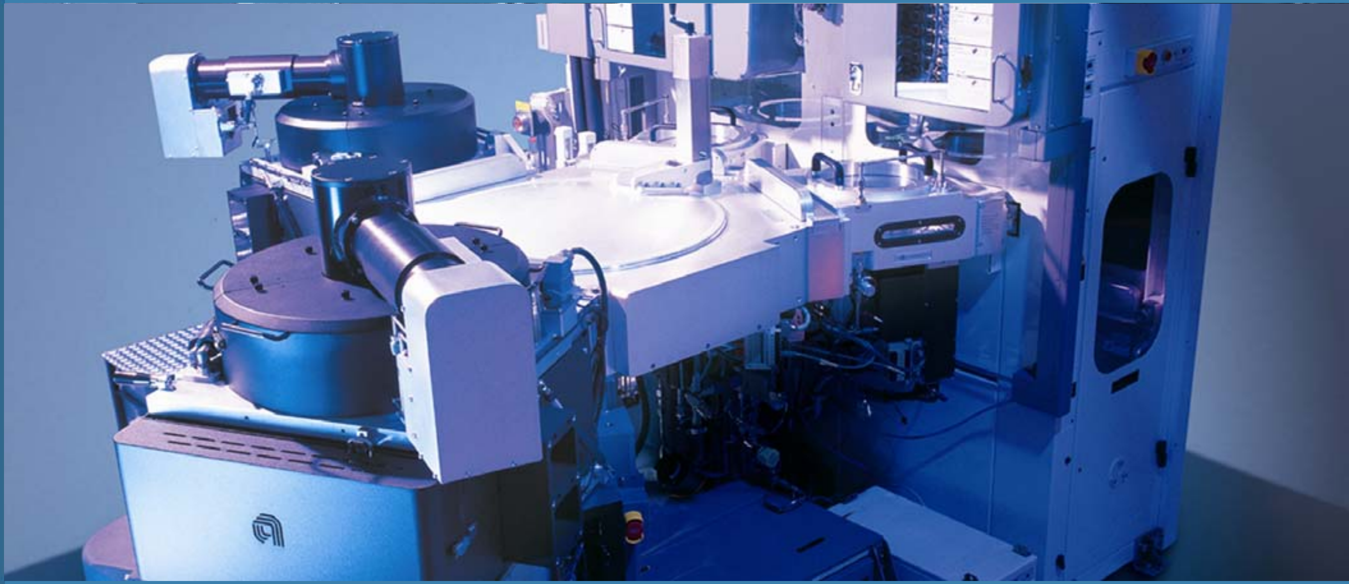

Advance Gate CD Control by Gate Dielectric Hard Mask Open Process Optimization

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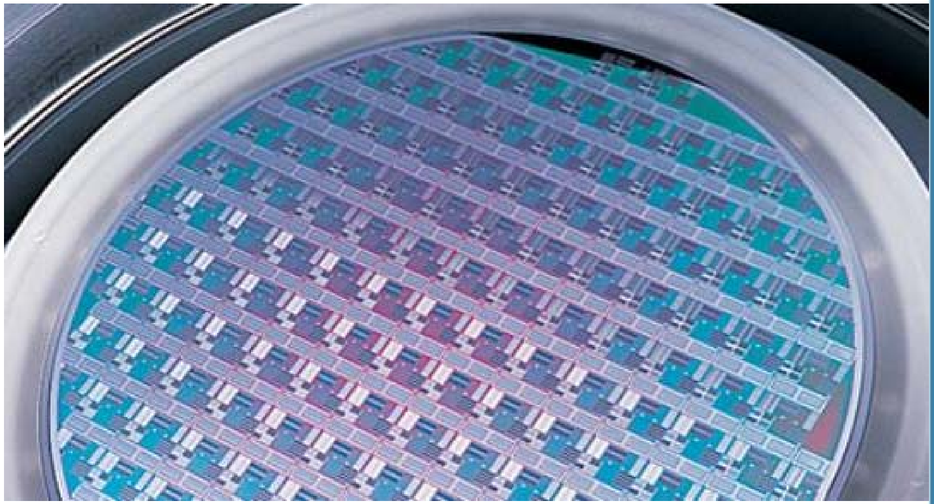
Plasma Etch User Group
American Vacuum Society
March 11, 2003

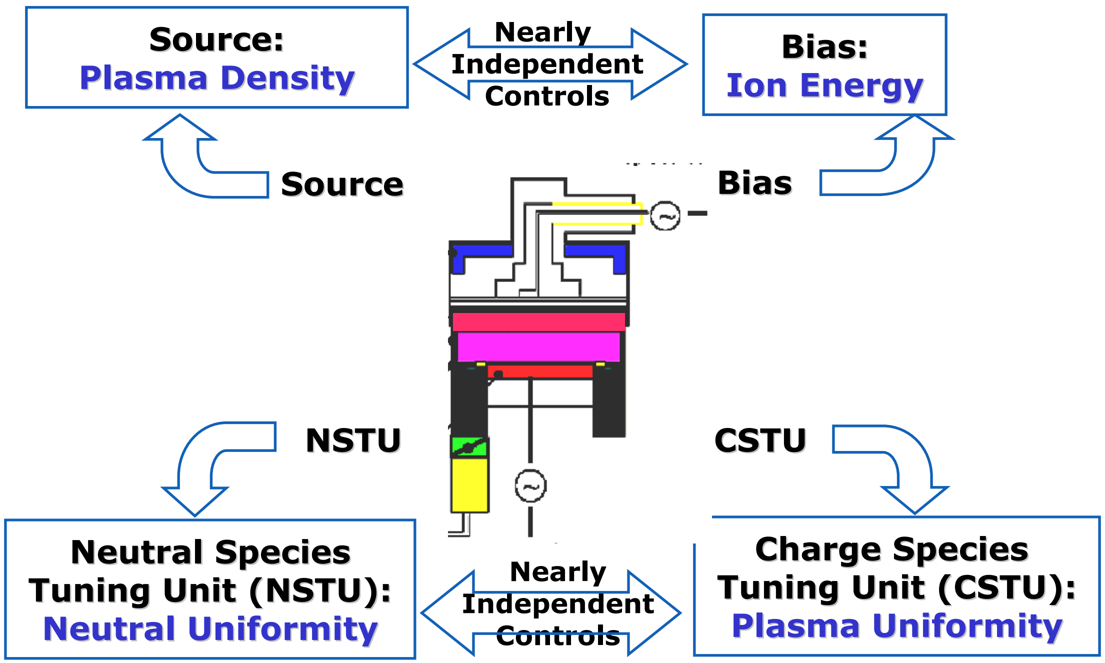
Outline

- Chamber Uniformity Control
  - Etch rate uniformity control
  - CD and profile uniformity control
- Gate Mask Open Process
  - Challenges and requirements
  - Profile control
  - CD bias control
  - CD bias uniformity control
- Summary



Enabler™ Chamber Technology

Wide Operating Window

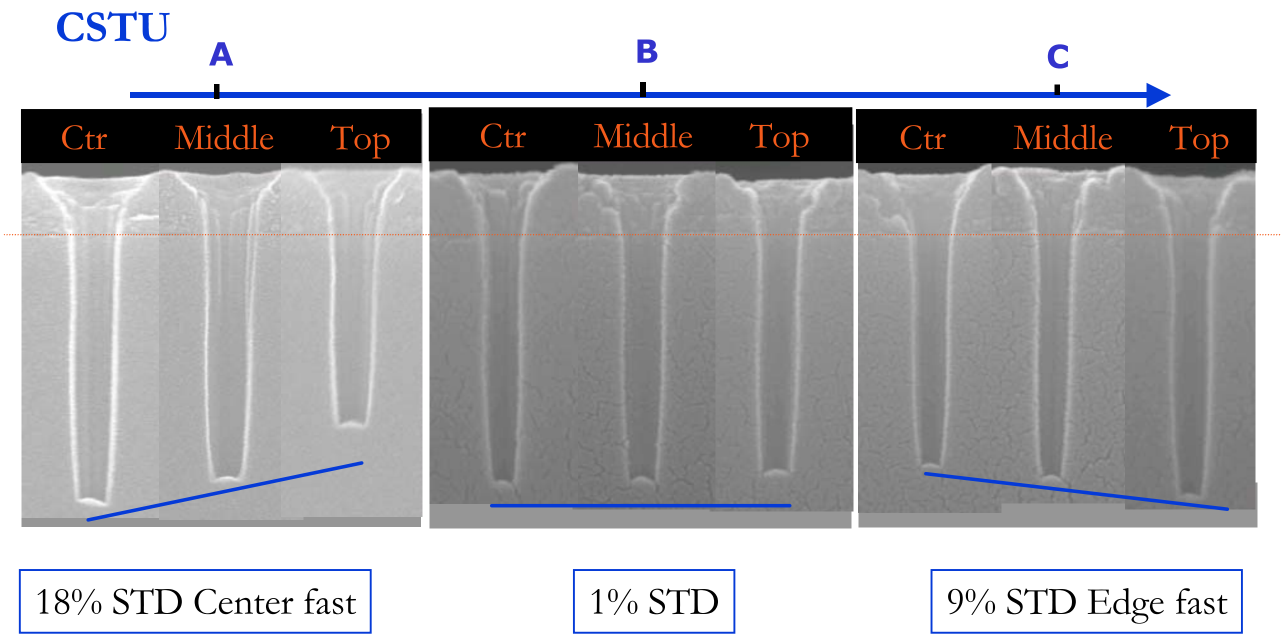


All in One Capability: Etch, Clean and Ash

Uniformity Control

E/R Uniformity Tuning: CSTU

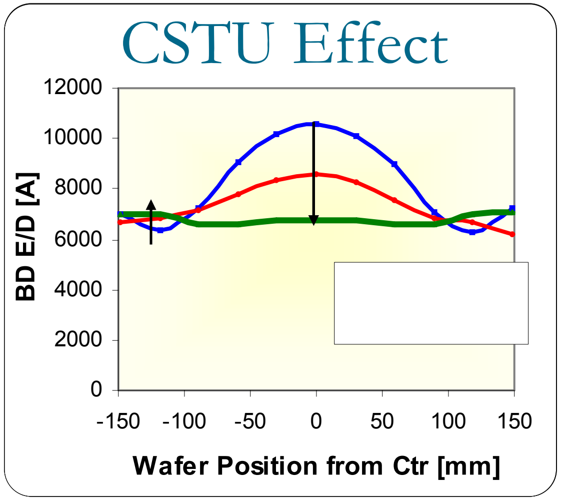
- TEOS E/R at Low Pressure

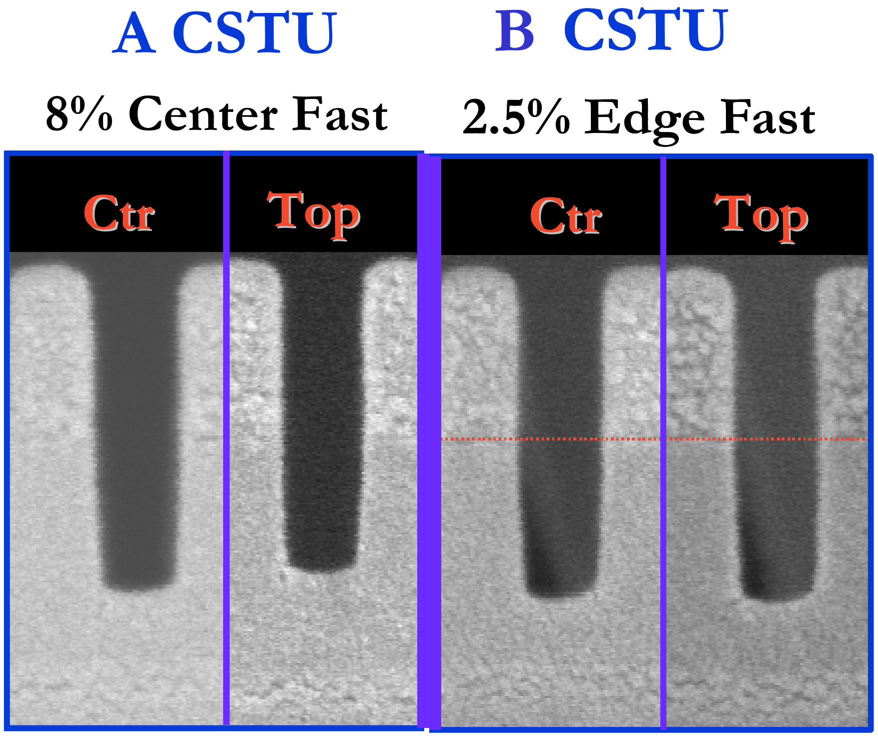


CSTU Tends to Redistribute the Power Towards the Edge of the Wafer.
CSTU can Tune Uniformity within 1%.

E/R Uniformity Tuning: CSTU

- Black Diamond E/R at High Pressure (200mT)

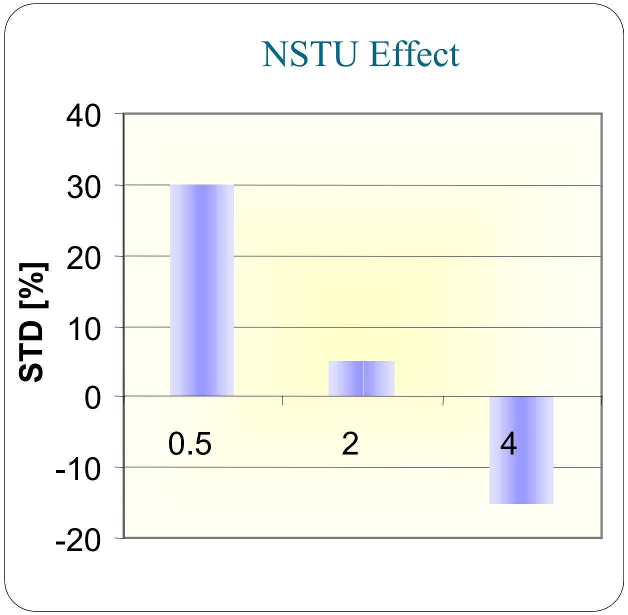




CSTU is Effective Tuning Uniformity at High Pressure in both blanket and pattern Wafers

NSTU Effect on Polymer Deposition

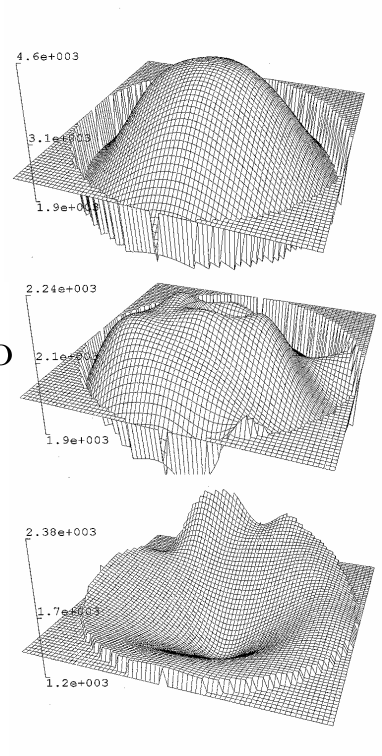
- Removing bias from the polymer rich HAR process over a 300mm blanket Silicon wafer will cause polymer deposition (directly related to neutral distribution).



0.5 Center High deposition STD **30%**

2 Flat depositio STD **5%**

4 Center Low deposition **-15%**

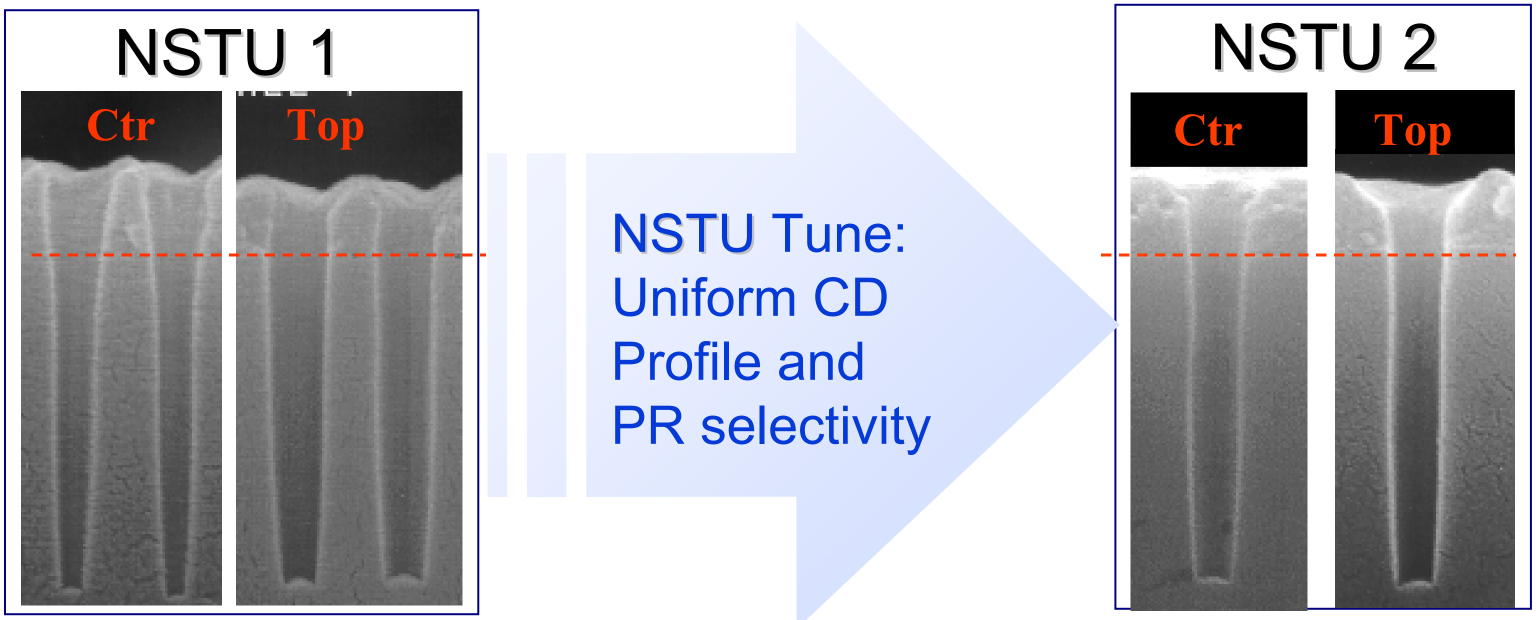


NSTU is a Strong Knob to Tune Polymer Deposition

APPLIED MATERIALS®

NSTU Effect on Profile (HAR)

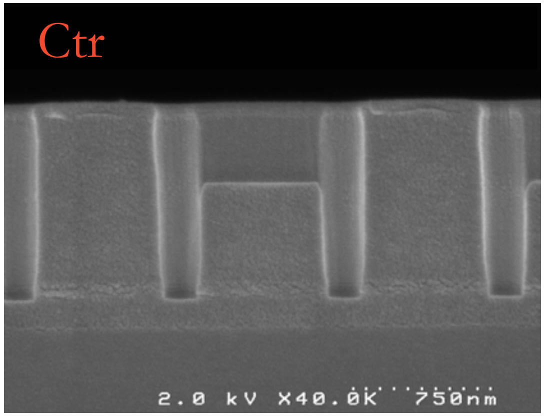
- Effect on profile and PR selectivity of changing the flow ratio using a High Aspect Ratio recipe

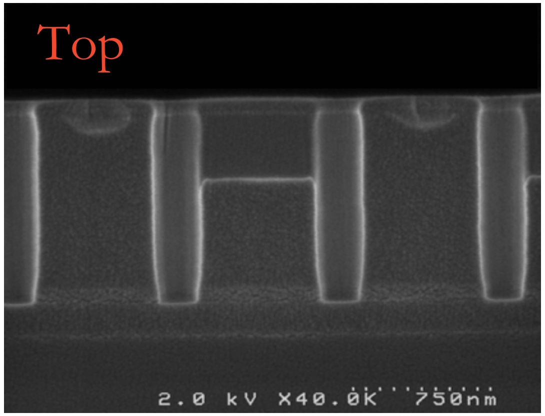


NSTU setting 1 Produces more Polymer at Center causing CD Shrink and Taper Profile

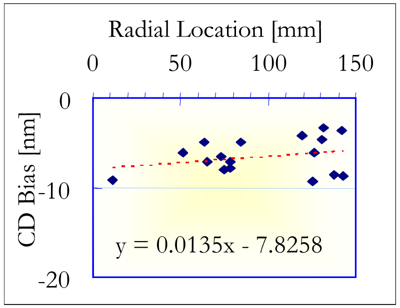
NSTU setting 2 improves Profile and CD Uniformity

DD Trench: NSTU Effect



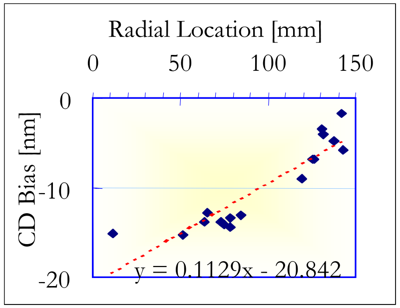


NSTU 1



CD	0.1011
min	-0.0093
max	-0.0034
average	-0.007
range	0.0059
3sigma	0.0059

NSTU 2

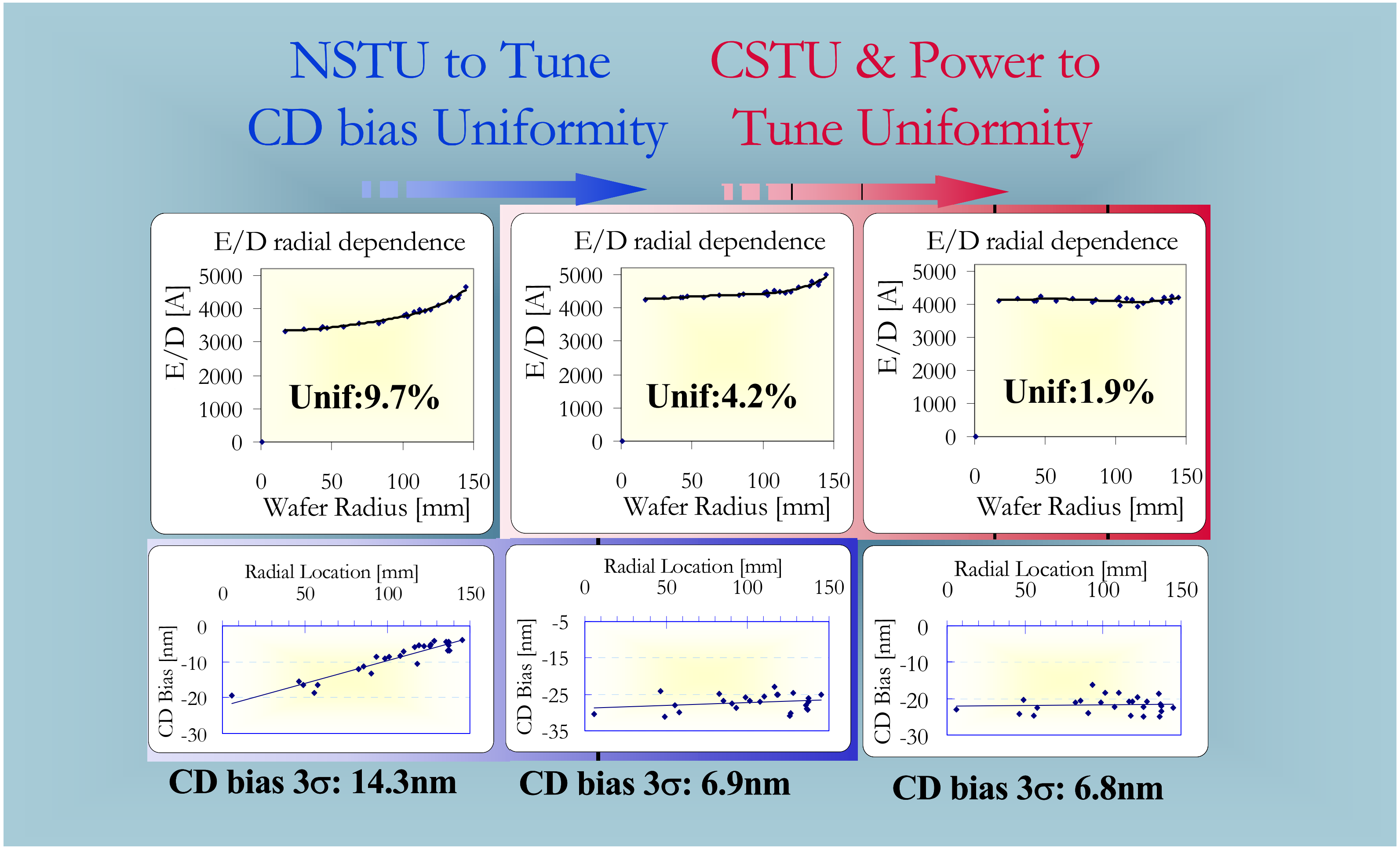


CD	0.0980
min	-0.0153
max	-0.0018
average	-0.010
range	0.0135
3sigma	0.0143

NSTU has a Strong Effect on CD Bias Uniformity

Enabler Tunability During a DD Demo

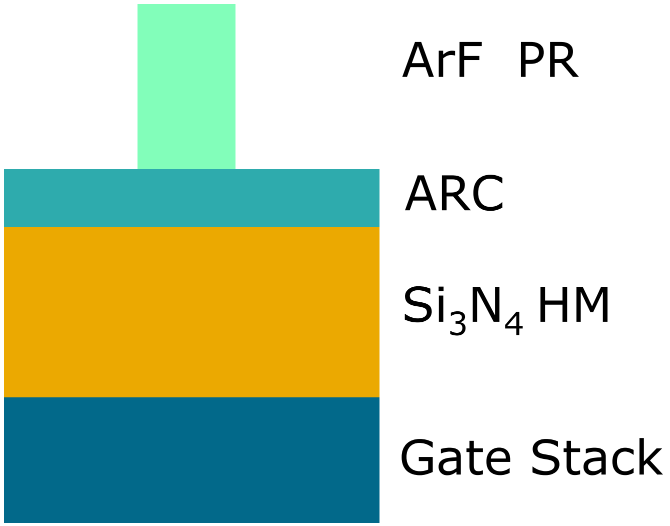
(65nm 193nm Foundry)



E/R and CD Uniformity Tunability Demonstrated

Gate Stack Mask Open (GCMO)

- GCMO Process
  - Define hard mask for gate stack etch
  - Gate CDs have direct impact on yield:
    - Large CD can lead to shorts
    - Small CD can cause high sub-Vt current leakage

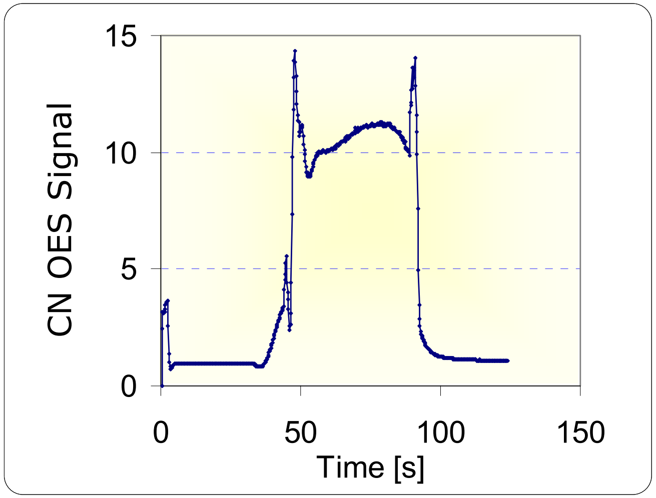


- GCMO Challenges
  - 193nm PR
    - Thinner
    - Less plasma resistant
    - Prone to line edge roughness and wiggling

- GCMO Process Requirements
  - PR selectivity
  - CD control
  - Straight profile
  - Line edge roughness

Mask Open Process

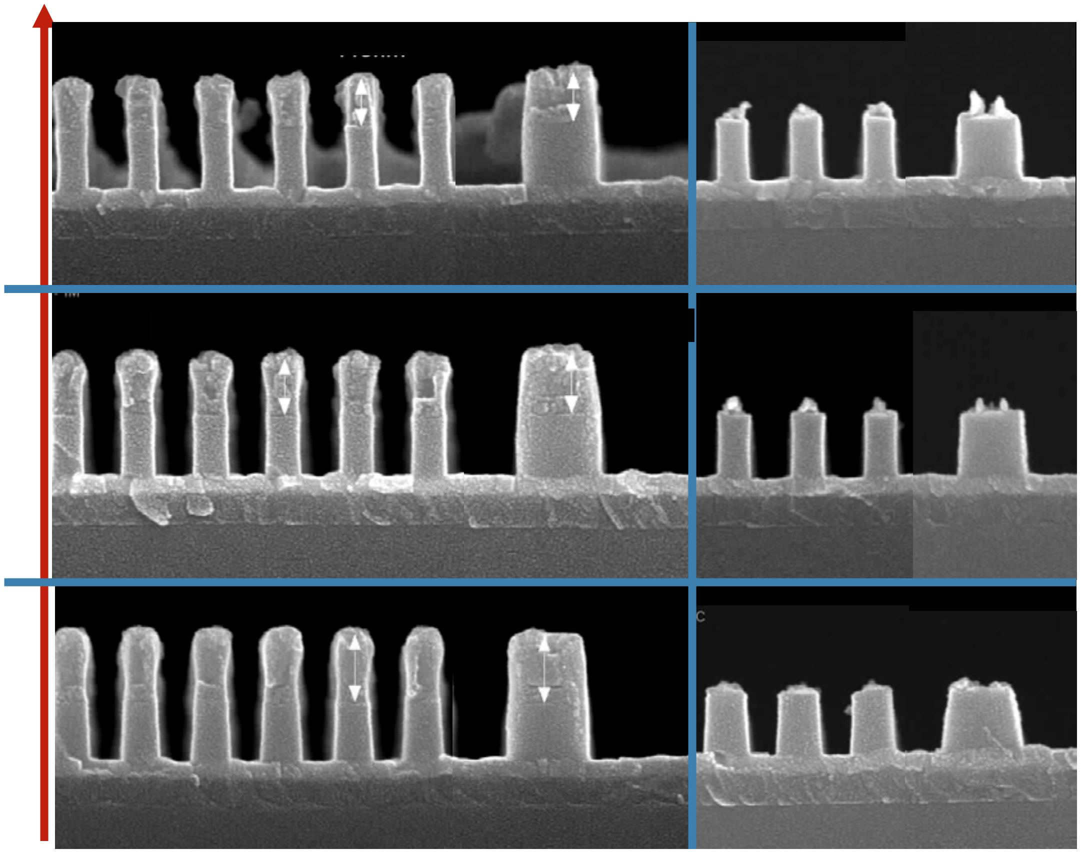
- 3-Step Process
  - ARC open
  - SiN Main Etch (ME)
  - SiN Over Etch (OE)

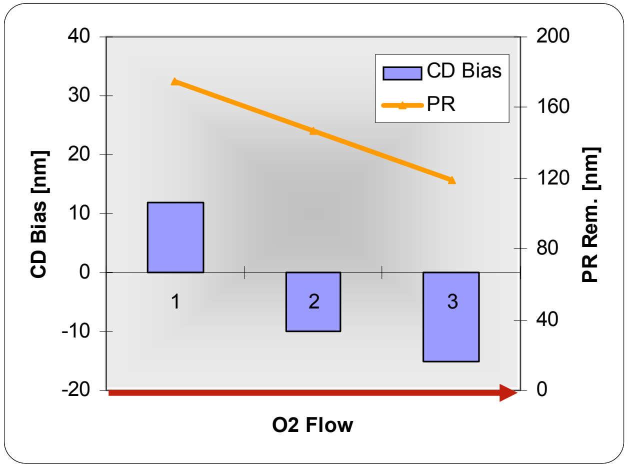


- Process Characteristics
  - Use high pressure to minimize line edge roughness
  - Use ME and OE combination to maximize PR left after etch
  - Use BARC step to tune CD bias
  - Use NSTU to tune CD uniformity

GCMO Profile Control

O$_2$ Flow



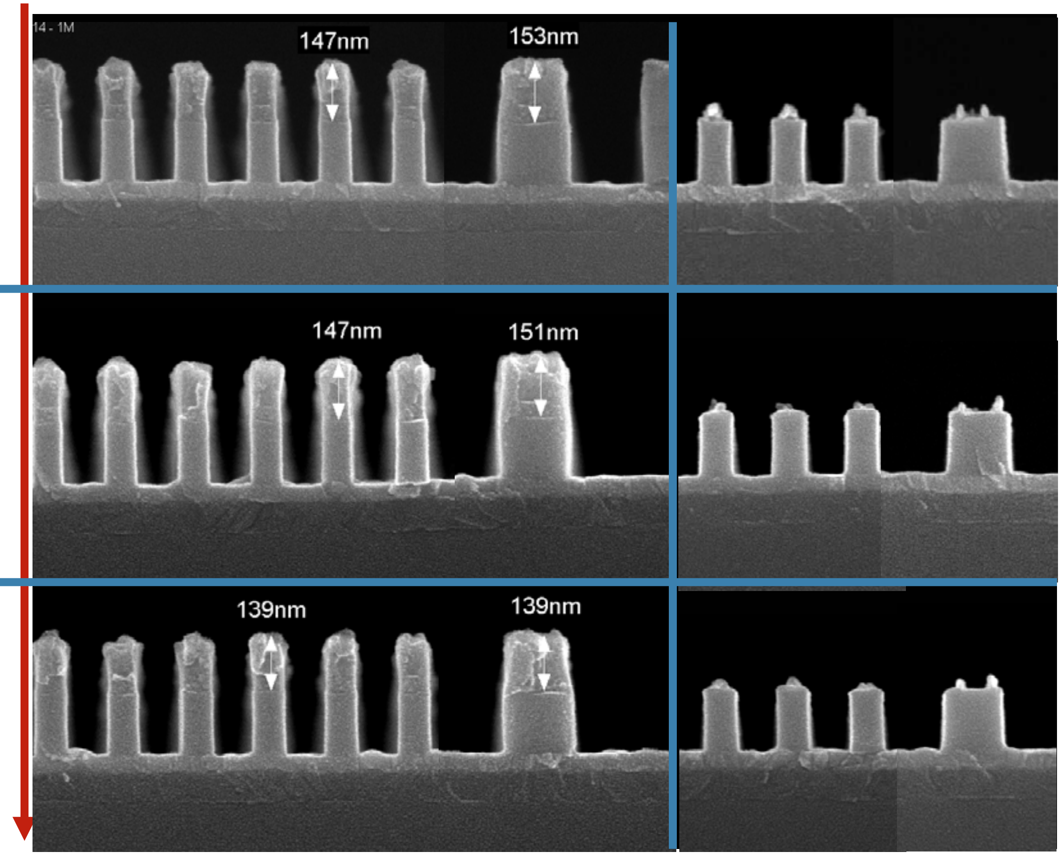


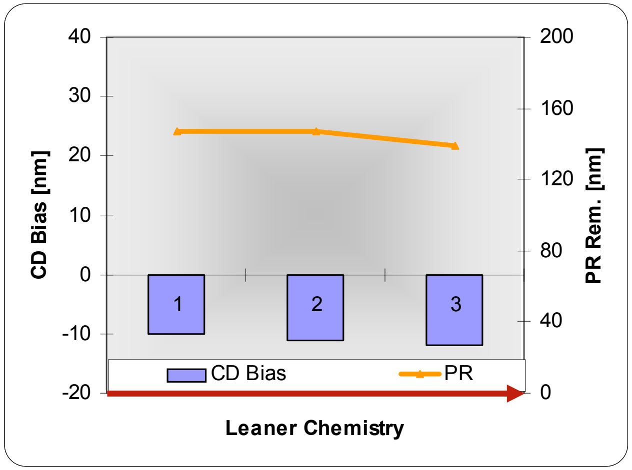
- Increasing O2:
- More Straight Profile
- Less PR
- Smaller CD

O2 Flow has Strong Effect on Profile but Trade-Off on PR Selectivity

Reactive Chemistry Effect on ME

Leanness



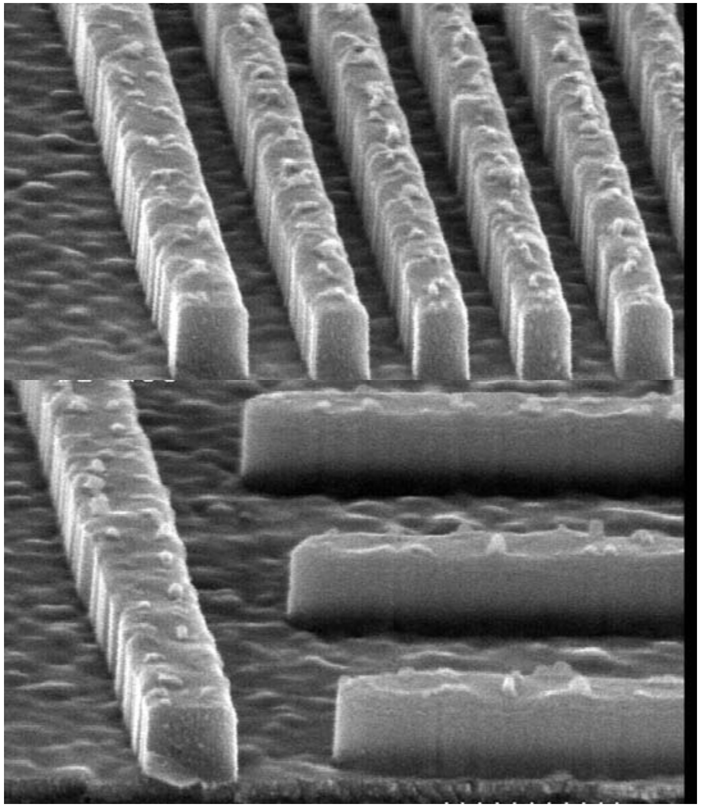


- Leaner Chemistry:
- Straight Iso Profile
- Smaller CD
- Less PR

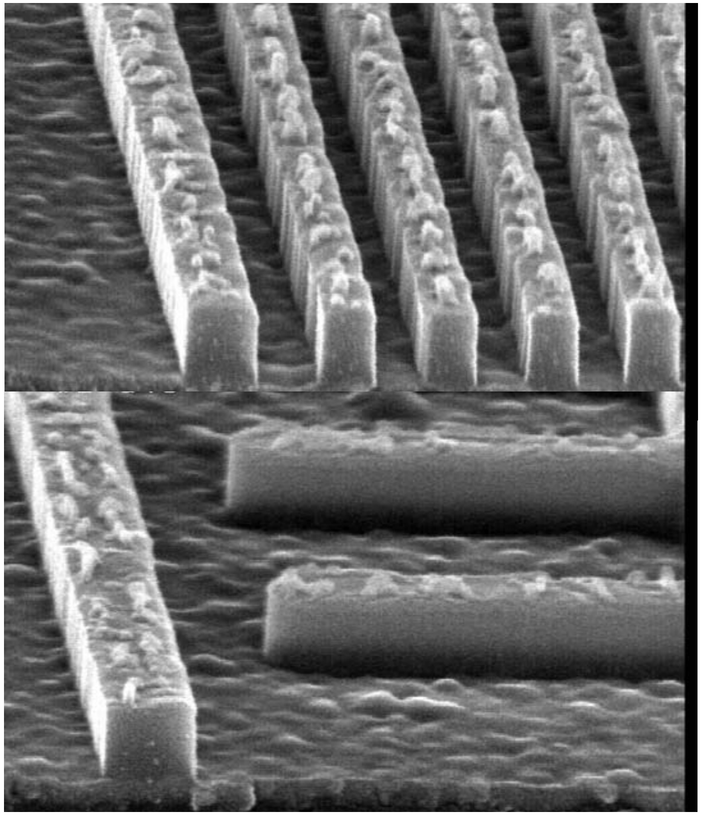
Chemistry Improves Profile with Less Impact on PR Selectivity than O2

GCMO Process: Minimizing LER

Low Pressure

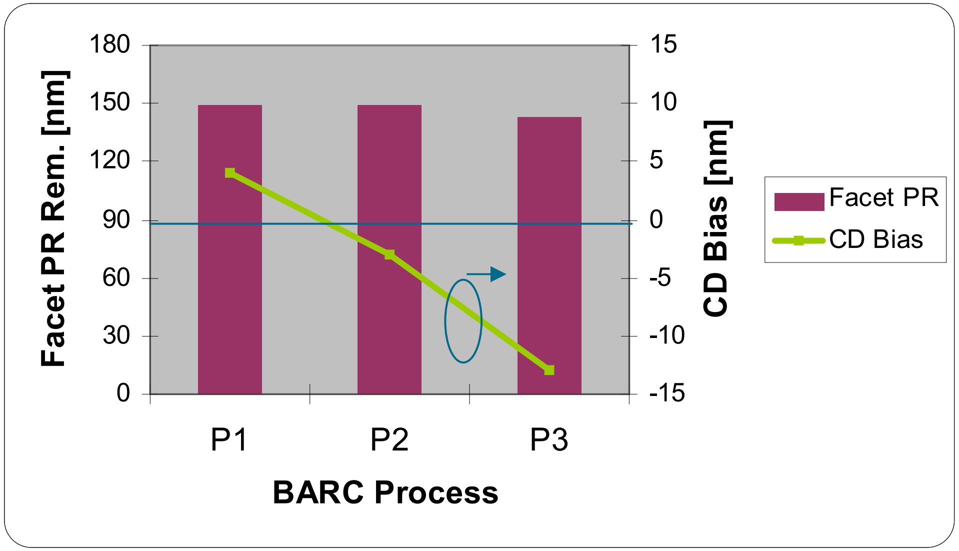


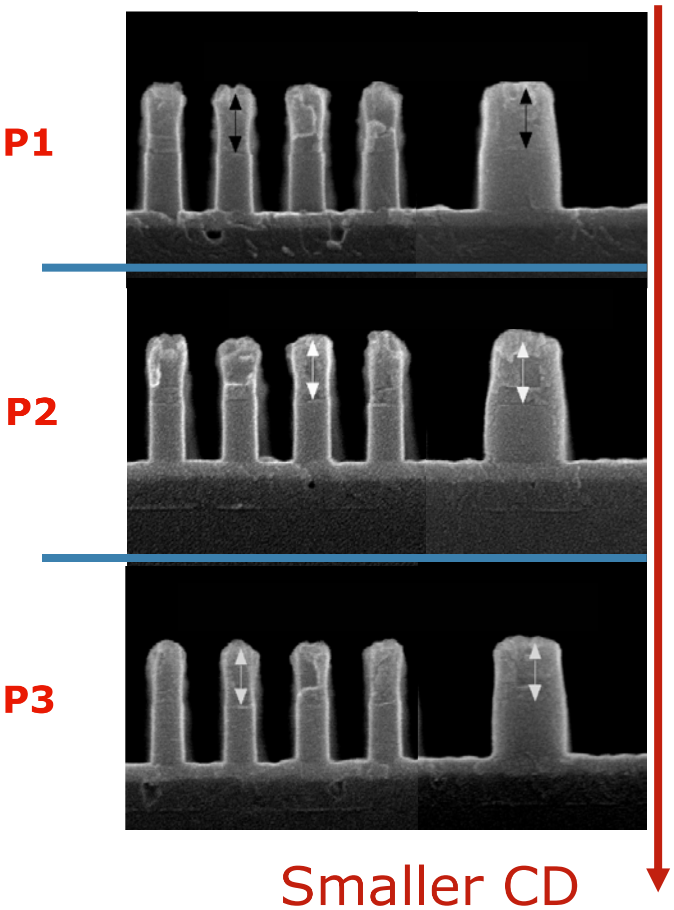
High Pressure



High Pressure Improves Line Edge Roughness

GCMO Process: CD Bias Control



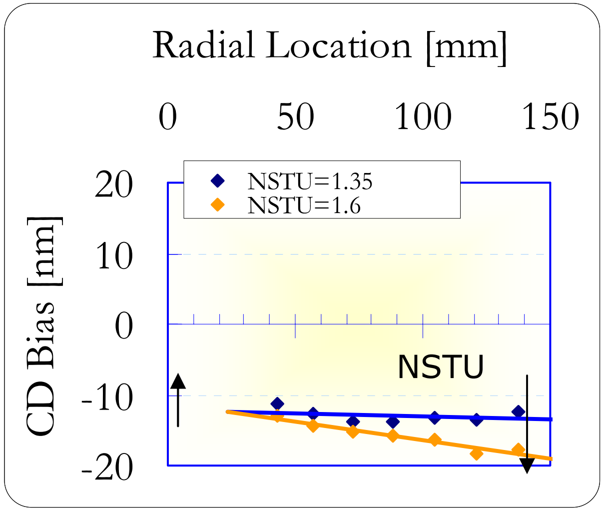


CD Bias can be Tuned Maintaining PR Selectivity and Profile Unchanged

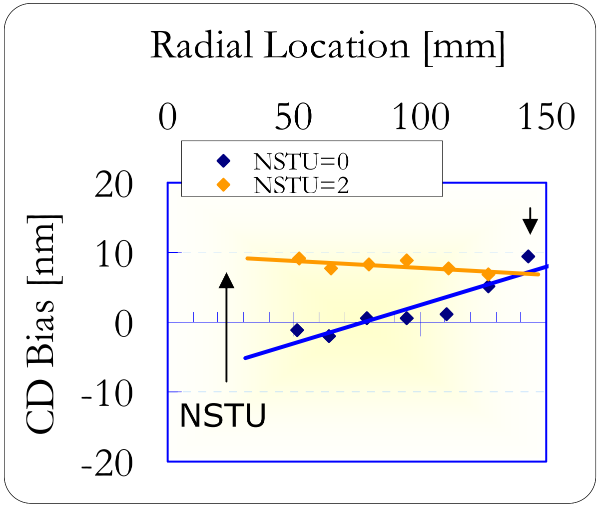
GCMO Process: CD Bias Uniformity

- CD Bias Uniformity can be tuned using NSTU in BARC and/or ME step

NSTU Effect during BARC step

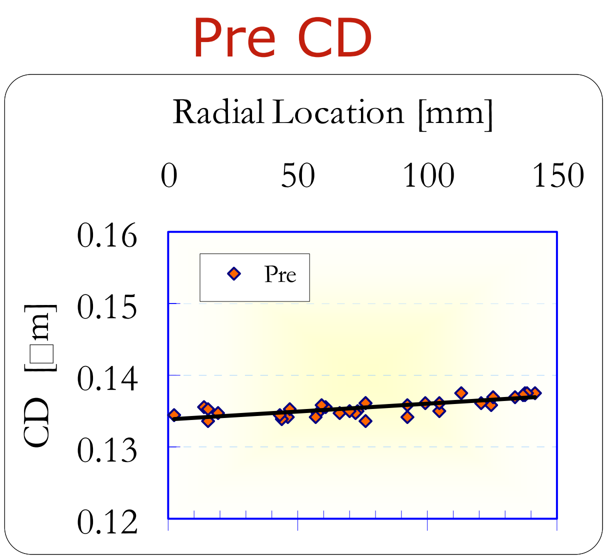


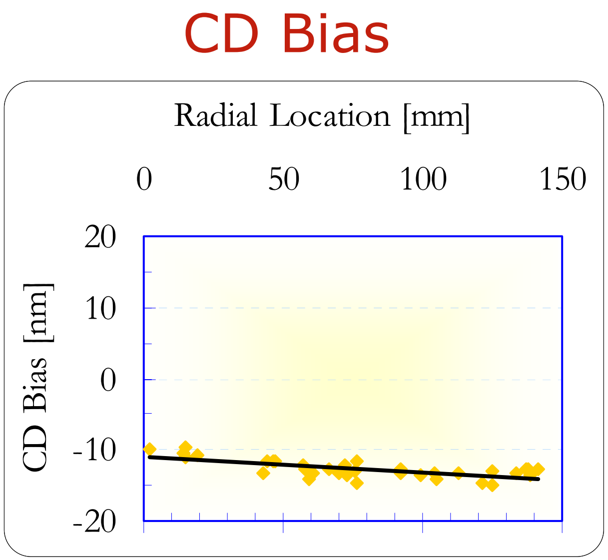
NSTU Effect during ME step

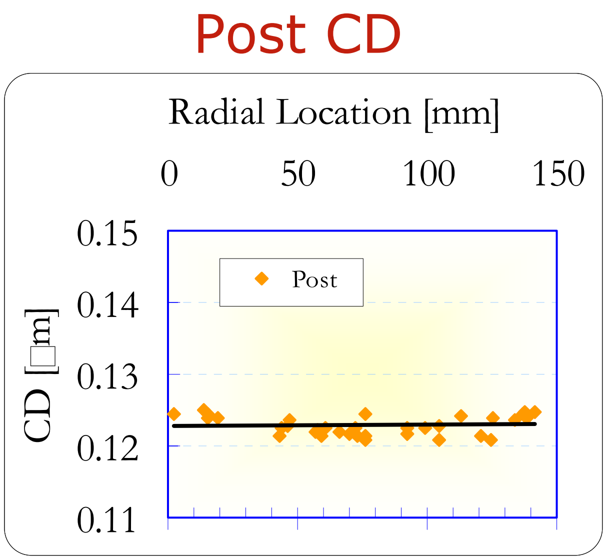


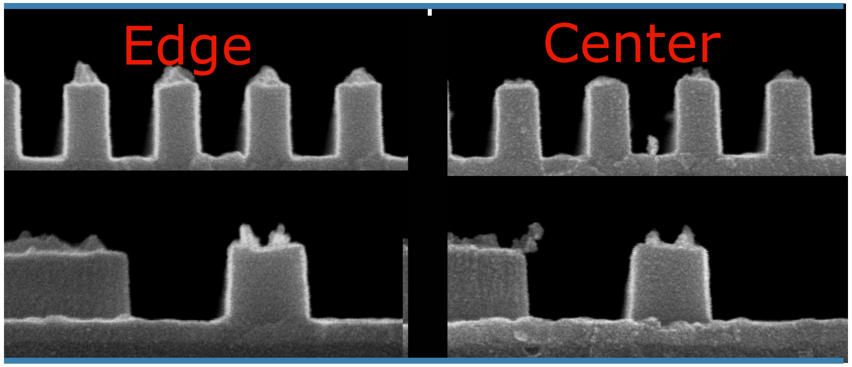
Increasing NSTU in BARC and ME Steps Reduces Edge CD

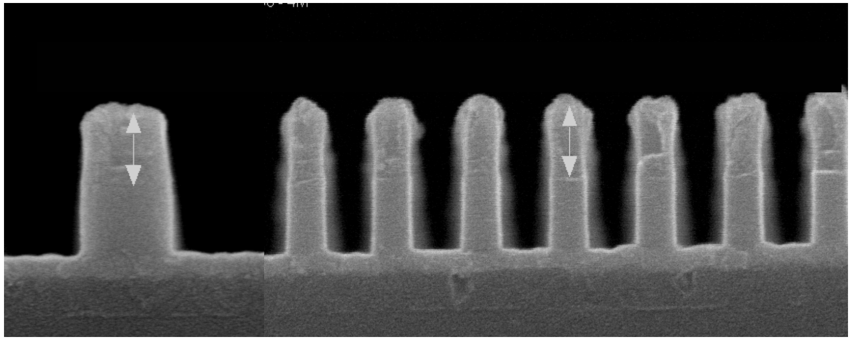
GCMO Example











CD Uniformity Tuned Using NSTU

Summary

- Advance applications requires strict control of uniformity in a wide operating regime
- Enabler reactor design provides a wide operating window and two independent knobs for uniformity tunability
- E/R Uniformity can be controlled using CSTU
- CD Uniformity can be controlled using NSTU
- Advance tunability was demonstrated for Hard Mask open using ArF PR
- High pressure was used to minimize striations
- Chemistry was used to tune profile while maintaining high PR selectivity
- BARC open was used to independently tune CD bias
- NSTU was used to independently tune CD bias Uniformity
- Independent tunability allows feed-forward and feedback techniques to further optimize CD bias and uniformity in an APC environment

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