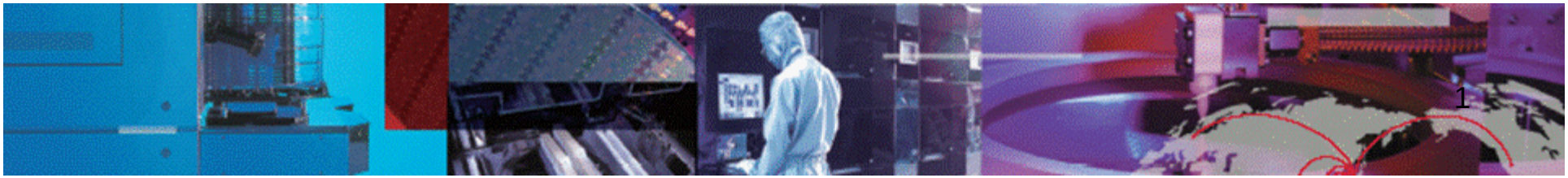
Track Technology for Sub-40nm Patterning

Glen Mori

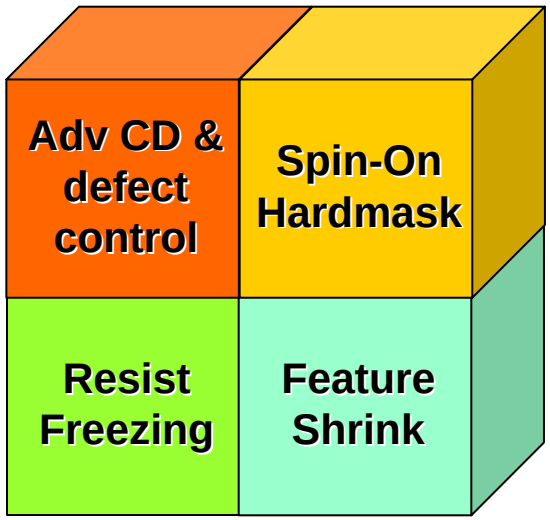
Sokudo Litho Breakfast
Semicon West 2008
July 16, 2008



Overview

- **Many patterning strategies at sub-40nm node – Sokudo focus on track "building blocks" as enablers**
- **CD and defectivity control will be more challenging than ever**
  - **additional knobs for compensating CD non-uniformity**
  - **Enhanced process capability & defect-prevention "insurance"**
- **Enabling technology for resist freezing**
  - **Resist freezing requirements**
  - **Partnering with materials vendors and customers to provide cost-effective solutions**
- **Optimized tool configuration and process integration for double-patterning, tri-layer resist and shrink**

Track Building Blocks to Enable Double-Patterning



Patterning Strategies

- Litho-etch-litho-etch
- Litho-litho-etch
- Self-Aligned DP
- Dual damascene
- Contact hole & trench shrink

Master the track building blocks....

and practice the applications to develop practical know-how in order to.....

help customers develop cost-effective patterning solutions

SOKUDO

Bake Capabilities for Enhanced CD Control

- **Plate-to-plate matching**
  - Temperature uniformity
  - Temperature ramp profile
- **PEB temperature biasing to improve:**
  - DICD uniformity
  - FICD uniformity
- **Hard-bake temperature biasing to improve:**
  - Post-shrink CD uniformity
- **Warped wafer compensation**
  - For contact
  - For BEOL

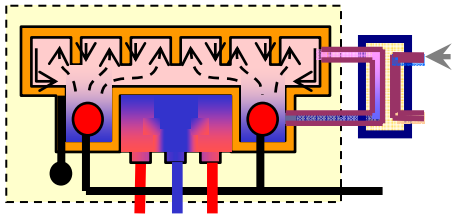
Sokudo PEB/PAB (resist) Bake Options

SRHP

- Fast response time

Applications

- KrF, ArF, Immersion



VRHP

- Vacuum chuck for warped wafers
- Single-zone, excellent stability

Applications

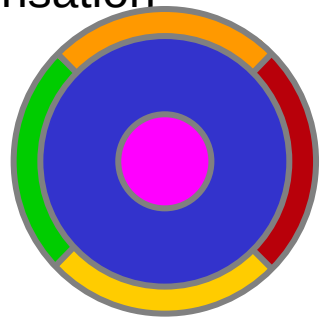
- KrF, ArF, Immersion
- Shrink Process for Contacts

BHP

- Biased Hot Plate (BHP)
- Warped wafer compensation

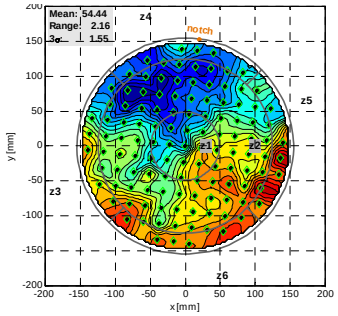
Applications

- KrF, ArF, Immersion
- CD Tuning



SOKUDO

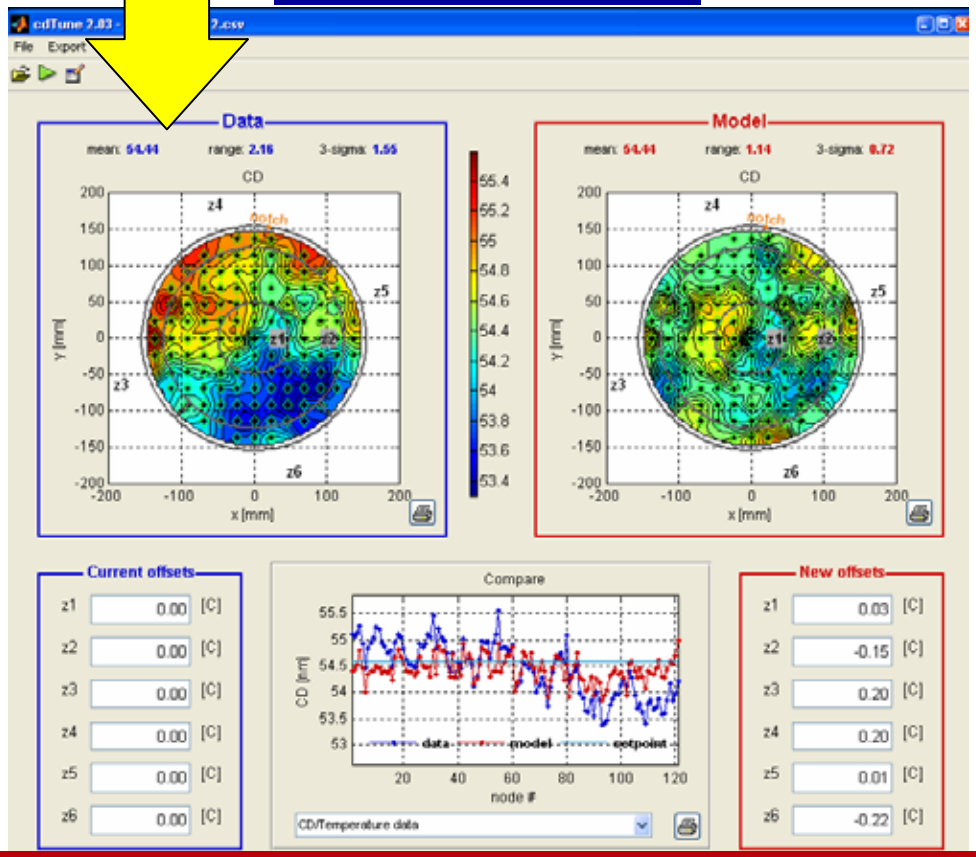
Model-Based (DI)CD Tuning Using BHP - Example

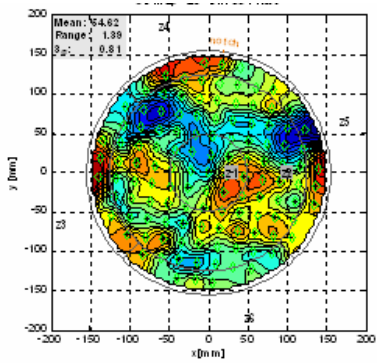


Input: Temp. Tuned CD Data

CD, nm	54.44
CDU, nm	1.55

cdTune™





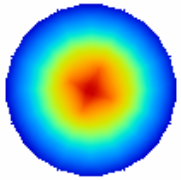
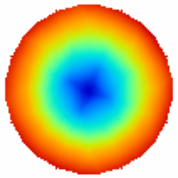
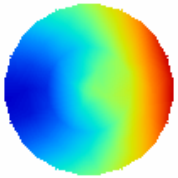
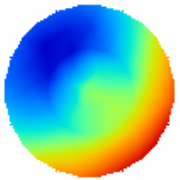
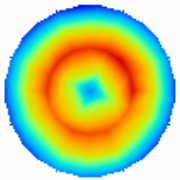
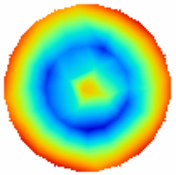
Output: Offsets and Model Prediction for CD Tuned Condition

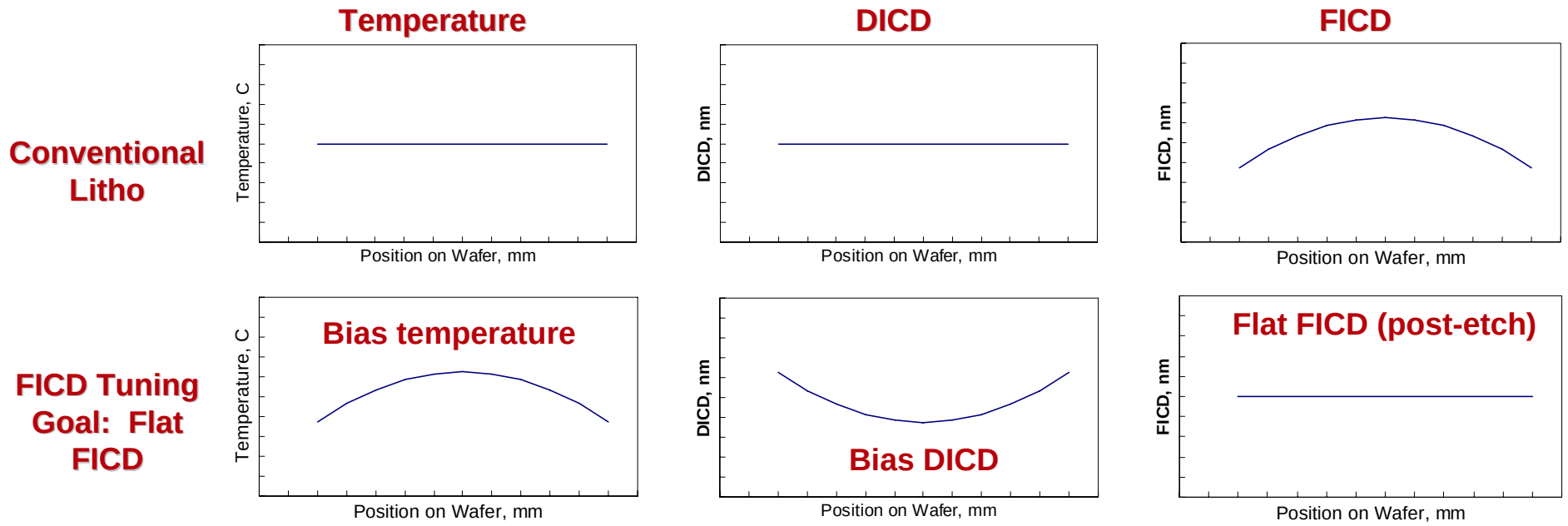
CD, nm	54.44
CDU, nm	0.81

"CD-tuned" in 1 iteration

SOKUDO

PEB Compensation for Post-Etch (FI)CD Improvement

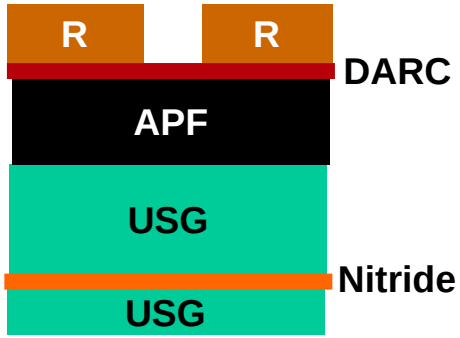
	Mountain (convex)	Valley (concave)	Wedge	Rotated Wedge	Annular Hot ("M")	Annular Cold ("W")
Sample Temperature Contour Maps						



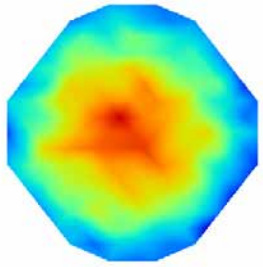
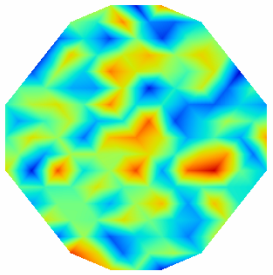
Potential for >35% (FI)CDU improvement

SOKUDO

VRHP CDU Improvement for Bowed Wafers



C/H process flow:
1. print 90nm C/H on stack as shown
2. Shrink to 72nm diameter
3. CD-SEM measured post-shrink.

PEB (Wafer bow >+200 μm)	SRHP (uncorrected)	VRHP
CD	**72.4**	**73.8**
CDU 3s	**15.7**	**3.9**
Range	22.3	5.6
CD Map		

4X CDU improvement for C/H process

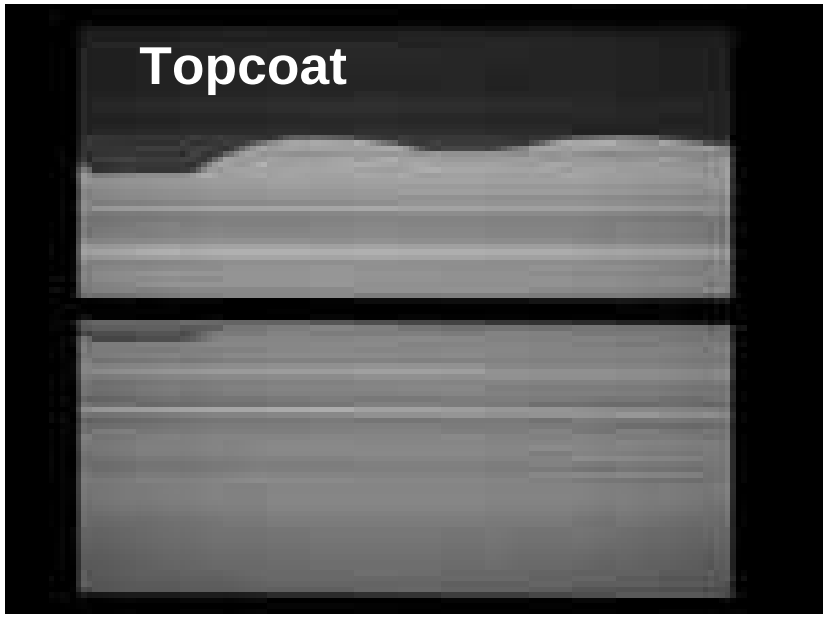
SOKUDO

Capabilities for Enhanced Defectivity Control

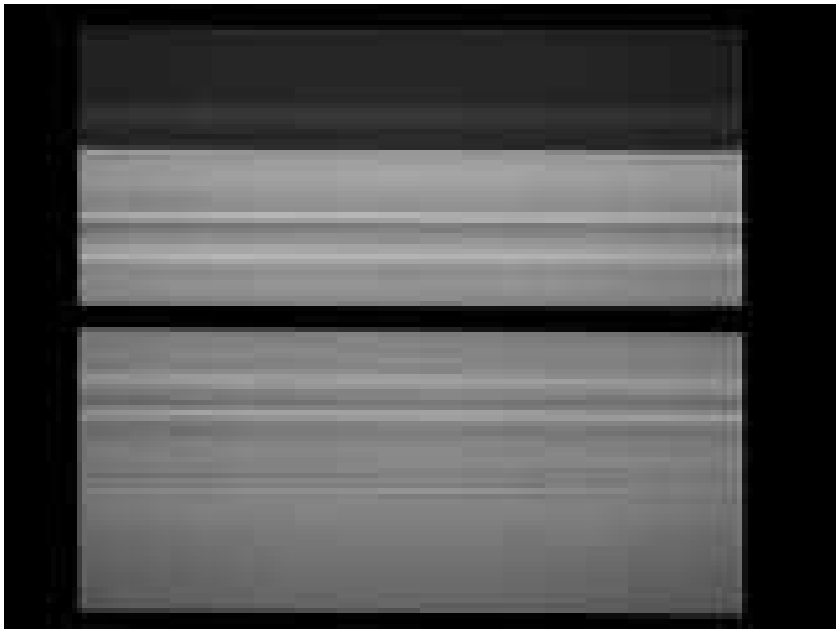
- **Bevel clean***
- **Precision edge engineering**
- **New Develop Rinse for Blob/Stain Reduction**

* - refer to SPIE 2008 proceedings for more information regarding bevel brush clean (BBC)

Improved EBR for Immersion Lithography



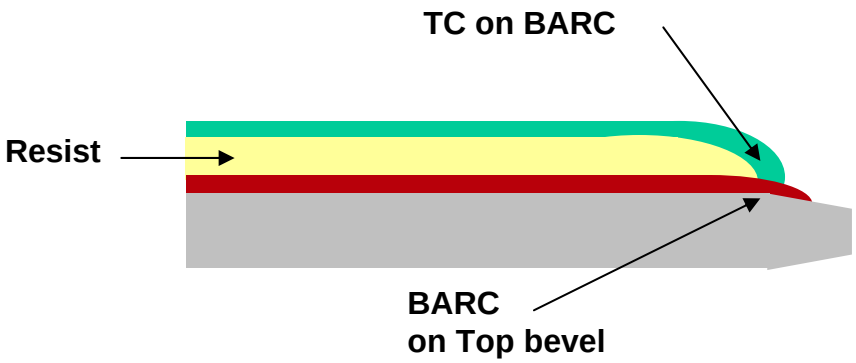
Conventional Back Rinse EBR

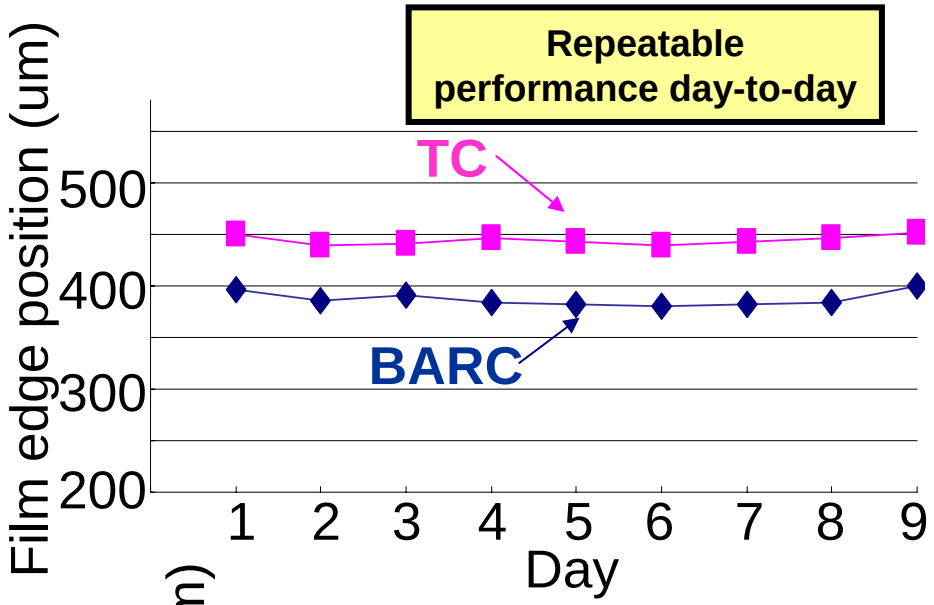


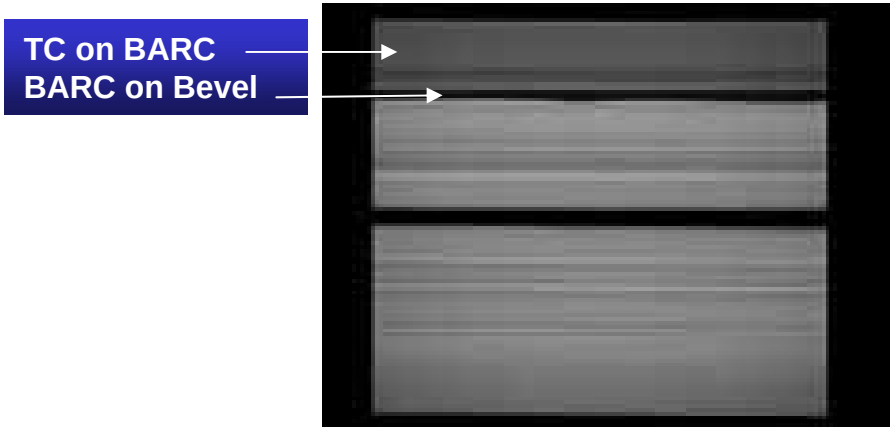
New Bevel Rinse H/W & Process

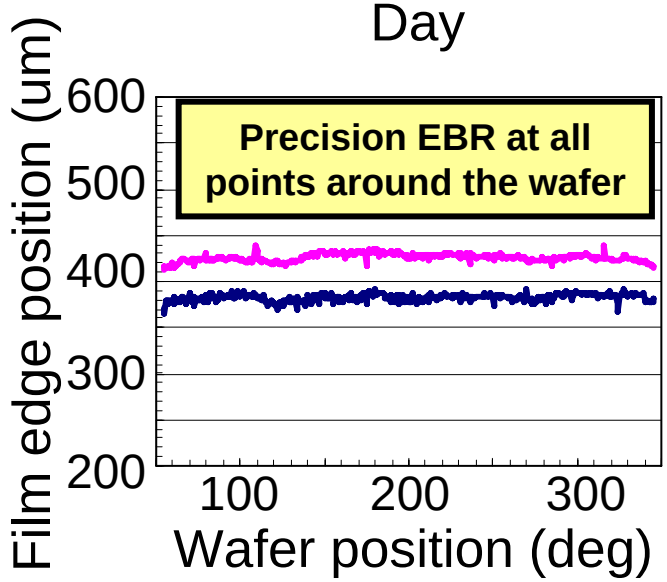
SOKUDO

New Bevel Rinse Performance



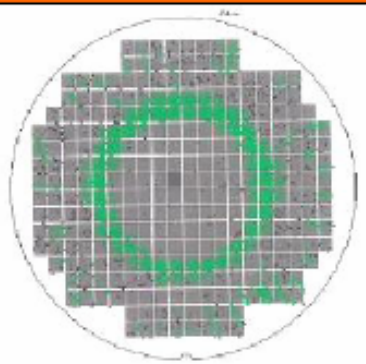
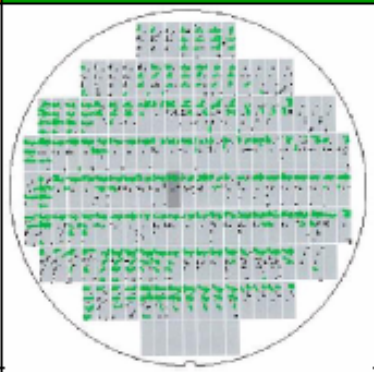
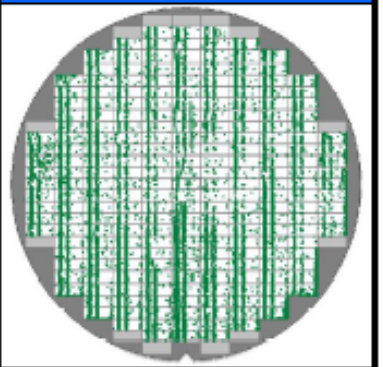
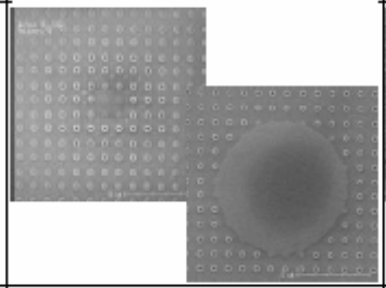
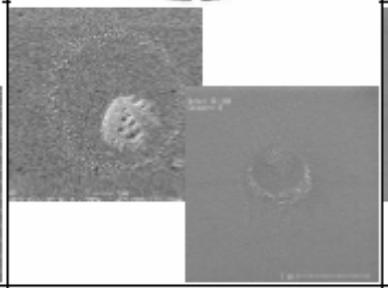
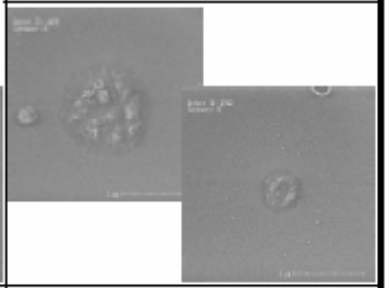






SOKUDO

Blob Defect Reduction is Needed

Resist	KrF	ArF	Immersion
Wafer Map			
SEM Image			
Defect Area	Dense	ISO	ISO

Hydrophobic topcoat-less resist requires a new develop solution

New Develop Rinse – Darkfield Mask

Blob Defect ~TArF-P6239~

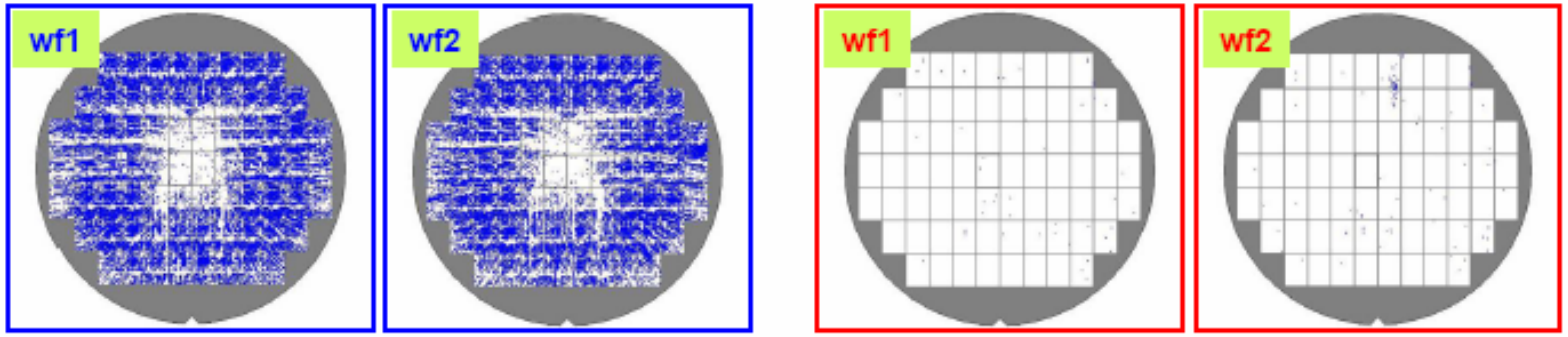
DIW Rinse

	wf 1	wf 2	Average
Total	49420	47791	48606
Blob	43984	41100	42542

New Develop Rinse

	wf 1	wf 2	Average
Total	80	268	174
Blob	8	23	16

99.96% Reduction



Blue dots mean detected defects.

Inspection	:KLA2360
Light Source	:DUV
Mode	:Random
Pixel Size	:0.16
Threshold	:35 (Auto)
Coverage	:100%

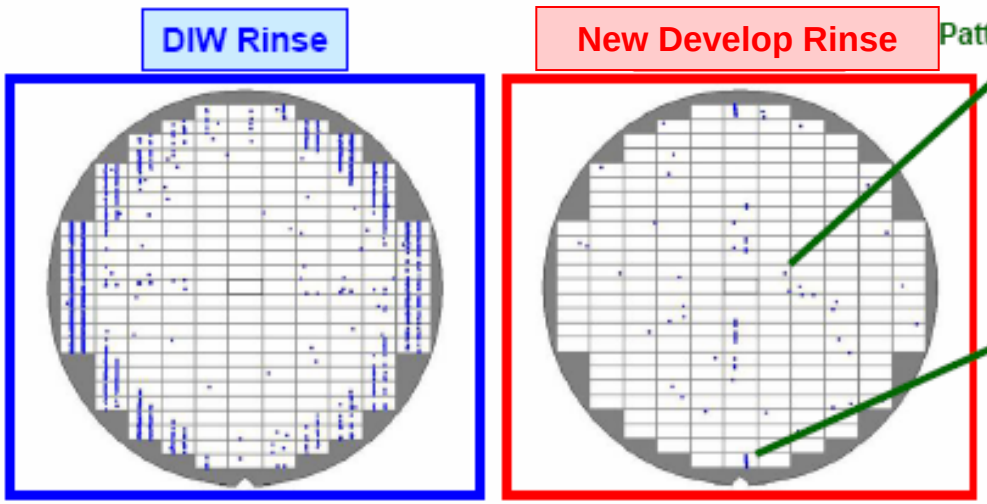
4

SOKUDO

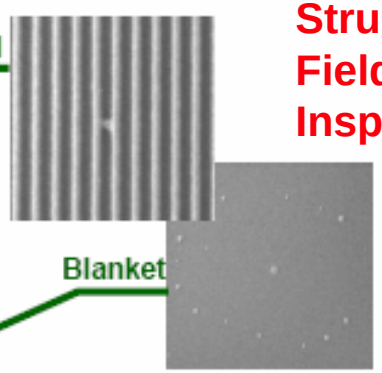
New Develop Rinse – Dense L/S Pattern

Line Pattern (65nm-hp) ~TArF-P6239~

	DIW				NEW DEVELOP RINSE			
	wf 1	wf 2	wf 3	Average	wf 1	wf 2	wf 3	Average
Total	5065	5955	5910	5643	125	134	121	127
Bridge	16	13	9	13	10	11	9	10
Particle (fall on)	10	8	10	9	8	6	10	8
Printing Particle	2	3	2	2	3	3	3	3
Blob	5037	5931	5889	5619	104	114	99	106



Blue dots mean detected defects.



Structure & Field Were Inspected

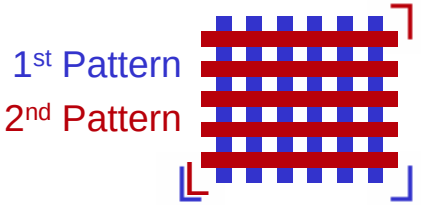
Inspection	:KLA2360
Light Source	:DUV
Mode	:Array
Pixel Size	:0.16
Threshold	:10 (Auto)
Coverage	:100%

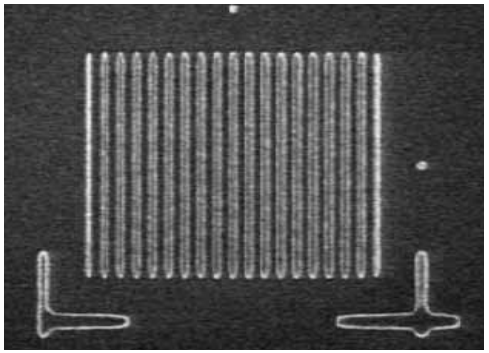
No New Defect Mode Was Observed

SOKUDO

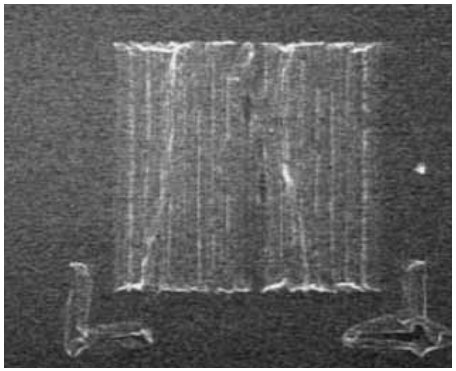
Resist Freezing Challenges

Negative result illustrates freezing challenges

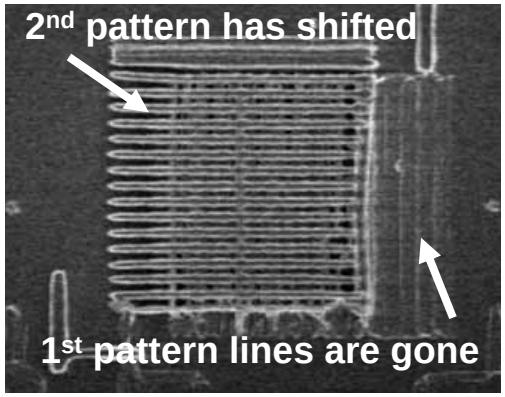




TREATMENT "A"
PATTERN FIDELITY RETAINED AFTER SOLVENT DISPENSE (to simulate 2nd coat)



TREATMENT "A"
PATTERN DESTROYED (Flood expose + develop)



TREATMENT "A"
1st PATTERN DESTROYED

Resist freezing technique must preserve pattern fidelity during 2nd resist coat (solvent) as well as 2nd exposure and develop

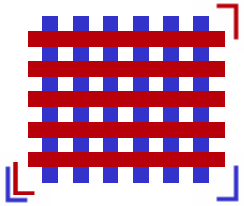
SOKUDO

Pattern Freezing Requirements

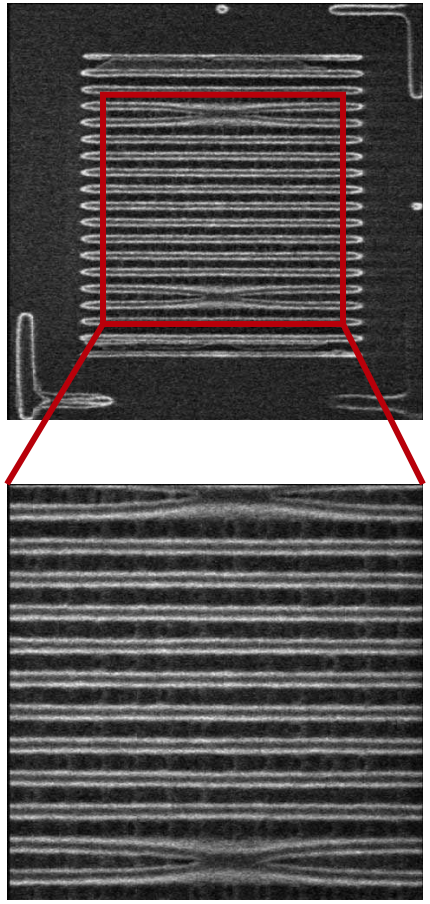
- No change to CD or resist profile of 1st pattern after 2nd coat/expose/develop/bakes.
- CD of 1st and 2nd litho are matched.
- Minimal resist height differences of 1st and 2nd litho.
- Minimal line end shrinkage/shortening, and no distortion of line corner features.
- Minimal impact on underlayer (BARC, HM, etc.) thickness and film properties.
- Minimal etch bias between 1st litho and 2nd litho lines.
- Technique compatible with a wide range of resist materials.
- Technique works on 2D line patterns, large line/pad features, through pitch
- Defectivity equivalent to (or better than) single litho flow.
- Compatible with litho process and tools (wafer should not leave the litho bay)
- Cost-effective

UV Cure Pattern Freezing With Optimized Resists

1st Pattern
2nd Pattern



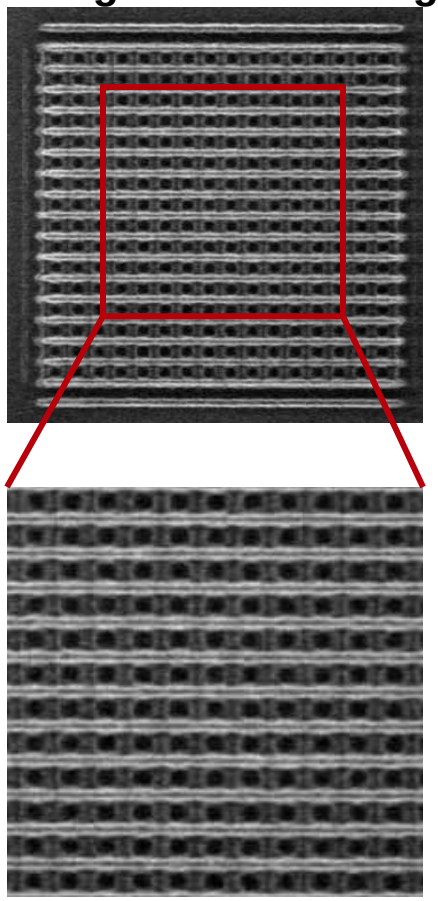
Resist A



Unsuccessful pattern freezing

Only residue of the first layer pattern remains after 2nd develop step

Resist B designed for freezing



80nm HP x-grid obtained

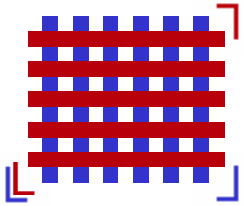
k1 = 0.385

Work with AMD and Rohm&Haas

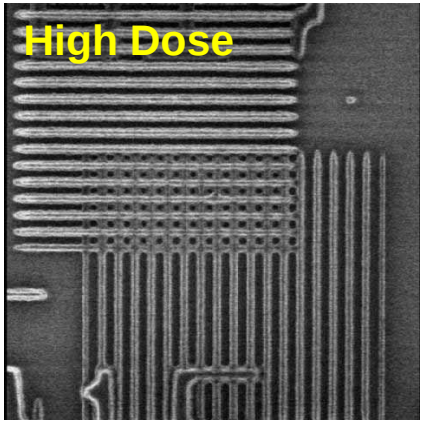
SOKUDO

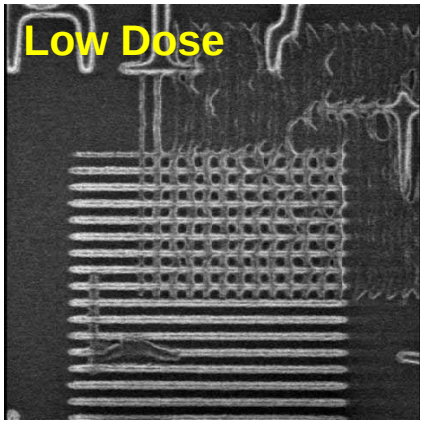
UV Cure Pattern Freezing With Optimized Resists

1st Pattern
2nd Pattern



Process X



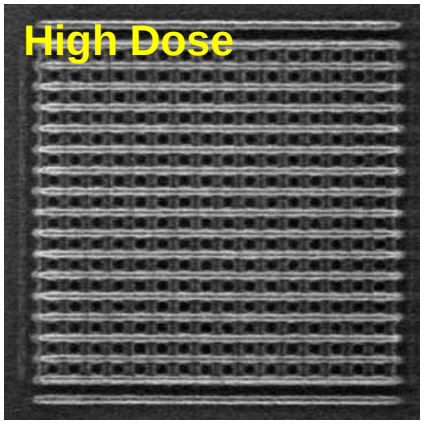


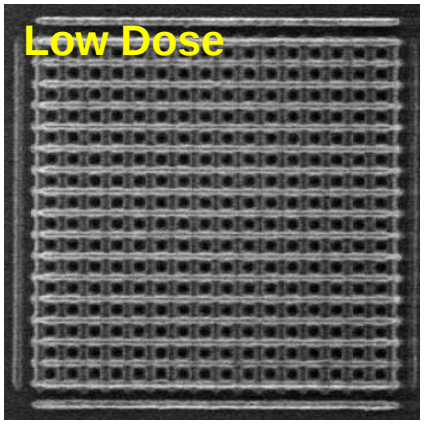
Unsuccessful pattern freezing

Low dose not sufficient to freeze first pattern.

Even for high dose, alignment to first layer fails indicating issue at 2nd coating step.

Process Y





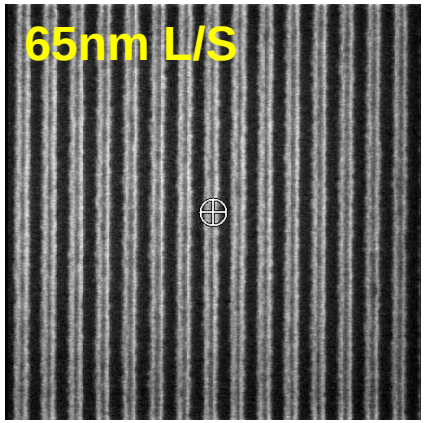
80nm HP x-grid

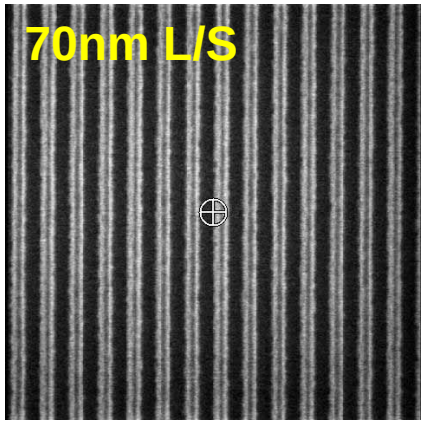
Process robustness.

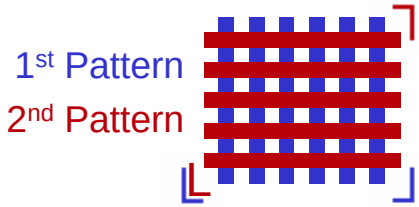
Work with AMD and Rohm&Haas

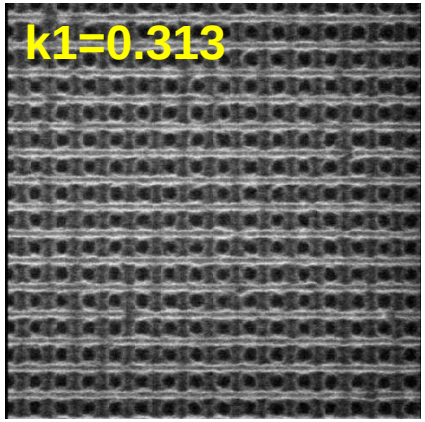
SOKUDO

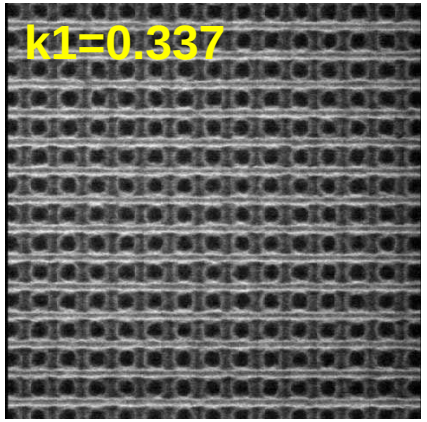
UV Cure Pattern Freezing With Optimized Resists











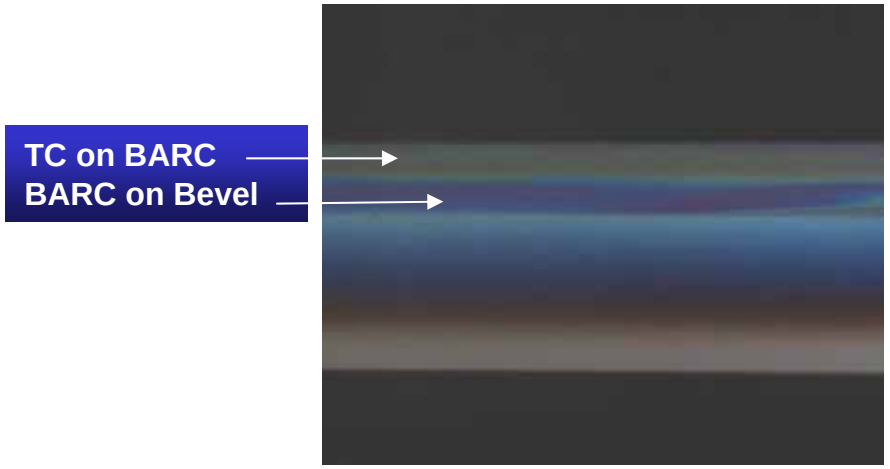
- **70nm and 65nm half-pitch x-grids obtained.**
- **Effective k1 factors below the single exposure contact limit.**

Work with AMD and Rohm&Haas

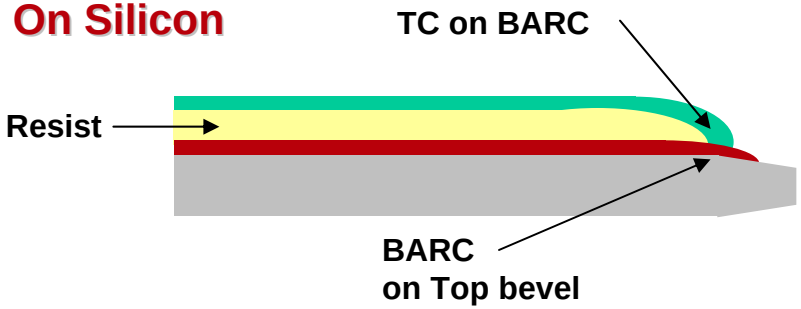
SOKUDO

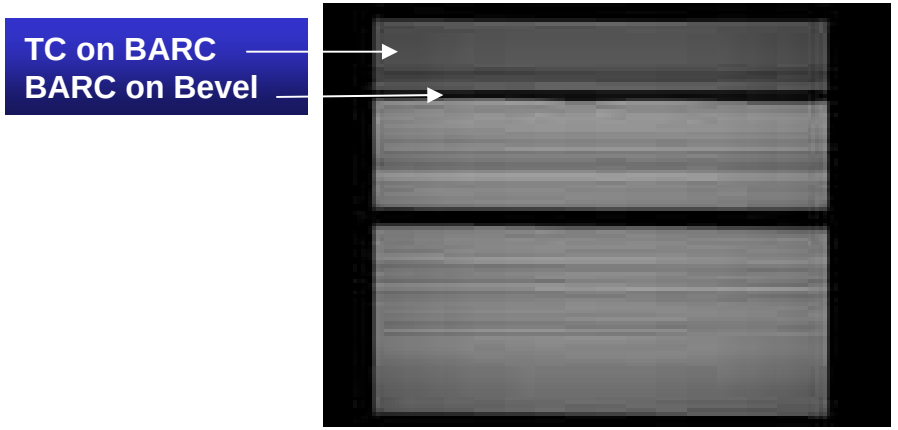
EBR Performance on Production Film Stack

On STI-like Film Stack



On Silicon

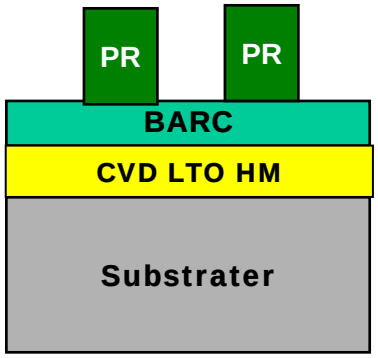




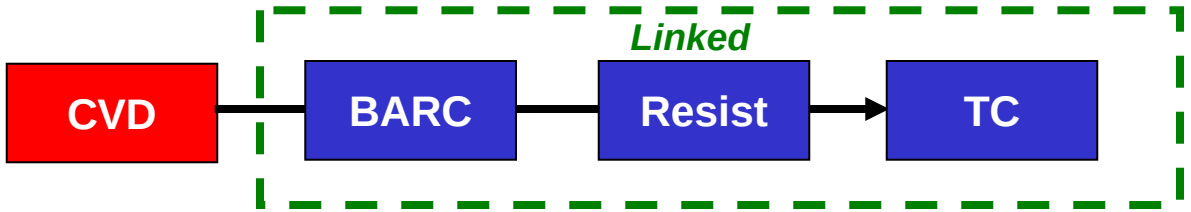
Excellent EBR results achieved on STI-like film stack

SOKUDO

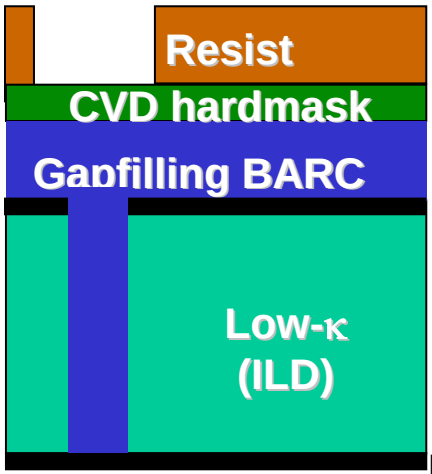
Patterning approach can influence track configuration



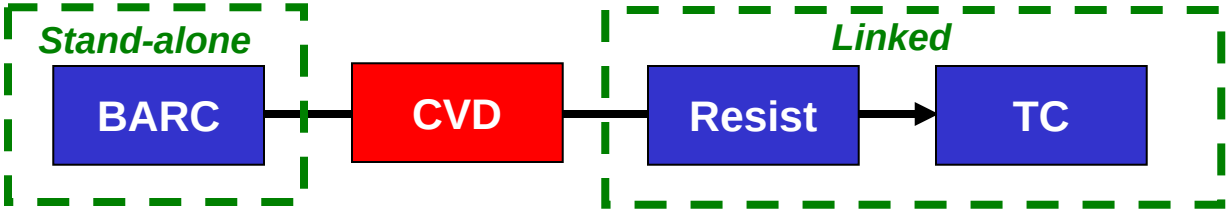
FEOL patterning



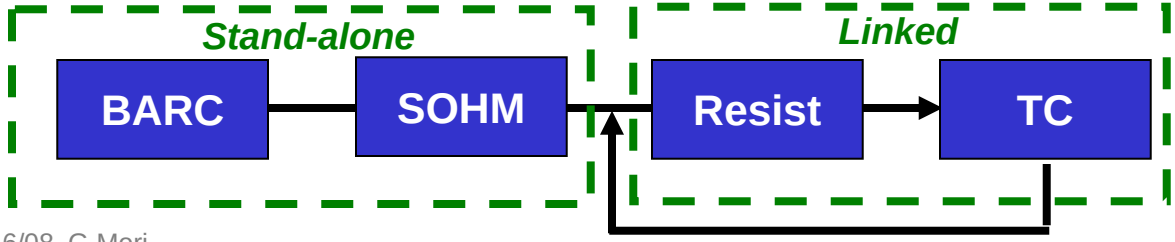
Single linked-track is logical



BEOL patterning



Separate BARC track makes sense



For Spin-On Hard Mask & Double-Patterning, Stand-alone BARC + SOHM track makes sense

SOKUDO

IMEC RF^{3S} + XT1900i

- JDPs and cluster baseline effort has started
- Includes soak, bevel clean (BBC), bevel rinse, BHP, integrated metrology
- Engagement with materials suppliers and member companies is starting

SOKUDO

Summary

- **Many patterning strategies at sub-40nm node – focus on track "building blocks" as enablers**
- **CD and defectivity control will be more challenging than ever**
  - **additional knobs for compensating CD non-uniformity**
  - **Enhanced process capability & defect-prevention "insurance"**
- **Enabling technology for resist freezing**
  - **Resist freezing requirements**
  - **Partnering with materials vendors and customers to provide cost-effective solutions**
- **Optimized tool configuration and process integration for double-patterning, tri-layer resist and shrink**

UV Cure Acknowledgements

Thomas I. Wallow, Ryoung-han Kim, Alden Acheta, Jongwook Kye, Harry J. Levinson

Charles R. Szmanda, Chi Truong

Thomas Nowak

Junyan Dai, Hiram Cervera, Nikolaos Bekiaris, Glen Mori


SOKUDO