Post-Process Effects on Line End Shortening and Image Distortion

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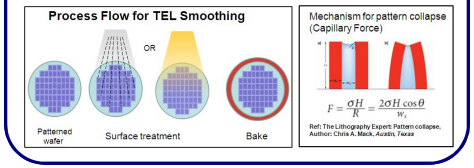
1. Introduction

As the resolution of EUV resist advances to enable imaging for 22 nm nodes and beyond, several critical items need to be addressed. Pattern collapse and LWR are among the key gaps in resolution limitations with respect to lithographic materials. Post-processing techniques are effectively employed to address both of these attributes. The objective of this work is to evaluate several post-processing techniques and their effects on line end CD changes and pattern distortion.

Three resists were evaluated using a 60 nm film thickness in conjunction with the following post-process techniques.

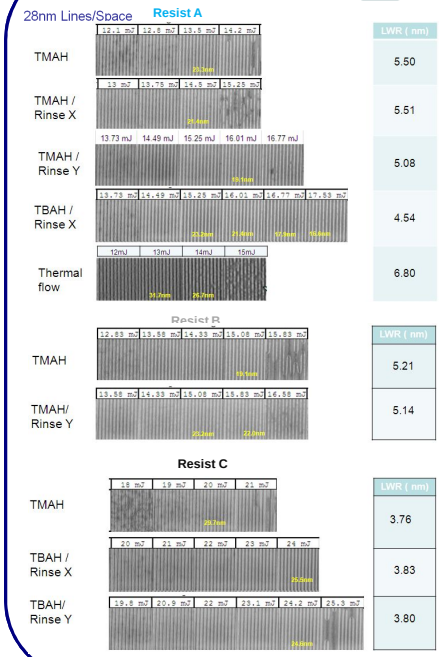
- TMAH develop, no rinse (control)
- Rinse X
- Rinse Y
- TBAH developer combined with rinse
- TEL Smoothing Process
- Thermal flow
- Combinations of the above processes

2. Process Flows and Mechanisms for Post Process Techniques



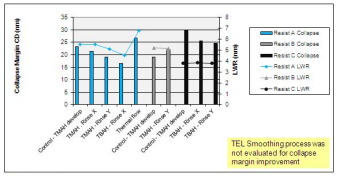
3. Comparison of Collapse and LWR

eMET



4. Pattern Collapse and LWR Summary

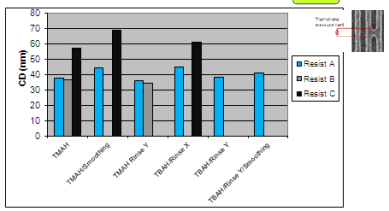
eMET

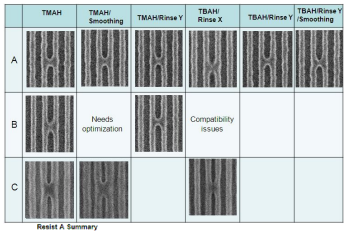


- Resist A:
  - Rinse Y with TMAH develop, and Rinse X combined with TBAH develop are the most effective techniques for mitigating collapse and reducing LWR
- Resist B:
  - Collapse margin is good for resist B with TMAH developer
  - Optimized rinse material and process are needed if additional improvement is desired
- Resist C:
  - Collapse margin improvements seen with post-processing, but still requires significant improvement
  - Improved LWR compared to resist A and B

5. Trench End CD Changes

ADT





Resist A Summary

- Of the 6 post-process techniques that yielded materials compatible patterning, the variation in trench end CD was statistically significant
- Further analysis using a multiple range test indicated that the sample means are divided into 2 groups
  - Group 1: The control process with TMAH develop, TMAH develop with rinse Y, and TBAH with rinse Y are not significantly different from one another
  - Group 2: The TBAH process with rinse X, the TMAH process with smoothing, and the TBAH process with rinse Y and smoothing are not significantly different from one another
- In addition to the measurable CD changes, top down CD SEM images indicate that the TBAH rinse X process may be indace line end profile changes. This is probably caused by resist thinning at the line end

Resist B Summary

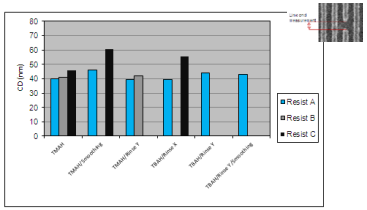
- The variation in CD is not statistically different for the 2 processes
- Line end profile changes are indicated for the TMAH control process

Resist C Summary

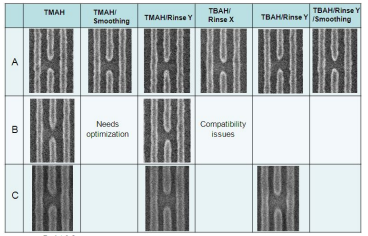
- The post-process techniques yield significantly different CD's
- Multiple range test indicates that TMAH and TBAH/rinse X are not significantly different from each other, but are different then TMAH/smoothing process

6. Line End CD Changes

ADT



6a. Line End CD Changes - continued



Resist A Summary

- Of the 6 post-process techniques that yielded materials compatible patterning, the variation in trench end CD was statistically significant
- Further analysis using a multiple range test indicated that the sample means are divided into 2 groups
  - Group 1: TMAH with smoothing process is significantly different then group 2
  - Group 2: All other processes are not significantly different from one another
- In addition to the measurable CD changes, top down CD SEM images indicate that most of the processes induce a small amount of line end profile changes. This is probably caused by resist thinning at the line end

Resist B Summary

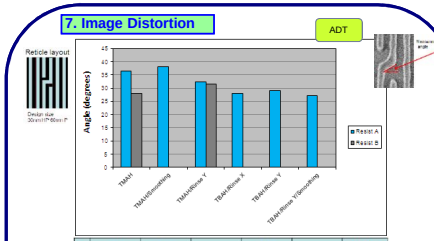
- The variation in CD is not statistically different for the 2 processes
- Line end profile changes are observed when the TMAH control process is used

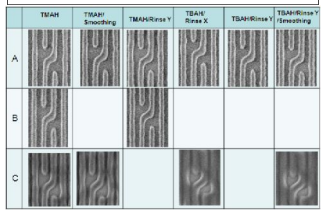
Resist C Summary

- The post-process techniques yield significantly different CD's
- The multiple range test indicates that TMAH/smoothing process and the TMAH with rinse X process are not different from each other, but they are different then the TMAH control process

7. Image Distortion

ADT





Resist A Summary

- Of the 6 post-process techniques that yielded materials compatible patterning, the variation in trench end CD was statistically significant
- Further analysis using a multiple range test indicated that the sample means are divided into 2 groups that are statistically different from each other
  - Group 1: TMAH, TMAH/smoothing, and TMAH with rinse Y are not significantly different from each other
  - Group 2: TBAH with rinse X, TBAH with rinse Y, and TBAH with rinse Y and smoothing are not different from each other

Resist B Summary

- The variation in CD is not statistically different for the 2 processes

Resist C Summary

- Resist C did not image well on the distortion pattern, prohibiting CD and angle calculations
  - Imaging issues were primarily caused by pattern collapse at the dose needed to get to the target CD

8. Summary and Acknowledgements

Summary

- Post-process techniques are an effective means of improving pattern collapse and reducing LWR
- Several post-processing techniques have a small but statistically significant effect on line end shortening and pattern distortion
- Post-process techniques should be identified and optimized prior to model building to ensure model accuracy

Acknowledgements:

- RMDC team - SEMATECH
- Shinichiro Kawakami & Shannon Dunn – TEL
- Greg McIntyre - IBM