ITRS Perspectives on DSA

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Purpose of the ITRS

- The ITRS serves as a guideline for the global industry for a 15-year outlook on projected technology needs and opportunities for innovation.

- The ITRS is a pre-competitive instrument, devised and intended for technology assessment only and is without regard to any commercial considerations pertaining to individual products or equipment.

Overview of ITRS Process

Manufacturers, Suppliers, Academia, Consortia, Government Labs

Determine Roadmap Objective → Steering Committee Identifies Technology Drivers → TWGs Identifies/ Updates Key Challenges → TWGs Quantify Technology Requirements → TWGs Identify Innovation Areas → *Reach Consensus (peer review)* → Revises & Distributes to Industry Community → Community Implements Roadmap → Community Inputs to Contributors → Determine Roadmap Objective

ITRS -> International Technology Roadmap for Semiconductors

TWG -> Technology Working Group

Background

- 2006: Critical capabilities identified to researchers
- 2007: Emerging Research Materials identified DSA as a potential technology o extend lithography
- 2009: Progress made on most capabilities except defect density
- 2011: SPIE reports of reduced defect density

2006 Challenges to DSA Researchers

- Demonstrate LWR of 1.1 nm 3σ by 2013
- Determine sub-lithographic limits
- Fabricate essential features
- Multiple sizes and pitches in the same layer
- Foundational understanding of defectivity mechanisms
- Path to meet ITRS alignment and registration requirements
- Anneal times that are competitive with projected ITRS throughput requirements
- Demonstrate sub-10 nm pattern formation
- Demonstrate competitive etch resistance
- Compatibility with Si processing

2007 Progress on Basic Structures

K5 processor photo courtesy of AMD

Isolated Line

Periodic Lines

Bends

Periodic Spots

Isolated Spot

T Junctions

Jog

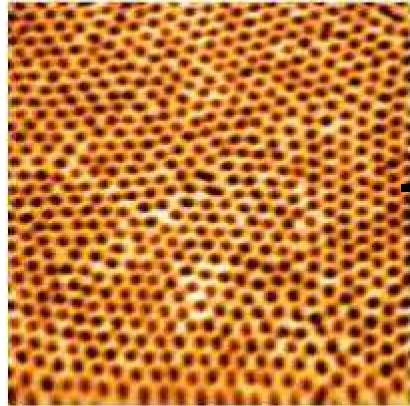
200 nm

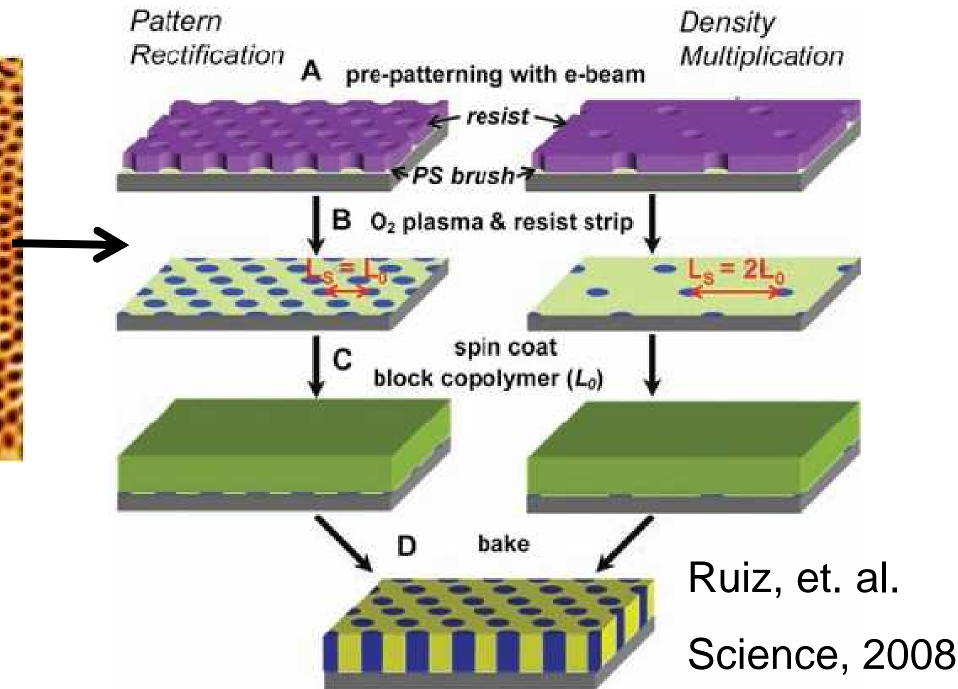
250 nm

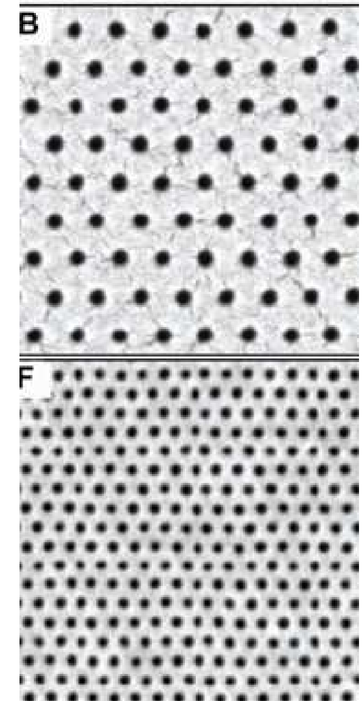
400 nm

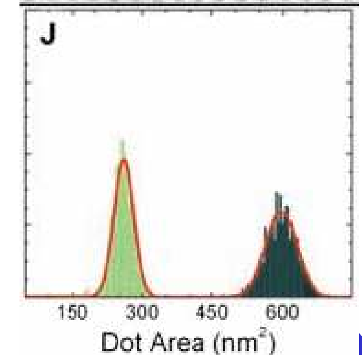
The International Technology Roadmap for Semiconductors, 2007 Edition. Semiconductor Industry Association. International SEMATECH: Austin, TX, 2007.

Directed Self Assembly









Ruiz, et. al.

Science, 2008

- **Block Co-polymer self assembly may extend lithography**
- **Rectification to improve control CD & LER**
- **Density multiplication for high density smaller features**

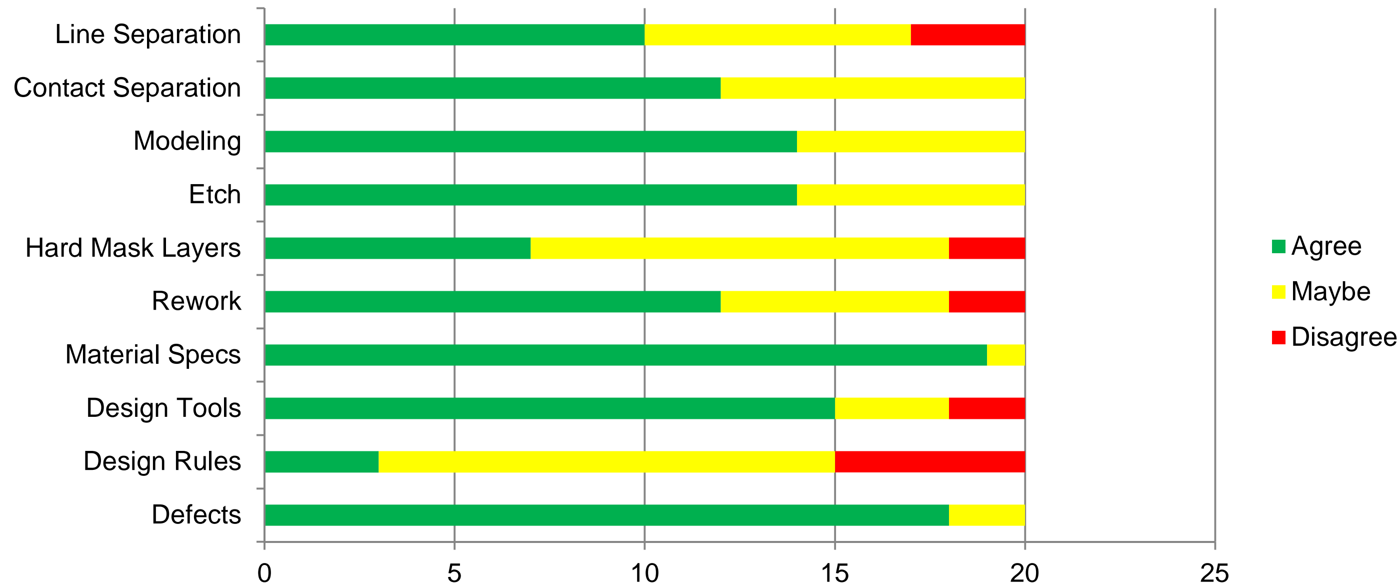
Defect Density Improvement

- Modeling and simulation of defect formation energetics
- 2010 DSA eliminates dislocations
- 2011:Low Defect Density <25cm^{-2} demonstrated by IBM & Applied Materials

2012 SPIE DSA Brainstorming Session (Sematech/ITRS)

- Goal: bring the stakeholders together onto a common platform to:
  1. Identify the pre-competitive issues in DSA
  2. Rank the pre competitive issues in order of priority
  3. Identify Institutions/consortia which should engage on these issues
     - I. Research Consortia (e.g. SRC)
     - II. Manufacturing Consortia (e.g. SEMATECH, IMEC, MIRAI etc.)
     - III. Gov't Labs & Standards Orgs (e.g. NIST, AIST, etc.)
- Participants : 39 participants from:
  - Intel, GLOBALFOUNDRIES, IBM, Toshiba, Hitachi, Micron, Hynix, IMEC, AMAT, Brewer Science, AZ, TEL, JST, TOK, DOW, Cadence, Synposys, Mentor Graphics, Standford University, NIST, KLA-Tencor, Georgia Tech,
  - 5 teams for brainstorming sessions
- A survey was conducted prior to the session:
  - What areas in DSA are precompetitive?
  - What precompetitive areas consortia such as SEMATECH should work on?

Pre-Meeting Survey results: Is the issue precompetitive?



- **75% Yes: Defects, Design Tools, Material Specs**
- **Metrology omitted on the survey…**

Pre-meeting Survey results: Should Consortia Work on the Issue?

Line Separation
Contact Separation
Modeling
Etch
Hard Mask Layers
Rework
Performance Specs
Material Specs
Design Rules
Registration to Existing Features
Photomask Design Tools
Defects

0 5 10 15 20

Agree
Maybe
Disagree

Consortia: Research Consortia or Manufacturing Consortia

- **High Agreement: Defects, Material & Performance Specs, Etch & Modeling**

Summary of the outcome

- Main precompetitive areas that consortia should work on (common to all teams):
  - Defects (definitions/characterization/measurements)
  - Simulations
  - Metrology (2D and 3D)
  - Registration
  - Design Tools
- Other areas that consortia should work on:
  - New block co-polymers with high χ
  - Electrical test design
  - Prediction/modification of surface energy to create new morphology

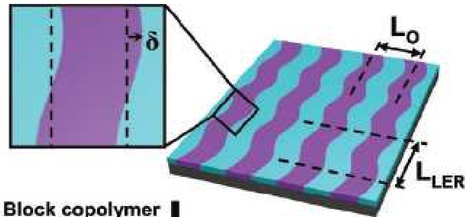
ITRS Gathering Input on DSA

- Could applications of DSA be implemented in 3-5 years?
- Does industry have plans to evaluate specific applications?

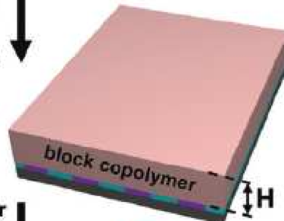
- Conducted a non-scientific poll of the "community"
- Poll of the views of individuals
- Participants identified their sector without validation
- Not Corporate Positions!!!

Potential DSA Litho Applications

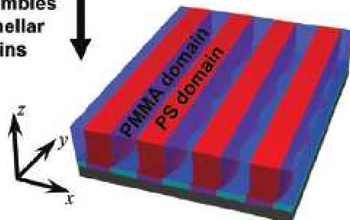
LER Rectification



Block copolymer film deposited on chemical surface pattern



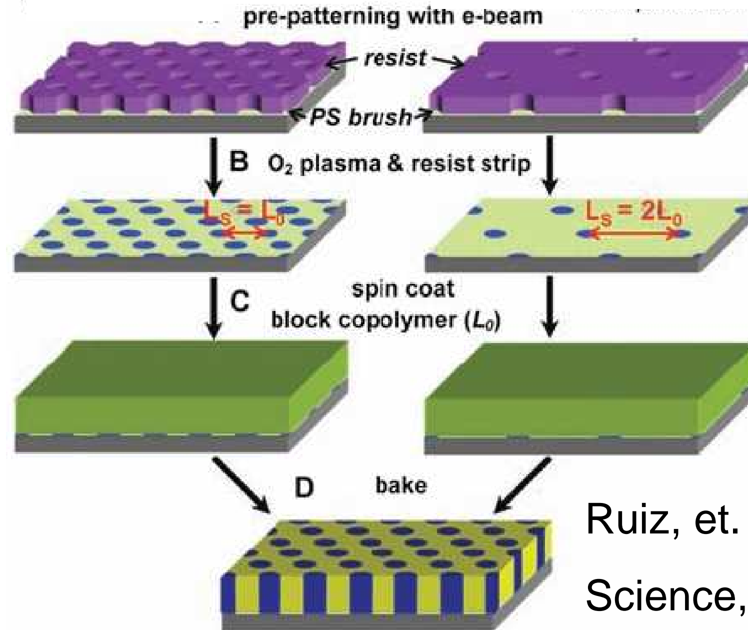
Block copolymer self-assembles into lamellar domains



Stoykovich, et. al.

Macromolecules, 2010

Contact/Via Rectification | **Density Multiplication**

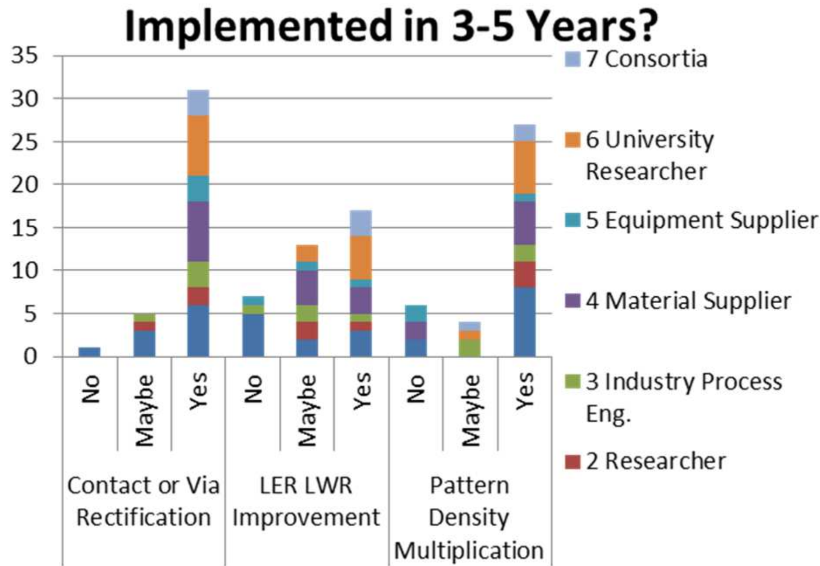


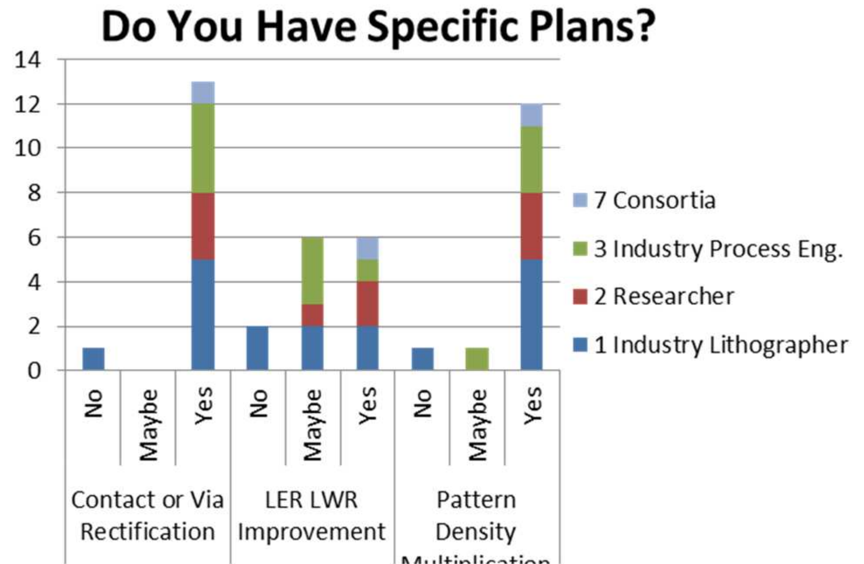
Ruiz, et. al.

Science, 2008

- LER Rectification to reduce LER and improve line CD control
- Contact/Via Rectification to reduce size and improve CD control
- Density multiplication for high density smaller features

Survey on DSA





- Contact rectification and pattern density multiplication had the highest support
- Most industry responders had plans to evaluate DSA

Summary

- DSA has made significant progress
- Consortia role has been identified
- Industry engineers indicate that they plan to evaluate DSA
  - Contact and via rectification
  - Pattern density multiplication
  - LER/LWR improvement
- Significant challenges must be overcome
  - Engineering vs. Fundamental

Acknowledgements

- Sematech for funding the SPIE "Rump" Session on DSA
- ITRS Members
  - Dan Herr, Former ERM Co-Chair
  - ERM Team