Line Width Roughness Control on Resist Process for EUV Patterning

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Introduction

Controlling line width roughness (LWR) is a critical issue in extreme ultraviolet lithography (EUVL). High sensitivity, high resolution, and low LWR are required for EUV lithography resist. However, it is difficult to achieve optimal properties simultaneously through chemical tuning. The track process is one of the factors that impacts LWR. Enhancing the track processes used in EUV lithography is necessary to control LWR.

This report describes our approach to mitigating LWR based on optimizing the track process. It will also present the results of our newly developed track-based smoothing process as well as the results of combining several techniques. The latest LWR performance from using track-based improvement and optimized processes will be included.

Evaluation Conditions

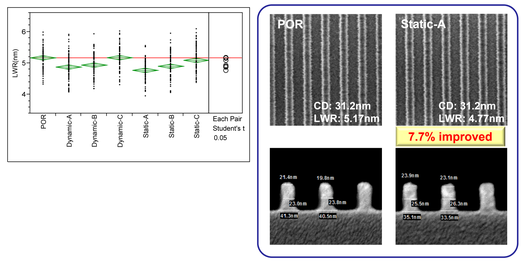
Coater / Developer
- System : CLEAN TRACK ACT™ 12 (Tokyo Electron LTD)
- Resist : EUV resist material, Film thickness 75nm
- Developer solution : TMAH, TBAH
- Rinse solution : FIRM™ Extreme and SPC407

EUV Exposure tool
- System : Alpha demo tool (ASML)
- Illumination : N.A.=0.25 σ=0.5 Conventional

Measurement
- SEM : Hitachi CG4000

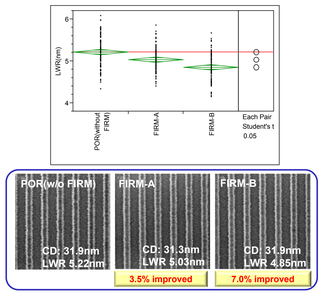
3 Techniques to Reduce LWR

Developer process optimization



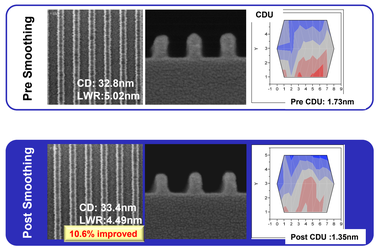
- ► Development process is one of the key factors for LWR improvement.
- ► LWR was improved by pattern profile control
- ► Static-A recipe showed the best result, LWR was improved 7.7% .

FIRM™ (Finishing up by Improved Rinse Material)

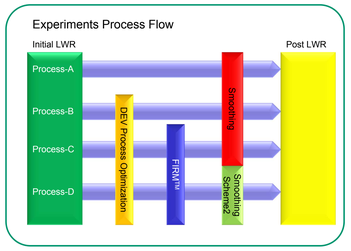


- ► LWR was improved up to 7.0% by FIRM process
- ► The effectiveness depends on FIRM chemical.

Smoothing Process

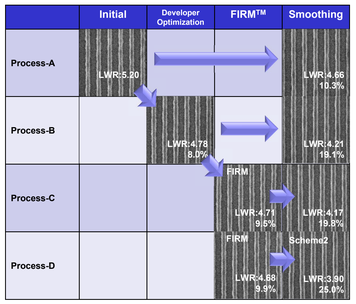


Evaluation Matrix



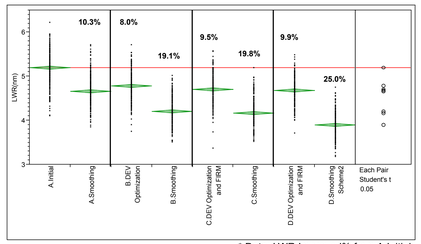
- Smoothing : Conventional Smoothing Scheme
- Smoothing Scheme2: Alternate Smoothing Scheme

Evaluation Results



- ► Individual techniques are additive techniques and those are available for combination process
- ► Smoothing process improves LWR 10-12%, and Smoothing scheme2 improves LWR 16%
- ► Process-D shows the best result, LWR was improved **25%**, LWR was **3.9nm**

Result Plots



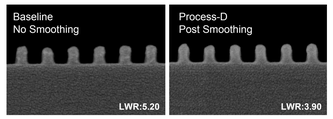
* Data: LWR Improved% from A.Initial

- ► DEV optimization, FIRM and Smoothing results show statistically significant differences
- ► All combined Process-D shows the best result; LWR was improved 25%, LWR was 3.9nm.

Summary

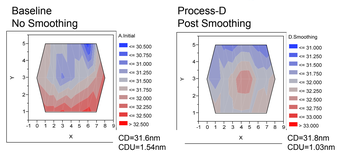
- **Three techniques were found for LWR improvement; DEV process, FIRM and Smoothing.**
  - LWR is improved up to 8% by development process optimization.
  - Up to 7% LWR improvement is confirmed by FIRM process, the effect depends on the FIRM chemical.
  - Smoothing process improve LWR 10-12%. Smoothing scheme2 shows further improvement, the improvement is 16%.
- **All techniques are additive techniques and full combination process flow shows 25% LWR improvement.**
- **Also LWR is improved 31% on trilayer film stack, final optimized LWR achieved is 3.6nm.**

X-section Images

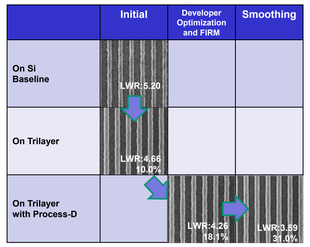


- ► There is no thickness loss
- ► Pattern deformation improvement was observed in post smoothing image
- ► Profile of post smoothing is greatly improved over baseline profile, pattern surface is smoother

CD Uniformity

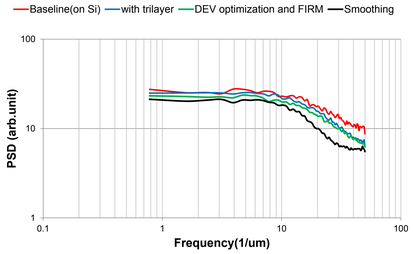


Best Process with Trilayer Resist



- ► LWR was 10% improved with trilayer film stack
- ► Total improvement was **31.0%** from Si baseline, final optimized LWR achieved was **3.6nm**

Power Spectra Density Analysis



- ► Tri-layer process, DEV process optimization and FIRM are effective in high frequency region.
- ► Smoothing process shows improvement in wider region of frequency, especially from middle to high.

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