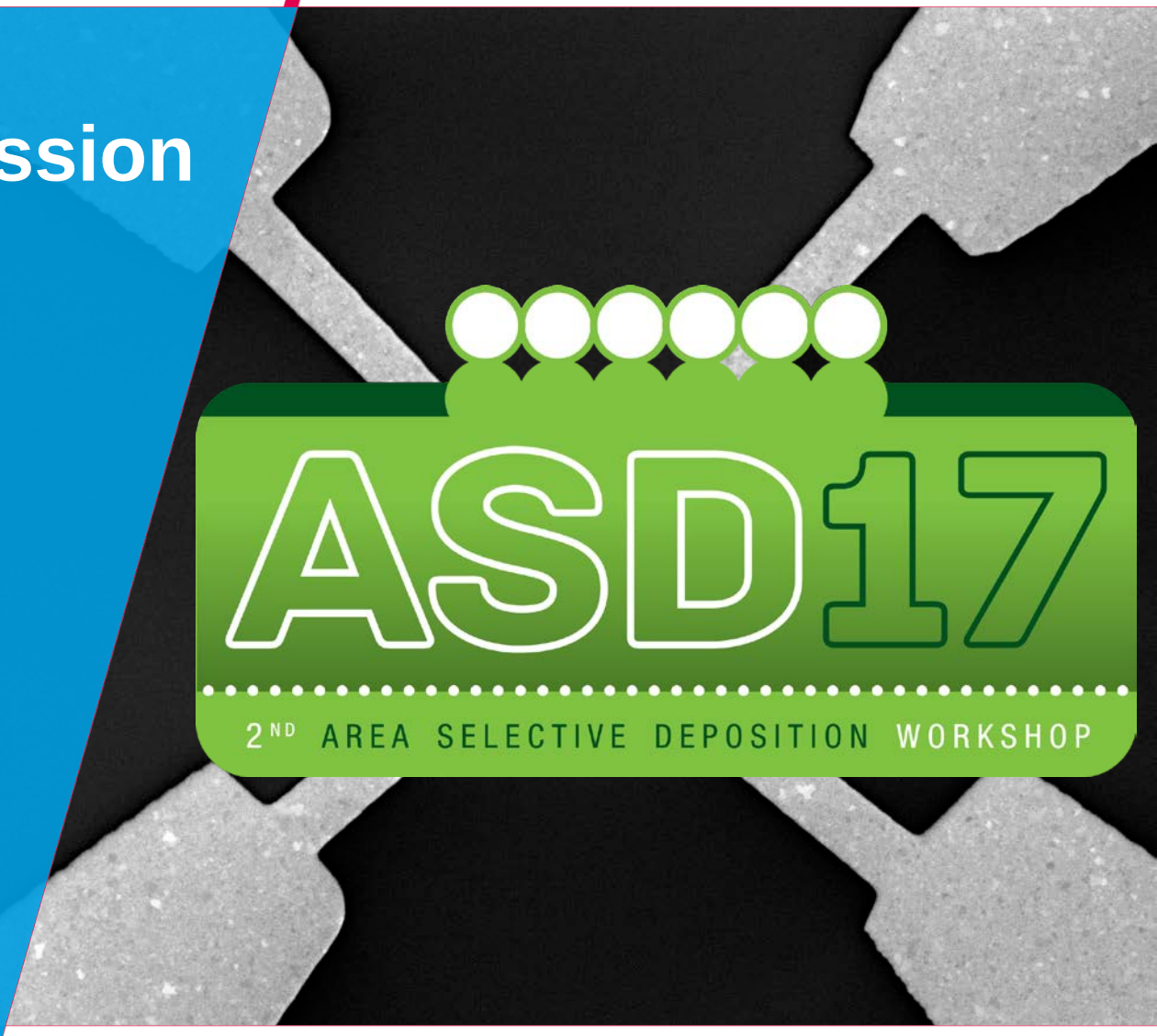
Technische Universiteit Eindhoven University of Technology

NC STATE UNIVERSITY

Discussion session ASD 2017



Moderated by:

Gregory Parsons

Adrie Mackus

Where innovation starts

Outline:

1. Discussion Topics (5 min each)

- John Abelson
  - The interface of the moving boundary
- Fred Roozeboom
  - Synchronized rapid temperature modulation
- Rong Chen
  - Selectivity degradation mechanisms
- Tahsin Faraz
  - Selectivity in deposition versus etching

2. Key Insight from Today (5 min)

3. Questions for the Community (20 min)

4. ASD 2018

Discussion topics

1. John Abelson
   The interface of the moving boundary

2. Fred Roozeboom
   Synchronized rapid temperature modulation

3. Rong Chen
   Selectivity degradation mechanisms

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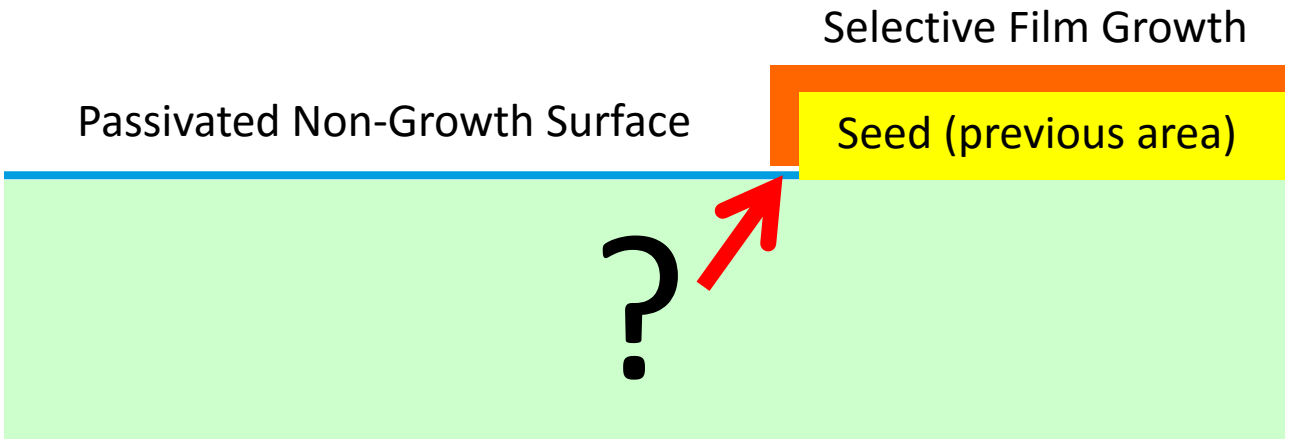
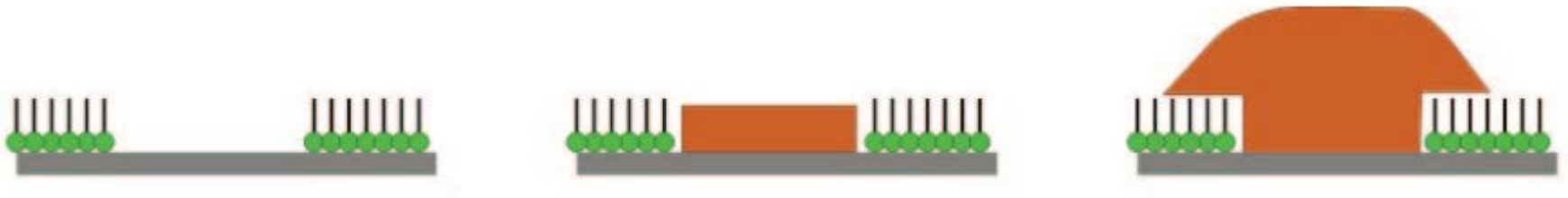
The Interface of the Moving Boundary

If we passivate the non-growth surface by chemical termination, SAM, etc.,
do we create a non-bonded seam?
Would it matter?



Lateral broadening– Mushroom-type growth



Ras *et al.* JACS 130, 11252 (2008)

- **What are the solutions for preventing lateral broadening?**
- **Is this a showstopper for the envisioned applications?**

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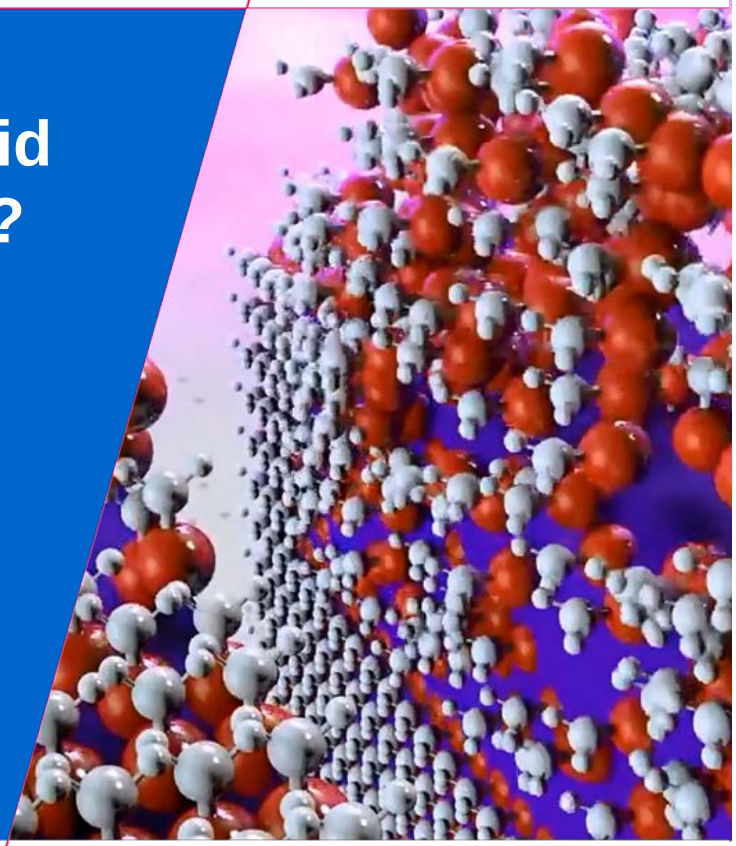
ASD17

2ND AREA SELECTIVE DEPOSITION WORKSHOP

Selective ALP with synchronized rapid (10-100 ms) temperature modulation?



Fred Roozeboom

TNO & TU Eindhoven

The Netherlands

TNO

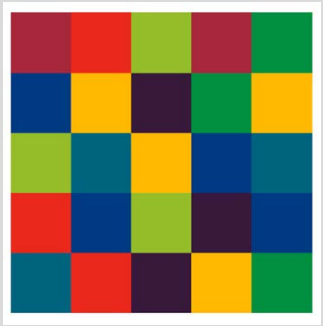
TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

Selective ALP with synchronized rapid (10-100 ms) temperature modulation?

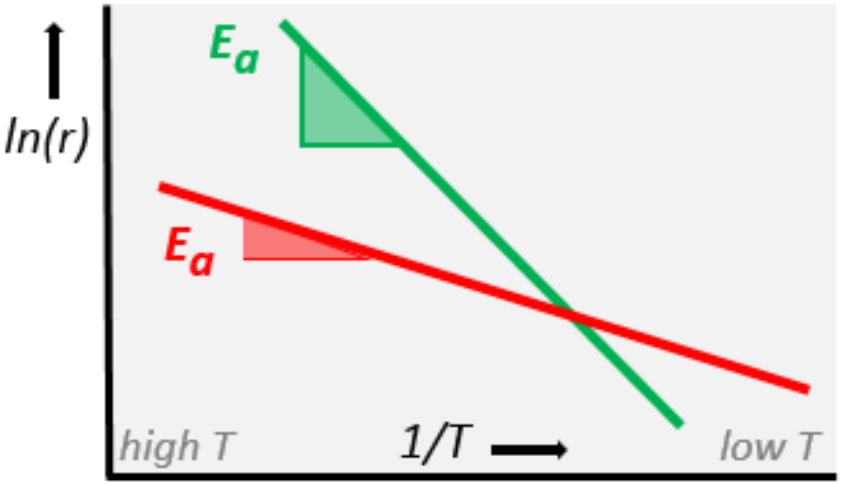
On everyone's wishlist:

Process just one material in a background of other materials

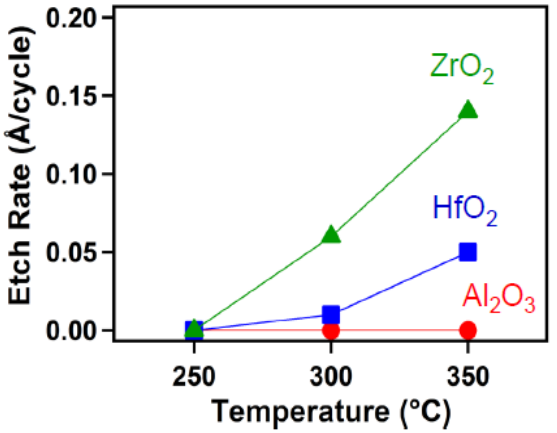


- Promote desired (half-) reactions* with high E_a
- Suppress undesired (half-) reactions with low E_a

* = dep, etch, clean, poison, desorb, anneal, …



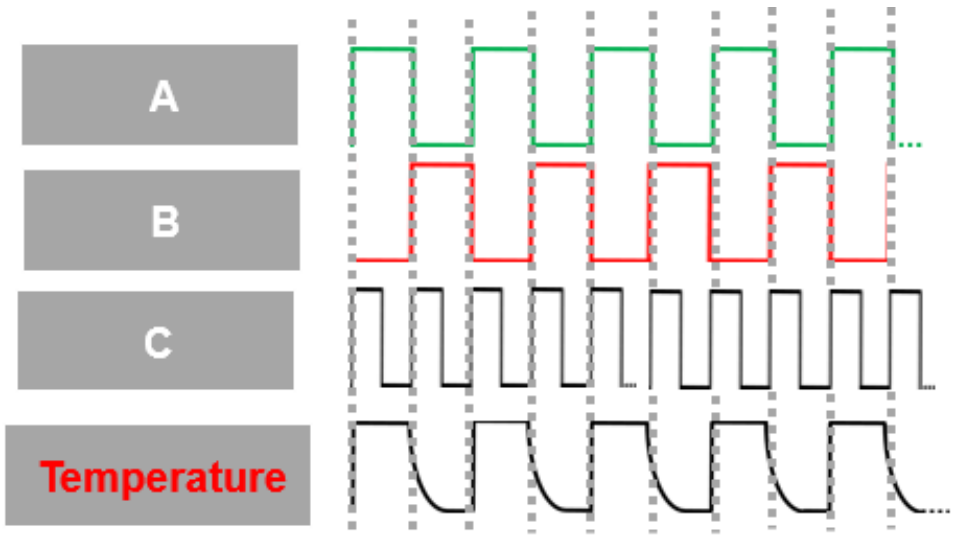
Selectivity Based on Temperature for ALE Using $SiCl_4$ as Metal Precursor

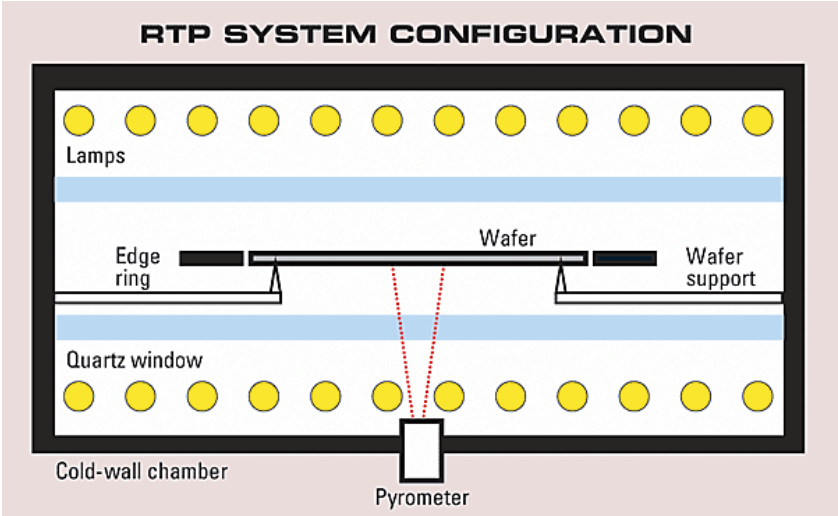


Younghee Lee

Selective ALP with synchronized rapid (10-100 ms) temperature modulation?

Mix of A-B-C etch/dep/inhibitor, *and flash* ?





ramp-up 100 ^{o}C/s

„ „ -down ~ 50 ^{o}C/s

- *Your opinion: nice to have or must have to get more selectivity?*
- *Manufacturers' viewpoint ?*

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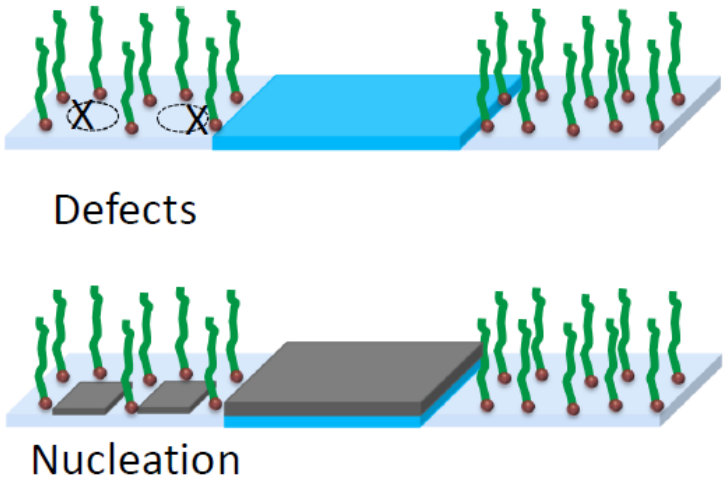
Selectivity degradation mechanism?

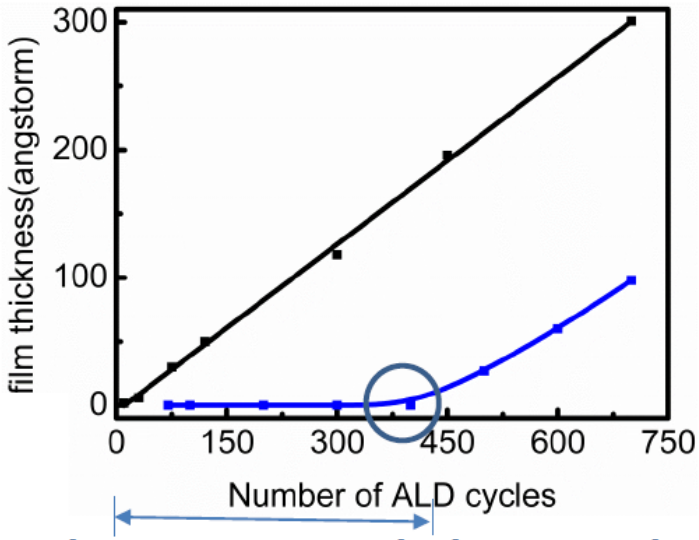
Rong Chen

Selectivity degradation mechanism?

Substrate modification



Nucleation delay



How do we characterize and obtain understanding of the influence of defects on the loss of selectivity?

understand the mechanism (steric, growth on, replacing ligands, etc.)
find a way to eliminate or reduce those defects

on the other hand, how to utilization those defects

- create those defects for better nuclation...
- what kind of defects ALD may passivate it successfully
- benigned processes that wont degrade inibitor or passivation layer

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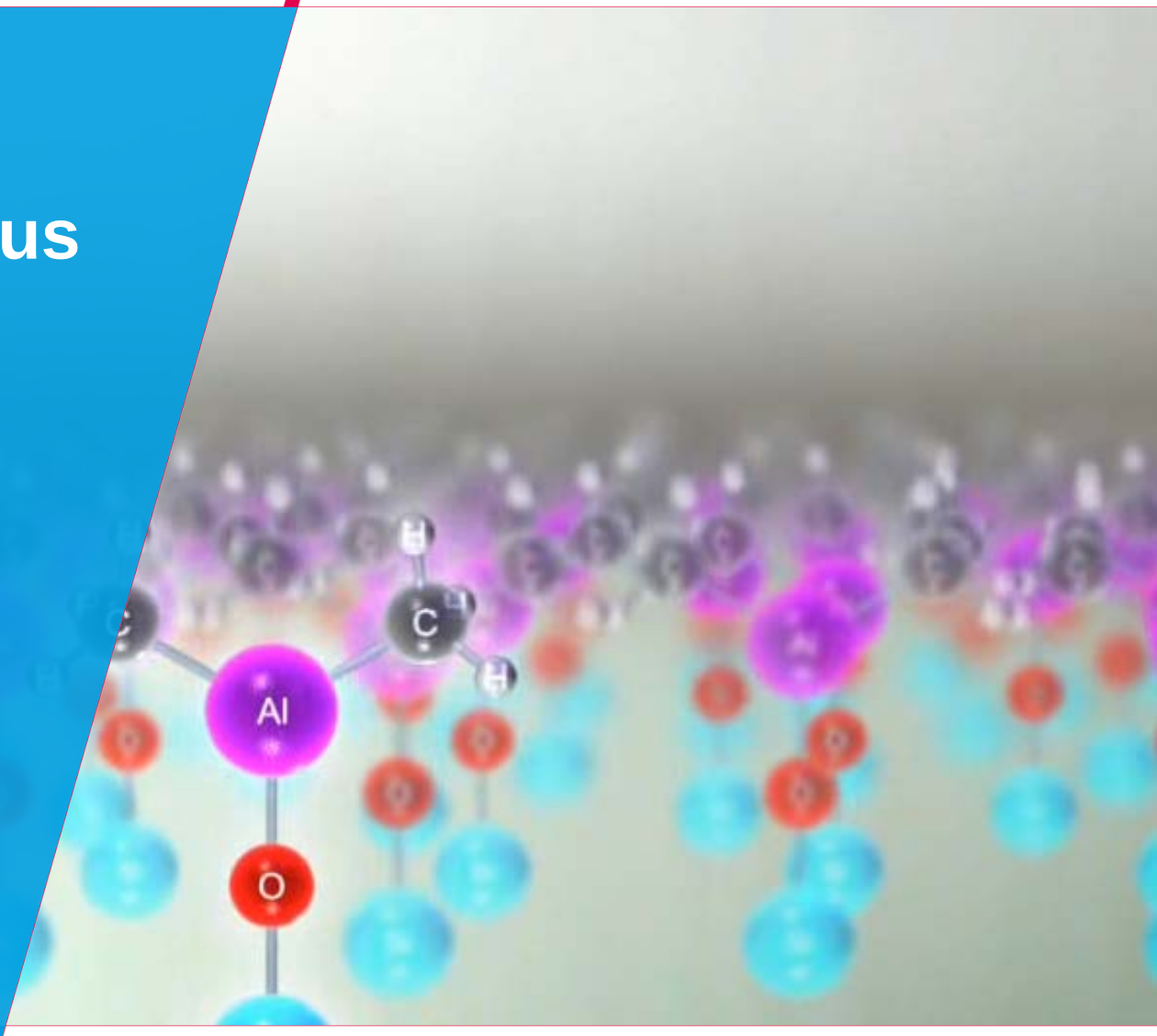
Selectivity in Deposition versus Etching



Tahsin Faraz

t.faraz@tue.nl
www.tue.nl/pmp

Where innovation starts

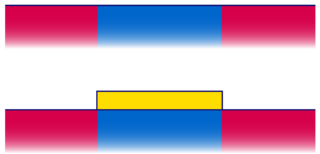
Selectivity in Deposition versus Etching

$$S_{Dep} = \frac{Dep\ rate\ on\ 1}{Dep\ rate\ on\ 2}$$

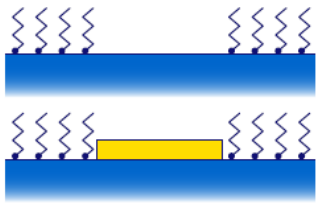
$$S_{Etch} = \frac{Etch\ rate\ of\ 1}{Etch\ rate\ of\ 2}$$

Ideal case

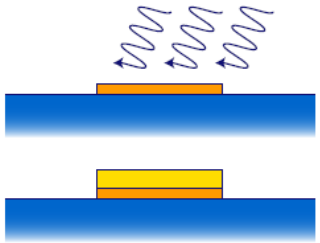
$S_{Dep} = \infty$



Inherent
Selective



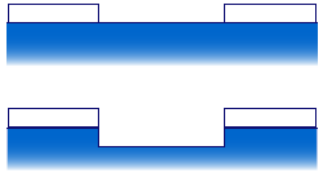
Selective by
deactivation

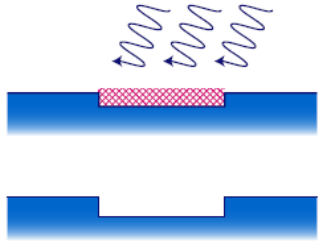


Selective by
activation

Ideal case

$S_{Etch} = \infty$





Donnelly *et al.*, JVSTA **31**, 050825 (2013)
Faraz *et al.*, J. Sol. State Sci. Tech. **4**, N5023 (2015)

Selectivity in Deposition versus Etching

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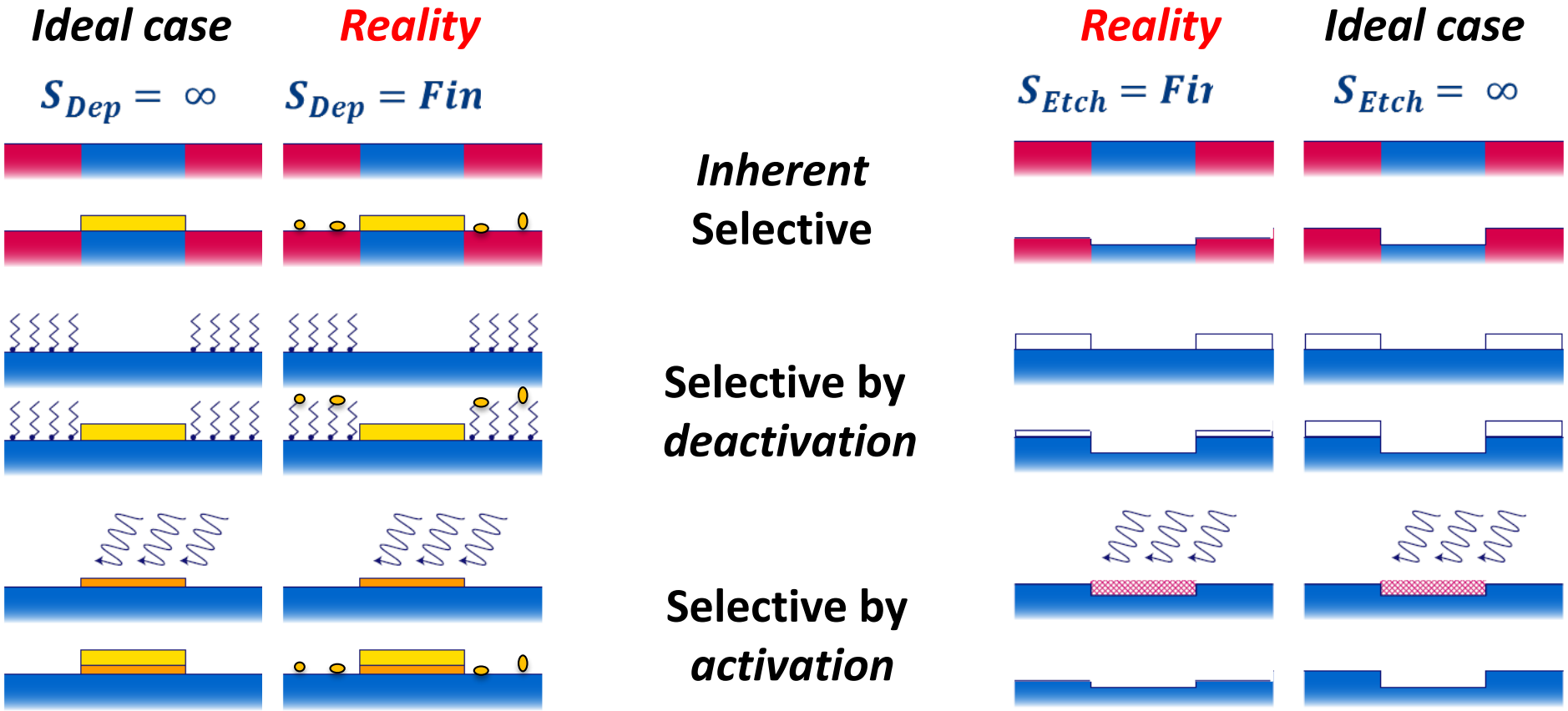
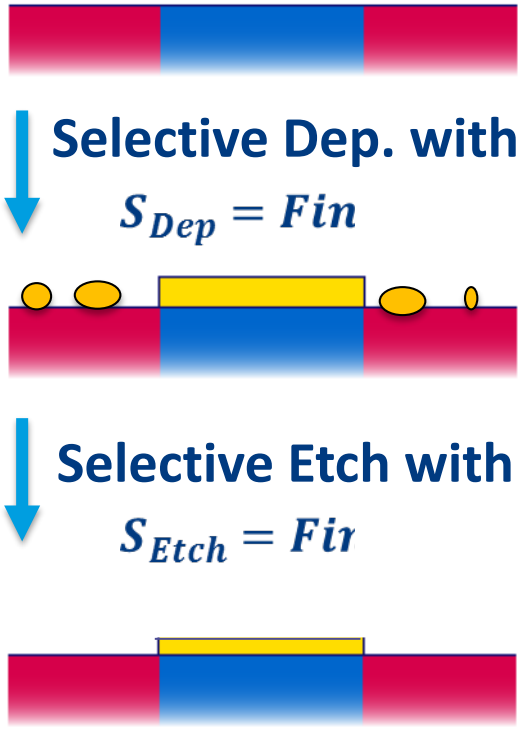


Donnelly *et al.*, JVSTA **31**, 050825 (2013)
Faraz *et al.*, J. Sol. State Sci. Tech. **4**, N5023 (2015)

Does ASD really need to be perfectly selective?

- ASD processes are typically not sufficiently selective for industrial applications.
- Etch process with high selectivity are well-known in the literature
- Is a combined **ASD + selective etch** technique the right way to go?

❑ ***Should we aim at improving the selectivity of deposition or will applications most likely involve selective etching steps anyway?***



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2. Key Insights from Today (5 min)

3. Questions for the Community (20 min)

Key Insights from ASD 2017

- Development of **plasma-assisted** ASD:
  - Plasma-assisted ALD of SiO_2 ALD (Alfredo Mameli)
  - PECVD of Si (Ekaterina Filatova)
  - Plasma-assisted ALD of Ta_2O_5 (Remy Gassilloud)
- Methods for **topographically selective** deposition:
  - Ion implantation + area-selective ALD (Stacey Bent)
  - Deposition on bottom-trench (John Ekerdt)
- **Metrology** – detection of defects / impurities is crucial to improve selectivity

Key Insights from ASD 2017: Continued

- Focus shifting: Blocking growth before deposition → **improving selectivity during deposition** by:
  1. **Etching**:
     - Self-correcting process: selective deposition + etching (Stacey Bent)
     - ALE for removal of unwanted ALD nucleation (Younghee Lee)
     - Gently etch-back unwanted deposit to suppress nucleation (Jean-Marc Girard)
     - Area-selective ALD + selective etching in supercycle (Sonali Chopra)
     - Nucleation delay + plasma etching in supercycle (Remy Gassilloud)
     - Etch followed by clean/reset (David Thompson)

  2. **Re-applying deactivation molecules**
     - SAM repair between ALD cycles (Stacey Bent)
     - Continuous dosing of inhibitors during CVD (John Abelson)
     - ABC ALD cycles with inhibitor (Alfredo Mameli)

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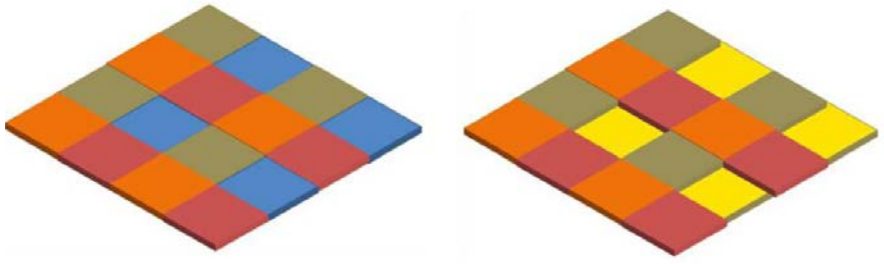
2. Key Insights from Today (10 min)

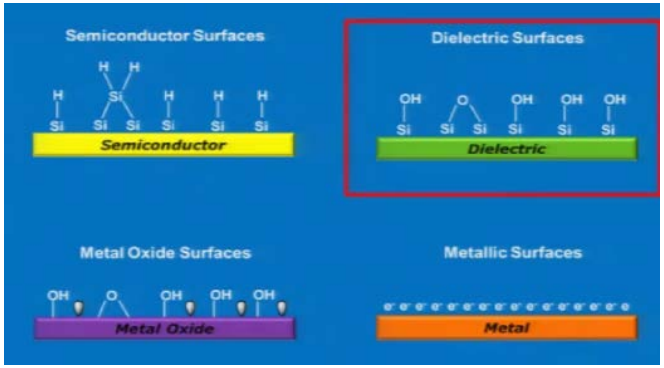
3. Questions for the Community (20 min)

Questions for the Community

1. Self-aligned fabrication will involve several materials.



Carver *et al.*, ECS JSSST 4, N5005 (2015)



Mayberry, ALD conference (2015)

- **What type of selectivity is preferred**?
- Oxide-on-oxide / metal-on-metal deposition?
- ASD on one specific material in the presence of other materials?

Questions for the Community – Cont'd

2. We need to compare different processes.
   - How do we quantify selectivity?
   - Is feature size important when comparing selectivity?
   - Require sub-100nm patterns?

3. How much selective deposition is enough?
   - Related to Thickness? e.g. "10 nm is enough" –?
   - Aspect ratio? e.g. "10 nm is enough for a 10 nm feature" –?

Questions for the Community – Cont'd

4. What fundamental knowledge is required to advance ASD?

5. Which applications beyond nanoelectronics could benefit from ASD?

6. What problems are most important to study?
   Edge effects?
   Substrate loading effects?
   Coupled etching/deposition?

ASD 2018

March/April 2018

Raleigh North Carolina USA

Chair: Gregory N. Parsons

North Carolina State University

ASD 2018

Sponsors: tbd

ASD 2018

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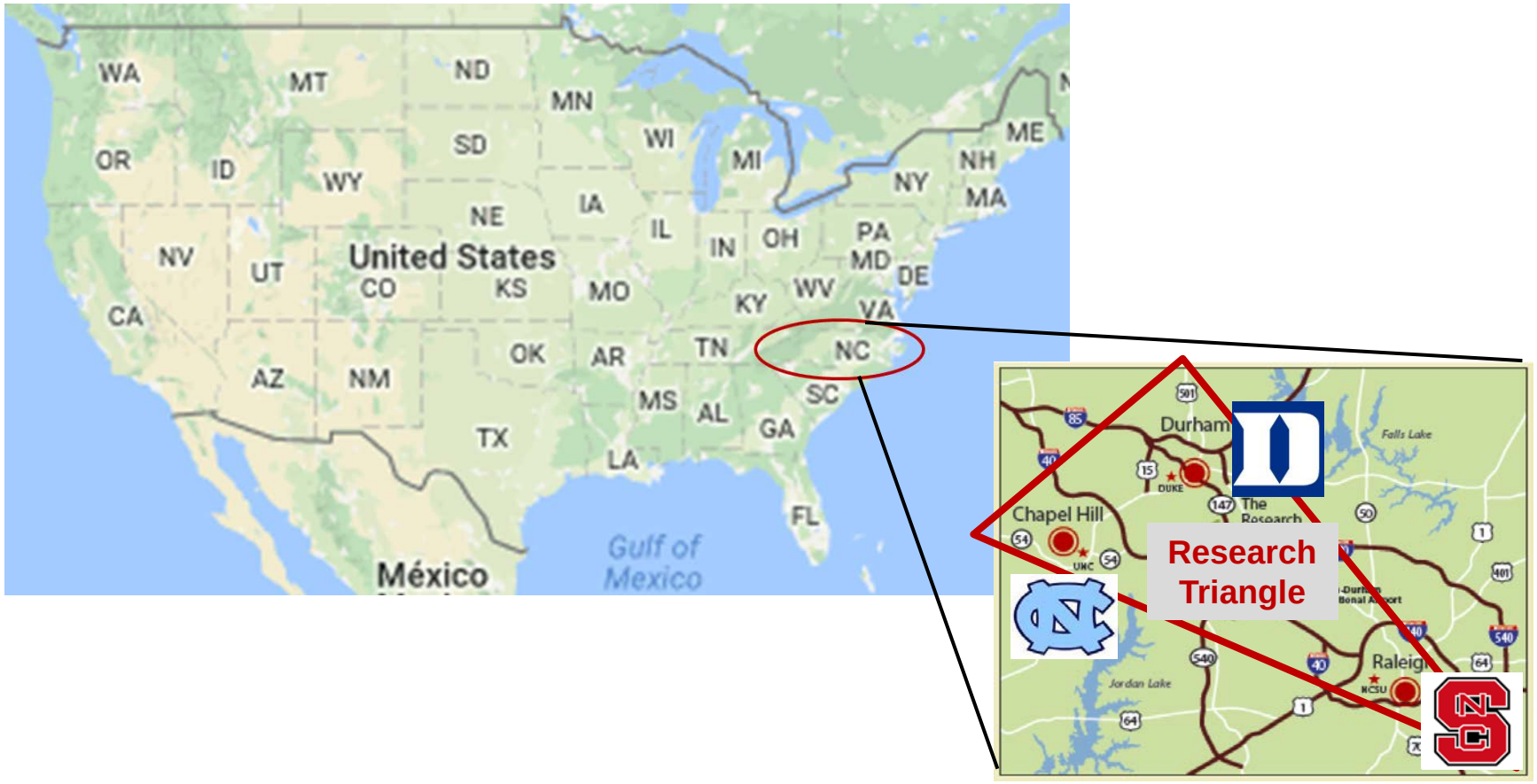

ASD 2018

March/April 2018

Raleigh North Carolina USA

Chair: Gregory N. Parsons
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Approximate Schedule:

Date, Committee, Website:	July 2017
Call for Papers:	October 2017
Abstracts Due:	8 weeks before meeting

ASD 2016 – 1 day
ASD 2017 – 1 day
ASD 2018 – 2 days (?)