Metal Oxide Photoresists:
Breaking Paradigms in EUV Lithography

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2017 EUVL Workshop

Overview

- Introduction
- Opportunity for improvement in post-etch roughness
- EPE control through use of selective etch

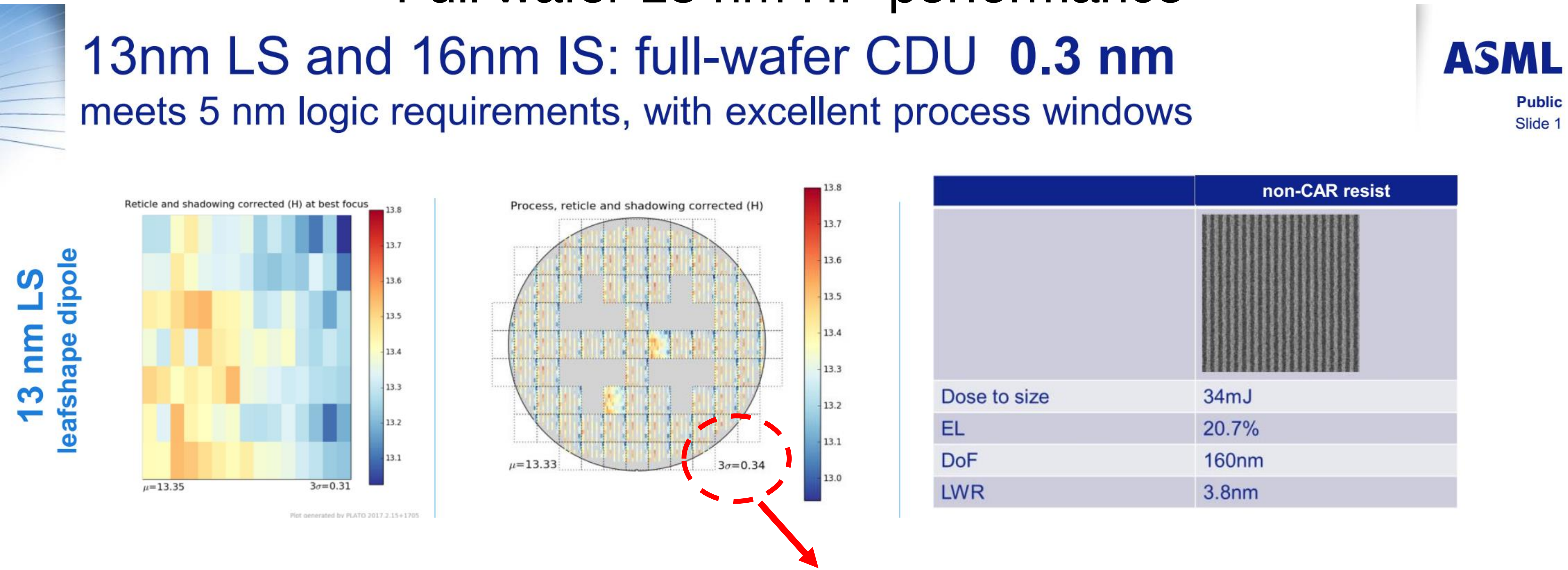
Introduction

Inpria - Metal oxide (MOx) photoresists

- Sn based – high EUV absorption
- Fab compatible organic casting solvent
- Fab compatible organic developer
- Negative tone
- Low Blur

Resist Performance (RLS)

Full wafer 13 nm HP performance



13nm LS and 16nm IS: full-wafer CDU **0.3 nm**

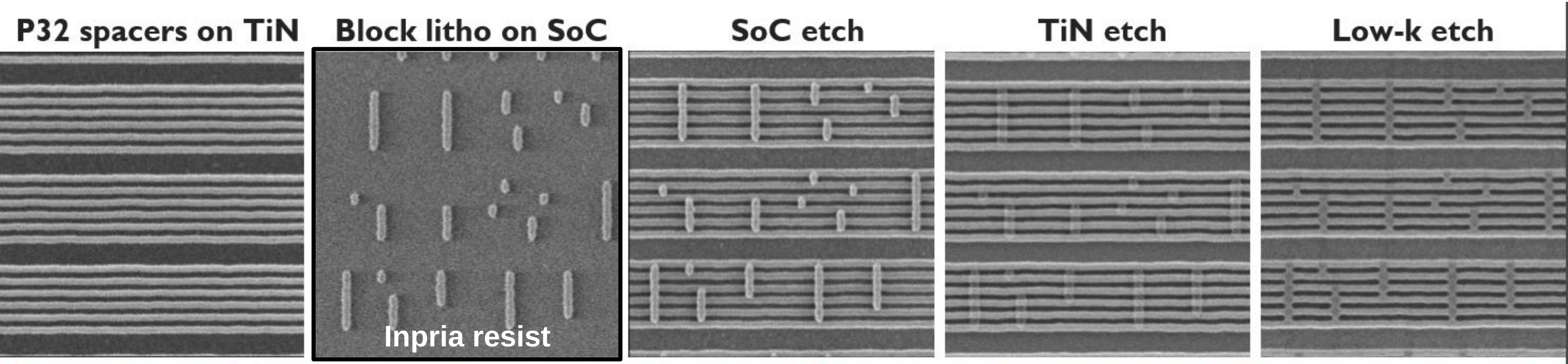
meets 5 nm logic requirements, with excellent process windows

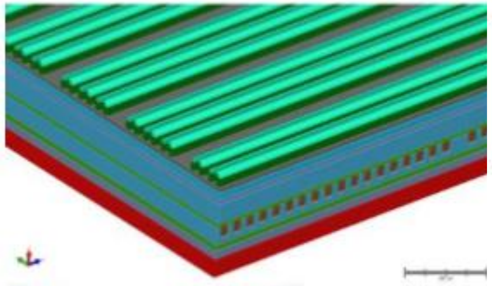
	non-CAR resist
Dose to size	34mJ
EL	20.7%
DoF	160nm
LWR	3.8nm

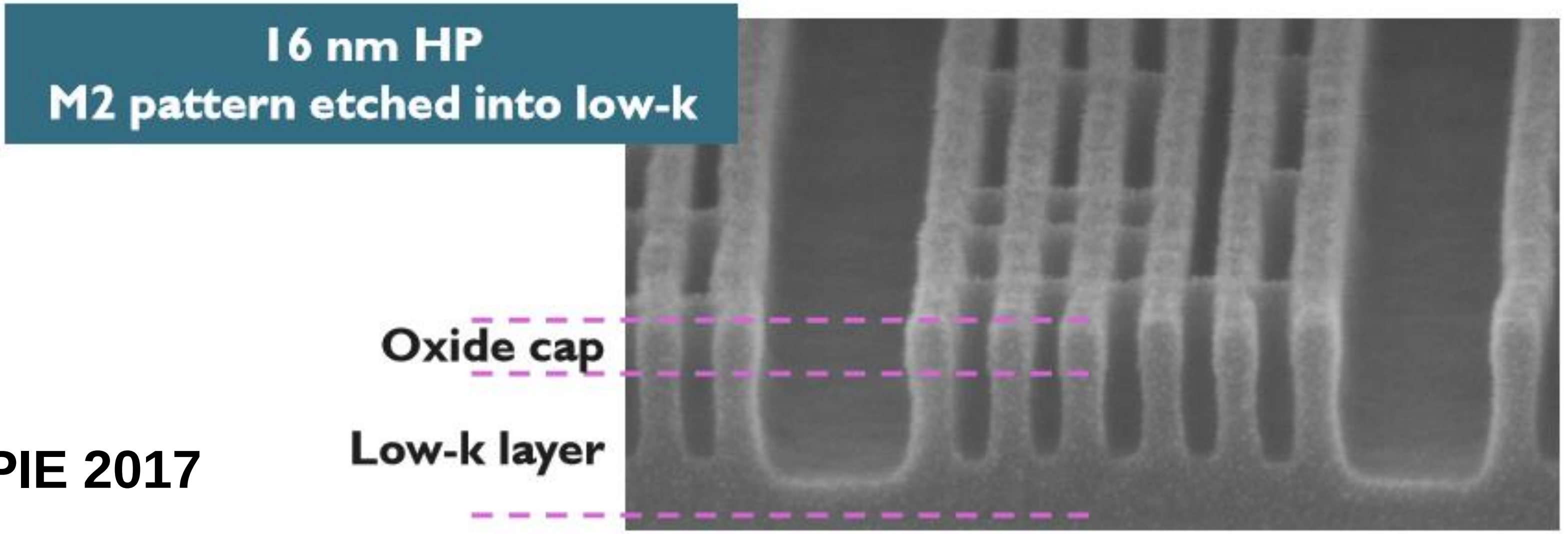
3σ CDU = 0.34

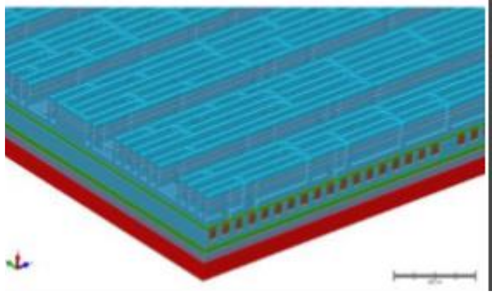
van de Kerkhof SPIE 2017

Inpria Resist for M2 Block Printing









Bekaert et al. SPIE 2017

Inpria resist integrated in 32nm pitch M2 flow

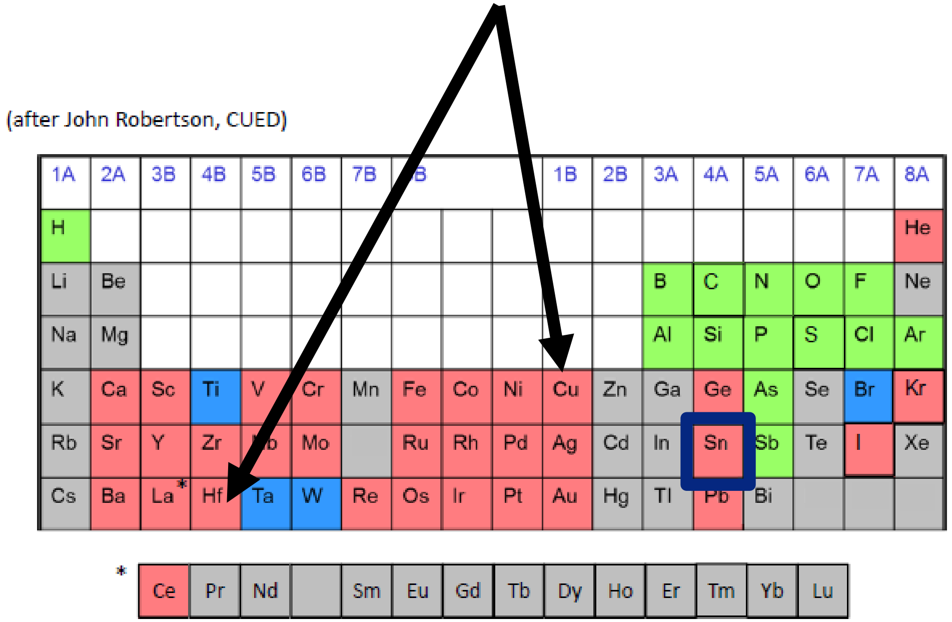
Device Requirements Drive Adoption of Many Elements

Examples of adoption driven by fundamental functional material properties

70's

80's

Today



(after John Robertson, CUED)

1A	2A	3B	4B	5B	6B	7B	B			1B	2B	3A	4A	5A	6A	7A	8A
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo		Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi			

*														
	Ce	Pr	Nd		Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

Today, nearly two thirds of the non-radioactive elements are used in every chip!

Inpria MOx Resist Platforms

Courtesy Ben Eynon

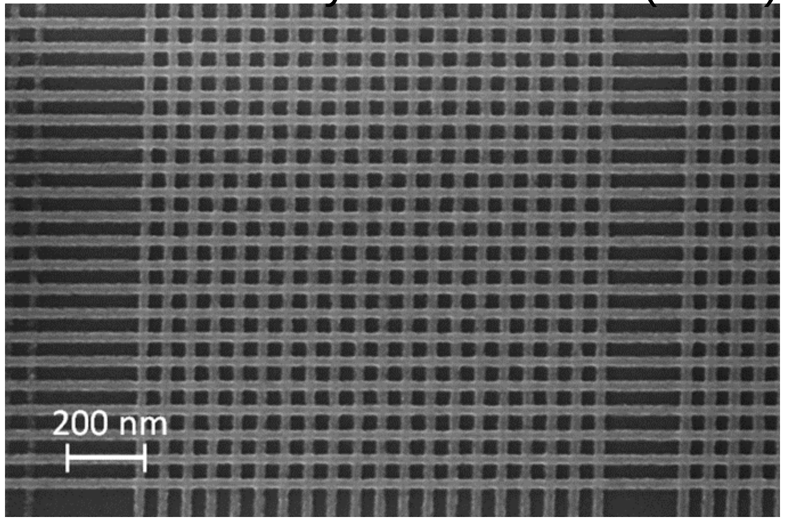
Opportunities for New Element in Patterning

- Inpria is introducing new (metal) element at the litho cluster
- Adoption of such a new material can only be driven by major gains in the performance and capabilities offered by the platform
- Full potential of MOx resists will be obtained as part of an integrated process, i.e., beyond the litho cluster
- Important to consider full value to integrated process (not only RLS) while weighing the risk of introducing a new material

Unique MOx Properties Realized through Etch

- After develop, Inpria resists are hardmask-like materials, similar to TiN or TiO_2. It is a patterned hardmask that is formed without a dry etch
- Patterns become inert to most later processing
  - Litho Freeze Litho Freeze

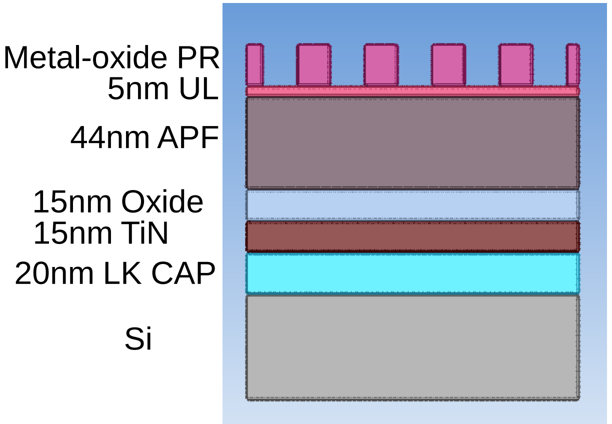
Telecky et al. JVSTB (2010)

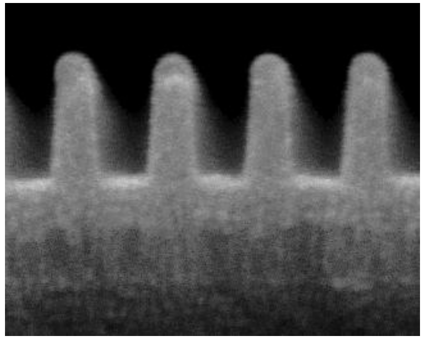


- The etch properties of Inpria materials create the opportunity for unique improvements at the intersection of litho and etch
  - Greater reduction of LWR/LER post-etch
  - Improving edge placement error through etch selectivity

ROUGHNESS THROUGH ETCH

Roughness through Etch

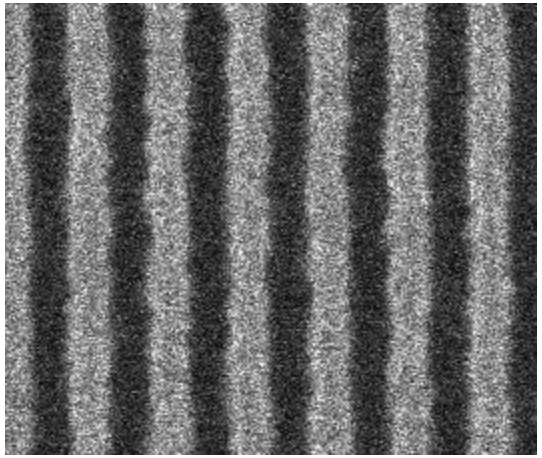




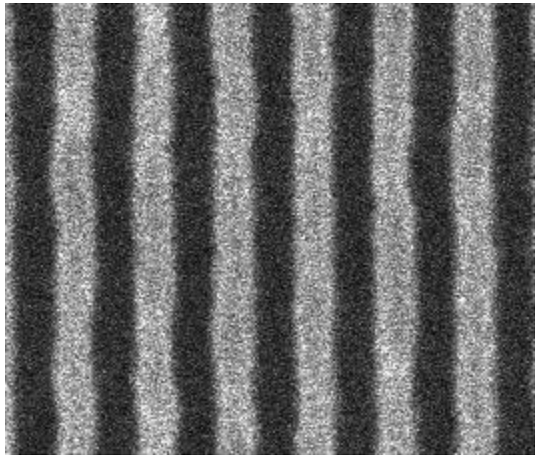
Post UL/APF Etch

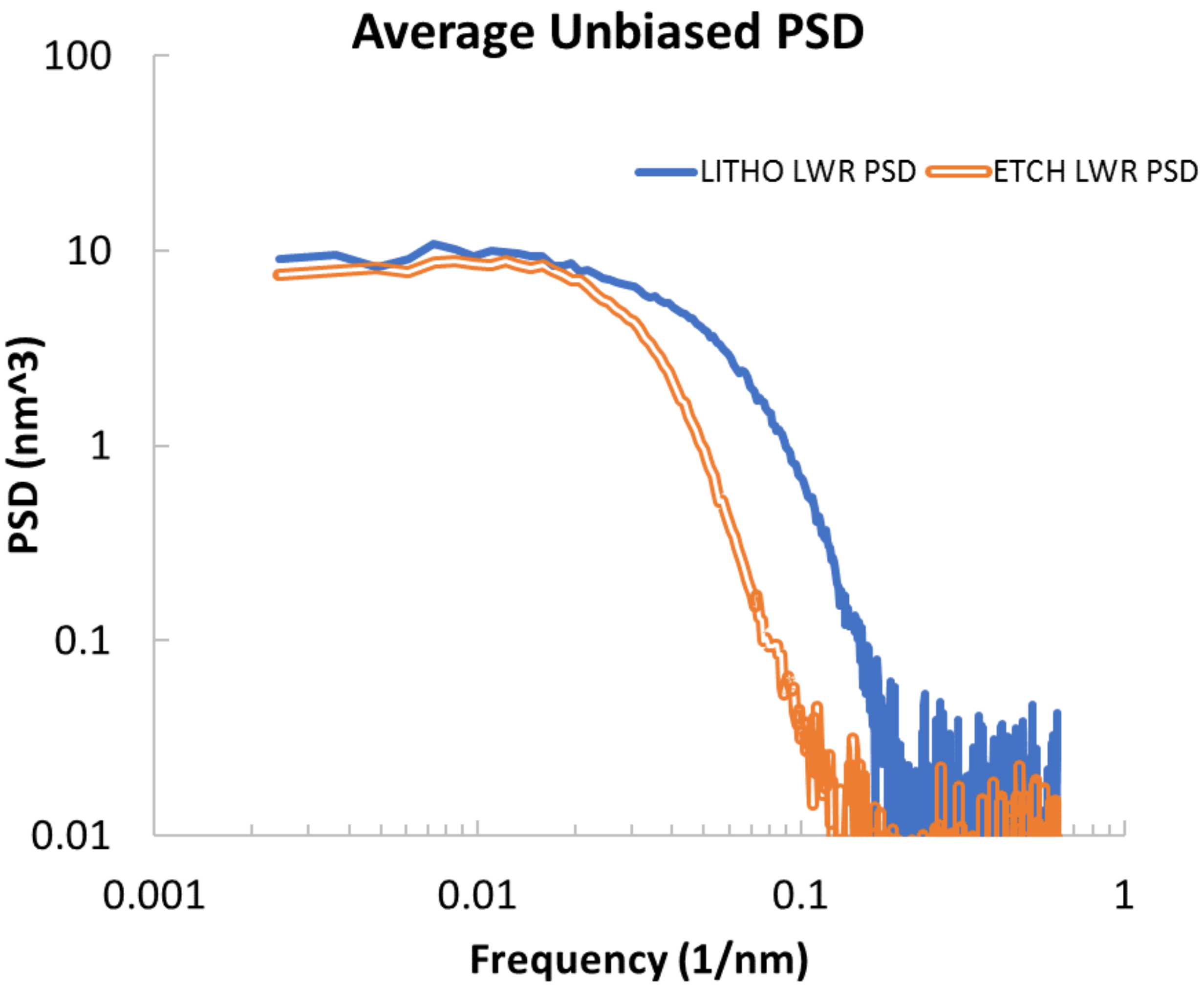
16 nm HP
LWR -31%

Litho



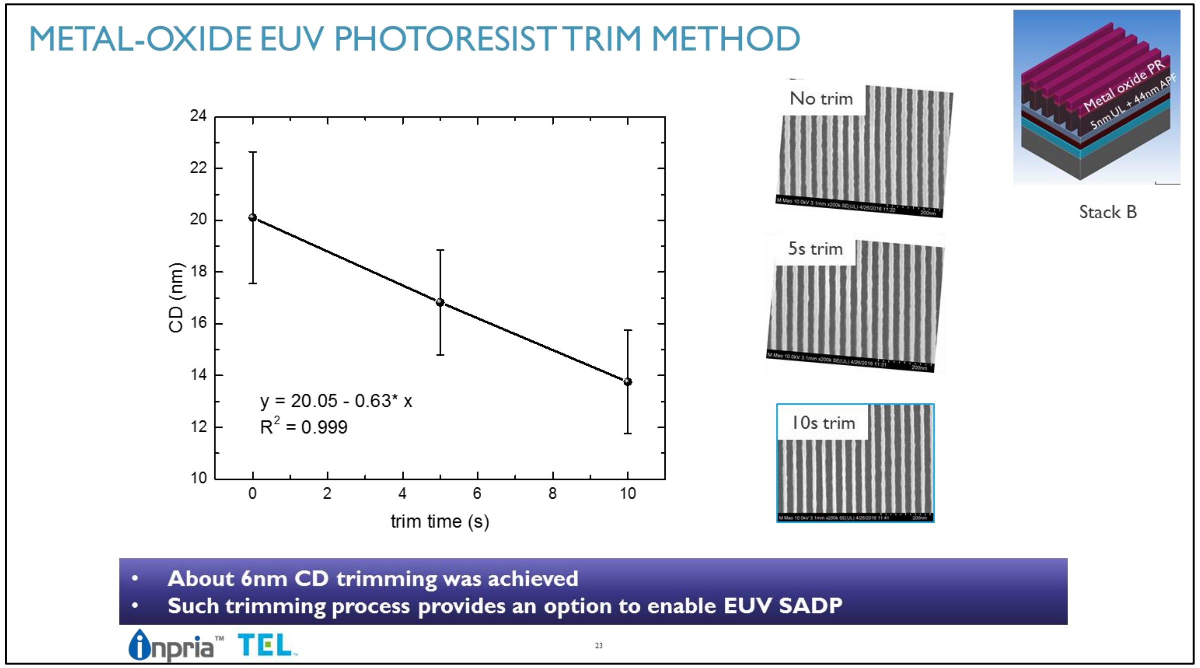
TiN Open





Roughness through Etch

- Any etch operation can have some smoothing effect
- Intentional LWR smoothing also acts as a trim step. The limits of a trim step is the thickness of resist needed for pattern transfer.

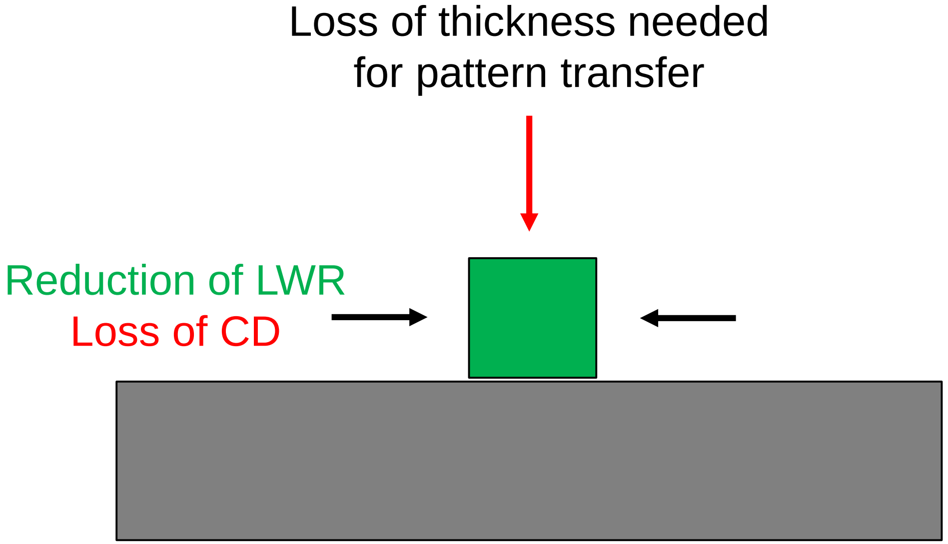


METAL-OXIDE EUV PHOTORESIST TRIM METHOD

- About 6nm CD trimming was achieved
- Such trimming process provides an option to enable EUV SADP

Mao et al. SPIE 2017

Trim Etch

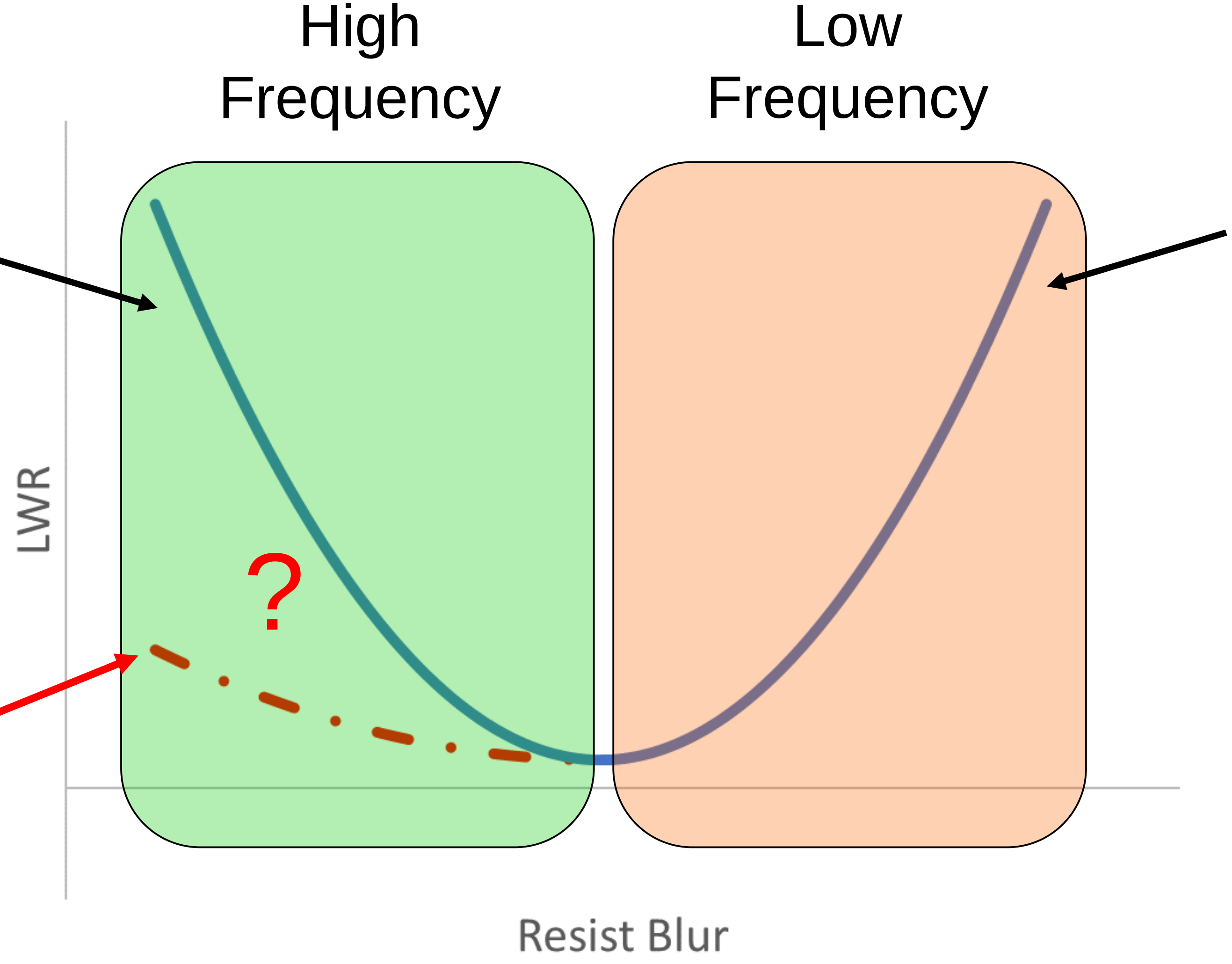


Loss of thickness needed for pattern transfer

Reduction of LWR

Loss of CD

Roughness through Etch



Decreasing LWR as blur smoothes photon shot noise

Increasing LWR as blur dominates

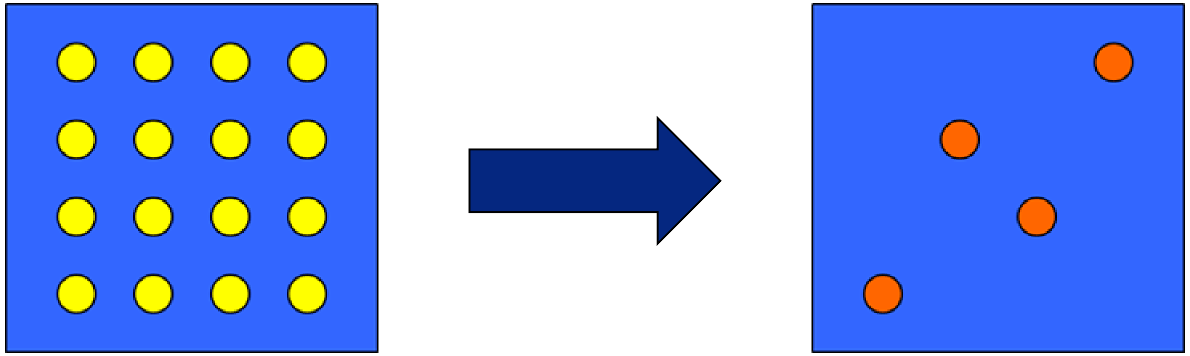
After Etch

Frequency distribution of LWR determined by both resist blur and etch

EPE CONTROL THROUGH USE OF SELECTIVE ETCH

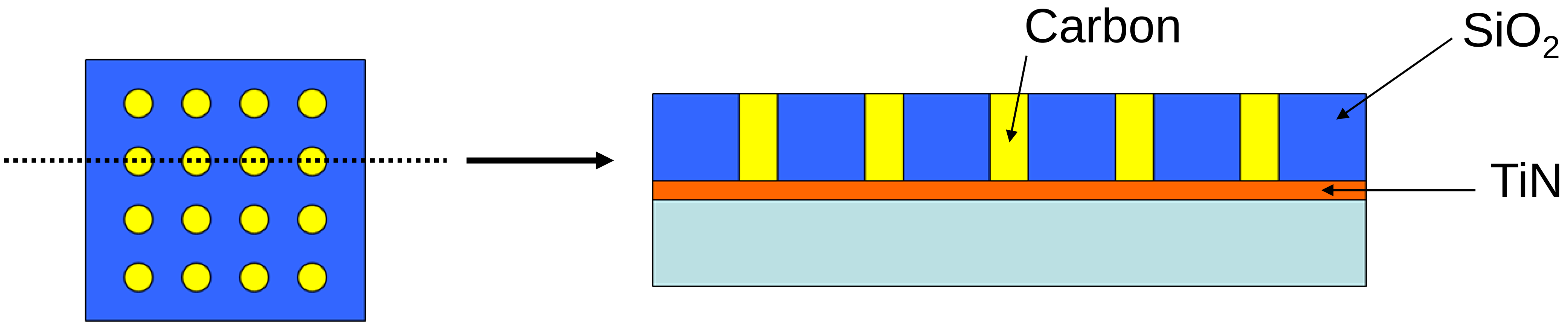
Controlling EPE Budgets

- Smart material selections and creative integration schemes can relax the EPE budget
- Example - sparse contact arrays
  - Start with a pre-patterned template, e.g., an array of holes
    - Patterned by two SADP processes or DSA
    - These features define the edges
  - Select the individual features required from the template

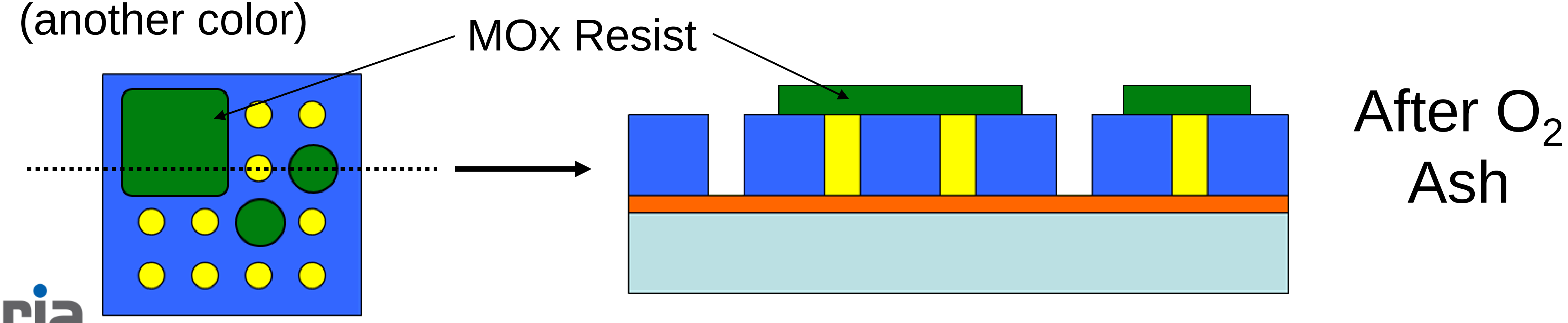


Controlling EPE Budgets

- Create surfaces with multiple materials (two or more colors for etch)

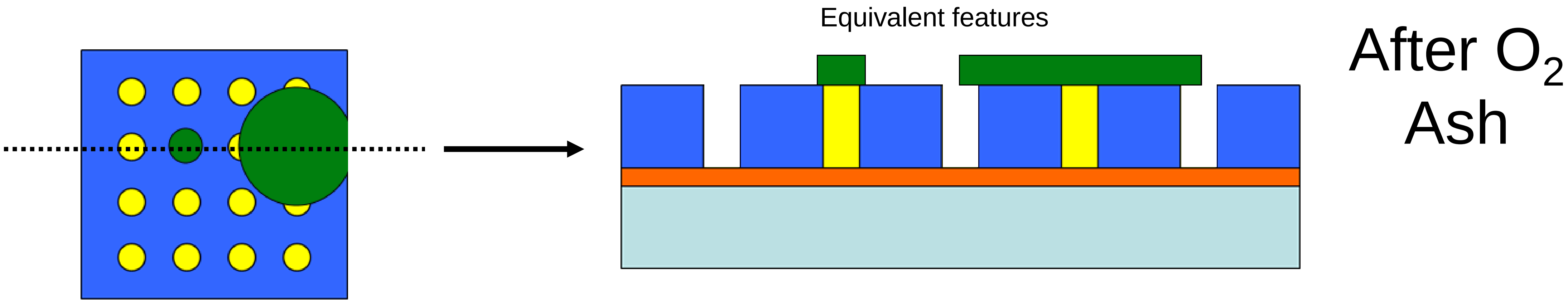


- MOx resists are a separate material used to select parts of the template (another color)



Controlling EPE Budgets

- Isotropic etch conditions enlarge the possible edge positions



- Similar to a SADP process, critical edge definition can be off loaded to another process
- Critical lithography step then becomes selecting the desired elements of the template
- Key is having a hardmask patterned by developer, not a dry etch, and that hardmask being a different etch color

Conclusions

- MOx resists provide substantial opportunity for LWR improvement through etch
  - Truly evaluating RLS requires looking after etch

- Full potential of MOx resists extends beyond RLS
  - Unique etch properties: high selectivity, and separate etch “color”
  - Powerful integration schemes enabled

- Overall: MOx resists provide significant opportunities for additional gain by co-designing litho & etch processes