ICIS Development Alliances

Integrated CD Shrink Methodologies for Contact Etch

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Content

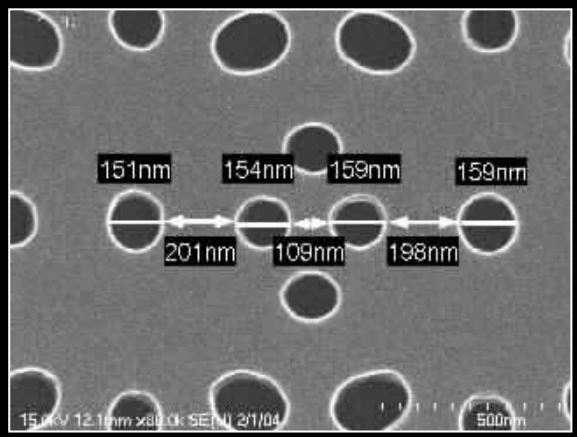
- Etch Challenges for 65nm and Beyond
  - Lithographic limitations
- Contact Etch Challenges vs. Plasma Control
  - Process challenges of 65nm Contact Etch
  - Requirements for Plasma Control
- Methodologies of CD Shrink for Contact Etch
  - Bilayer Resist Scheme
  - SiARC Scheme
  - ARC 40 Scheme
- Summary

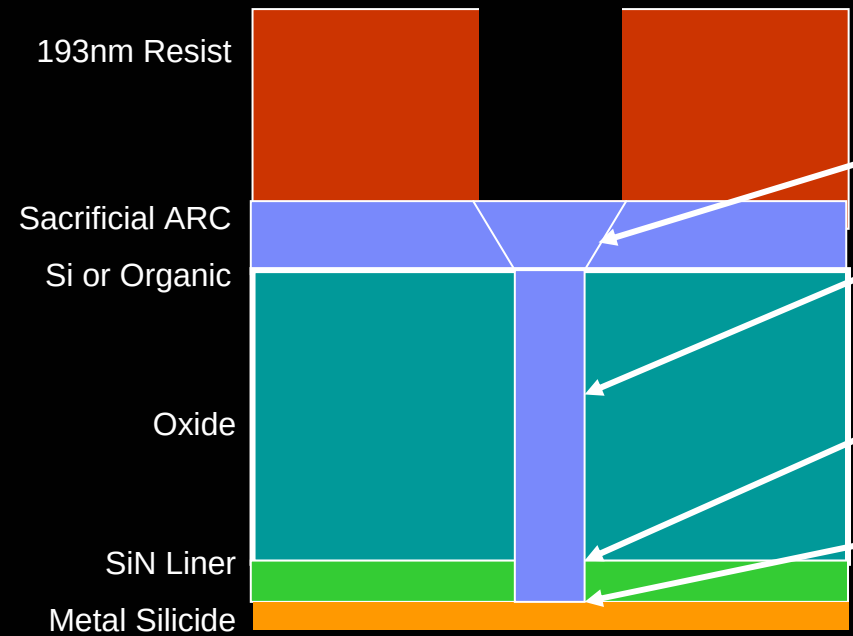
Introduction

- **CD shrink in via etch processes are required to alleviate lithographic limitations in meeting design ground rules for 65nm and beyond**
  - Resist trim techniques
  - Tapering of a sacrificial masking material
- **Resist mask thicknesses will be scaled down continually due to reduced depth of field, therefore, requiring**
  - Highly selective etch process
  - Control of micro-loading, Profile, Line edge roughness and Uniformity
- **This talk will focus on different CD reduction methodologies for Contact Etch developed jointly by IBM and Applied Materials.**

Challenges of Contact Etch

Example of Post Litho Top-down SEM





Challenges:

- >40nm CD shrink through ARC Open
- Oxide etch profile & LER Control, Open all sizes
- Selectivity to liner
- Soft etch of liner with high selectivity to fragile silicide

Contact Etch Challenges vs. Plasma Control Knobs

	Key Challenge	Plasma Control Knob
1	CD Shrink & CD uniformity	▪ Innovative chemistry ▪ Polymer type, amount & uniformity
2	Etch Rate Micro-loading and Non-Uniformity	▪ Ion Energy Distribution Function (IEDF) ▪ Ion density & uniformity ▪ Polymer management
3	Resist integrity (LER, Pinhole, Striation)	▪ Soft etch with low ion energy ▪ Polymer management
4	Profile Control	▪ IEDF & Ion current ▪ Polymer management
5	Selectivity to Liner	▪ Chemistry
6	Silicide Integrity	▪ Soft landing with low ion energy ▪ Exclusive chemistry

In this presentation, we will discuss in detail how to address these challenges through process development and optimization on the Enabler etcher.

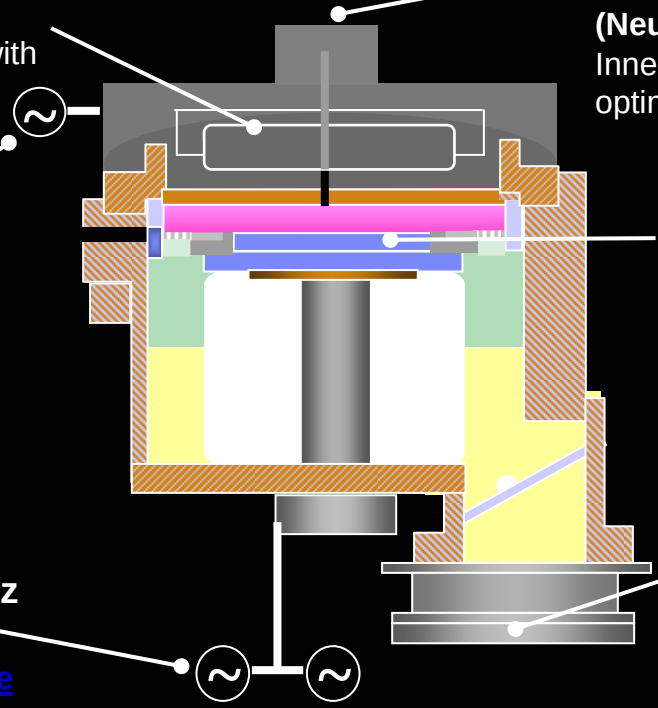
Enabler Etcher used for Contact Etch Development

CSTU- Etch Depth Uniformity

(Charged Species Tuning Unit)
Plasma non-uniformities adjusted with low level magnetic field. Shapes Plasma.

NSTU- CD Uniformity

(Neutral Species Tuning Unit)
Inner/Outer Gas Flow ratio can be optimized to tune CD non-uniformity.



162 MHz Source

Plasma density range from 10^{10} (high selectivity) to 10^{11} (efficient clean).

Wafer Temperature Control

Uniform temperature control improves CD non-uniformity.

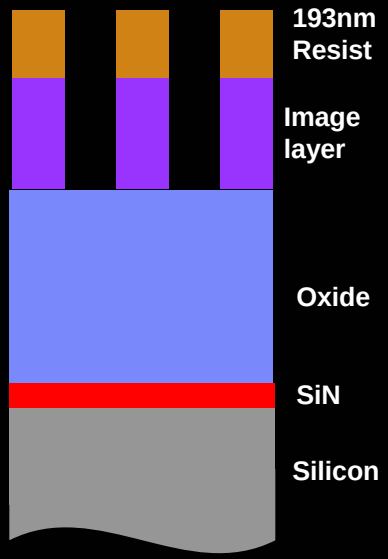
Dual Frequency Bias

(DFB Option) 2MHz/13.56MHz
13.56MHz only for Soft Etch
Mix of 2/ 13.56MHz allows Tunable IEDF to control Profile, Micro-loading and Etch uniformity.

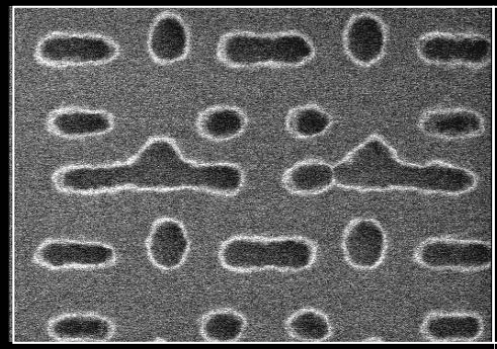
3000 LPM Turbo Pump (Option)

High Flow/Low Pressure
Polymer and resident time control

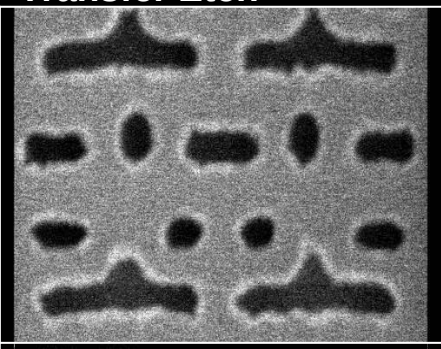
Soft Etch for Bi-layer Resist Image Transfer

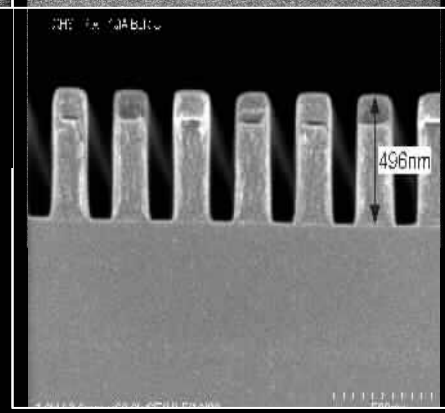


Pre-Etch

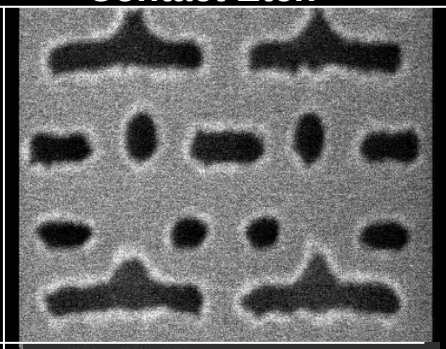


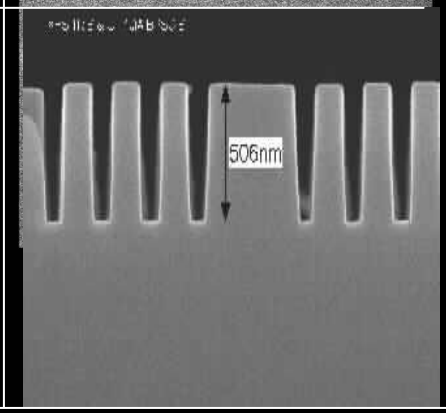
After Bi-layer Image Transfer Etch





After All Integrated Contact Etch





- Controllable etching of the imaging layer is the key for patterning transfer without LER and CD enlargement.
- Using low bias of single 13.56MHz allows soft etching of the imaging layer.
- The process was easily transferred from 200mm to 300mm wafers with simple and well defined scaling factors.

CRITERIA	Target	Performance
LER after Integrated Etch	None	Minimal
CD Bias - XHS (nm)	0	5nm (20% OE)
Residue	None	None
Profile	89	89-90
Etch Rate (Å/min)	6000	8000

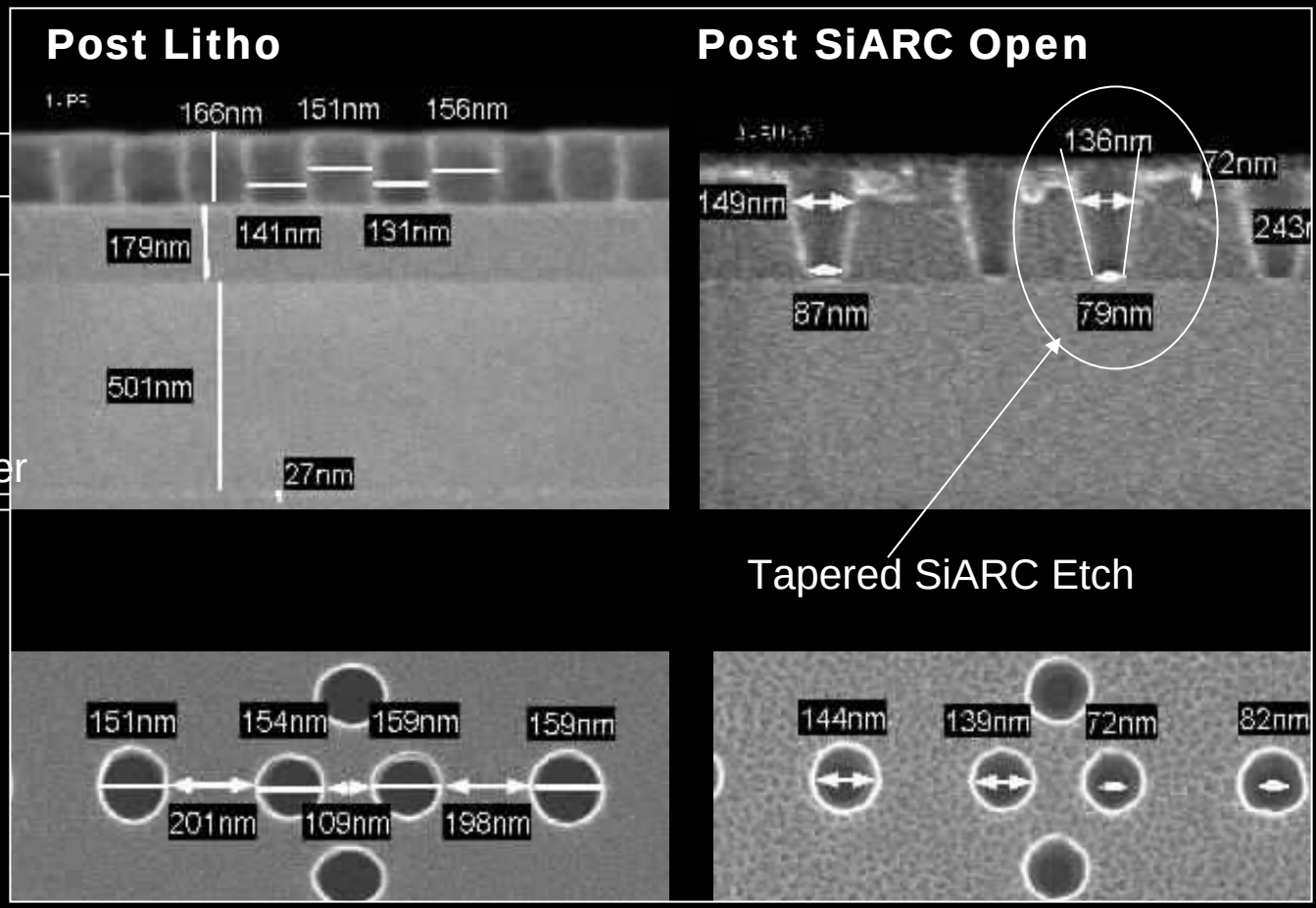
CD Shrink through Tapering of SiARC Mask

PR

SiARC

Oxide

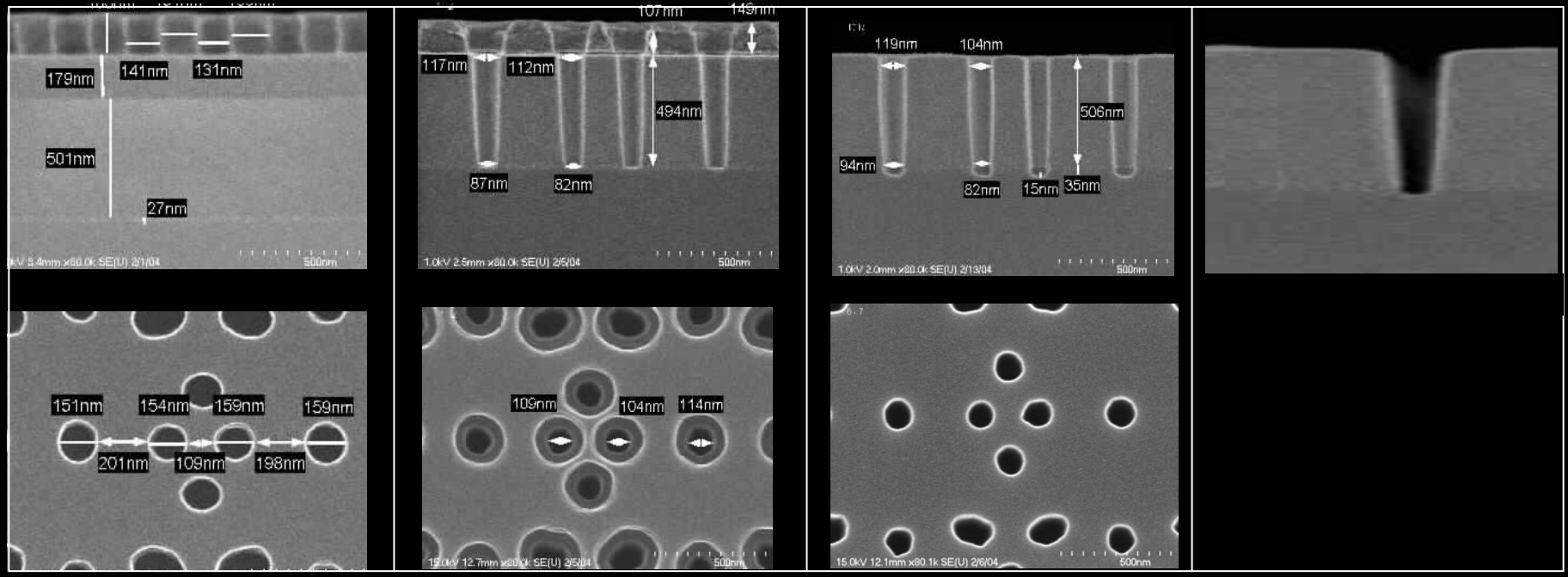
SiN Liner



- CD shrink of >70nm is achieved through tapering of SiARC layer.
- The key is to control polymer and ion energy.

Contact Shrink after Integrated Etch using SiARC Mask

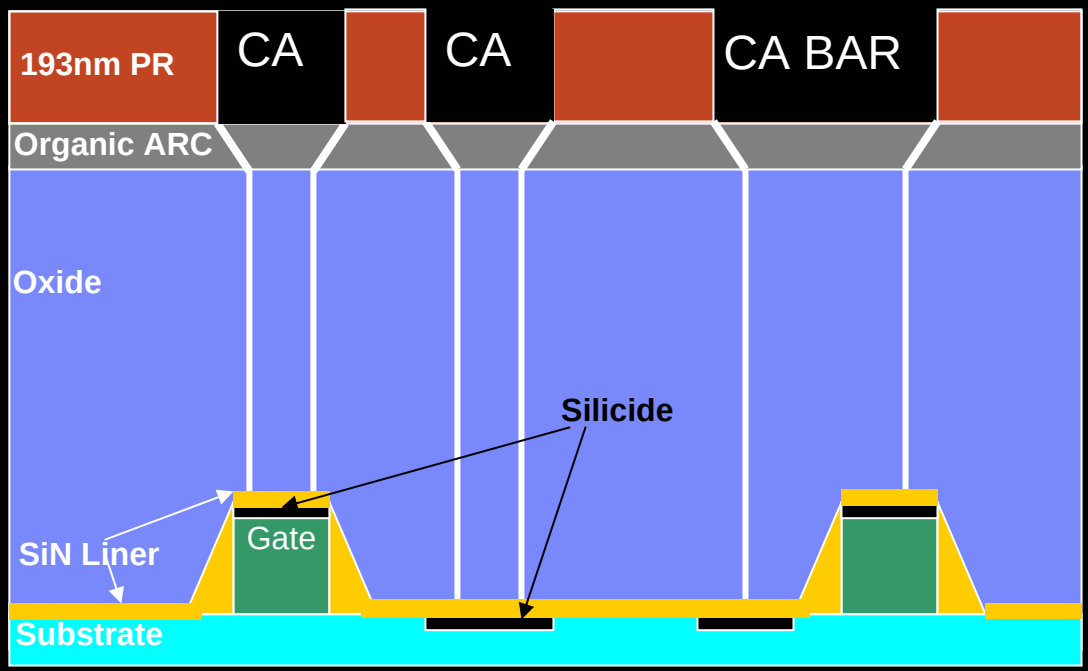
Pre Litho	Post SiARC Open + Oxide Etch + Resist Strip	Post SiN Open & SiARC Mask Removal	Simultaneous Open of Large Features

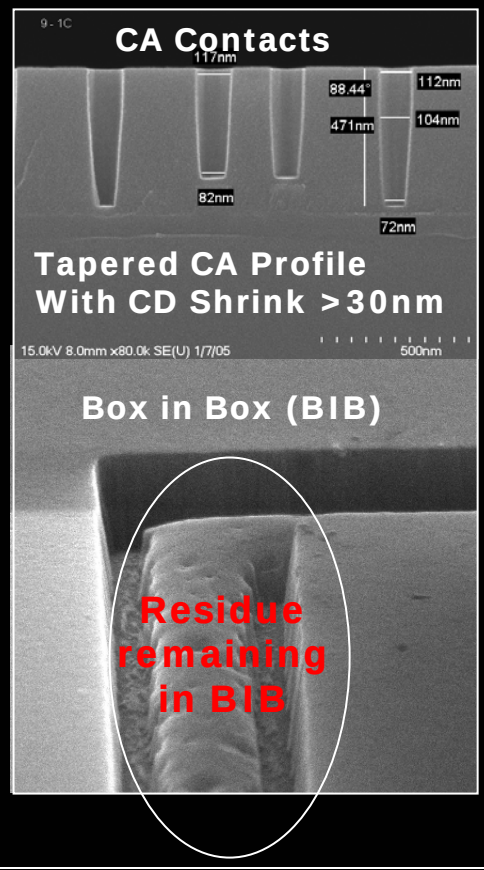


- Process window is large even using only 13.56MHz bias through all etch steps while maintaining CD shrink and etching down all features.
- The key is to control ion density (source power), ion energy (bias power), polymer chemistry and pressure for each step.

New Challenge: Contact Etch using Organic ARC Mask

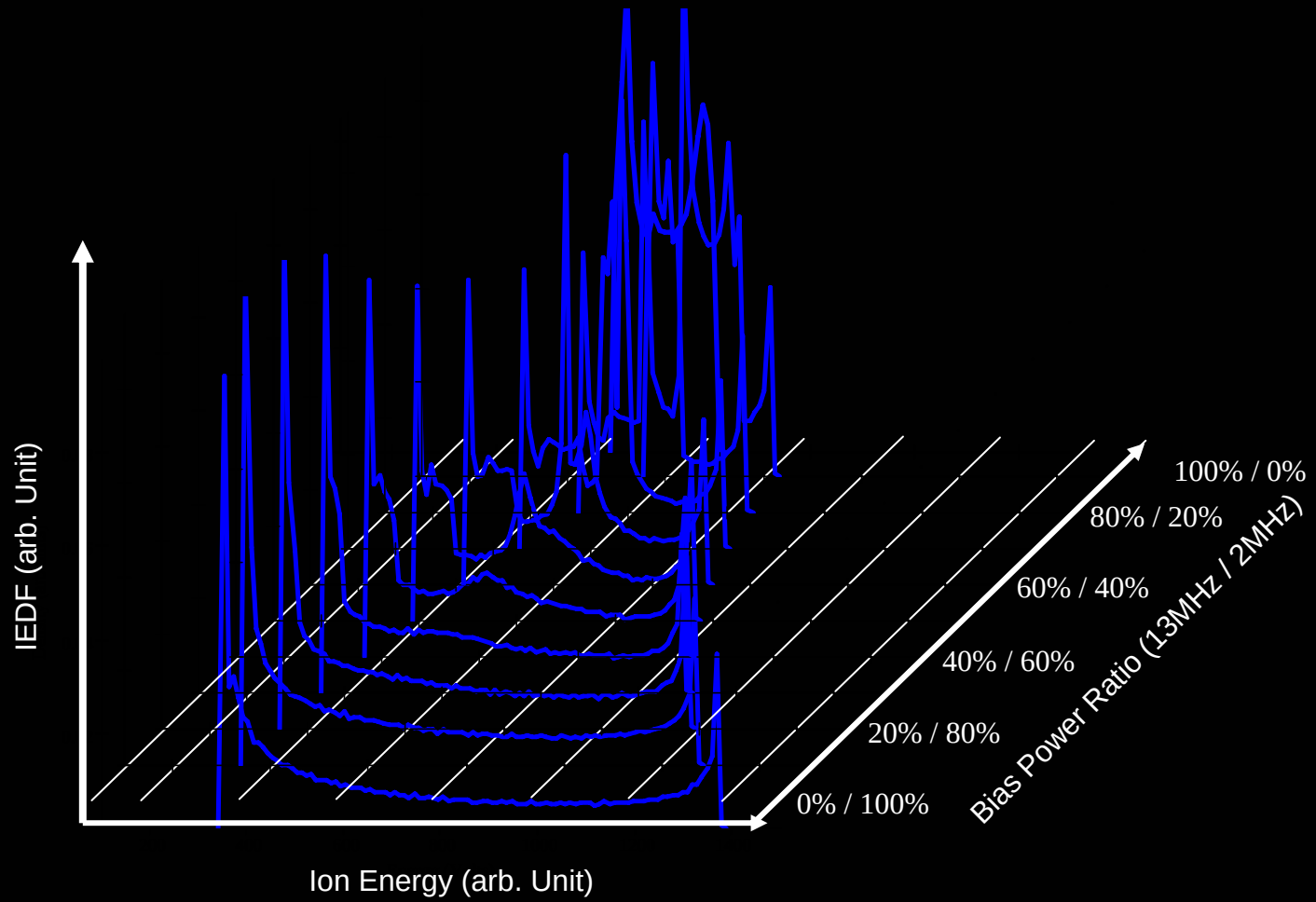
Multiple Size and Multiple Level Contacts





- CD shrink using soft organic ARC mask requires more selective processes.
- Etching multiple size features requires very large process window.

New Approach: Tunable Ion Energy Distribution using DFB



- Mixing 2MHz and 13MHz bias (DFB) can tune the width of (IEDF) .
- More ions move to the higher energy peak with higher percentage of 2MHz power.

Process Window Enlarged using DBF

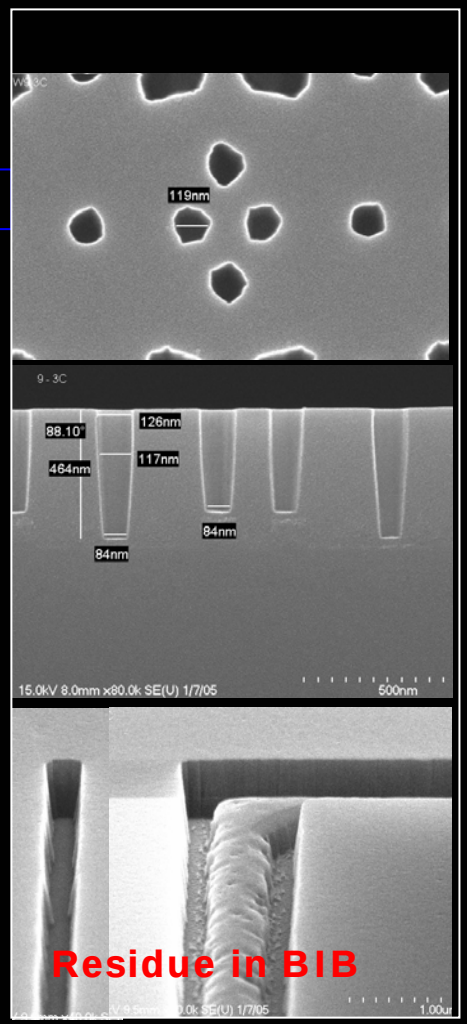
13.56MHz Bias

2MHz & 13.56MHz Bias

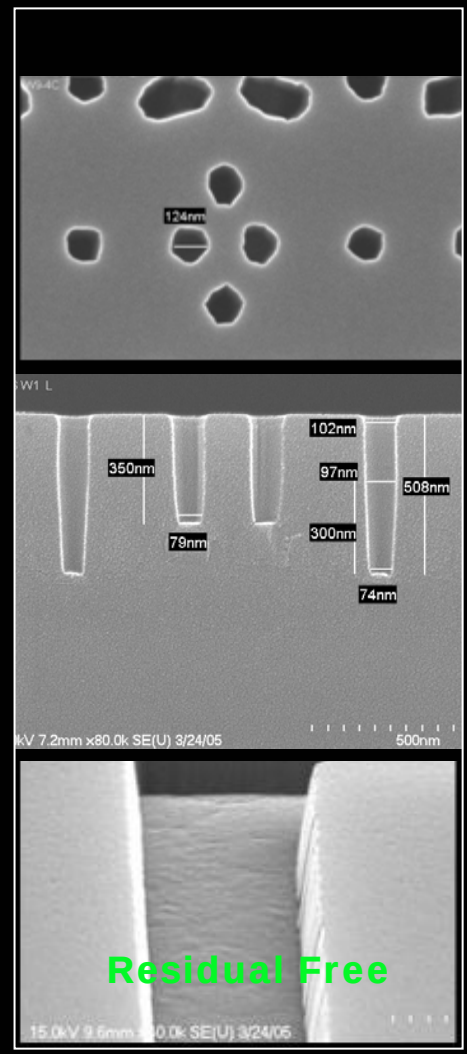
CA Top View

CA Profile

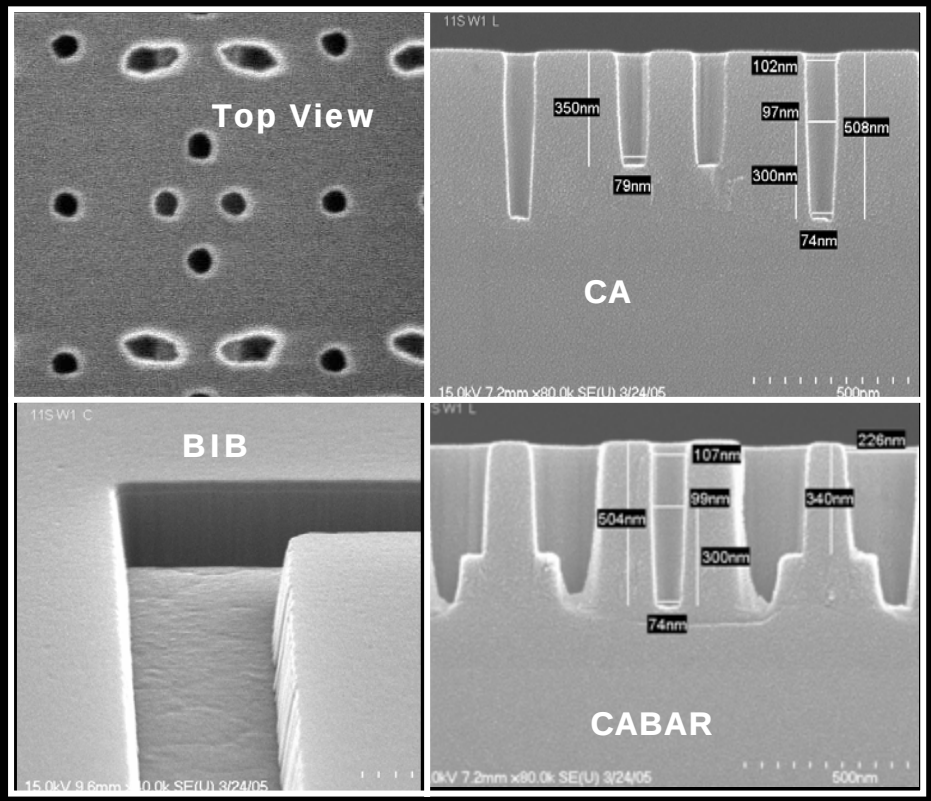
AM/BIB

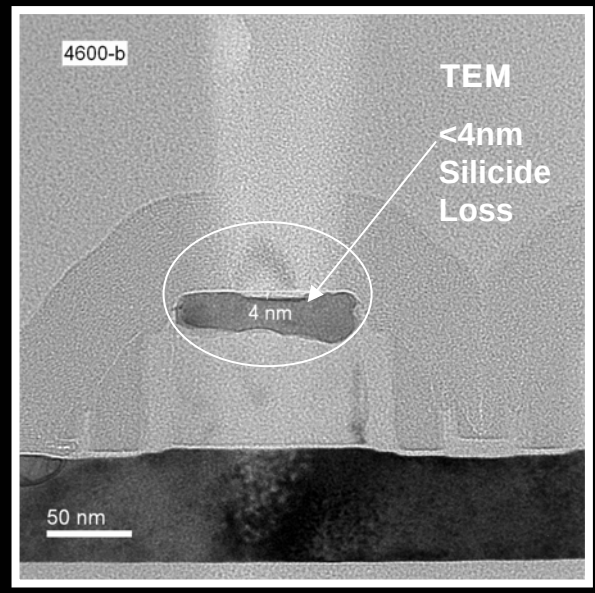


Mixing 2MHz bias with 13.56MHz in oxide etch step clearly improves large area open.



Optimized 65nm Contact Etch

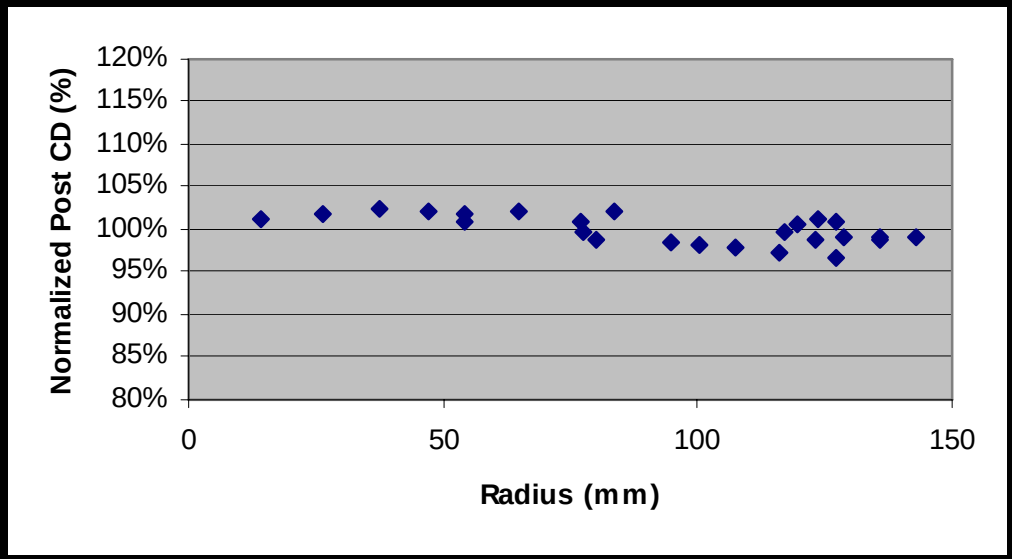


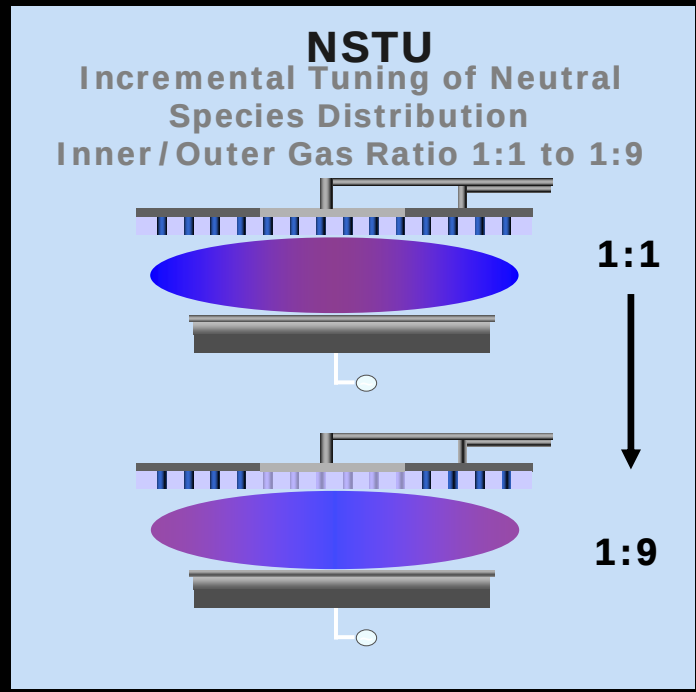


- The DFB feature is particularly useful to achieve CD shrink of >40nm while meeting all other targets.
- Satisfactory contact yield has been demonstrated.

Criteria	Target	Current Result
Profile, degree	>88	>88
TCD/BCD, nm	105/80	104/74
Middle CD, nm	98	97
Post CD Unif, nm	10-15 (C/E)	5 (3S)
SiN Loss, nm	No Punch Thr	No Punch Thr
SiN Profile	No Undercut	No Undercut
Silicide Loss, nm	<5	4nm
Silicide damage	None	None
Striation	Free	OK
Pin Hole	None	None
AM Open	Yes	Yes
BIB Open	Yes	Yes

Contact CD Uniformity Control





- For CD shrink technology, the final CD uniformity could be a challenge.
- Adjustable center to edge gas flow ratio (NSTU) proves to be a useful tuning knob on Enabler for achieving <5.6nm (3 sigma) CD uniformity and <6% CD range.

CD Shrink Scheme Summary

- Many new challenges will present for semiconductor processing of 65nm and beyond.
- Contact etch, as one of the critical FEOL etch modules, is particularly challenging due to limited lithography process window.
- The talk has been focused on the key challenges for Contact etch, in particular on different methodologies for CD shrink.
- We have demonstrated that the etch challenges can be met through methodological process development in conjunction with good understanding of plasma reactor control knobs.