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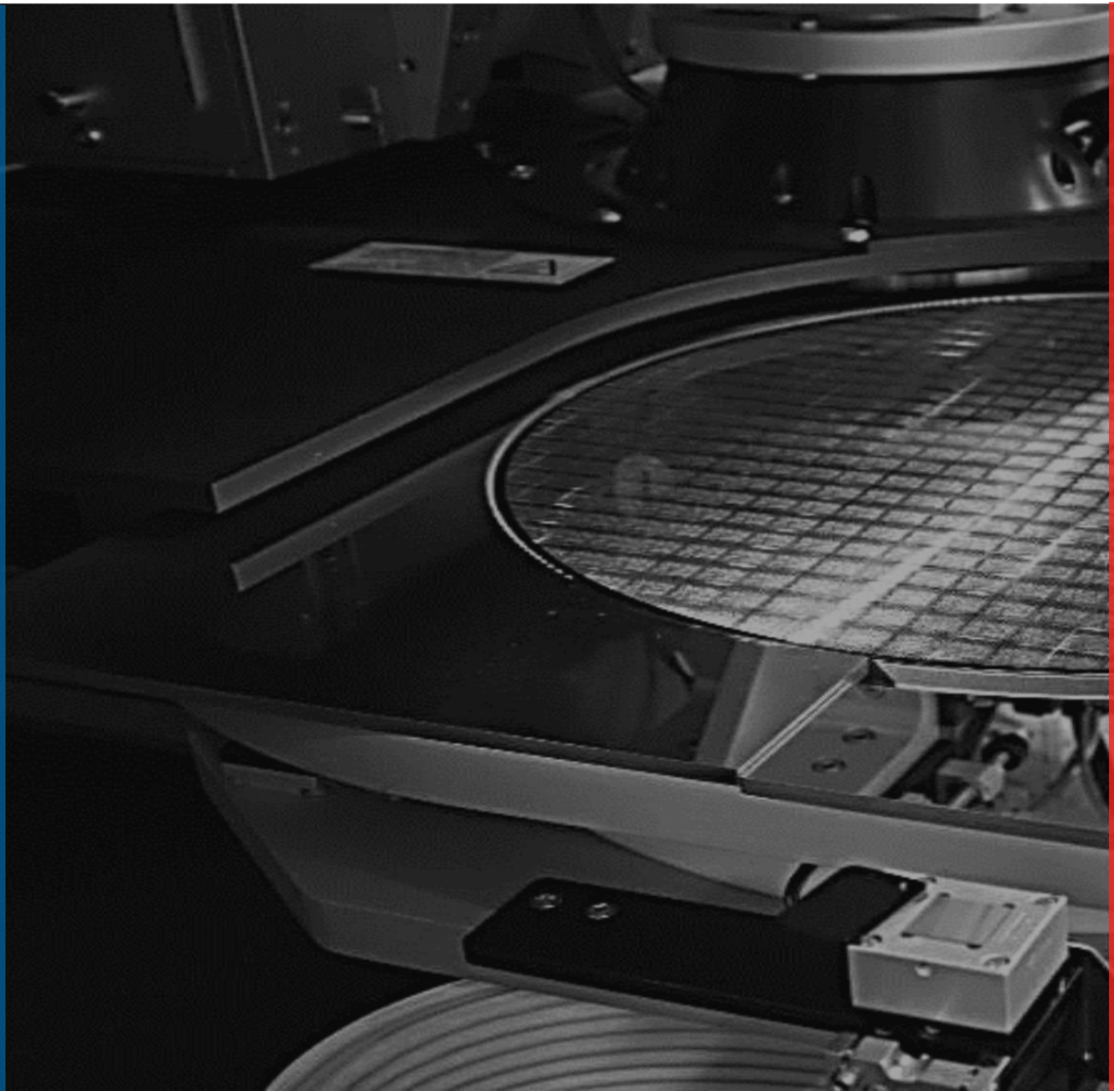

Ion Beam Technology Roadmap for EUV Mask Deposition and Absorber Etch Processes

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CXRO, LBL ▪ Berkeley, CA

Outline

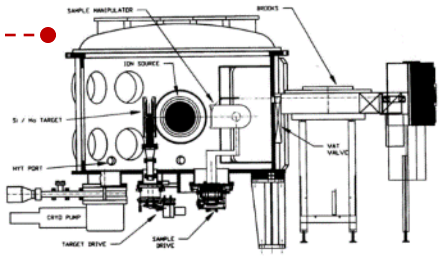
- Veeco Overview
- Multilayer (ML) Deposition Roadmap
- Veeco Engagement with EUV Mask Ecosystem
- Next Generation ML Deposition Tool
- Ion Beam technology for High K Absorber and att-PSM Layers
- Summary

Veeco's >20 Years History of EUV Mask Blanks Deposition

Lawrence Livermore National Laboratory

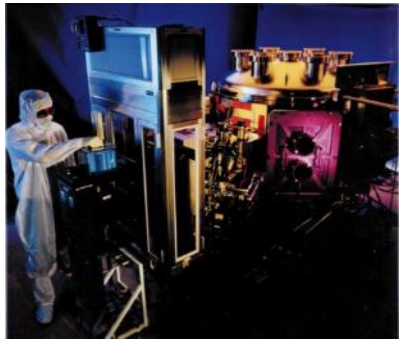
SEMATECH

1996 — *First EUV Multilayer R&D System*



LLNL RD 100 Award 1997

R&D Award



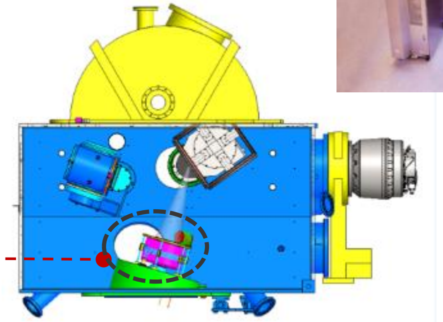
1999 — *New Source Configuration*

Self-Aligned Grids

2003 – 2010

SEMATECH JDA -
System Optimization

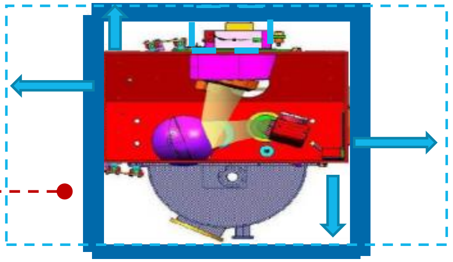
ESC Development, Rotating Targets
Shield Treatment, Ion Assist
PAM Module, Neutralizer Development
Particle Trap Door



2014 — *Odyssey Upgrade*

2019 – 2020 — *Trailblazer Upgrade*

2021 — *NEXT GEN HVM Platform*



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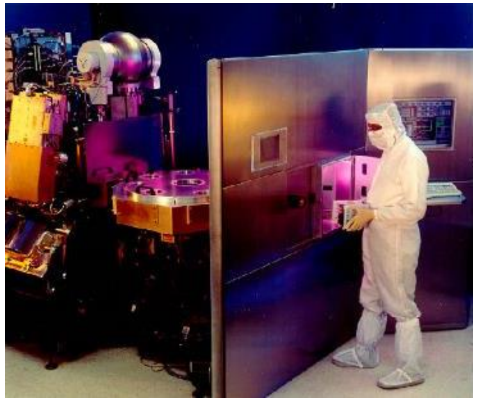
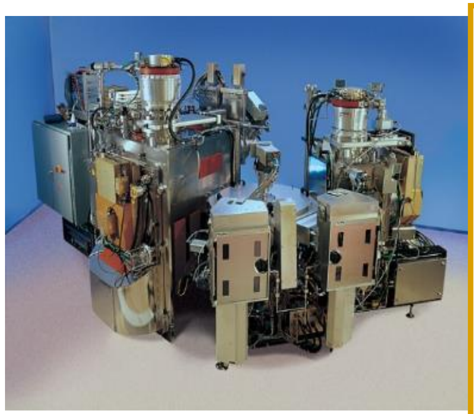
Veeco IBD Product Lineup





IBD-350	IBD-DS	IBD-LDD
General purpose IBD	**Optimized for IB/OB Symmetry**	**Optimized for Low Defects**
Materials • Oxides / dielectrics • Metals • Magnetic films Applications • Disk drive • Optical coatings- laser facets	Materials • Oxides / dielectrics • Metals • Magnetic films Applications • Disk drive	Materials • Mo, Si, Ru Applications • EUV mask blank deposition
Configuration: • IBD-210 Dep Source • RIM 350 Assist source • 13in TS	Configuration • IBD-210 Dep Source • RIM 350 Assist source • 19in TS • Linear scanning fixture	Configuration • IBD-210 Dep Source • RIM 350 Assist source • ESC fixture • Vertical configuration,

- IBD-LDD is the process tool of record for EUV mask blank's Mo/Si layers deposition process
- IBD-LDD has extremely low defect densities with excellent uniformity and film properties
- Current IBD-LDD platform qualified for 5nm node
- Ongoing improvement efforts and roadmap are required to address 3nm and beyond technology node
  - Particle reduction - yield
  - CWL uniformity and thickness control - reflectivity

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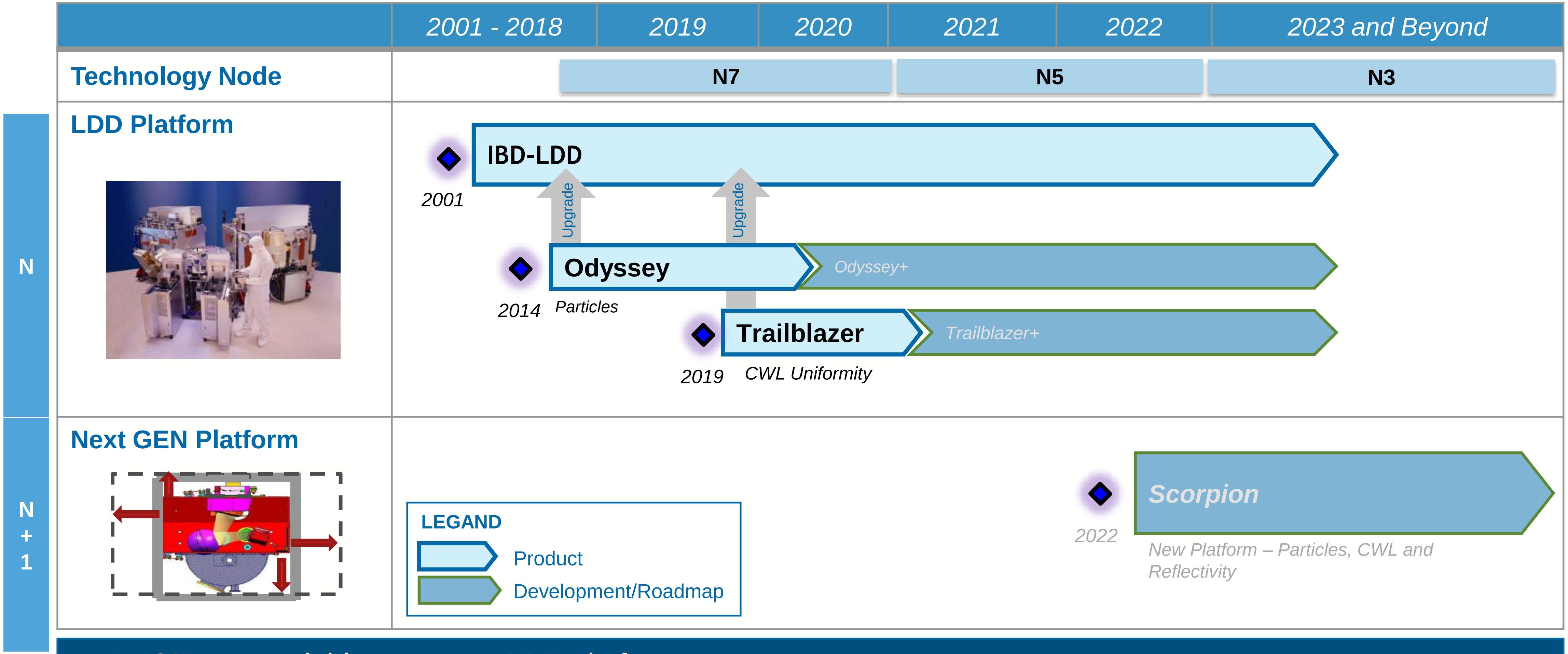
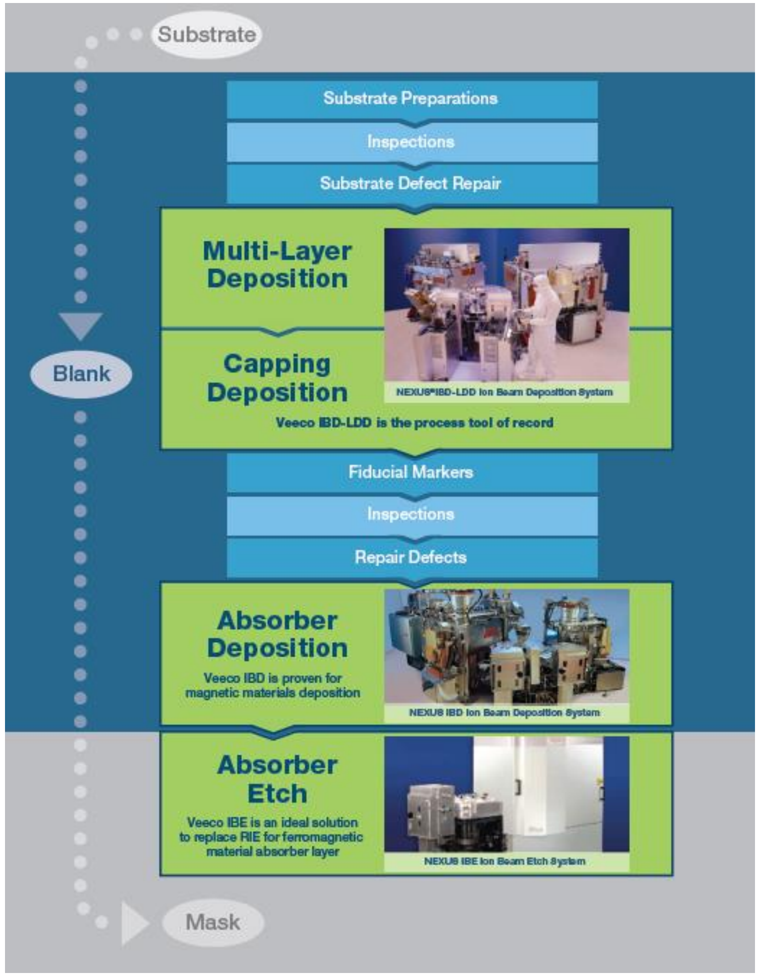
Veeco ML Deposition Product Roadmap

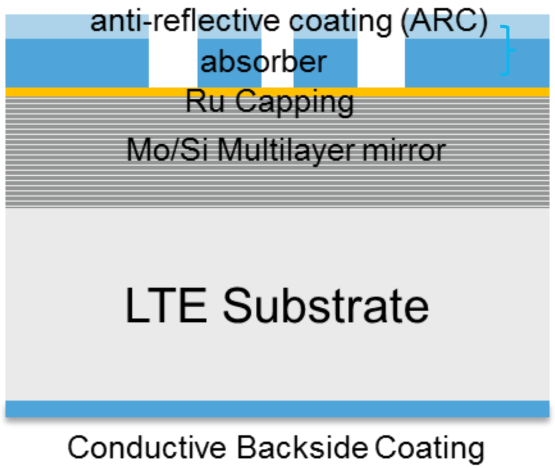


- N: CIPs upgradable to current LDD platform
- N+1: Roadmap new platform caters for technology beyond 3nm; Plan/timing pending validation

Broader Veeco Involvement in EUV Mask Blank Manufacturing

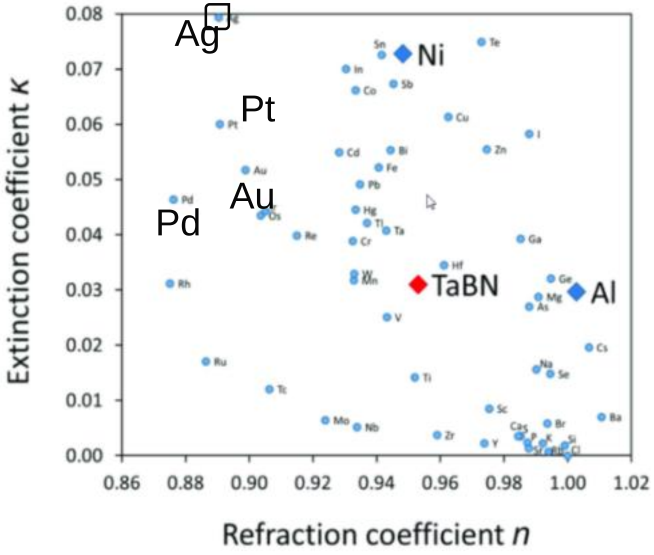


- Multilayer/capping deposition – improvement required for 3nm node and beyond
  - ML layers inter diffusion
  - Potential new materials for ML
- Absorber deposition and etch – high k material is required for future technology node



Thinner Ni/CO/Alloy < 30nm

Particle defect Thickness control



Continue to improve mask particle defect and reflectivity
Participate in activities to reduce mask 3D effects

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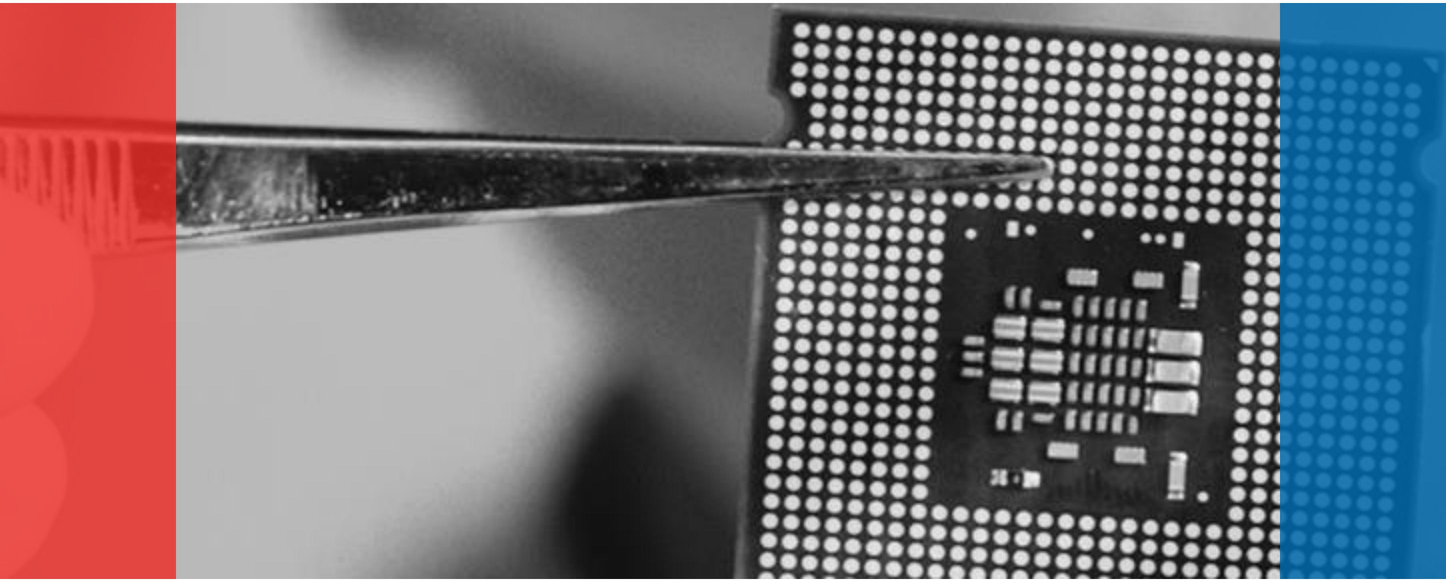
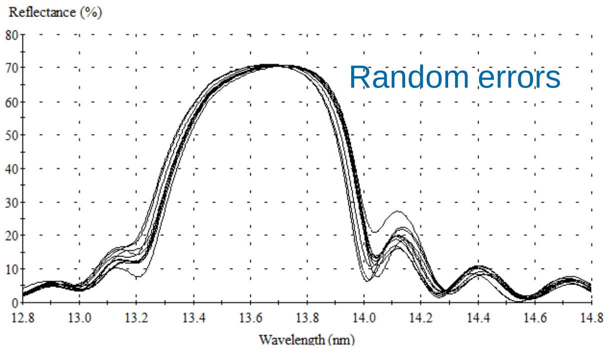
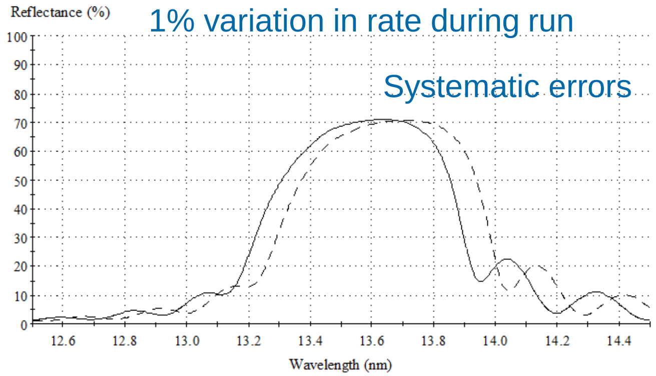


Next Generation ML Deposition Tool

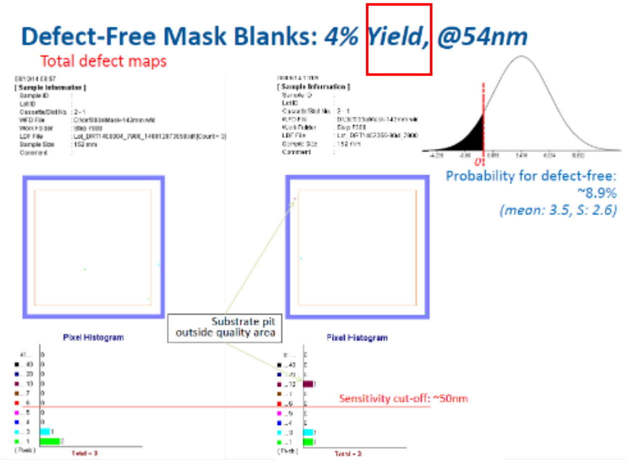
ML Deposition: Major Challenges for <3nm node

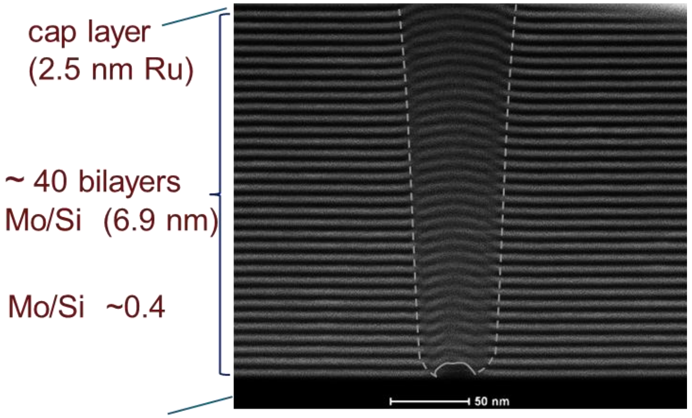
- **Thickness / Interface control**
  - Improve reflectivity of the ML stack
  - CWL variation <0.02 nm





- **Reduce particles**
  - Impact on EUV multi-patterning
  - 0 defects >30 nm with ≥ 50% yield
  - Reduce energy of ion source while maintaining rate





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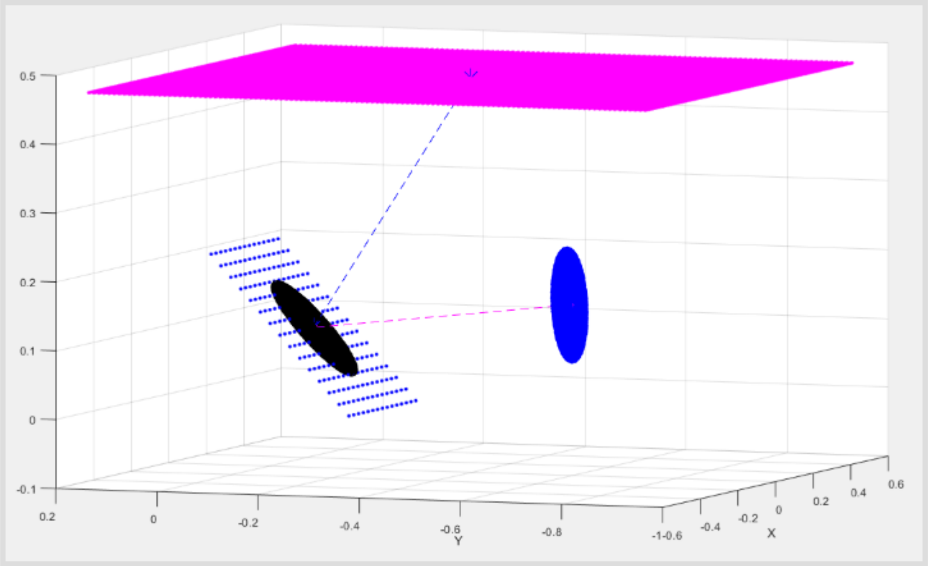
Areas of the LDD system enhancements

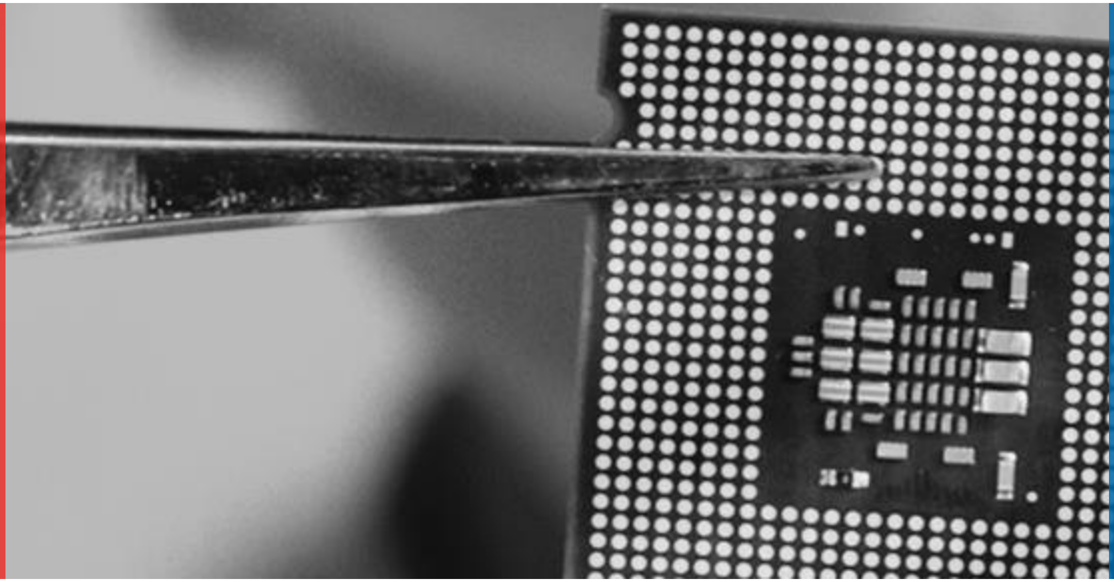
- Most favorable configuration of ion source – target –fixture
- New source: Lower ion energies while maintaining depo rate
- Develop electrostatic traps
- Optimized chamber size to accommodate all of the above

Modeling Optimal Configuration



- Fully parameterized model to explore different configurations.
  - Source configuration
  - Erosion profiles
  - Relative orientation between target and fixture tilt
  - In-plane and out of plane configuration

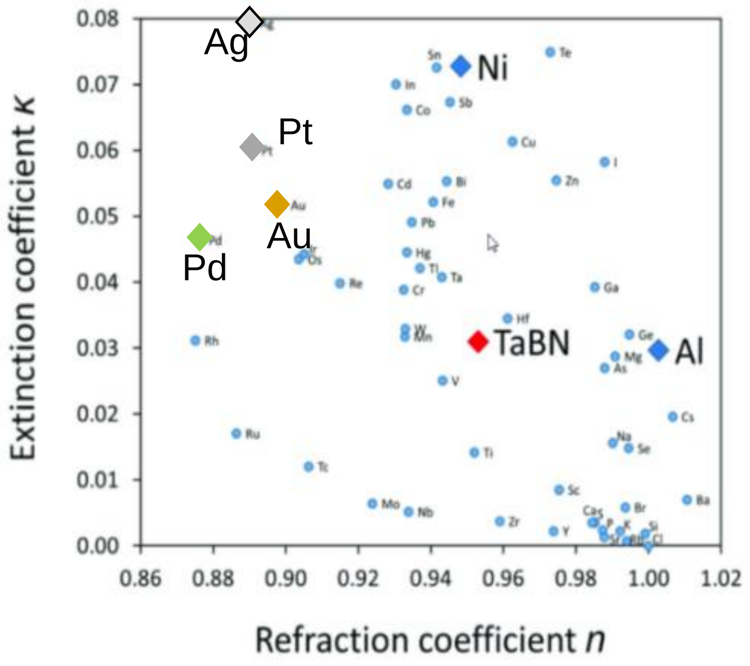
Changes	Results
Uniformity Improvements	CWL uniformity
Control of layer thicknesses	W2W uniformity
Near normal substrate angle	Defect reduction (reduction in defect decoration and enhance smoothing
Beam angle and target rotation	Nodule reduction
Larger source	Reduced intermixing of layer



Ion Beam technology for high k absorber and att-PSM layers

Next-Generation EUV Absorber Materials

- Absorber deposition requirements
  - Thinner layers would need better uniformity and thickness control
    - Do not see major roadblocks with IBD
- Absorber Etch
  - Materials (Me, MeX (binary), MeXY (ternary)
  - RIE not suitable for Me compounds
    - Low volatility; ineffective chemistry
- Ion Beam etch a viable solution



Ref: Appl. Sci. **2018**, 8, 521; doi:10.3390/app8040521

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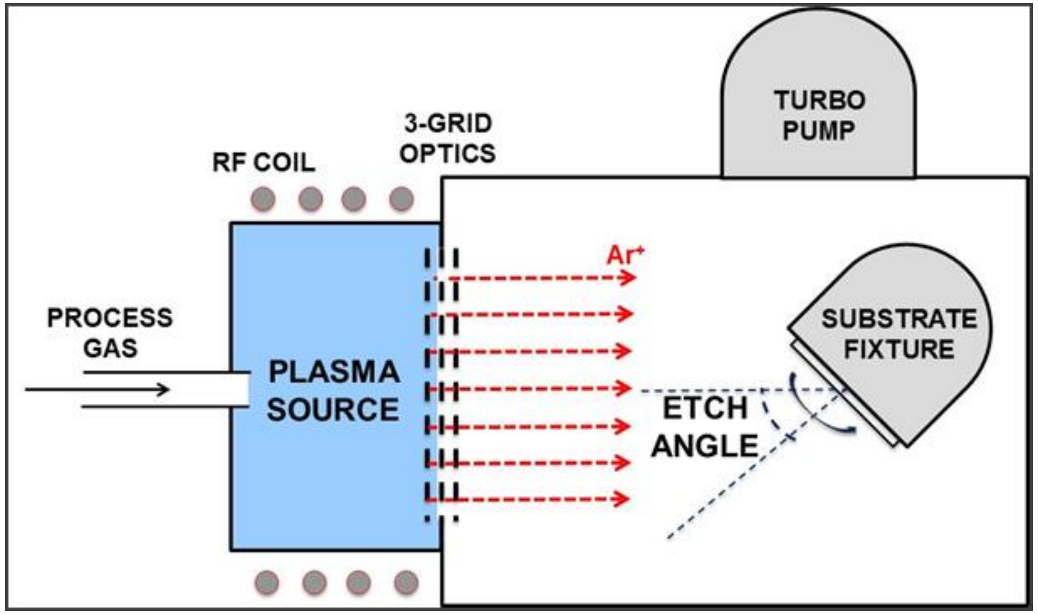
Veeco Ion Beam Etch Overview

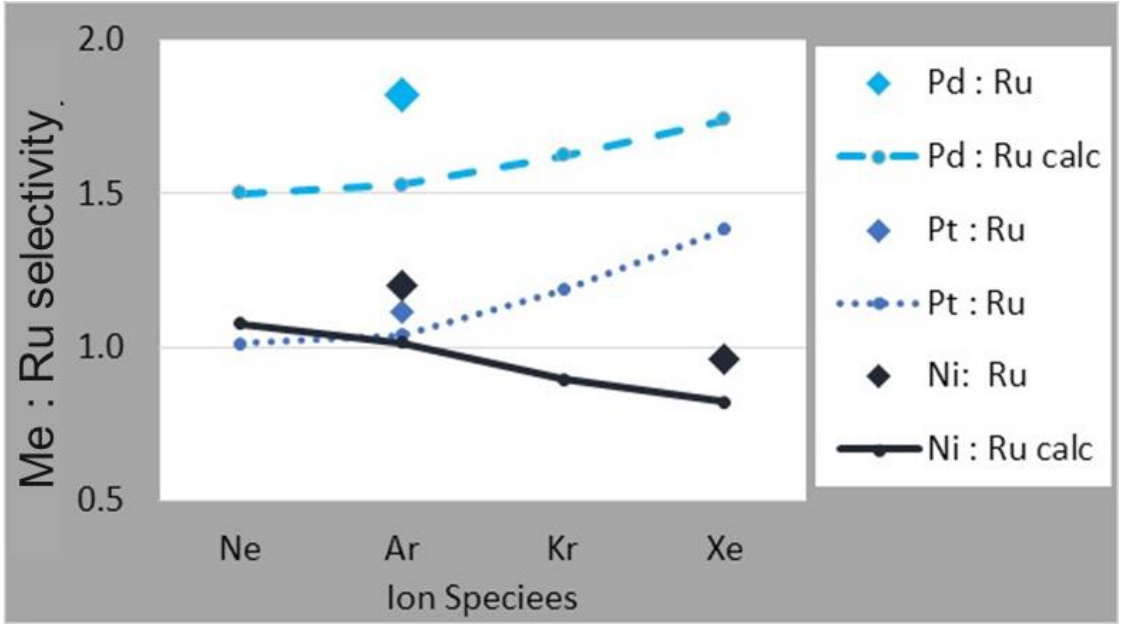


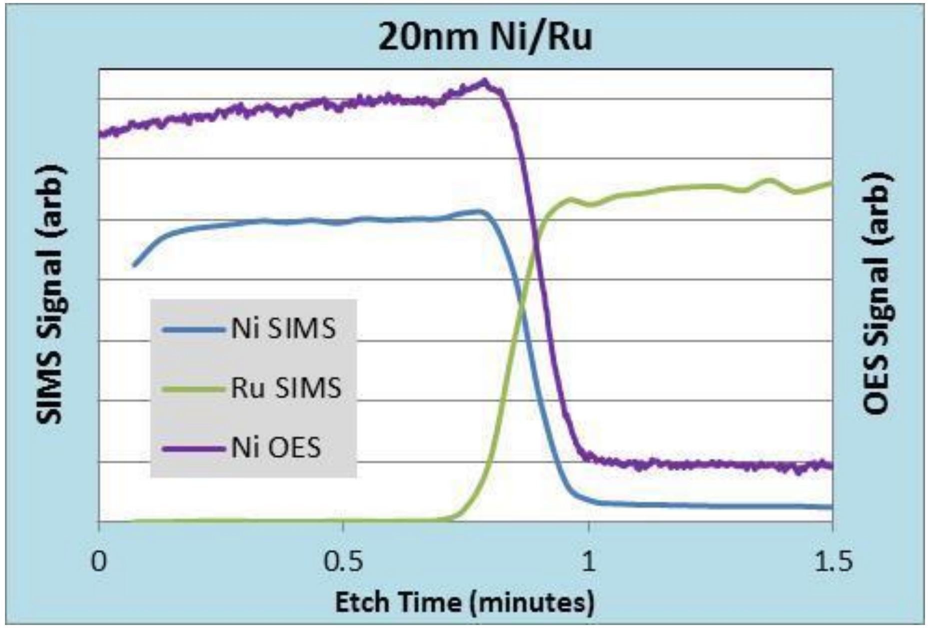
IBE Feature	Selected Benefits
Physical etch	**Any material - no chemistry dependence**
	Complex compounds or multilayers
	No chemical damage/residues
	No chamber conditioning, memory effects
	Same rate for dense & isolated features
Directional ion beam	Anisotropic etch
	Device shape & sidewall angle control
	Eliminate re-deposition
Ion source isolated from substrate	Low pressure: low contamination & re-deposition
	Low energy capability, down to 50V
	Low temperature operation

Industry standard for magnetic and novel material etch

Etch Selectivity to Ru Capping Layer

Ni: Key Me for high –k absorber layer





Selectivity can be optimized via ion species

End point can be successfully controlled

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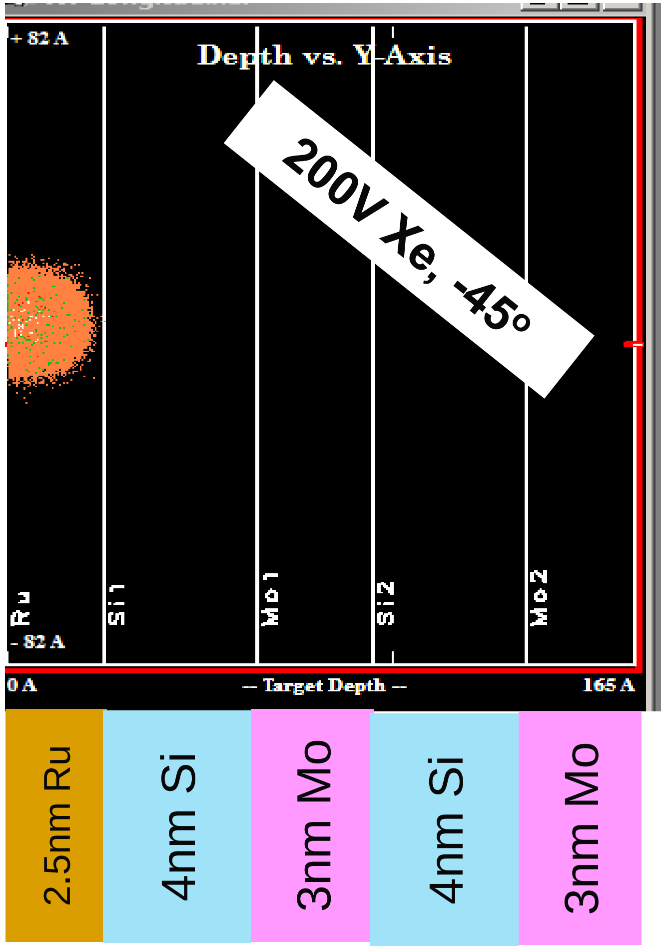
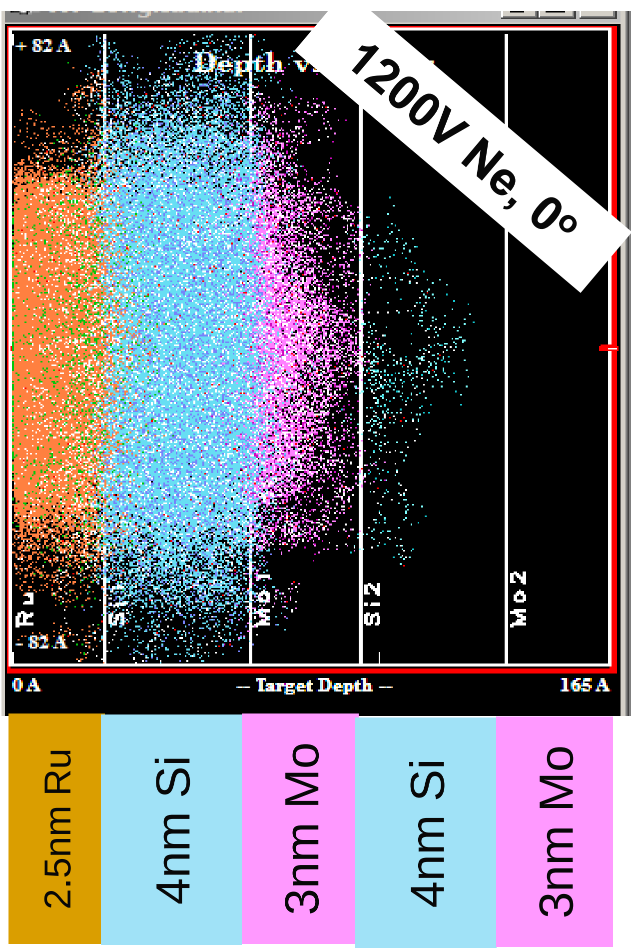
Stopping Range of Energetic Ions into Ru Cap & Mo/Si Reflector





Ion damage can be limited by appropriate combination of ion species, ion energy and fixture angle

SRIM Simulation

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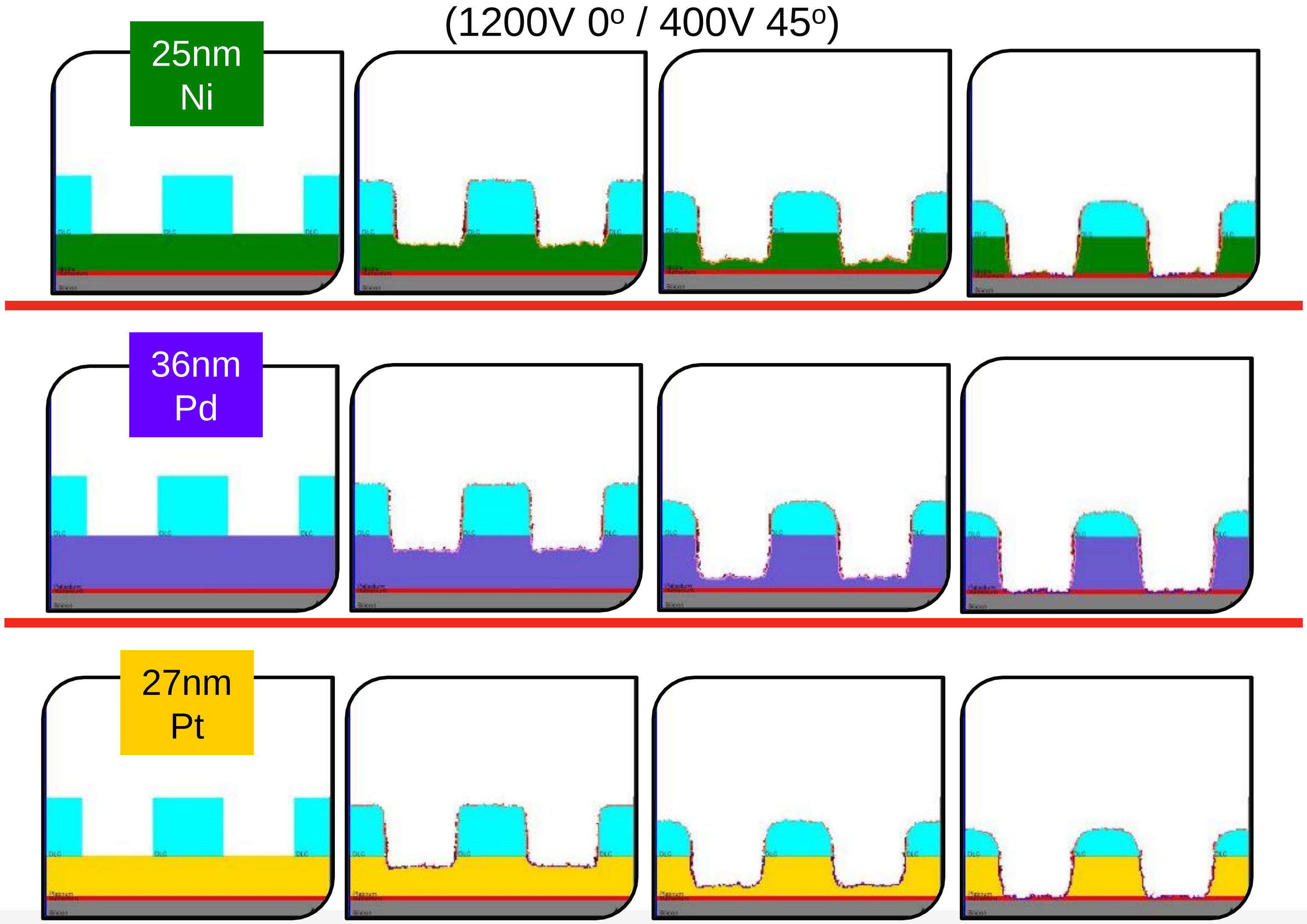
Simulated Etch Progression : 48nm HP Absorber Structure



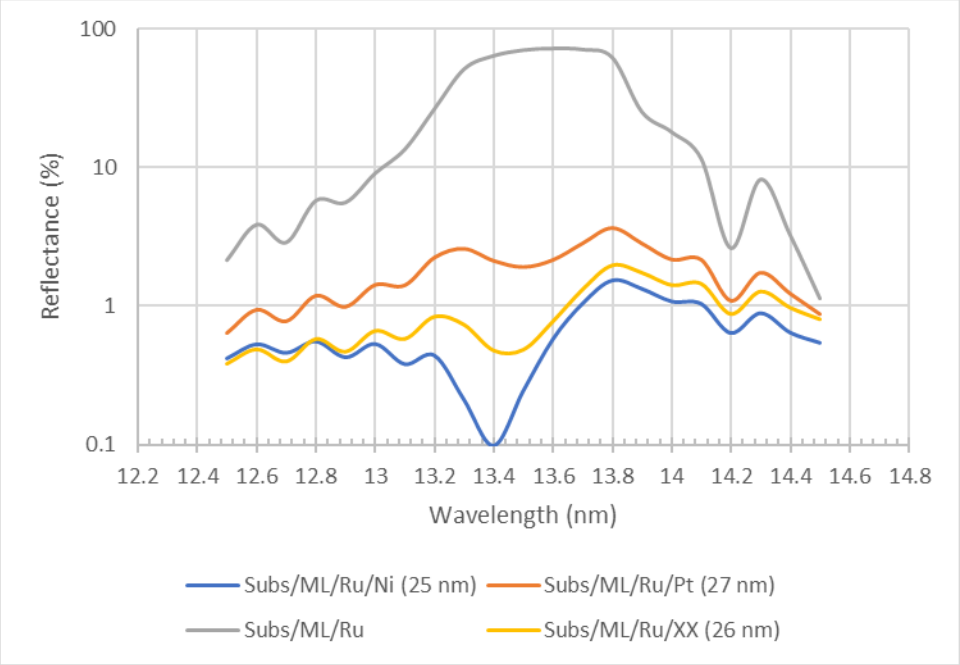
CRITICAL DIMENSIONS

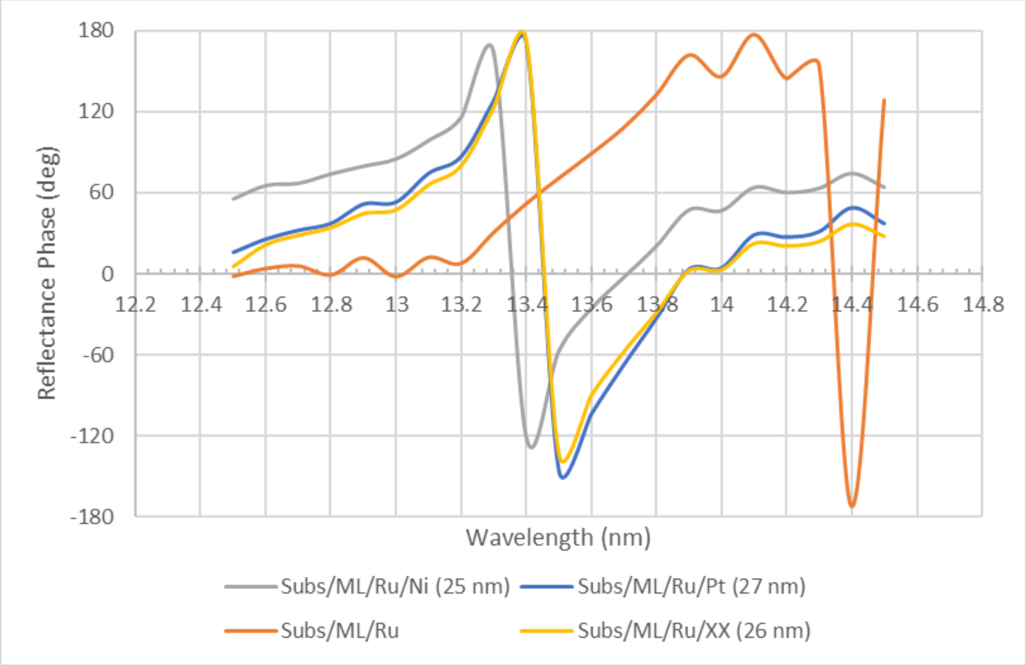
Me	Thickness (nm)	Top CD (nm)	Bot CD (nm)	SWA	Mask Left (nm)
Ni	25	49	55	83º	25
Pd	36	47	53	86º	17
Pt	27	46	56	81º	19

t_{min}^{abs} *required*

Effective patterning at 48nm HP for Ni, Pd or Pt

High-k Att-PSM Materials Modeling





	Subs/ML/Ru (2 nm) / Ni (25 nm)	Subs/ML/Ru (2nm) / Pt (27 nm)	Subs/ML/Ru (2nm) / MeXYZ (26 nm)
Phase change (deg) wrt Subs/ML/Ru (2nm)	-114.8	-192. 8	-178.7
%R (13.6 nm)	<1%	~2%	<1%

Summary

- Continue to drive ML deposition roadmap based upon EUV reticle roadmap
- Ion Beam etch (IBE) a viable solution for high-k and att-PSM absorber materials
- Unified vision on new absorber strategy
  - Strong partnership to develop standards for high-k and att-PSM material(s)
  - Understand the challenges for high-k material not only from technology point of view but commercial aspect too (example cost, manufacturability, process control)
  - Validate the performance and durability of materials
  - Mitigate the risks for etch, clean and repair

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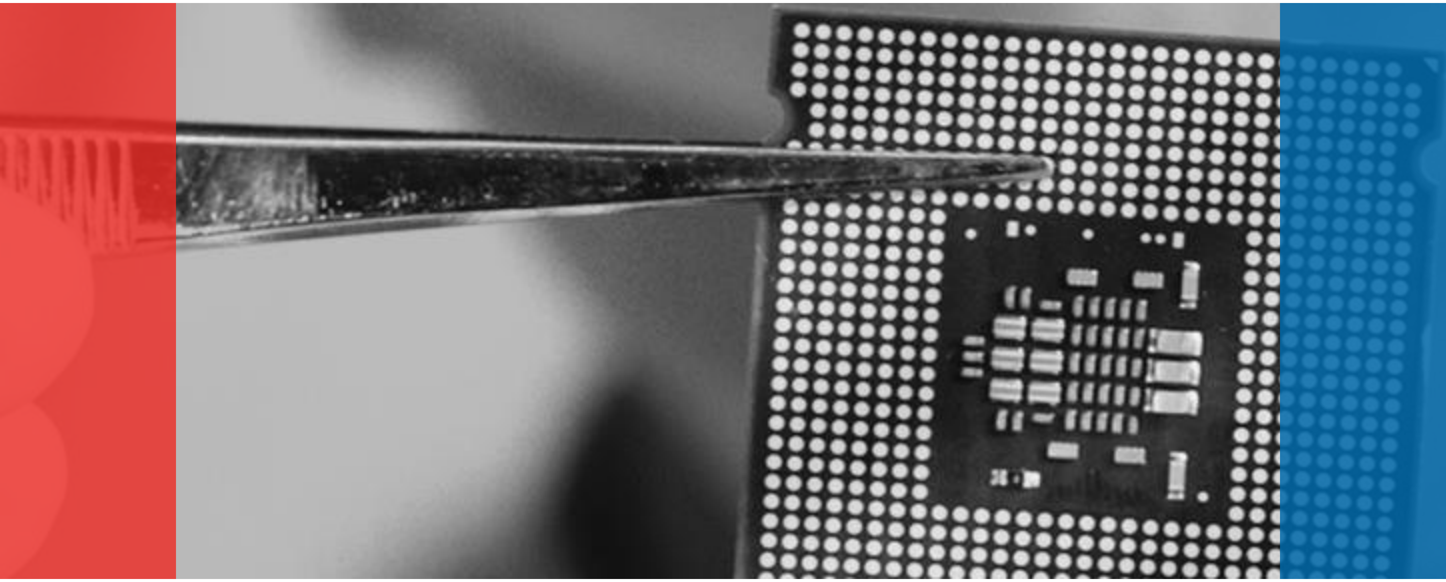

Thanks!!