

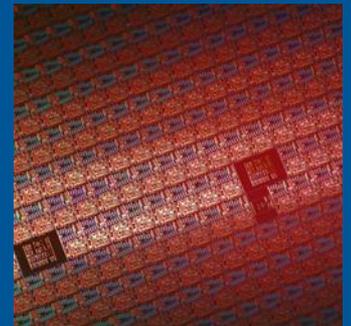


Accelerating the next technology revolution

## Embedded Killer Particle Defects on EUV Substrates and Strategy for Their Removal for Improved Yield of EUV Mask Blanks

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SEMATECH,  
Albany, NY  
10/10/2013



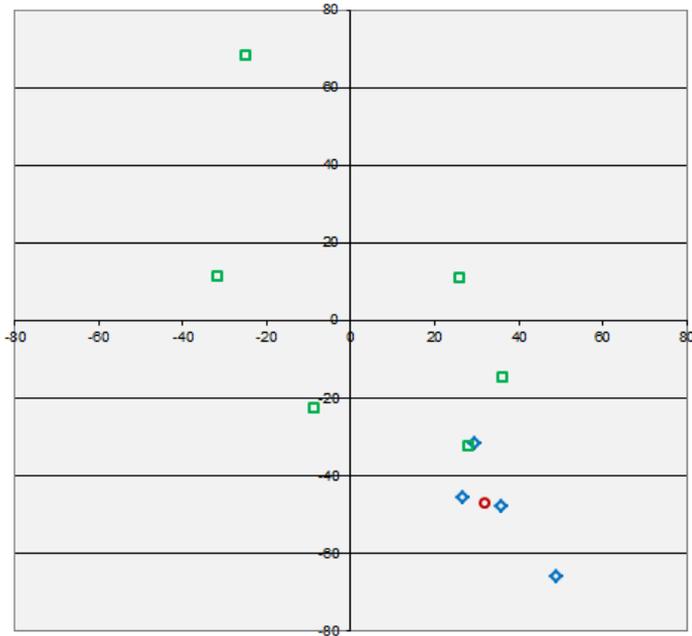
# Outline



- Killer particle defects on substrates
  - Hard to remove defects of **size > 40 nm** SiO<sub>2</sub> equivalent
  - Effect on substrate yield and blank defectivity
- Strategy for yield Improvement by removing all large size particles
  - Cleaning process development
- EUV Blanks deposited on substrates with no particles
  - Blank properties
  - Remaining defects
- Smoothing printable pits on substrates
  - Pit smoothing technique
  - Integrated tool and process development for defect free mask blanks with high yield

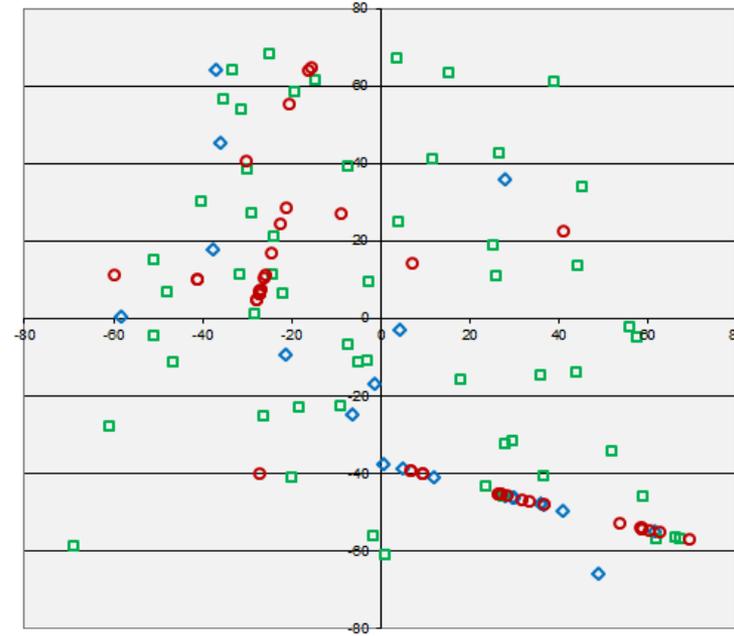
**Cleaning process discussed applicable only to low quality substrates**  
**For good quality substrates different cleaning processes are used**

# Impact of Substrate Defects on Blanks



Deposition

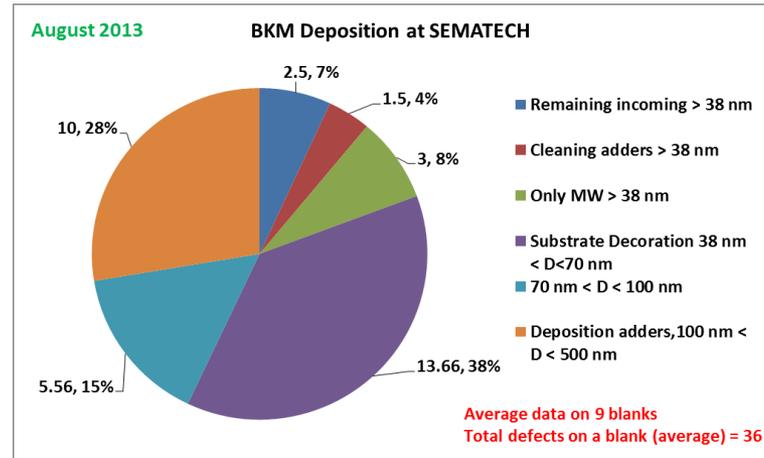
- ◇ Par
- Pit
- Scr



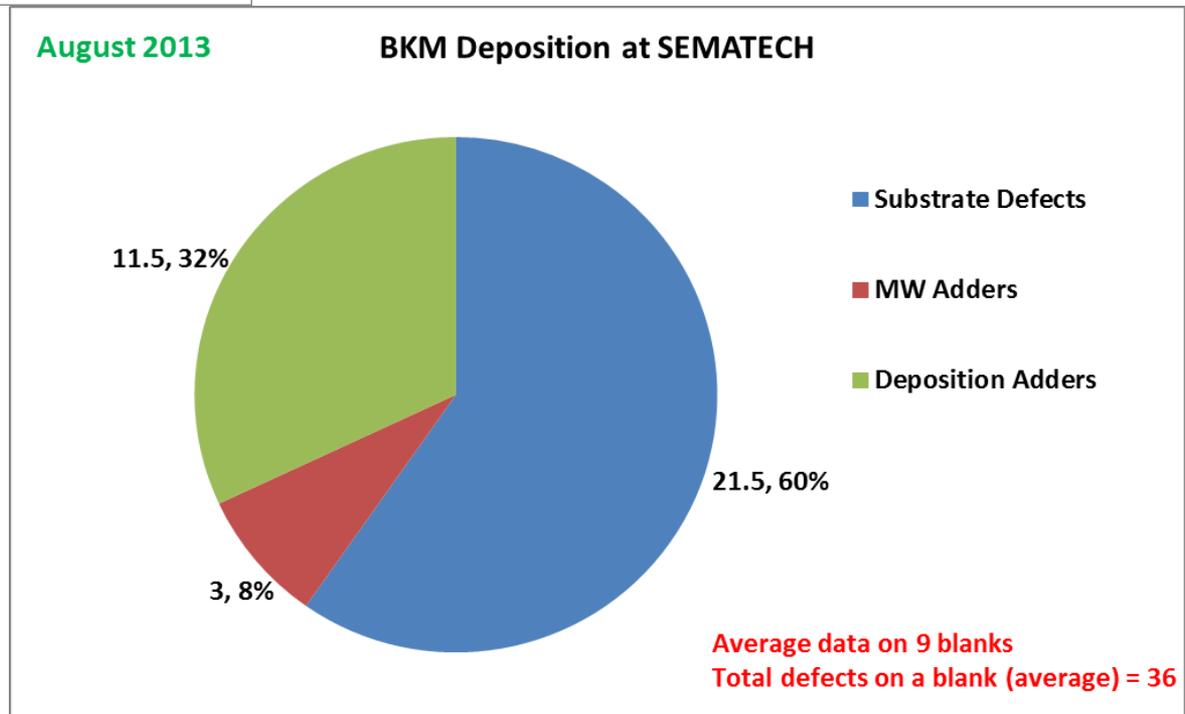
11 Defects @ 40 nm

120 Defects @ 45 nm

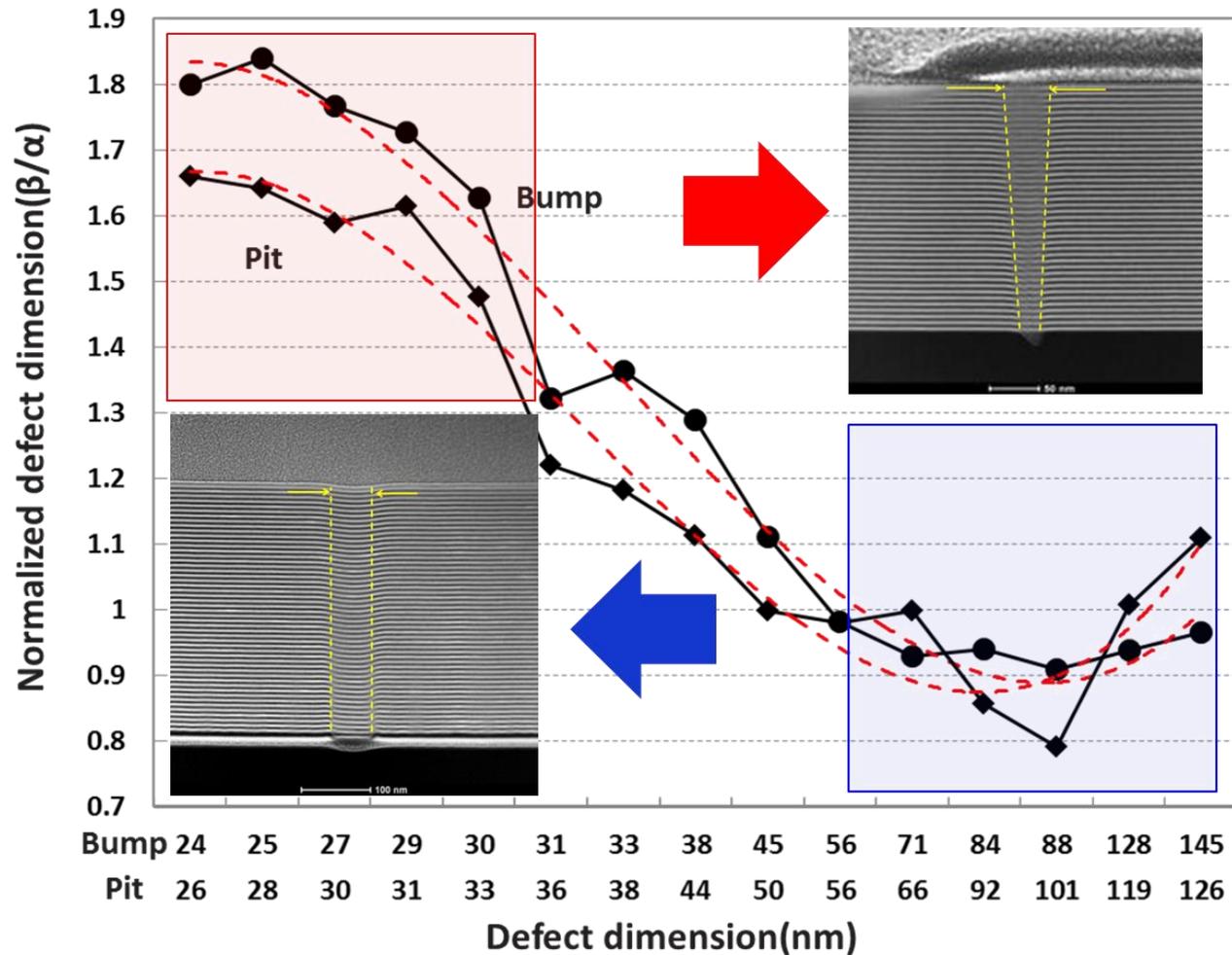
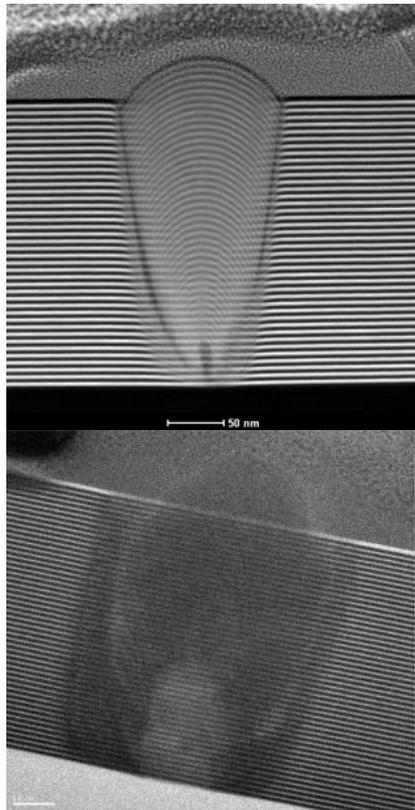
# EUV Blank Defect Source



**Substrate defects, if present dominate multilayer blank defects**

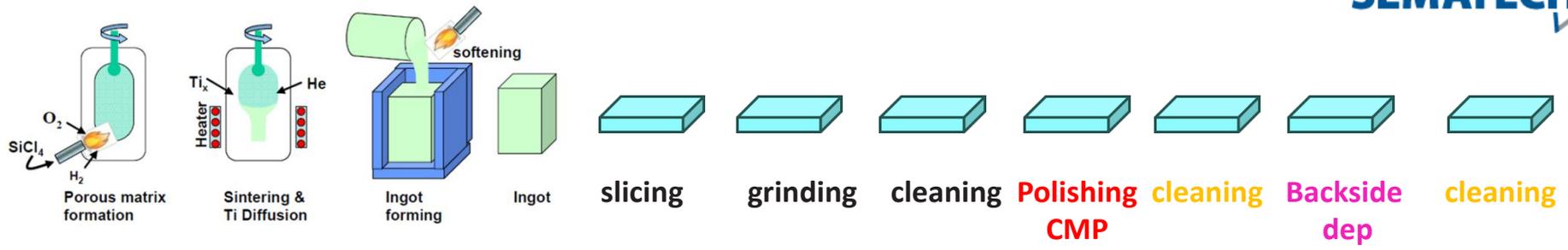


# Substrate Defect Decoration



Defects > 100 nm and < 50 nm on substrates increase in size on blanks by decoration

# Substrate Defect Source



**Pits**

Polishing

Megasonics

Particle Removal

**Scratches**

Polishing

Shipping and handling

**Particles**

Polishing

Backside Deposition

Cleaning

Storage

Shipping and handling

**Residues**

Polishing

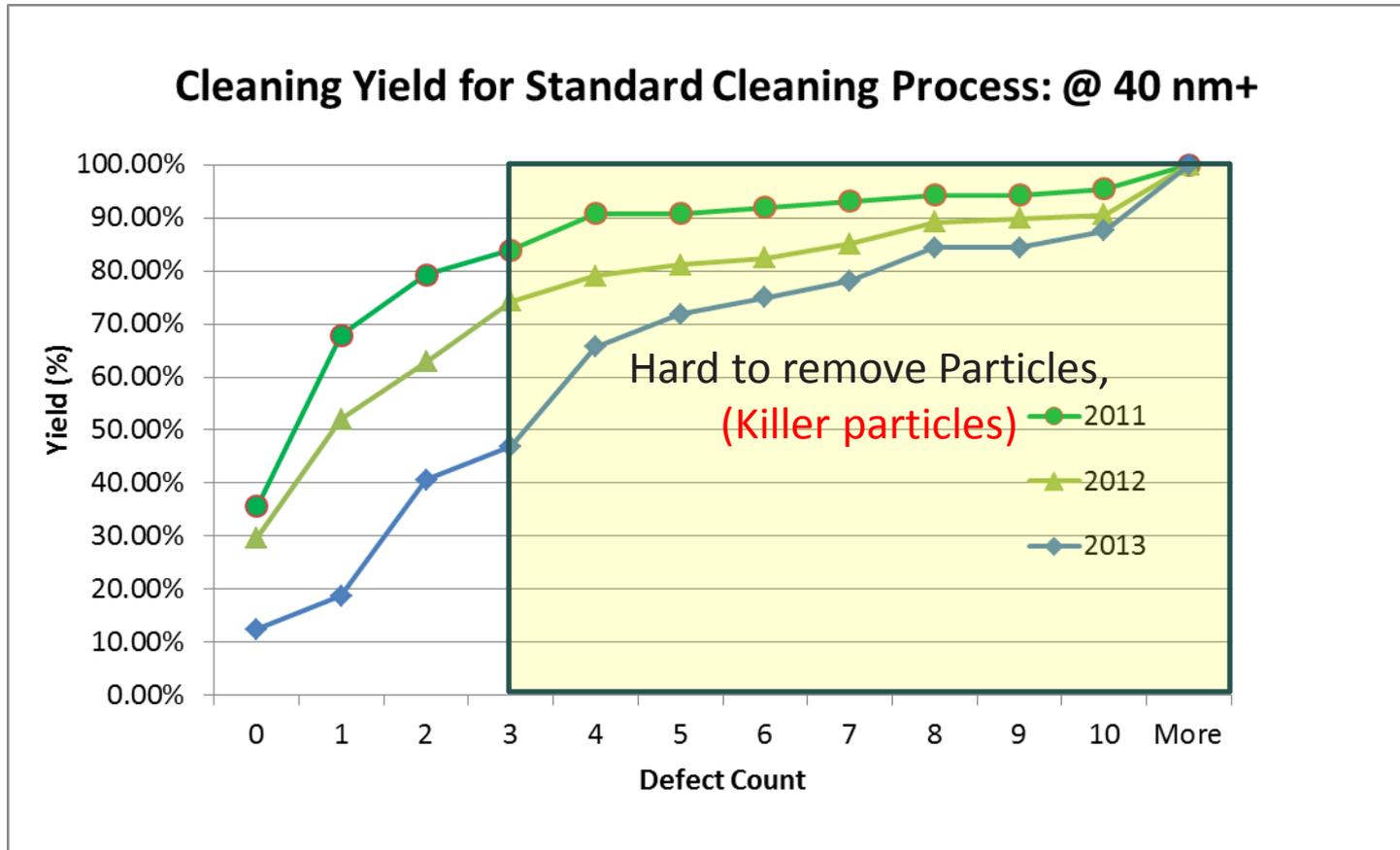
Cleaning

Storage



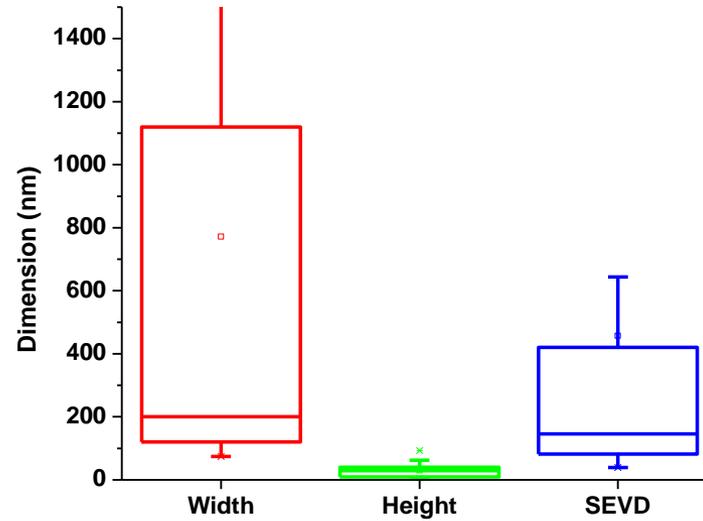
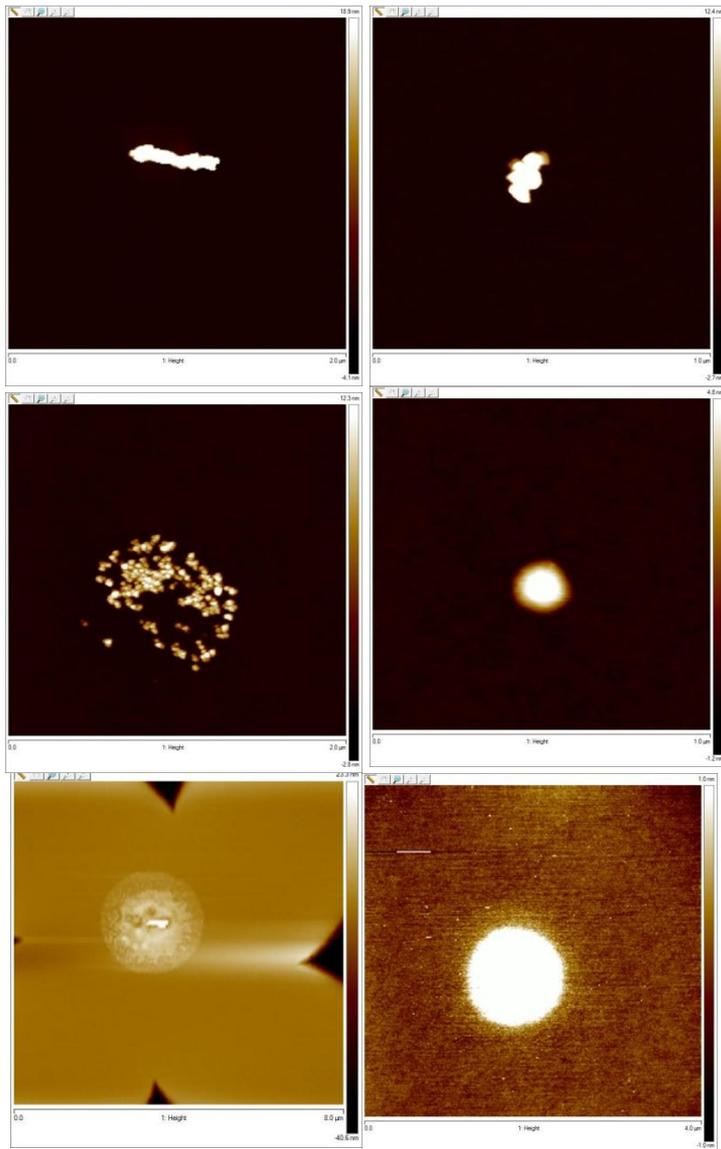
**Polishing adders are killer particles (hard to remove)**

# Impact of Killer Substrate Defects on Substrate Yield

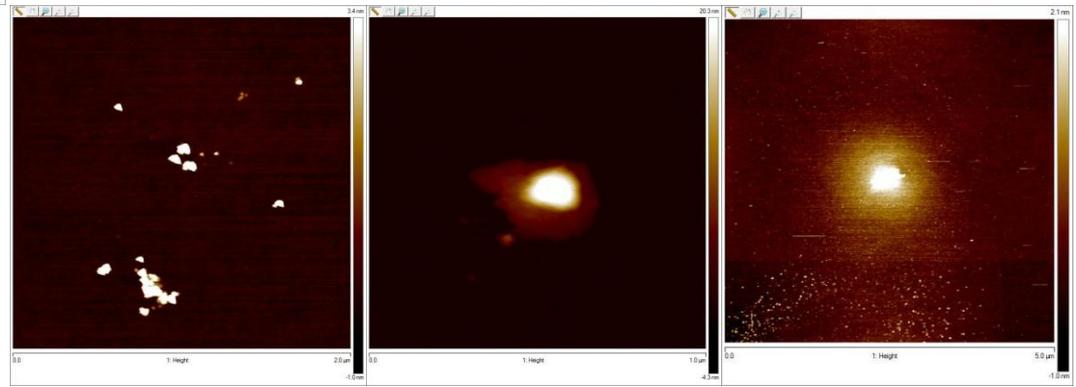


Cleaning yield is reduced by the presence of **hard particles (embedded substrate particles)** which are not easily removed by cleaning

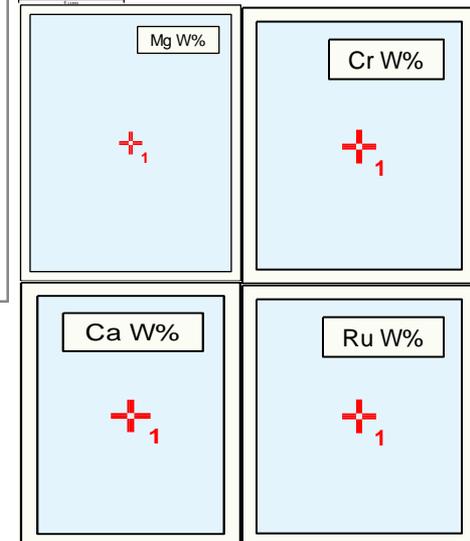
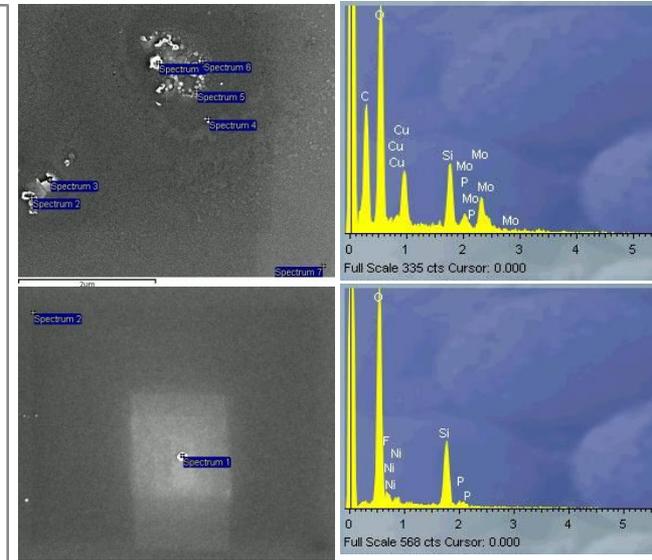
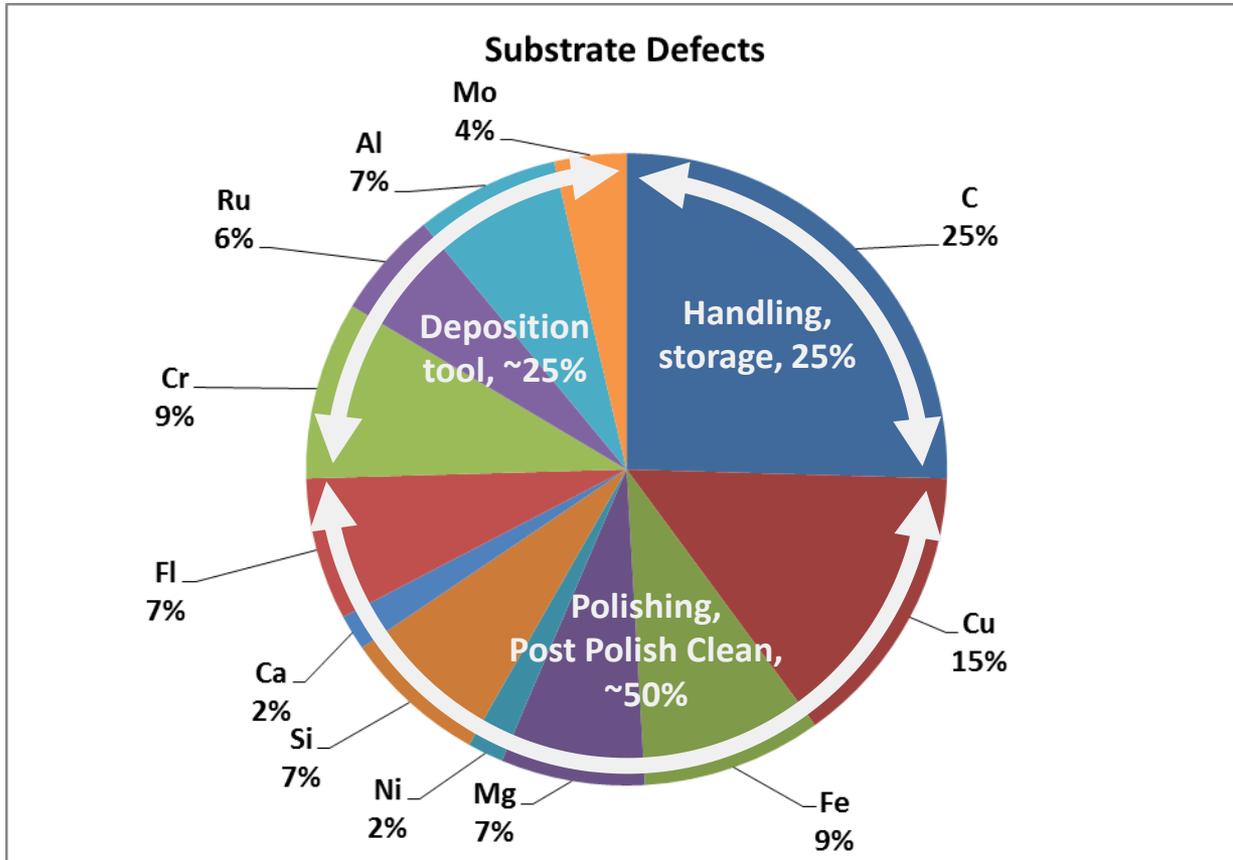
# Size and Shape of Killer Particles



Flat particles embedded on surface



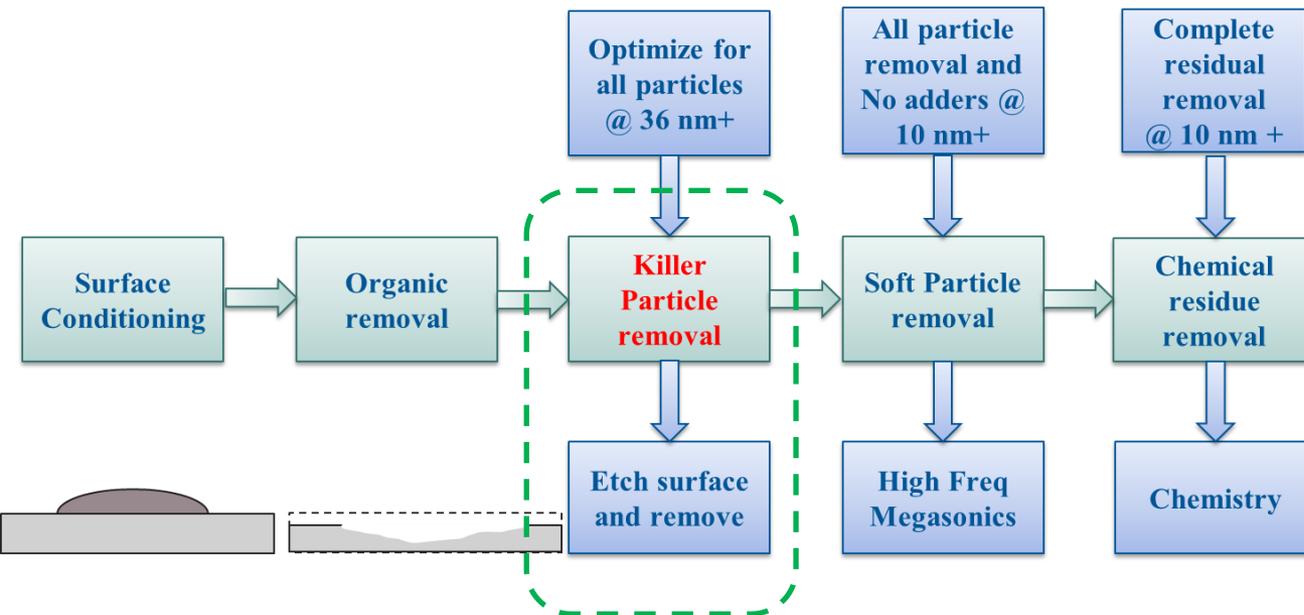
# Composition of Killer Particles on Substrates

Composition Identified from SEM/EDX, 5BL deposition and TEM/EDX: **Mostly Metallic residues with Carbon**

# Substrate Quality Improvement by Cleaning

- **Goal:** Improve quality of substrates by removing all killer particles and residues by cleaning

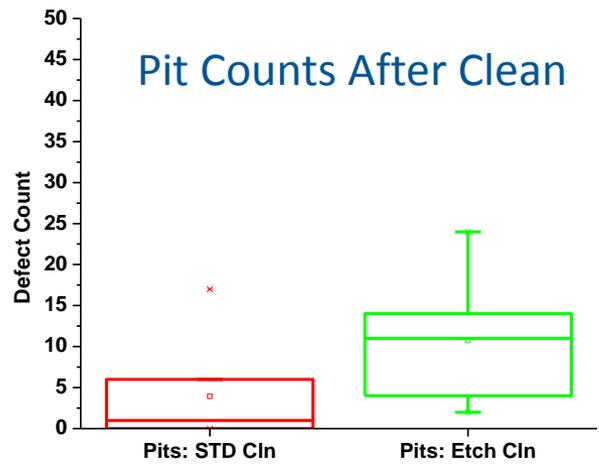
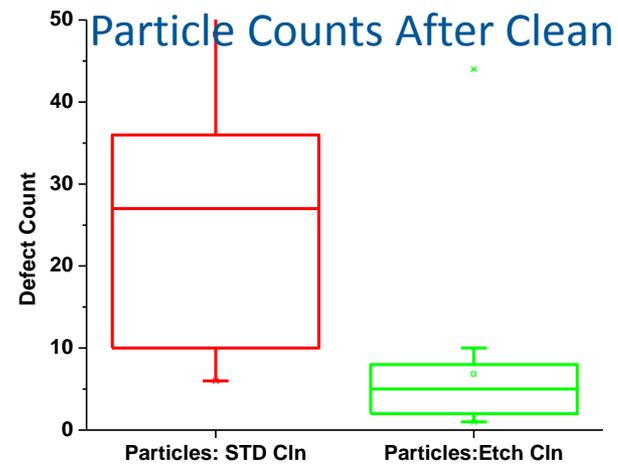
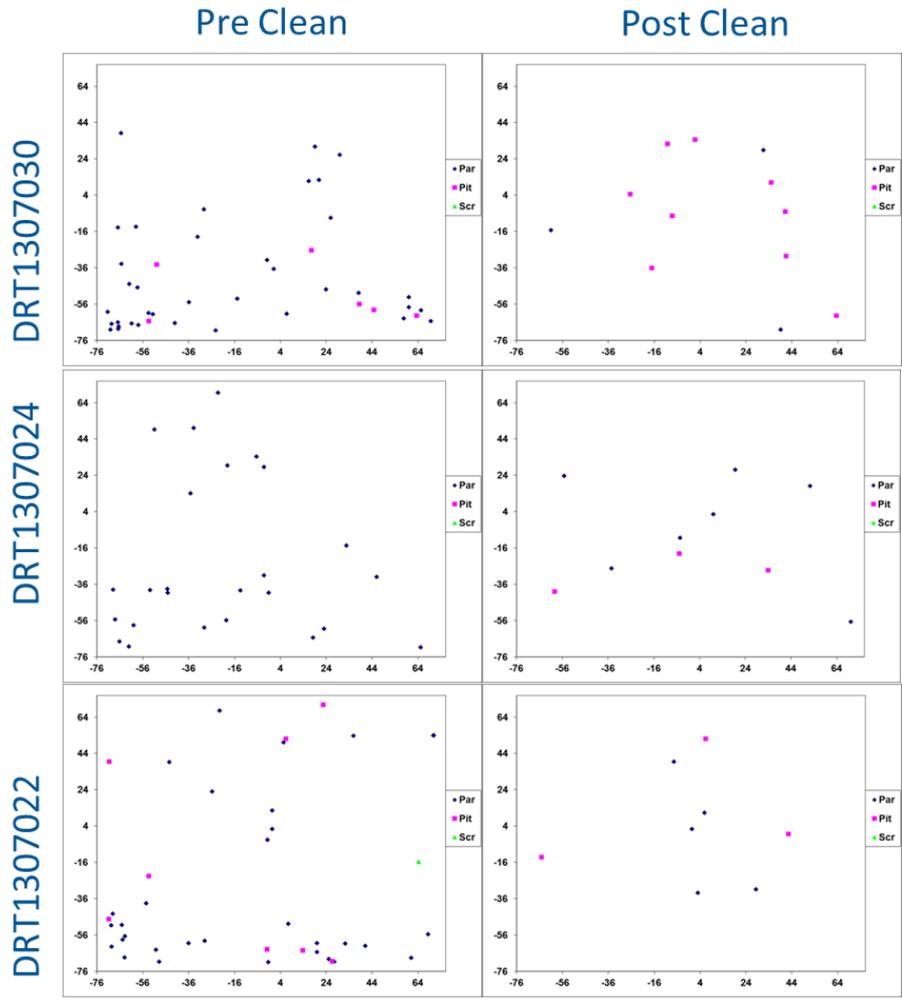


Standard mask cleaning tool is modified for substrate cleaning with hard particle removal



Image courtesy: SUSS-Microtec

# Cleaning Performance on Substrates with Killer Defects

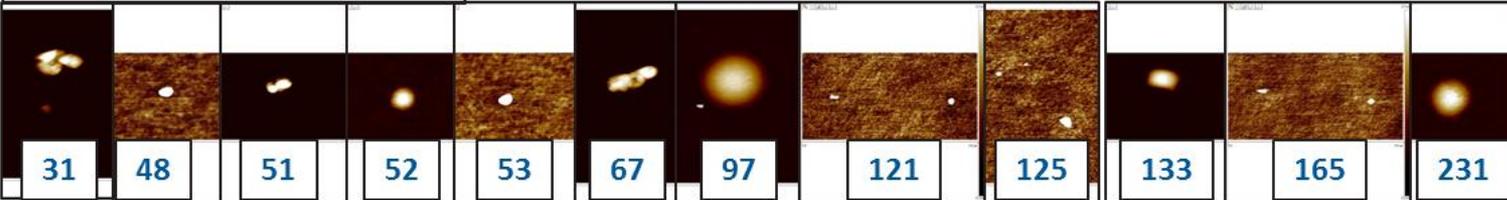


Pit Counts increase as particles are removed by etching the surface

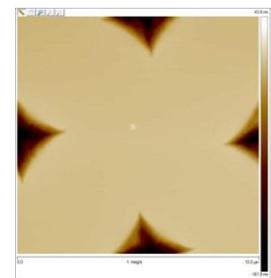
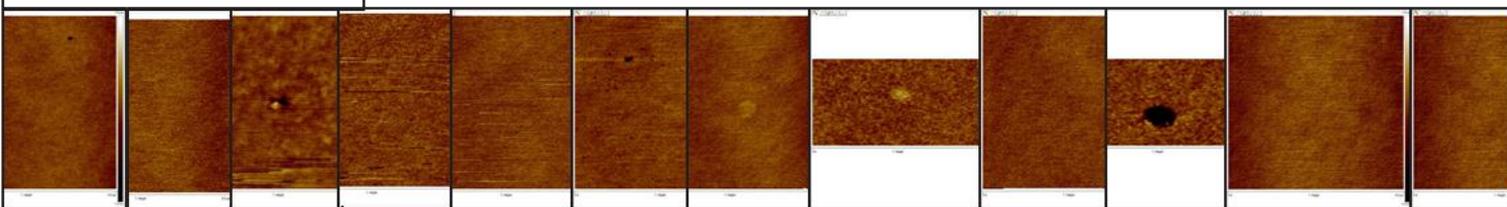
# Cleaning Results with Defect Review on Substrates with Killer Defects



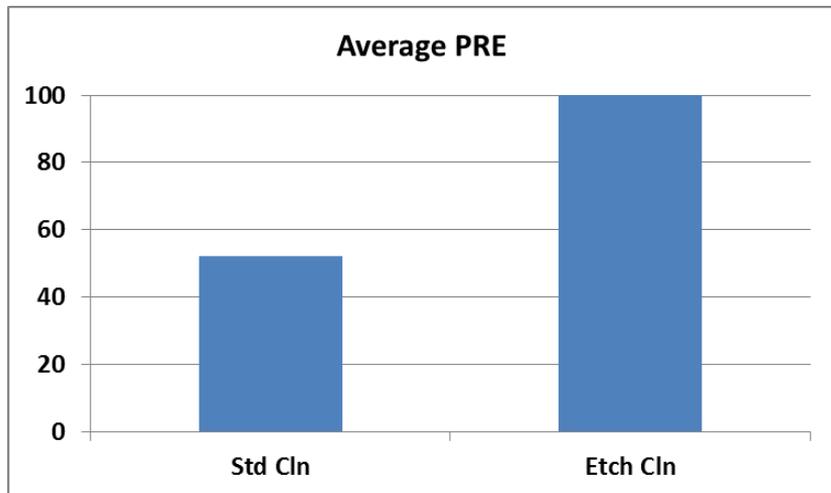
## Post Standard Clean



## Post Etch Clean

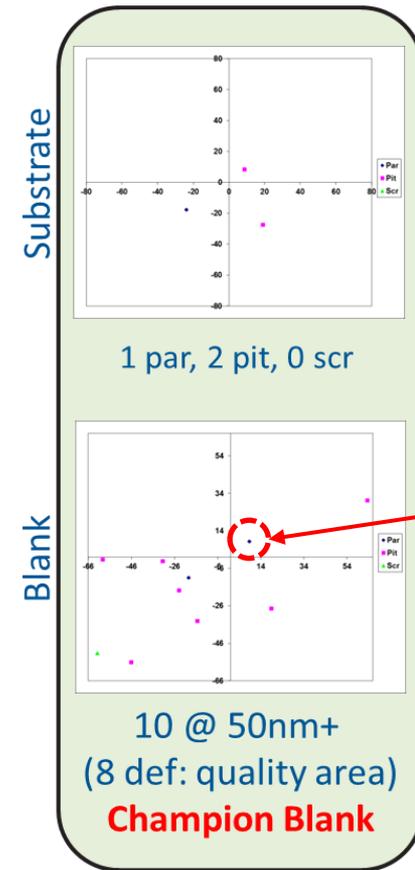
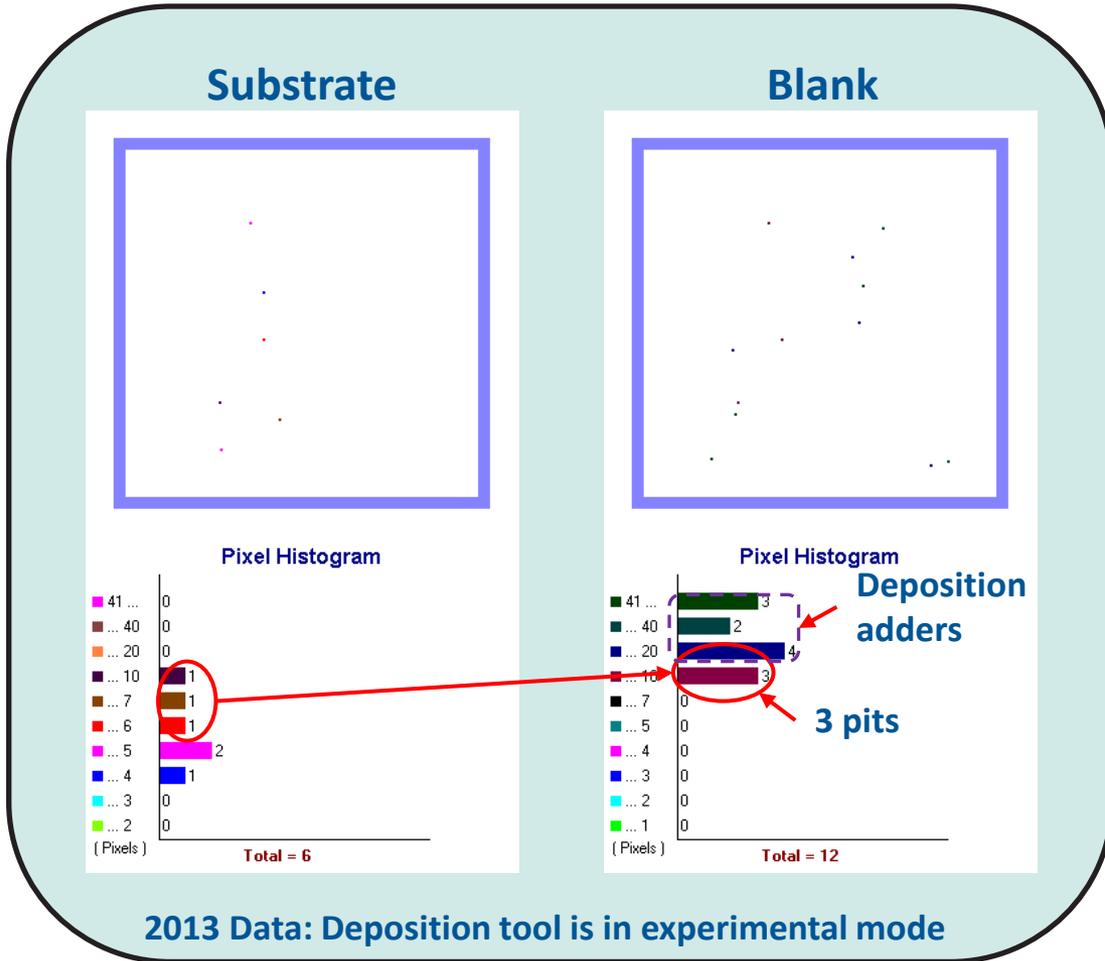


AFM accuracy is maintained by enclosing defects within punch marks



100 % particle removal efficiency is achieved @ 38 nm+

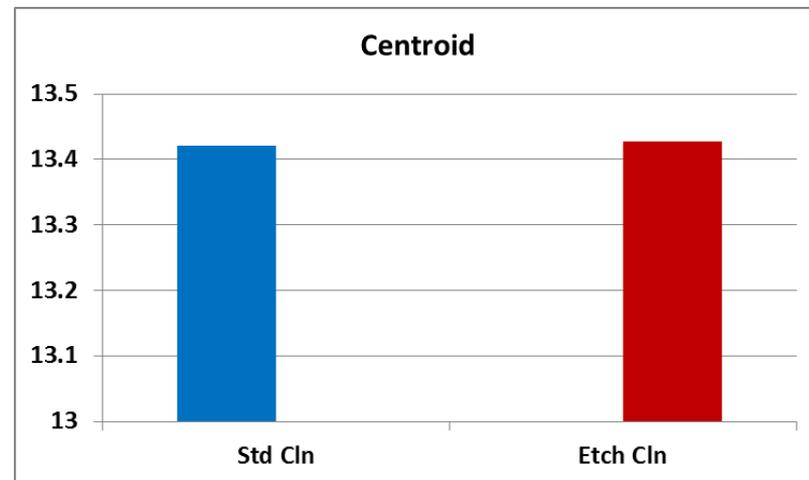
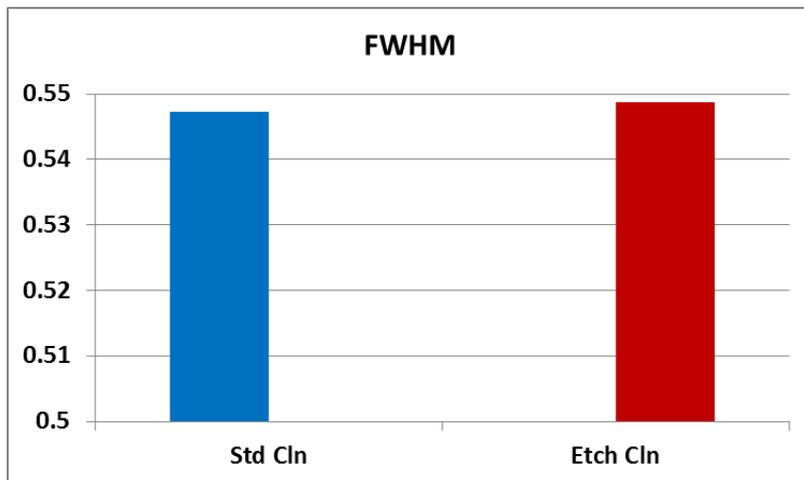
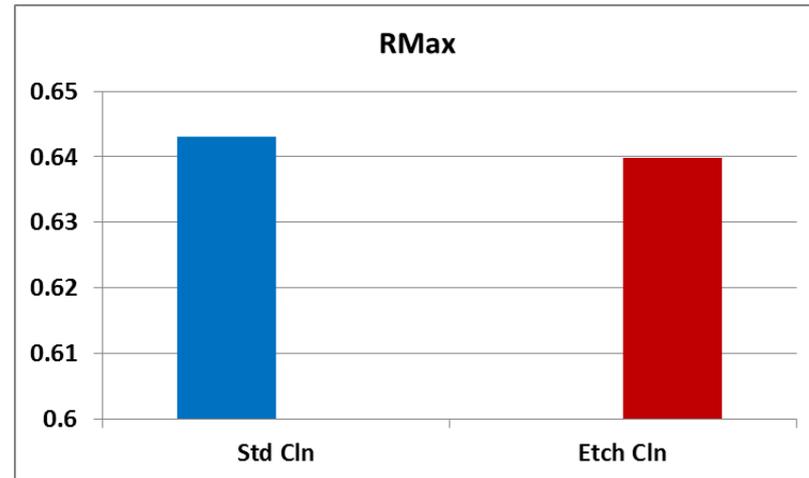
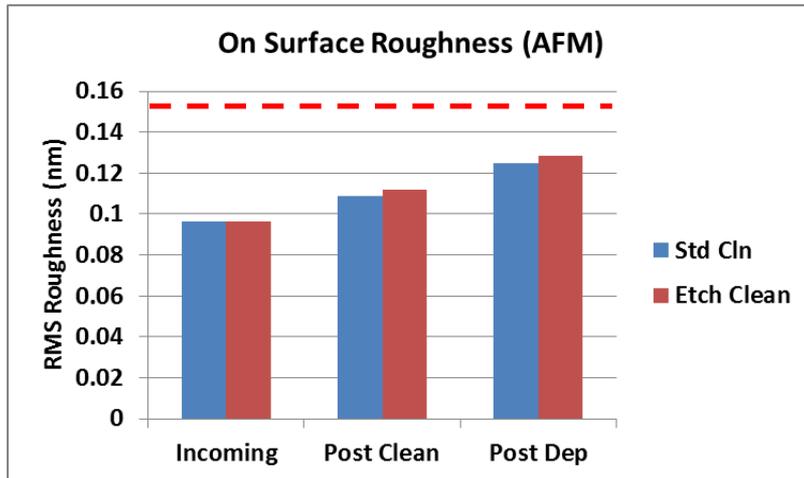
# EUV Blanks After Etch Clean of Substrates



A. JohnKadaksham et al., Proceedings of SPIE, Photomask Technology, Volume 8522, November 2012

**Capability for zero or near zero particle blanks exist**

# Roughness and EUV Characteristics of Blanks

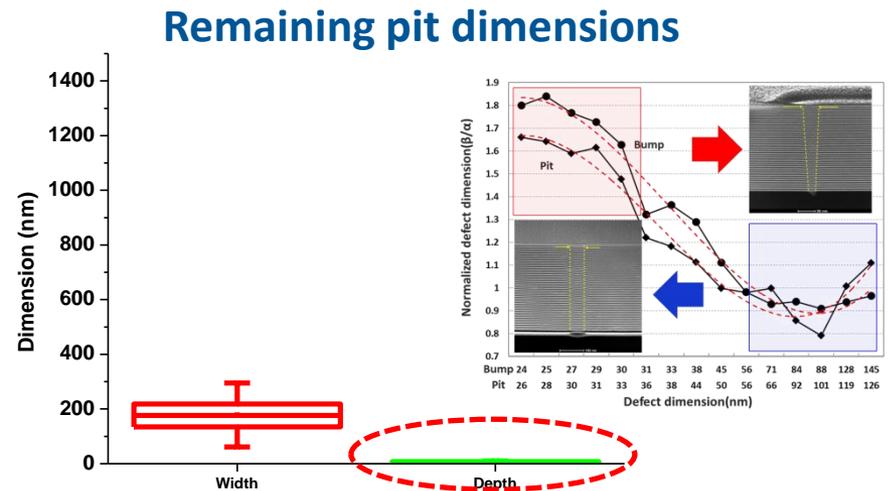
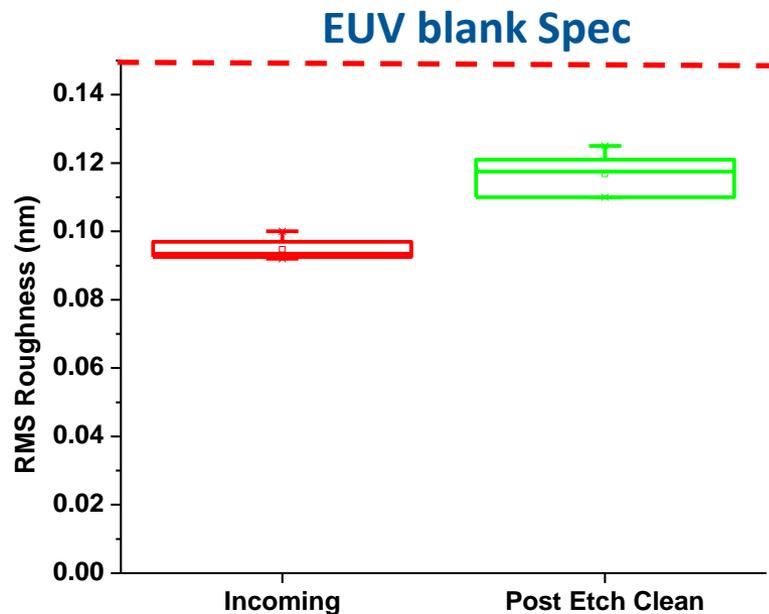


**Reflectivity of blank with etch clean in reduced by ~0.3%**

# Substrate Roughness and Remaining Pits after Etch Clean



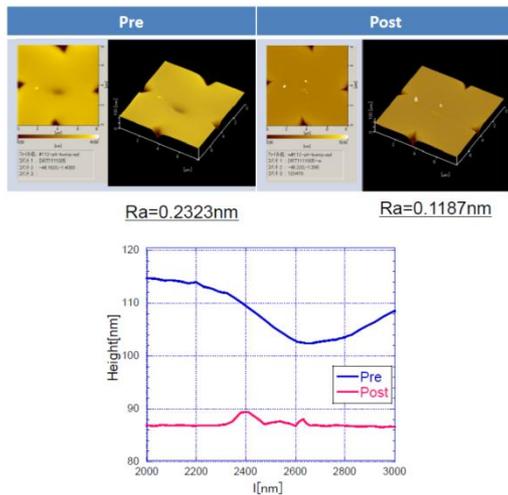
- Etch clean Process increases roughness of substrates and leaves pits in some cases by removing embedded particles



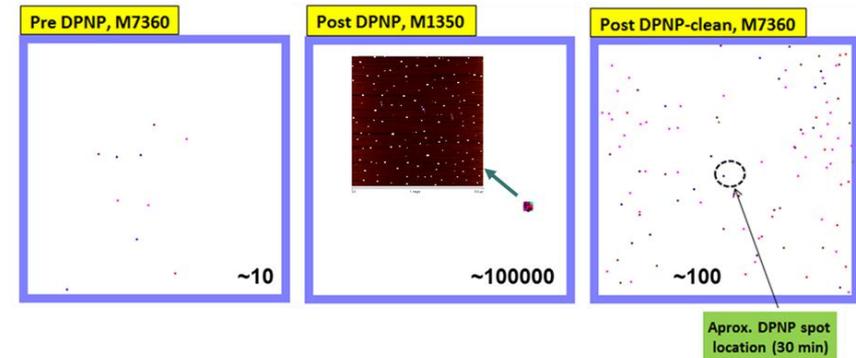
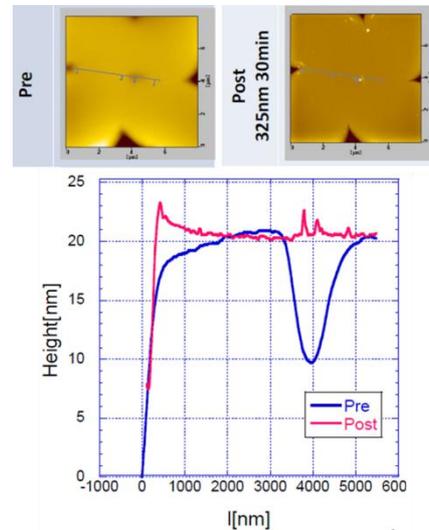
**Remaining pits are 5 - 10 times smaller in width and 5 times smaller in depth than the particles removed**

# Pit Mitigation Strategy

- Although pits are shallow and fewer after etch clean, some of them still can decorate and become printable on a EUV mask
  - A complementary pit reduction process is required for defect free blanks
- DPNP (Dressed Photon Nano-polishing) has been identified as a potential technique for pit smoothing



Pit smoothing by DPNP

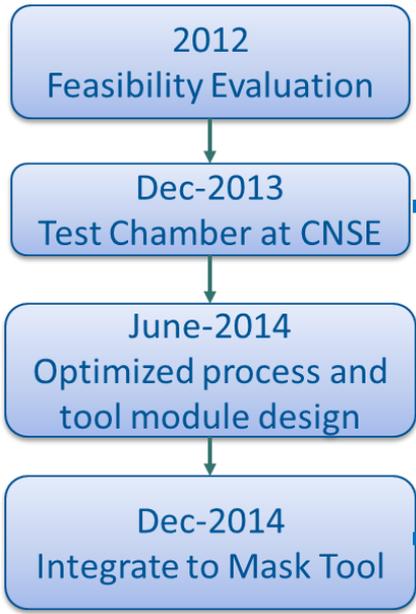


DPNP process leaves residues which are readily removed by cleaning

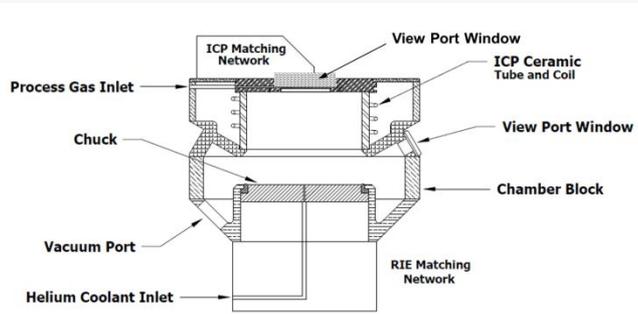
# Timeline: Substrates with High Yield

- Potential for pit smoothing with DPNP has been established
- Next step is to optimize process, build a chamber and integrate to mask cleaning tool

## DPNP Timeline

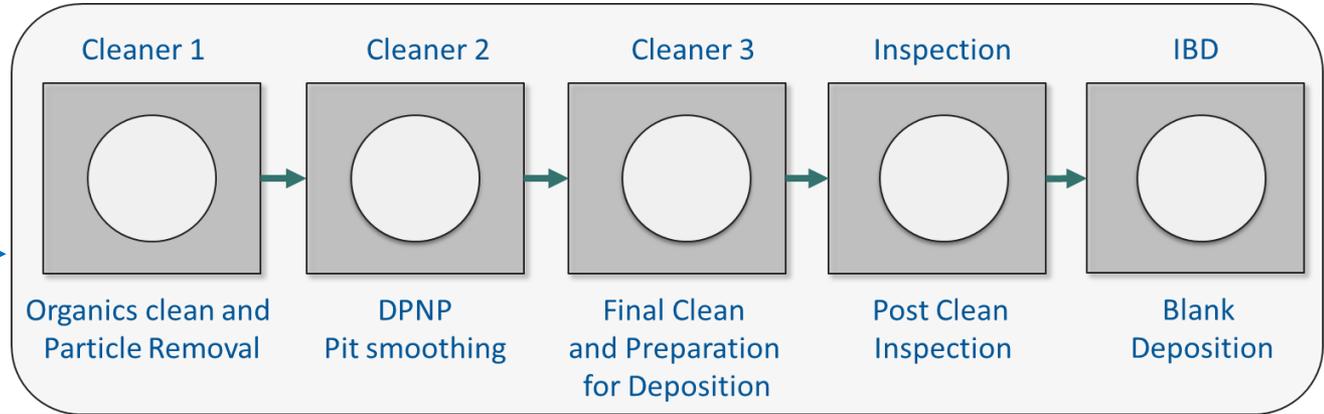


**Test chamber built at CNSE**

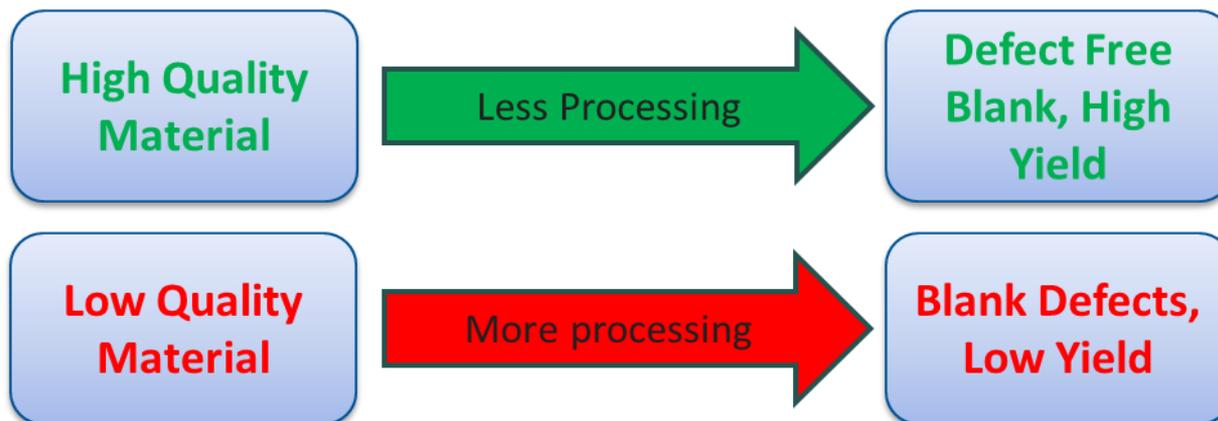
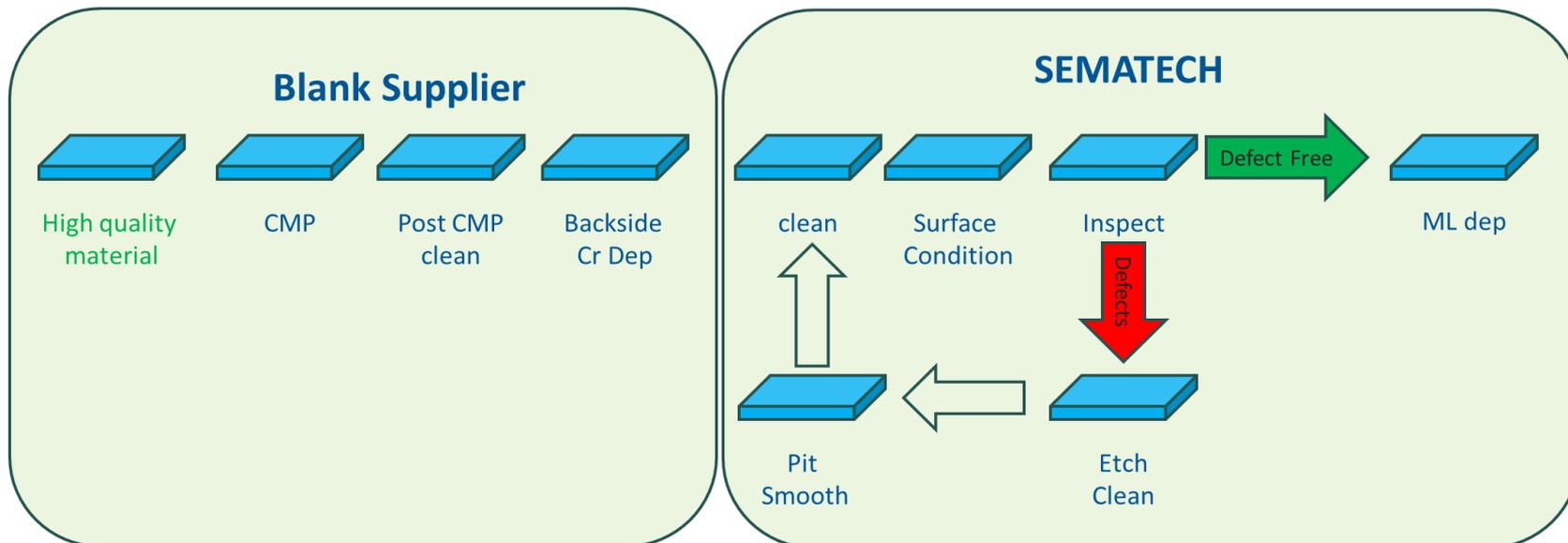



Overall Process Chamber

## Process Integration



# Substrate Processing Steps for Zero Defect Substrates



# Summary



- **Capability for zero substrate particles @ 38 nm+ on low quality substrates is demonstrated using a surface etching process**
  - All killer particles are removed from EUV substrates which helps to improve blank yield
- **EUV blanks with near zero particle defects is demonstrated on substrates cleaned with this process**
  - EUV properties of the blanks are shown to be within specs
- **All Process knowledge is transferred to blank supplier**
- **A pit mitigation strategy and timeline for significant pit defects is presented**
  - DPNP is identified as a potential technique for pit smoothing
- **A cleaning tool integrating DPNP process and avoiding additional handling and storage steps is being developed**
  - Integrated tool and process is essential for defect free blanks

# Acknowledgements



- Nancy Lethbridge, Lenny Gwendon, Matt House, Martin Samayoa: Cleaning tool support
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## Thank you