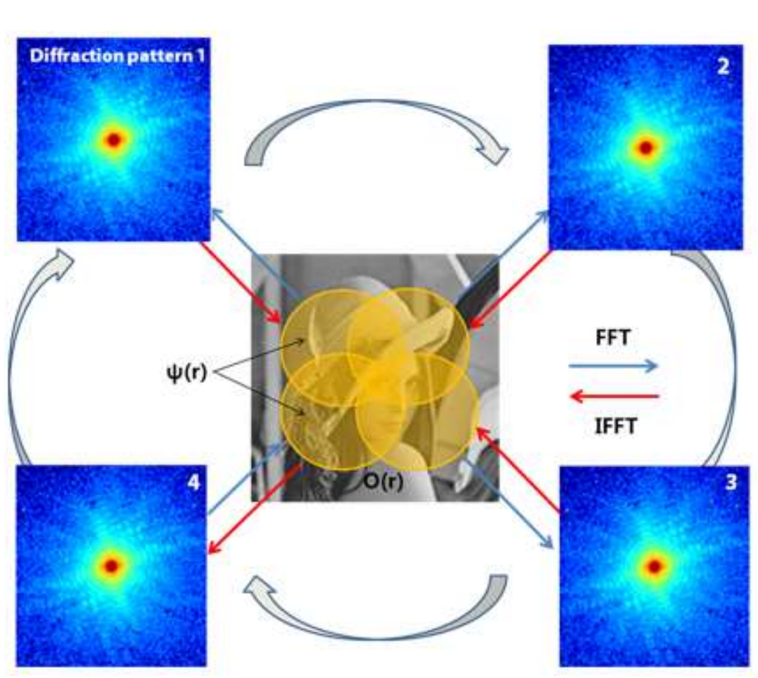
- Numerical aperture of ESLI (@reticle) is about 0.1256
- Resolution of ESLI is about 53.74nm theoretically
  - ➢ Noise caused by probe instability and position inaccuracy may deteriorates resolution

EXPERIMENT

❑ Imaging method (Ptychography)



< convolution of probe and object function >



$$O_{n+1}(\mathbf{r}-\mathbf{R}_l) = O_n(\mathbf{r}-\mathbf{R}_l) + \beta U(\mathbf{r})\left(\Psi_{n,l,\text{new}}(\mathbf{r}) - \Psi_{n,l}(\mathbf{r})\right)$$

$$U(\mathbf{r}) \equiv \frac{|P(\mathbf{r})|}{\max(|P(\mathbf{r})|)}\frac{P^*(\mathbf{r})}{|P(\mathbf{r})|^2+\alpha}$$

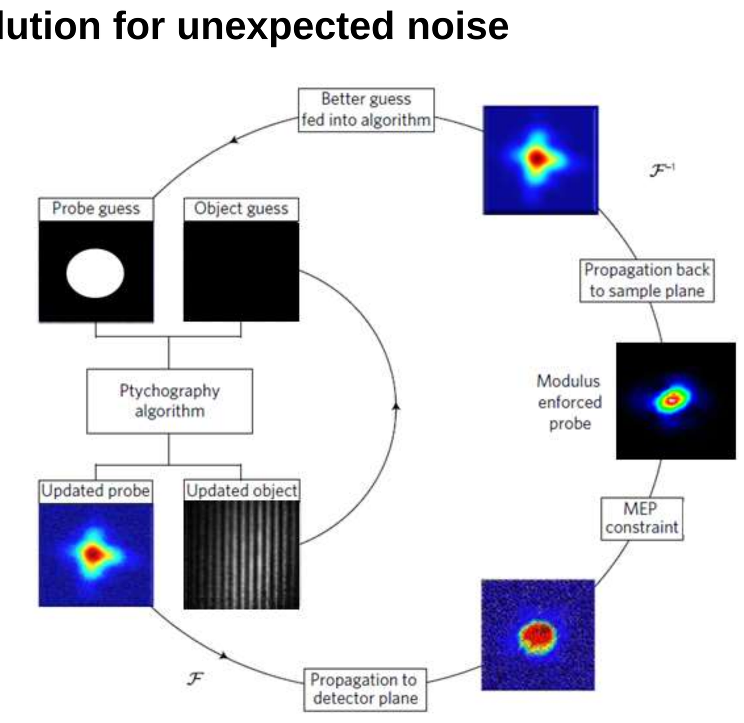
$$\Psi_{n,l}(\mathbf{r}) = P(\mathbf{r})O_n(\mathbf{r}-\mathbf{R}_l)$$

O(r) : Object function → Answer
P(r) : Probe function, R_l : Relative distance → Input

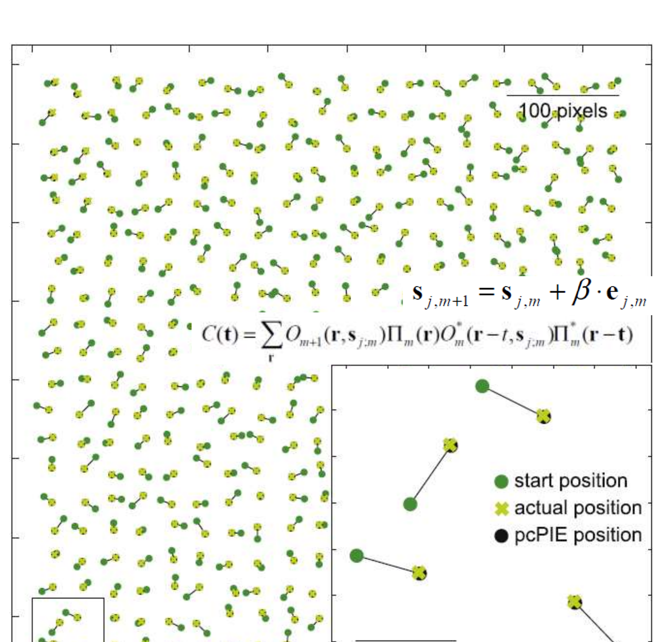
< Schematic view of ptychographical iterative engine (PIE) > < Mathematics in PIE >

- PIE - An iterative method based on coherent diffraction imaging (CDI) for solving the object function in high resolution using overlapping of probe positions
- Separating probe function and object function ⇒ Image stitching from separated object function
- The object function is updated during iteration of the algorithm
  - ➢ Ptychography requires finite probe function and accurate relative position between diffraction patterns

❑ Solution for unexpected noise



< Solution for probe instability >

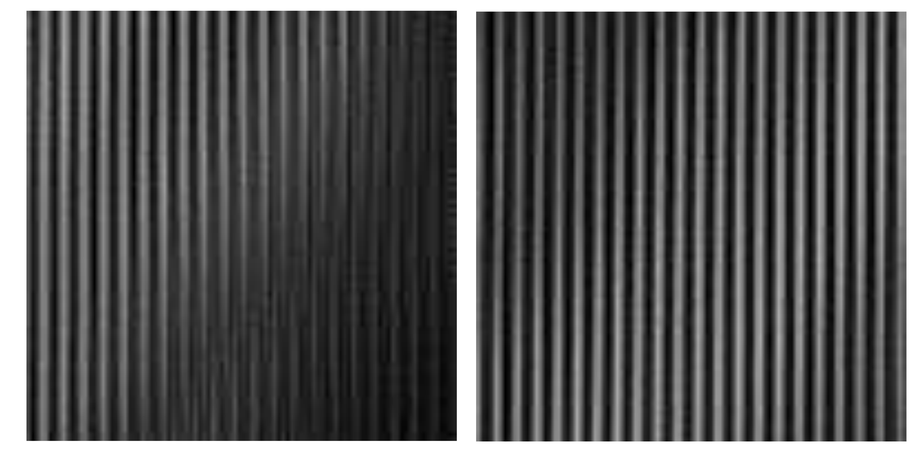


< Solution for position inaccuracy >

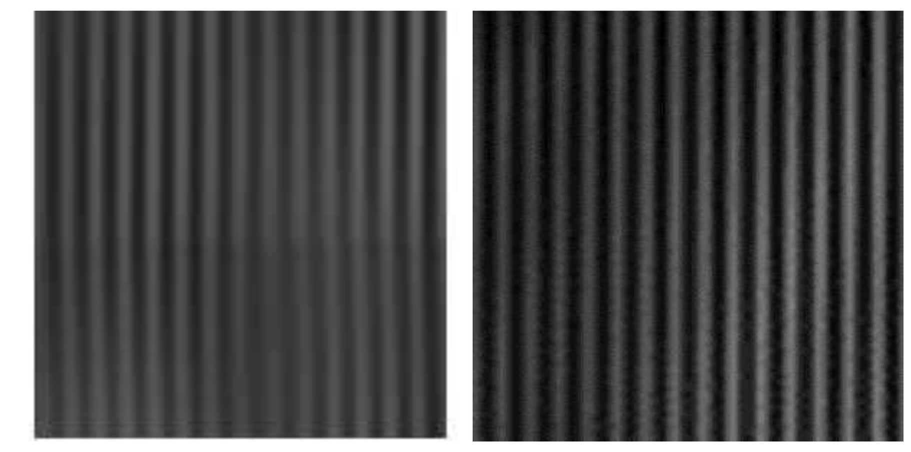
- Input probe information is replaced with real probe measurement data **(Probe constraint method)**
- Updated phase of probe is keep replaced during iterations
- Relative shift error between input and actual position can be obtained by using cross correlation

RESULTS & DISCUSSION (Applying noise solution)

❑ ESLI results after applying noise solution (128nm L/S pattern @ mask scale)



< Imaging results before (left) and after (right) applying position correcting math >



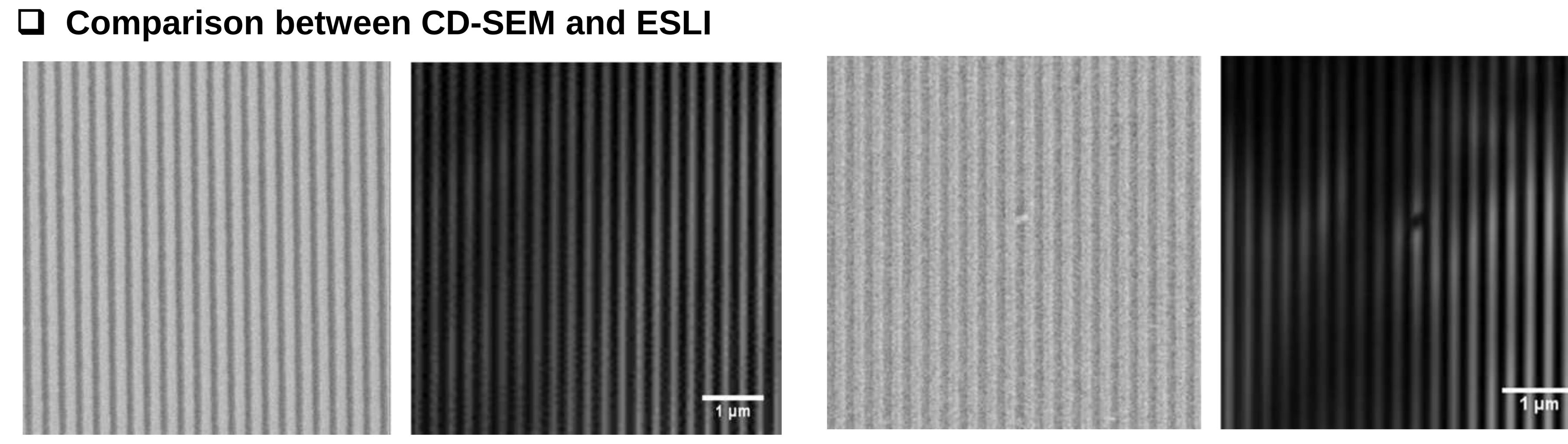
< Imaging results before (left) and after (right) applying probe constraint >

- Resolution deterioration occurs where its position information is not accurate
- Fringes are observed in the results where solutions are not applied

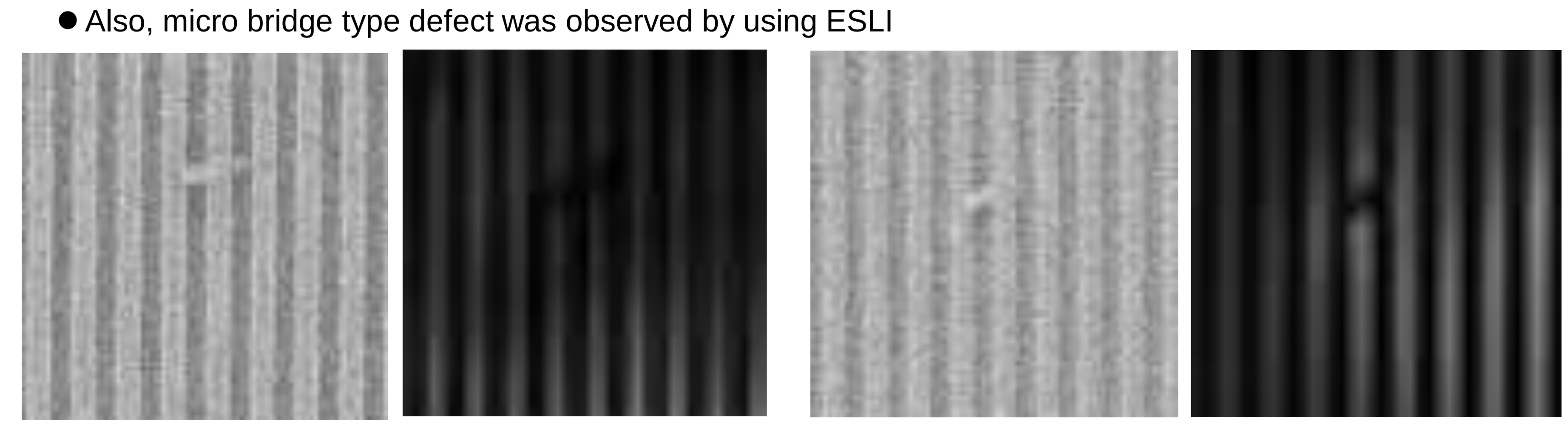
➢ Inaccurate edge definition and fringes can be eliminated by applying probe constraint and position correcting math

RESULTS & DISCUSSION (EUV mask imaging & Through pellicle imaging)

❑ Comparison between CD-SEM and ESLI

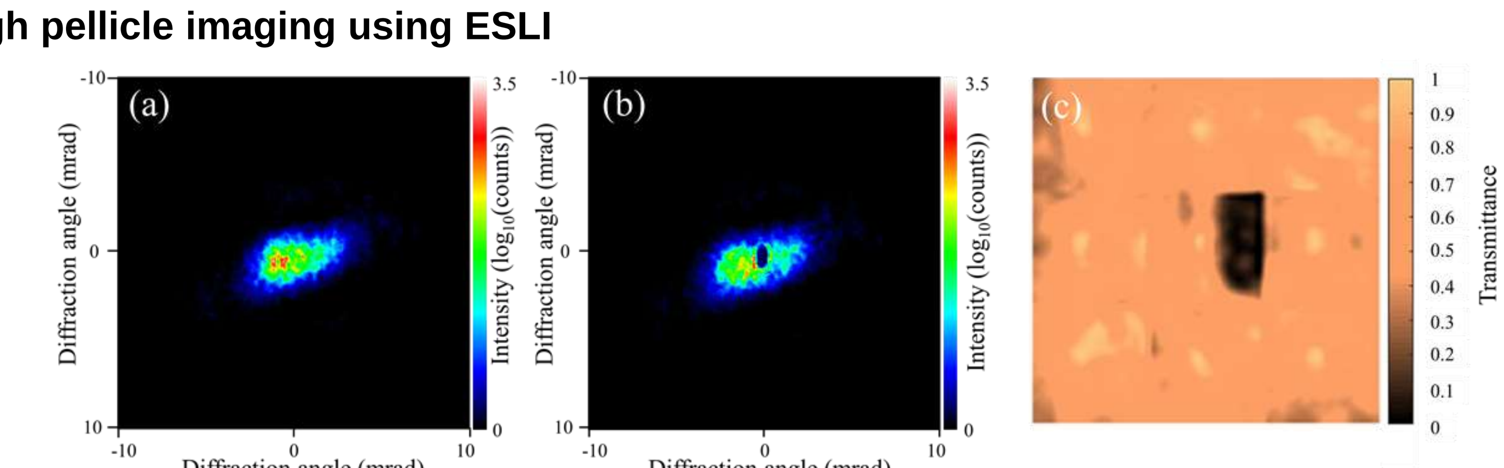


- 5 X 5 diffraction patterns with a step size of 1㎛ between scan positions
- ESLI shows comparable resolution with CD-SEM and shows better contrast
- Also, micro bridge type defect was observed by using ESLI

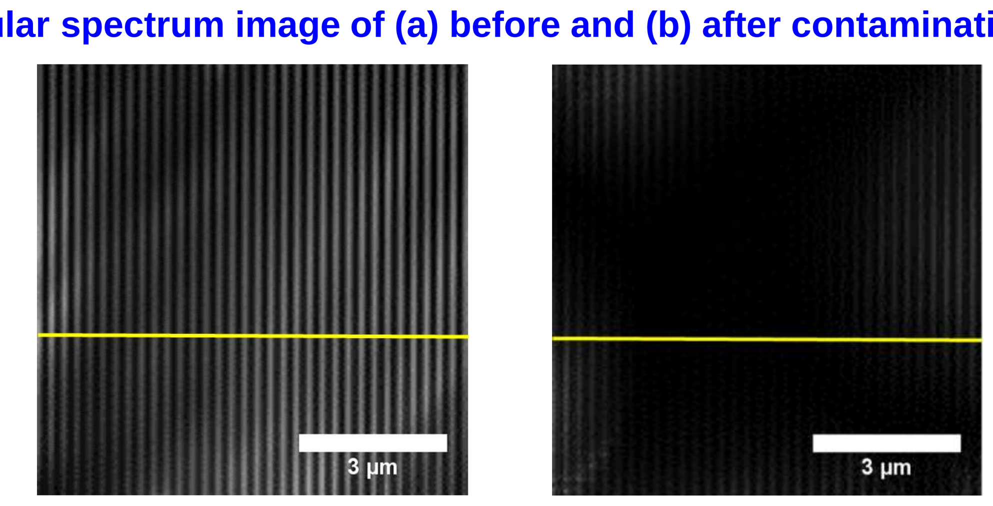


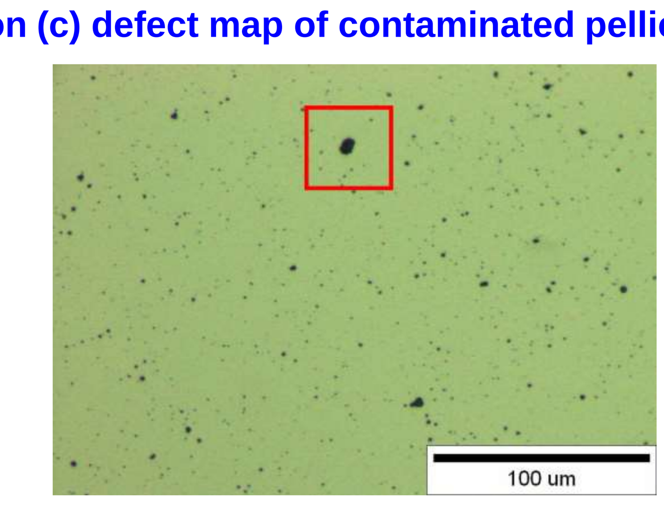
< Defect inspection results using ESLI >

❑ Through pellicle imaging using ESLI

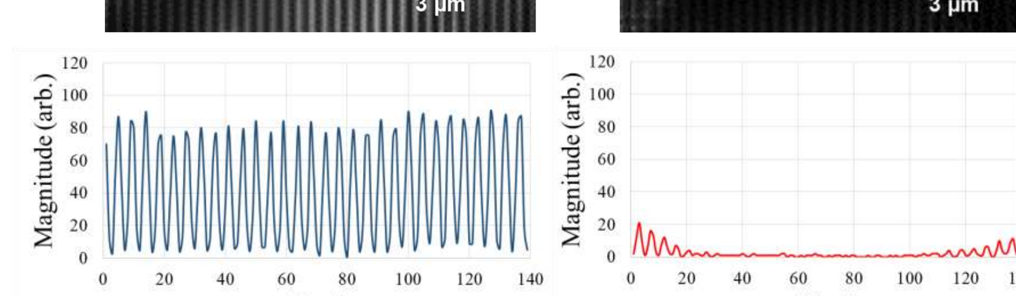


< Angular spectrum image of (a) before and (b) after contamination (c) defect map of contaminated pellicle >

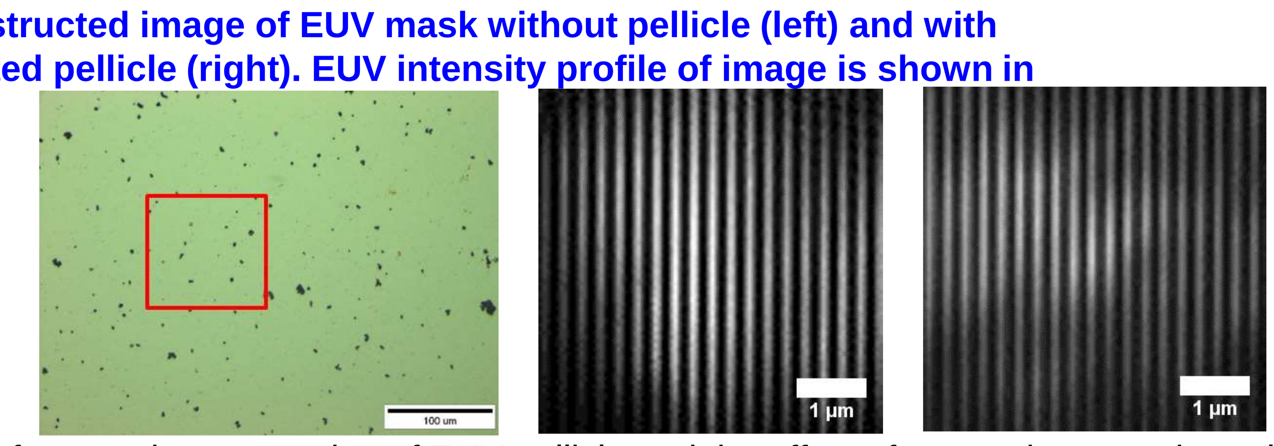




< Optical microscope image of contaminated pellicle and red box represents scanned area using ESLI >



< Reconstructed image of EUV mask without pellicle (left) and with contaminated pellicle (right). EUV intensity profile of image is shown in



- Possibility of contaminant mapping of EUV pellicle and the effect of contaminant on the pellicle was investigate through printability study

SUMMARY & CONCLUSION

- High-order harmonic generation (HHG) EUV-ptychography microscope has been developed for actinic inspe
- Ptychography requires finite probe information and accurate position between diffraction patterns
- Unexpected noises are properly handled by using modified ptychography algorithm
- EUV mask imaging and through pellicle imaging can be provided for printability study