Accelerating the next technology revolution

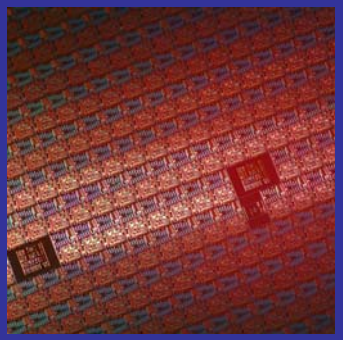
Substrate, Blank and Mask Cleaning Contribution to EUV Mask Defectivity and Lifetime

Abbas Rastegar

Arun John Kadaksham, Byunghoon Lee, Matt House, Dominic Ashworth, Masahiro Kishimoto

SEMATECH

Albany-USA



EUVL Symposium 2010

Copyright ©2009
SEMATECH, Inc. SEMATECH, and the SEMATECH logo are registered servicemarks of SEMATECH, Inc. International SEMATECH Manufacturing Initiative, ISMI, Advanced Materials Research Center and AMRC are servicemarks of SEMATECH, Inc. All other servicemarks and trademarks are the property of their respective owners.

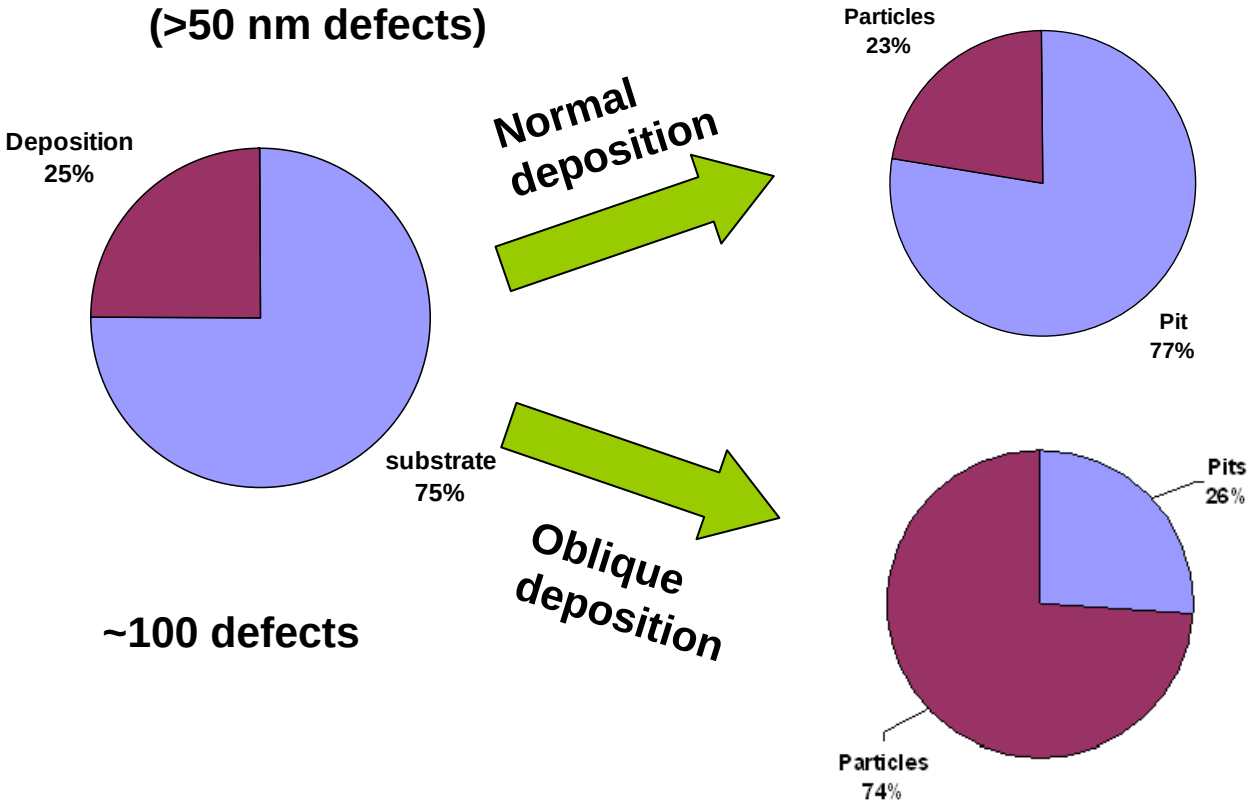
Outline

- **Substrate defectivity**
  - **Defectivity trend**
  - **Substrate cleaning challenges**
- **Blank defectivity**
  - **Backside contamination**
  - **Blank lifetime**
- **Storage of blanks**
  - **Storage environment**
  - **Storage box**
- **Removal Carbon contamination from EUV masks**
  - **Worse case scenario**

Blank defectivity

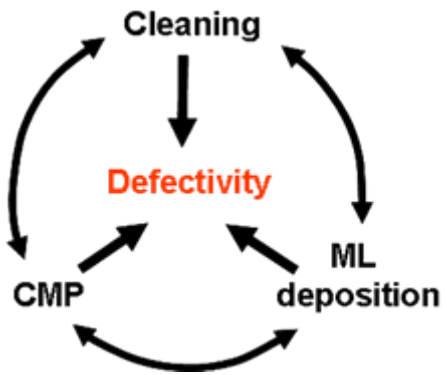
Blank defect type
(>50 nm defects)

Typical blank defectivity
(>50 nm defects)



~100 defects

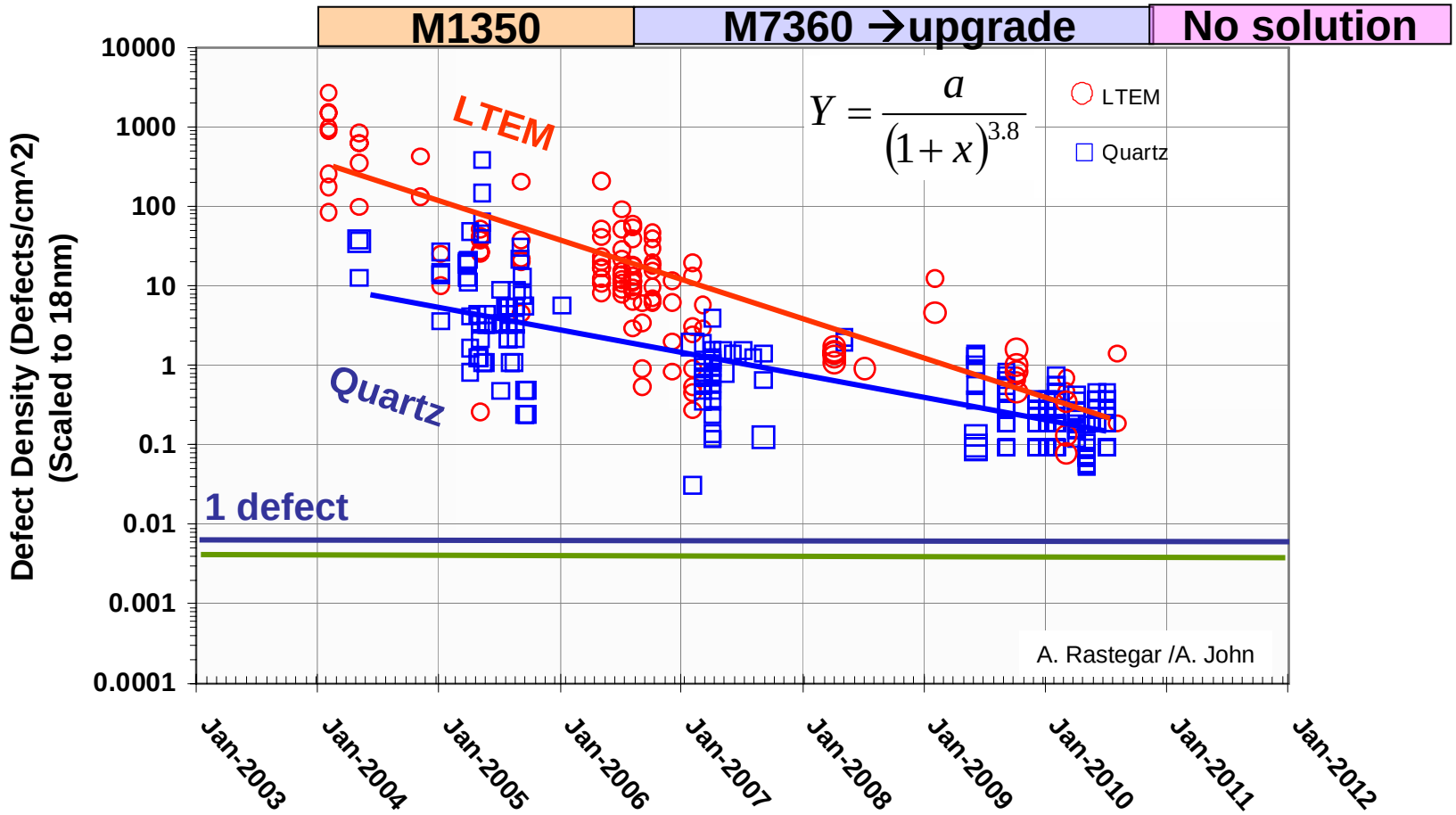
Pit should be smoothed
on substrate



Small particles should be
removed from substrate

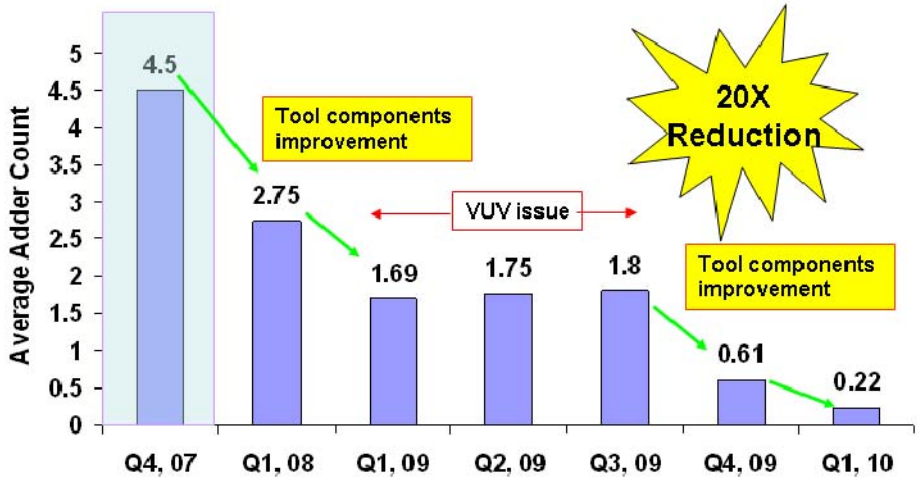
- Substrate defectivity is the main contributor to blank defectivity.
- Defect reduction is only possible through close collaboration between CMP, cleaning, and ML deposition .

SEMATECH's EUV substrate defect trend (post-cleaning)

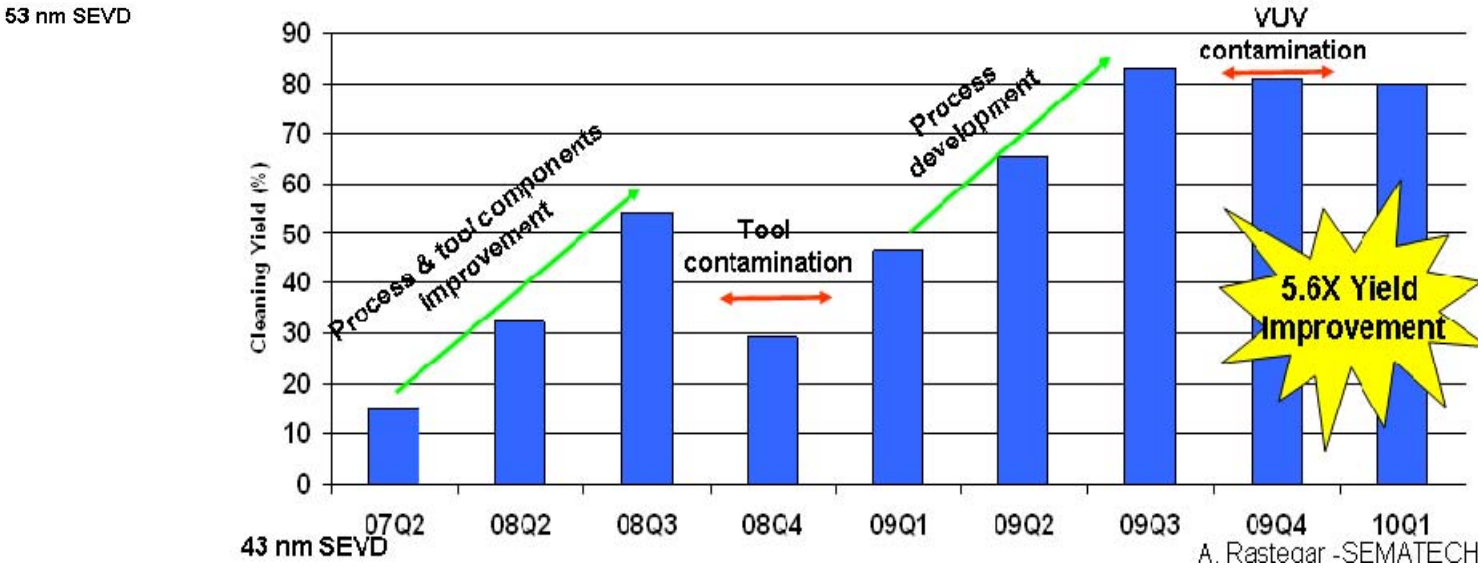


- **Substrate defectivity is continuously improving**
- **Defectivity gap between LTEM and quartz material is reducing**

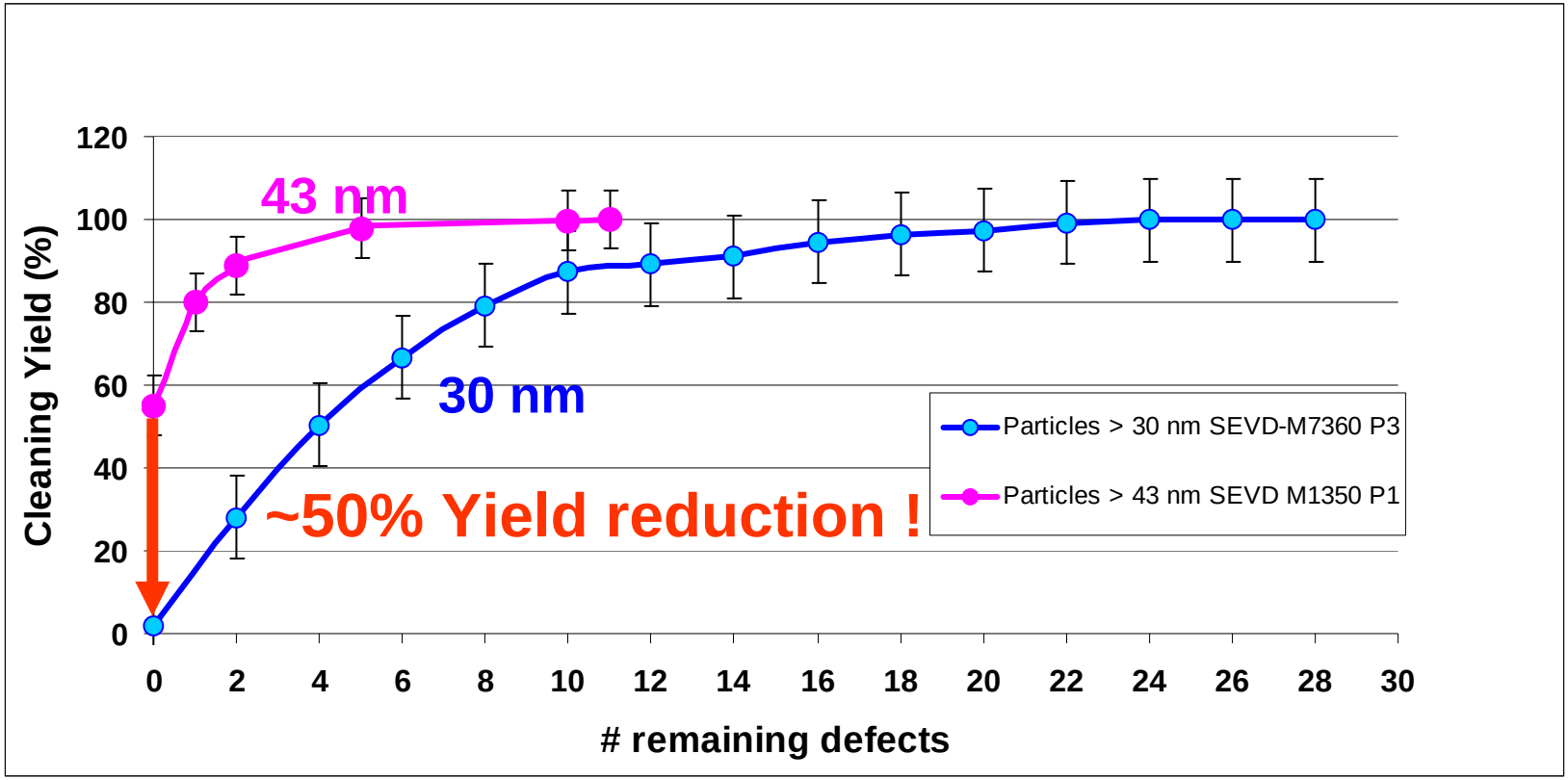
Trend of substrate defect reduction by SEMATECH



- **Improving cleanliness of the cleaning tool and process has resulted increase in the cleaning yield of mask substrates**



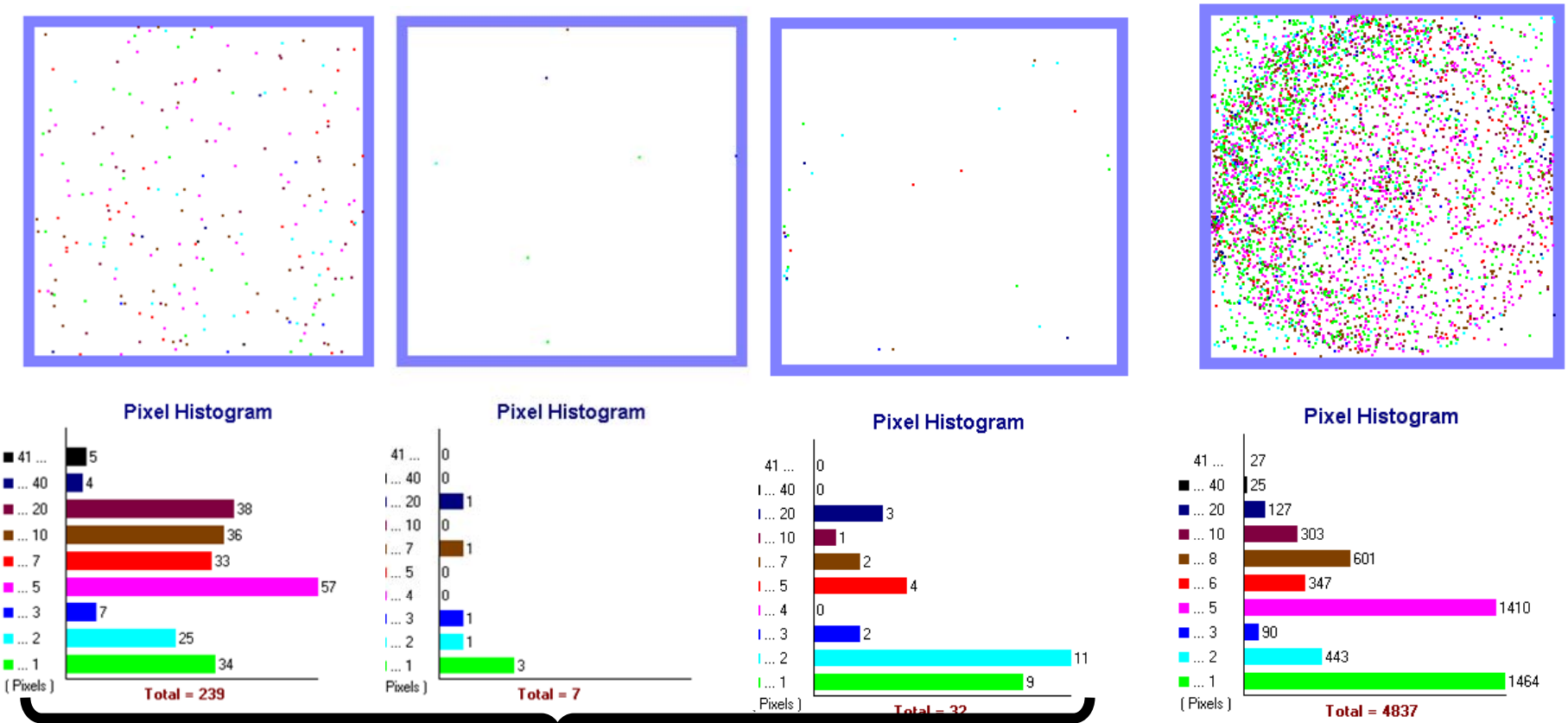
Challenges of substrate cleaning: cleaning tool and process capability



- **Yield of cleaning processes drastically reduces for smaller defects**
- **Yield loss is due to low PRE and high adders for small defects**

Challenges of substrate cleaning: pits

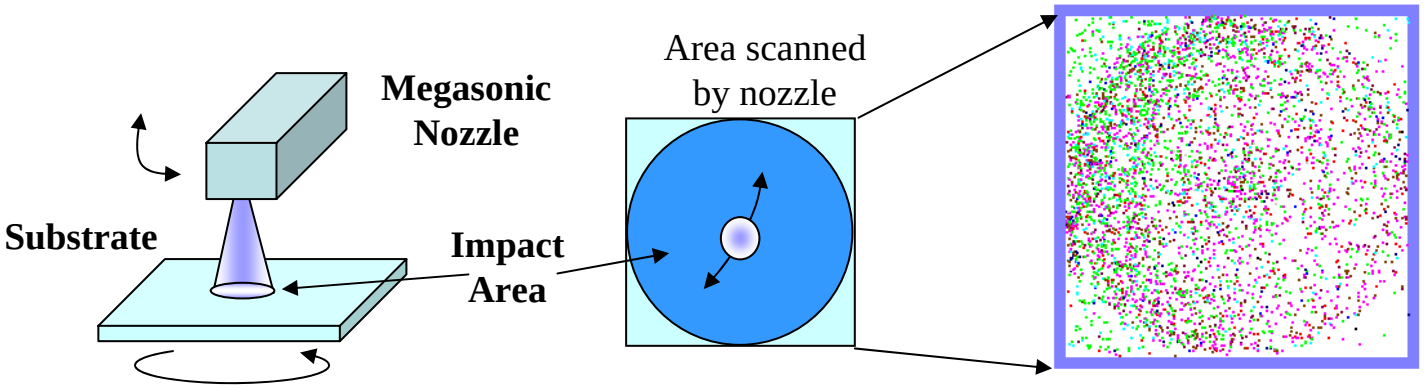
Before cleaning | After **1X** cleaning | After **100X** cleaning | After **100X** cleaning

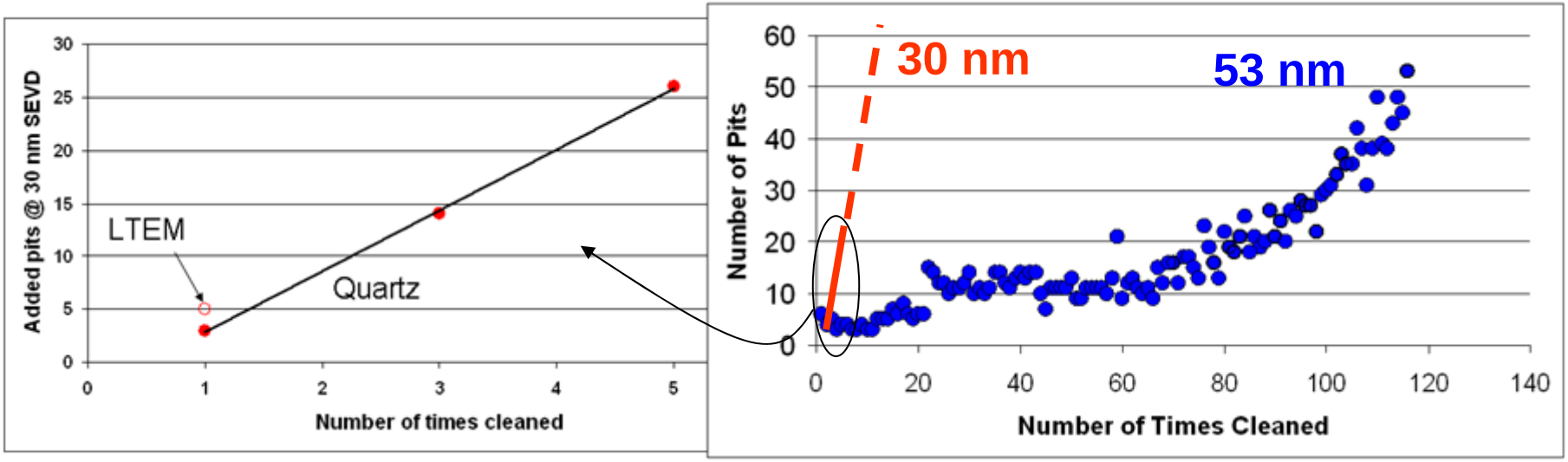


~43 nm inspection sensitivity **~30 nm inspection**

- **Cleaning processes create sub 40 nm pits on substrate detectable only by M7360**

Origin of small pits

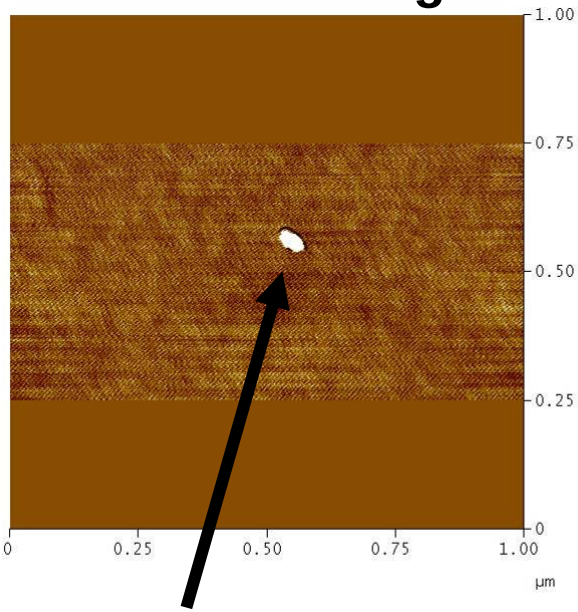




- **Sub-30 nm pits are added by cleaning at a much higher rate than 50 nm pits**

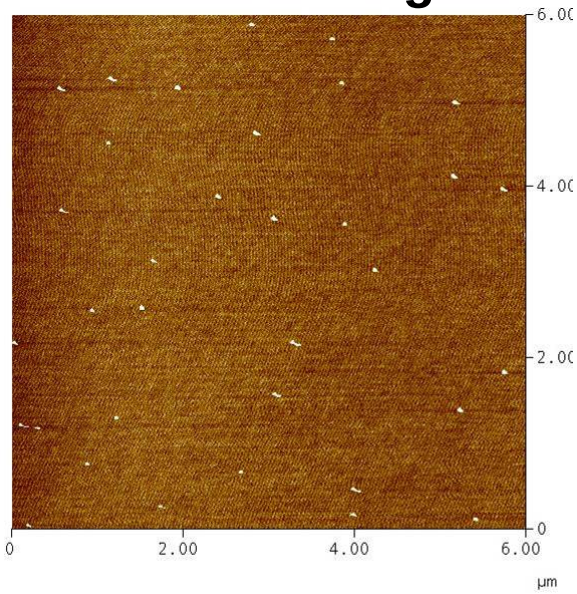
Challenges of substrate cleaning: small particles

Before cleaning

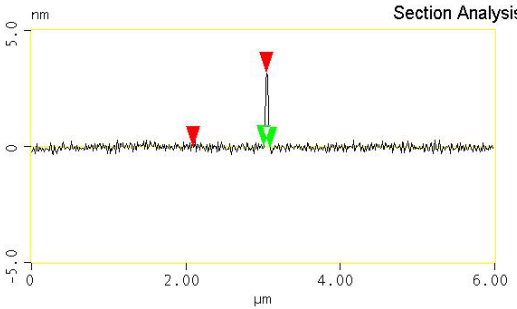


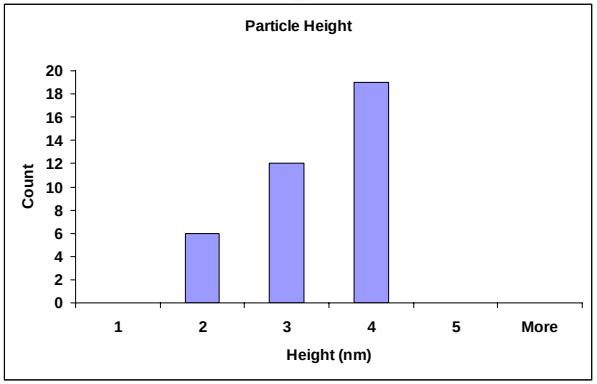
Intended defect removed

After cleaning



Many small particles were added by cleaning

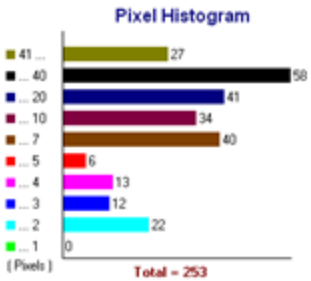




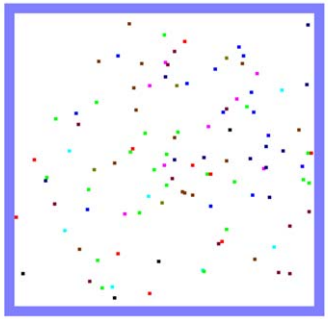
- **Cleaning tool/ processes add very small particles (~ 10 nm to 17 nm) that CANNOT be detected with existing defect inspection tools**
- **These can be smoothed by ML deposition for 22 nm HP**
- **New cleaning tool and technology is required for 16 nm HP node**

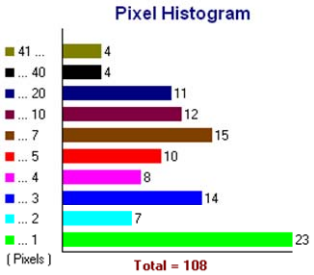
Cleaning of Ru-capped MoSi blanks

Before cleaning

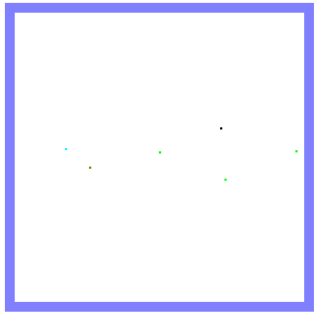


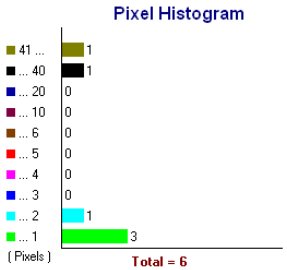
After cleaning



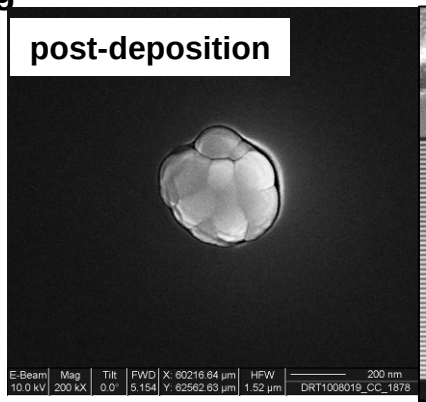


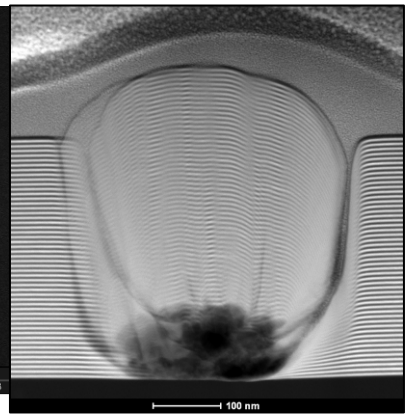
Added by cleaning



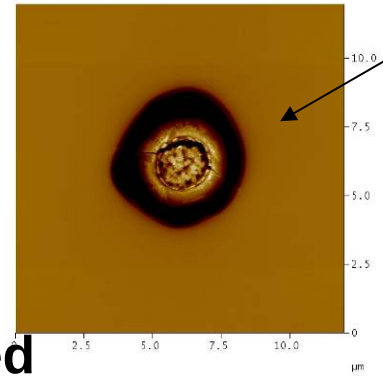


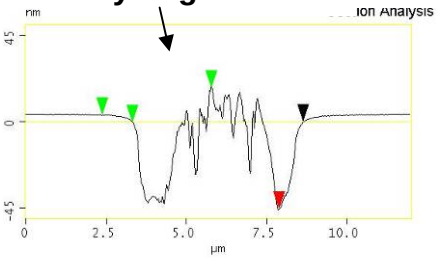
post-deposition

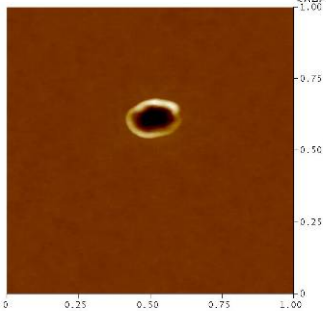




post-cleaning
Very large defects





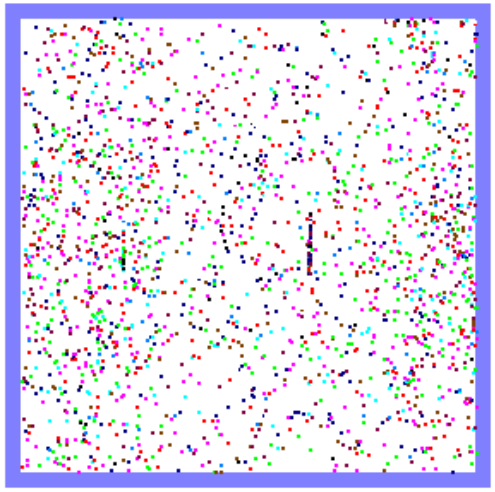


- **Soft defects (>70 nm) are easily removed**
- **Most remaining defects are embedded**
- **Large embedded defects can be etched**
- **Cleaning can create pits on the multilayer**

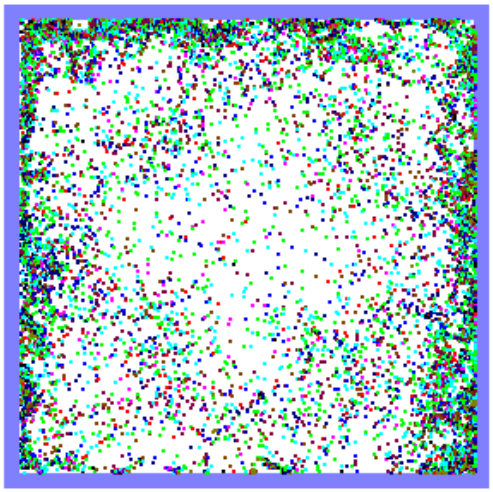
TEM: Jenah Harris-Jones

Backside defects of EUV masks

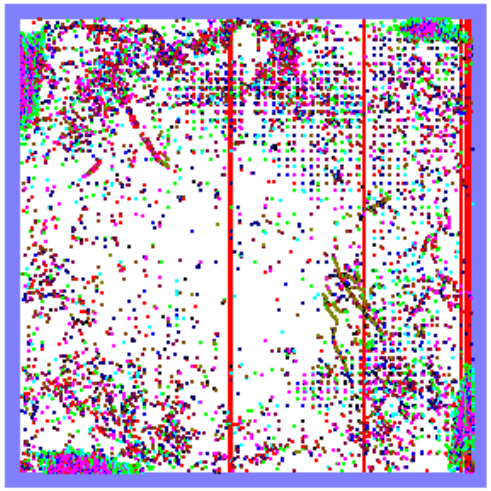
Typical MoSi ML blank after ML deposition



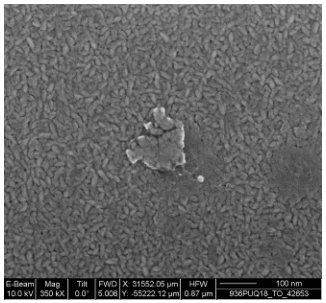
Typical EUV mask after patterning and final clean



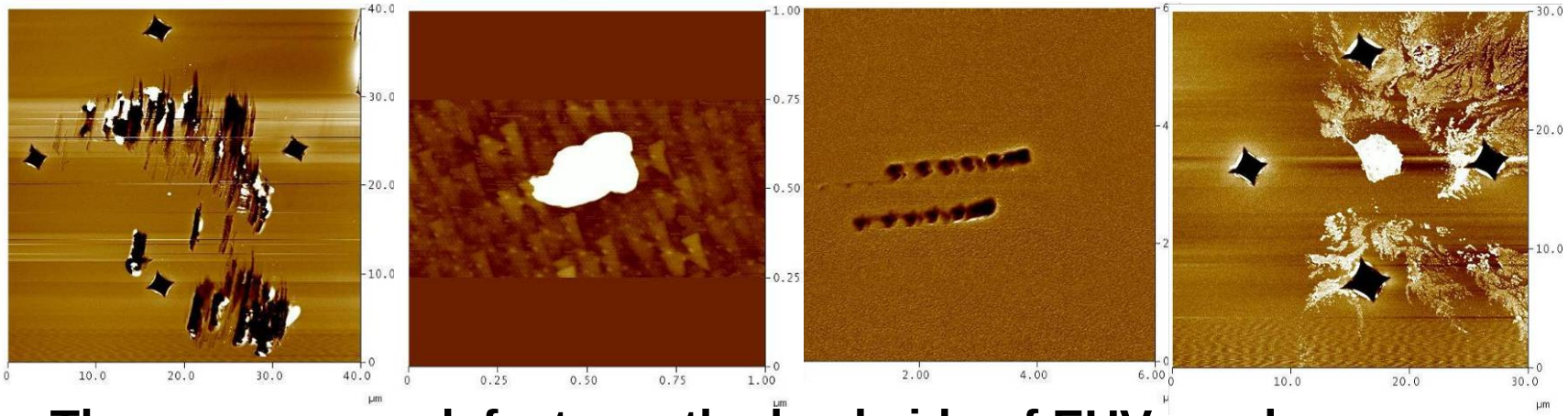
Typical EUV mask after chucking multiple times in exposure tool



small defect

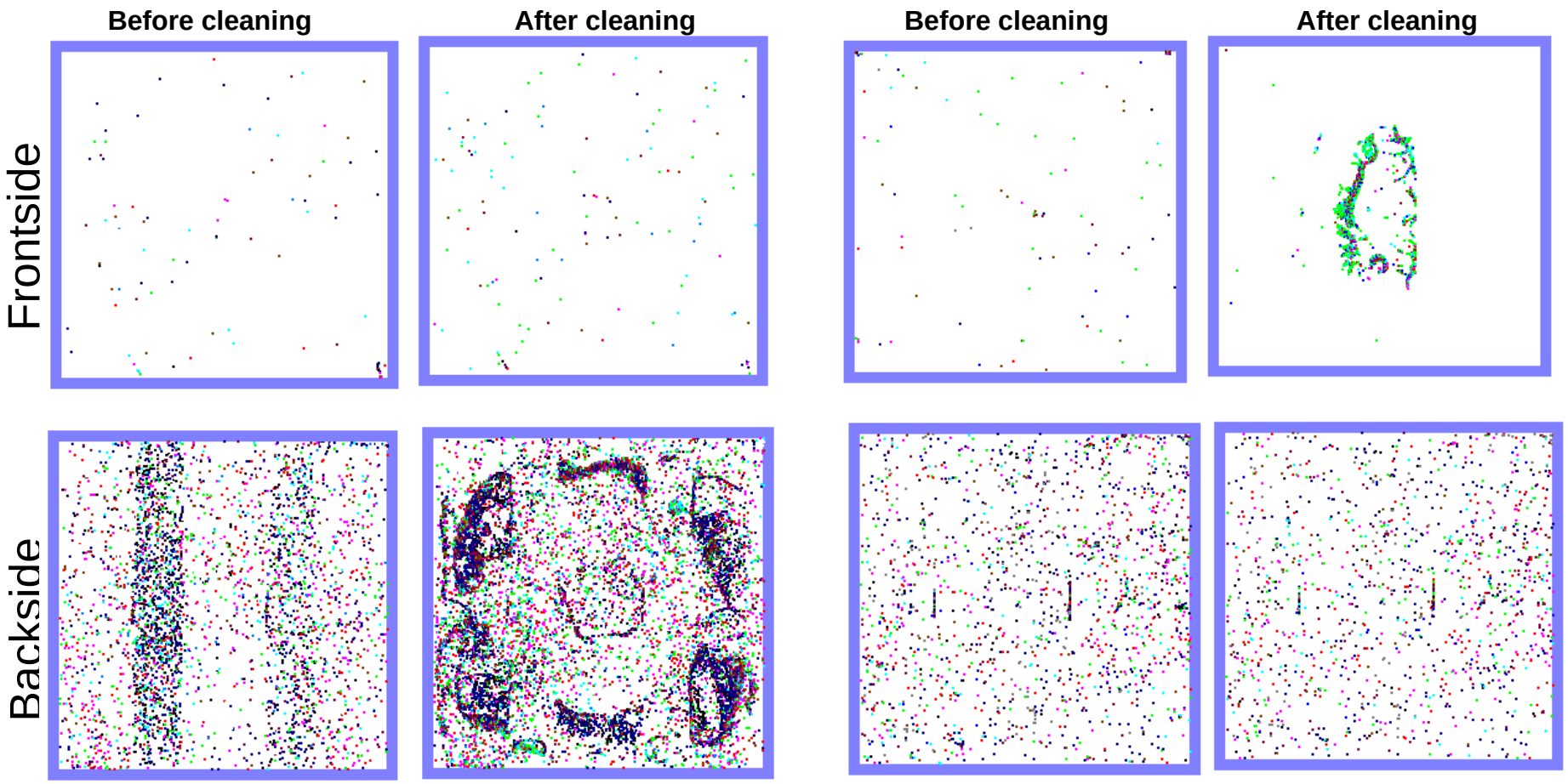


Large defects



- **There are many defects on the backside of EUV masks.**
- **All particles larger than 1 µm should be removed.**

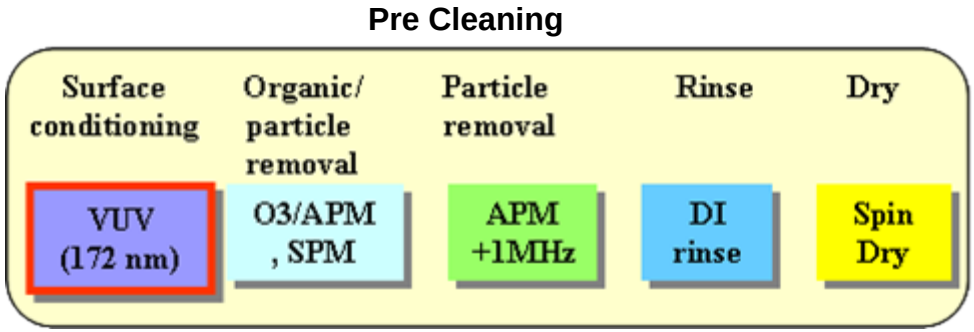
Challenges of backside cleaning



Only frontside cleaning
No backside cleaning

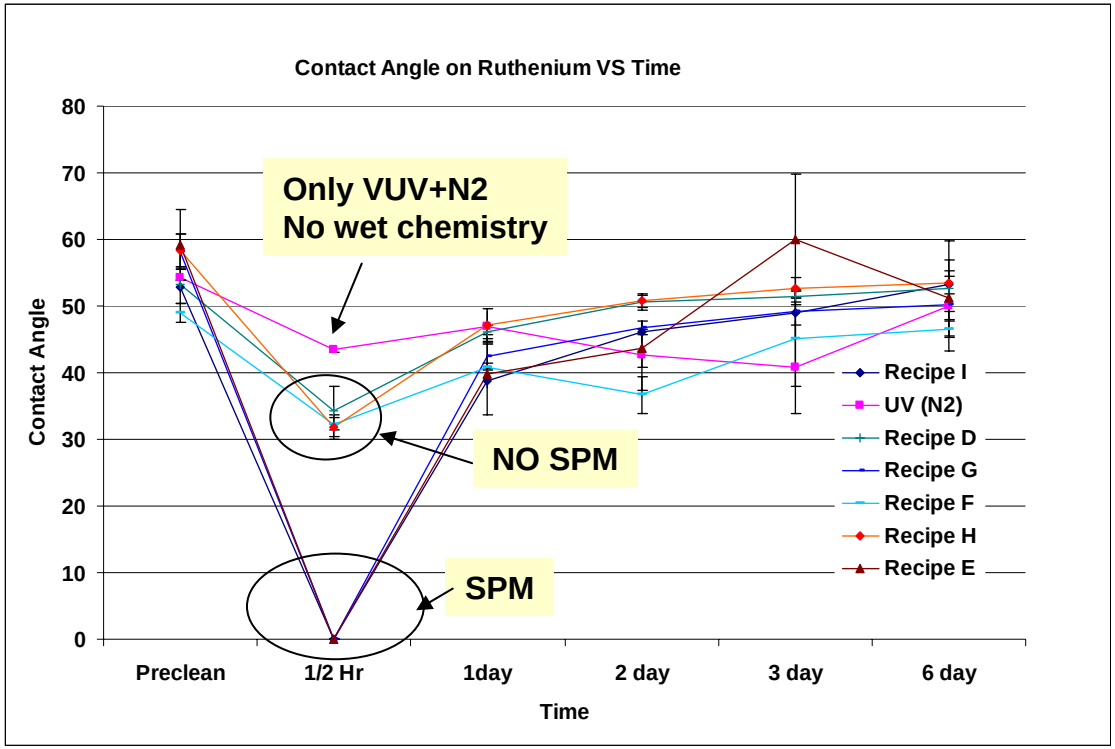
SPM (Front)→ SPM (back)
→ SPM (Front) cleaning

Mechanism of frontside contamination during backside cleaning



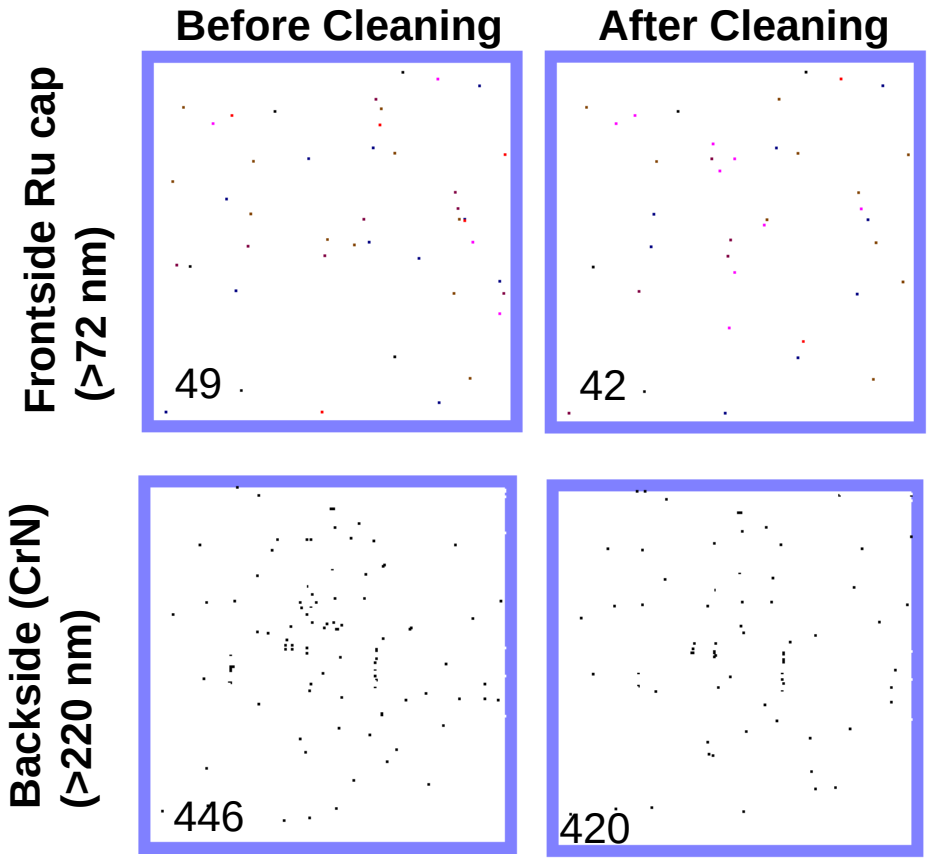
APM: $NH_4(OH)/H_2O_2/H_2O$

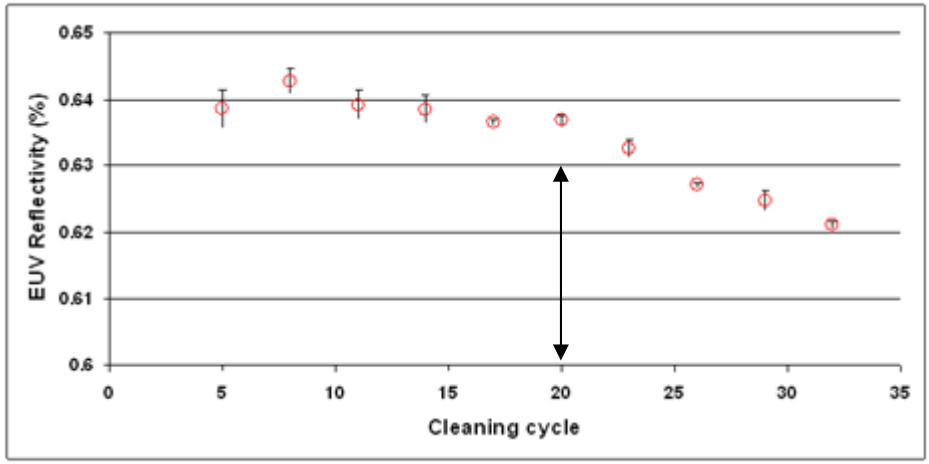
SPM: H_2SO_4/H_2O_2



- **Surface energy of Ru changes rapidly by exposure to different gases and chemicals**
- **Only SPM chemistry can reduce Ru surface energy for a longer period of time**

How many times a mask can be cleaned? (Mask lifetime)

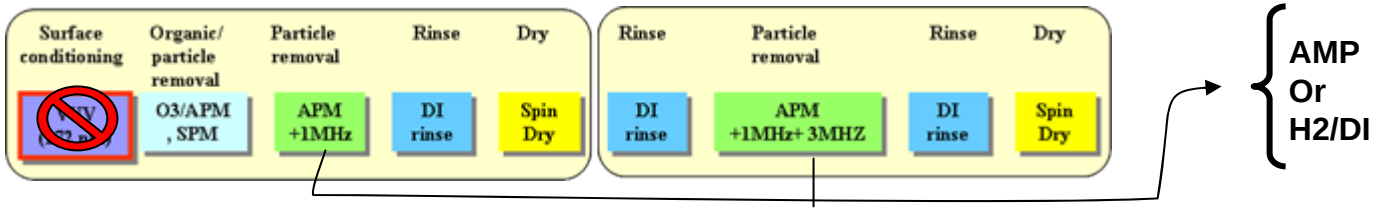


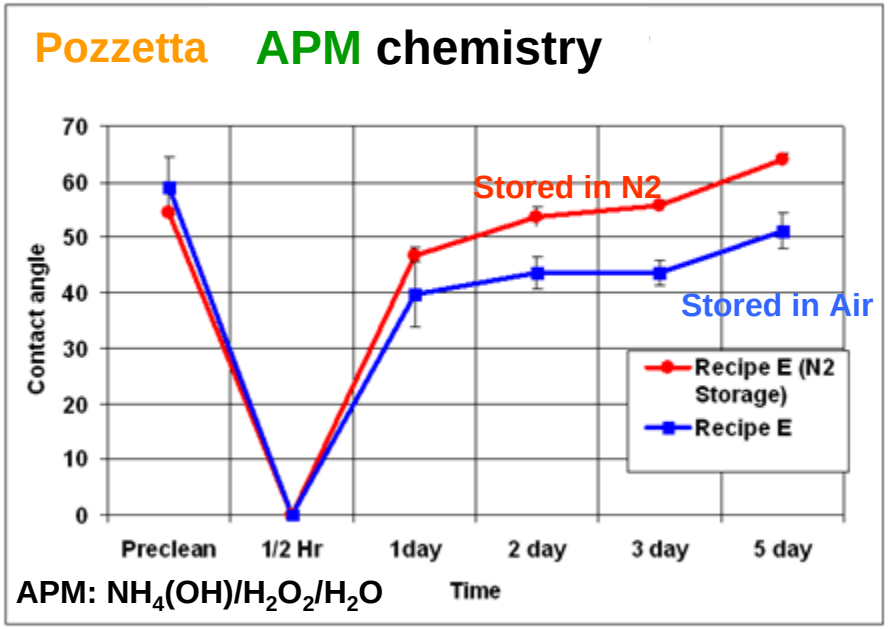


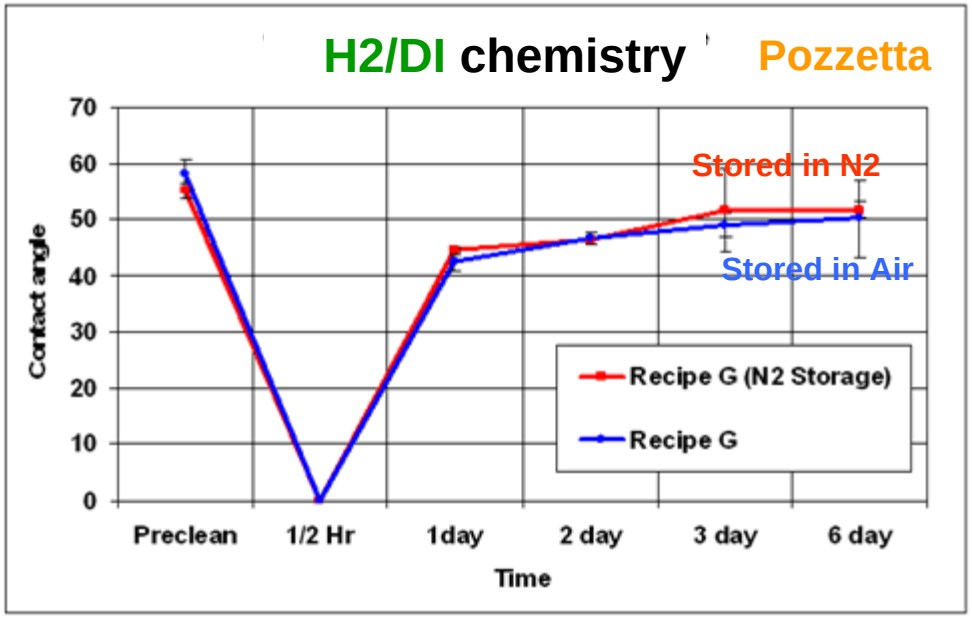
0.19% change in EUV reflectivity by 20X cleaning is better than that of standard SPM process

- **New cleaning processes were developed can clean front and backside of the mask without contamination by control of Ru surface energy**
- **Masks can be cleaned up to 20X with these processes**
- **Further process development is in progress to increase mask lifetime**

Effect of cleaning chemistry on storage lifetime of Ru-capped blanks

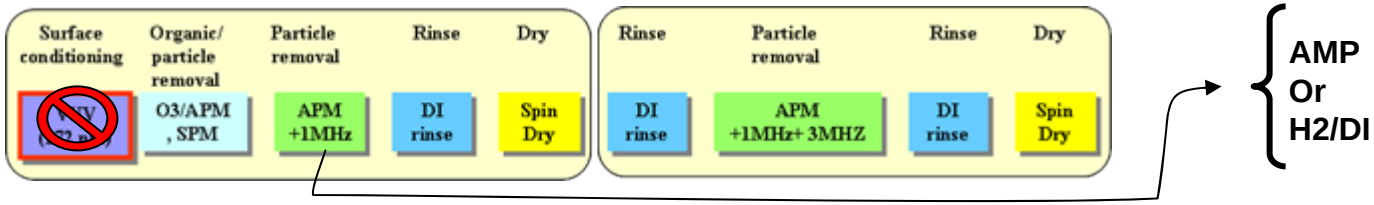


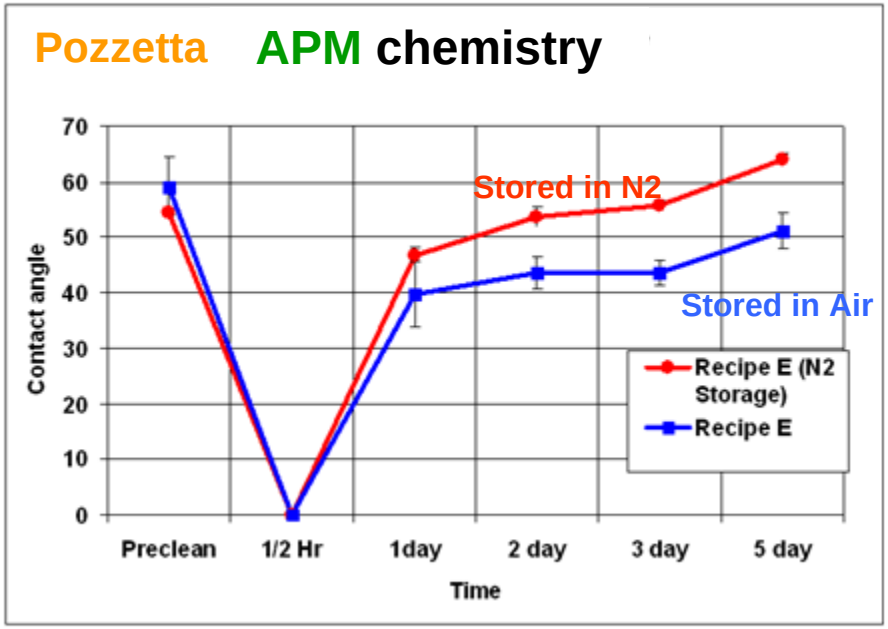


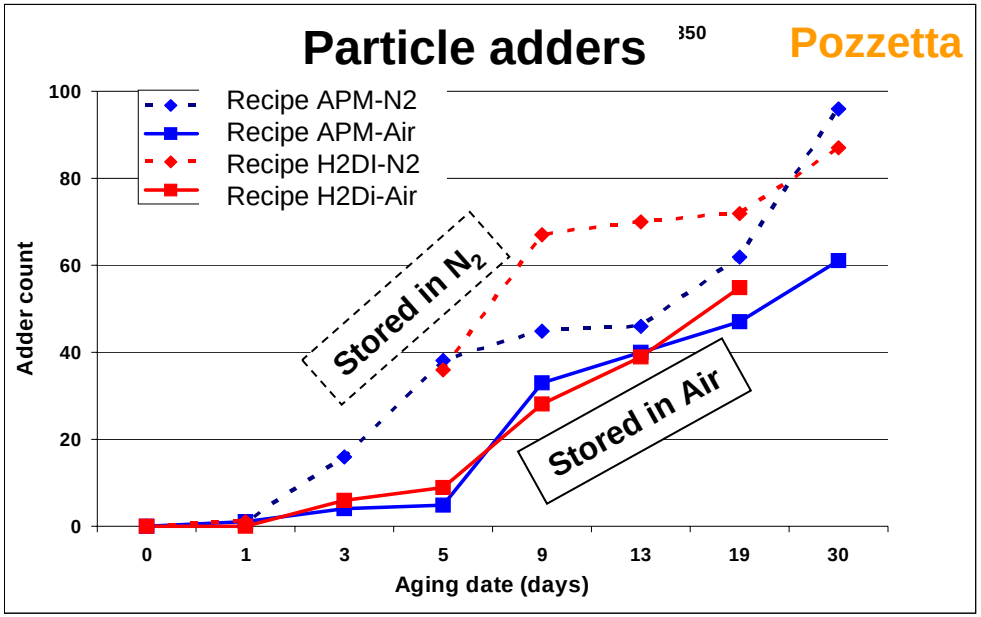


- **Surface energy of Ru changes when stored in N_2 environment depending on cleaning processes.**

Surface Energy &particle adders

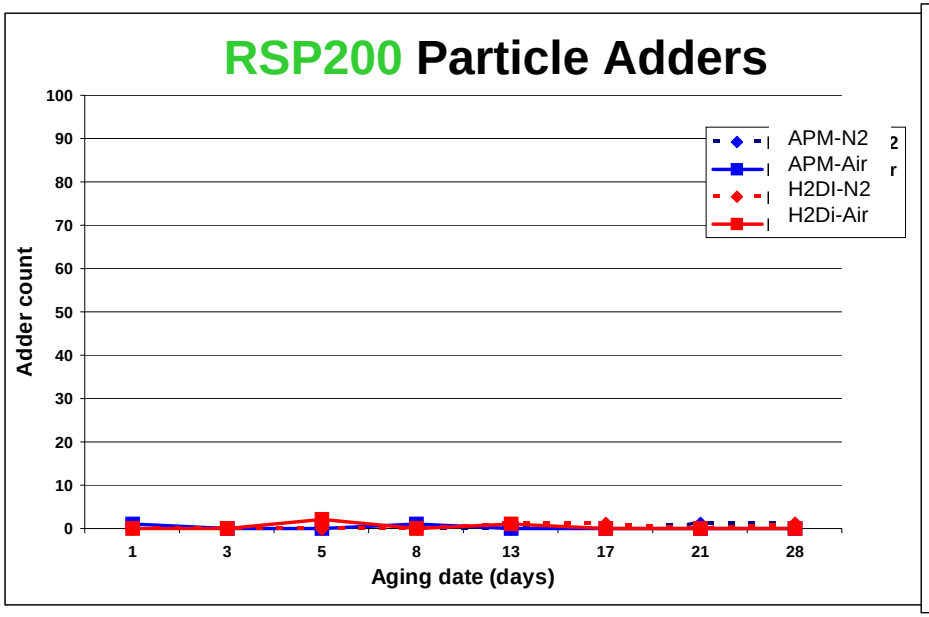


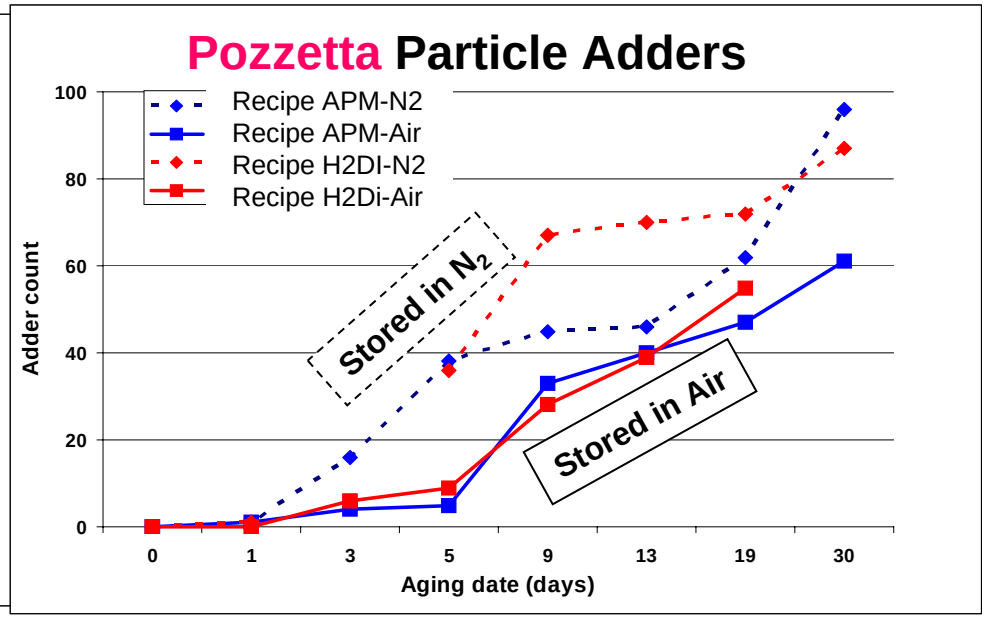




- **There is a correlation between number of particle adders and Ru surface energy (i.e., contact angle).**
- **More particles added in N_2 atmosphere than in the air.**

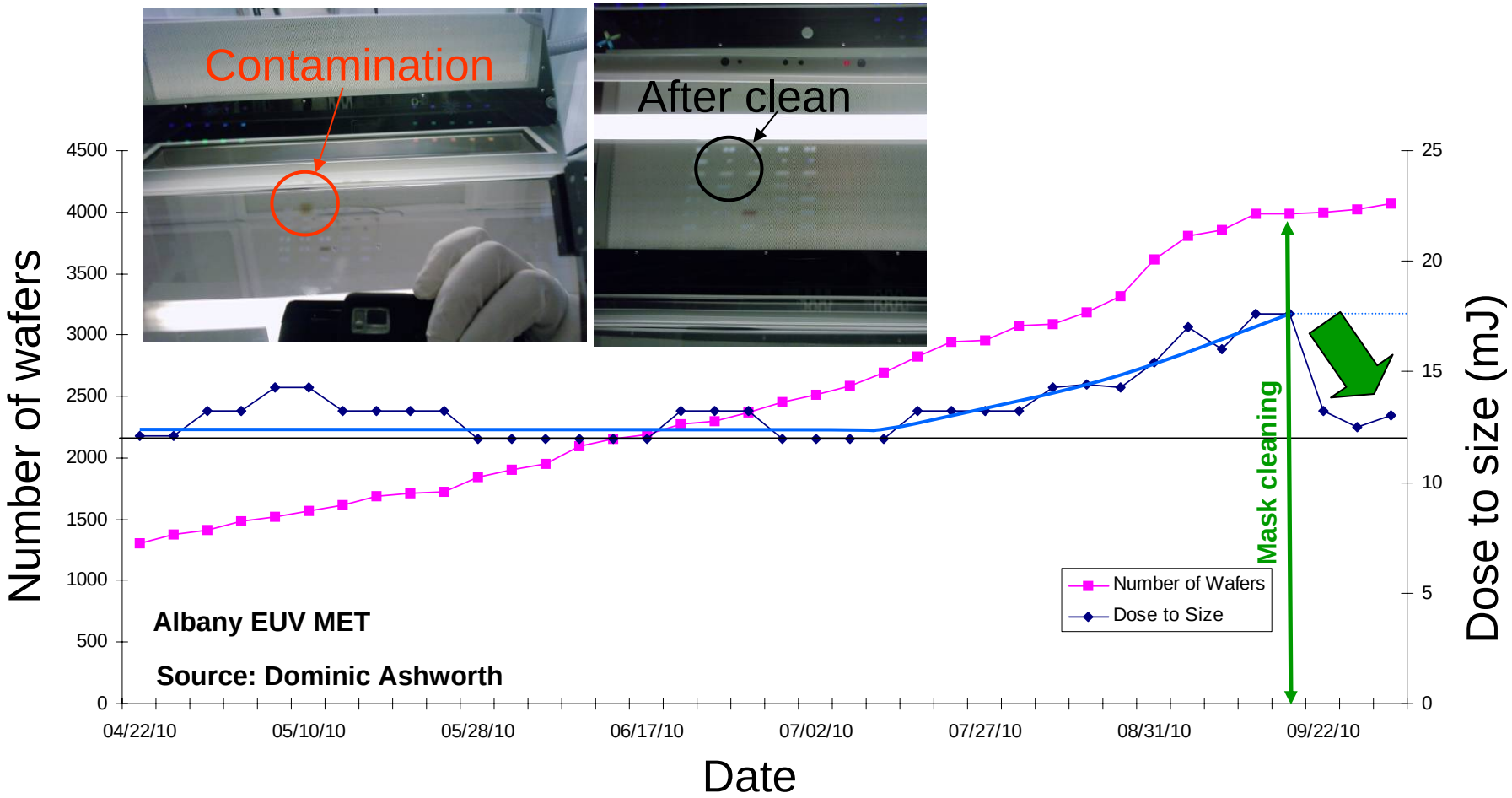
Storage lifetime of Ru-capped blanks: effect of storage pod





- **Plates stored in new RSP 200 did not have particle adders during 28 days, regardless of storage atmosphere and cleaning chemistry.**

Cleaning of carbon-contaminated EUV masks after 4000 wafer exposures (1025 resists)



- **Recently developed cleaning processes removed EUV mask contamination after EUV (micro) exposure of >4000 wafers (77 dies per wafer) and 1025 different resists and recovered the dose.**

Conclusions

- **Mask Cleaning Readiness**

Surface/node	22nm HP	16 nm HP	Critical Issues
Substrate	on schedule	Need New Clean technology	Inspection tool PRE, Adders
Blank (Ru cap)	on schedule	Need New Clean Technology	Ru damage Lifetime, Adders
Patterned mask	on schedule	Need New Clean Technology	Particle inspection PRE, damage

SEMATECH Focus: New Cleaning Technology Development

- **Storage**
  - Particle deposition depends on storage atmosphere
  - Work in progress on storage in vacuum and other gases
- **Lifetime**
  - 20X optimized processes are available
  - Work in progress to extend lifetime to 50X cleaning cycles