Aerosol Concentration Calibration Method for Particle Sizes from 1 to 8 Microns

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This talk describes a calibration method for instruments that determine aerosol particle concentration, such as optical particle counters (OPC's). Superficially, this goal appears simple; one presents aerosol samples of known concentration to a measurement instrument, and then compares the known and measured values. However, in practice, three main sources of difficulty arise: 1) absence of a traceable aerosol number concentration standard (Yli-Ojanpera *et al* 2012), 2) aerosol generation with a controlled constant particle concentration and 3) transfer losses. Here, we discuss approaches for potential solutions of 1) and 2) for micron-sized particles.

Prior aerosol concentration standards have been established for particle sizes between 0.01 and 0.5 µm using an aerosol electrometer (AE) and a condensation nuclei counter (CNC) (Fletcher *et al* 2009, Yli-Ojanpera *et al* 2010). However, it is difficult to extend this approach to particle diameters larger than ≈ 0.5 µm. An inkjet aerosol generator has been used as a secondary standard to calibrate a CNC up to approximately 10 micron (Yli-Ojanpera *et al* 2012). Recently a method to establish a primary level concentration standard for micron-sized particles was demonstrated (Li *et al* 2014).

Wafer Surface Scanners (WSS) are commercial instruments widely used the semiconductor integrated circuit industry for qualifying silicon wafers that are able to detect surface defects and deposited particles down to at least 0.1 micron in size. Standard silicon wafers on the order of 20 cm in diameter can be scanned in minutes.

In our calibration approach, a monodisperse aerosol generated at a stationary rate from a suspension of polymer spheres is introduced simultaneously to an OPC and to an aerosol settling chamber. A Si wafer was used as deposition surface in the reference chamber, and a WSS certified its cleanliness before exposure, and provided a total particle count afterward. Comparison of the total counts on the wafer to the OPC total counts permits a determination of OPC efficiency. Experimental design details and sources of uncertainty are provided in Li *et al* 2014. However, autonomous operation and speed of the WSS processing makes analysis of multiple samples with large numbers of particles feasible. Additionally, the uncertainty of the WSS measurements can be independently characterized by lithographically constructing "particles" of a specified size at known, selected locations onto reference silicon wafers. These structures then serve as artifacts that can be used to either cross check different WSS devices, or the same device in time. Figure 1 shows a comparison of CNC correction factors measured with an AE, with factors obtained with the WSS. The two methods extend the combined particle size range nearly three decades, and excellent agreement between the two methods is shown in the overlapping size region.

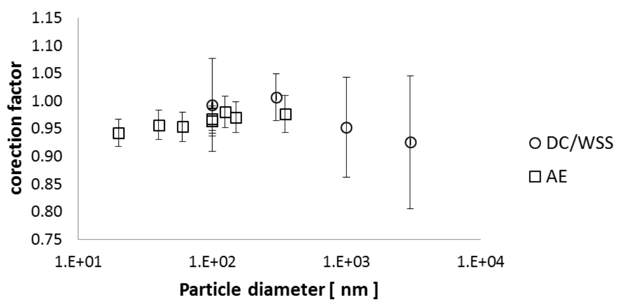

Figure 1. This is a comparison of two methods of aerosol concentration measurement standard determination.

Using this as a method to determine OPC concentration measurement efficiency for particle sizes in the micron range permits construction of a standardized aerosol generator to provide specific known number concentrations. We have developed a simple design based on a Collison nebulizer as an aerosol source, and an OPC to monitor total output particle concentration. The OPC output data is used to provide feedback control of the nebulizer pressure and hence its generation rate. The nebulizer output is mixed with a controlled flow of conditioned dilution air for the final aerosol output. With this arrangement, we have demonstrated; (a) controlled particle concentration to a level where temporal variation of particle counts is dominated by Poisson statistics, and (b) dynamic, real-time control of the concentration level over a number concentration range by a factor of at least 8x. The absolute value of aerosol concentrations can be selected over a wide range, based on the concentration of polymer bead liquid suspension. Total flow is monitored, and can be selected over a range from 20 to 60 lpm. L2 Defense, Inc. (Columbia, MD, USA) plans to offer a commercial version of this device later this year (2016).

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