Novel Dry Etch Process Technology Enabling Precision at the Nanoscale: Pushing the Limits of Advanced EUV Patterning

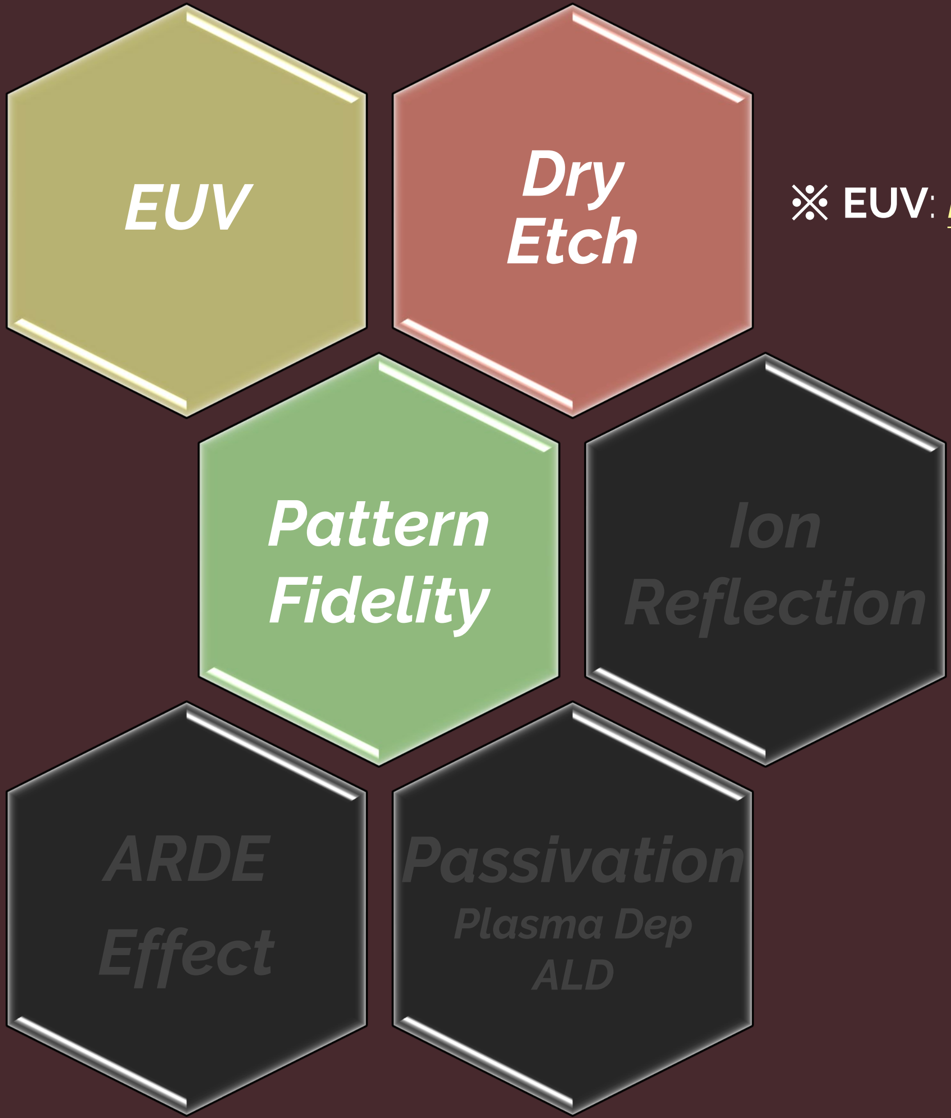
Jasmine Chang[1], Yashvi Singh[2], Chi-Sheng Chang[2], Song Guo[2]
Micron Technology Taiwan[1], Micron Technology USA[2]

Author: Jasmine Chang
ADT PEE Dry Etch
Micron Technology
GSA WLI WISH 2025

These Words Will Keep Coming Up

- EUV
- Dry Etch
- Pattern Fidelity
- Ion Reflection
- ARDE Effect
- Passivation
  - Plasma Dep
  - ALD

※ **EUV**: Extreme Ultraviolet Lithography
※ **ARDE**: Aspect Ratio Dependent Etching
※ **ALD**: Atomic Layer Deposition

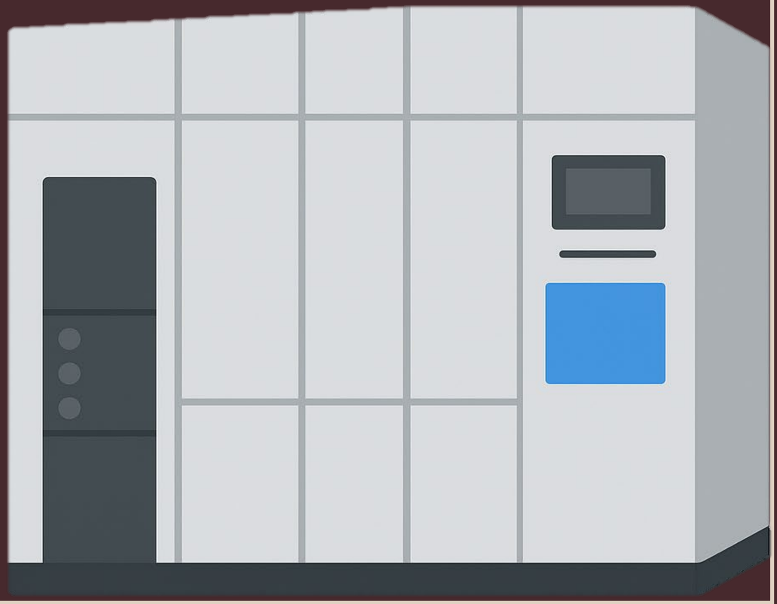


※ EUV: Extreme Ultraviolet Lithography

Why EUV for DRAM?

- DRAM scaling requires finer patterning beyond ArF immersion limits
- EUV enables single-patterning for critical layers, reducing process complexity
- Improves edge placement accuracy and CD uniformity
- Supports advanced DRAM nodes

- **Future trend:**
  - Hybrid lithography and multi-pattern EUV for sub-10nm features

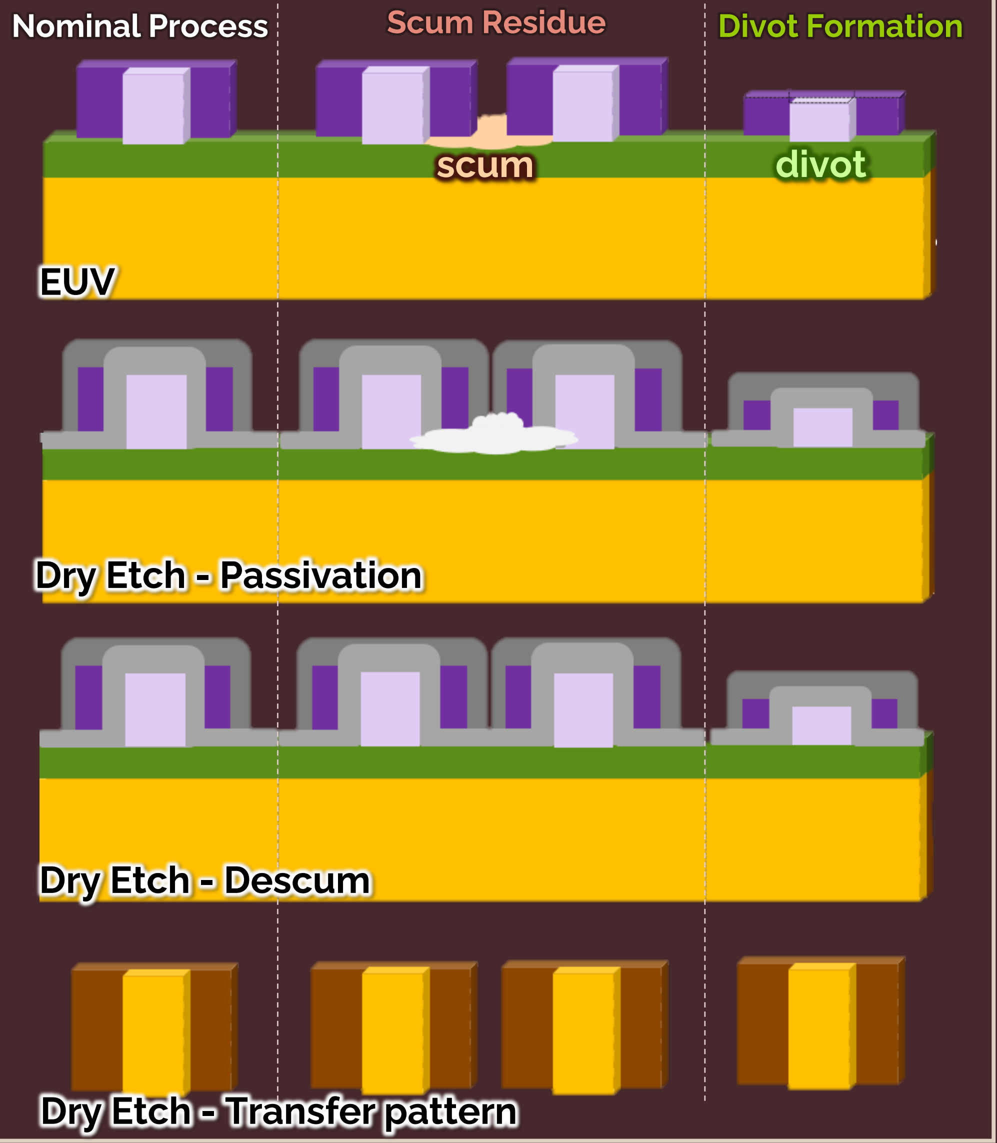


micron

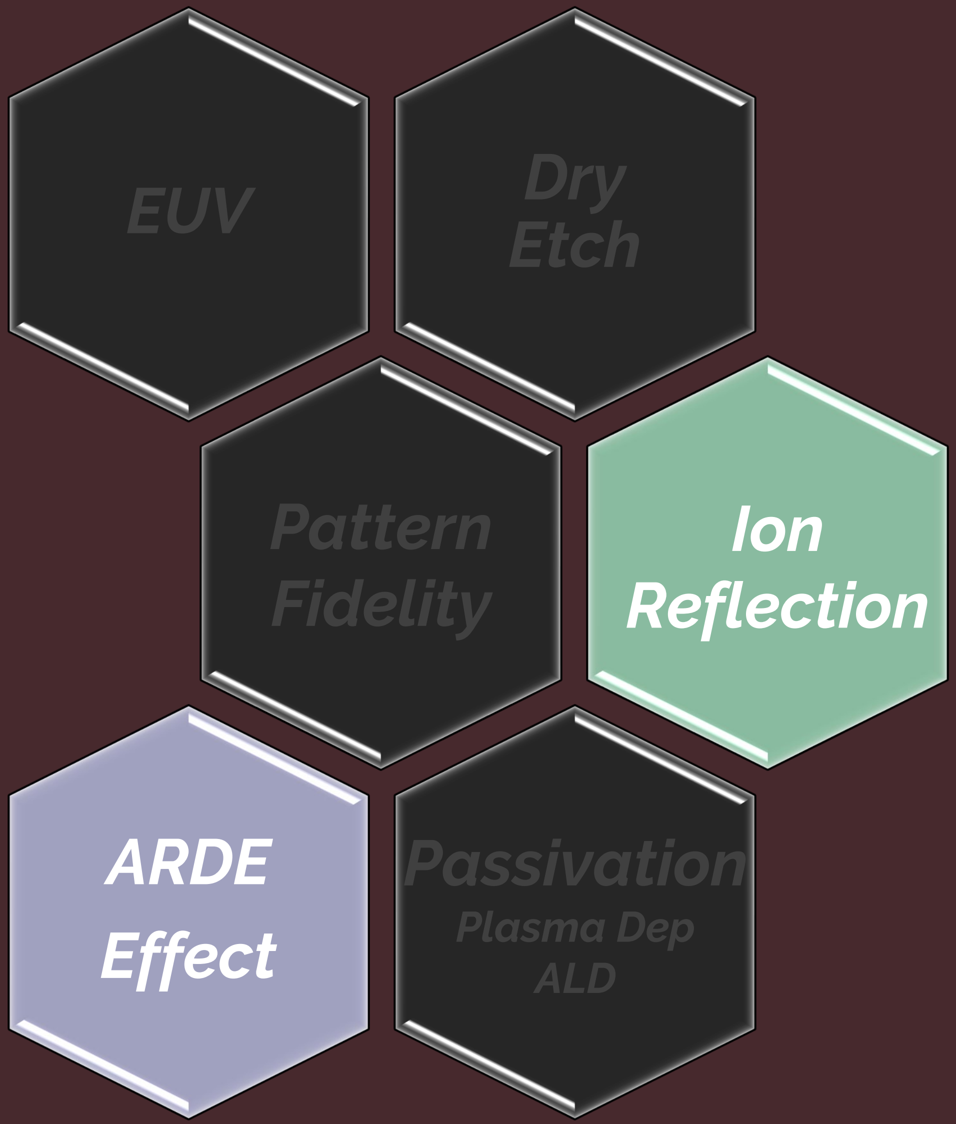
What Are Dry Etch Challenges in EUV Patterning?

- Critical for accurate pattern transfer
- Enhances anisotropy and pattern fidelity

- **Challenges:**
  - Selectivity between EUV resist and film stack
  - Complex hybrid pattern
  - High-Aspect-Ratio Structures



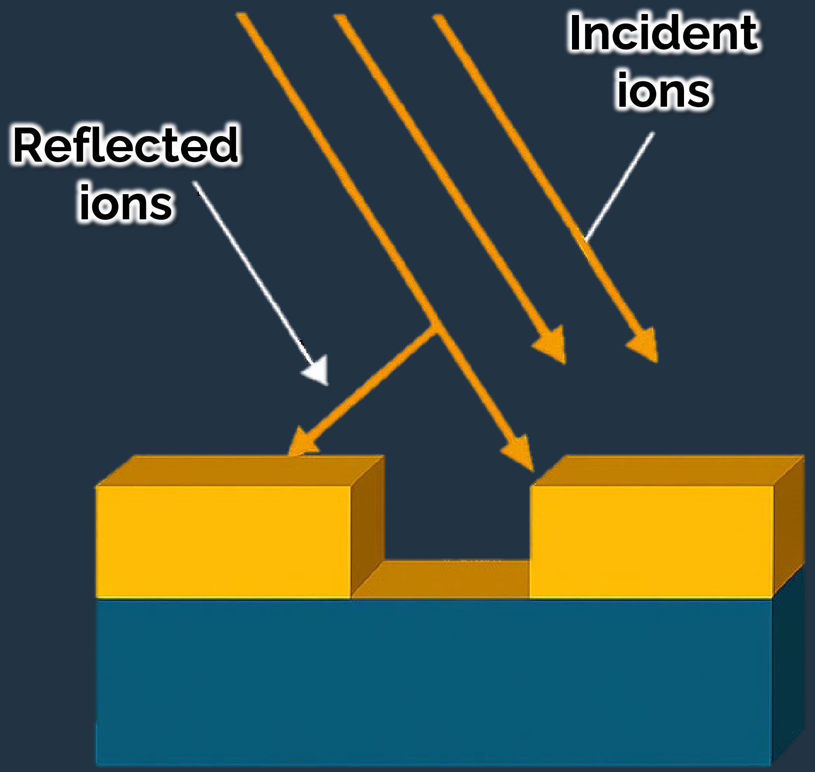
Micron Confidential



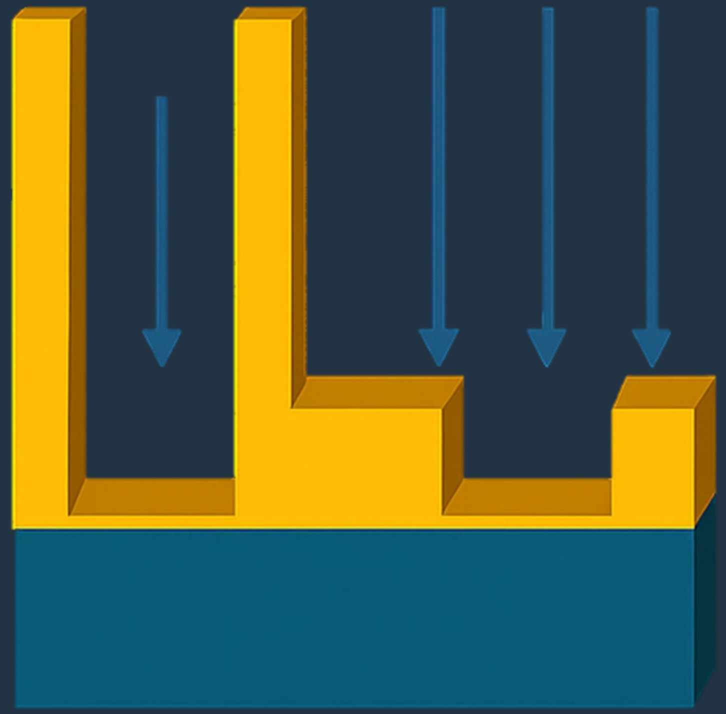
※ **ARDE:** Aspect Ratio Dependent Etching

Single pattern

Key Etch Effects in Ion-Based Processes



***I**on **R**eflection effect*

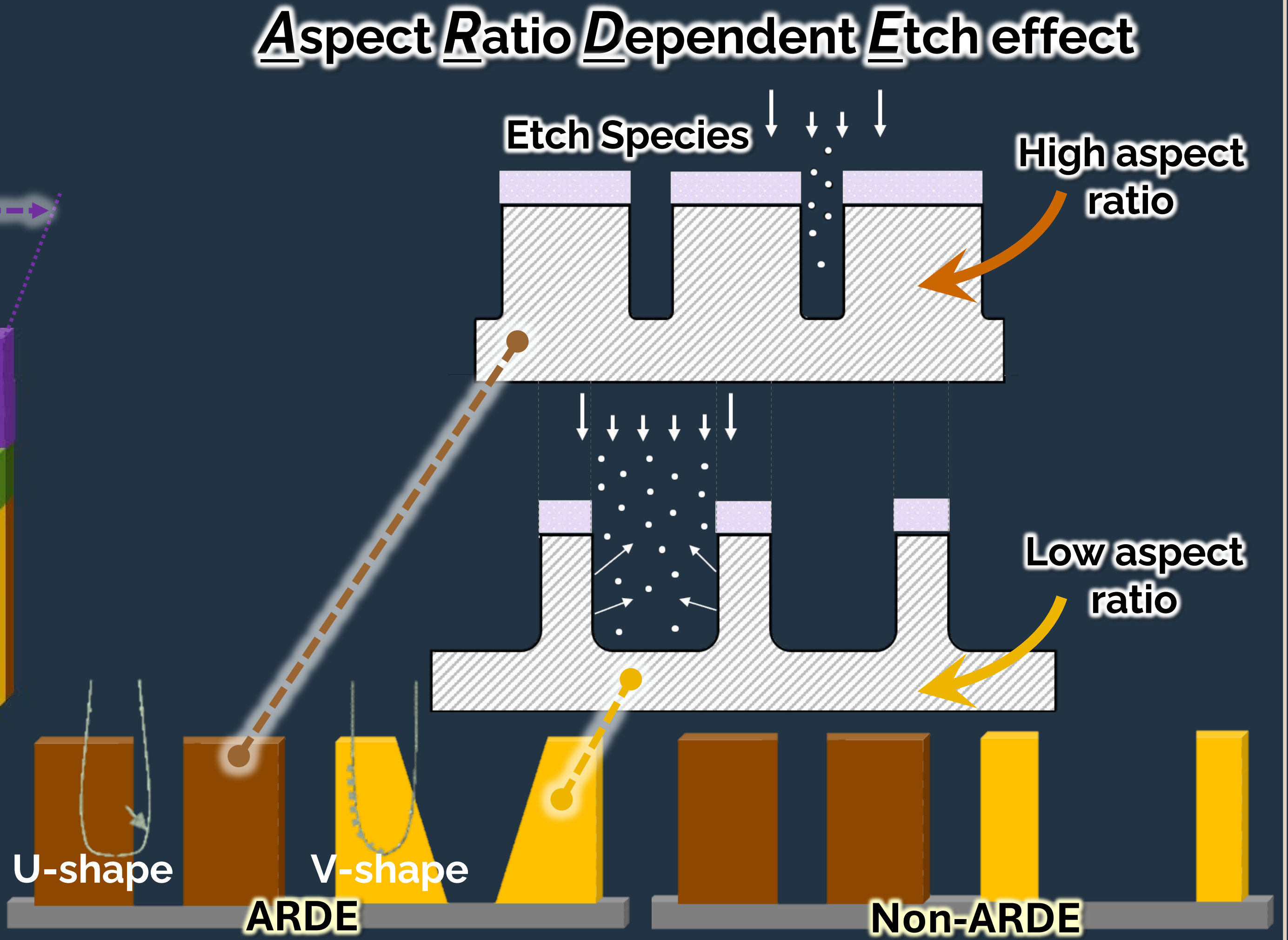


***A**spect **R**atio **D**ependent **E**tch effect*

Ion reflection and aspect ratio effects are critical factors influencing etch profile control in ion-based dry etch processes.

micron

Key Etch Effects in Ion-Based Processes



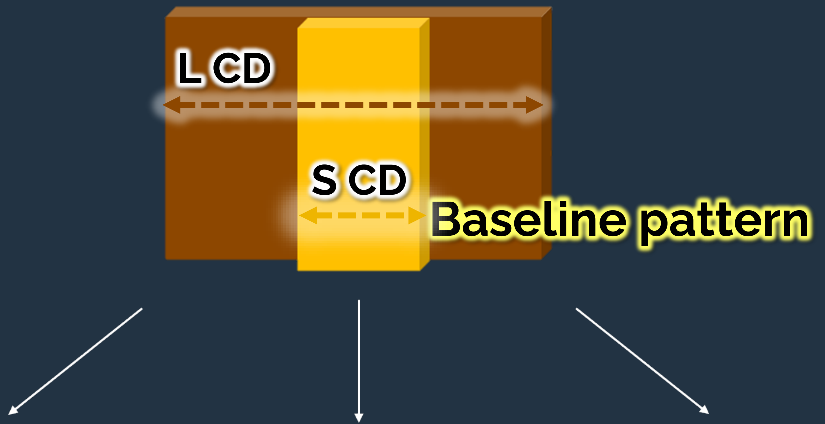
Ion reflection and aspect ratio effects are amplified in EUV hybrid geometry patterns, making etch profile control more challenging.

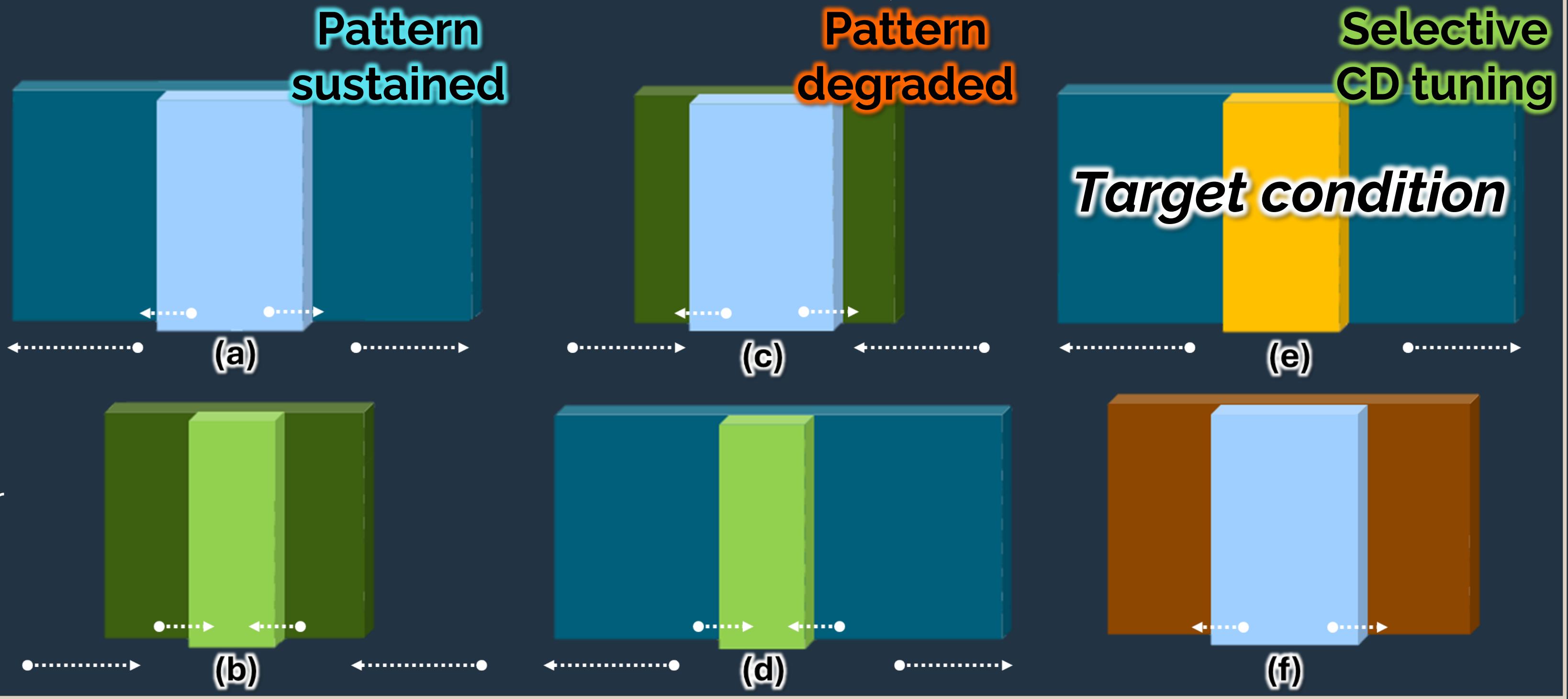
micron

Micron Confidential

Selective CD Tuning for EUV Pattern Preservation

Case	L CD post Dry Etch	S CD post Dry Etch	L-S CD post Dry Etch	Sustain shape of EUV pattern
(a)	↑	↑	Keep	Yes
(b)	↓	↓	Keep	Yes
(c)	↓	↑	Decreases	No
(d)	↑	↓	Increases	No
(e)	↑	-	***Increases***	***Proposed***
(f)	-	↑	Decreases	No

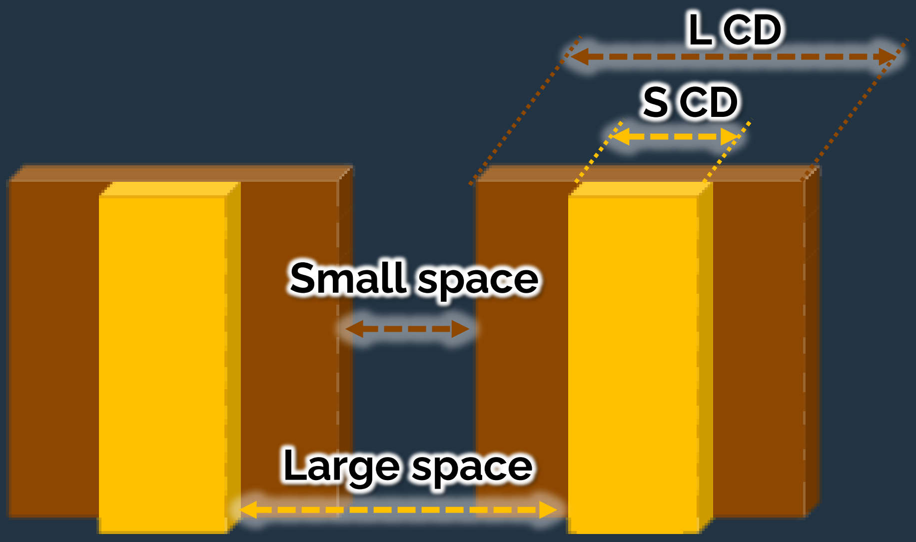




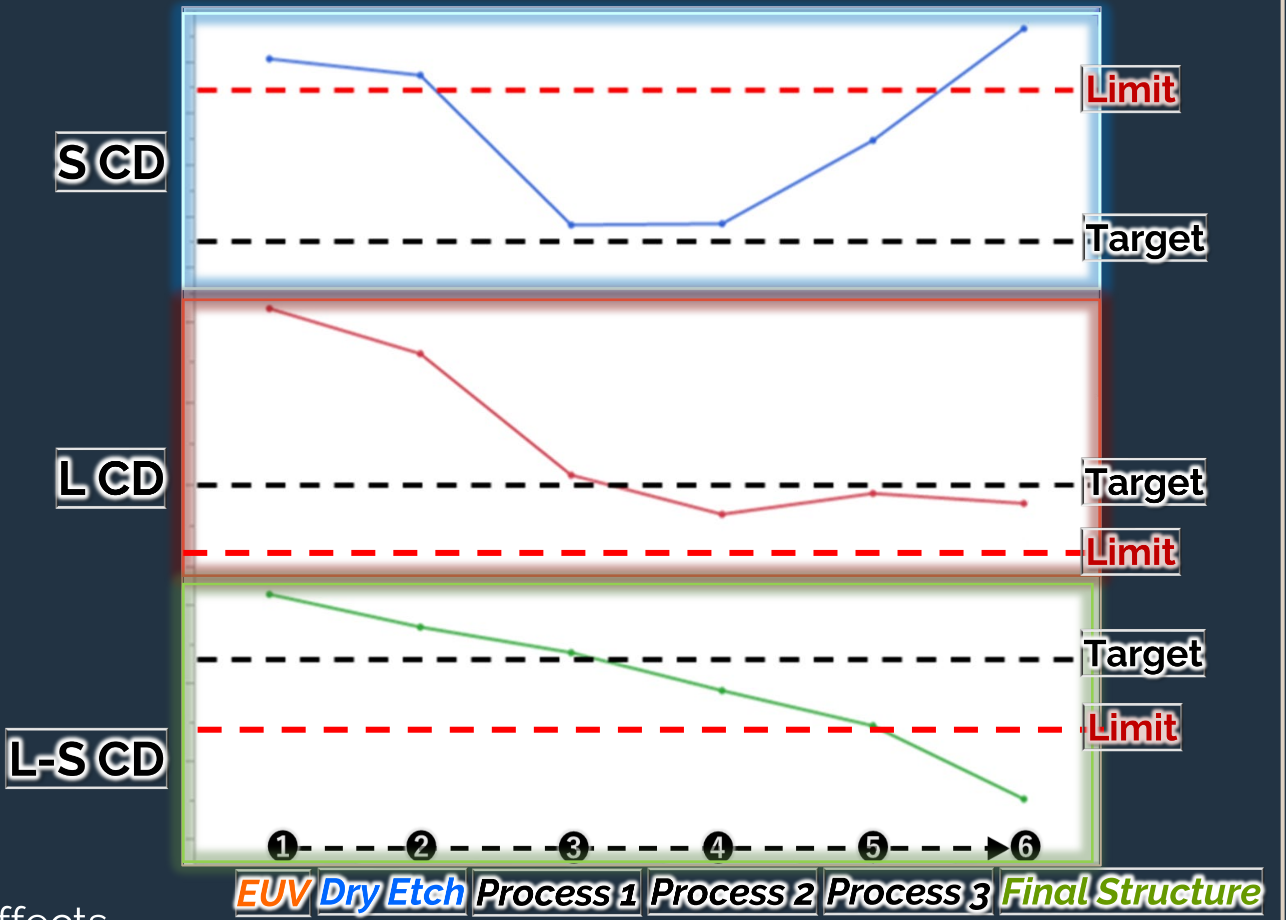
In EUV-defined novel patterns, case (e) is targeting condition, the faster erosion of L CD poses a challenge for Dry Etch control.

Hybrid Geometry Patterns

Progressive CD Loss

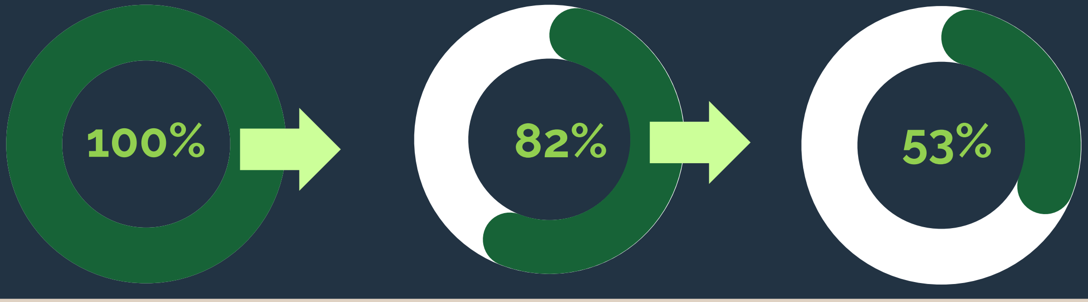


※Pattern Ratio = L-S CD

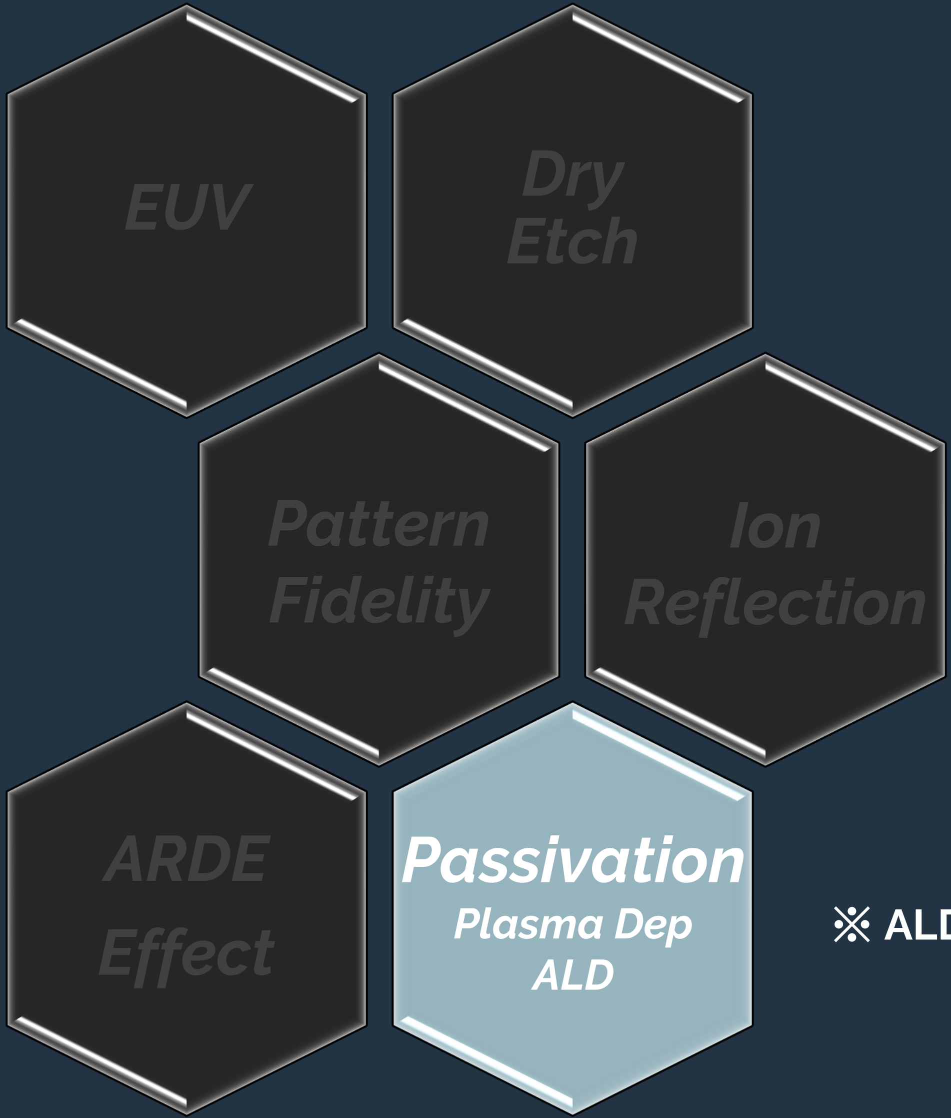


Progressive L-S CD loss results from cumulative etch effects, such as ion reflection, ARDE, and space-dependent erosion. Effective dry etch tuning is essential to mitigate.

L-S CD loss



micron

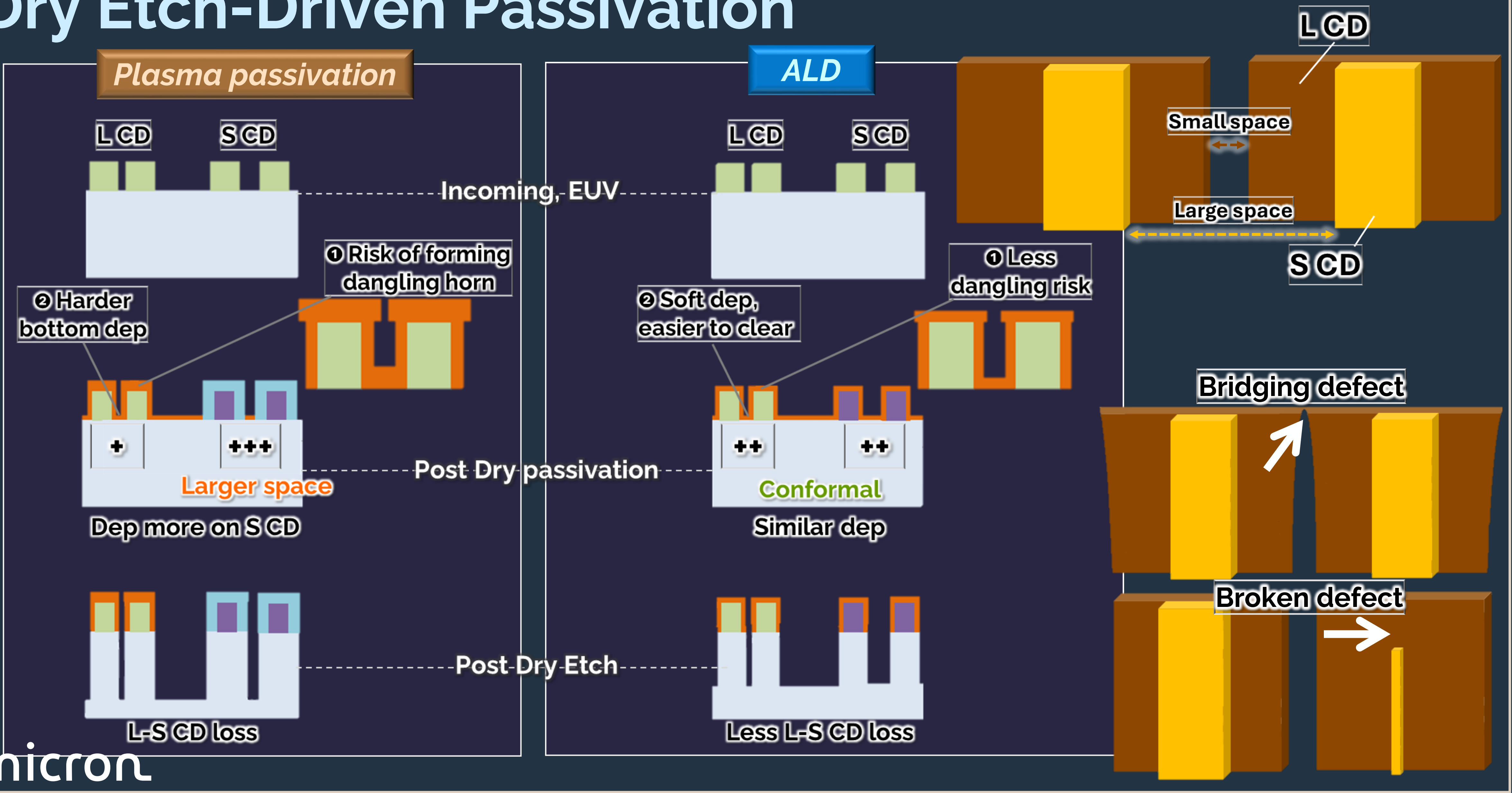


※ **ALD**: Atomic Layer Deposition

Micron Confidential

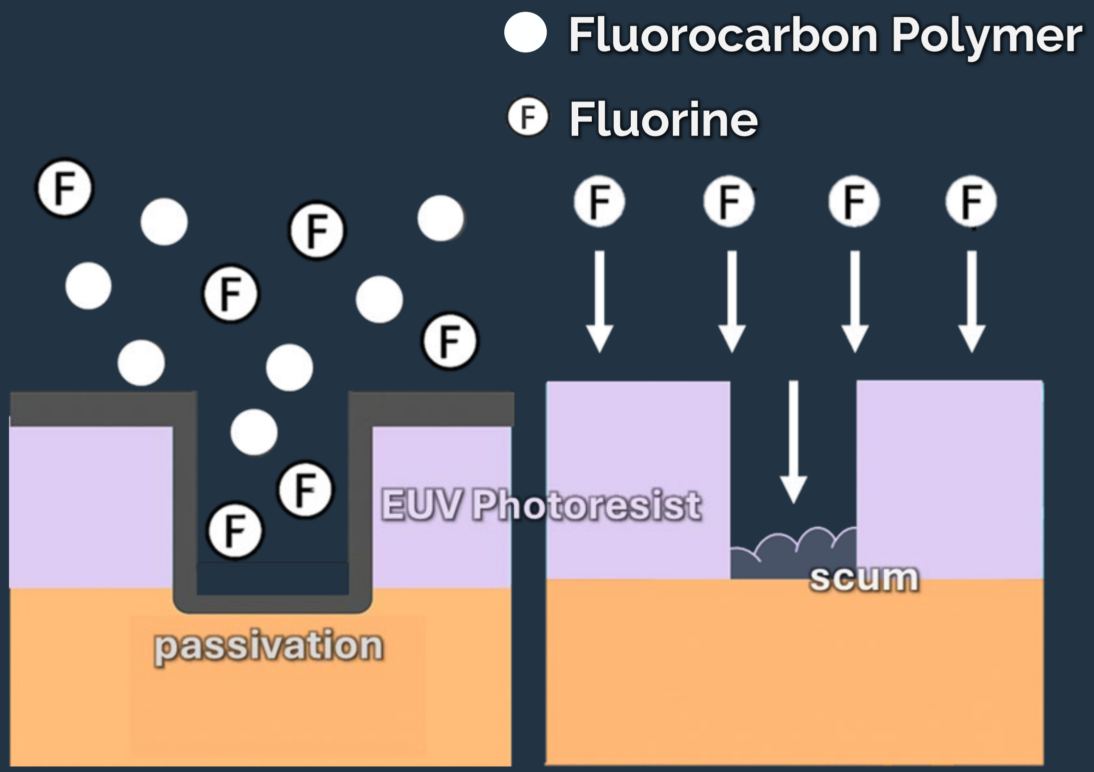
Hybrid Geometry Patterns

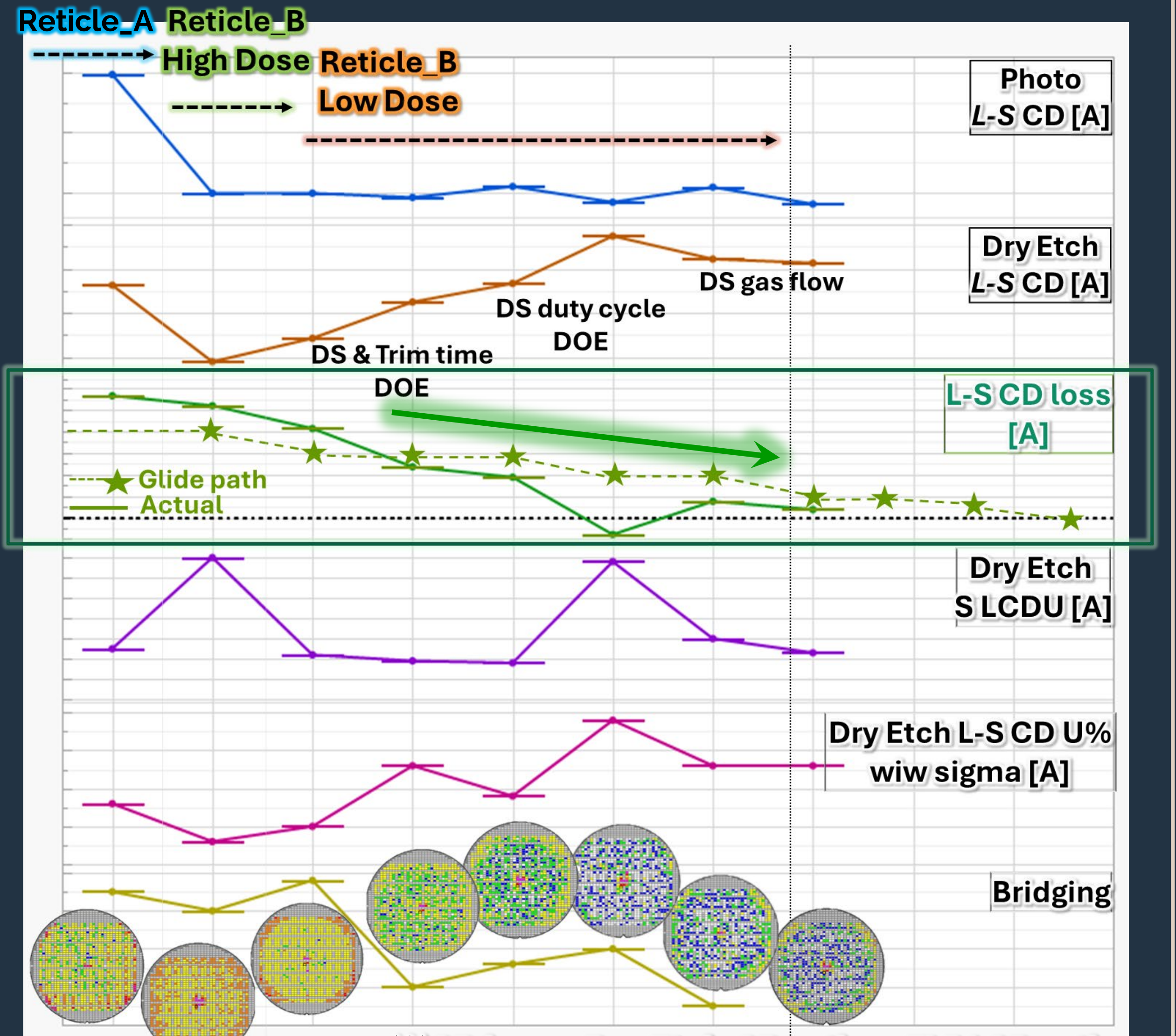
Dry Etch-Driven Passivation



micron

Suppressing CD Loss through Dry Etch Engineering





※CD loss = Dry Etch CD ratio – EUV CD ratio

Effective suppression requires a balanced Etch approach, integrating ***Descum*** and ***Trim*** processes while carefully managing passivation and etching dynamics.

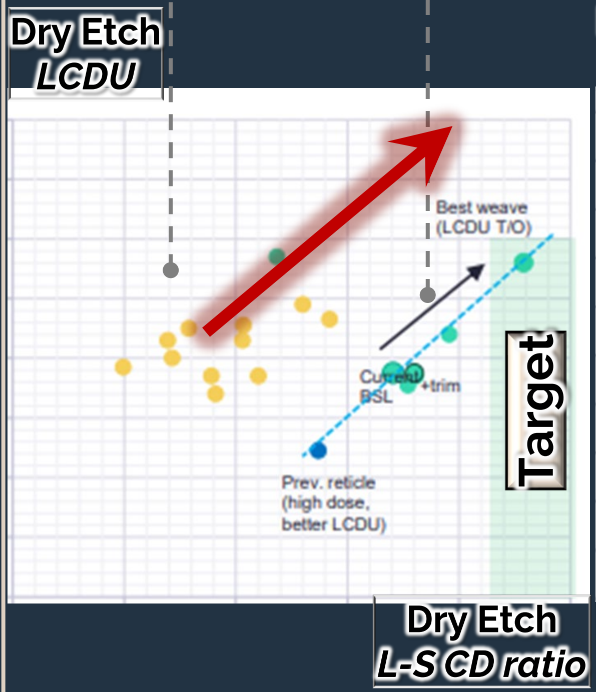
micron

Dual Pattern Etch Roadmap - Let’s Dive In

Dry Etch Key Stages to Expand EUV process Window

Initial Stage

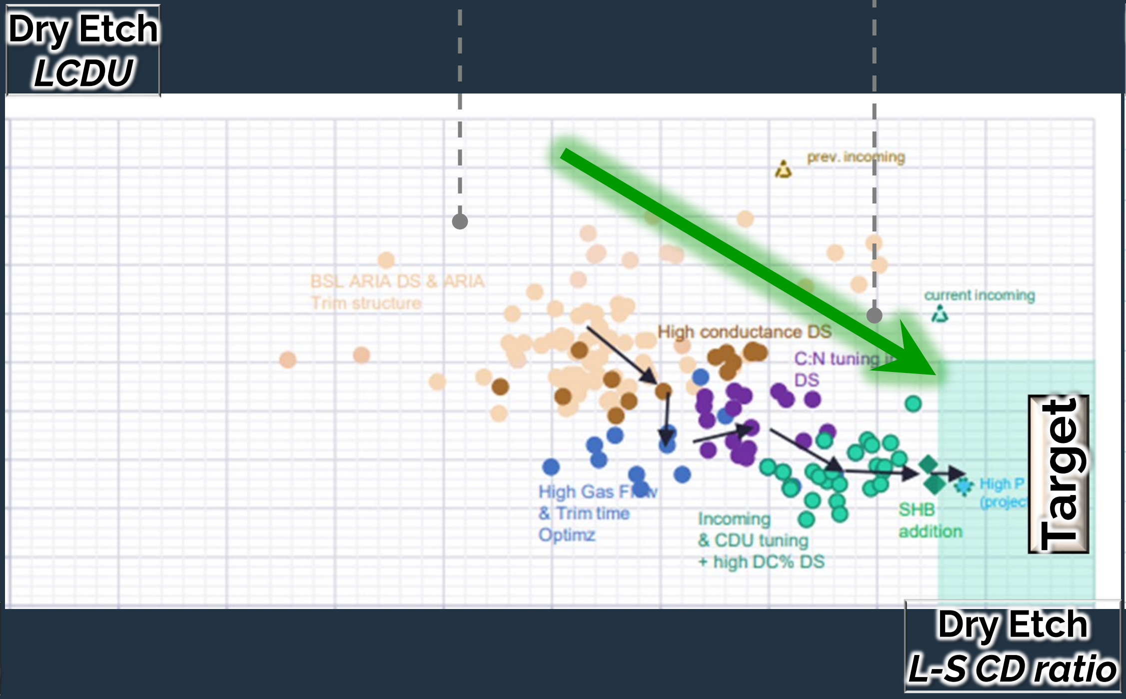
Trade-off



Process trade-off challenge

Intermediate Stage

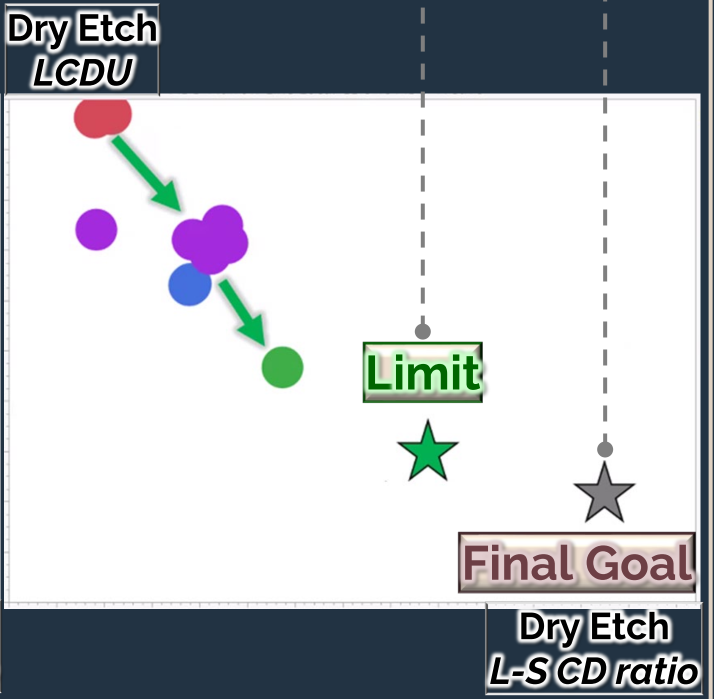
Descum & Trim Process Development | **Trade-off Resolution**



Break trade-off from Descum and Trim process

Final Stage

Implementation of New Approach



Integrated EUV and Dry Etch for advanced and novel hybrid geometry pattern control

micron

※LCDU = Local Critical Dimension Uniformity ≈ 3σ

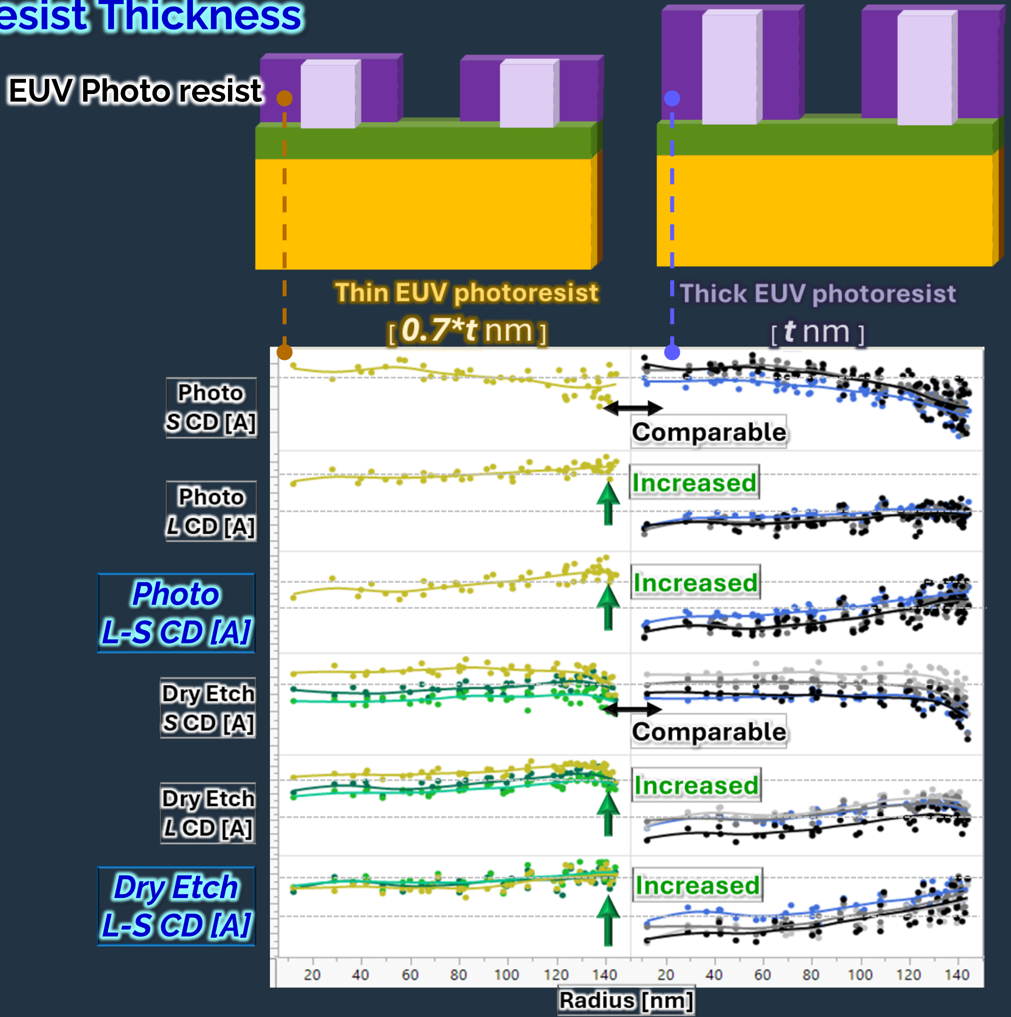
Beyond Etch: Where Else Can We Win?

micron

Hybrid Geometry Patterns

Opportunities in CD loss - *EUV Lithography*

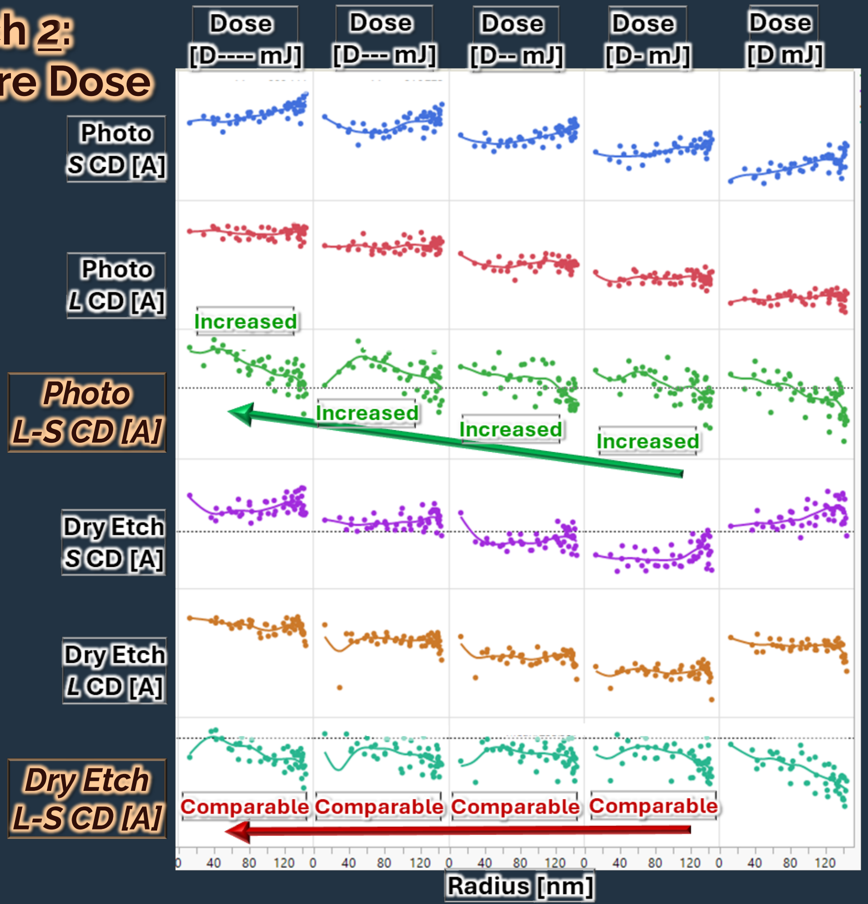
Approach 1: EUV Resist Thickness

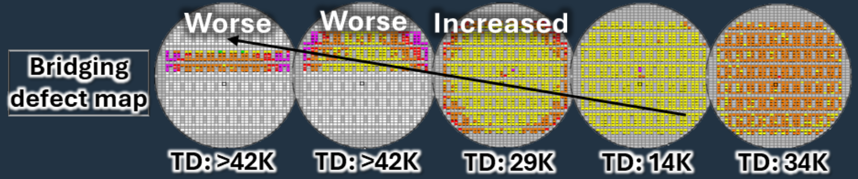


micron

Thinner resist brings *higher EUV CD ratio*

Approach 2: EUV Exposure Dose





Trade-off between *Dose, CD ratio* & *Bridging*

Hybrid Geometry Patterns

Technical Highlights

EUV Lithography [13.5nm wavelength]

Key Features

- Enable scaling to advanced semiconductor nodes
- High resolution
- Process simplification

Challenges

- Mask defectivity
- Resist materials

Dry Etch [Hybrid patterns]

Challenges

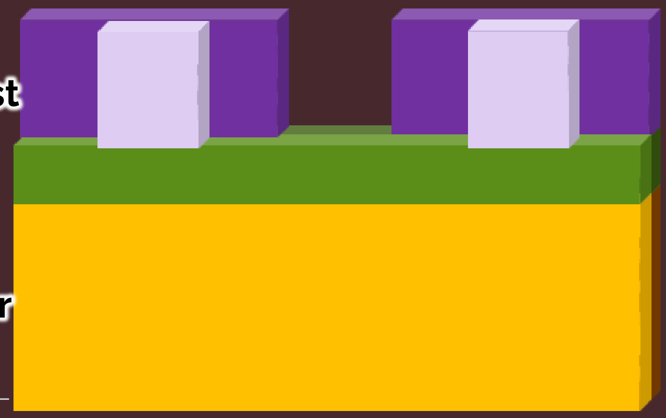
- Ion reflection causing CD loss
- Aspect Ratio Dependent Etching effect
- Micro loading

Mitigation

- Passivation techniques
- Gas chemistry selection

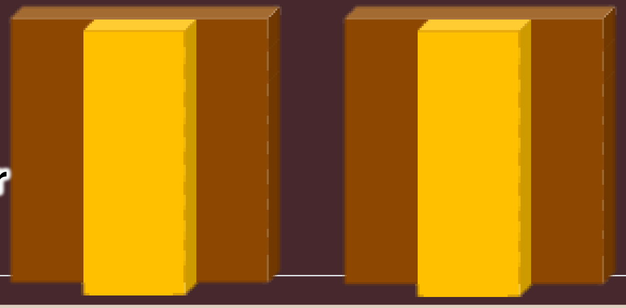
Hybrid pattern definition

EUV Photo resist



Underlayer

Pattern transfer to underlayer



Underlayer

micron

Co-Author

Yashvi Singh, Micron Technology

Chi-Sheng Chang, Micron Technology

Song Guo, Micron Technology

Jasmine Chang

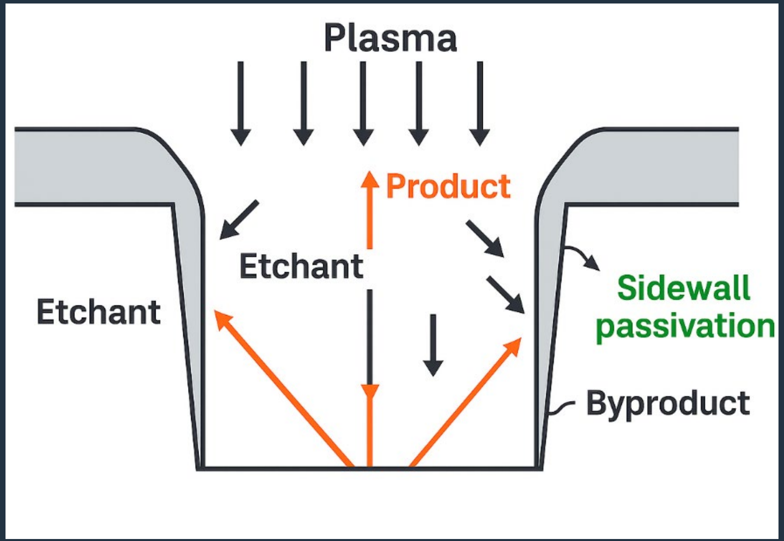
Micron Technology

jchang@micron.com

Single pattern

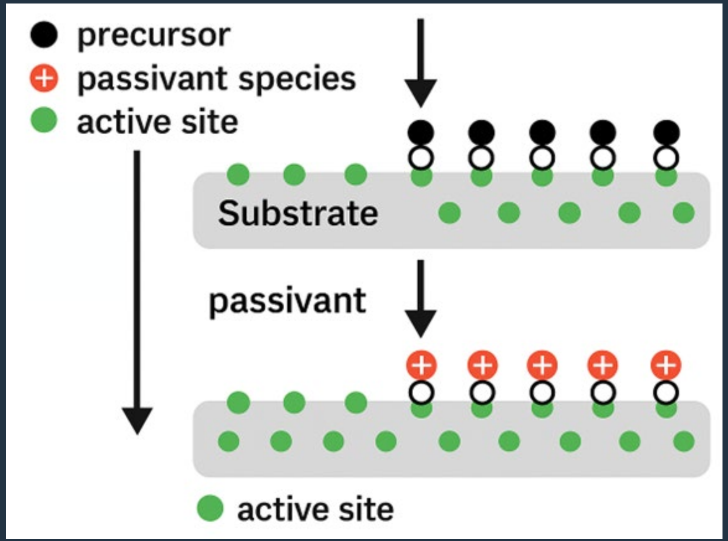
Strategies to Mitigate CD Loss: Dry Etch Passivation

Strategy ❶ : Plasma passivation



G. S. Oehrlein et al., *Sidewall surface chemistry in directional etching processes,* Materials Science and Engineering: R: Reports. Volume 24, Issue 4, 15 December 1998, Pages 153-183.

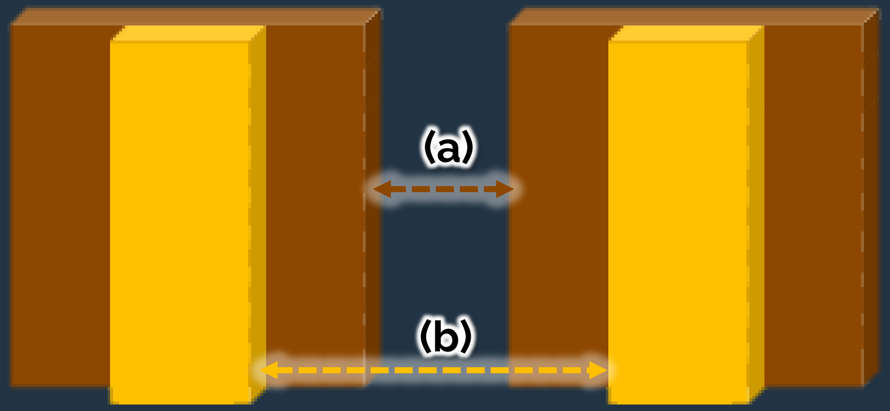
Strategy ❷ : ALD passivation

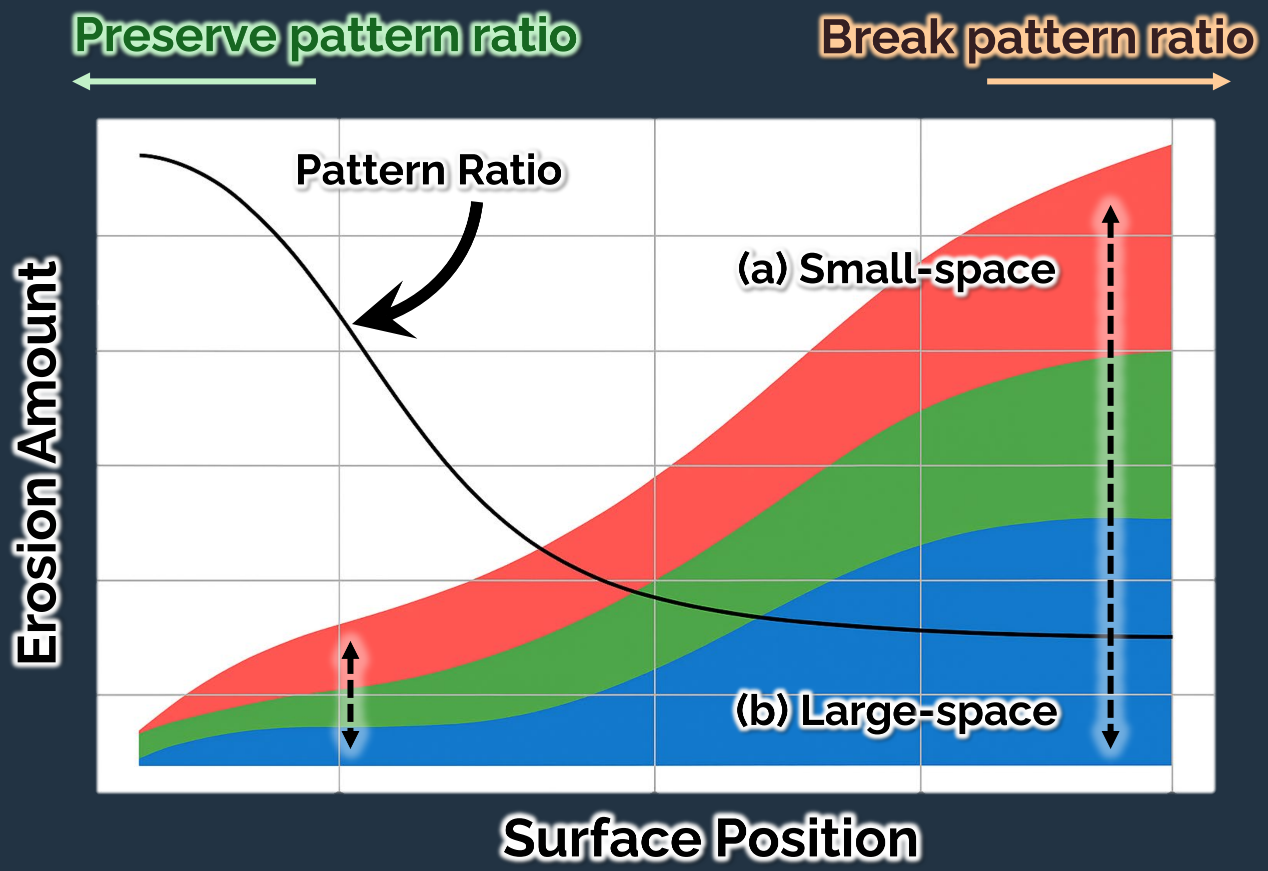


Nanomanufacturing: ALD Fundamentals, Eindhoven University of Technology.

Both plasma and ALD passivation offer viable dry etch strategies to mitigate CD loss, with distinct mechanisms suited for different pattern geometries and process requirements.

How Space Size Affects Pattern Integrity?

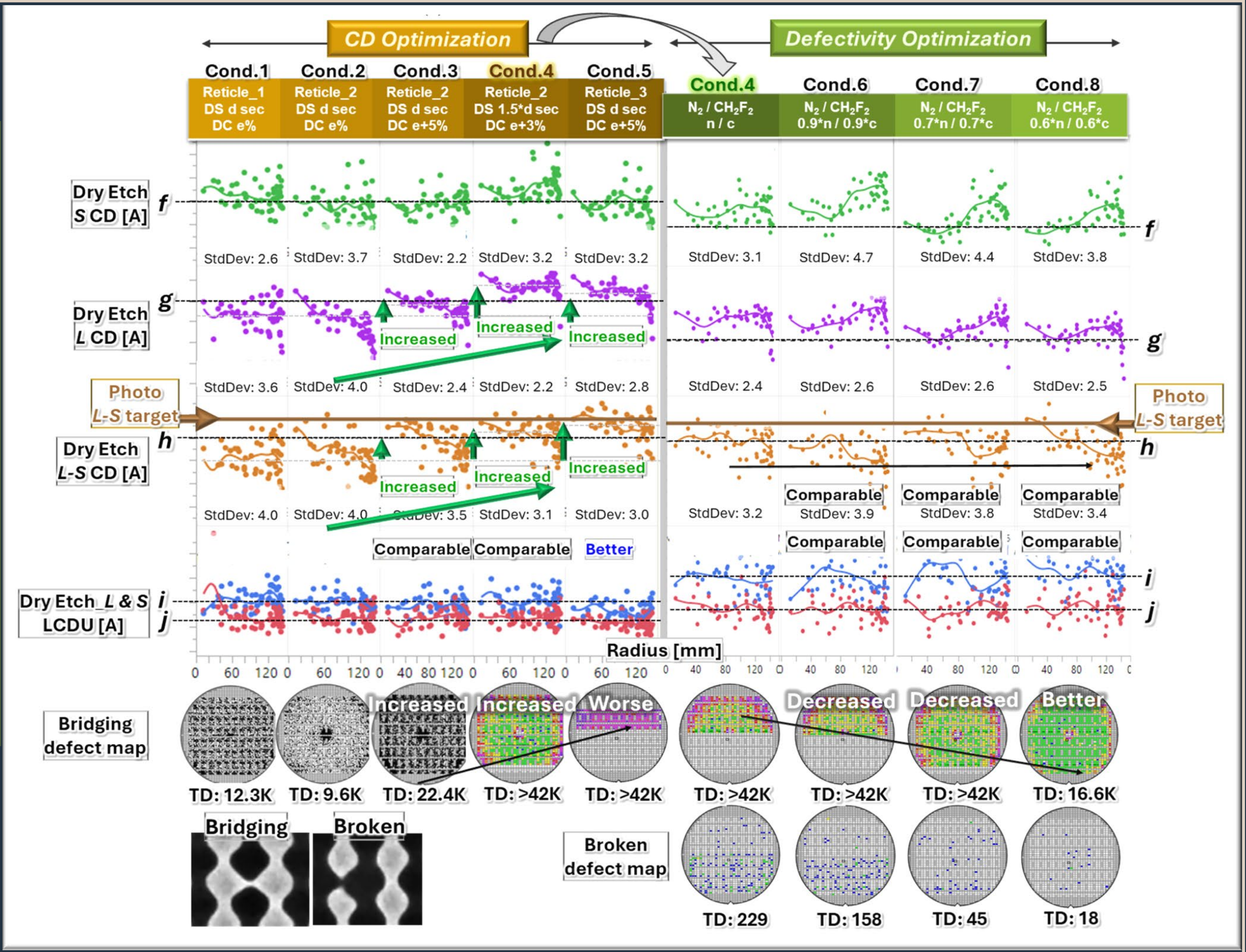




Smaller space features exhibit faster erosion rates, leading to pattern ratio distortion and increased risk of profile degradation.

Achievement

- ***CD:*** Achieved ***L-S CD loss <5A***
- ***Methodology:*** Identify optimal balance between ***Descum*** & ***Trim*** steps through DOE
- ***Defectivity:*** Determine ***gas flow*** is key factor of ***L-S CD*** & ***defectivity*** trade-off
- ***Forward looking:*** Good methodology for future planar DRAM scaling - How to ***etch EUV-defined complex patterns***



micron