Control of Contact Hole Distortion by Using Polymer Deposition Process (PDP) for sub-65nm Technology and Beyond

Judy Wang
J_Wang@amat.com

Applied Materials, Etch Product Business Group,
Dielectric Etch Division.
974 E Arques Ave., Sunnyvale, CA 94086, USA

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Co-authors:
Shing-li Sung and Shawming Ma

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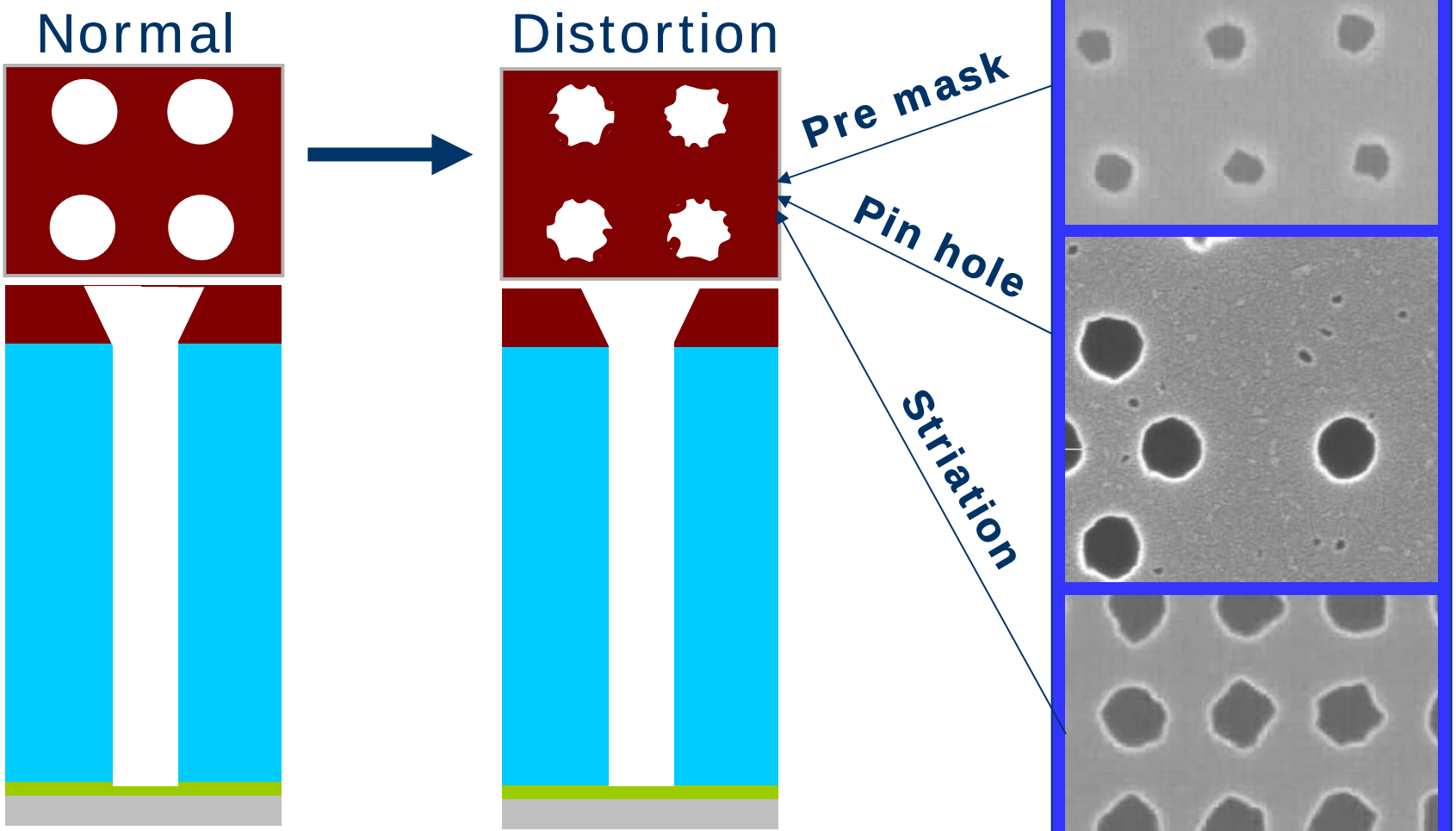
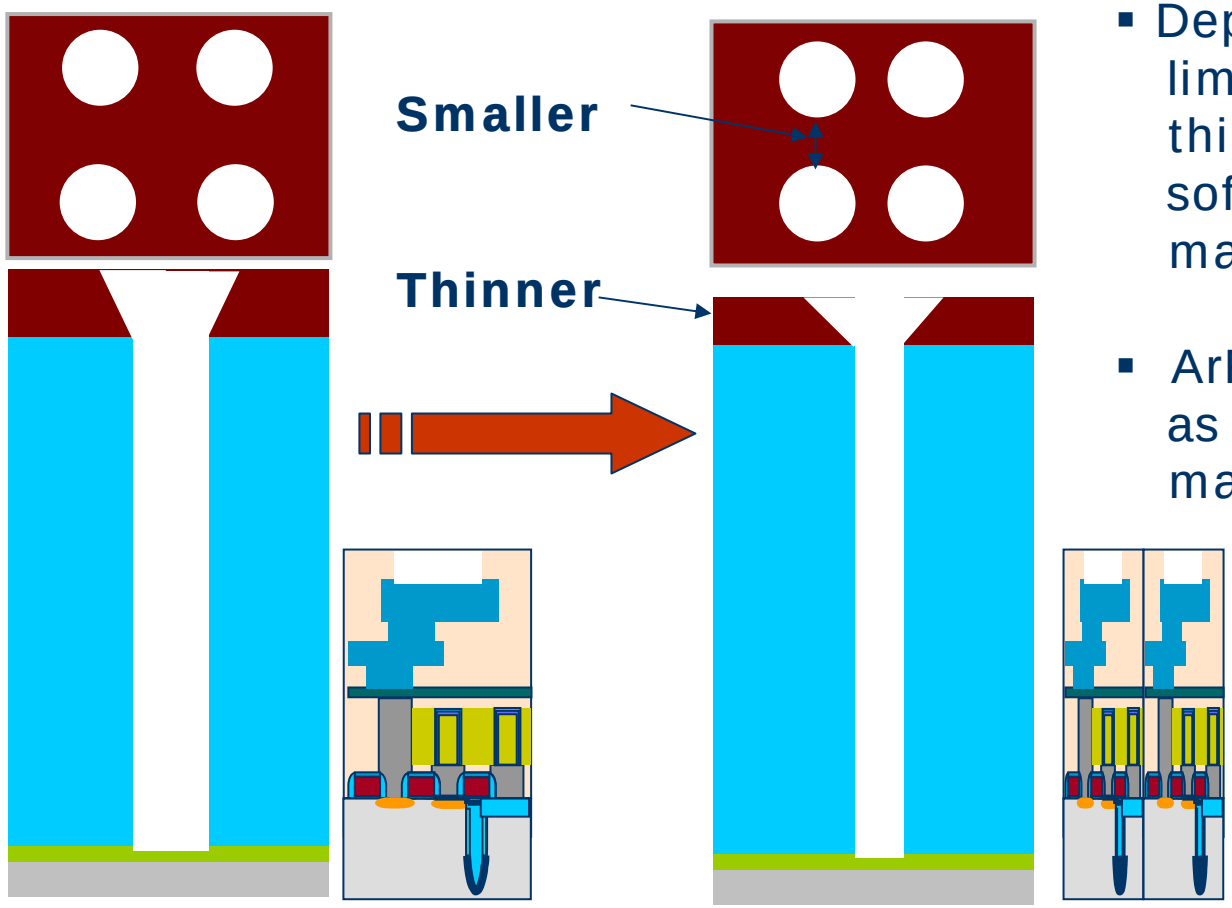
Problem Definition



Three examples of the distortion of contact hole

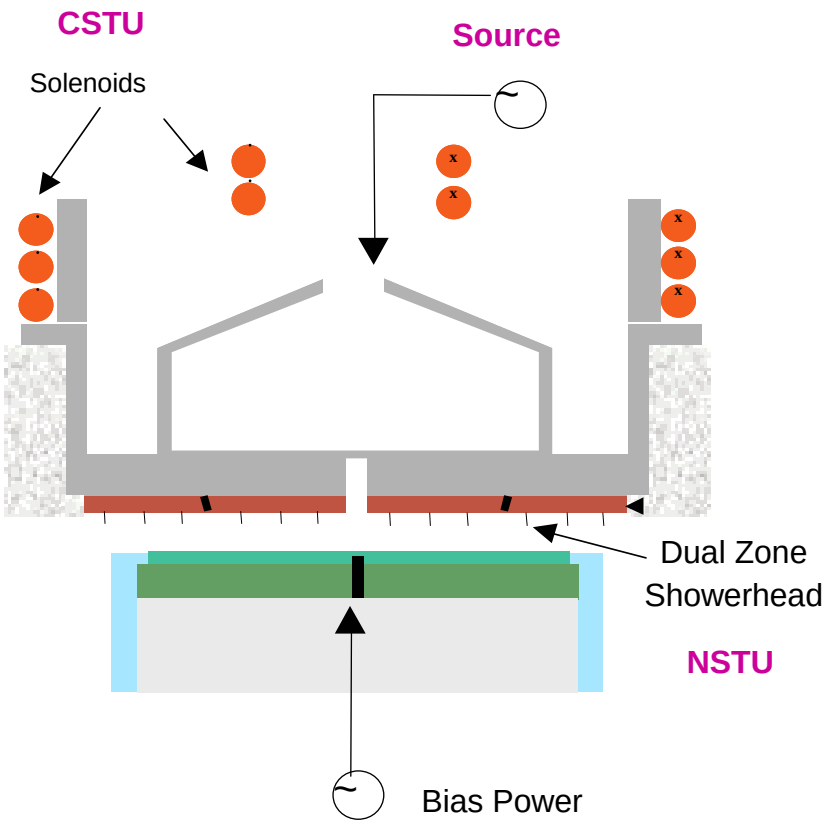
Background

- Small line width and space between metal interconnection



- Depth-of-focus limitation of ArF causes thinner PR height and soft feature of ArF material
- ArF or C-rich PR resist as mask showed low mask selectivity and striation or pitting by resist degradation

Experimental System



Ion Flux Control- Etch Depth Uniformity

(Charged Species Tuning Unit)

Plasma non-uniformities adjusted with low level magnetic field

>100 MHz Source – High Efficiency Clean

Wafer Temperature Control- ESC

Uniform temperature control improves CD non-uniformity

Dual Gas Feed- CD Uniformity

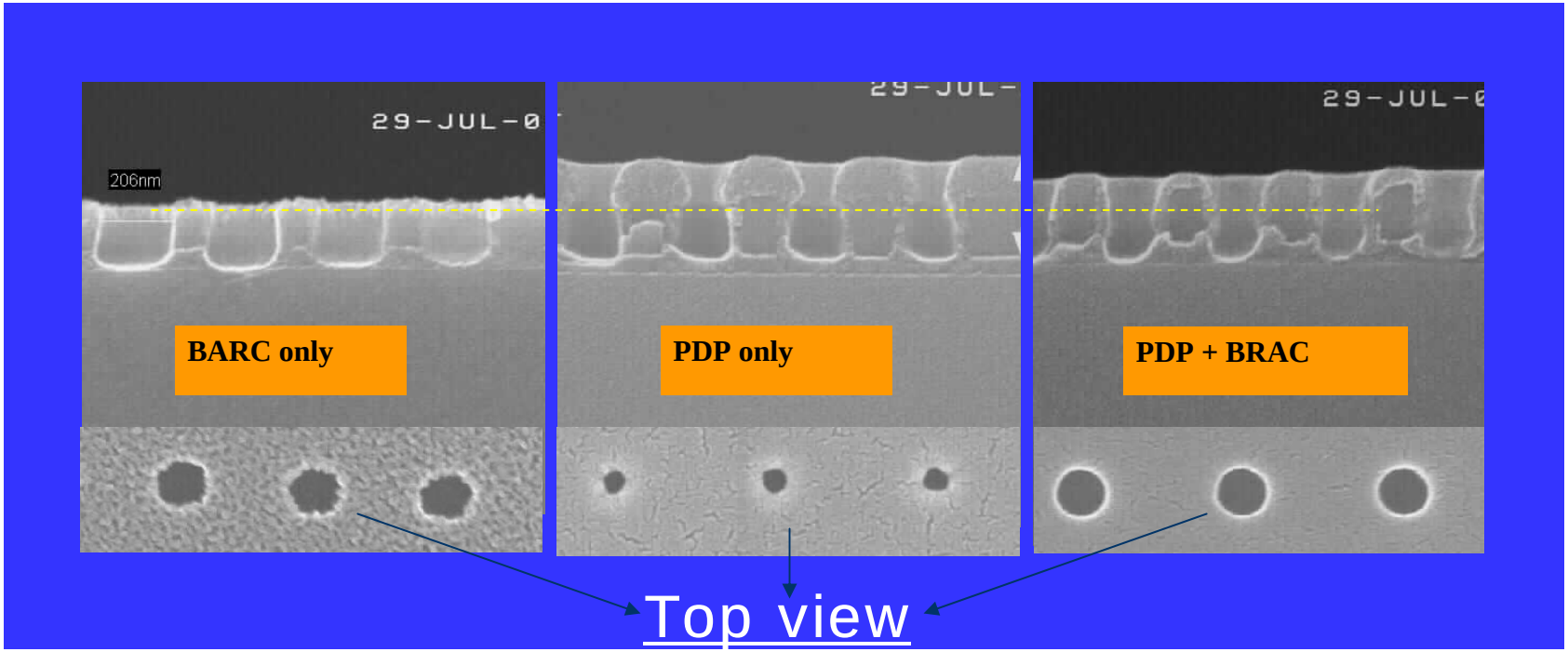
(Neutral Species Tuning Unit)

Inner/Outer Gas Flow ratio can be optimized to tune CD non-uniformity

Dual Frequency Bias

Tunable ion energy for improved profile control and good etch uniformity.

BARC Open Comparison between with and without PDP Step



- BARC-only process showed large bottom CD, low PR selectivity, and roughness surface
- PDP-only process showed the thick layer of mask which increased PR selectivity but low etch rate on BARC open
- PDP combining with BARC open process showed good PR selectivity, tight bottom CD control, and less top striation.

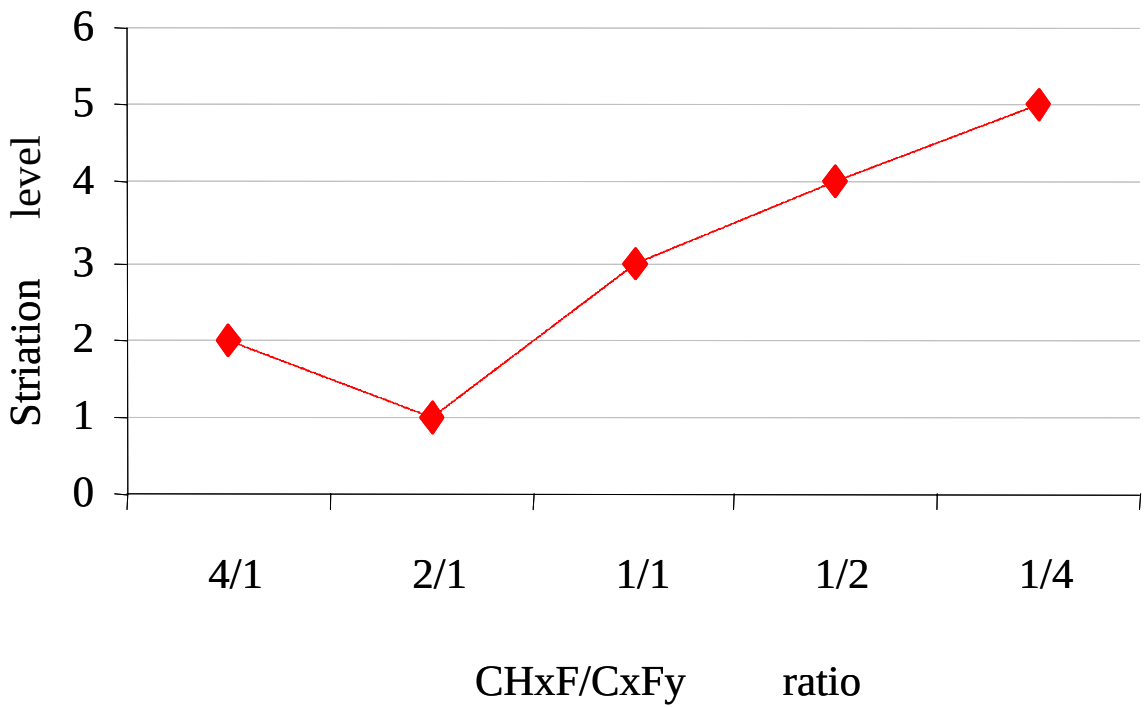
PDP Chemistry Selection Summary

CH_xF/C_xF_y (Flow ratio)	O_2 (sccm)	CO (sccm)	Ar (sccm)	Striation level
2/1	0	50		0-1
1/0	10			1
1/0	0	50		2
4/1	20		100	2
1/2	20	300		2
1/4	20	300		2
4/1	20			3
1/0	0			3
2/1	10			3
0/4	10			5
4/0	0	50		5

*The striation level from 1 to 5 indicated the via hole distortion from less to more.

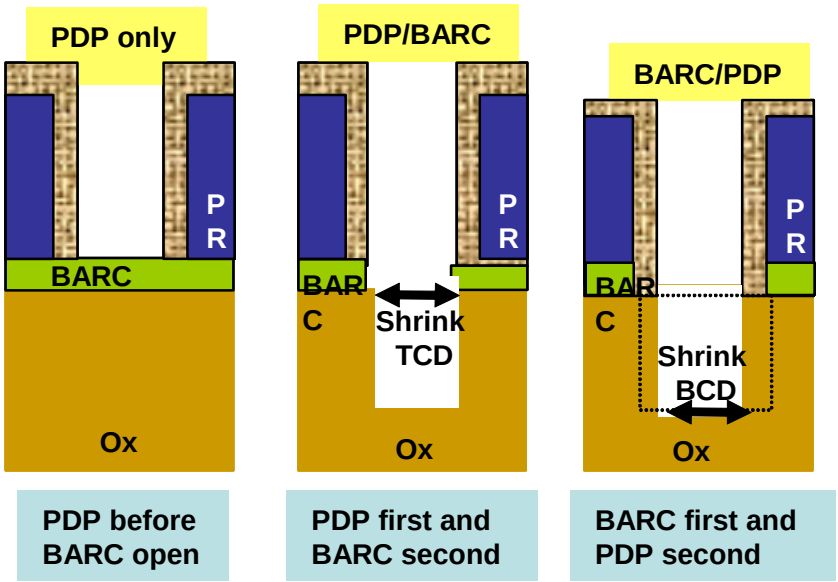
- CO replaced O2 showed the better striation performance
- Process combining CHxF and CxFy improved striation
- CHxFy and CxFy played the key roles on striation and PR remaining
- CHxF/CxFy/CO was chosen as PDP baseline recipe and was used in the rest of study

CHxF/CxFy Ratio Effect on Striation

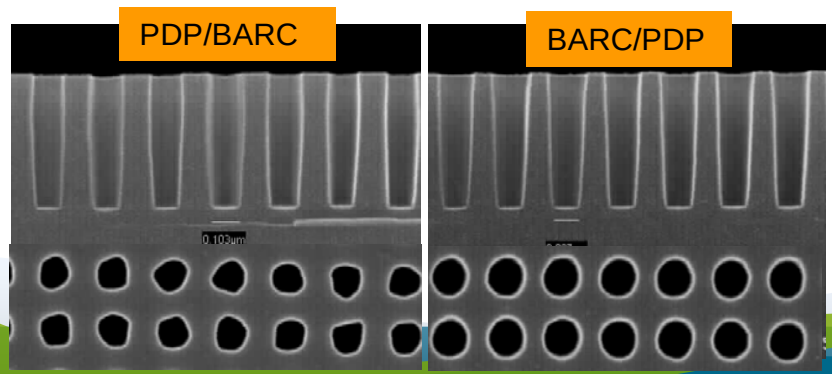


- **The flow ratio 2:1 of CHxF/CxFy presented better top surface striation**

PDP Sequence Effect on CD Control and Striation



Sequence:	-PDP -BARC -Oxide etch	-BARC -PDP -Oxide etch



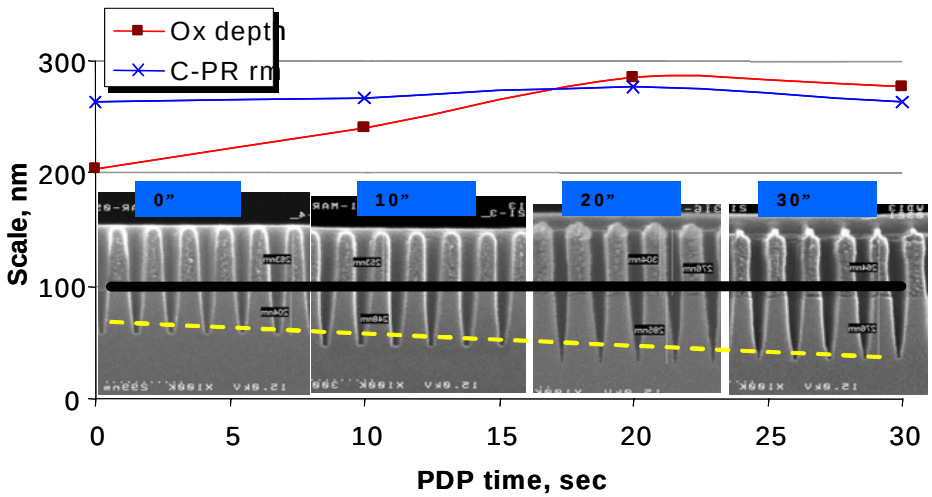
PDP / BARC sequence

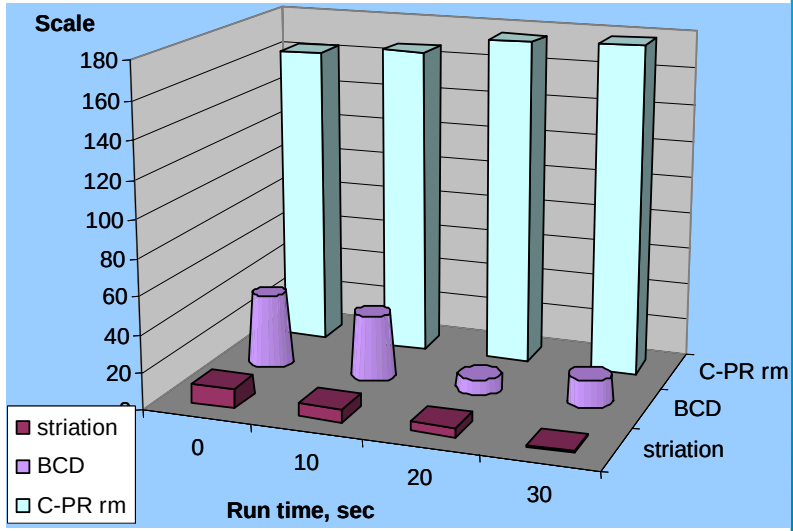
- PDP deposited a layer of polymer on the top of mask, which increased mask selectivity and reduced top CD
- During BARC open, the CFx chemistry etched not only BARC but also the PDP layer, which potentially caused the mask deformation

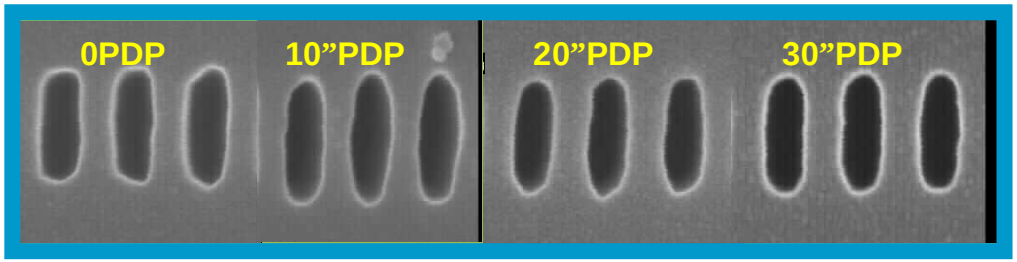
BARC / PDP sequence

- During BARC open first, the some mask got etched away and the BARC bottom CD was blew-up
- PDP remained the polymer layer on the mask and provided the high selectivity to mask which improved the striation
- Bottom CD would be well controlled by BARC / PDP sequence

PDP Time effect

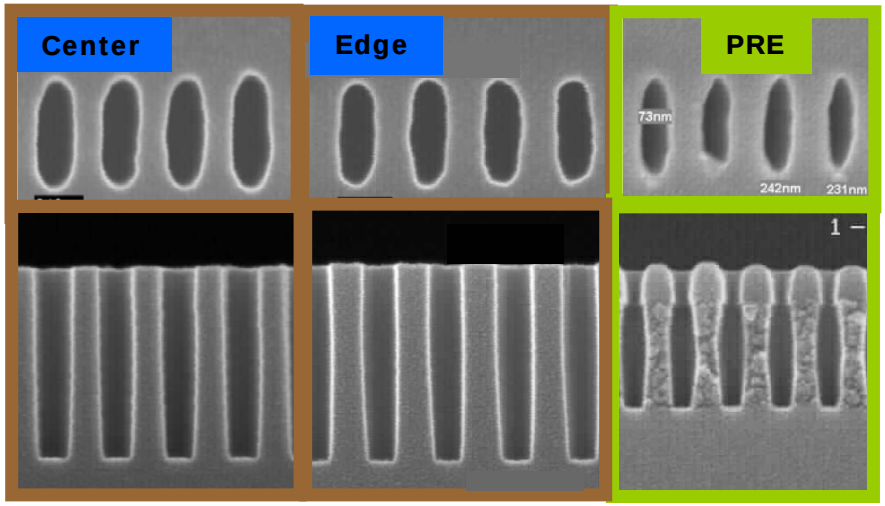


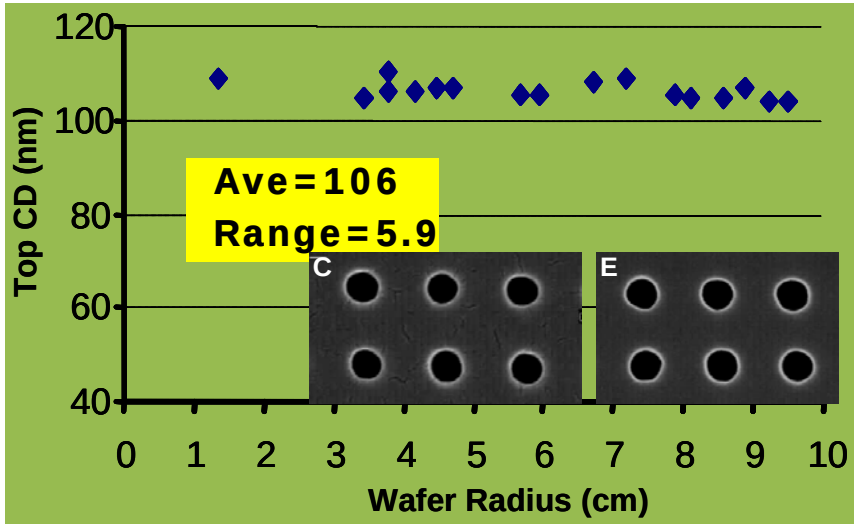




- Longer PDP time showed the better striation
- 20" PDP time indicated the good top striation, high etch rate, and high mask selectivity

C-PR Mask Contact Etching Comparison between Pre and Post Process and Post CD Result





- Comparing with pre mask surface roughness and mask open cross section, an improved contact hole distortion with a very decent profile was obtained with adding PDP for 20sec before BARC open

- A 5.9nm tight CD range was achieved after oxide etching with PDP addition after BARC open

Conclusion

- The surface distortion was strongly correlated with
  - surface striation
  - pinhole
  - degradation
- The polymer rich process enclosed polymer chemistry like CxFy and dilute gas like CO can be used as polymer deposition process to help profile distortion
- The PDP did not only deposit a layer of thick polymer on the top of mask to increase mask selectivity but also improved mask surface quality to prevent the surface degradation
- Longer and shorter PDP time would cause the trade off between contact hole distortion and profile control
- Using PDP before or after BARC really depended on the mask surface roughness and following etching process limitation
- PDP time was decided by the process regime on surface distortion and profile control requirement

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