# Calibration of Optical Particle Sizer by Wafer Surface Scanner

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## Abstract:

**An optical particle sizer (OPS) is typically calibrated using polysterene latex (PSL) spheres and an electrometer, or similar instruments. However, these current calibration methods require high particle concentrations. Our project designed a low-concentration calibration method with micrometer-sized PSL particles for the OPS. By depositing a controlled number of particles on the wafer surface, we could calibrate the OPS based on the wafer surface scanner's (WSS) analysis of the deposited particles. In this experiment, we used a settling chamber for deposition. Residue particles were a primary problem. A long differential mobility analyzer (DMA) and a virtual impactor were included to decrease residue particles and increase the 3 $\mu$m particle concentration into the targeted range of 10-100 particles/L. We also tested for background residue particles and the application of an electric field in the deposition chamber. Our best trial obtained 70%-80% 3 $\mu$m particle deposition. Future work will explore residue particle sources, WSS accuracy, DMA effectiveness, and flow rate control.**

## Experimental Procedure:

In Figure 1, our general deposition and calibration process is outlined. Stemming from a compressed air source, we used a nebulizer without an impactor plate that was effective with 3 $\mu$m PSL spheres as our aerosol source. Two driers evaporated droplets and combated residue particles created by empty droplet deposition.

The virtual impactor with a 0.185 cm nozzle increased the 3 $\mu$m concentration. The total-minor flow ratio controlled the impactor's cutoff diameter. The cutoff diameter was 2.9 $\mu$m for a 10:1 flow ratio [1]. We sought a slightly smaller ratio, 3 liter per minute (lpm) total flow and 0.35 lpm minor flow, so that the majority of the 3 $\mu$m particles would be collected from the minor flow exit.

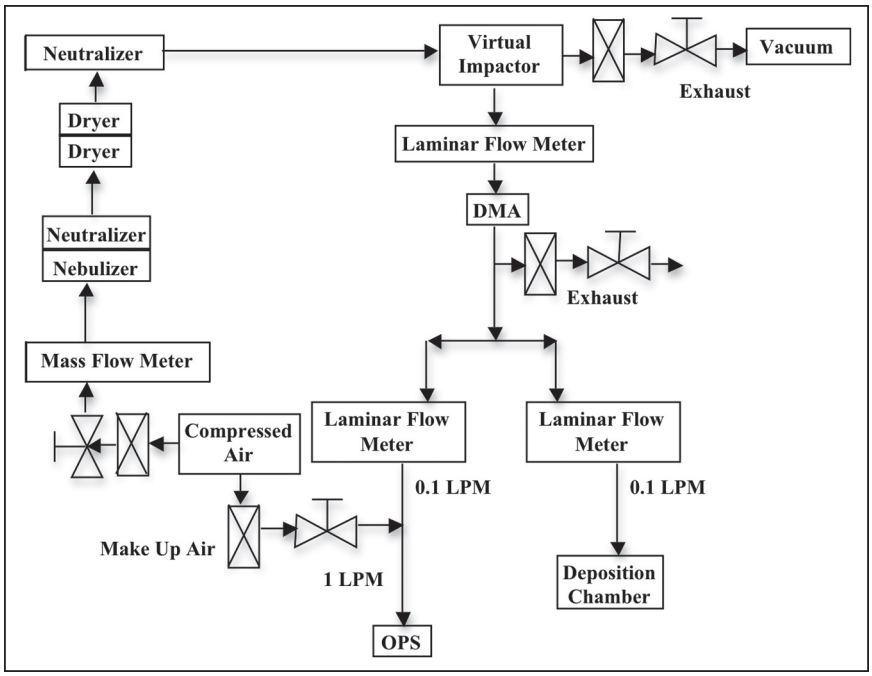


*Figure 1: Experimental setup used for OPS and WSS comparison.*

The long DMA helped create a monodispere aerosol of single-polarity doubly-charged 3 $\mu$m particles at a 0.3 lpm aerosol flow, 1.4 lpm sheath flow, and 9 kV potential [2]. We decided to use the higher sheath flow and pass through doubly-charged particles in order to decrease the likelihood of residue particles diffusing through the DMA.

Using a flow splitter and laminar flow meters (LFM), we ensured equal particle concentration and controlled flow rates entered the OPS and deposition chamber for accurate particle count comparison. Inside the self-enclosed settling deposition chamber, the wafer had a 5 mm separation from

the aerosol entrance. For 3 $\mu$m particles, the deposition radius calculated to fit within a wafer diameter of 4 inches (10.16 cm) was solved as 1.69 inches (4.3 cm) for a flow rate of 0.1 lpm [2]. Because the settling velocity was greatest for gravitation when compared to electrostatic precipitation and thermophoresis, it was deemed the primary method for particle deposition. However, an electric field in the settling chamber was employed to increase particle settling velocity and enhance deposition results. From the chamber, the wafer was physically transferred to the WSS to have particles sized and counted.

| | Wafer 6301 | Wafer 6303 | Wafer 6304 |
|---|---|---|---|
| Input Flow (LPM) | 3 | | |
| Aerosol Flow (LPM) | 0.35 | | |
| Sheath Flow (LPM) | 1.4 | | |
| DMA Voltage (kV) | 0 | 9 | 9 |
| OPS Particle Count (3.01 µm) | | 958 | 835 |
| WSS Particle Count (0.6 µm–4µm) | | 744 | 1721 |
| WSS Particle Count (0.7 µm–4µm) | | 675 | 1516 |
| Notes | Cleanroom contamination test | Best trial | Electric field (-6 kV/cm) |

*Figure 2: WSS and OPS test conditions and particle count comparison.*

## Results:

Figure 1 illustrates our deposition setup. Figure 2 describes the test conditions for each wafer deposition trial and the comparison of particle counts between the OPS and WSS. It should be noted that the OPS had a sharp peak at its 3 $\mu$m channel while the WSS had a flat and broad peak from its 0.6 and 0.7 $\mu$m channel to the 4 $\mu$m channel. The significant number of particles smaller than 0.6 $\mu$m identified by the WSS were probably from corona discharge inside the DMA. However, there was also concern that the WSS may not be assigning particles to the correct sizing bin. Preliminary checks of WSS sizing accuracy with a scanning electron microscope confirmed our suspicions and indicated that particles from the 0.6 $\mu$m channel through the 4 $\mu$m channel were actually 3 $\mu$m PSL spheres. For this reason, we included counts in this range from the WSS for our particle deposition totals.

From wafer 6301, we estimated cleanroom contamination as 20 particles per channel from 0.4 $\mu$m to 7 $\mu$m channels. Figure 3 shows wafer 6303, our best trial. Approximately 70% to 80% of the 3 $\mu$m particles identified by the OPS were captured. In Figure 3, the deposition pattern appears even and few particles were identified near the edge. This result corroborated our calculations for the settling radius and validating our settling technique. Wafer 6304 was set at a potential of -6 kV/cm to increase the deposition velocity of 3 $\mu$m particles increase deposition. The wafer particle deposition significantly exceeded OPS measurements. Due to this result and the burn marks found inside the chamber, we concluded that electrical arcing within the deposition chamber may be creating additional small particles to settle on the wafer.

## Future Work:

We seek a 3% to 10% uncertainty in our combined deposition-WSS method. A refined method of measuring the 0.1 lpm flow to the OPS and deposition chamber is needed. Also, the effectiveness of DMAs at low sheath flow rates should be investigated. To decrease residue particle size and concentration, an impactor plate may be added to the aerosol nebulizer to minimize the production of large droplets. While the electric field increased total particle deposition, the effects of arcing should be explored. Finally, the WSS's size channel allocation accuracy should be evaluated further with a calibration wafer or by other trials with various PSL sphere sizes.

## Acknowledgements:

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## References:

[1] Bernard Olson (private communication).

[2] Hinds, W.C., Aerosol Technology, John Wiley & Sons, Inc., New York 1999.

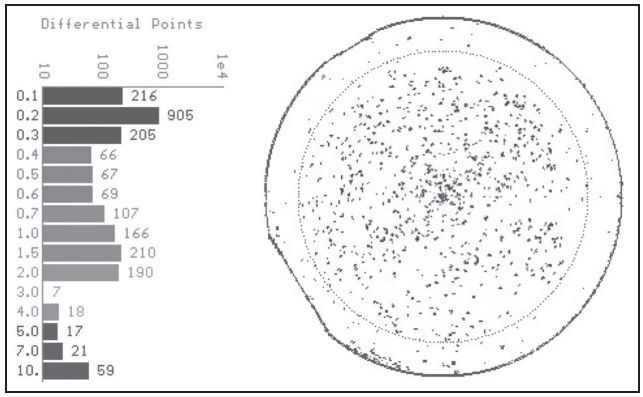


*Figure 3: Wafer 6303 (best trial) deposition and size distribution.*