SCREEN SOKUDO APPLIED MATERIALS

“Defect Free” DSA Patterning Spin-on Coat & Anneal Track

SOKUDO Lithography Breakfast Forum

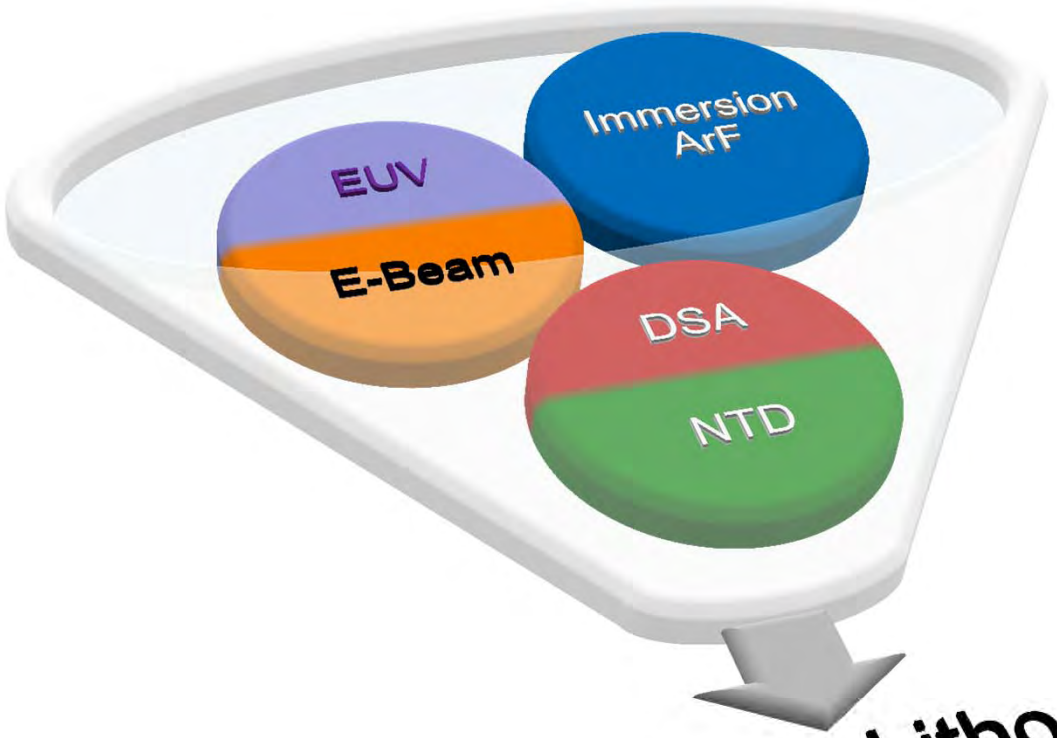
The DSA Patterning Puzzle: Assembling an IC Manufacturing Solution

2012 July 11

SOKUDO DUO

DSA Track

Mix of Lithography Technologies for 10nm node



10nm node Lithography
HVM Solution 2014+

Next 3 Years – Key Lithography Technologies

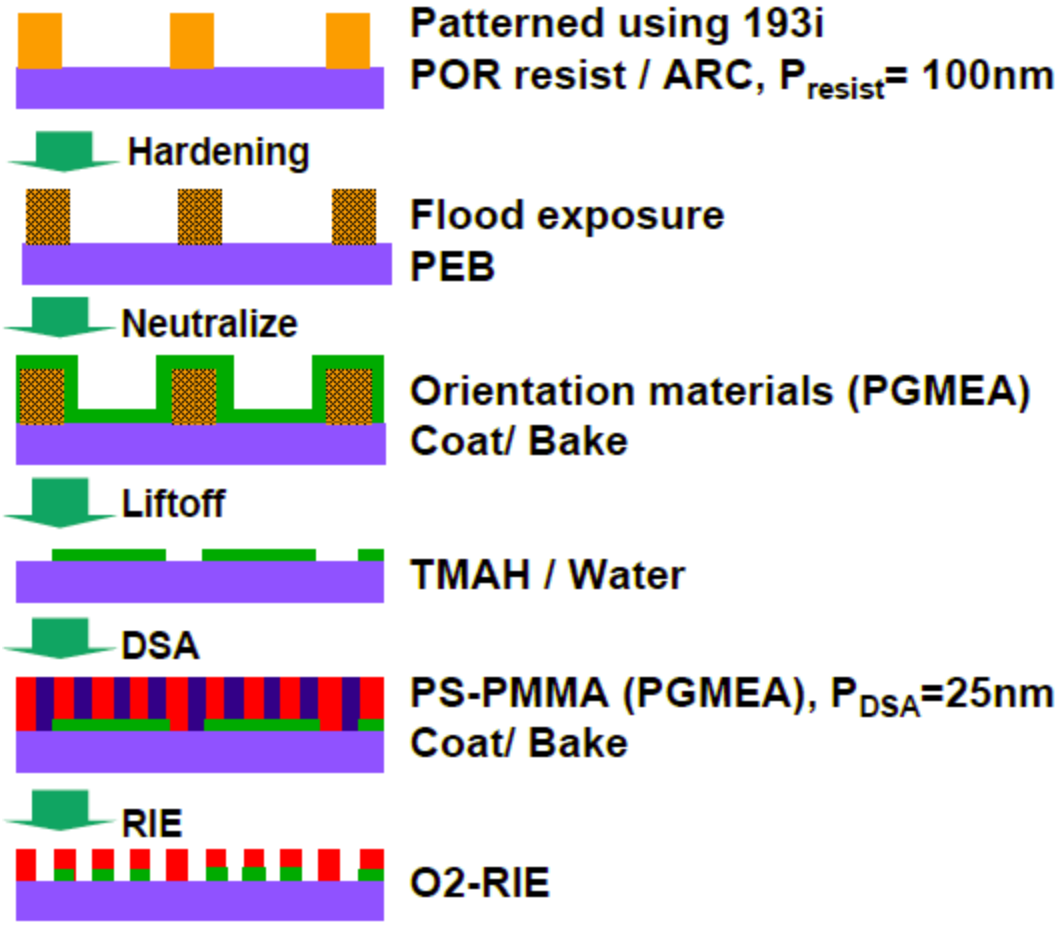
Develop → Pilot → HVM

Topic	Current	2012	2013	2014
Other: NTD, DSA	Negative Tone Develop (NTD)	Directed Self-Assembly (DSA) R&D	DSA Process Integration Test	DSA Integrated Production Layers
Immersion	Double Patterning	Multi-patterning	200wph+ Imm. ArF 14nm Multi-Pattern	Complementary Litho. Integration
EUV	Resist Baseline	Process R&D NXE:3100	Pilot Production NXE:3300 <60wph	EUV Yield NXE:3300 <120wph
E-Beam	Off-line Process Alpha Tools	→	MAPPER 1~5wph	10~100wph

DSA

SOKUDO DUO
DSA Track

Track is key tool in center of DSA process flow



Cheng SPIE 2009
Sanders SPIE 2010
Cheng ACS Nano, 2010
Sanders JPhotopolymerSciTech, 2010

DSA Process Development on SOKUDO Track Platforms

2010	2011	2012	2013

300mm DSA Pilot Line SOKUDO Track

DSA Process Development on SOKUDO Track Platforms

2010	2011	2012	2013

SOKUDO DUO
DSA Track

SOKUDO RF3 Coat/Develop Track
@ Applied Materials,
Maydan Technology Center (MTC)

APPLIED MATERIALS®

**Sunnyvale,
California USA**

**Directed
Self
Assembly**

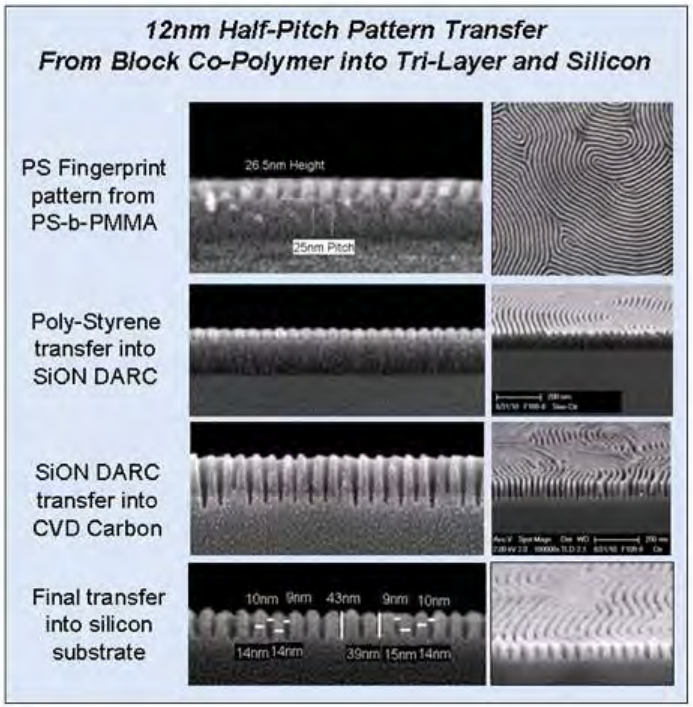
(DSA)

SOKUDO DUO
DSA Track

2010 … Initial SOKUDO DSA Process Start

Directed Self-Assembly for sub-15nm:

12nm Lamella fingerprint baseline has been established
on AMAT's Sokudo RF^3 300mm Spin Track



22 LithoWorkshop2010 / IEEE Seminar

APPLIED MATERIALS

Litho Workshop 2010 (IEEE), "Patterning for 15nm half-pitch (NAND Focus),"
Chris Bencher, Advanced Patterning Group, Maydan Technology Center, Applied Materials

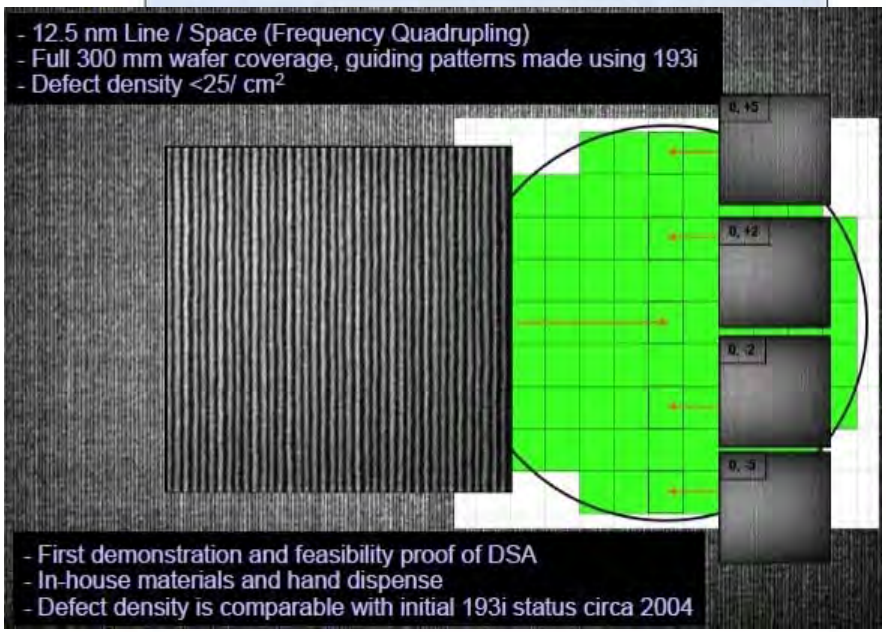
SOKUDO DUO
DSA Track

2011 … 300mm Full-Wafer DSA Process Demo

Directed Self-Assembly for sub-15nm:

12nm Lamella fingerprint baseline has been established
on AMAT's Sokudo RF^3 300mm Spin Track

12nm Half-Pitch Pattern Transfer
From Block Co-Polymer into Tri-Layer and Silicon



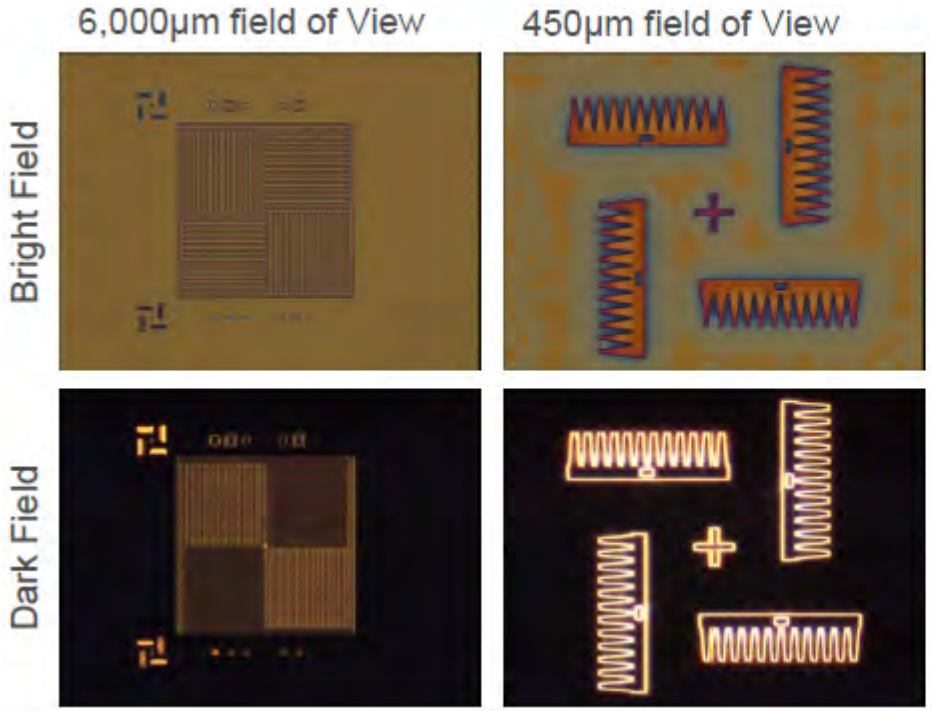
22 LithoWorkshop2010 / IEEE Seminar

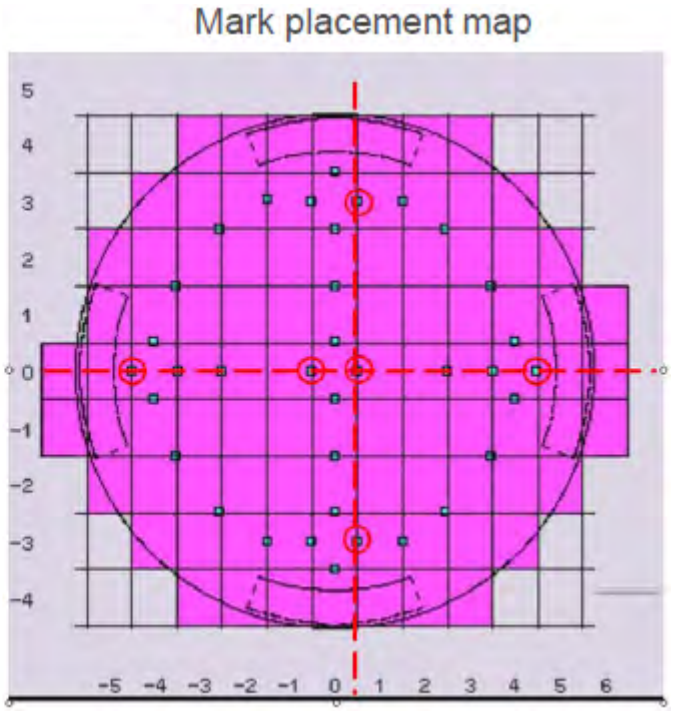
APPLIED MATERIALS

Chris Bencher, et.al. "Self-Assembly Patterning for sub-15nm Half Pitch: A Transition from Lab to Fab,"
Alternative Lithographic Technologies III, Proc. of SPIE Vol. 7970 © 2011 SPIE

2012 ... Year of DSA Process Defect Study

Zero-Level Marks introduction in DSA metrology

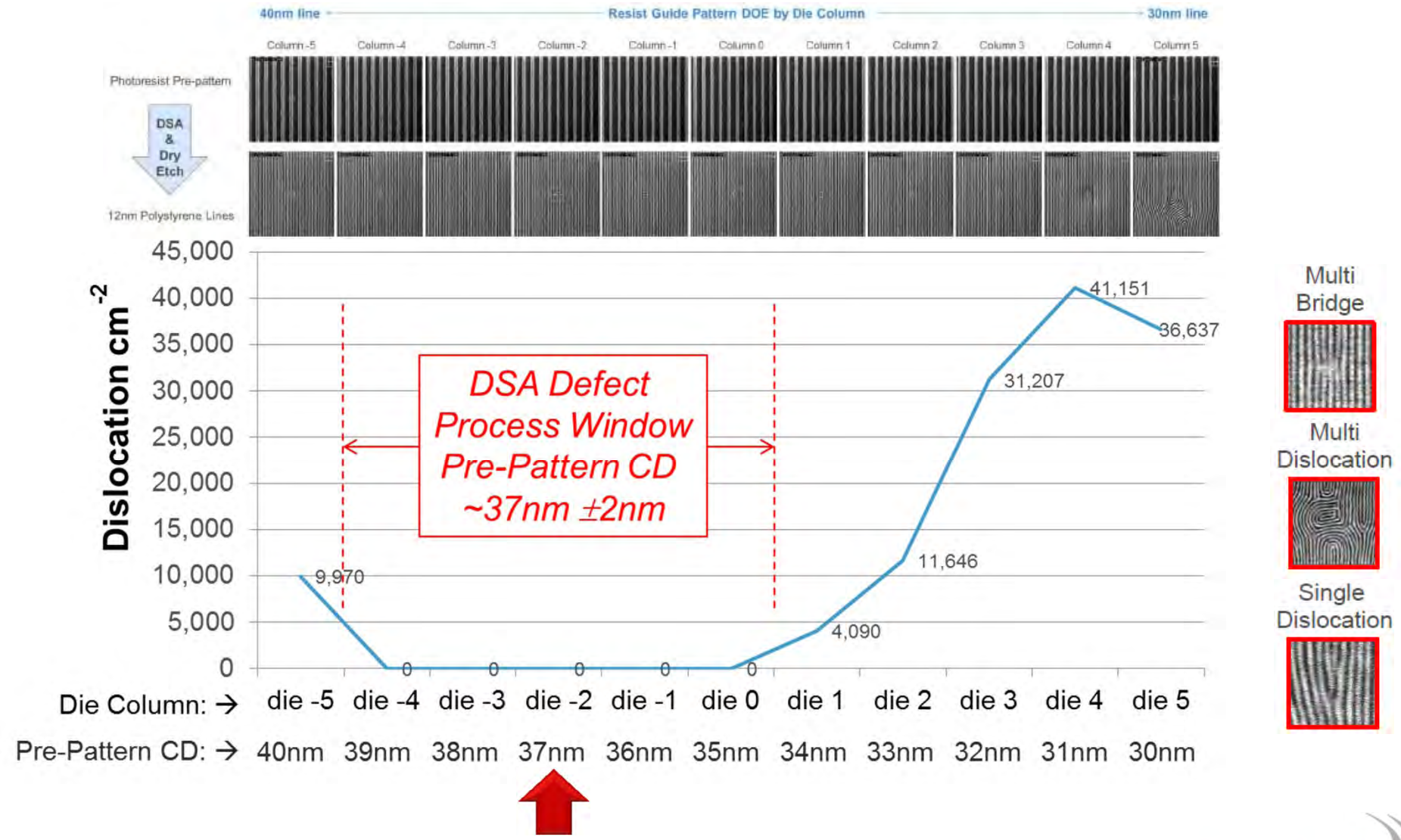




With sub-micron wafer registration
defect inspection and review was scaled to full 300mm wafer

Chris Bencher, et.al. “Directed Self-Assembly Defectivity Assessment,”
Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

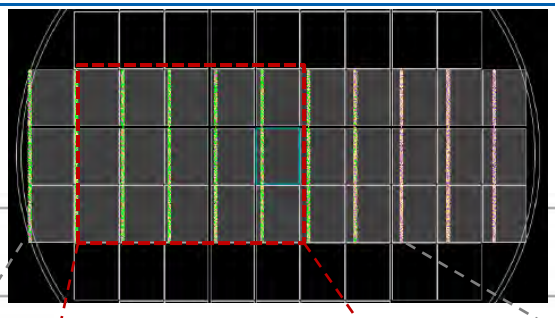
Chemo-Epitaxy Pre-Pattern CD ⇔ DSA Defect Density



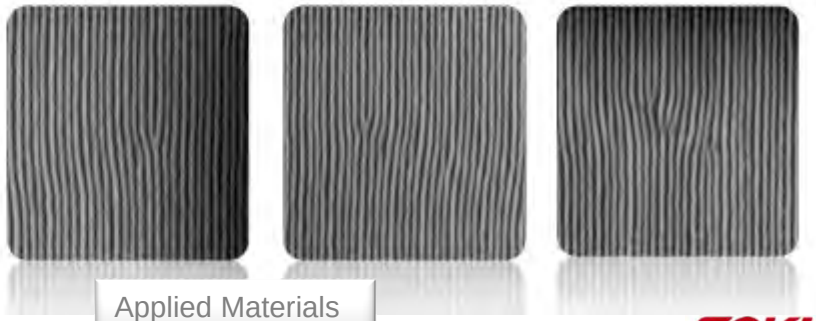
Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

Applied Materials SEMVision™ G4

Detailed SEM Review found few dislocations



- Filtered database to defects with a dislocation signature
- SEM Reviewed another 1,000 defects in these columns
- Found 3 dislocations

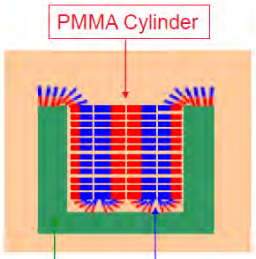


Note:
These could be due to pre-pattern problem
Process prints 37nm resist lines (as developed)

Applied Materials
SEMVision™ G4

Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

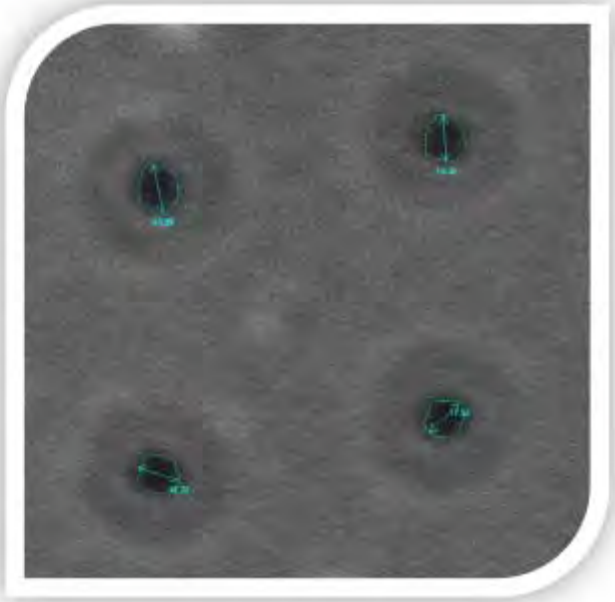
Contact Hole DSA Shrink Process …



65~80nm CH

20~24nm CH

Grapho-Epitaxy Stencil Litho, Etch, Ash, Clean	→	PS-b-PMMA DSA Spin-coat, anneal, CD-SEM

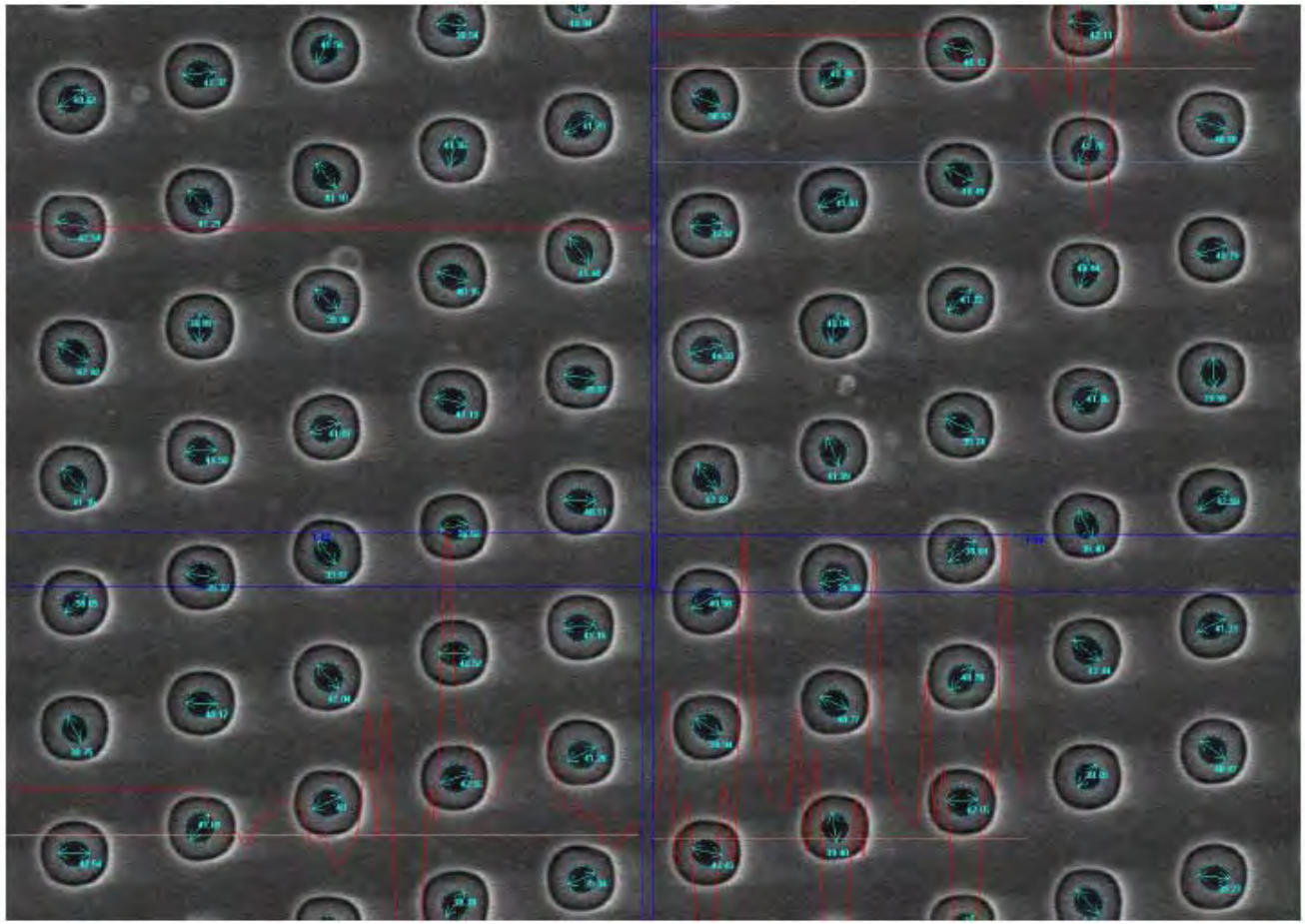


Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

Contact Hole DSA Shrink Defect Study

CD & Overlay in SPIE paper

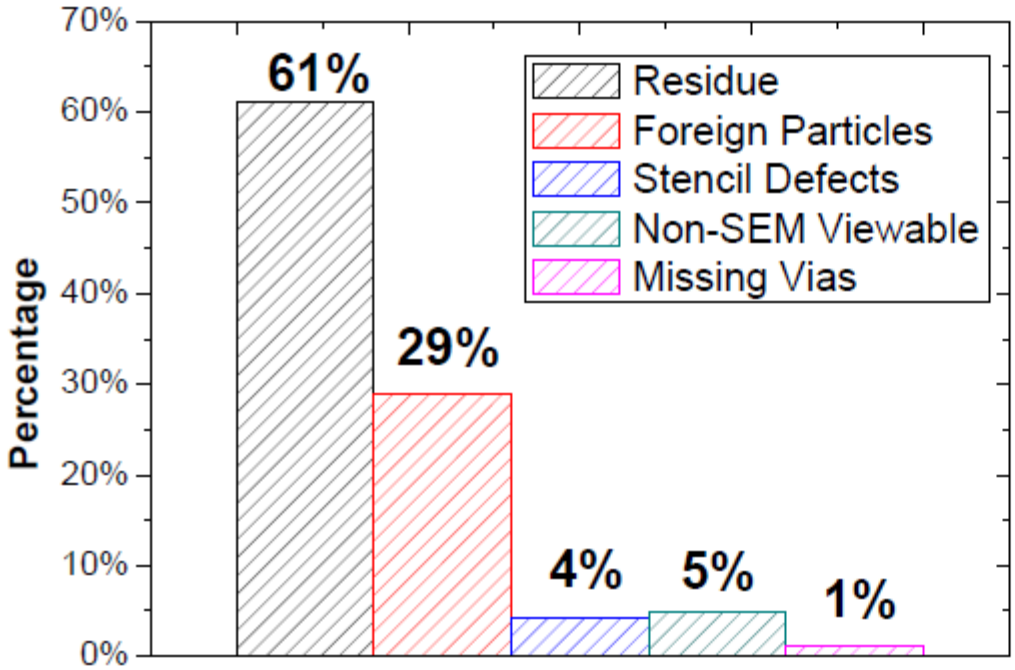
1. Phase Separation CD-SEM Measurements
2. PMMA Dry-Etch CD-SEM Measurements
3. Hole-in-hole registration accuracy
4. Missing Via Defect Rate

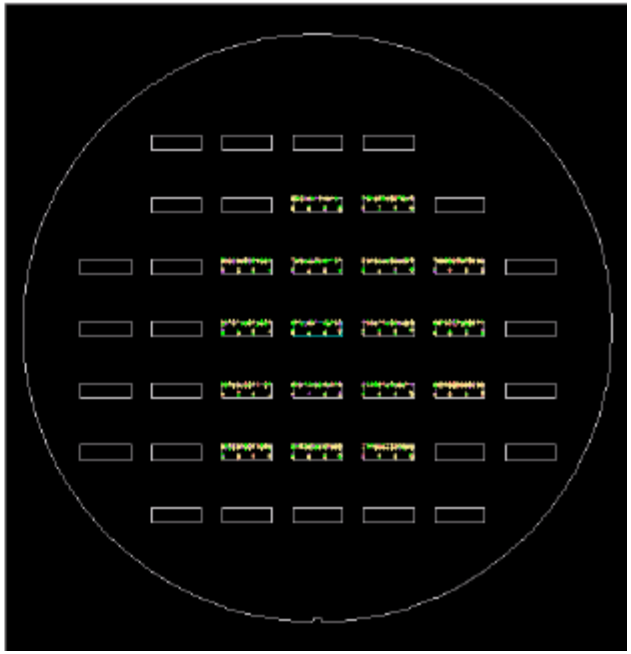


Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

550 Million Vias inspected on 300mm wafer

Inspection Tool	Uvision™ 3
# of Dies Scanned	17
Total Area Scanned	16million μm²
Total # of Vias Within	~ **550,000,000**
# of Defects	2643





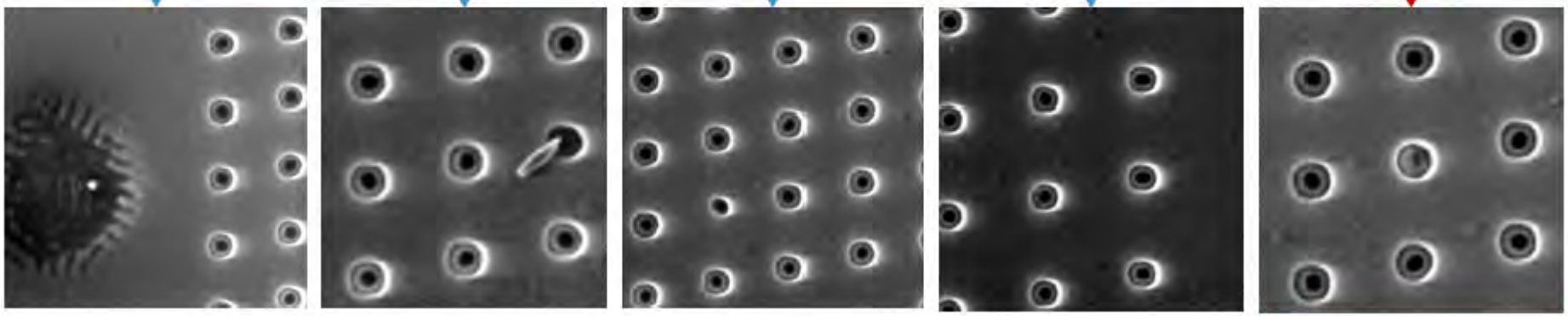
Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

Applied Materials
UVision™ 3

Key Focus … Missing Vias (DSA)

All 2,643 Defects Photographed by SEMVision™ G4

Residue	Foreign Particles	Stencil Defects	Non-SEM Viewable	Missing Vias
1592	753	111	125	**22**



Density:
1 per 25 million

Solutions Known

DSA Specific

Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

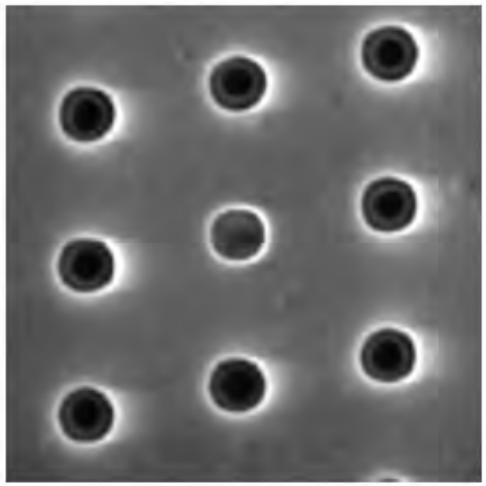
Applied Materials
SEMVision™ G4

SOKUDO DUO
DSA Track

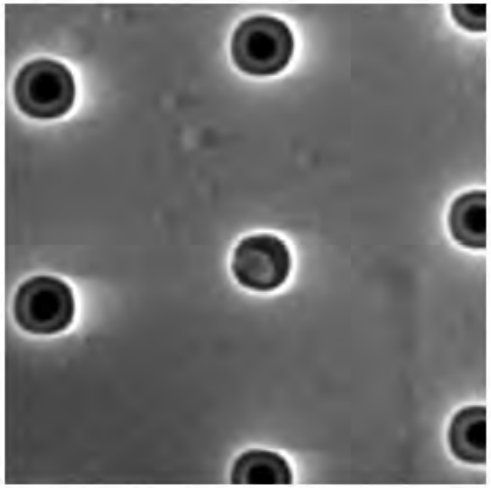
DSA Defect Density: 1 per 25 million (4 x 10^{-8})

22 Thermodynamic "Phase-Separation" Defects

14 Missing Via
Bad Phase-Separation



8 Missing Via
Some particle inside

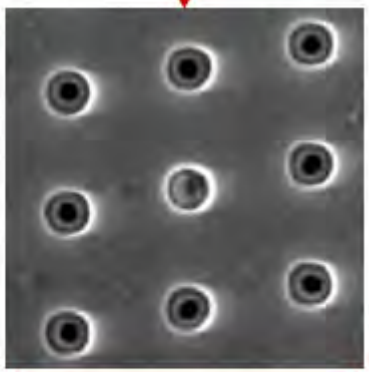


Particles tend to interfere with phase-separations.

…clean stencils is important

Missing Vias

22



Density: 1 per 25 million

DSA Specific

Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

Applied Materials SEMVision™ G4

SOKUDO DUO DSA Track

Extensive Metrology Required for DSA Study

CD SEM Metrology

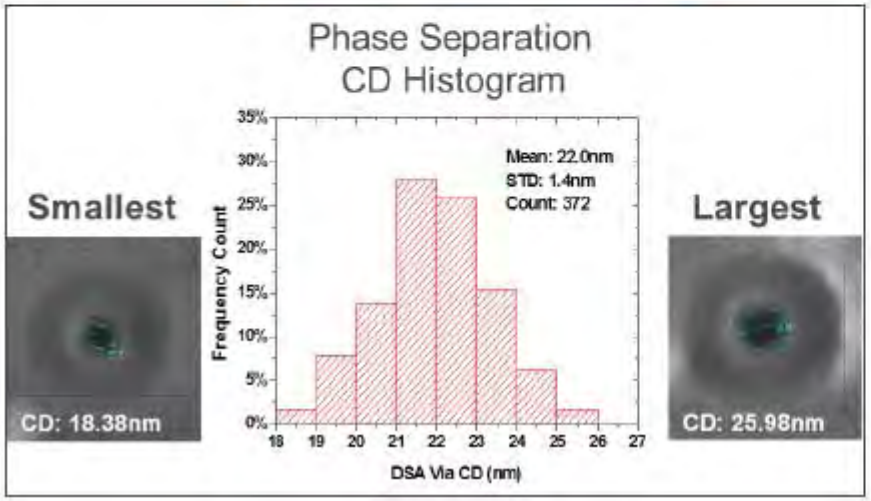
VeritySEM™

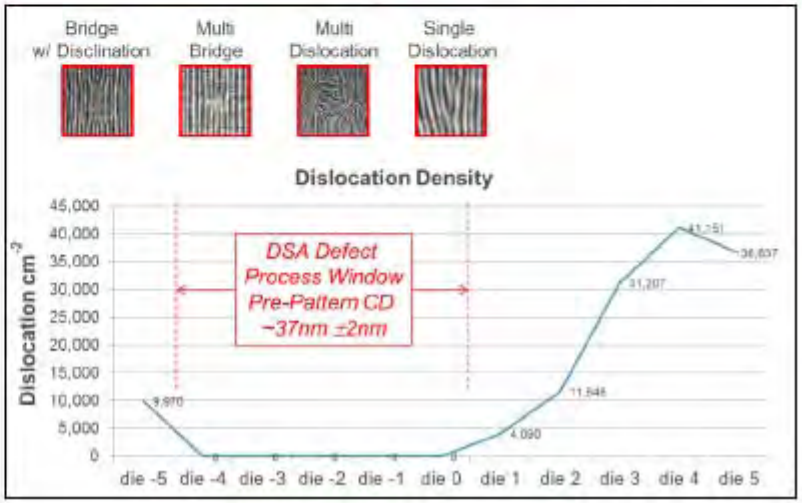
Bright-field Inspection

Uvision™

SEM Defect Review & Analysis

SEMVision™





Chris Bencher, et.al. "Directed Self-Assembly Defectivity Assessment," Alternative Lithographic Technologies IV, Proc. of SPIE Vol. 8323 © 2012 SPIE

SOKUDO DUO DSA Track Conclusions

- **"Defect Free" DSA Track process achievable**
  - Now transitioning to dedicated DSA process tools "SOKUDO DUO DSA Track"
- **"Stand-Alone" SOKUDO DUO DSA Track niche**
  - New application opens market share growth opportunity
  - Pilot DSA tracks 2012→2013
  - HVM production systems 2014+
- **Partnership Sites help establish DSA baseline**

APPLIED MATERIALS®

cea leti

imec

SOKUDO DUO DSA Track

SCREEN

SOKUDO DUO

DSA Track