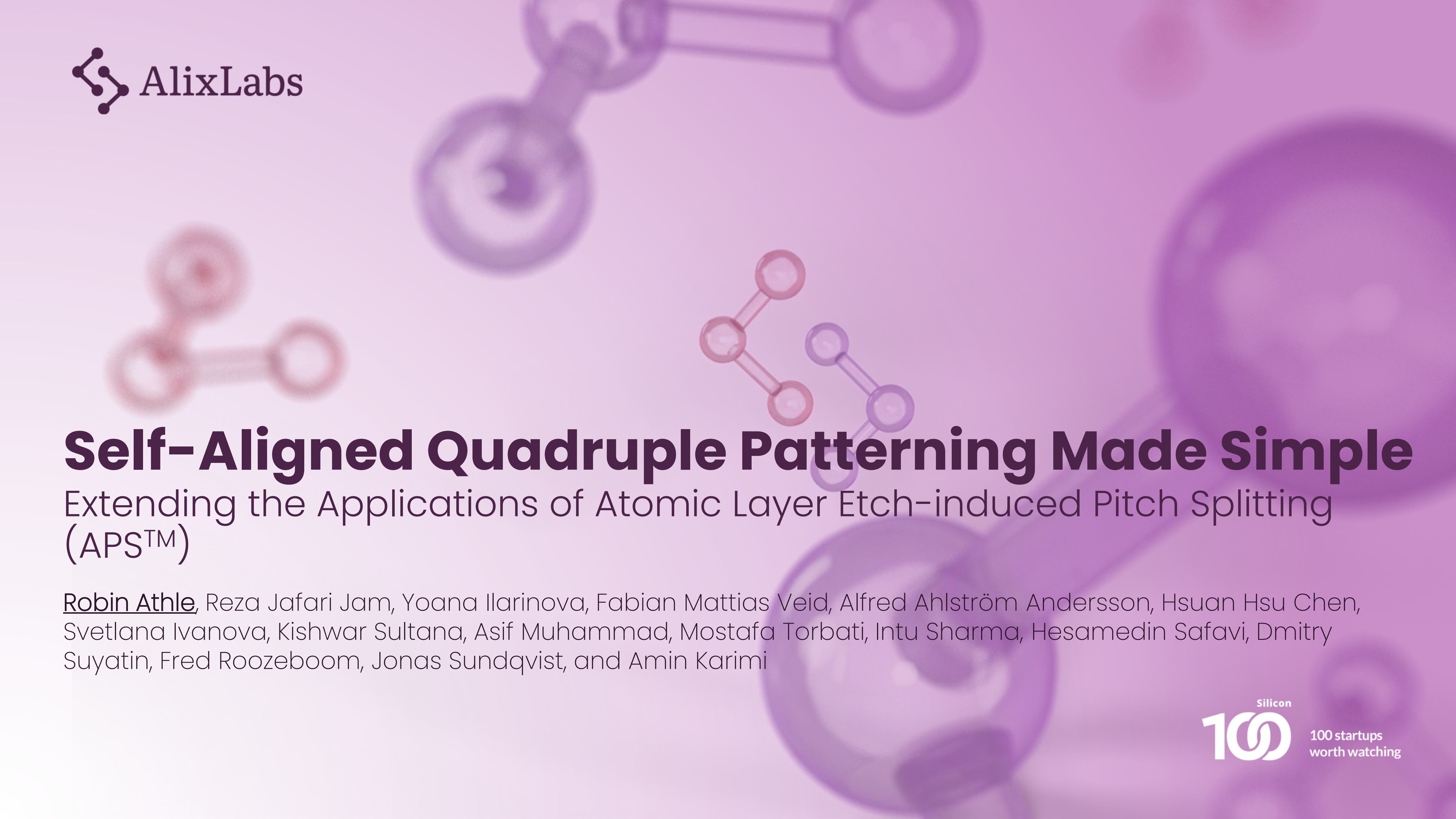
AlixLabs



Self-Aligned Quadruple Patterning Made Simple

Extending the Applications of Atomic Layer Etch-induced Pitch Splitting (APS™)

Robin Athle, Reza Jafari Jam, Yoana Ilarinova, Fabian Mattias Veid, Alfred Ahlström Andersson, Hsuan Hsu Chen, Svetlana Ivanova, Kishwar Sultana, Asif Muhammad, Mostafa Torbati, Intu Sharma, Hesamedin Safavi, Dmitry Suyatin, Fred Roozeboom, Jonas Sundqvist, and Amin Karimi

Silicon 100
100 startups worth watching

AlixLabs

- Start Up & Spin-Off from Lund University.
- Founded in Lund, Sweden 2019.
- Strong team of 14 experts.

Managed by experts in ALE and semiconductor equipment

Jonas Sundqvist, PhD

CEO & Co-founder

- Developed ALD and CVD processes since 1999
- Over >25 years' experience in semiconductor manufacturing
- Passionate entrepreneur who delivers on promises
- Strong network in semiconductor market

Dmitry Suyatin, PhD

CSO & Co-founder

- Over 15 years of experience in advanced processing of nanostructures
- Author of more than 30 publications
- Well-known ALE expert in ecosystem

Amin Karimi, PhD

CTO & Co-founder

- Hands-on experience in Nanofabrication
- Expert in semiconductor devices and materials

Per-Anders Eriksson

Deputy CEO and COO

- Business Development
- Semiconductor Equipment industry

Robin Athle, PhD

R&D Manager

- APS^{TM} process lead
- Expert in emerging memories, semiconductor devices and materials

Peo Hansson

Advisor Semi Equipment

Garry Miner

Advisor Semi Equipment

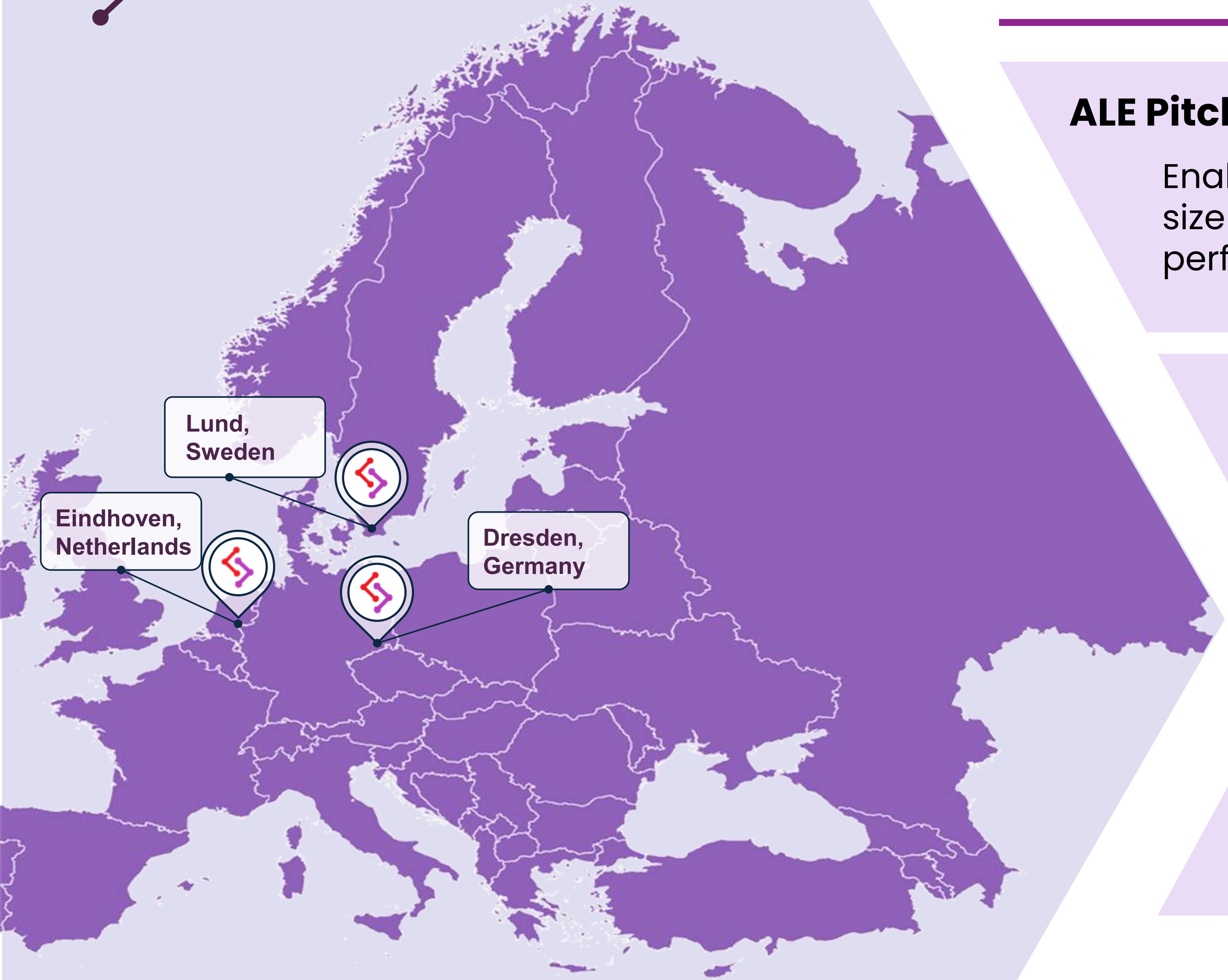
Robert Cadman,

Advisor Business Development

Navigare Ventures FORWARD.one Industrifonden

AlixLabs

What **We Do**



ALE Pitch Splitting - APS™

Enabling advanced node size scaling. Enhancing performance and efficiency.

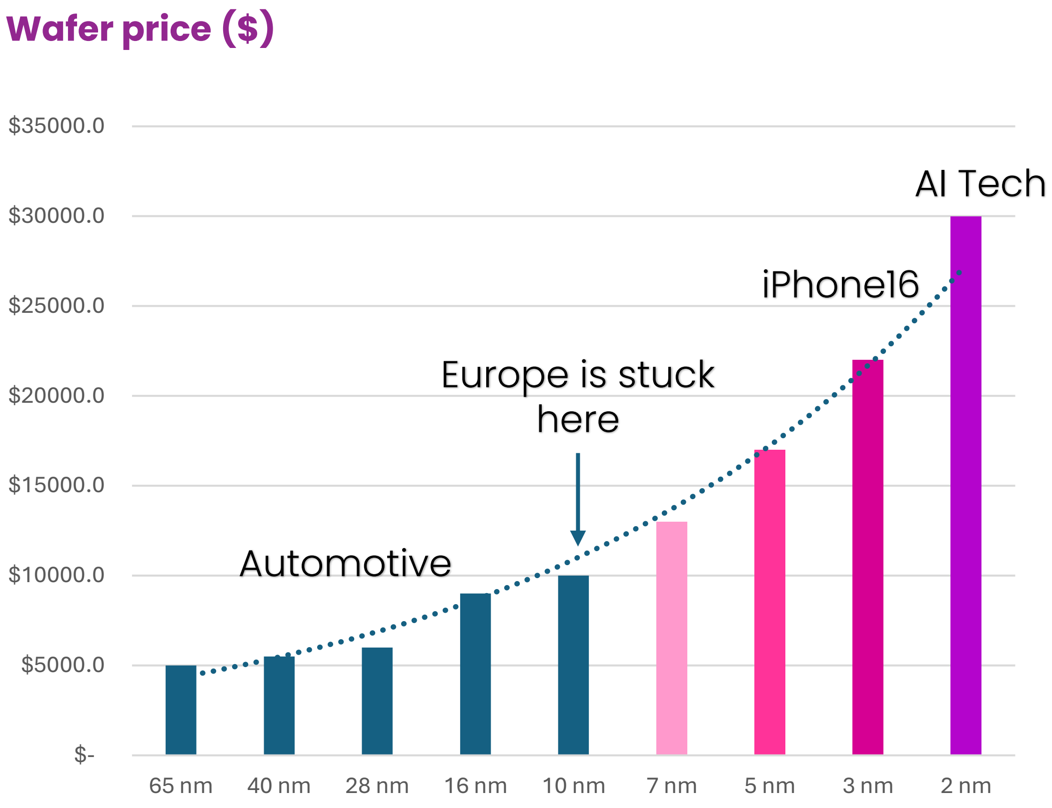
ALE for Power Electronics

Specialized ALE applications for III-Vs, GaN and SiC.

ALE Equipment

First 300 mm ALE equipment provider in Sweden.

Escalating manufacturing costs challenge the industry as demand for smaller nodes continues to rise



Source: TSMC Wafer Price by manufacturing node, The Information Network

Wafer prices are increasing at an unsustainable rate, driven by consumer applications such as AI.

The exploding wafer price is due to rising process complexity, especially advanced patterning using EUV or multi-patterning schemes (LELE / SADP / SAQP).

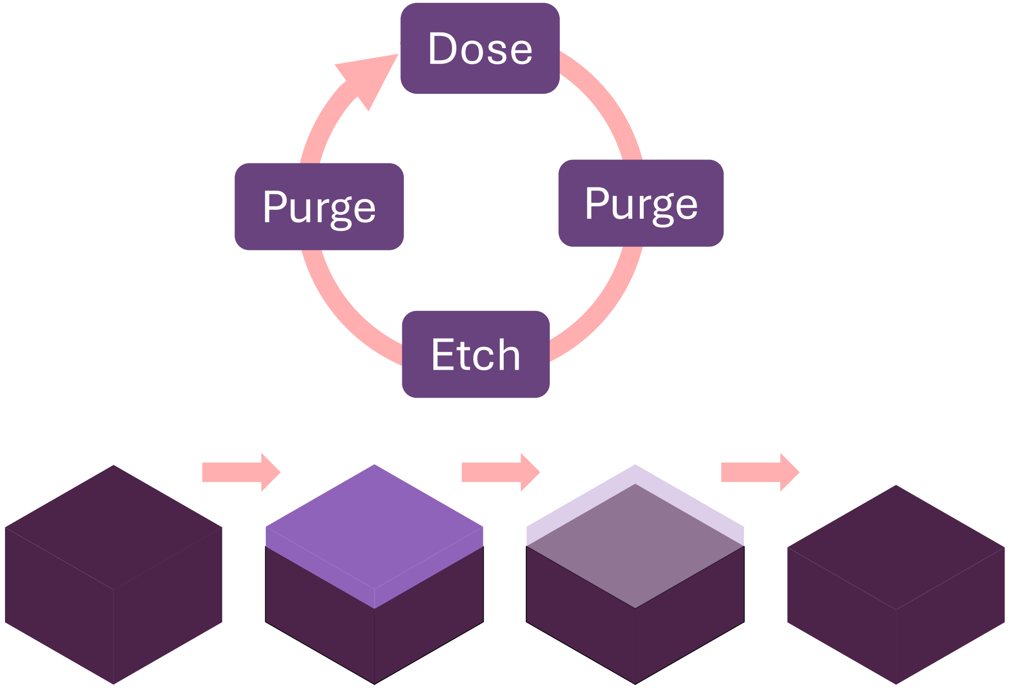
Every extra lithography and etch step increases cost, variability and integration risk. Is there a better way?

The million dollar questions: Can we reduce pitch and CD without multiplying lithography steps?

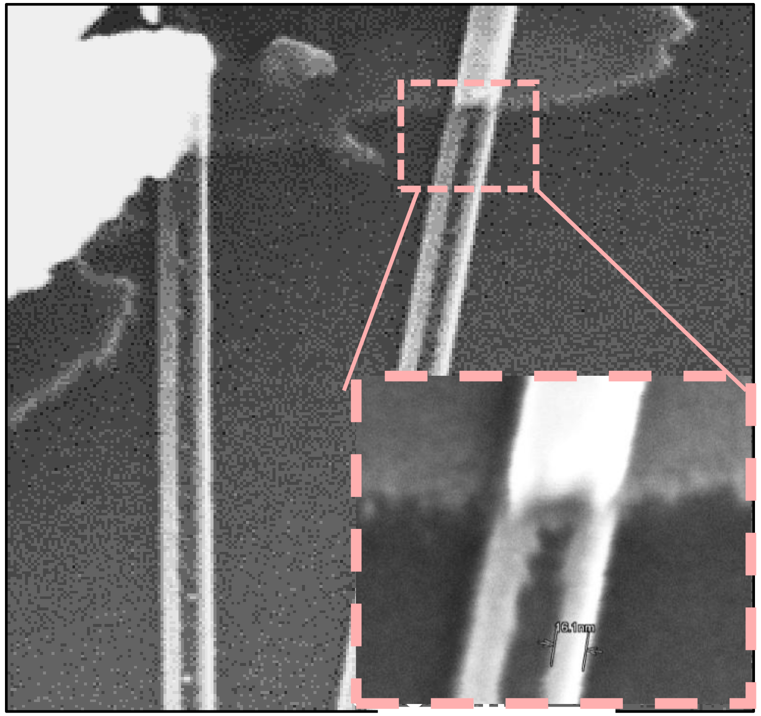
Atomic Layer Etching & Pitch Splitting

AlixLabs

Atomic Layer Etching (ALE) -The inverse of ALD. Atomic level surface control using self-limiting chemistries.



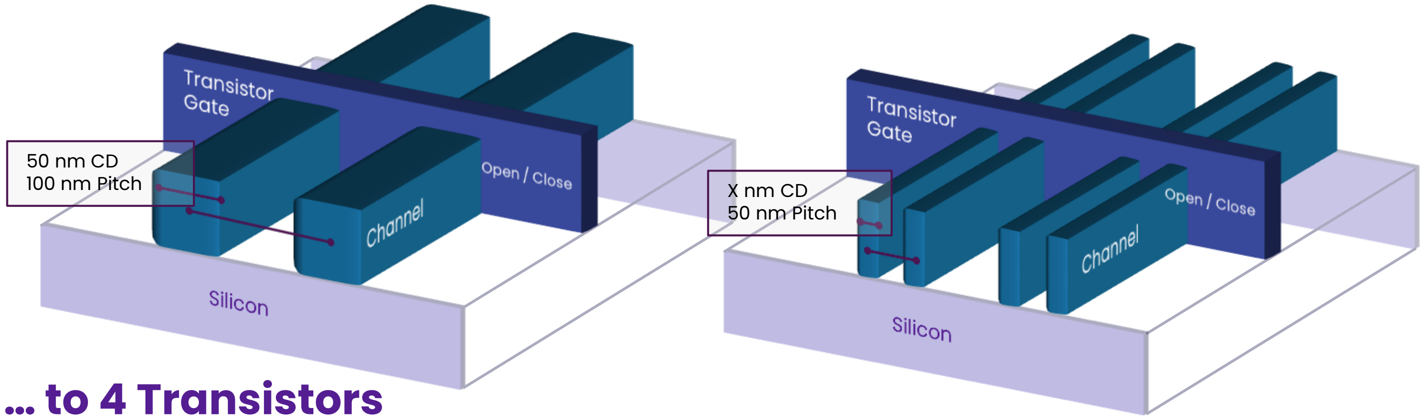
Atomic Layer Etch Pitch Splitting (APS^{TM}) – First demonstration in 2016 of GaP Nanowires on Si.



Pitch and CD reduction without additional lithography or deposition!

APS^{TM} Doubles On-chip Feature Density

From 2 Transistors



… to 4 Transistors

Without additional lithography or deposition!

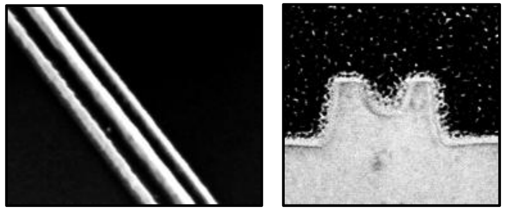
- APS^{TM} allows for a doubling of fins on chip without any additional lithography or deposition process.
- More transistors per chip allows for increased compute.
- APS^{TM} offers reduced complexity and improved sustainability compatible with current fab equipment.
- Advanced process nodes without investing in expensive EUV.

APS™ Development Timeline

2016

Discovery

APS™ on GaP NWs.

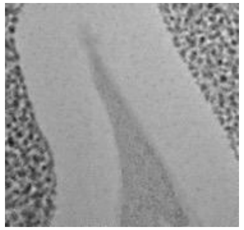


2019

2023

Patterned GaP

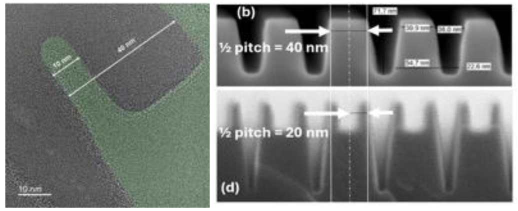
First demonstration on EBL patterned structures.



2024

Patterned Si

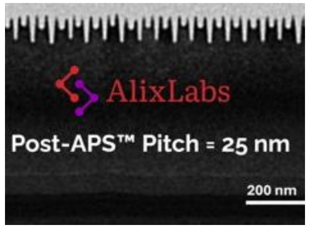
APS™ on EBL Si.



2024

External Validation

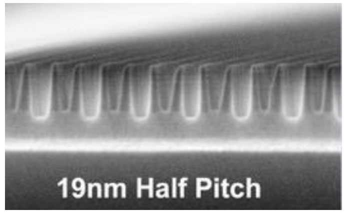
Intel EBL samples.



2025

ArFi

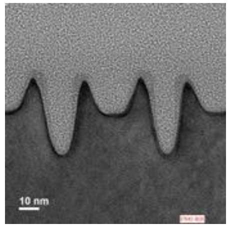
UMC wafer demo.



2025

Partnership

Lithography Partnership initiated.



2026

SPIE 2026

SAQP Equivalent using APS™.

APS^{TM} Development Timeline

2016
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APS^{TM} on GaP NWs.

2019

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First demonstration on EBL patterned structures.

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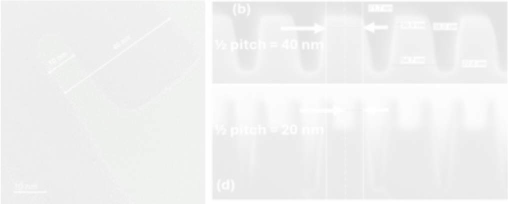
APS^{TM} on EBL Si.



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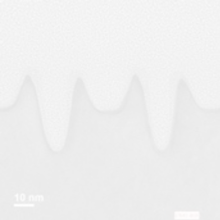

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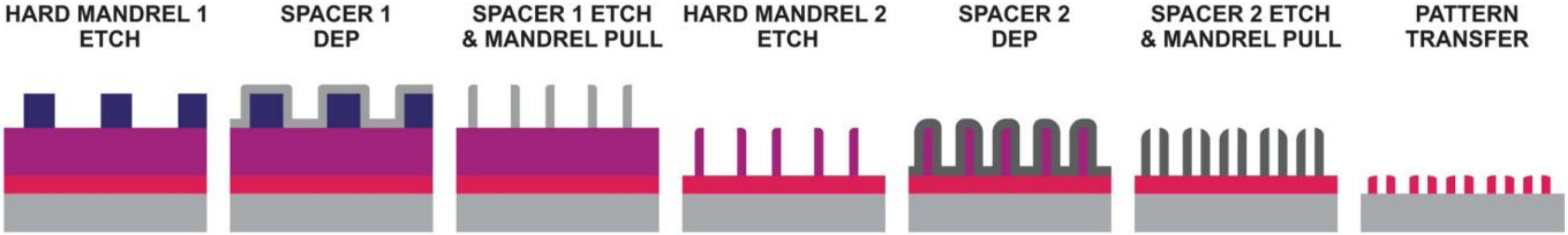
SPIE 2026
SAQP Equivalent using APS^{TM}.

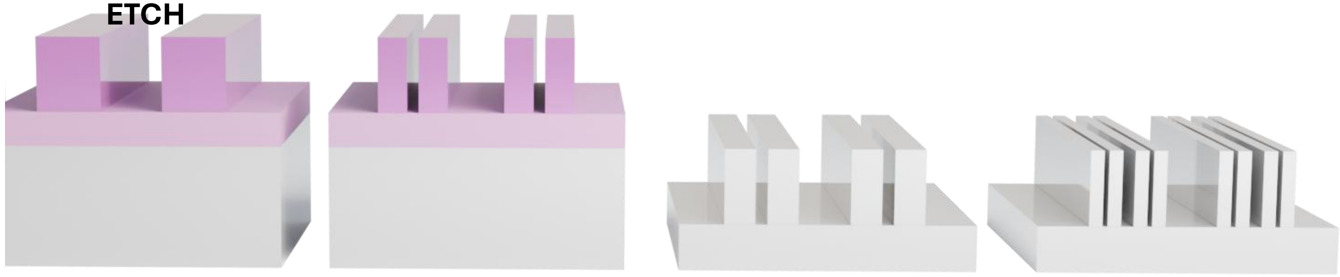
Comparing SAQP with APS™

Simplified SAQP Process Flow



E. Altamirano-Sánchez et al, SPIE Newsroom (2016)

APS™ Pitch Quartering



HARD MANDREL ETCH

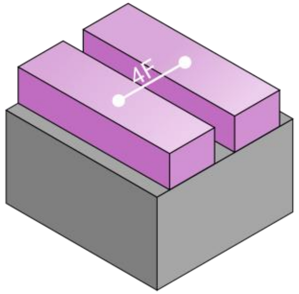
APS™ 1

TRANSFER ETCH

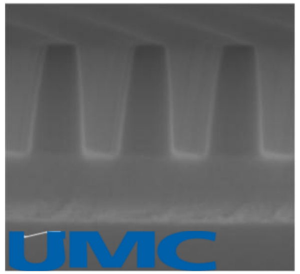
APS™ 2

Simplifying Quadruple Patterning by APS™

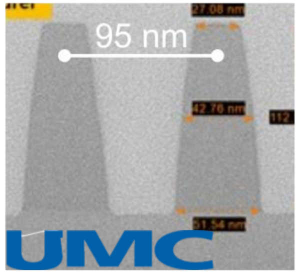
As-received



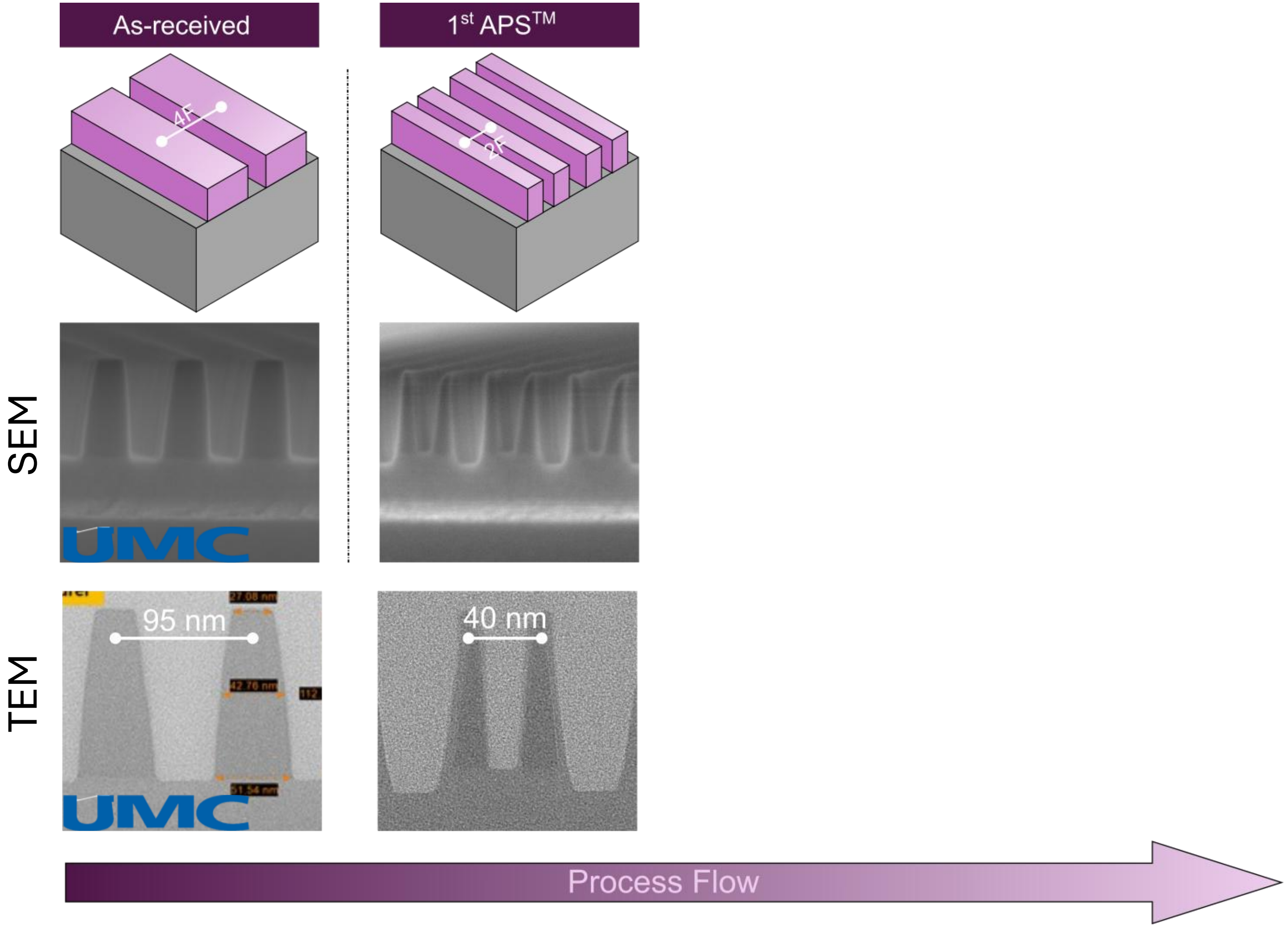
SEM



TEM



Simplifying Quadruple Patterning by APS™



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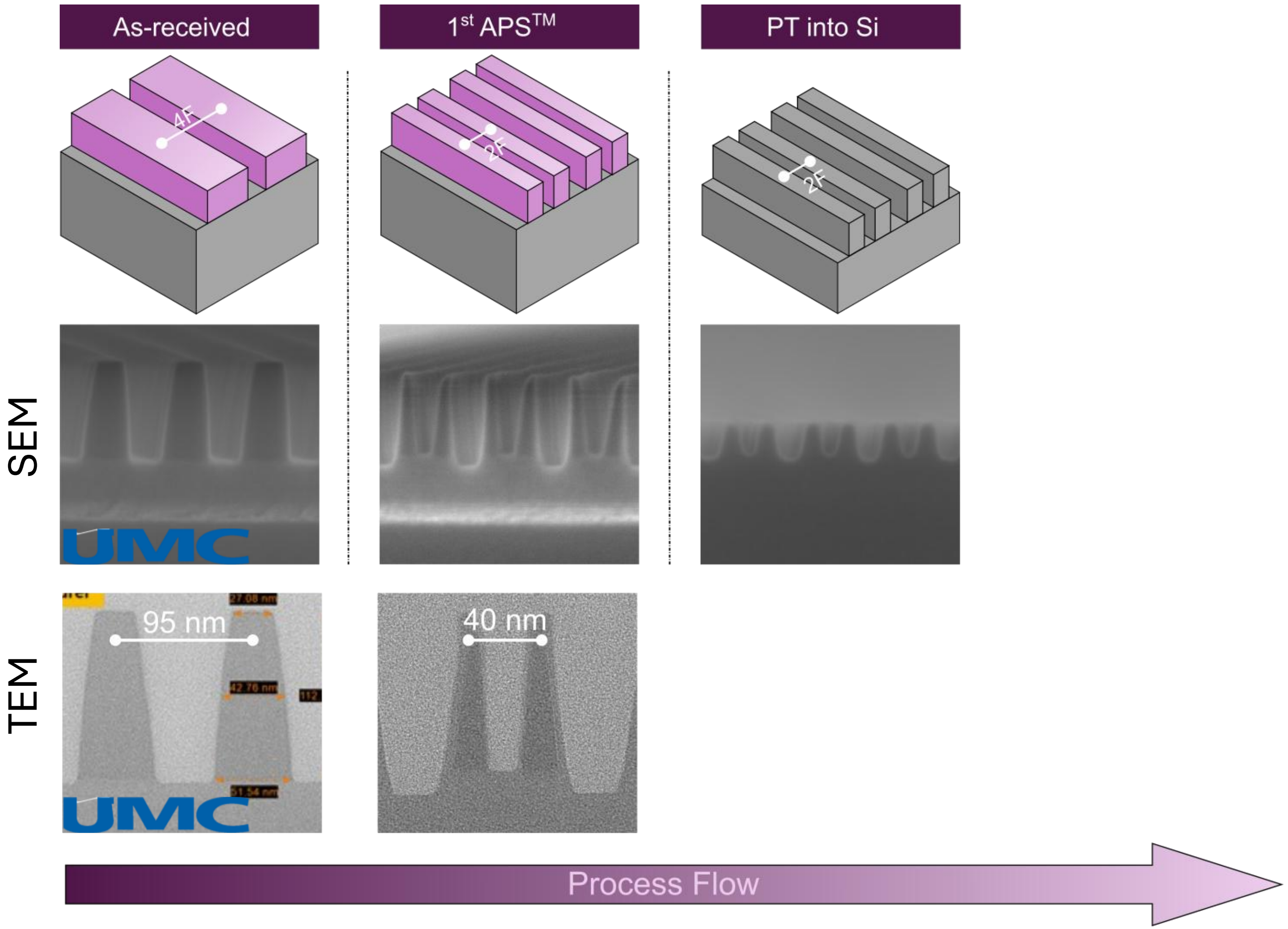
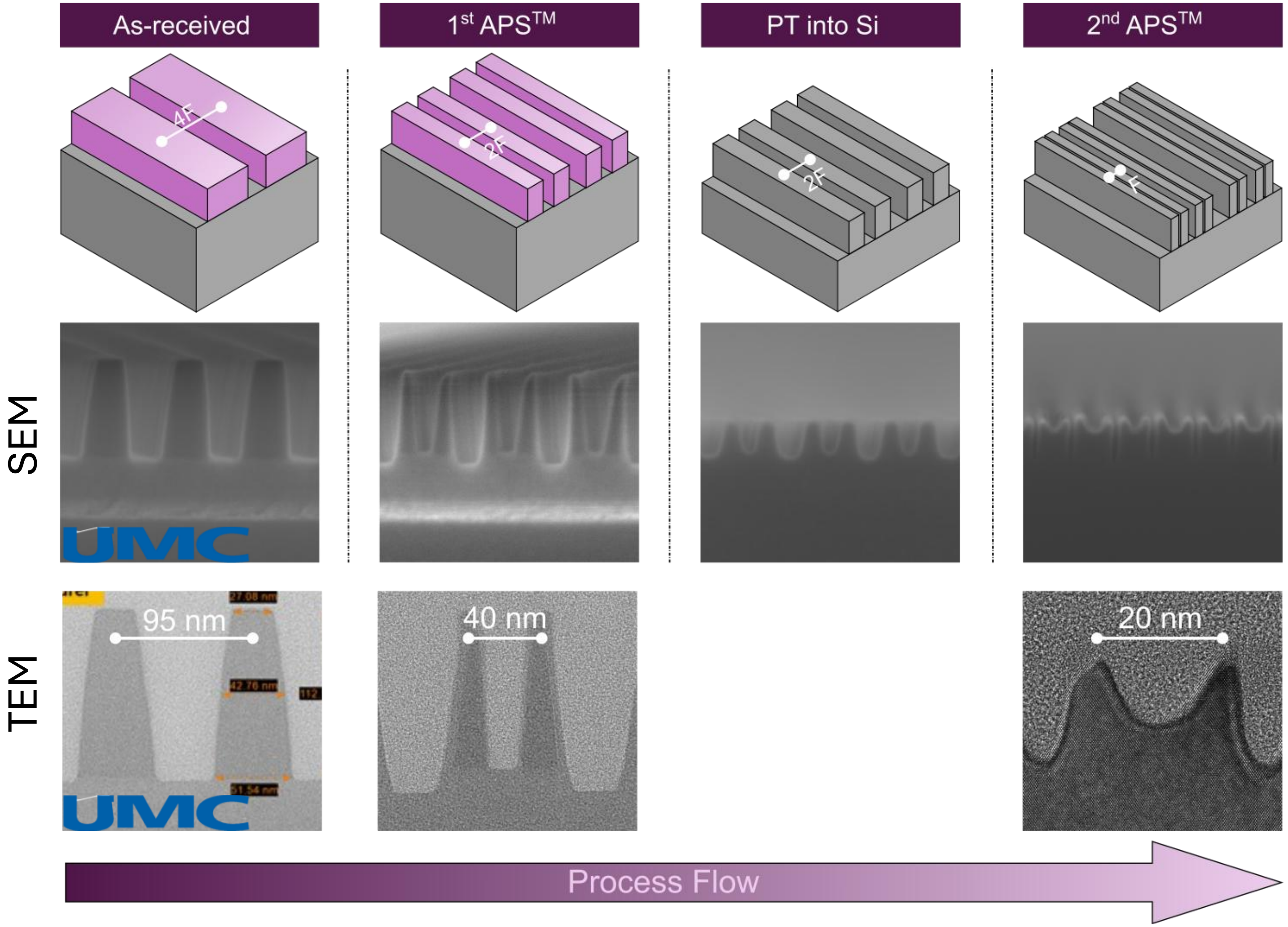
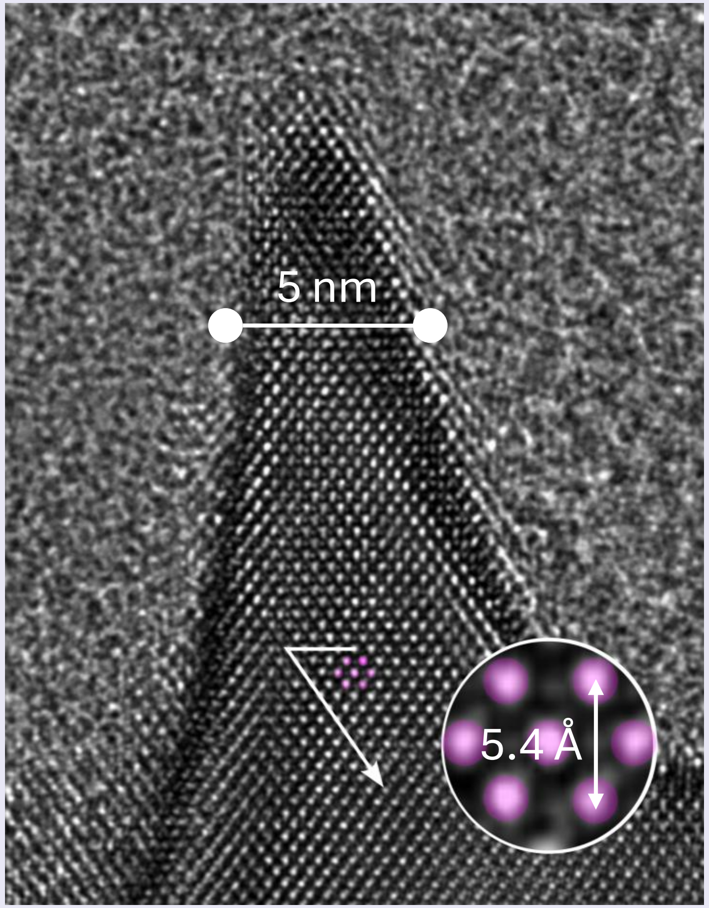


Simplifying Quadruple Patterning by APS™

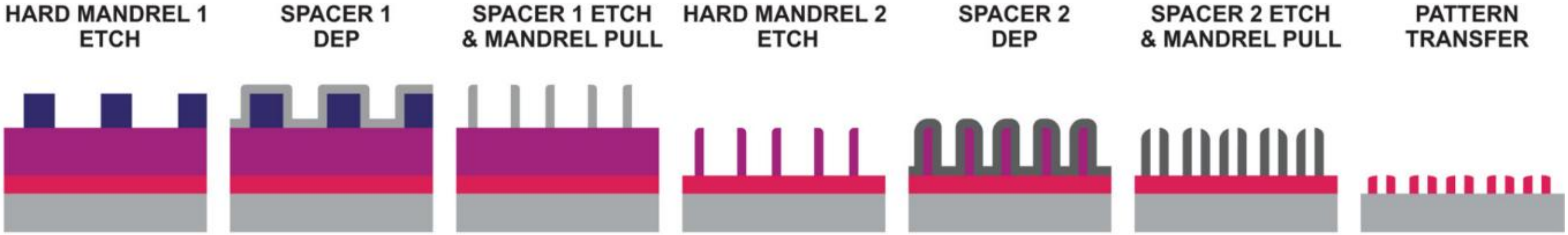
AlixLabs





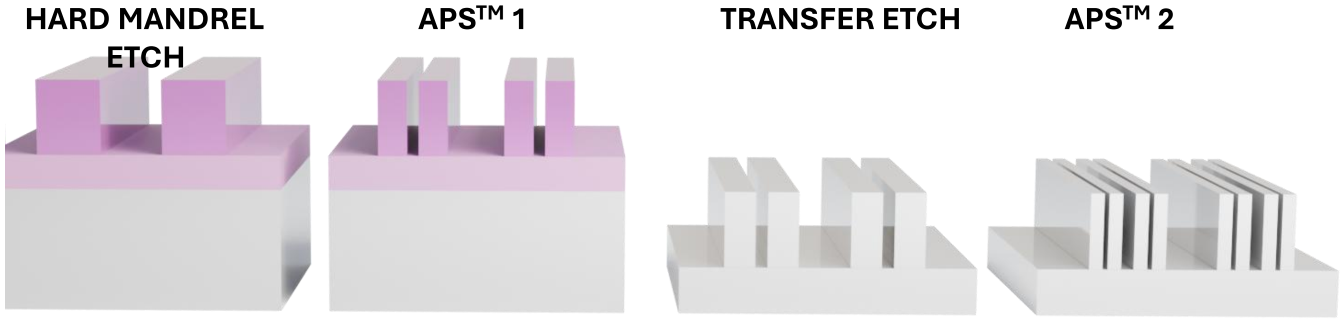
Comparing SAQP with APS^{TM}

Simplified SAQP Process Flow



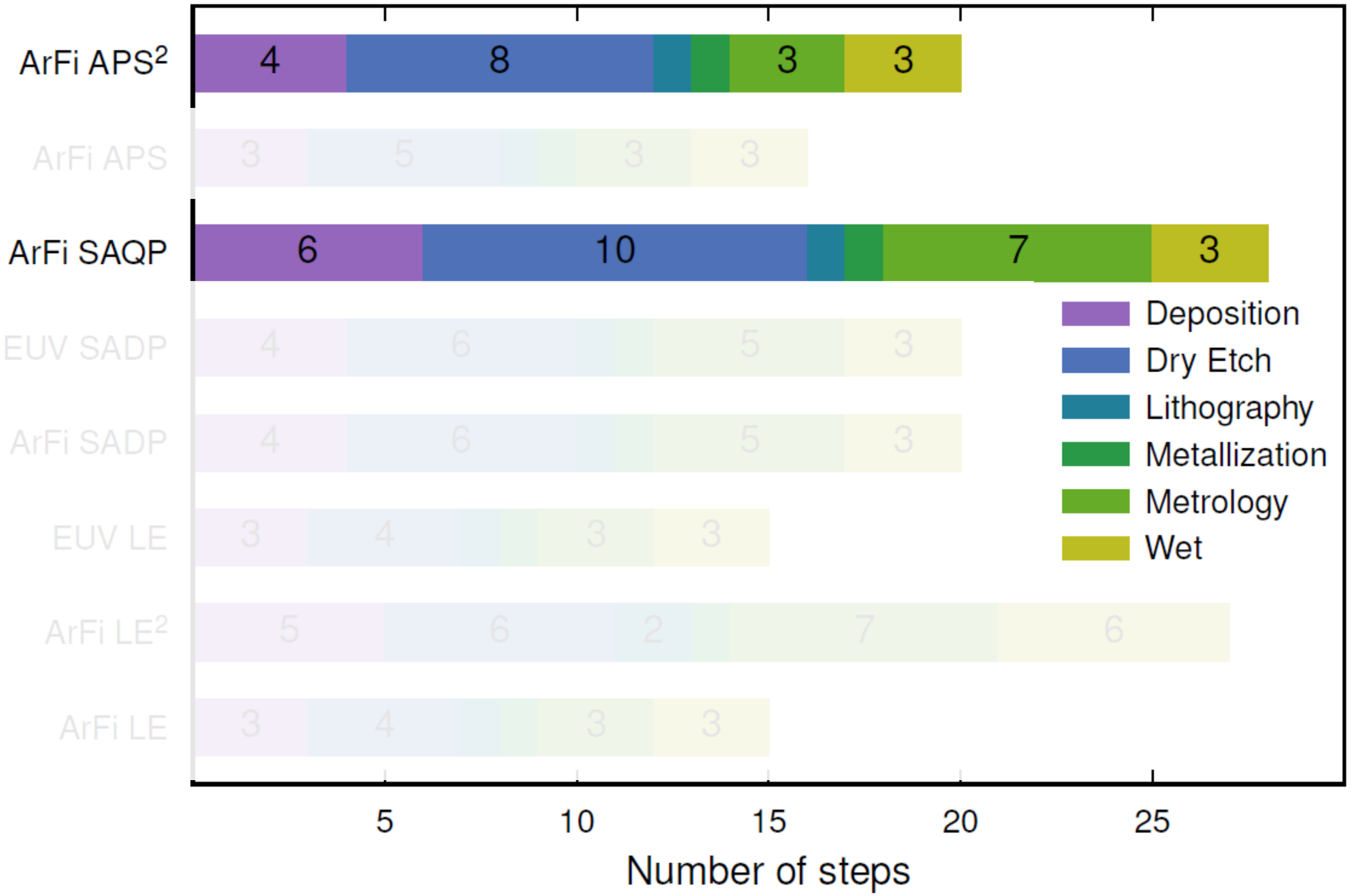
E. Altamirano-Sánchez et al, SPIE Newsroom (2016)

APS^{TM} Pitch Quartering



- No deposition steps required.
- No additional intermittent hard masks needed.
- Improved control over CD and pitch walk.

Process Simplification Achieved Using APS™



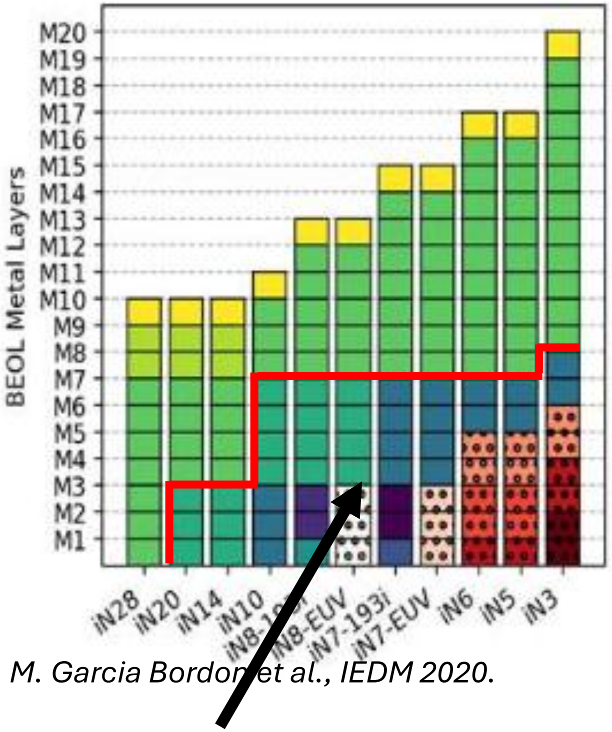
- Several different multiple patterning approaches exist.
- Litho passes are expensive, SADP/SAQP schemes become attractive as only one litho pass is required. Removes overlay concerns.
- However, pitch walk is incredibly hard and costly to control in SAQP.
- APSTM allows for significant reduction in process complexity compared to SAQP:
  - No deposition required (2 steps + metrology)
  - No intermediate HM for structural stability needed.

APS™ for Greener Semiconductors

AlixLabs

APS:
Atomic
Layer
Etching
Pitch
Splitting

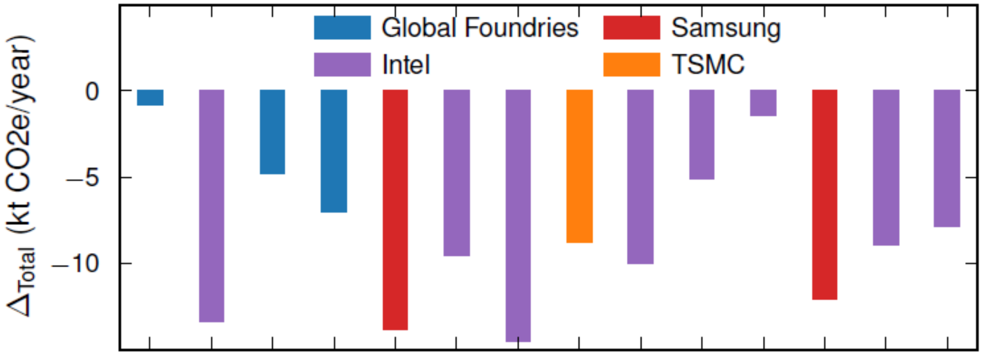
APS™ Applications



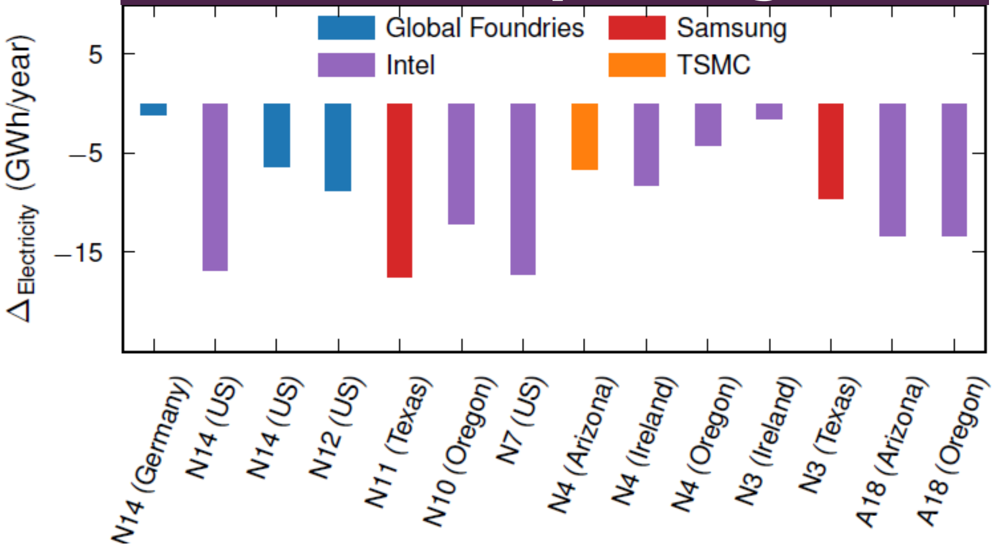
M. Garcia Bordon et al., IEDM 2020.

Multiple patterning implementation region.

CO2eq Savings



Electricity Savings



**Data from Tech Insights open source database. Manuscript in preparation.*

APS™ Development Timeline

AlixLabs

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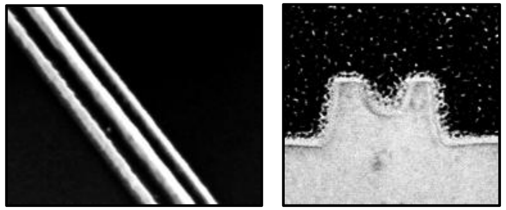

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AlixLabs

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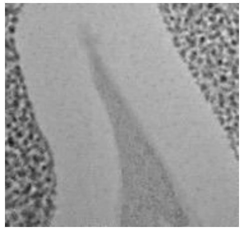

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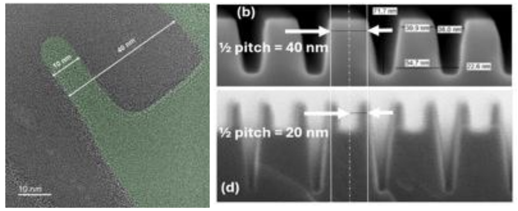
APS™ on EBL Si.



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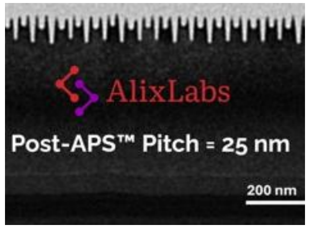

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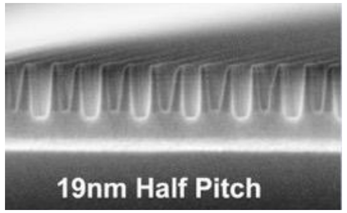

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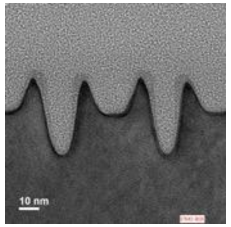
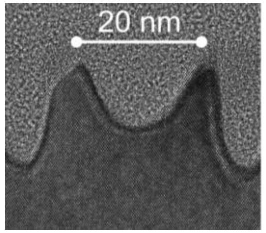


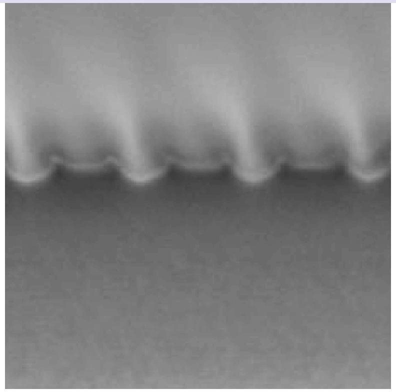
2026

SPIE 2026

SAQP Equivalent using APS™.



APS™ Outlook – New Applications



2026

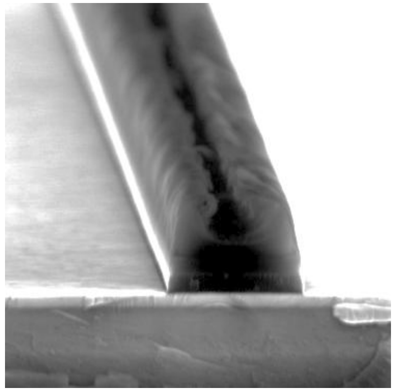
Hard Masks

APS™ on hard mask

2026

Photoresist

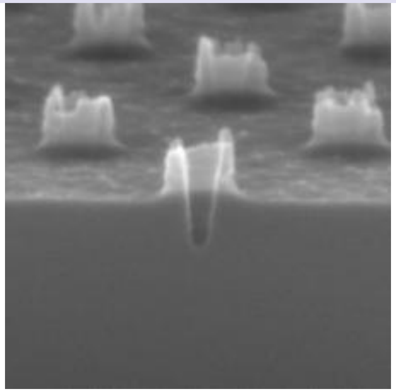
APS™ on resists.



2026

Vias

APS™ on vias.

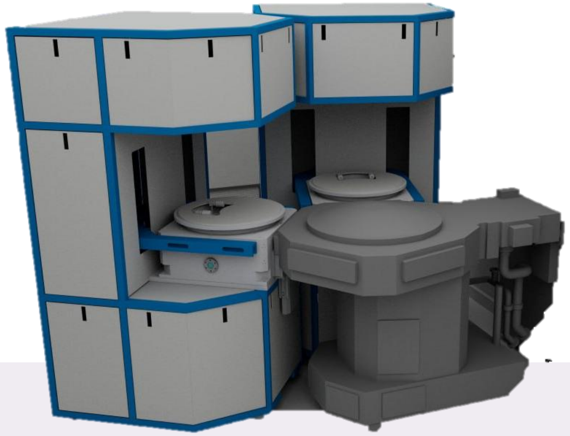


AlixLabs APS™ & ALE Equipment

Alpha

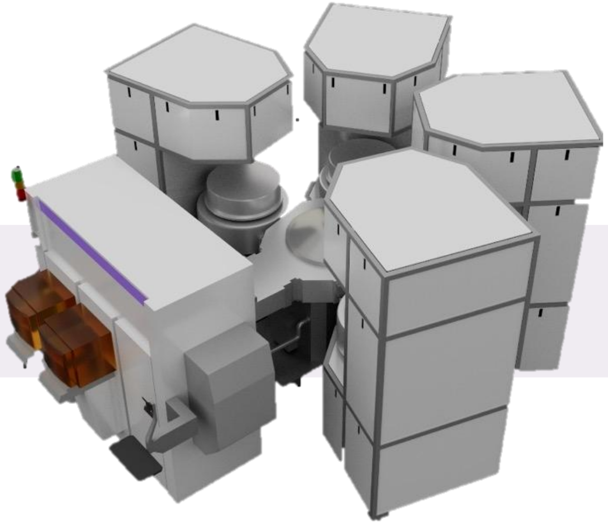
300 mm wafer capabilities.
Available for demos.

Beta



Cluster tool with multiple chamber processing and automatic handling.
Ready in Q3 2026.

Gamma



Gamma platform
Production ready HVM.
(conceptual design)

Concluding Remarks

Costs and complexity in advanced nodes are largely driven by complex patterning processes.

APS™ offers a new approach of accessing advanced process nodes without investing in new lithography.

APS™ can reduce cost and complexity while improving yield when compared to SADP and SAQP.

APS™ has the potential to lower CO2eq emissions and reduce electricity consumption for more sustainable fabrication!


AlixLabs