



Detection of small size particles in low pressure and for component evaluation

IEUVI Mask TWG
Miami, October 16, 2011

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CNSE

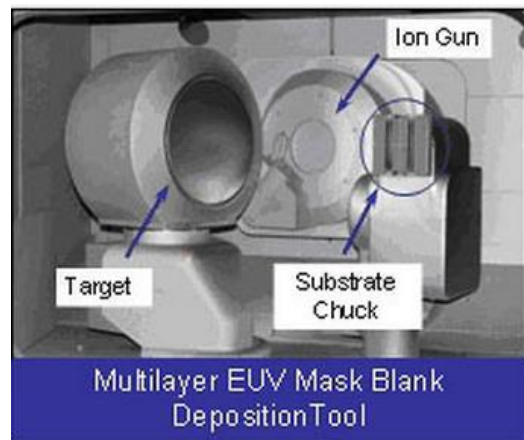
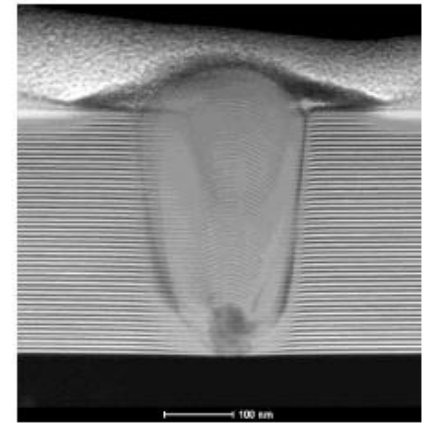
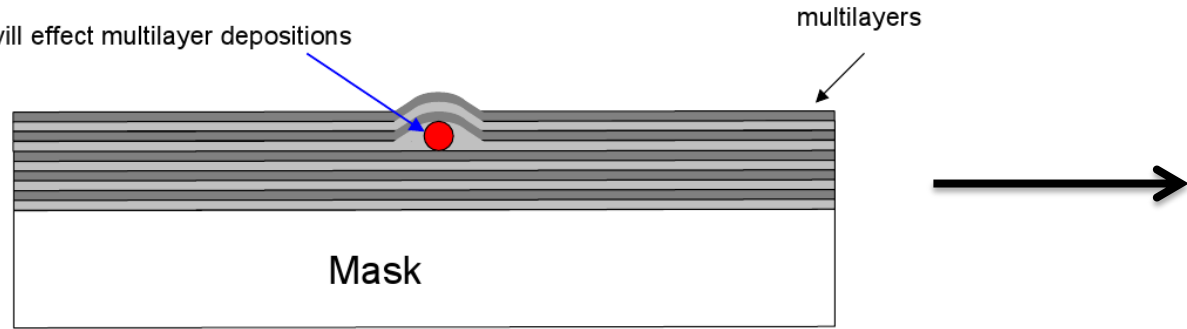
Vibhu Jindal, Patrick Kearney, and Frank Goodwin
SEMATECH



Introduction

- Defect-free masks still a critical challenge for adoption of EUV lithography in semiconductor industry
- Understanding of particle transport will be helpful for avoiding particles landing on the mask during fabrication and use

particle, will effect multilayer depositions



References: 1. Getting up to speed with roadmap requirements for extreme-UV lithography, V. Jindal et. al, SPIE 2011.
2. <http://cpmi.illinois.edu/2009/02/27/pace-plasma-assisted-cleaning-by-electrostatics/>
3. FEI Tool Applications – EUV mask blank defect reduction program, SEMATECH



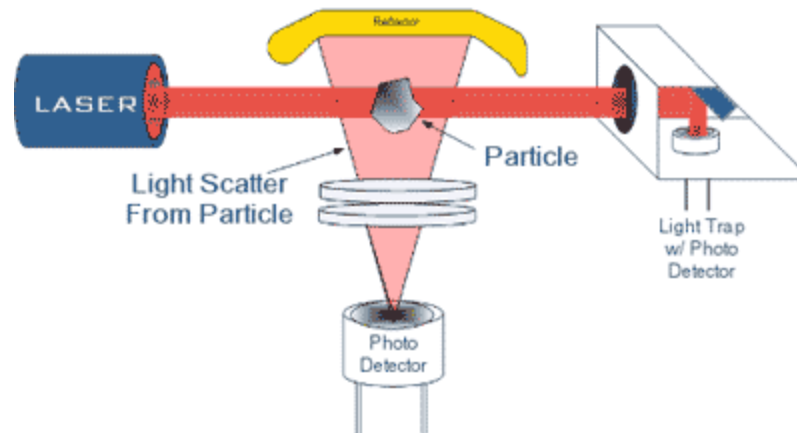


- **Optical Particle Counters (OPCs)**
 - Based on light scattering from particles
 - Technique, in general, can detect only down to ~50 nm sized particles
 - Give real-time particle counts and size distribution
- **Impactor plates**
 - Trap particles by simple impaction
 - Need multiple stages and very high flowrates to trap particles smaller than 100 nm easily
 - Trapped particles analyzed offline by Scanning Electron Microscopy (SEM) and Energy-dispersive X-ray (EDX) spectroscopy
- **Condensation Particle Counters (CPCs)**
 - Alcohol/water is condensed on smaller particles which cannot be detected by OPCs
 - These grown droplets are then detected optically
 - Range of detection is 2 nm – few microns



Optical particle counters

- Based on detecting light scattering from air-borne particles
- A light source (laser) illuminates stream of particles
- Amount of light scattered from each particle by refraction or diffraction is detected
- Real-time simultaneous measurement of size and number of particles
- Particle size determined by intensity of scattered light
- Particle detection limit determined by refractive index of particle - generally can detect particles larger than 50 nm





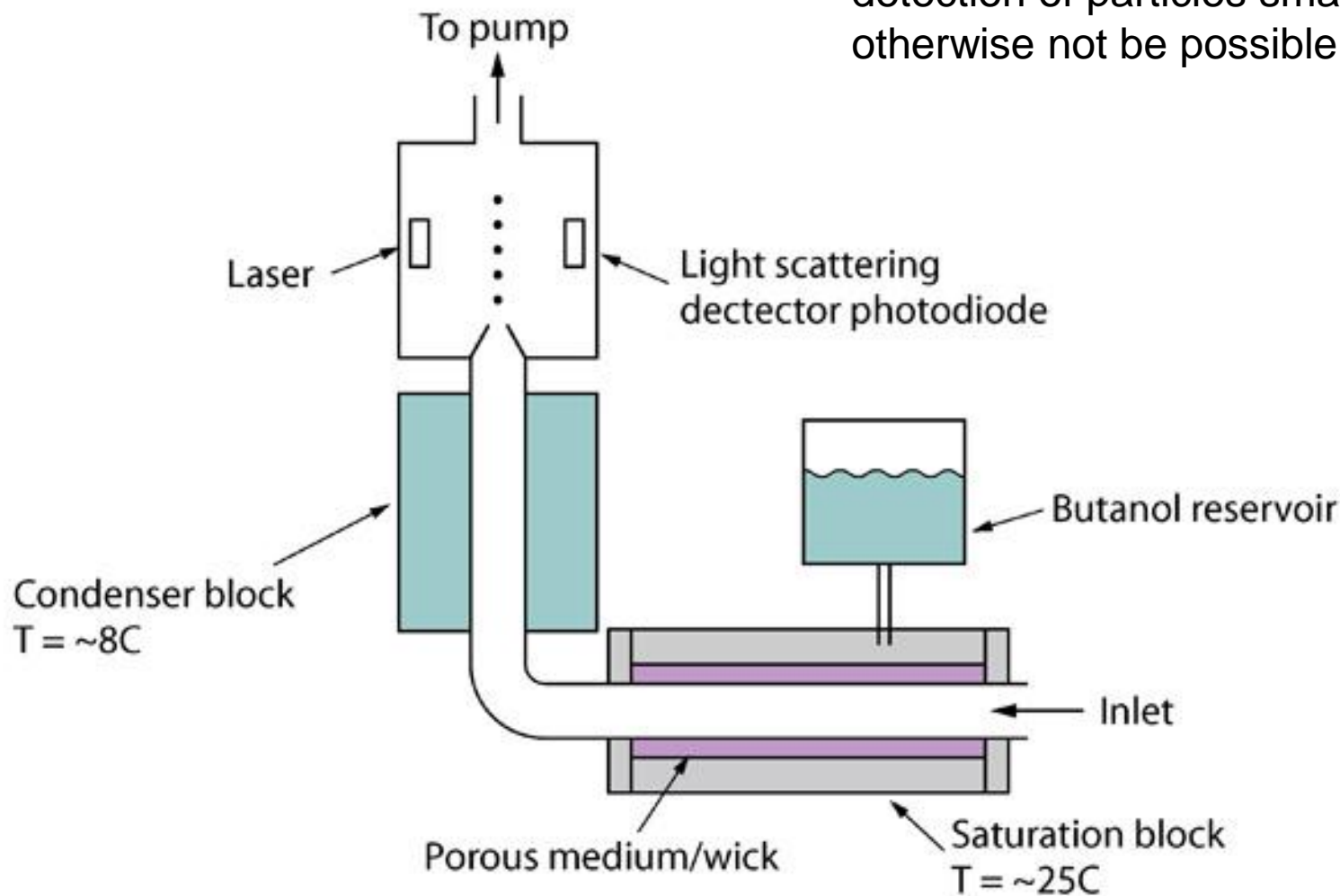
- Detects particles as small as 2 nm in size
- Works by condensing alcohol on small particles and growing them into larger droplets
- These larger droplets are then detected by an optical particle counter
- It works only in atmospheric pressure
- Can be connected with Scanning Mobility Particle Sizer (SMPS) to get size distribution

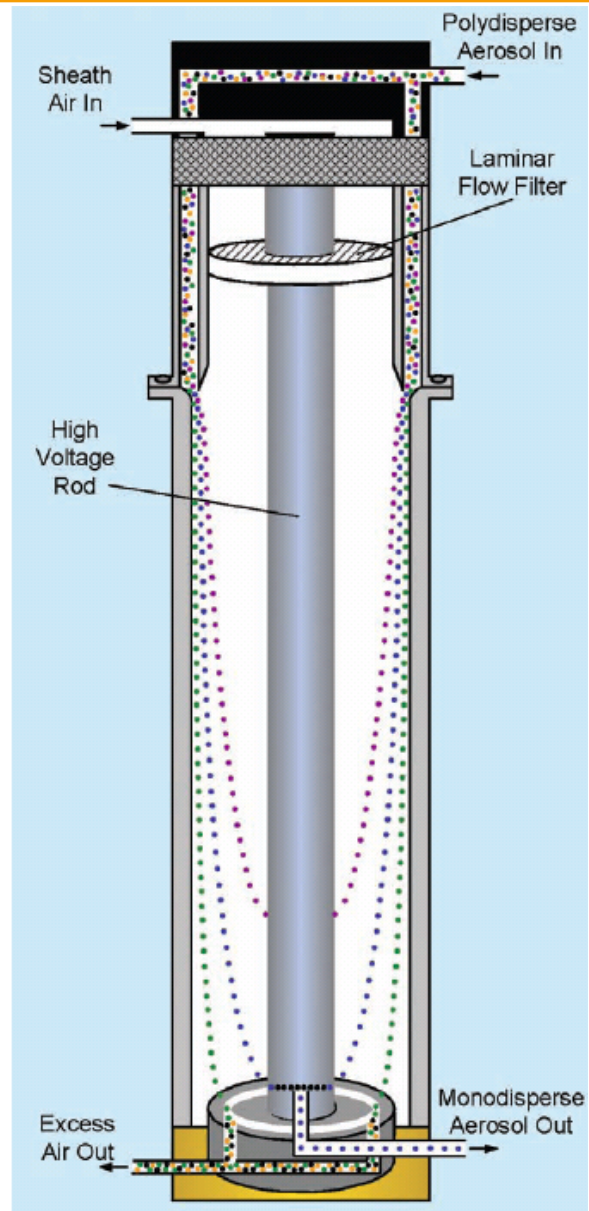




Schematic of a CPC

Condensation around particle allows detection of particles smaller than would otherwise not be possible optically



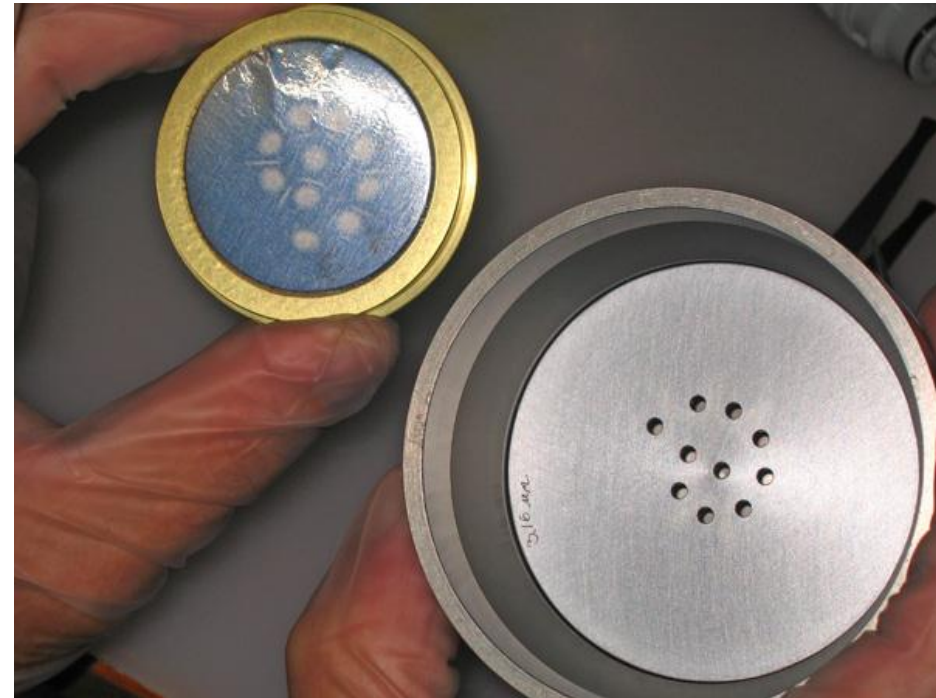
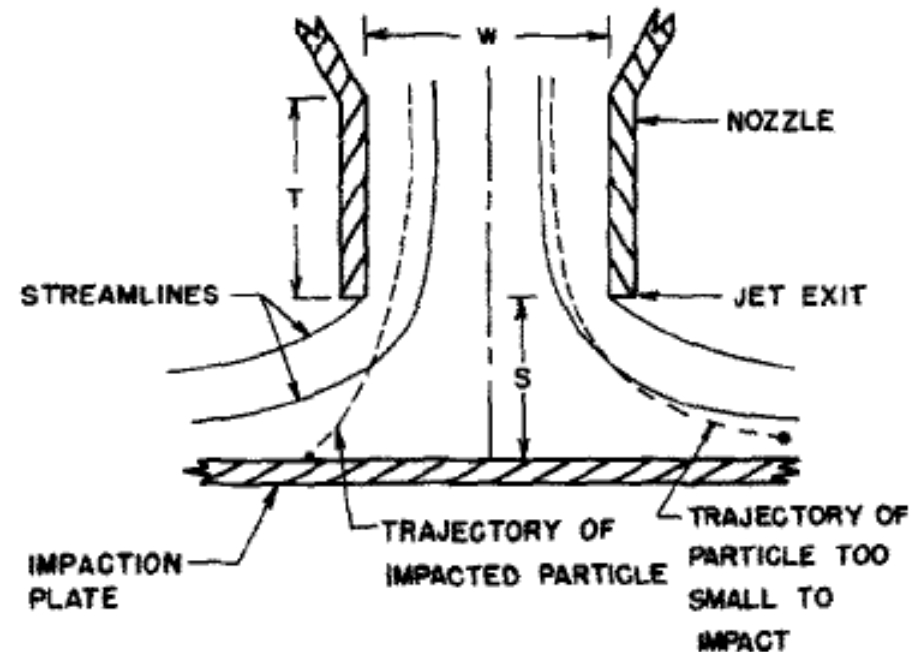


Scanning Mobility Particle Sizer (SMPS)

Electrostatic mobility is filter for size selection
to be coupled to CPC for detection

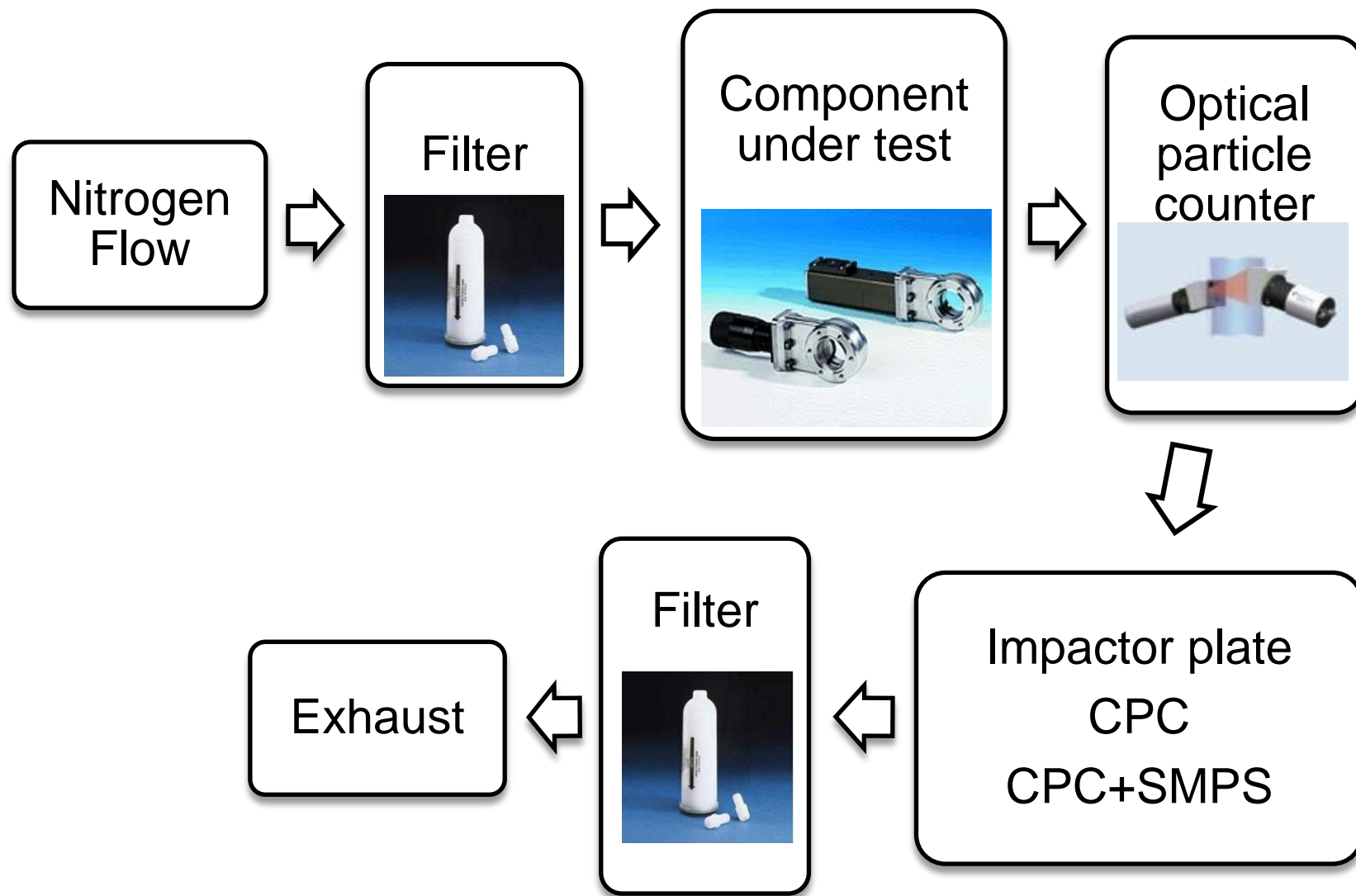


- Stream of particles are directed on a surface
- Particles with enough inertia will impact the surface
- Smaller particles will follow the streamlines and not impact the surface
- Surface is coated with grease to reduce particle bounce





Schematic of experimental setup



References: 1. Sensors and Transducers e-digest, No. 8, 2002.

2. <http://www.opticsplanet.net/pall-hepa-capsule-pall-life-sciences-12144.html>, Pall HEPA Capsule, Optics Planet.



Experimental Conditions

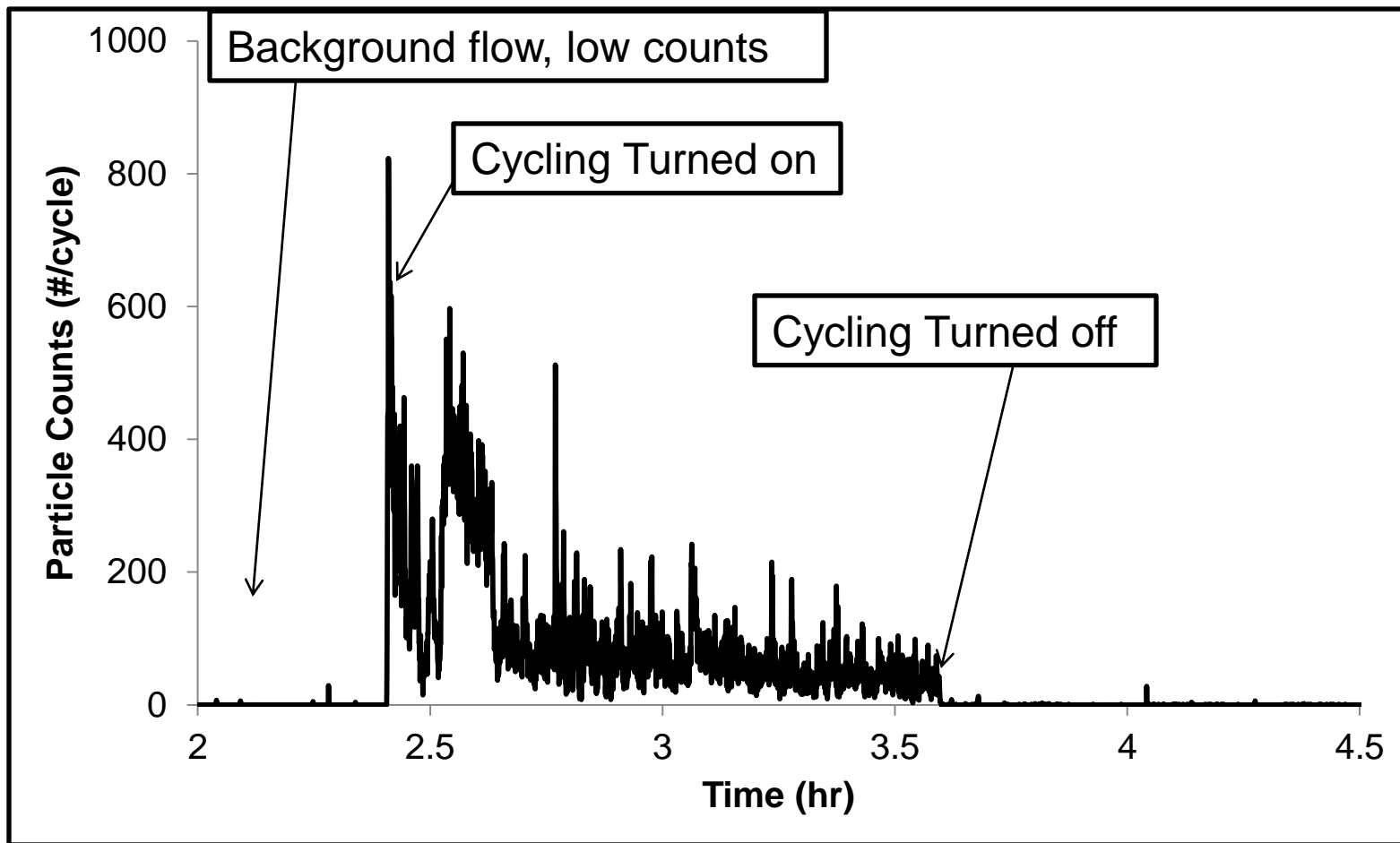
- Valve type: VAT Series 10 Mini UHV gate valve*
- Type of seal of valve: Viton
- Valve open/close cycle time: 2 sec
- Impactor plate: Wafer spincoated with 200 nm Apiezon Grease
- Inficon Stiletto optical particle counter used for measurement of particle counts and size distribution
- Nitrogen flow: 4.2 l/min

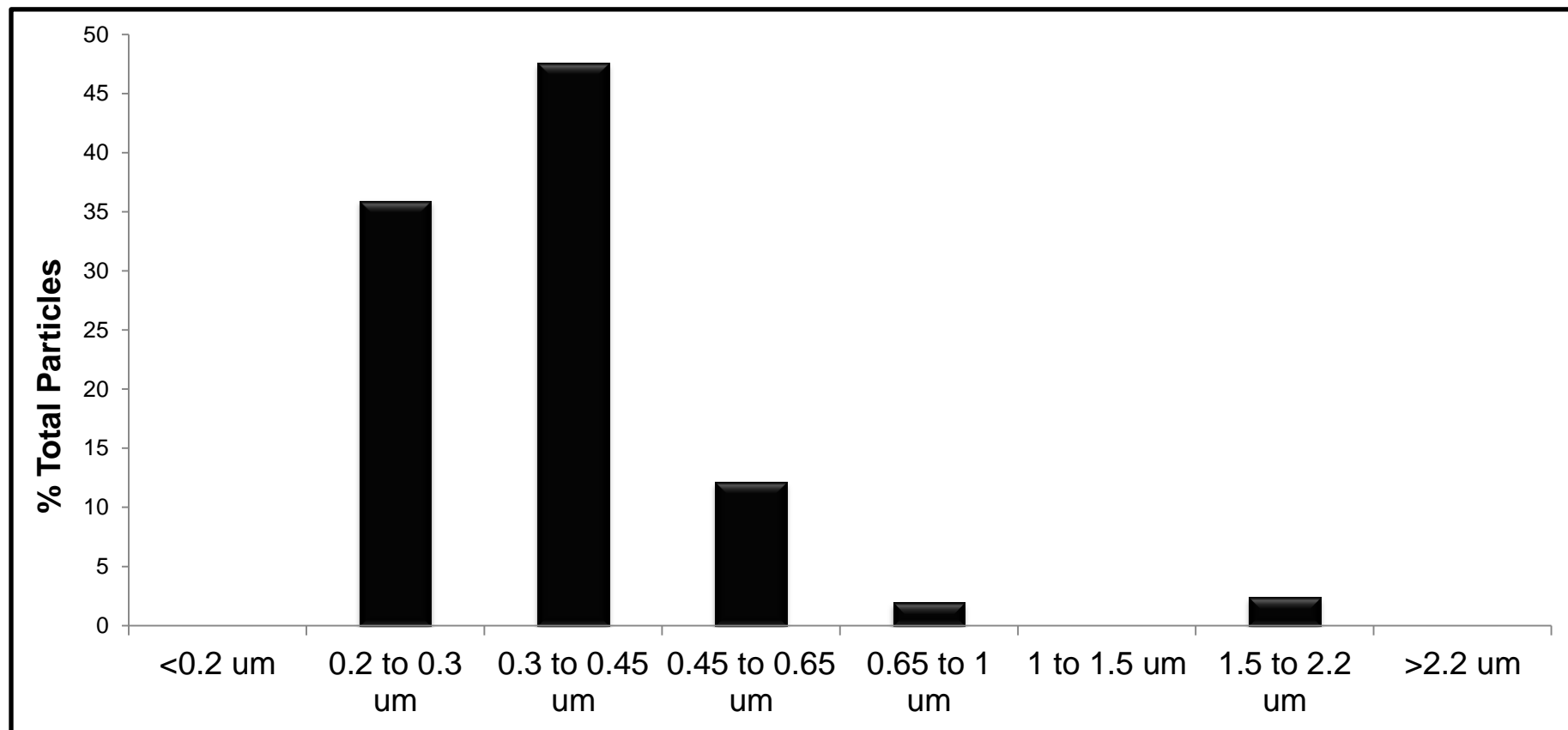


*For these preliminary tests, a used, dirty valve was used
results are not representative of new, clean valves



Results – OPC particle counts



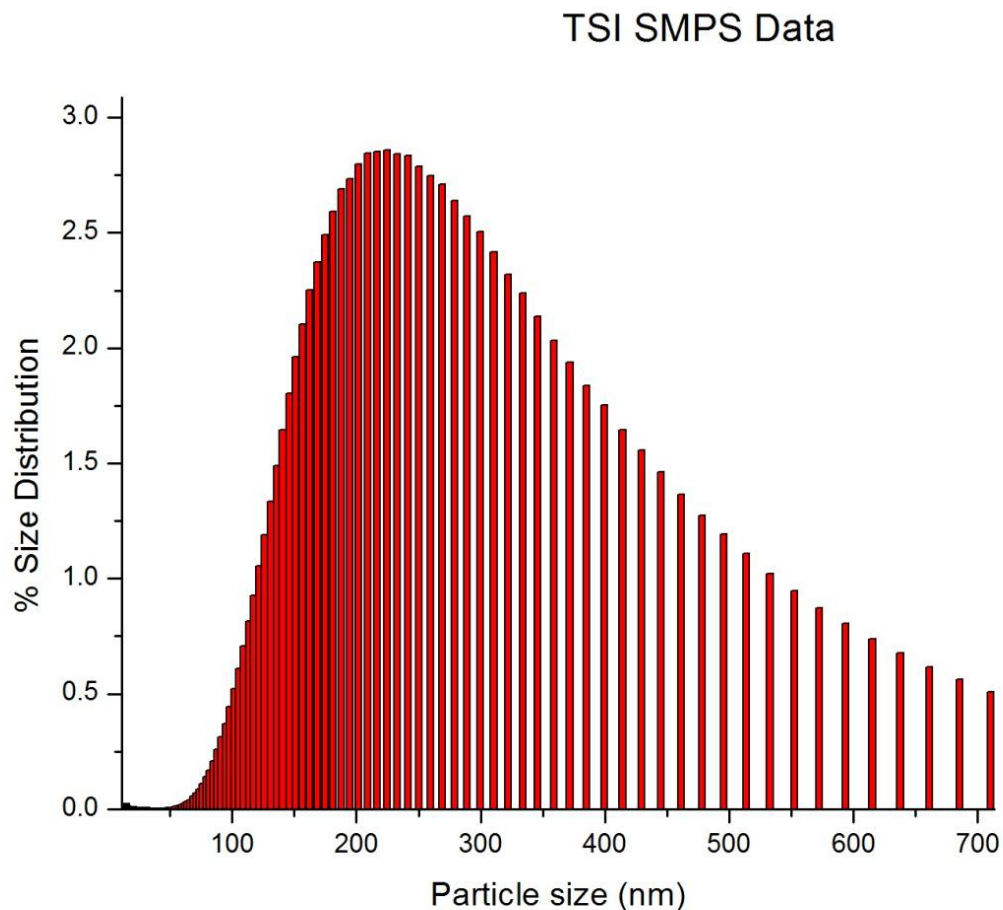


NOTE: The Stiletto particle counter has capability of measuring particles in the size ranges between 220 nm and 2.2 microns.



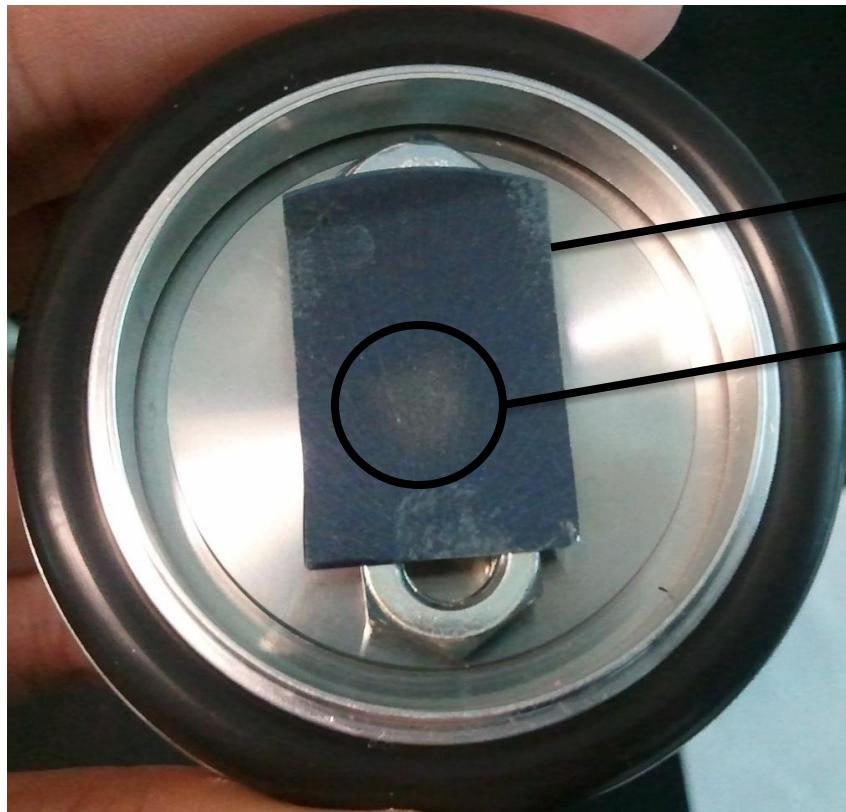
- TSI 3772 CPC was connected to TSI SMPS Sizer
- The SMPS gives size distribution based on electrical mobility

From this valve,
mean particle size
> 200 nm





Results – Impactor plate



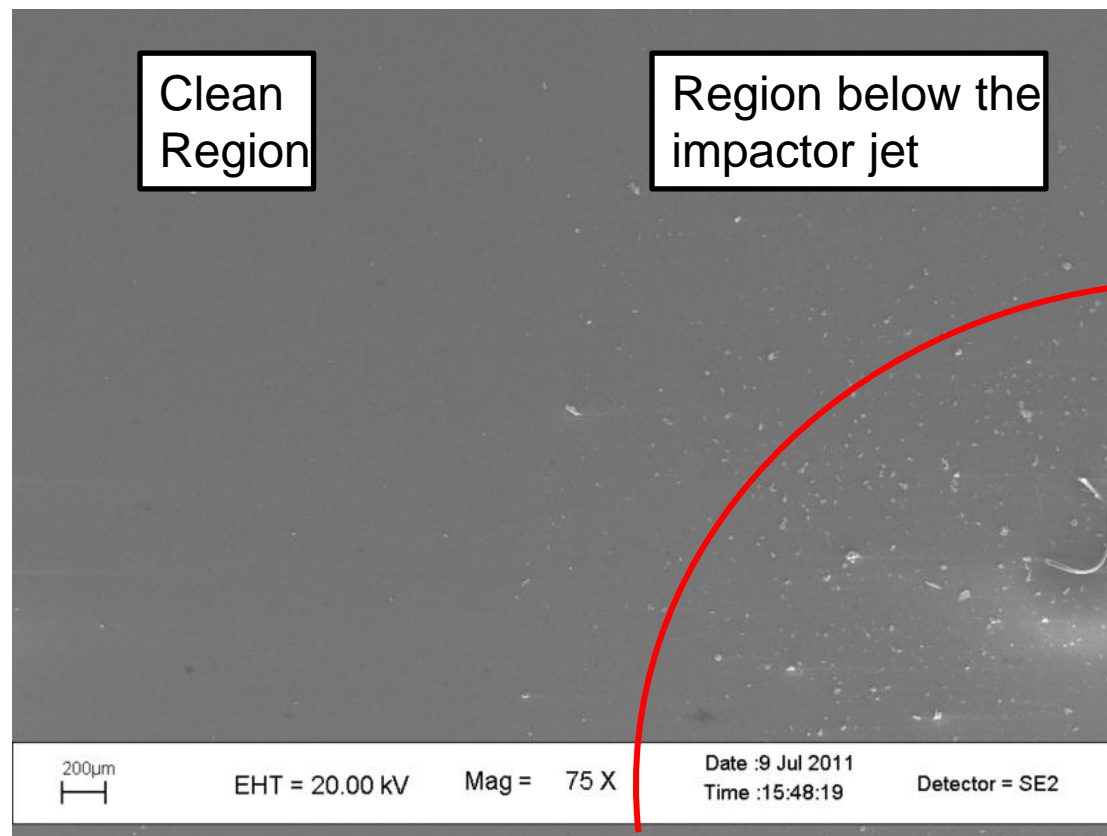
Impactor plate

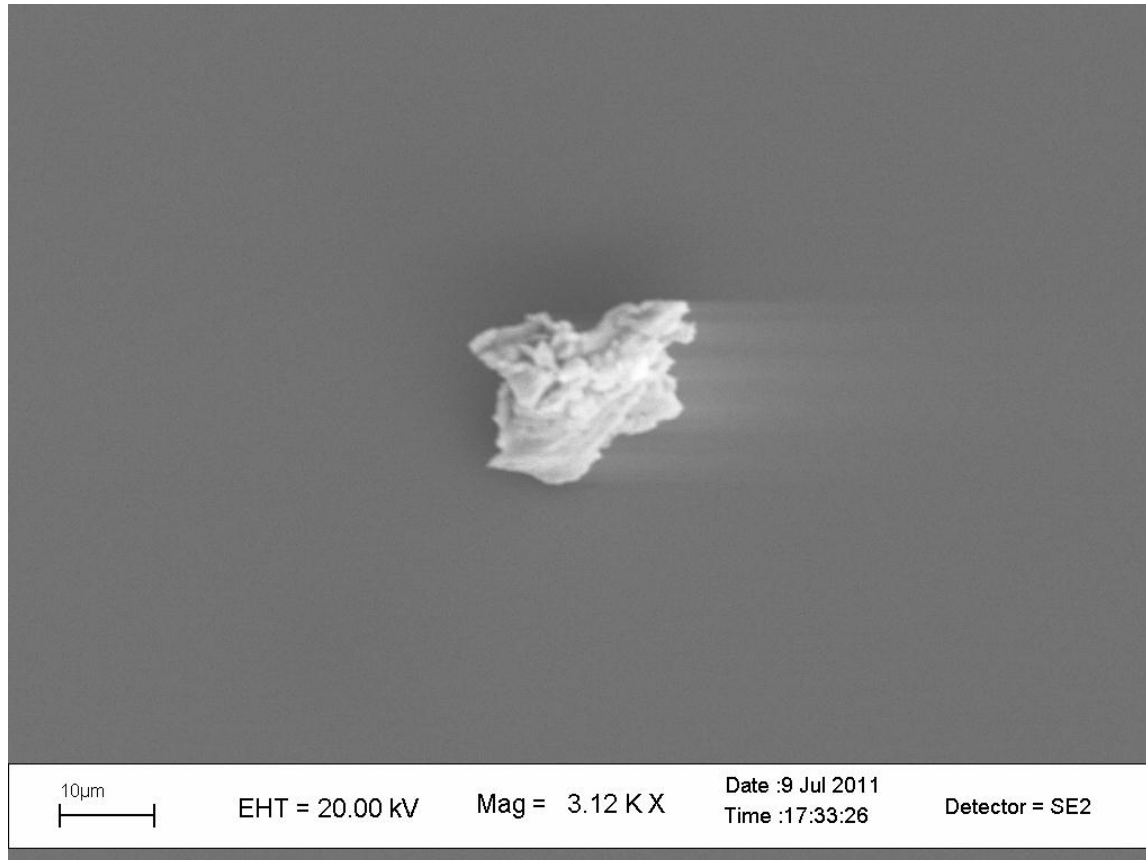
Visible spot – exactly below
Impactor jet



SEM of impactor plate

- Impactor plate coated with 3 nm gold before SEM and EDX analysis
- Clean region is clearly distinguishable from the region right below the Impactor jet



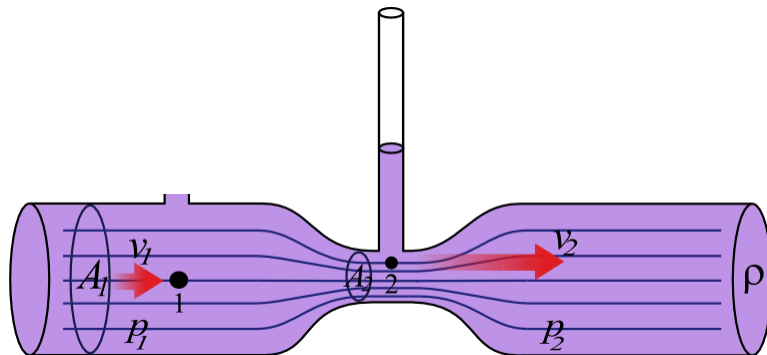


Element	At%
C	72.32
O	3.71
Cr	2.89
Fe	17.66
Ni	3.42
Total	100.00

- Carbon detected is most likely from the spin coated Apiezon grease
- Clean indication of metallic components – possibly stainless steel from bellows



- There is a need to monitor particles in mask tools which operate in vacuum – to sizes not achievable with optical particle counters
- At atmospheric pressure, aerosol particle tools can be used for particle counting (CPC), particle size measurements (SMPS + CPC), and composition analysis (Impactor + SEM/EDX)
- Methods to cleanly transport particles from vacuum to these atmospheric pressure detection and analysis tools are not readily available
- One of the potential solutions we are examining is to use Venturi pumps for this clean extraction of particles from vacuum for measurement





- Integrating vacuum system with CPC for real-time detection of particles 5 nm and larger
- Improve impactor plate design to trap particles with a broad size distribution
- Study transport of particles in presence of ion beam
- Study interaction of different shield materials