



2004 EUVL-Symposium

Design and Preliminary Results of a Vacuum Chamber to Evaluate Nanoparticle Protection Schemes for EUVL Vacuum System

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Nanoparticle Contamination Studies for EUVL Systems



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Related Presentations:

Poster (HaP01):
Atmospheric Chamber Study

Poster (HaP03):
Modeling Studies

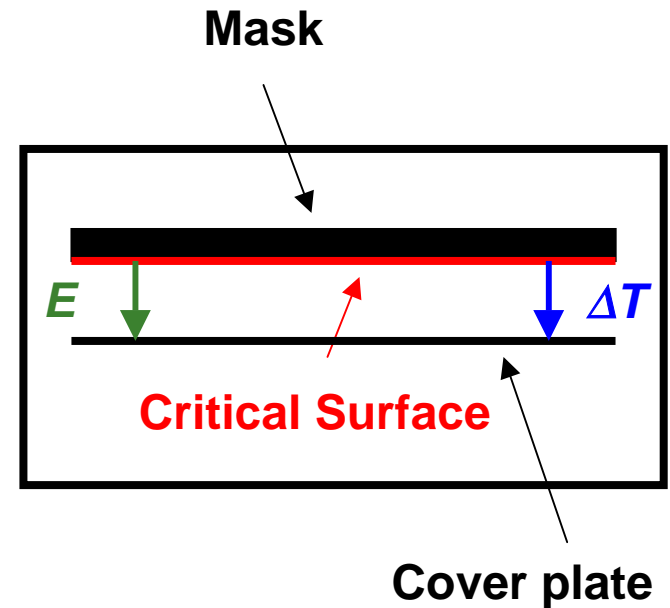
Dr. Kevin Orvek, Dr. Arun Ramamoorthy, and Dr. Pei-Yang Yan
Intel Corporation



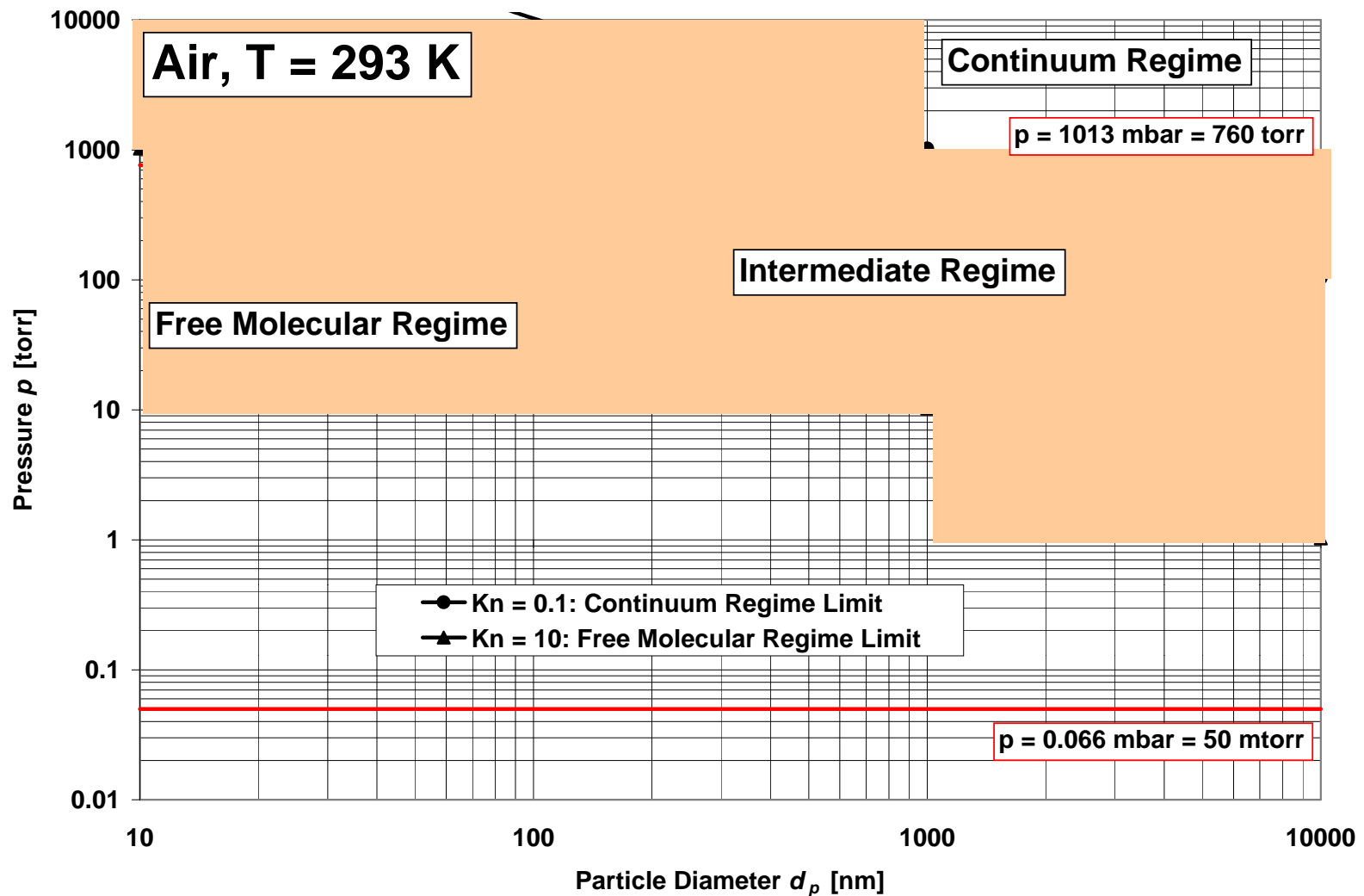
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Introduction

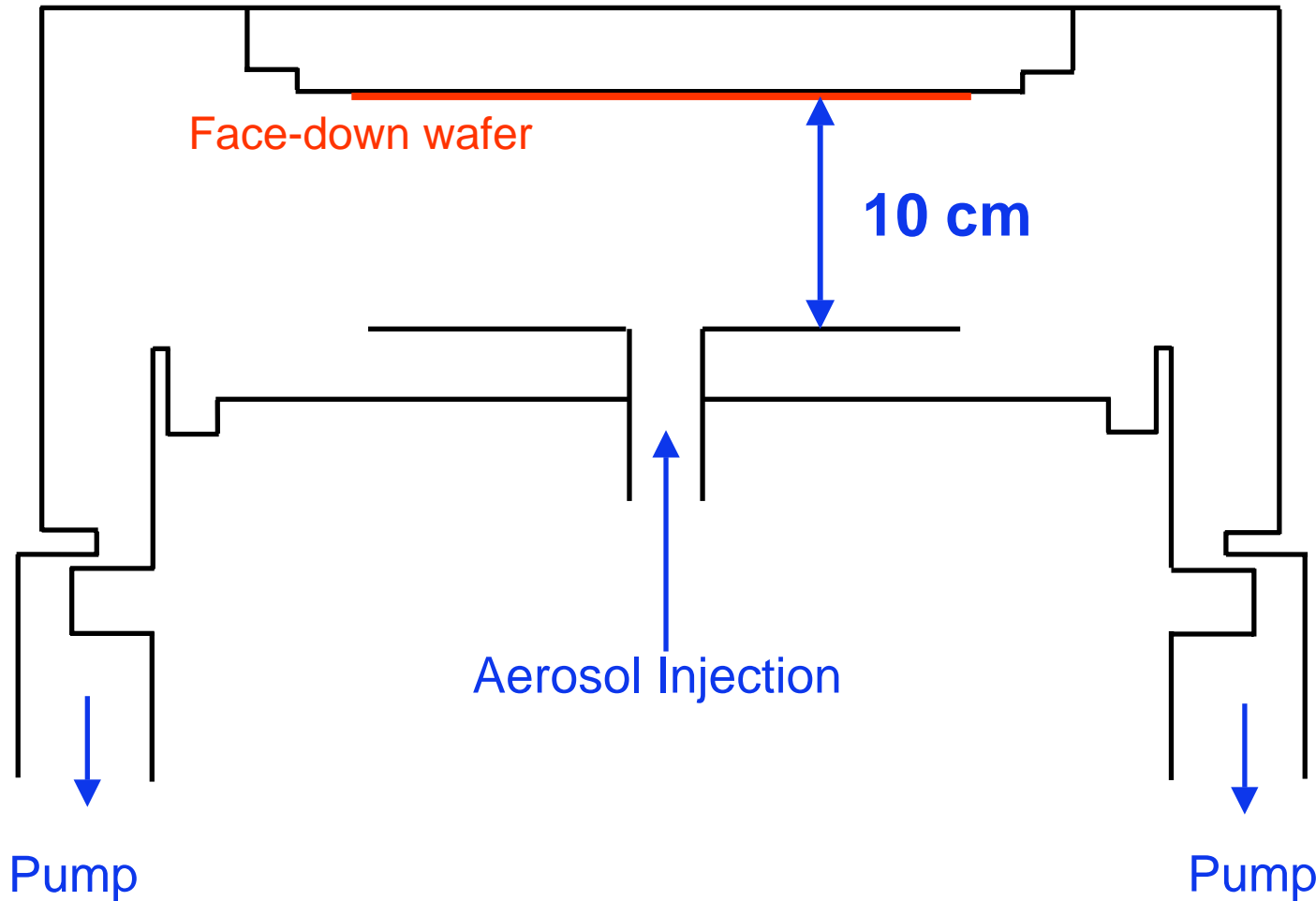
- Investigated system: Mask in a vacuum chamber
- Protection schemes:
 - Mask upside down
(use of gravity)
 - Cover plate underneath
(risk volume reduction)
 - Temperature difference
(use of thermophoresis)
 - And/or electric field
(use of electrophoresis)



Introduction: Different Pressure Regimes

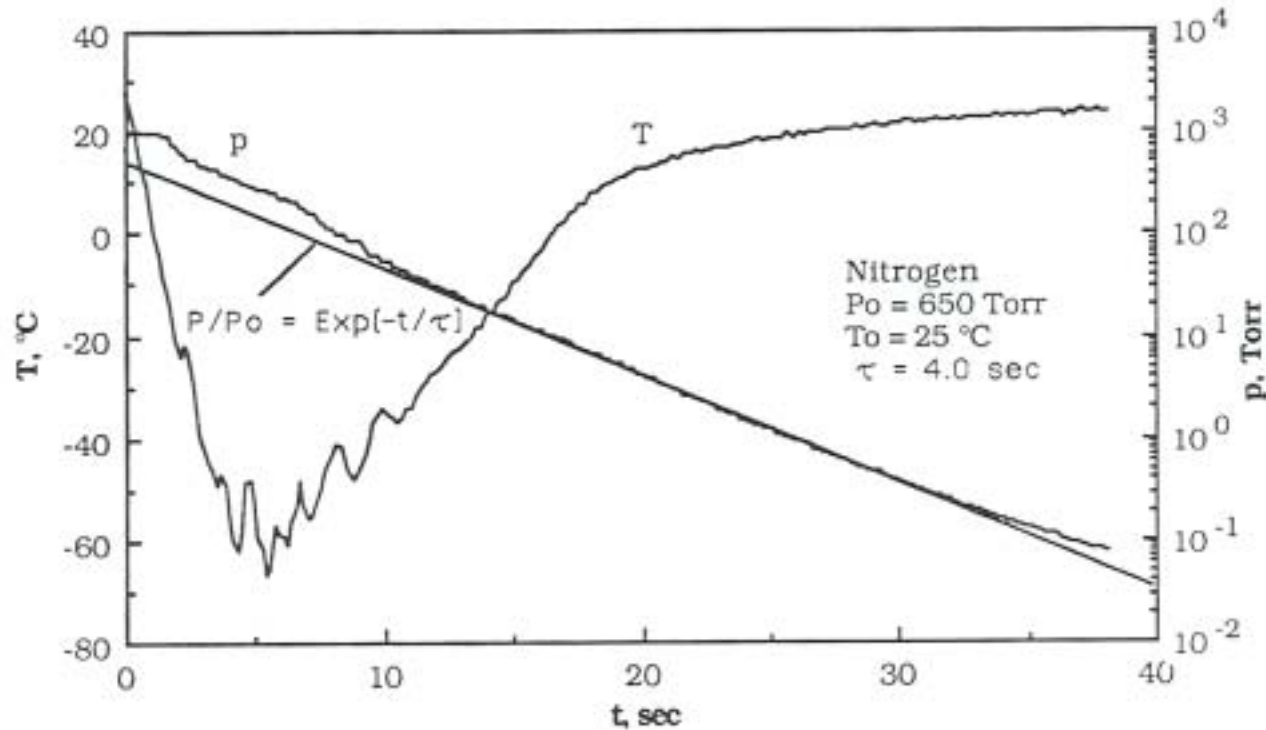


Vacuum Chamber



Vacuum Pump-Down

Ref: Zhao's Ph. D Thesis, UMN, 1990



System temperature abruptly decreases at initial pumping

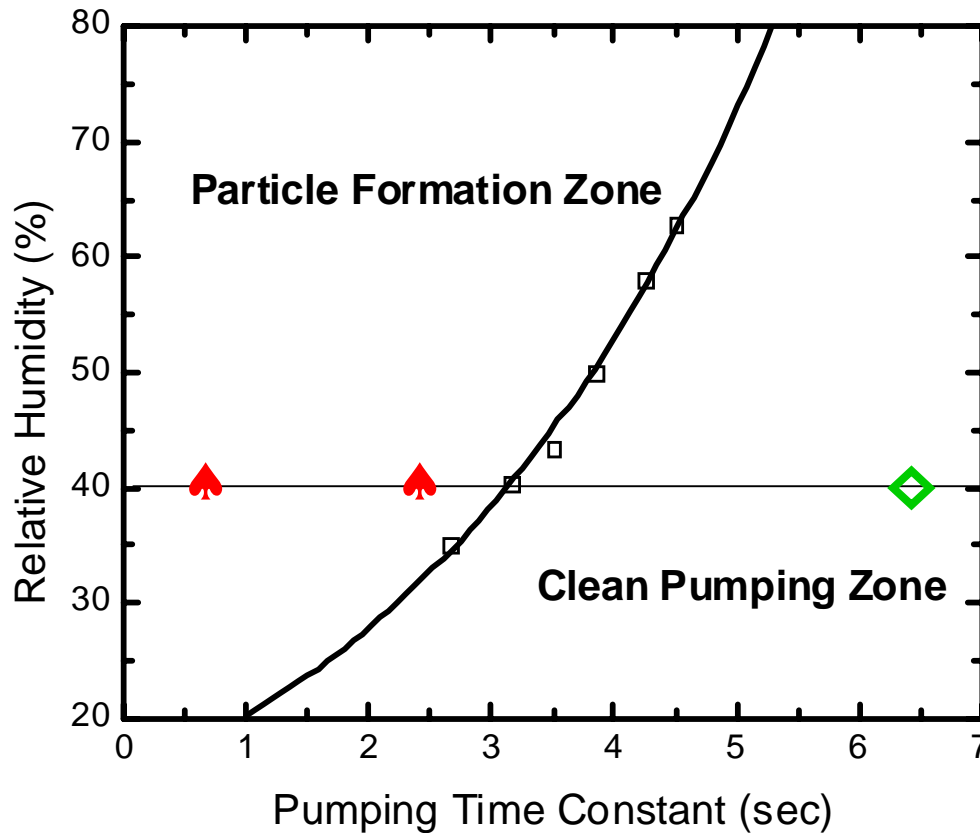


Supersaturation



Particle formation

Vacuum Pump-Down



Pumping time constant:

$$\tau = -t / \ln(P / P_0)$$

♠ : Particles formed during pump-down

◇ : Clean pump-down

Safe Criteria for Particle-Free Pump-Down

- For Clean Room Air (40% RH)

$$\tau \geq 25 \text{ sec}$$

based on $V = 20$ liter and $S_e \leq 50$ slpm

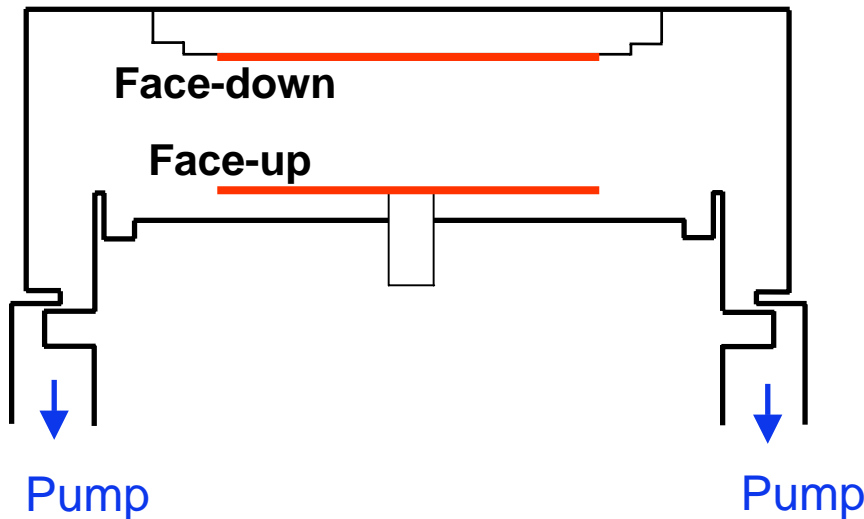
- 2) For Dry Nitrogen

$$\tau \geq 2 \text{ sec}$$

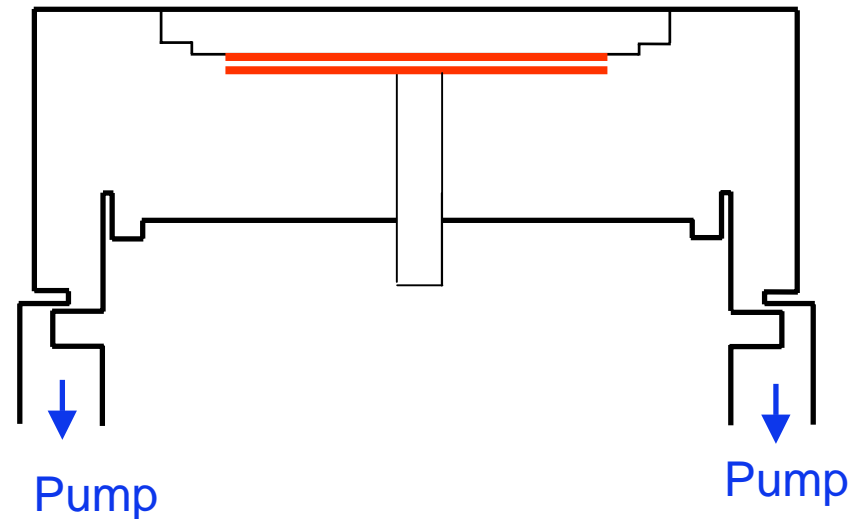
based on $V = 20$ liter and $S_e \leq 600$ slpm

Effect of Gap Spacing on Particle Deposition During Pump-Down

Gap = 10 cm



Gap = 0.5 cm

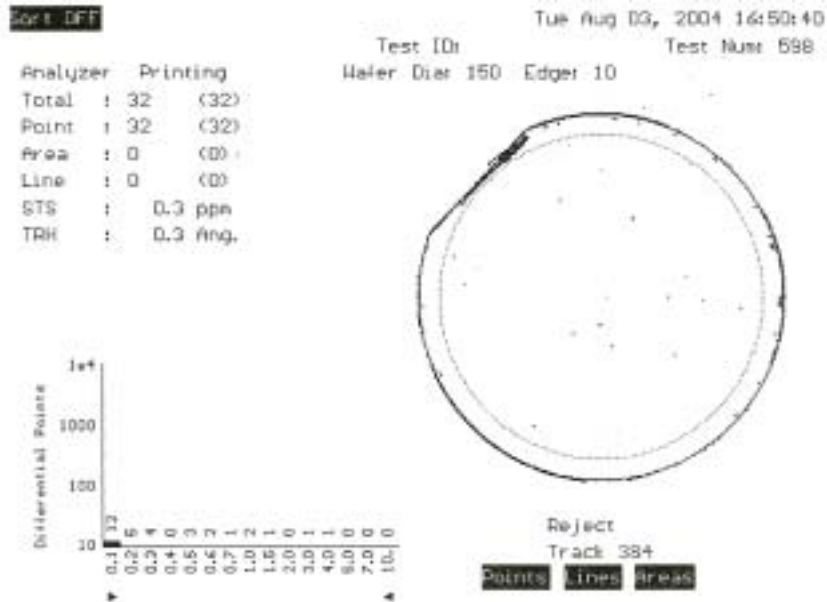


- Step1: Fast pump down with particle formation
- Step2: Examine particle deposition on wafers

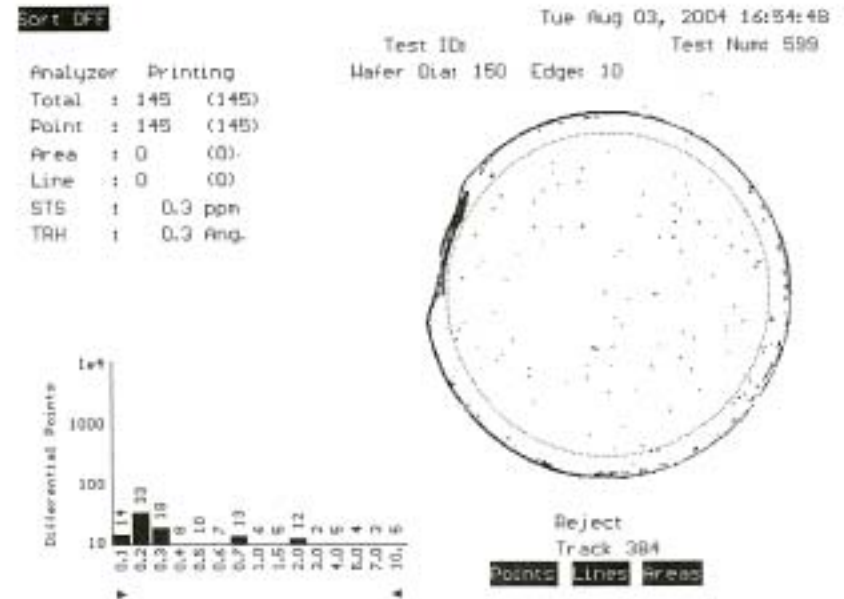
Effect of Gap Spacing

Fast Pump-Down at $\tau \cong 1$ sec

Gap = 10 cm



Face-down wafer after 10 cycles: 30 particles added



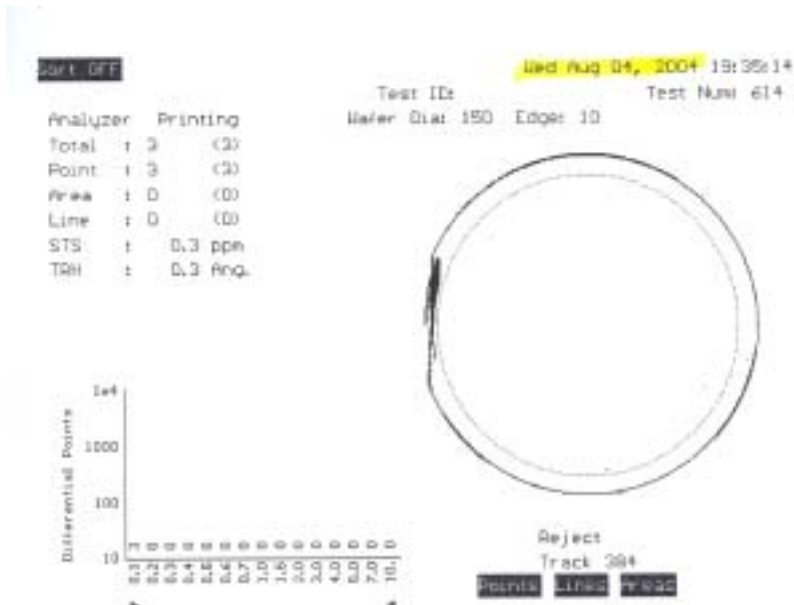
Face-up wafer after 10 cycles: 142 particles added

⇒ **Face-down is not completely sufficient for protection**

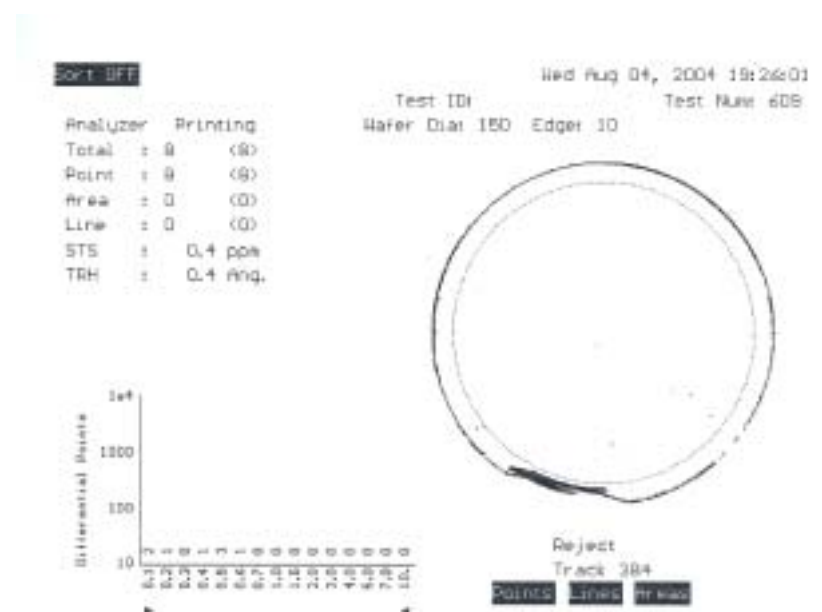
Effect of Gap Spacing

Fast Pump-Down at $\tau \cong 1$ sec

Gap = 0.5 cm



Face-down wafer after 10 cycles: No particles added



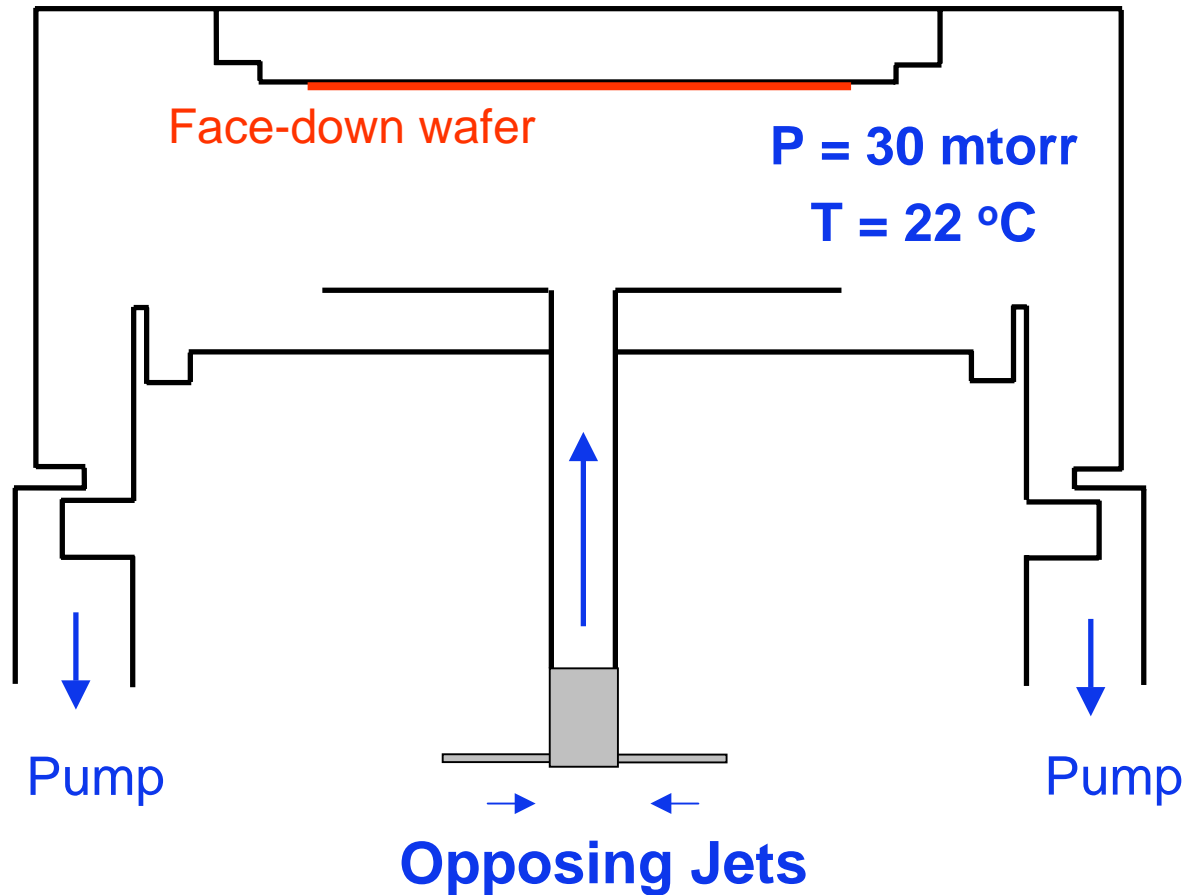
Face-up wafer after 10 cycles: No particles added

⇒ Smaller gap spacing improves protection

Summary: Pump-Down

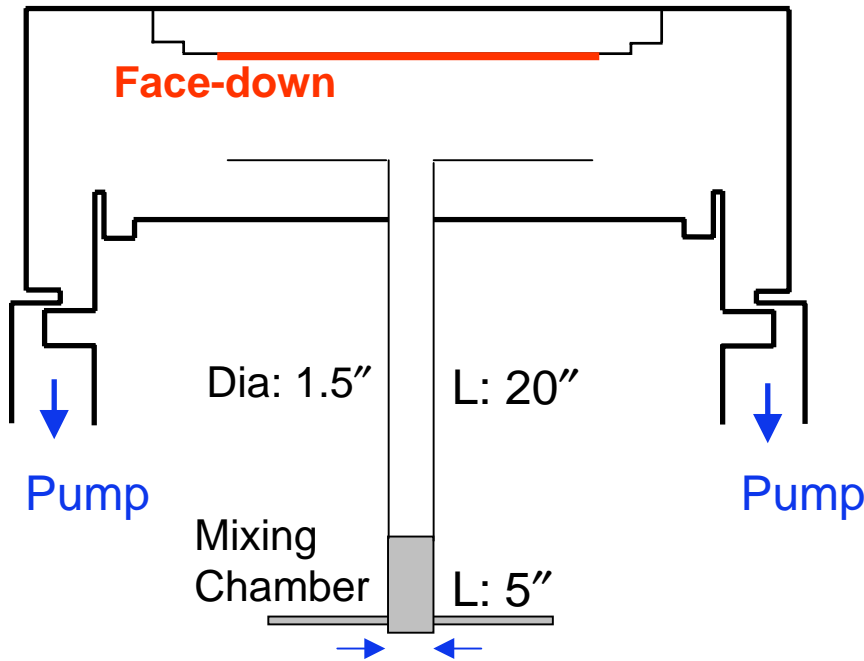
- Place sensitive surface face-down to reduce particle deposition
- Reduce pump-down speed to avoid particle formation
- Reduce gap space with cover plate to further protect the sensitive surface
 - 10 cm gap: 30 particles added
 - 0.5 cm gap: No particles added

Aerosol Injection



125 nm PSL Particles

Aerosol Injection

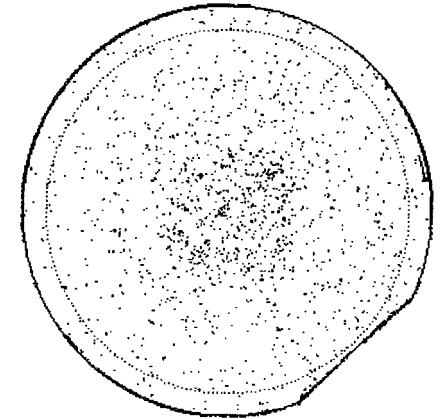
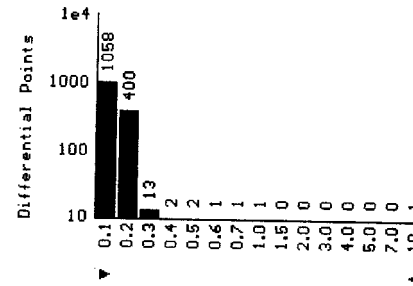


Orifice diameter: 100 μm
 $Re \approx 500$; 125 nm particles at
 Particle velocity ≈ 80 m/s

Sort OFF

Analyzer Printing
 Total : 1479 (1479)
 Point : 1479 (1479)
 Area : 0 (0)
 Line : 0 (0)
 STS : 0.4 ppm
 TRH : 0.4 Ang.

Sat Sep 18, 2004 18:33:48
 Test ID:
 Wafer Dia: 150 Edge: 10
 Test Num: 658



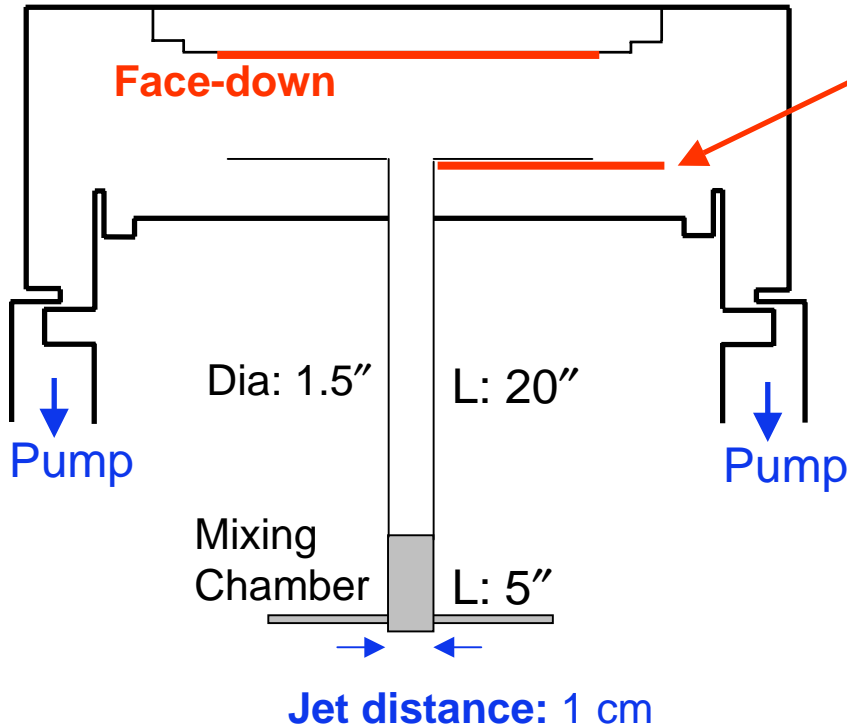
Reject
 Track 384
 Points Lines Areas

Uniform deposition

injected $\approx 10^5$

added $\approx 10^3$

Examine Ballistic Behavior

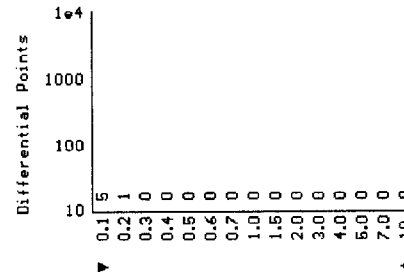
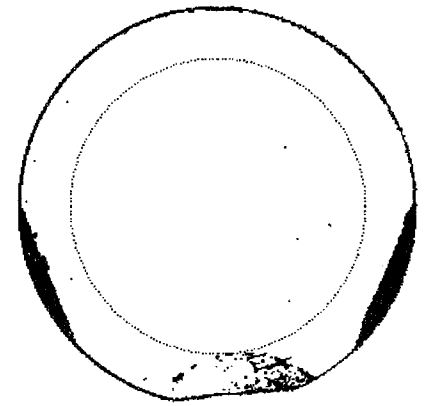


Orifice diameter: 100 μm
 $Re \approx 500$; 125 nm particles
 particle velocity ≈ 80 m/s

4" Witness wafer (face-down)

Analyzer Printing
 Total : 6 (6)
 Point : 6 (6)
 Area : 0 (0)
 Line : 0 (0)
 STS : 0.6 ppm
 TRH : 0.4 Ang.

Sat Sep 18, 2004 18:43:08
 Test ID:
 Wafer Dia: 100 Edge: 13
 Test Num: 661



**No particle addition
 (5 particles on bare wafer)**

No ballistic behavior occurred

Summary: Aerosol Injection

- Used opposing jets to provide uniform mixing of aerosol
- Achieved uniform deposition on the face-down wafer
- Observed no ballistic behavior at the injection speed of 80 m/s at 30 mTorr

Thermophoresis Study

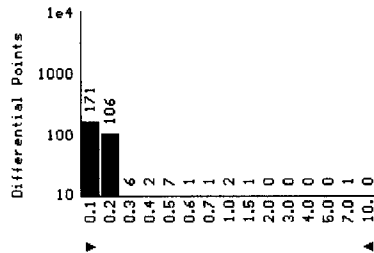
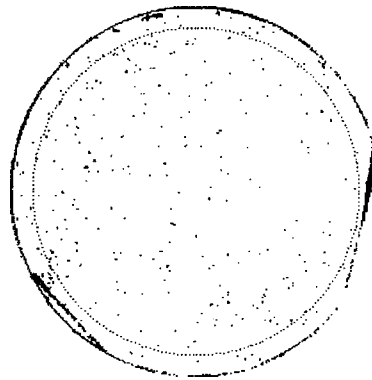
Injection speed 4.8 m/s at 400 mTorr

Sort: OFF

Mon Sep 20, 2004 11:42:17

Test ID: Test Num: 671
Wafer Dia: 150 Edge: 10

Analyzer Printing
Total : 298 (298)
Point : 298 (298)
Area : 0 (0)
Line : 0 (0)
STS : 0.4 ppm
TRH : 0.4 Ang.



No heat applied

Before-count : 17

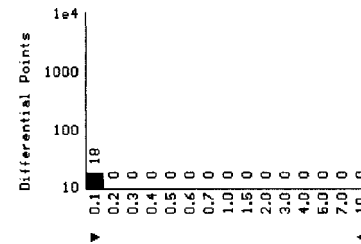
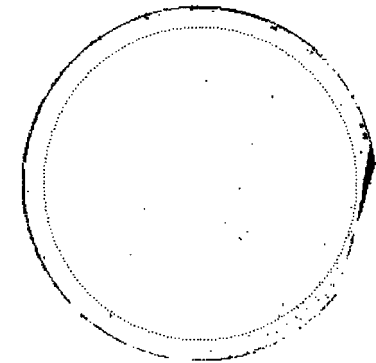
After-count: 298

Sort: OFF

Mon Sep 20, 2004 14:23:07

Test ID: Test Num: 673
Wafer Dia: 150 Edge: 10

Analyzer Printing
Total : 18 (18)
Point : 18 (18)
Area : 0 (0)
Line : 0 (0)
STS : 0.4 ppm
TRH : 0.4 Ang.



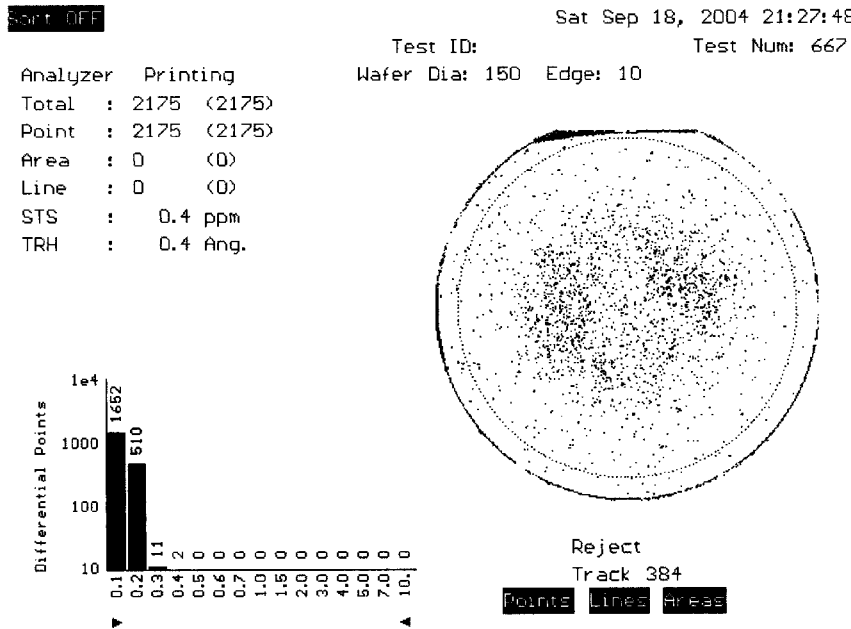
$\nabla T = 4$ K/cm

Before-count : 16

After-count: 18

Thermophoresis Study

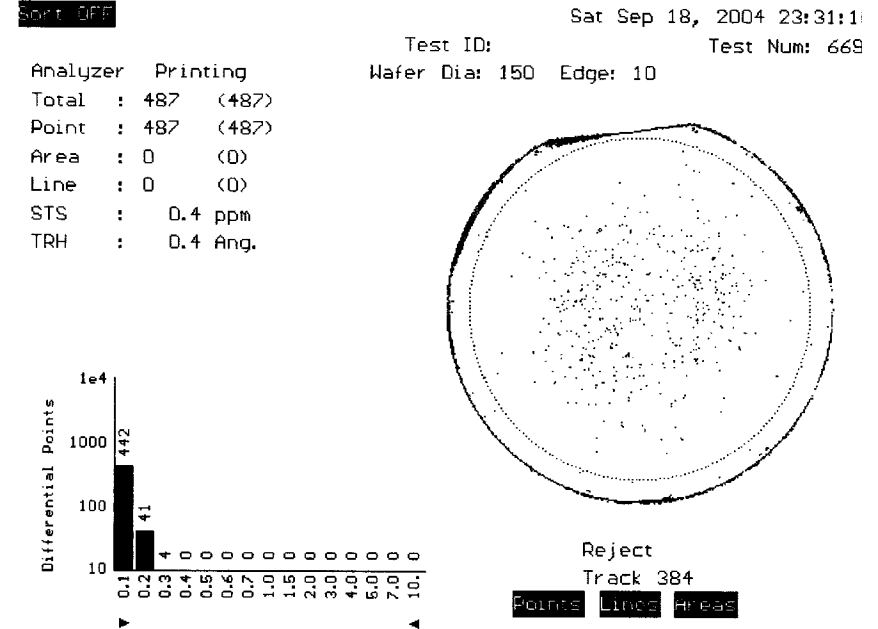
Injection speed 80 m/s at 30 mTorr



$\nabla T = 1.5 \text{ K/cm}$

Before-count : 15

After-count: 2175



$\nabla T = 11 \text{ K/cm}$

Before-count : 15

After-count: 487

Summary: Thermophoresis Study

- Use thermophoresis to prevent particle deposition at 5 m/s at 400 mTorr
- Observe more particle deposition at 80 m/s at 30 mTorr
- Will perform further systematic evaluations
 - Pressure range: 20 mTorr ~ 100 mTorr
 - Temperature range: 1 ~ 20 K/cm