

Economics of Mask

October 3, 2023

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Mask Technology Center

Micron Technology Inc.



Agenda

Examination of the photomask economy

1. Capital
2. Materials
3. Software

Micron's Mask Technology Center perspective

Future Considerations

SPIE Online BACUS Overview of Photomask Technology




BACUS Webinar: Overview of Photomask Technology

Glen Scheld of Micron gives an overview of Photomask Technology. Hosted by Doug Resnick of Canon Nanotechnologies Inc.


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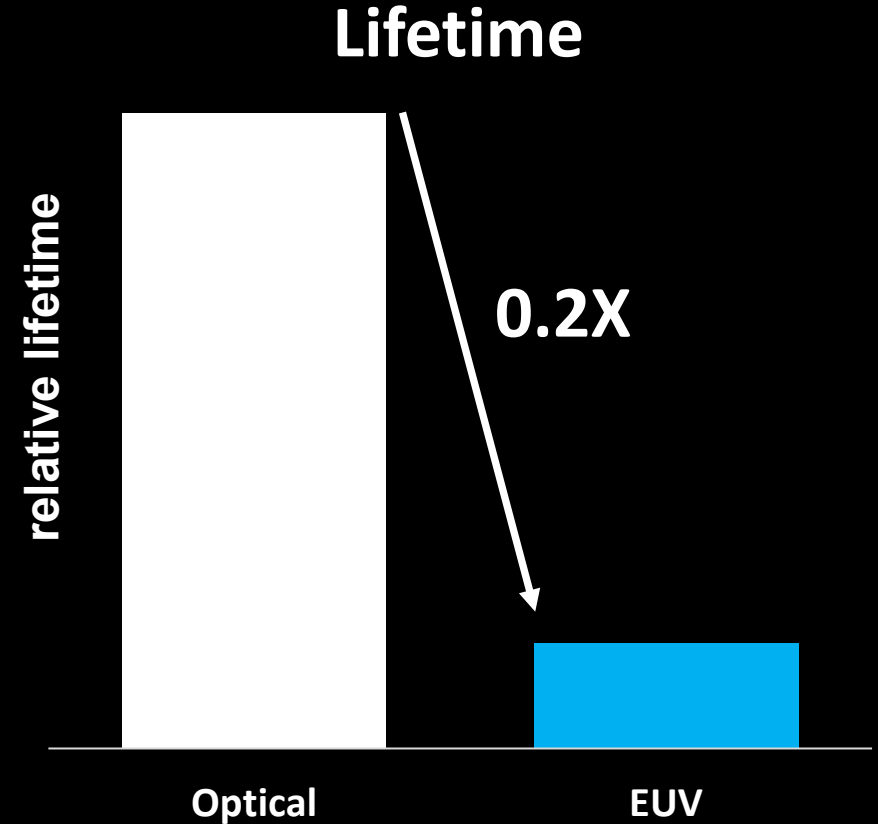
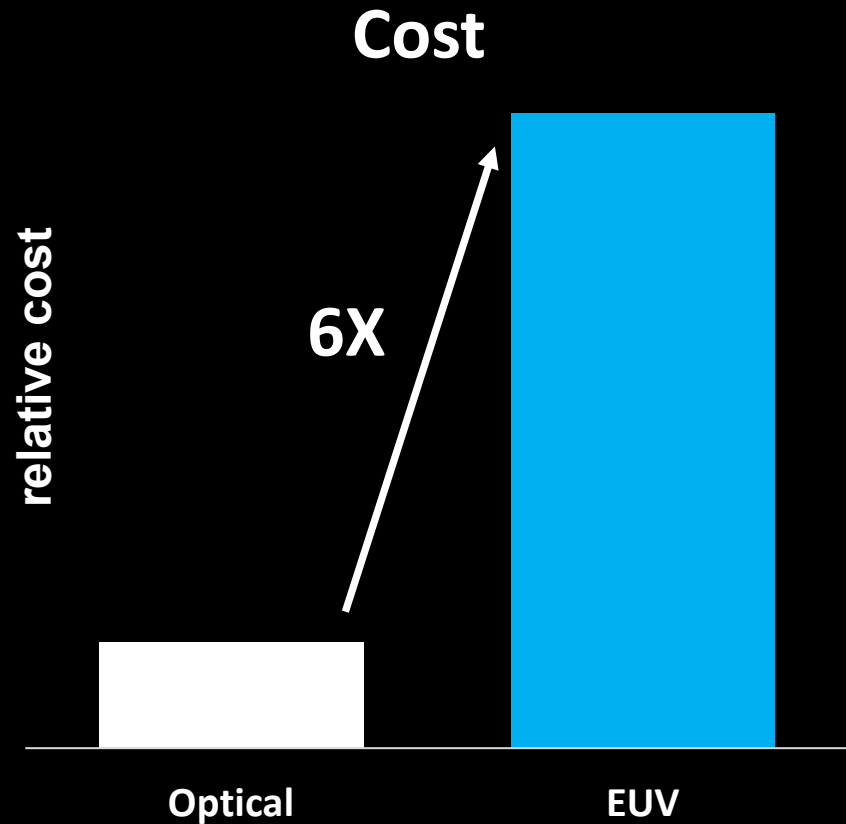
 Responsible Operations

Founded on
October 5, 1978

Headquartered in
Boise, Idaho USA



EUV mask projection 2025-2026

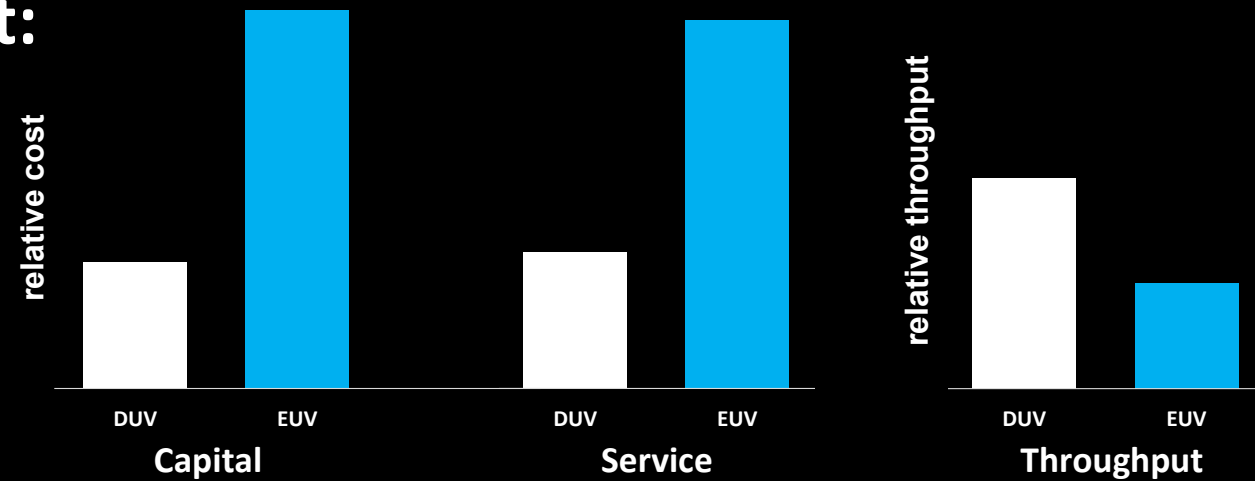


EUV mask costs may be as much as 30x optical with equivalent lifetime.

Increasing Cost of Ownership

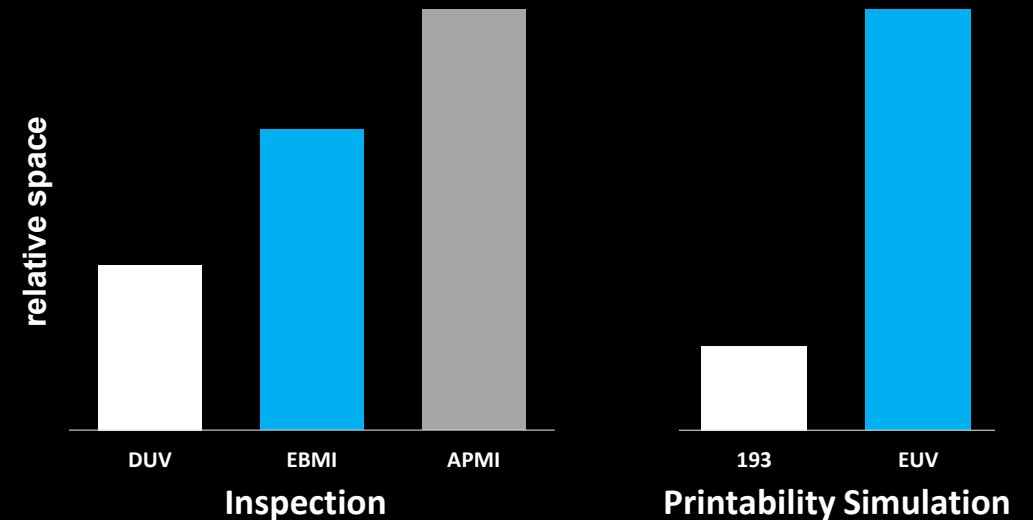
Capital & Service Cost vs. Throughput:

- Complex optics and multi-beam arrays
- EUV light generation source
- Specialized labor



Facility Space:

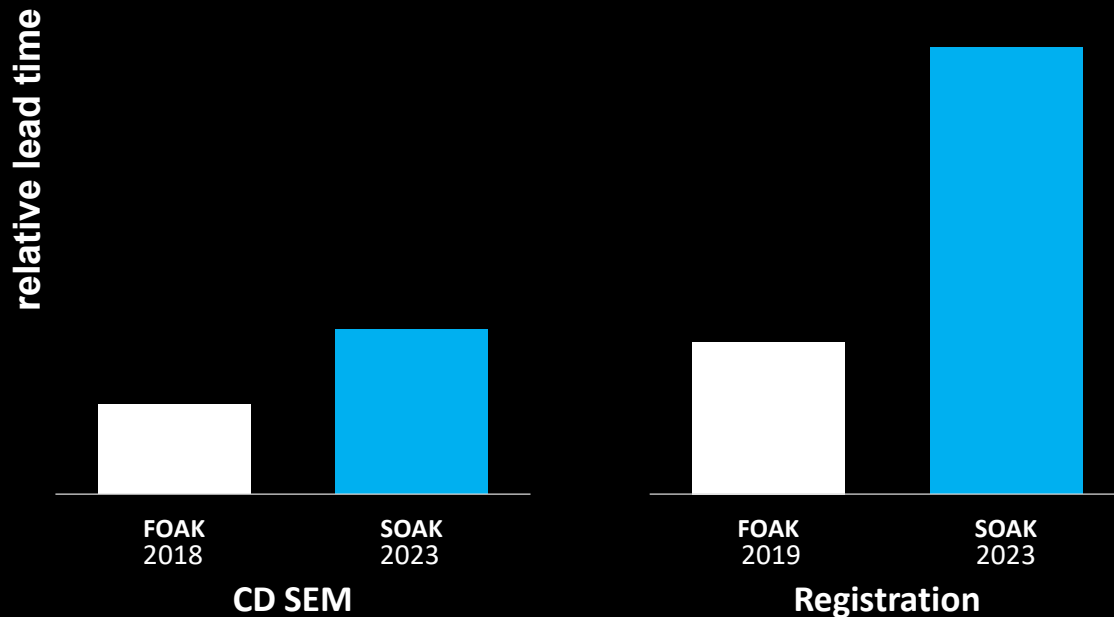
- Larger EUV source systems
- Vacuum chambers
- Support equipment



Longer Equipment Lead Times

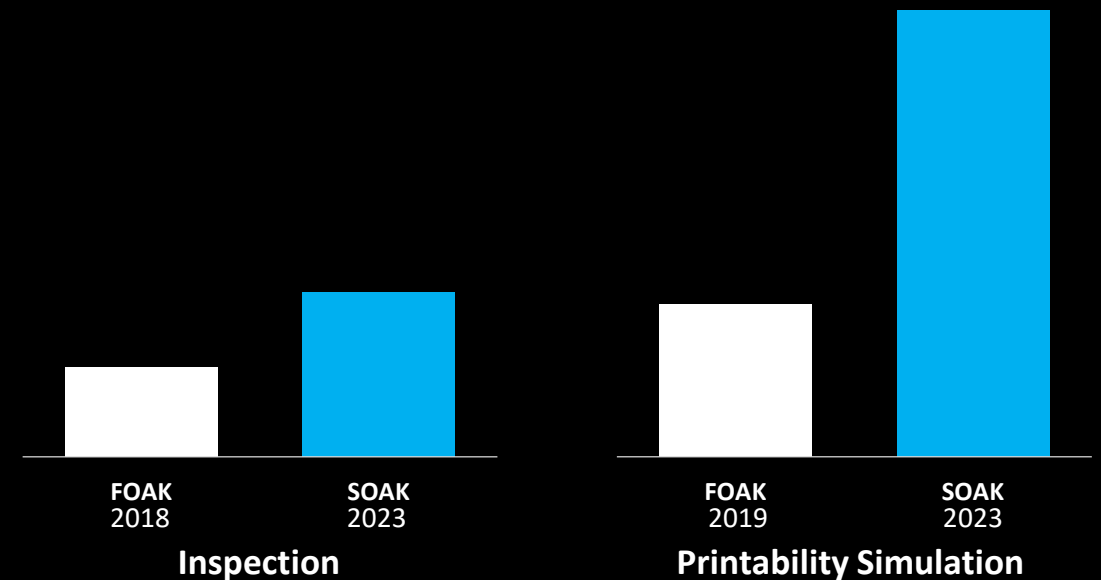
Baseline Equipment Causes:

- Macro-economic factors
- Supply chain quality
- Supply and demand



EUV Equipment Additional Causes:

- Complex technologies
- Limited supply chain
- Supply chain bottlenecks



Creating State-of-the-Art Through Partnership

Hardware

- Capability aligned to the market
- Risk reduction for supplier
- Cost reduction for mask maker

Software

- Cloud based MPC and MDP

Materials

- Customer specific innovations
- ASML TNO qualifications

Protected IP sharing

- Third-party cloud providers



Wafer fab reticle equipment demands

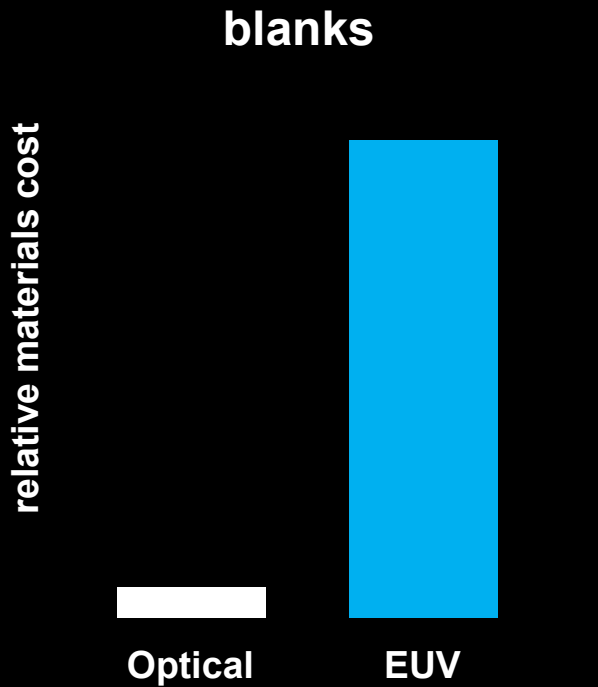
Mask equipment in the wafer fab is required for EUV reticle management:

- Cleaning
- Inspection
- Particle removal / analysis
- Pod-in-Pod cleaning
- Stockers / cabinets
- Pellicle support

Micron's expansion is adding mask equipment, software, and materials around the world.

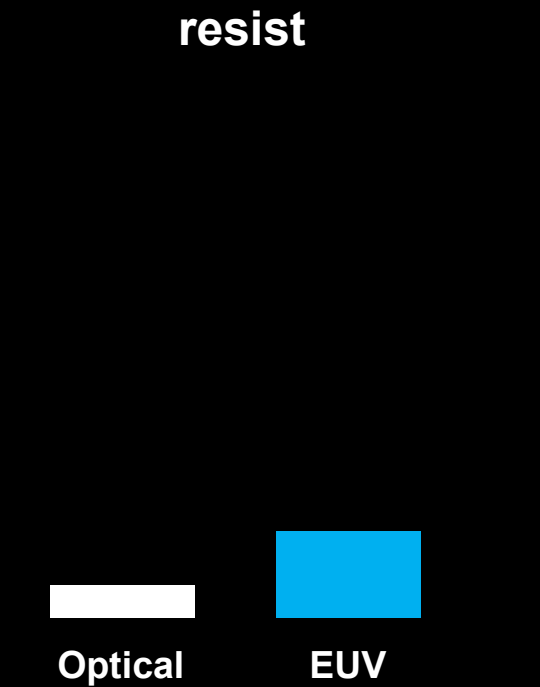


Cost of Materials

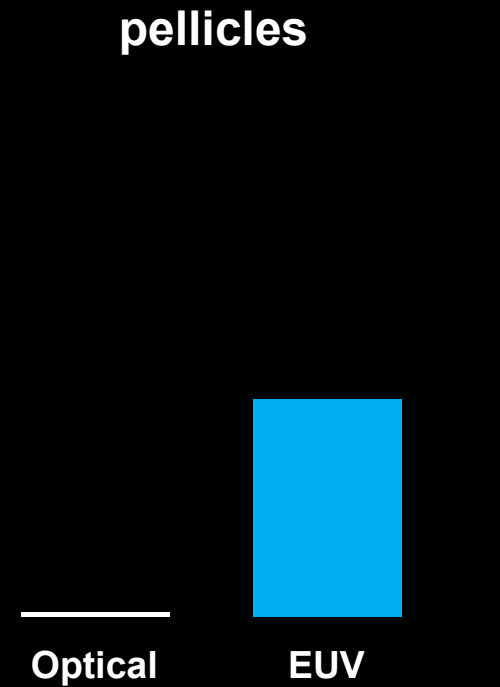


“An EUV mask blank with tighter specs can cost more than \$100,000.”

semiengineering.com

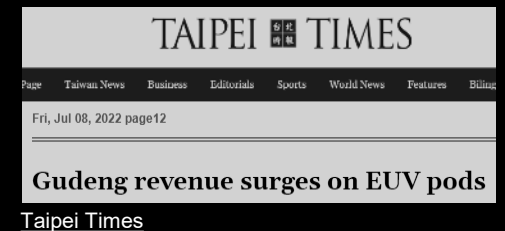
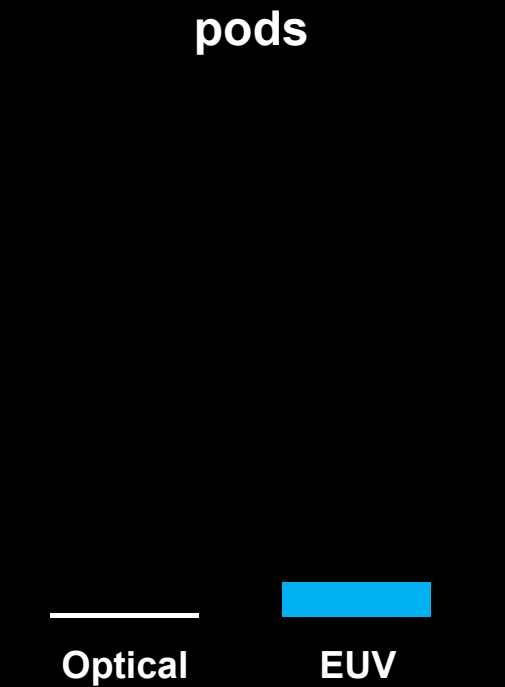


Low sensitivity resists using advanced polymers, PAG and specialty components required for EUV.


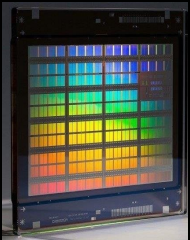
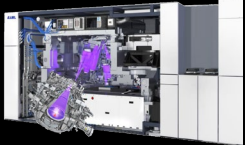


“...pellicle themselves are also very expensive, in the tens of millions of won...” [tens of thousands of dollars]

ELEC



EUV Pellicle Considerations

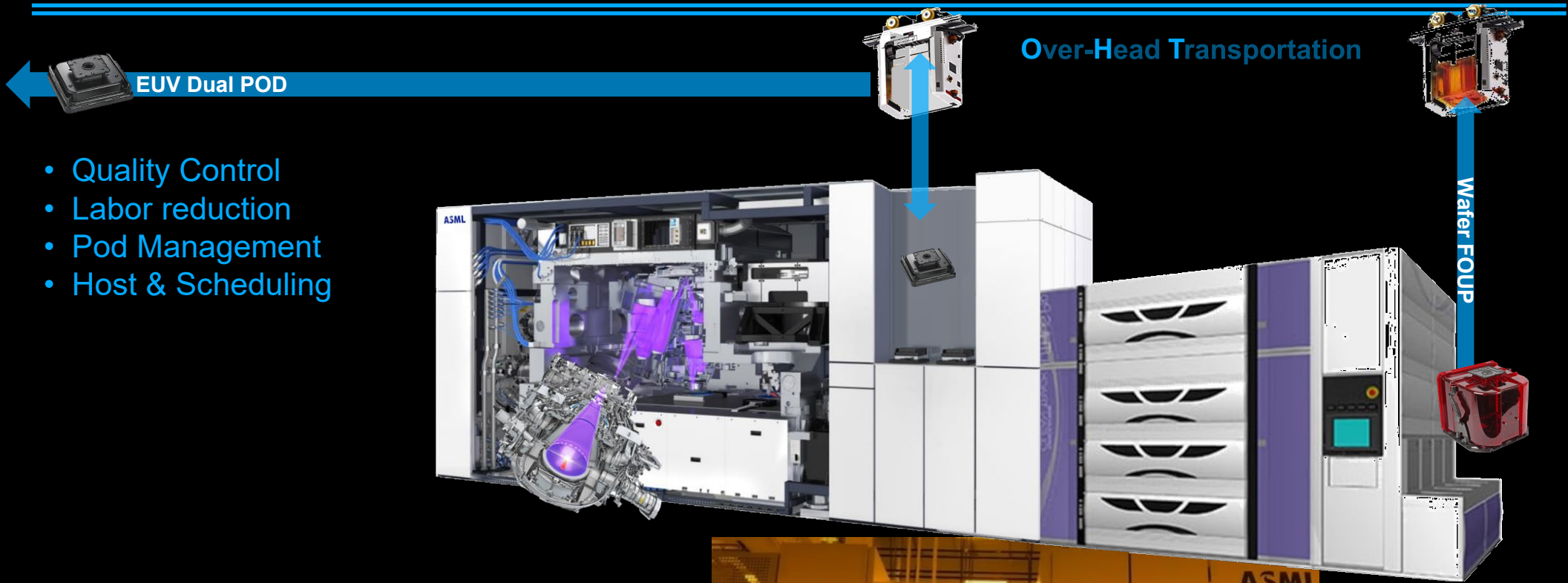
	Considerations with Pellicle	Considerations without Pellicle
Pellicle 	<p>Pellicle unit costs, inventory space, and labor.</p> <p>Pellicle lifetime, replacement costs.</p> <p>Pellicle compatible pods</p> <p>Pellicle equipment</p> <ul style="list-style-type: none"> • MDR (mount-demount-remount) • Transmission, Inspection, particle analysis, and removal. 	N/A
Mask 	<p>Periodic inspection, potentially using APMI.</p> <p>Longer lifetimes due to less frequent cleaning.</p> <p>Small reduction in aerial CD uniformity.</p> <p>Less frequent requirement for mask defect management.</p>	<p>Higher risk of defectivity, repairs required.</p> <p>Less mask productive time.</p> <p>More backup masks.</p> <p>More frequent mask defect management / capital eq.</p>
Scanner 	<p>Downtime due to damaged pells.</p> <p>Throughput loss due to transmission including addition of DGL membrane</p>	<p>Downtime due to scanner actions in response to mask defects.</p>

EUV Handling Creates Significant Infrastructure

Automatic Reticle Transportation

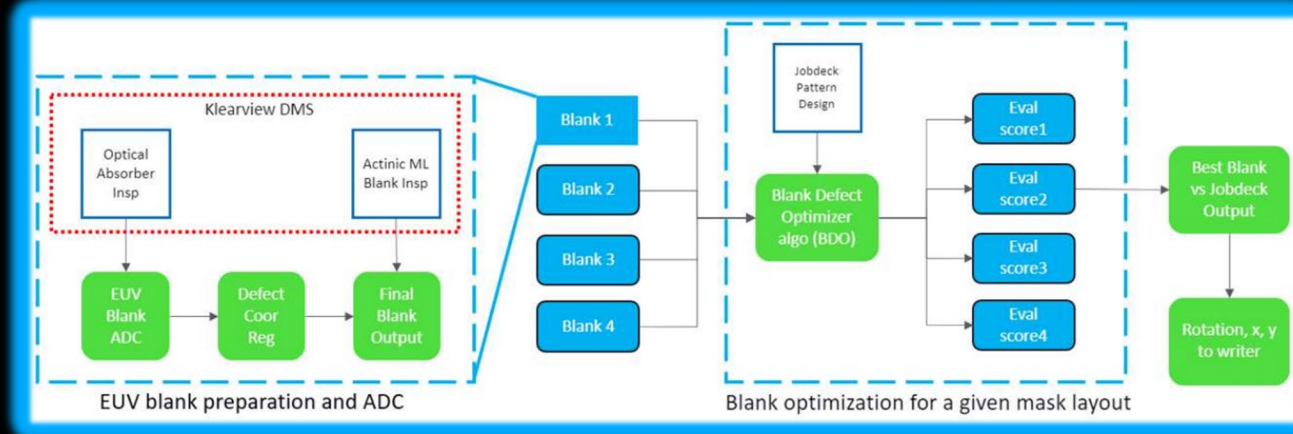
[Reticle Handling]

- Pod Stocker
- Pod Cabinets
- Pod Washer
- Pod Inspection (option)
- Pod Inspection ADC (option)

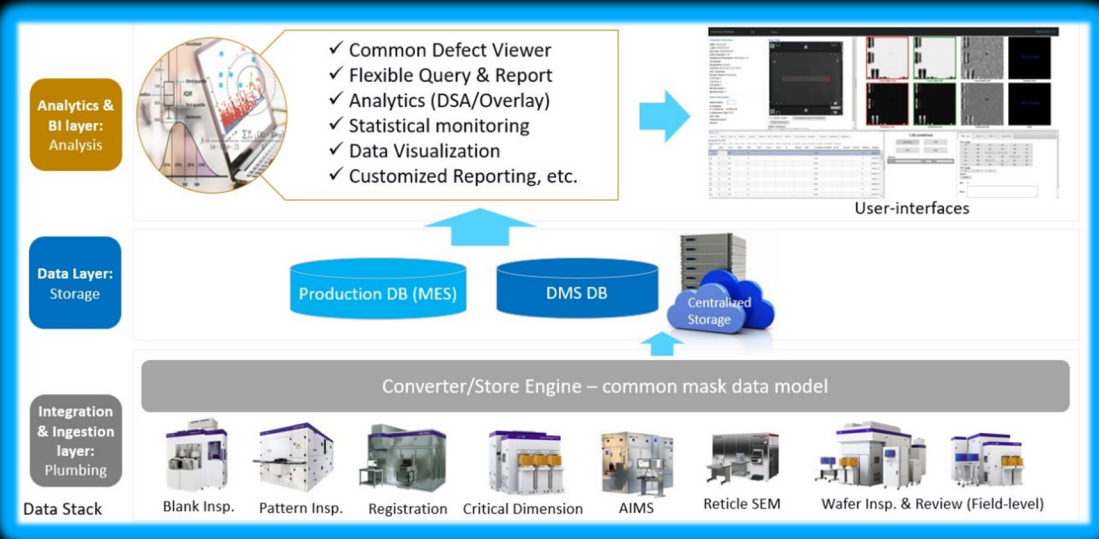


Mask Shop Specific Software

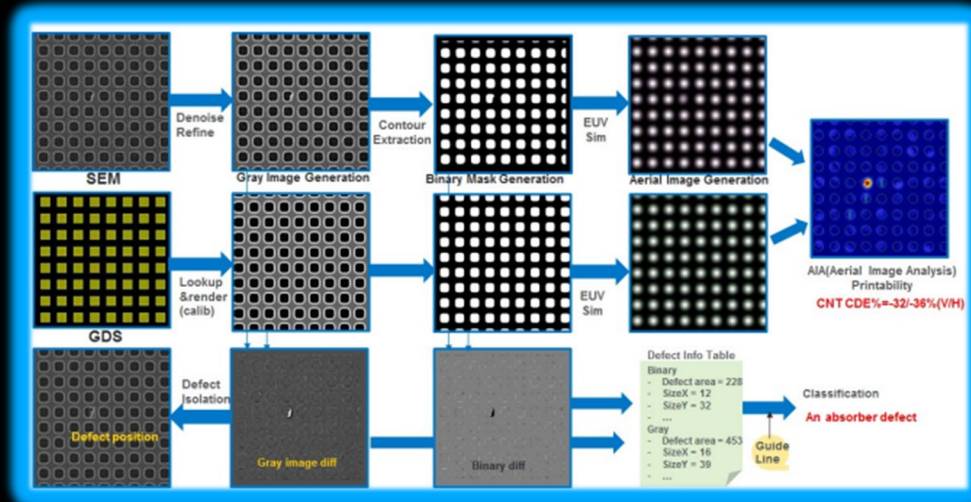
Photomask specific software tools, further motivated by EUV, is enabling advanced analytics in the mask shop.



Production flow for EUV defect avoidance using KlearView database and blank defect optimize (BDO)
 Comprehensive extreme ultraviolet blank defect avoidance system: BACUS 2022, Micron & KLA



Building blocks of an effective DMS architecture
 Need for comprehensive reticle data management and analytics: BACUS 2020, Micron & KLA



SEM ADC workflow
 Classification and printability of EUV mask defects from SEM images: BACUS 2017, Micron & KLA

Future considerations

High NA / Hyper NA EUV

- Expected further evolution of the photomask infrastructure already in place.
- Considerations of an alternative mask size can create significant capital and facility cost impact.

Continued pricing pressure

- High-end materials and equipment required to meet next generation specifications will likely create new cost challenges.

Software

- Expanded focus on data security to protect IP with increased data sharing.
- Increased use of deep learning/AI/data science tools within mask shops to maximize efficiencies and improve capabilities.

Thank you for listening!



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