Advanced Deposition Techniques For Next Generation EUV Mask Blanks

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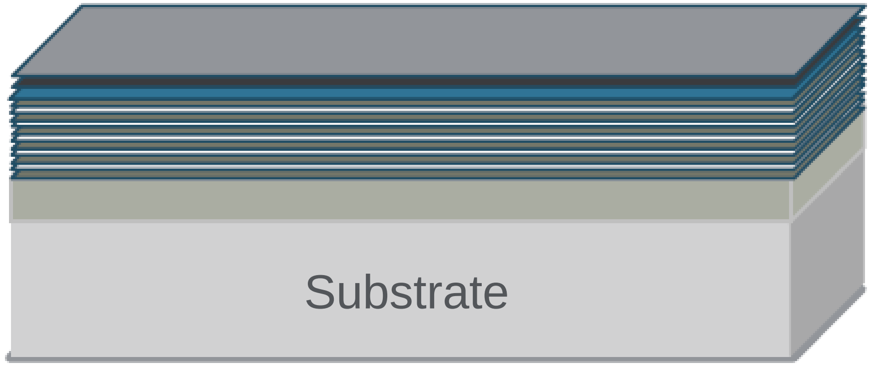
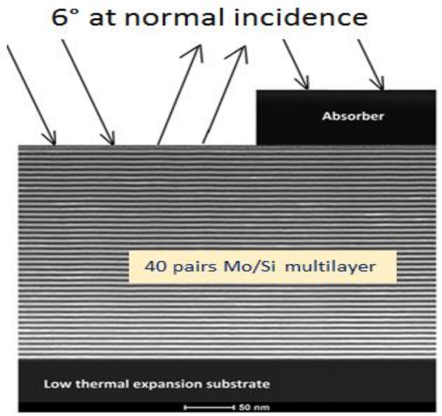
Current EUV Mask Blank Structure



EUV Mask Blank Materials System

Absorber: **TaN**
Cap: **Ru**
Mirror: **40x Mo/Si**

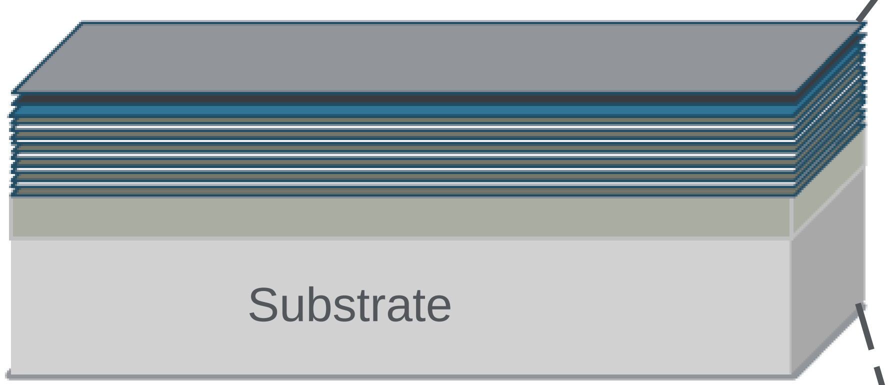
Backside coating: **CrN**



TEM

Backside (CrN)	Substrate	Mirror (40X Mo/Si)	Cap (Ru)	Absorber (TaN)
• Resistivity • Coeff of friction • Hardness • Roughness • Optical density • Defects • Non uniformity	• Defects • Roughness • CTE • PV, Bow • Dimension	• Defectivity • CWL, Reflectivity • Non uniformity • FWHM • Roughness • Interface mixing and roughness	• Thickness • Durability • Reliability • Etch selectivity • Roughness	• Defects • Reflectivity • Non uniformity • Thickness • Etch properties • Cleaning reliability

Drivers for Next Generation EUV Mask Blank



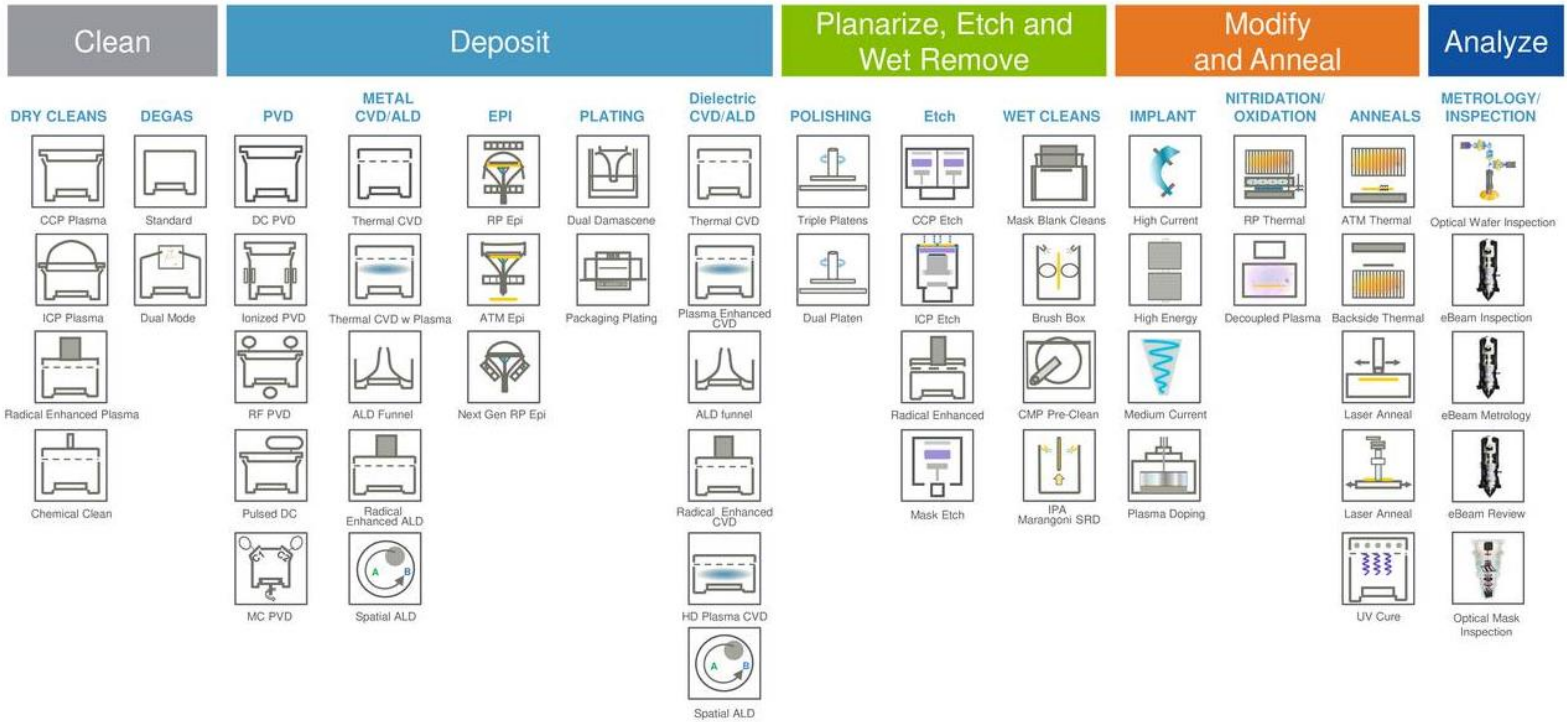
EUV Mask Blank Materials System

	Key Drivers	Implication
Absorber	• Reduced thickness with Higher Absorption	• New Materials • New etch and clean chemistries
Cap	• Durability and Reliability • Integration with Thin Absorber	• New Materials • New etch and clean chemistries
Mirror	• Low Defectivity • Higher Reflectivity • Reduced NU	• Interface engineering
Substrate	• Low Defectivity • PV/Bow	• Polishing and clean control
Backside	• Hardness to improve durability maintaining μ and resistivity	• New Materials

Precision materials engineering techniques needed for next generation EUV mask requirements

Next Generation EUV Mask Blanks Requires Materials Innovation and Defect Control

Applied: Largest Set of Materials Engineering Capabilities



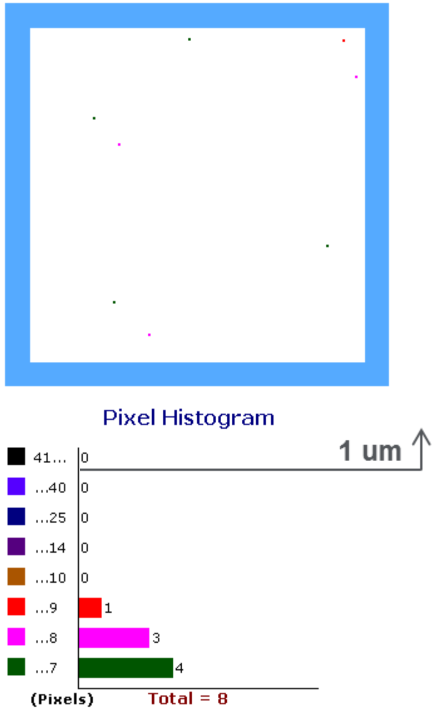
Applied's Advanced Deposition Technologies Enables Custom Films Development to Address EUV Mask Drivers

http://ir.appliedmaterials.com/phoenix.zhtml?c=112059&p=irol-eventDetails&EventId=5272062

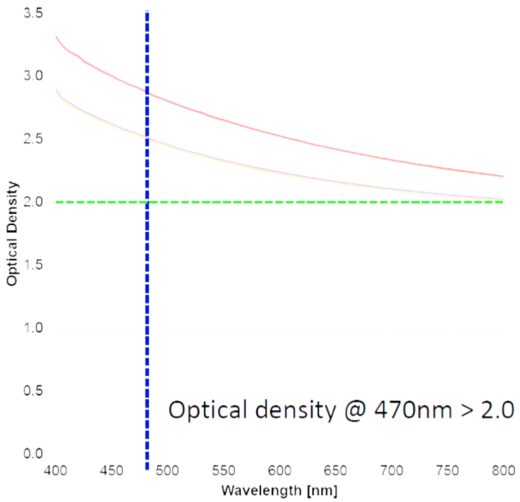
Backside Coating Optimization

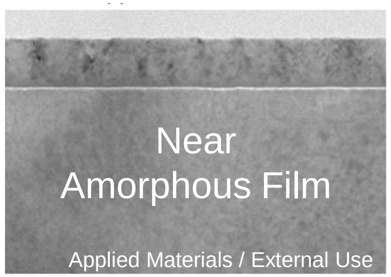
	Key Drivers	Implication
Backside	• Hardness to improve durability maintaining μ and resistivity	• New Materials

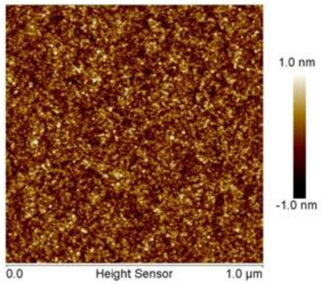
	Benchmark test coating	Applied CrN
Critical load (mN)	392	>500
CoF		<0.25
Roughness		0.2 nm
Sheet resistance		<50 ohm/sq
Scratch resistance	Meets / few scratches	Exceeds / no scratches

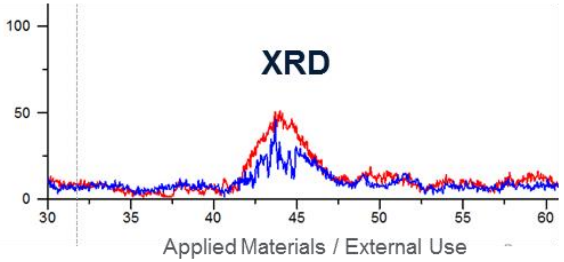


Defects during CrN deposition: 0 @1um







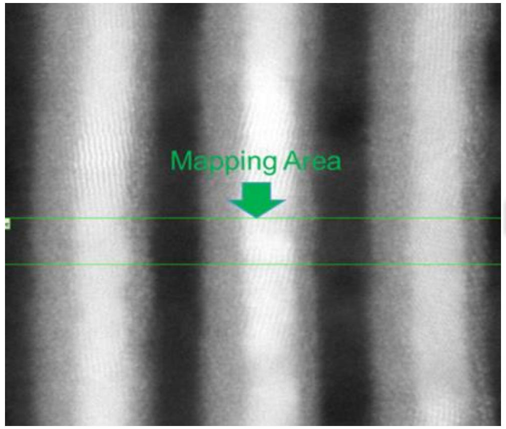


- **Optimized CrN performance using advanced deposition methods**
- **Investigating additional material systems for further improvement**

Mirror Multi-Layer Optimization

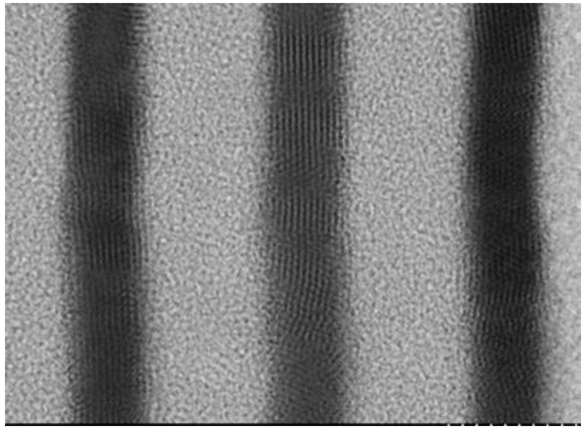
	Key Drivers	Implication
Cap	• Durability and Reliability • Integration with Thin Absorber	• New Materials • New etch and clean chemistries
Mirror	• Low Defectivity • Higher Reflectivity • Reduced NU	• Interface engineering

Applied Materials / External Use TEM



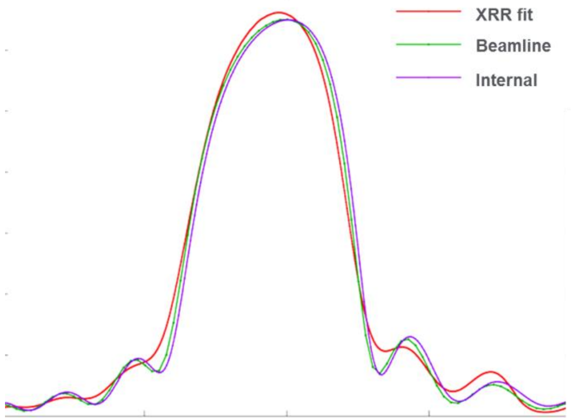
Mo/Si Intermixing
~2nm silicide formation

Applied Materials / External Use TEM



Sharp interface engineering
with Applied's deposition technology
Sub-nm silicide formation

Applied Materials / External Use



Reflectivity comparison with beamline

- **Engineering interfaces to minimize intermixing and <u>maximize reflectivity</u>**

Mirror Multi-Layer Optimization

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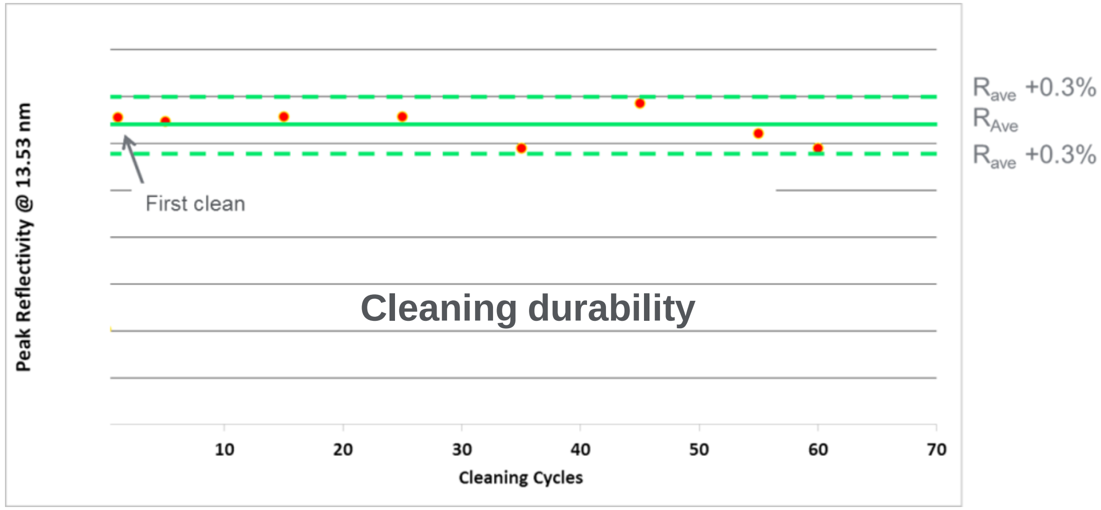
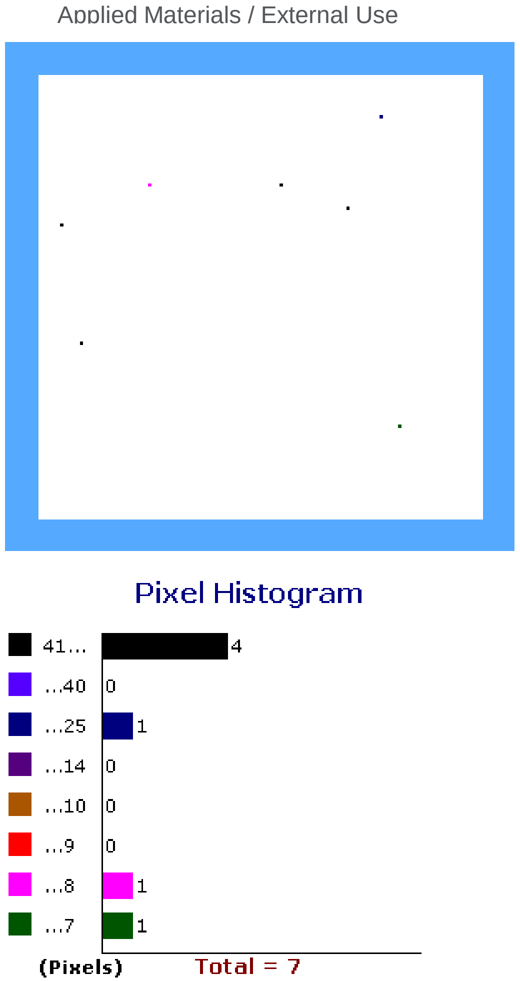
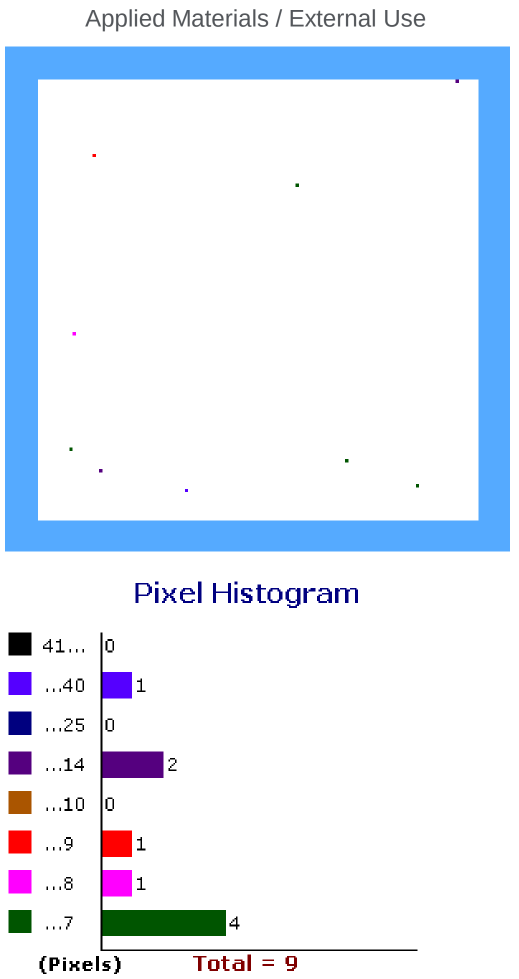




ML + Ru adders: 7 @50nm

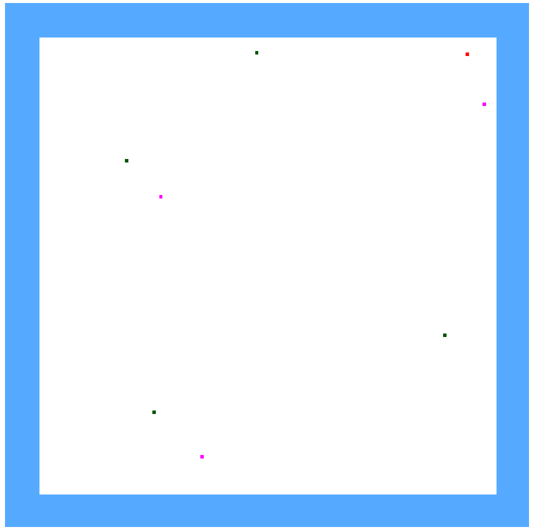


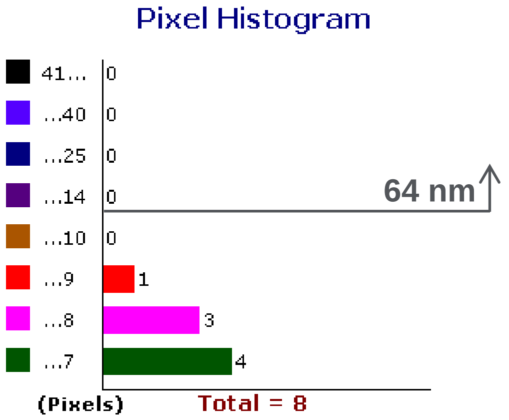
ML + Ru adders: 9@50nm

- **Low Defectivity. Dense Ru layer with no damage observed from Etching/Cleaning processes**
- **Developing capping materials to address future <u>Durability/Etching</u> requirements**

TaN Absorber Benchmark

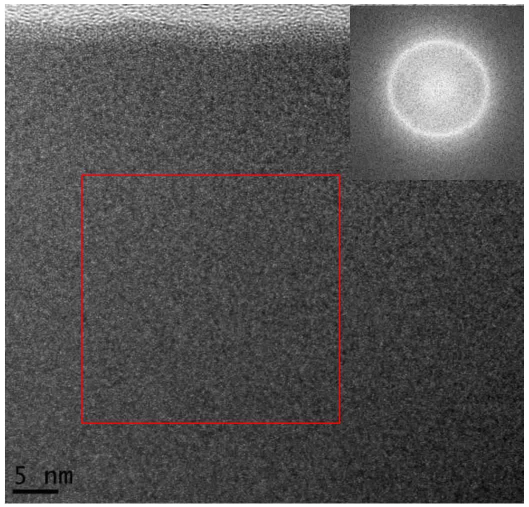
Applied Materials / External Use

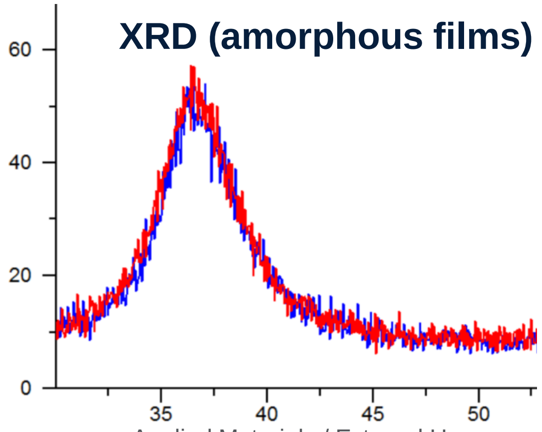




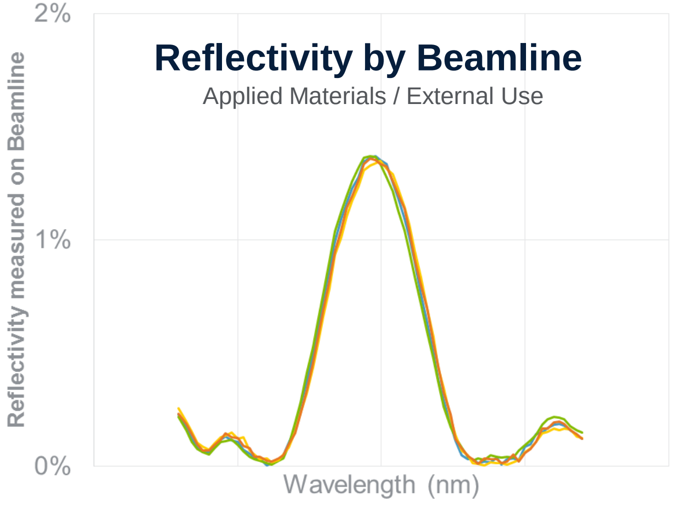
Defects during TaN deposition

Applied Materials / External Use TEM

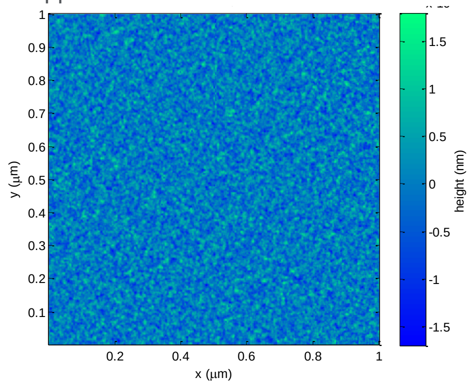


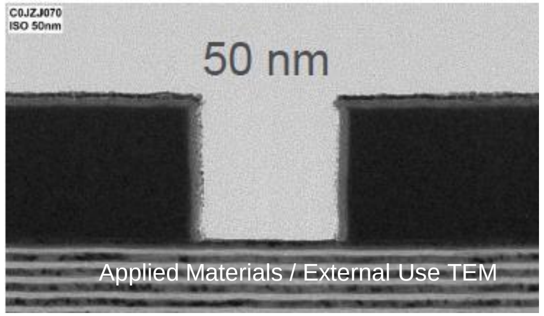


Applied Materials / External Use



Applied Materials / External Use AFM





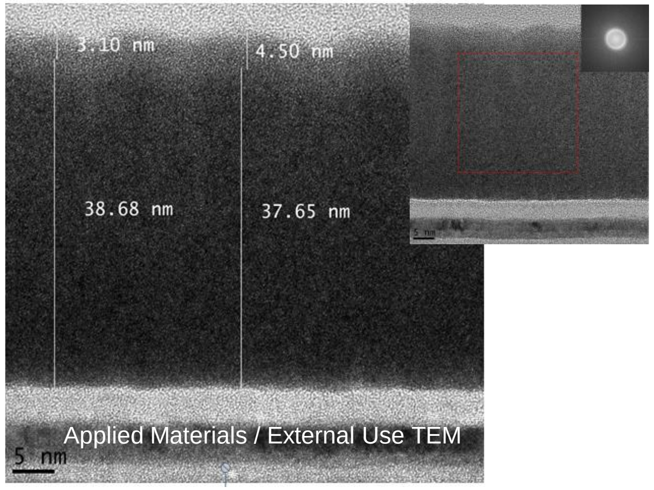
- **Need for Advance Absorber to <u>reduce M3D</u> effects**

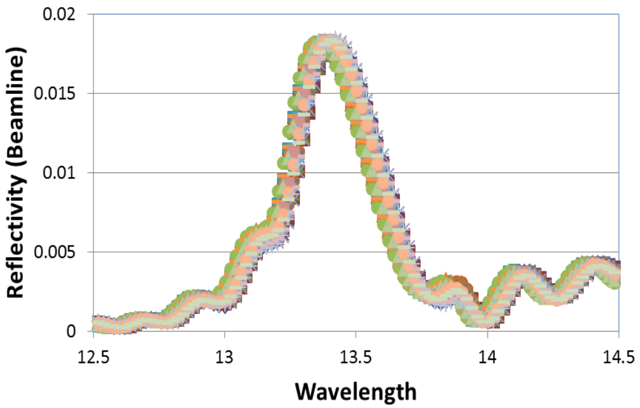
Advanced Absorber Development

- Key Attributes
  - n and k values which can provide less than 2% reflectivity for less than 45nm thickness on ML+Ru
  - Single phase, amorphous & stable films
  - Cleaning durability and etch-ability
  - Good adhesion and etch selectivity with capping layer
  - Operating temperature and hydrogen resistant
  - Low surface roughness, Low or compensated stress, DUV contrast for inspection
  - Repair

Material System A

ML		Absorber (A)		Beamline Verification
Reflectivity	CWL	Thickness (nm)	Reflectivity	Reflectivity
66.3%	13.54	35	3.5%	
66.5%	13.54	40	<2%	<2%
66.0%	13.52	45	0.2%	

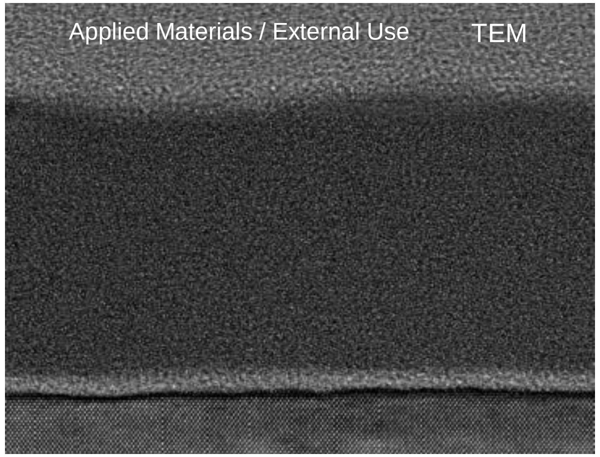




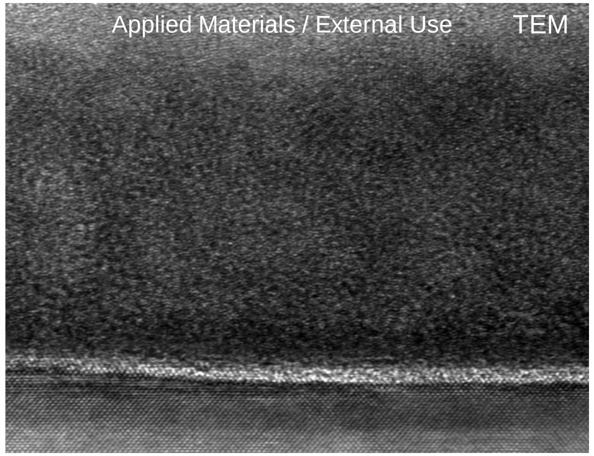
- **Novel use of simulation methods and empirical materials library identified thin absorber candidates**
- **Optimized deposition techniques provide amorphous, low reflectance films**

Advance Absorber Development (cont'd)

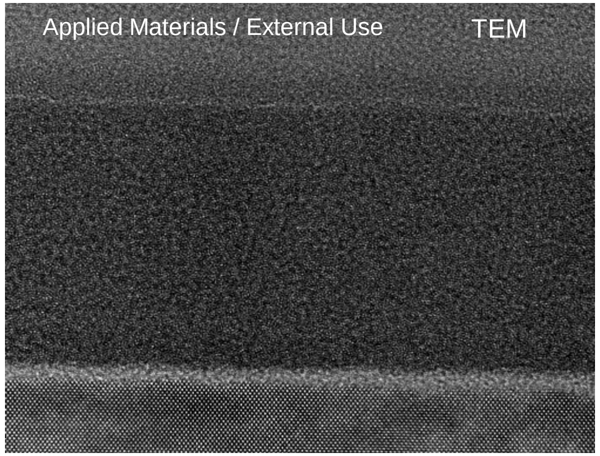
Material System B



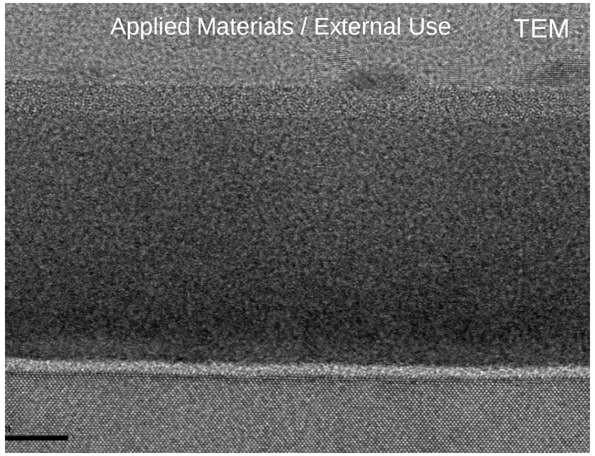
Material System C



Material System D



Material System E

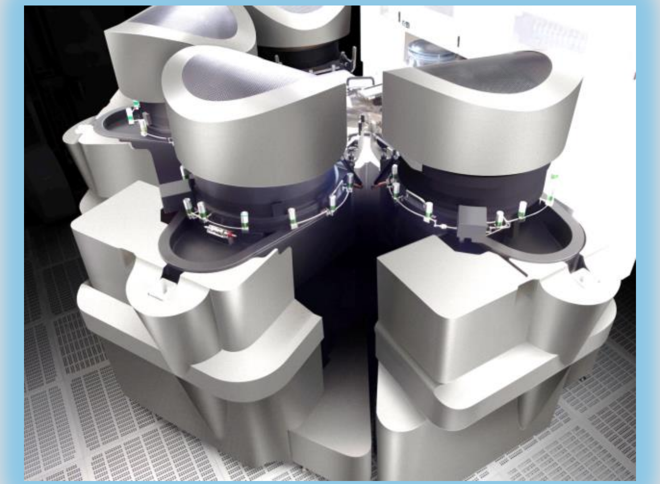


- **Multiple other material systems exhibit amorphous single phase that provide less than 2% reflectivity for sub 45 nm thickness**
- **Etch compatibility validation is in progress**

Tetra™ Z – EUV Features and Benefits

Chamber and Source RF Design
- Enhanced CDU control
- Wider Process Window

RF with Full Digital Control
- Fast tuning and improved striking/stability
- Advanced source and bias pulsing and control for wider process window
- RF stability and control independent of position



Advanced Cathode Design
- New Cathode/lift design for min contact
- Reduced backside etching
- Improved CDU
- Lower Defects

Advanced End Point Control
- State-of-the-art REP combined with OES and IEP technologies with advanced algorithms
- Absorber and black border ML etch
- Partial ML etch for EUV PSM applications

Tetra™ Z EUV

Next Generation Chamber Materials
- New chamber materials
- Lower defects

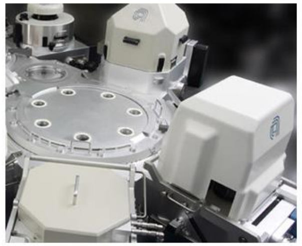
Recursive Multi-port Gas Injection
- Uniform Gas Injection Module
- Enhanced CDU Control

- **Tetra™ Z EUV Chamber Developed and Used for Next generation EUV Mask Requirements**

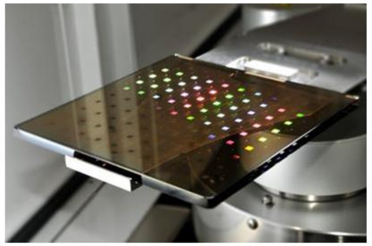
Next Generation EUV Mask Blanks Requires Integrated Solution for Customers

Applied's Portfolio for EUV Masks

Applied Suite for Mask Blank



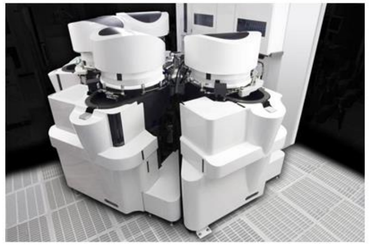
Ultra-Low Defect, High Throughput Cluster Tool Platforms



Mask Blank Deposition

Reticle and substrate Clean

Mask inspection: Aera 5



Mask Blank Etch: Tetra

<u>In-house capabilities</u>

- Polishing technologies
- Planarization technologies
- Low defect BKMs and handling systems
- Ability to develop end-to-end hardware/equipment
- Defect metrology and characterization tools
- Thin film diagnostic and characterization tools
- Dedicated Class I Mask Fab

Applied Suite for Photomask

MASK COAT SERIES

MASK PATTERNING

MASK CLEAN SERIES

MASK BAKE SERIES

MASK DEVELOP SERIES

- Applied's broad and deep photomask infrastructure and R&D capability offers unique ability to enable custom materials engineering and modifications to address customer's problem

Summary

- Applied's Advanced Deposition technologies can address future EUV mask requirements
- Using various materials engineering techniques, Applied has
  1. improved CrN backside properties,
  2. reduced the Mo/Si intermixing for the mirror layer,
  3. optimized the TaN layer,
  4. identified viable thin absorber materials,
  5. and continues to explore material systems at an accelerated pace.

- Next steps include validation of new material systems as an option for next generation EUV mask blanks
  - validation of etch-ability, cleaning durability, and imaging performance

APPLIED MATERIALS®

make possible