

# LithoVision | 2011

- Status of Masks -

Current Status and Issues for ArF Extension

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**DNP**

*Member of the eBeam Initiative*

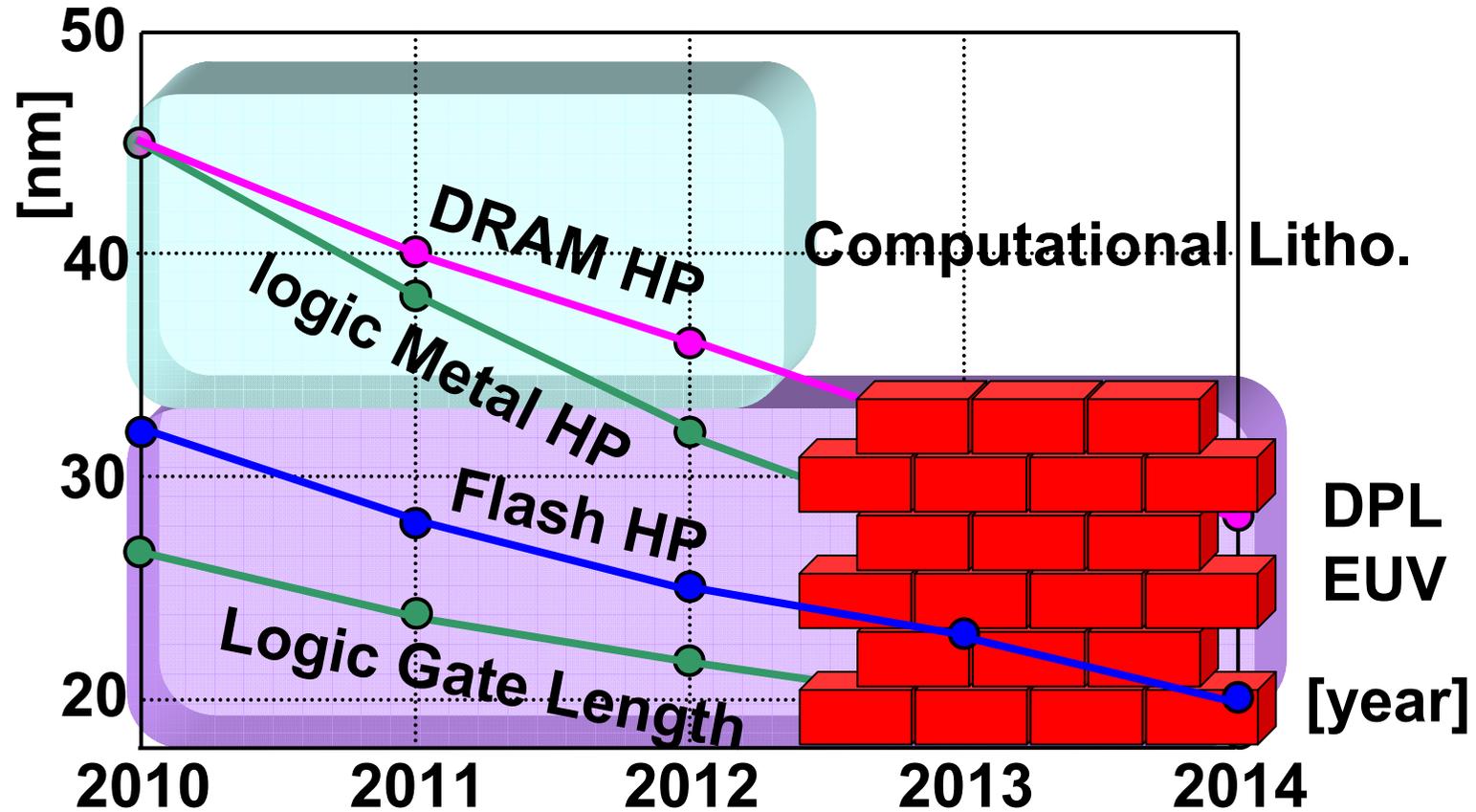
# Outline

- **Roadmap & Challenges**
- **Complex Photomasks**
- **Approaches**
- **Trials & Examples**
- **Further Investigation**
- **Acknowledgement**

# Roadmap & Challenges

ITRS Roadmap 2010

## Scaling & Scaling

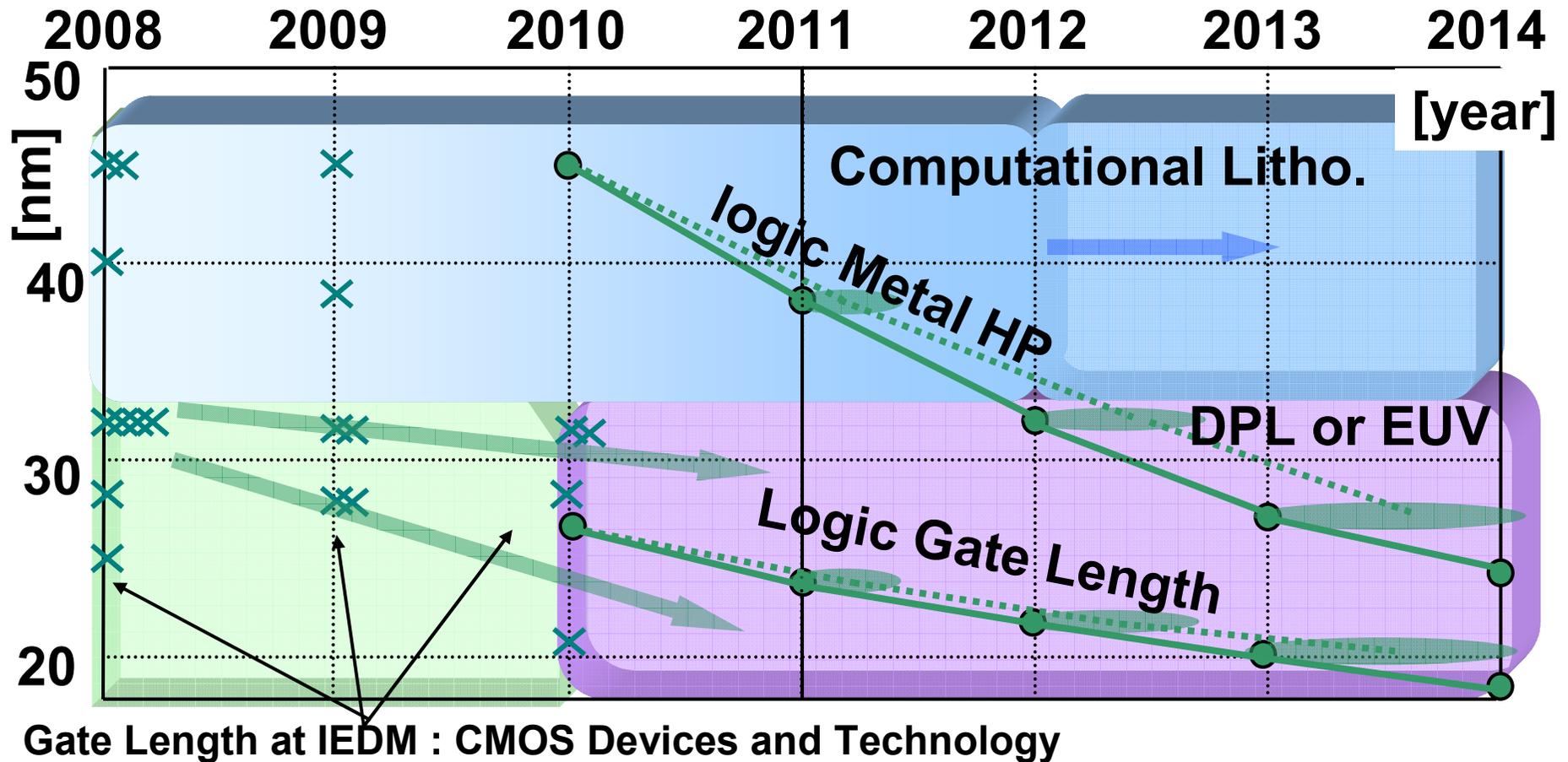


ITRS Roadmap : keep scaling

Rapidly approaching a brick wall

# Roadmap & Challenges

from IEDM trend



**32nm CMOS : still mainstream at IEDM**

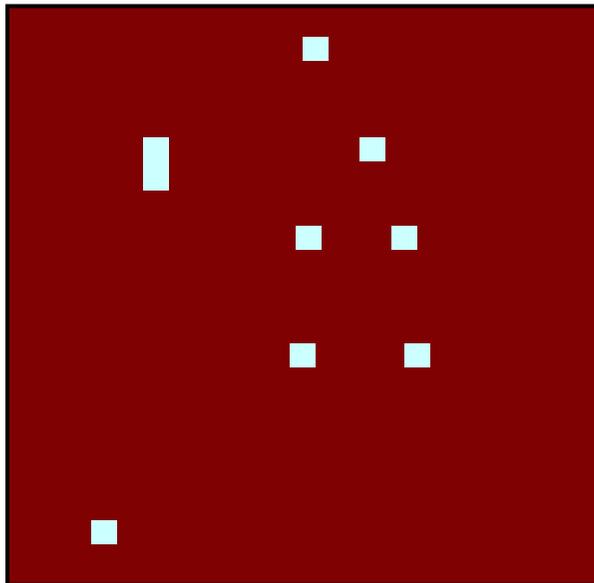
**Computational litho opportunities growing**

# Complex Photomask

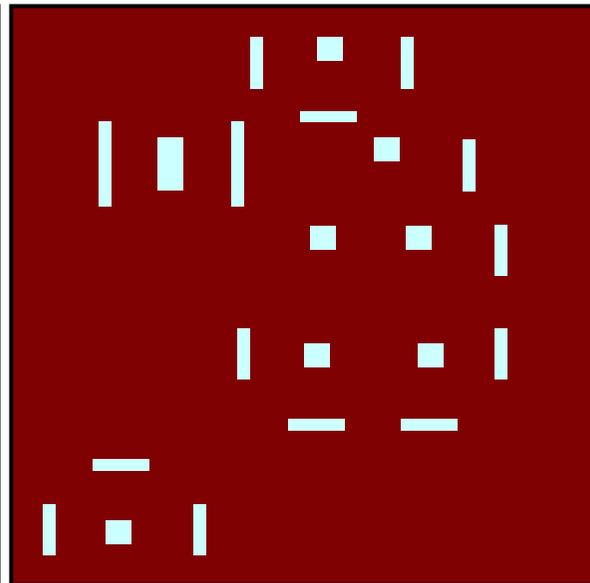
Computational Litho.

Computational Mask Correction → more & more complex

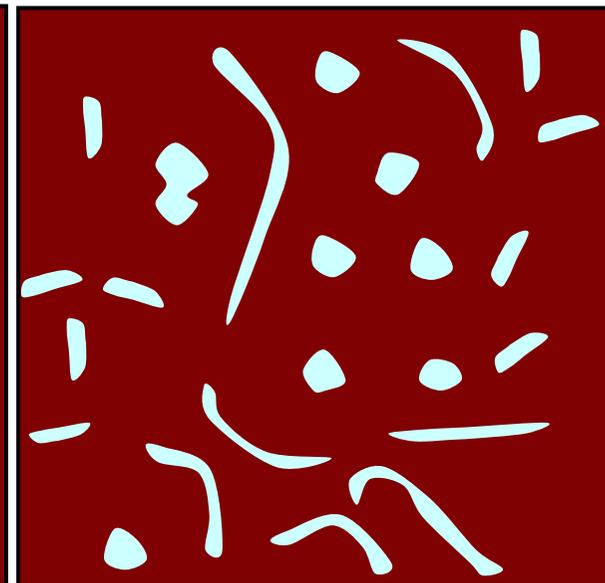
conventional



early OPC



current advanced



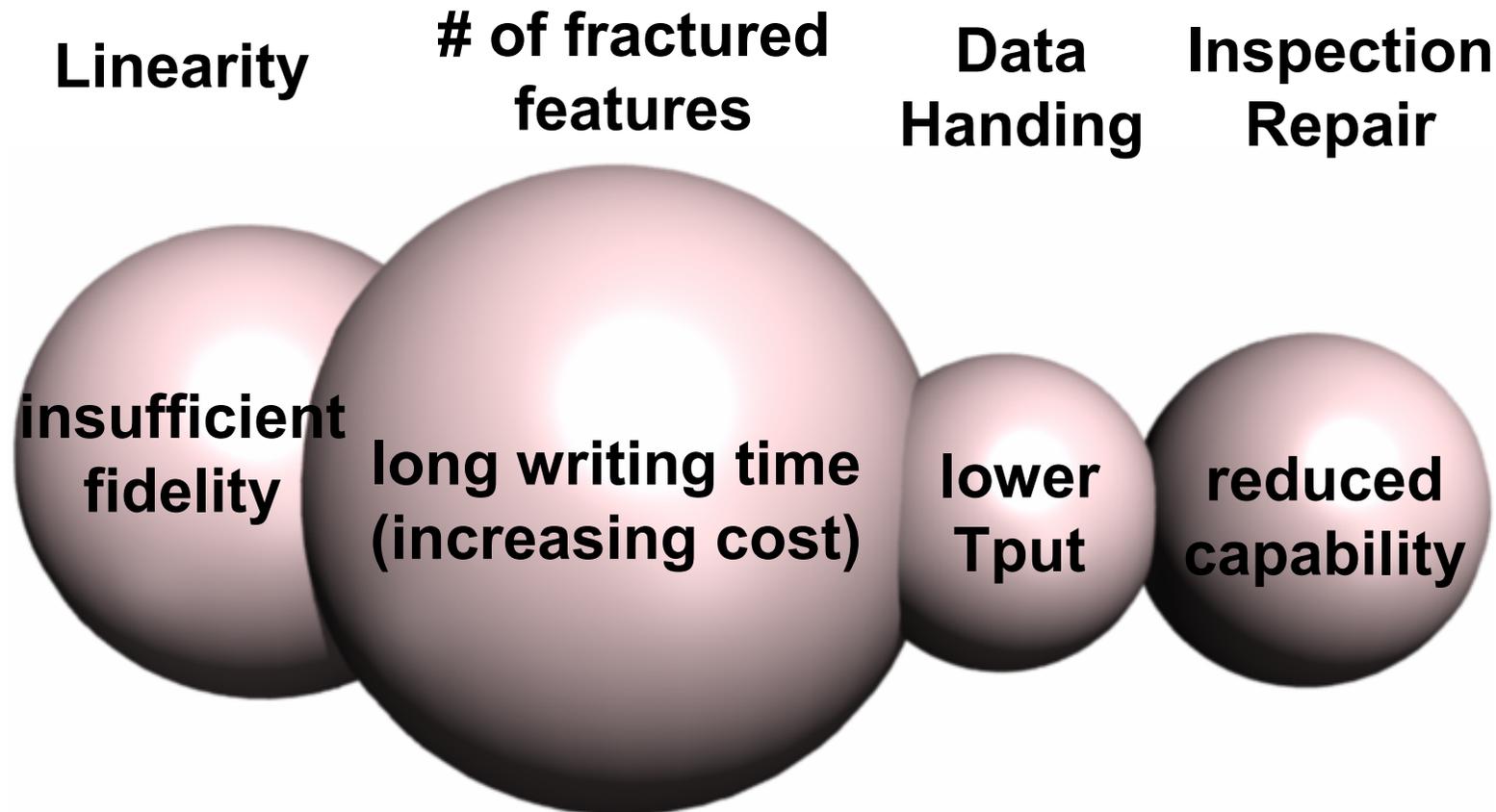
more complex : # of features  
smaller features  
curved features

\*\* virtual pattern

# Complex Photomask

## Issues

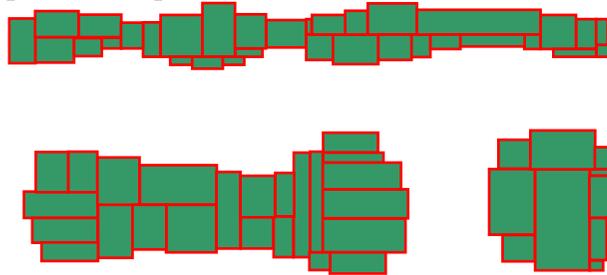
Computational mask correction  
→ complex photomask data



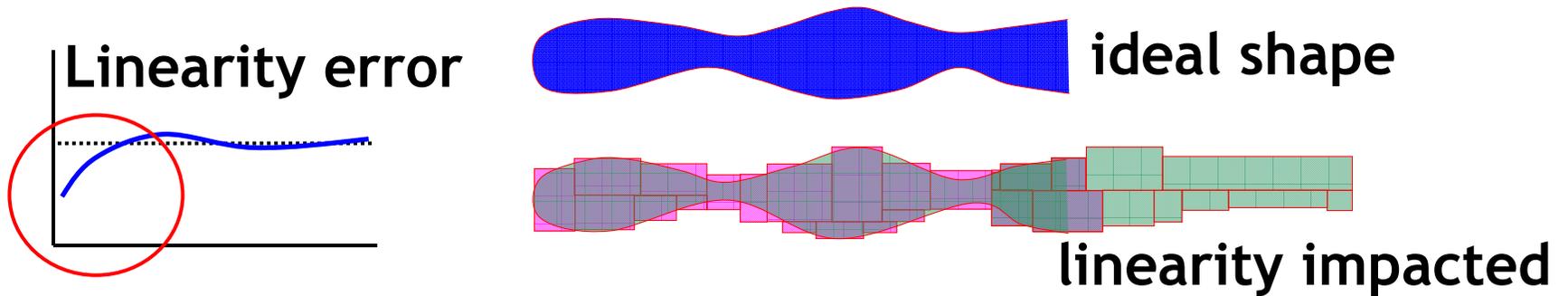
# Approaches

## issues, and more

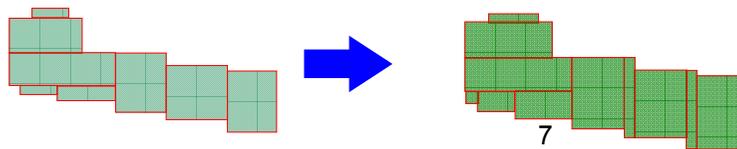
a) Complex pattern fracturing : too many features



b) Linearity : small features smaller



c) Process bias inconsistency :  
process bias induced number doubling



\*\* virtual pattern

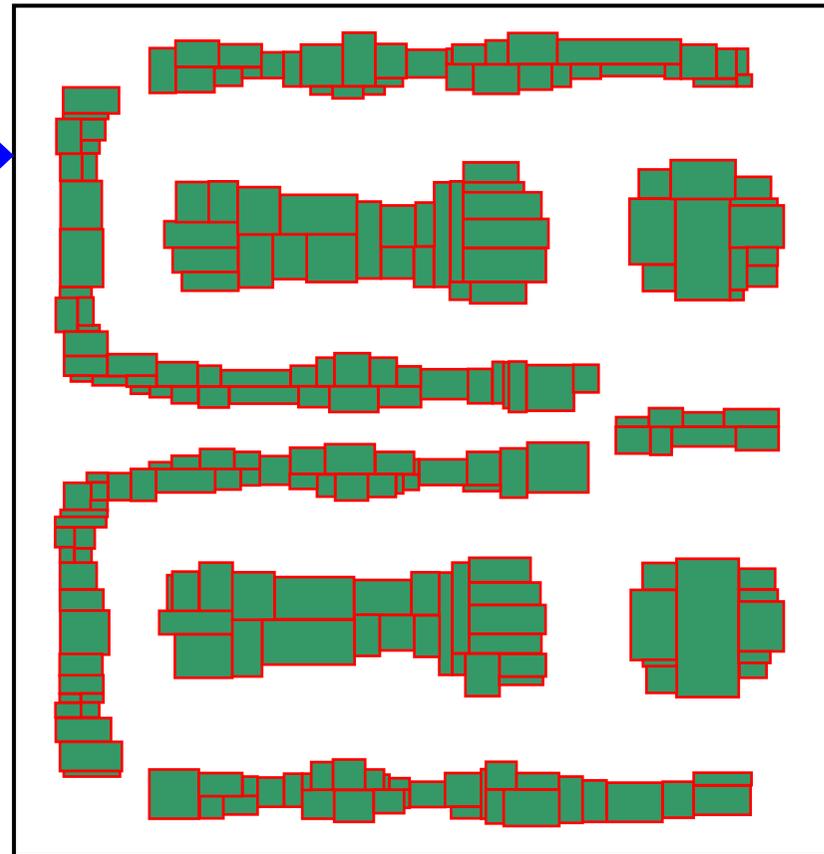
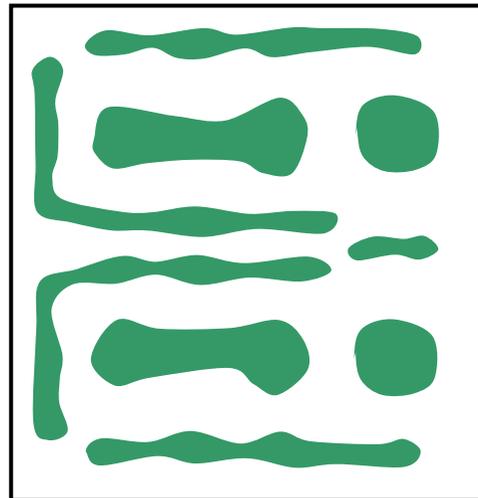
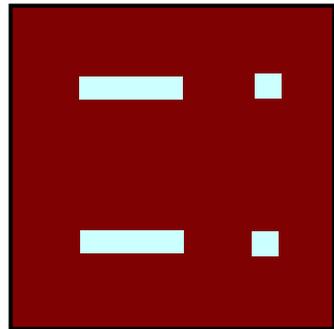
# Complex Photomask

# of writing features

design

ideal writing pattern

expected fracturing



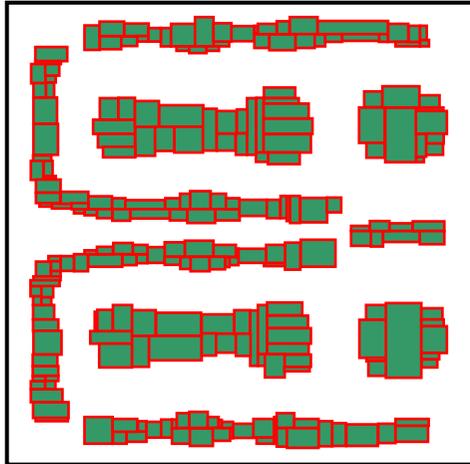
- without correction
- uncontrollable CD
  - unstable linearity
  - less Depth of Focus

Courtesy of  
Luminescent Technologies.

\*\* virtual pattern

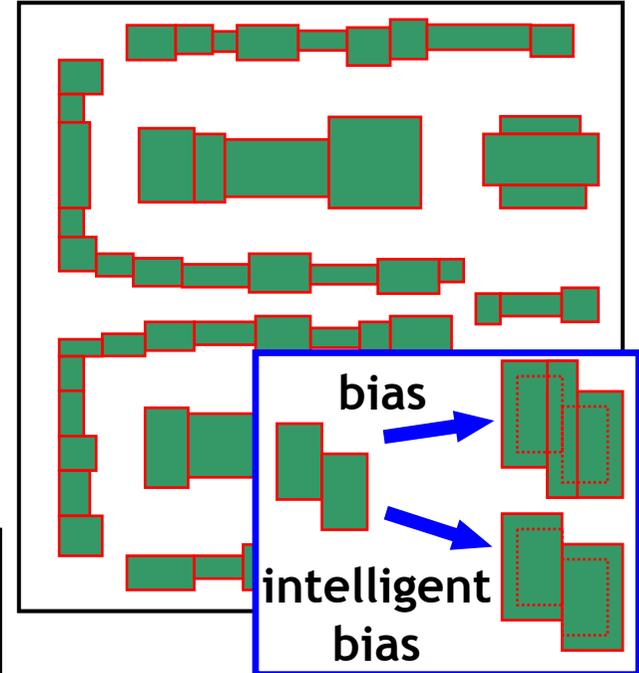
# Approaches

conventional fracturing



optimized fracturing

reducing writing time



litho-check

MB-MDP\*  
overlapped shots

litho-check  
EB writing check

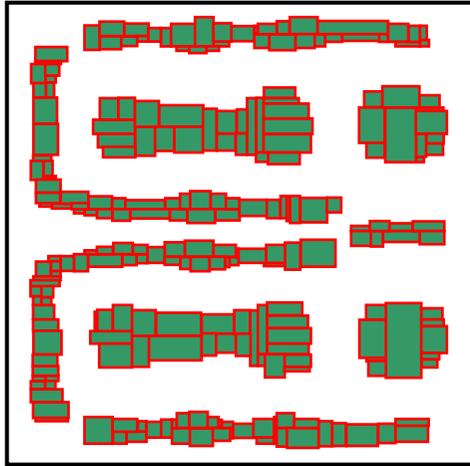
Fewer features  
optimal effect

\*MB-MDP : Model-Based  
Mask Data Preparation

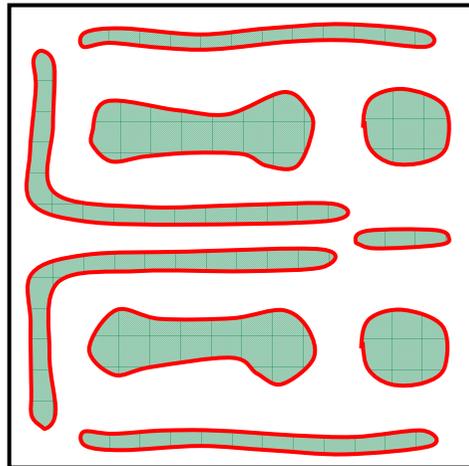
\*\* virtual pattern

# Approaches

conventional fracturing



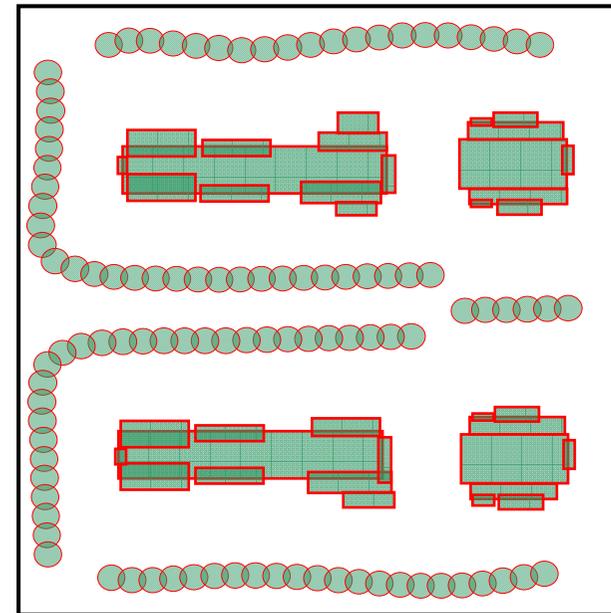
simplifying assist features



reducing writing time

**MB-MDP**

**overlapped shots  
with circular shape**

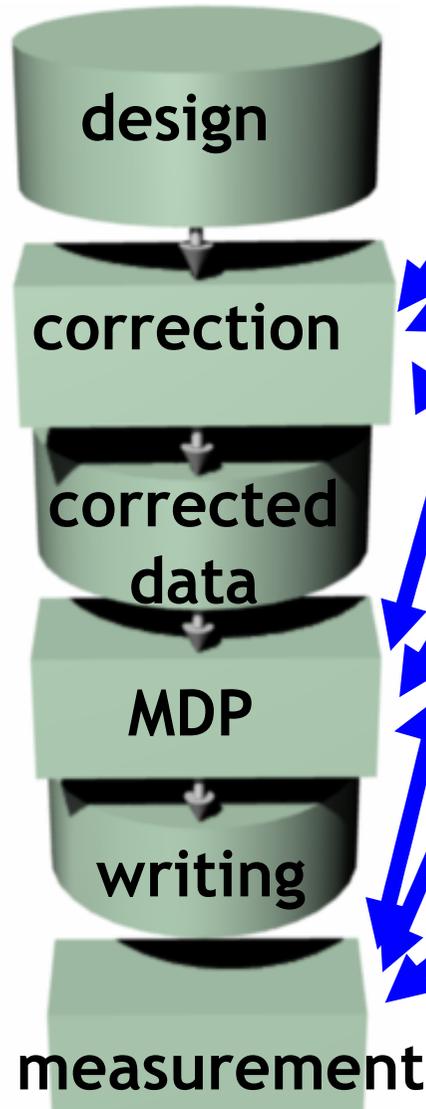


**Fewer features  
optimal effect**

\*\* virtual pattern

# Approaches

## supposed environment



a) Linearity : small features smaller  
- Linearity-aware Correction  
- Mask Process Compensation

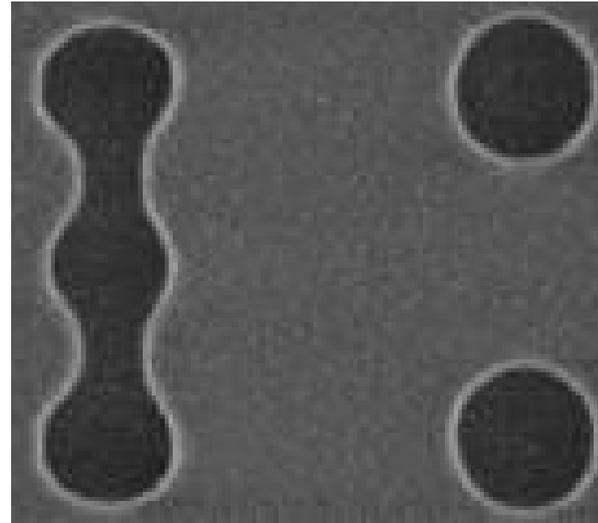
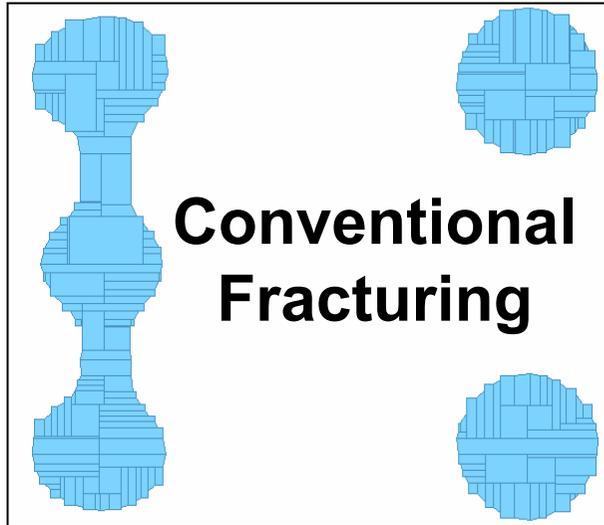
b) Writing time : too many features  
- Litho-aware Correction  
- MDP-aware Correction

c) Process bias inconsistency :  
process bias induced number doubling  
- Bias-aware Correction  
- Specific bias

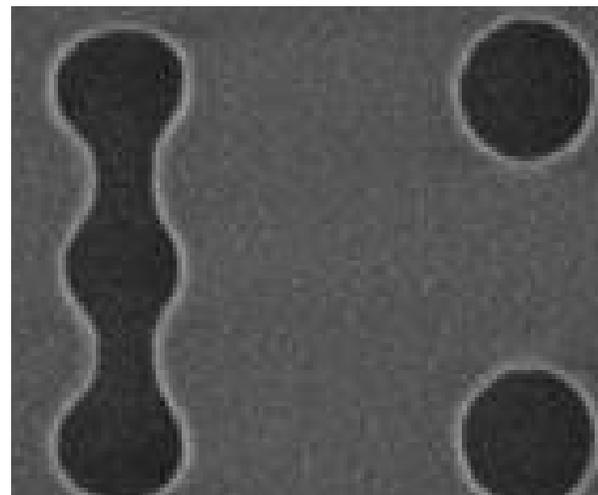
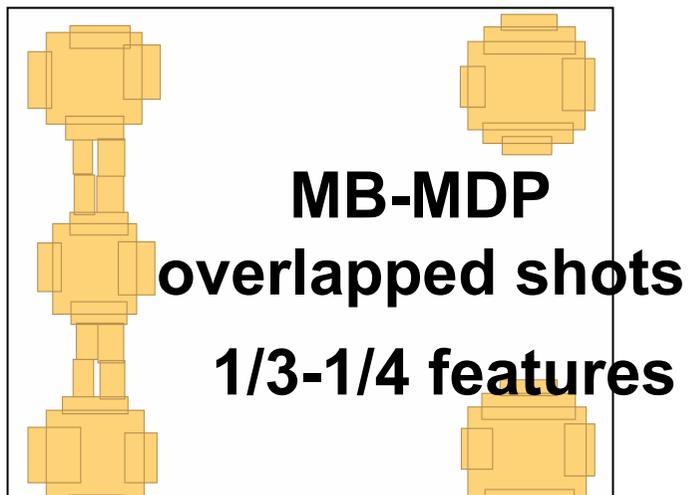
Independent "correction", "MDP" doesn't work

# Trials & Examples

## overlapped fracturing



Resist  
SEM MFG:75K



Courtesy of  
D<sub>2</sub>S, Inc.



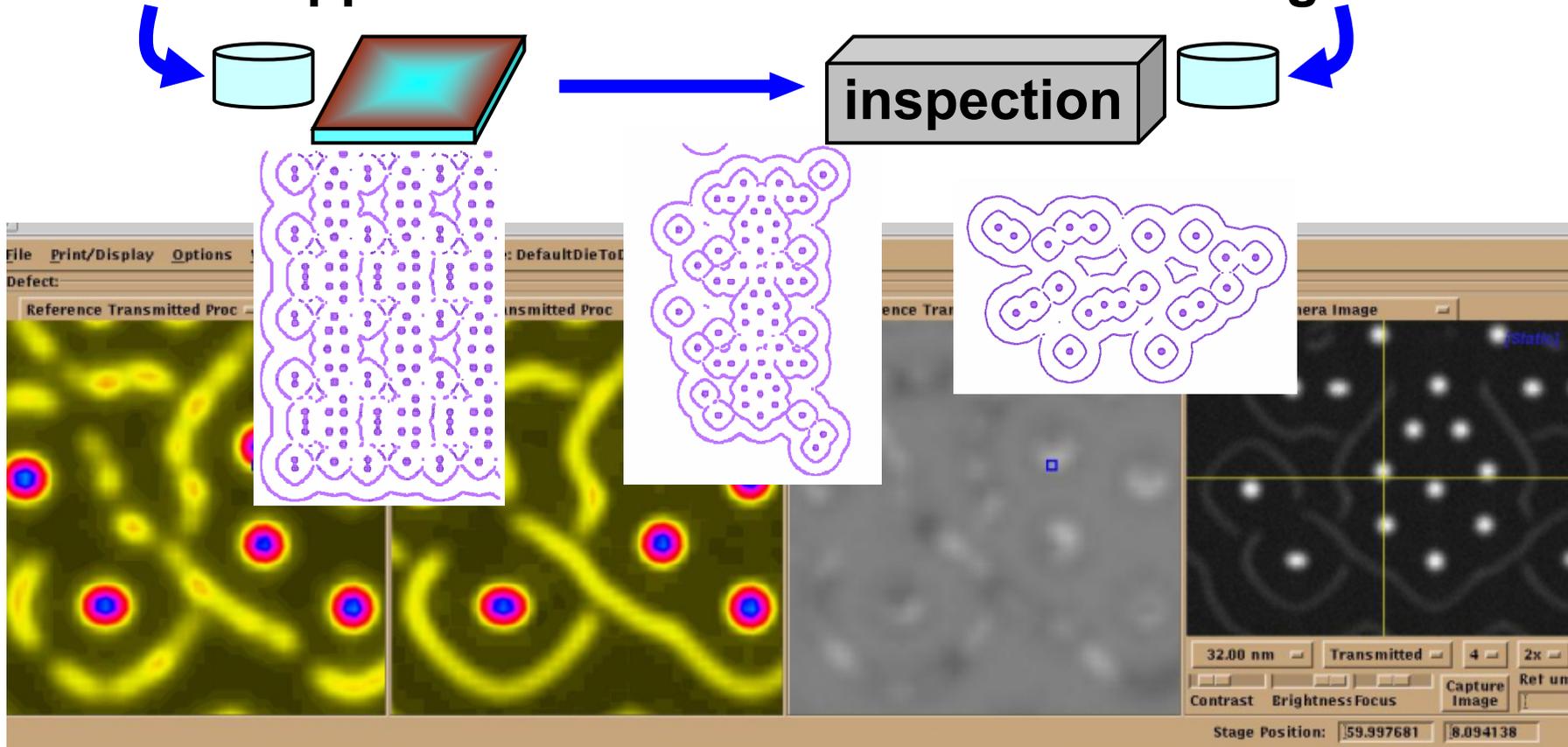
**Overlapped fracturing reduces the number of features**

# Trials & Examples

inspection

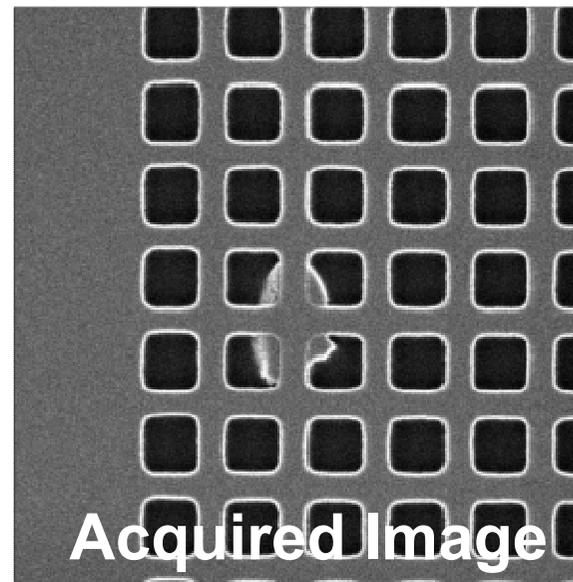
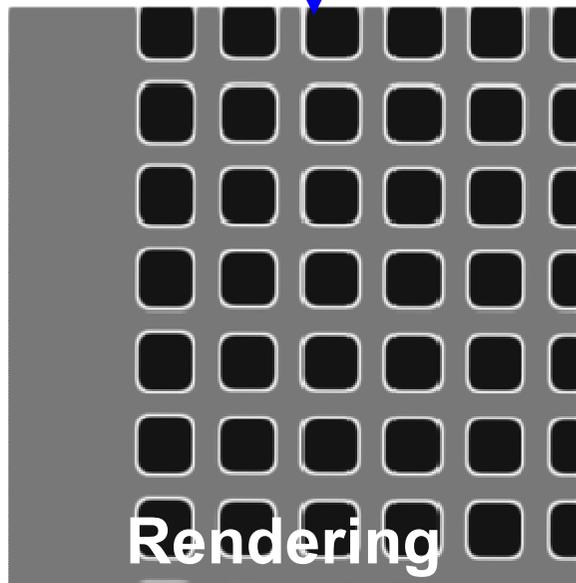
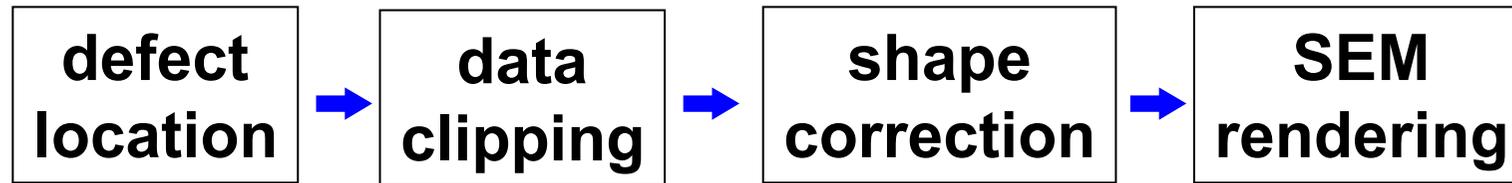
written with MB-MDP  
overlapped shots

inspected with conventional  
fracturing



**Confirmed : No alignment-error, No dimension error**

# Trials & Examples



Repaired-image-reconstruction including complex ones available

Courtesy of  
Luminescent Technologies.

# Summary

- ArF will be extended more than ITRS expectations
- Photomask data is becoming more complex and intensive
- Successful trials are underway using overlapped shots with MB-MDP
- Data correction & MDP need to be more closely linked

## Probe further

- Practical process compensation approach
- Effective inspection & repair
- Linearity improvement as well
- Total load estimation

## Acknowledgement

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Ohara-san : Nippon Control System;  
and DNP Japan related to this topic.