

# EUVL Thermophoretic Mask Protection

Sponsored by International SEMATECH

Daniel E. Dedrick, Lennie Klebanoff, Dan Rader  
Sandia National Laboratories, Livermore, California

October 17, 2000

## EUVL Thermophoretic Mask Protection Project Motivation

Standard pellicles cannot be used during EUV exposure:

- EUV absorption
- Degradation under EUV beam resulting in mask failure/contamination

EUVL Approach:

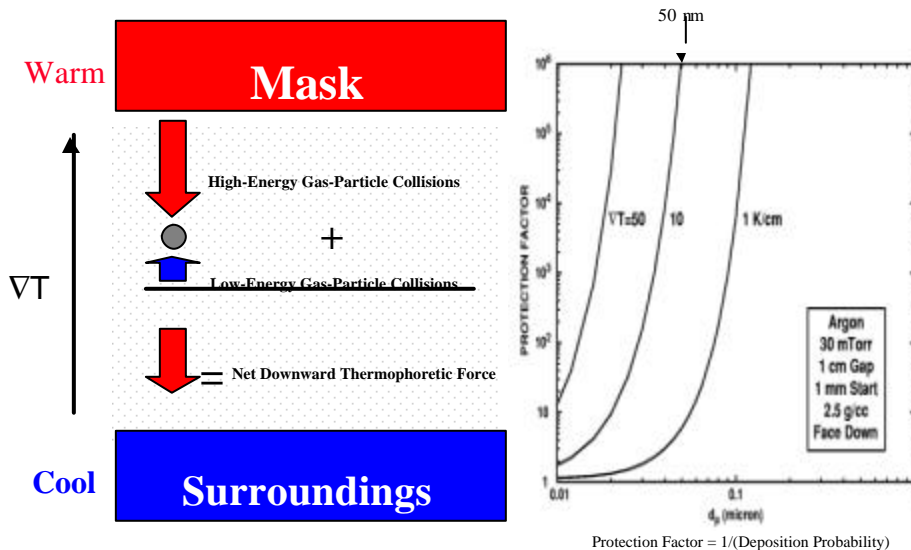
- Exploit thermophoresis for mask protection during EUV exposure.

## Thermophoretic Protection for EUVL Requires Experimental Demonstration at Low Pressure (~50 mTorr)

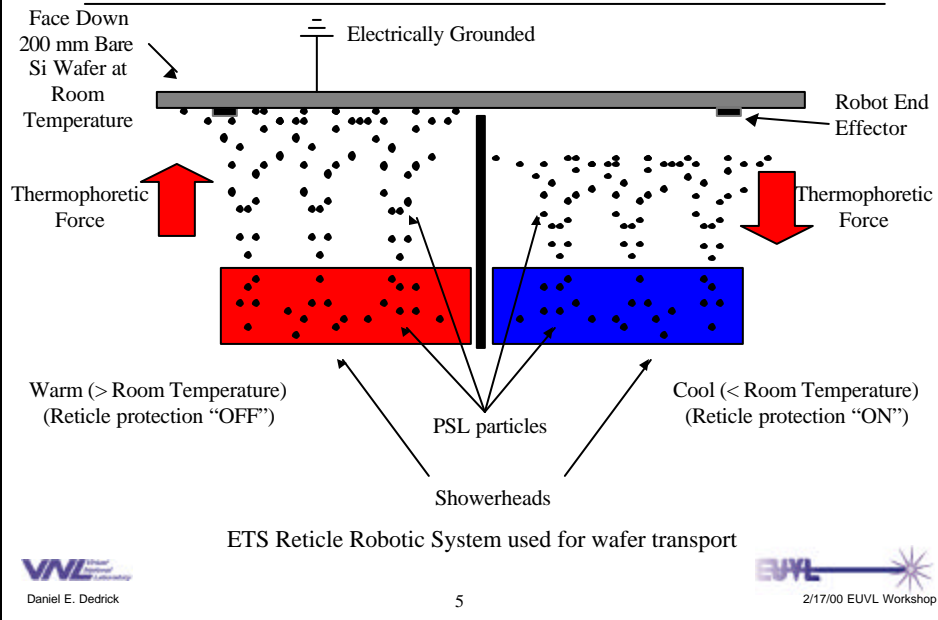
Prior demonstrations of thermophoresis have all been completed above ~4 Torr

- **Atmospheric Pressure:**  
Y. Ye et al. J. Aerosol Science. Volume 22, No. 1 p.p. 63-72 (1991).
- **~ 4 Torr:**  
R. Buss and D.J. Rader (1996), video, SNL, unpublished.

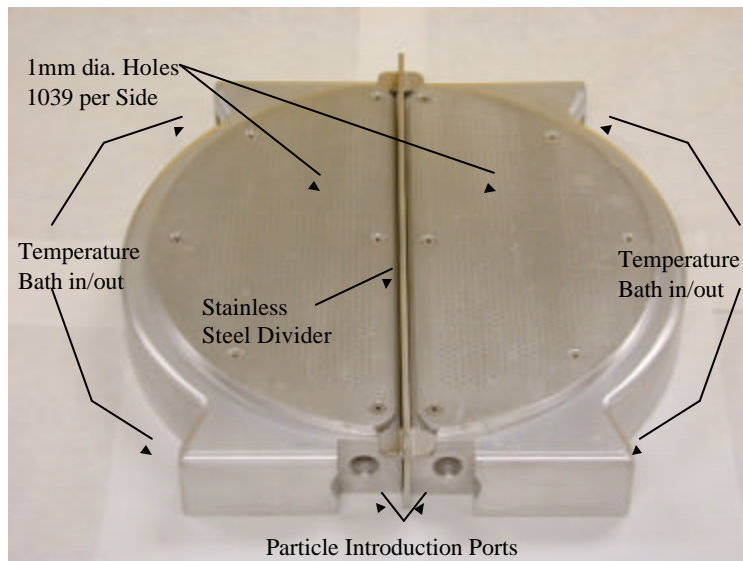
### Principles of EUVL Thermophoretic Protection



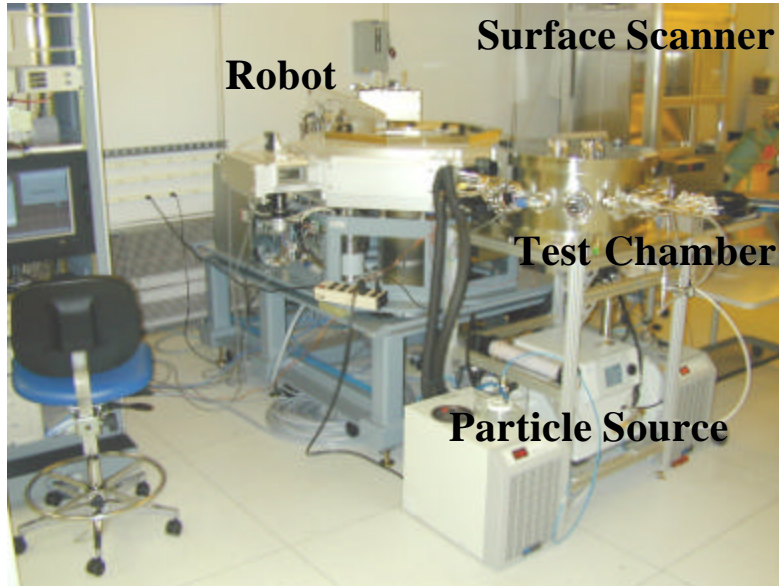
## Thermophoretic Protection Experimental Approach and Showerhead Design



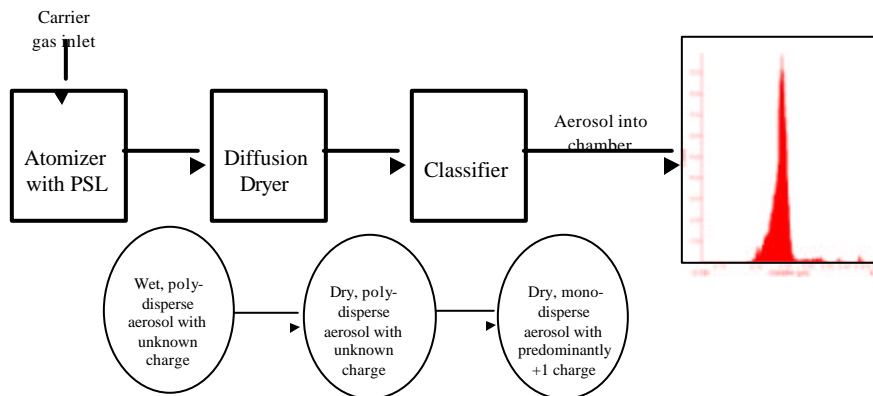
## Showerhead Designed to Minimize Electrostatic Fields



## New Thermophoretic Test Facility is Fully Operational



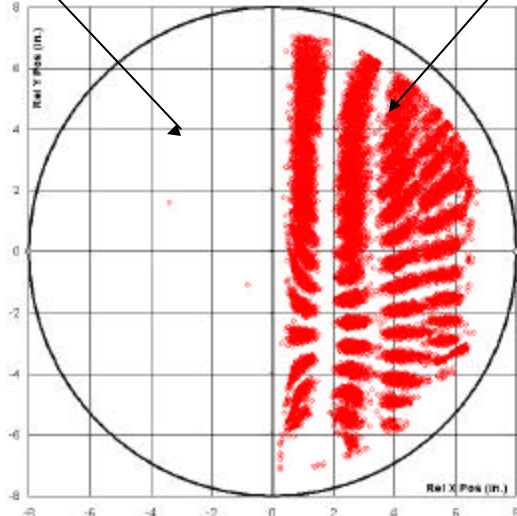
## Particle Source Provides Aerosol Control



## Thermophoretic Protection Results at 1 Torr in Air

2 Particles

25965 Particles



Wafer Temp: ~294 K  
ON Showerhead: 279 K ( $\nabla T \sim +15$  K/cm)  
OFF Showerhead: 309 K ( $\nabla T \sim -15$  K/cm)

Plotted Particles: 210nm - 270nm PSL  
Plot excludes identified pre-scan particles  
Plot includes handling adders( 3-10 per side typical)

Protection: ON(+  $\nabla T$ ) | OFF(-  $\nabla T$ )

VNL  
Daniel E. Dedrick

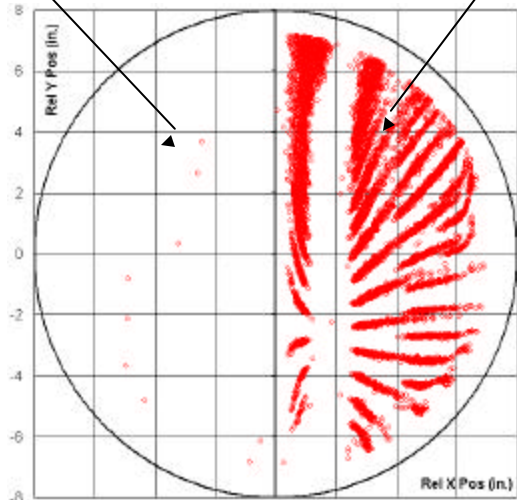
9

EWL  
2/17/00 EUVL Workshop

## Initial Results of Thermophoretic Protection at 530 mTorr

9 Particles

11786 Particles



Wafer Temp: ~294 K  
ON Showerhead: 278 K ( $\nabla T \sim +15$  K/cm)  
OFF Showerhead: 310 K ( $\nabla T \sim -15$  K/cm)

Plotted Particles: 210nm - 270nm PSL  
Plot excludes identified pre-scan particles  
Plot includes handling adders( 3-10 per side typical)

Protection: ON(+  $\nabla T$ ) | OFF(-  $\nabla T$ )

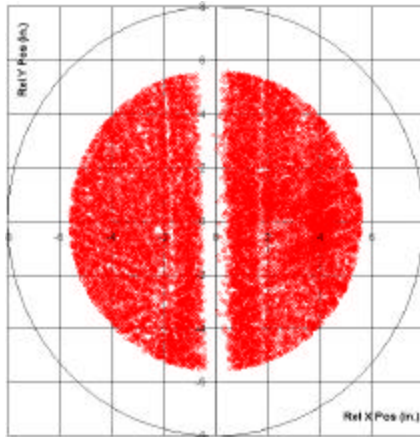
VNL  
Daniel E. Dedrick

10

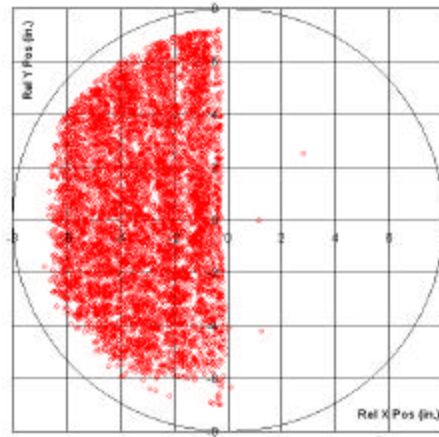
EWL  
2/17/00 EUVL Workshop

## Thermophoretic Protection Requires Minimizing Electric Fields

220-300nm PSL in air at ~3 Torr, +1 charged particles,  $\nabla T \sim \pm 15$  K/cm  
Wafer Ungrounded | Wafer Grounded



OFF(-  $\nabla T$ ) | ON(+  $\nabla T$ )



OFF(-  $\nabla T$ ) | ON(+  $\nabla T$ )

## Summary

- New Thermophoretic Testbed and Facilities Established and Operational
- Strong Thermophoretic Protection Observed in air at 1 Torr and 530 mTorr

Future Work: Demonstrate thermophoretic protection using argon and helium at pressures down to ~50 mTorr

Acknowledgements:

Carmelo Romeo, International SEMATECH

Lennie Klebanoff, Dan Rader, Alvin Leung, Mike Tootle, VNL