
NanoVision Technology®

Enables Particle Monitoring of High Molecular Scatter Chemistries

Abstract

Semiconductor manufacturing utilizes ultra-pure chemistries which frequently have significant molecular scatter. This high molecular scatter reduces the signal-to-noise efficiency of older particle metrology technology and in some cases prevents its application in more demanding chemistries. In production, an adaptable metrology solution is required to effectively characterize the broad range of chemistries and solutions in use. NanoVision Technology, integrated into the UltraChem family of products, includes a self-referencing correction that eliminates molecular scatter variations from the measurement. UltraChem products are available in both in-line and discrete sampler configurations to provide a flexible metrology solution in continuous distribution and process point-of-use measurements. This improvement in data quality and repeatability provides the most accurate measure of process chemistry quality throughout the semiconductor manufacturing process.

Challenging Sample Media

Specialty liquid chemicals are used throughout semiconductor manufacturing for lithography, deposition, etching, planarization and stripping applications. With the exception of planarization slurries, these chemistries are ideally devoid of particulates. Chemistries range from pure acids and bases to blended solutions in a wide range of concentrations. Each chemical variant offers its own unique mix of refractive indices, molecular scatter and vapor pressures. Molecular scatter in this instance refers to light scattered from the chemical molecules themselves. The mechanisms that influence molecular light scatter intensity in pure fluids include density, anisotropy, and temperature/density fluctuations¹. Molecular scatter in solutions is also impacted by additional mechanisms including concentration fluctuations and intramolecular interference.²

Common high molecular scatter fluids include photoresists, solvents (ethyl lactate, PGMEA), developers (TMAH), and concentrated acids like H_2SO_4 . As with any particle metrology system, it is imperative that the sample media be delivered in a manner to optimize data quality. Sample locations should be chosen to ensure a well-mixed and representative sample. If using an inline pressurized delivery system, ensure flow restriction is made below the particle counter to avoid pressure drop within the measurement cell, which could otherwise cause bubble formation. While sample handling and conditioning has been addressed for many years, until recently it was not possible to accurately compensate for molecular scatter variances.

Limitations of Legacy Technology

All optical particle counters (OPCs) designed for use at $< 1 \mu m$ utilize a form of optical scatter measurement. Essentially, the sample medium is bombarded by a high intensity light source and the light scattering off the particles and sample medium is then directed in whole or in part to a detector for analysis (Figure 1).

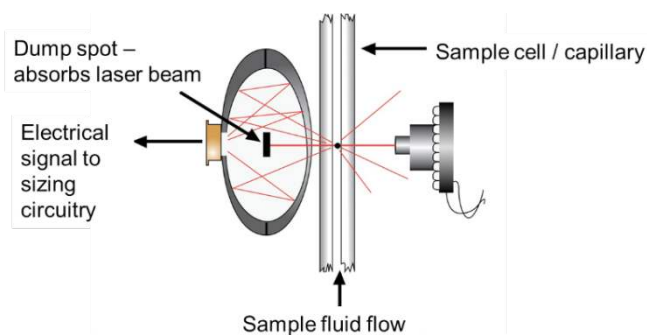


Figure 1 Conceptual liquid optical particle counter

Older particle counting techniques utilize single element photo detectors or simple array detectors. In single element detectors, the aggregate molecular scatter from the entire view volume within the cell creates a baseline noise level. In arrayed detectors, the aggregate molecular scatter is essentially divided by the number of elements within the detector array. As the molecular scatter increases, the particle counter's ability to differentiate between molecules and particles diminishes (a reduction in signal-to-noise ratio). In extreme cases, the particle counter becomes optically limited and counts noise, which typically occurs in the first size channel. **Figure 2** illustrates this effect in a conventional optical particle counter as measured with an oscilloscope directly from the detector. Particles near first channel sensitivity and the resultant electronic signal are shown in ultra-pure water and a high molecular scatter chemical. When viewing reported OPC data, excessive molecular-scatter-induced false counts typically appear as an abnormal particle size distribution (**Figure 3**).

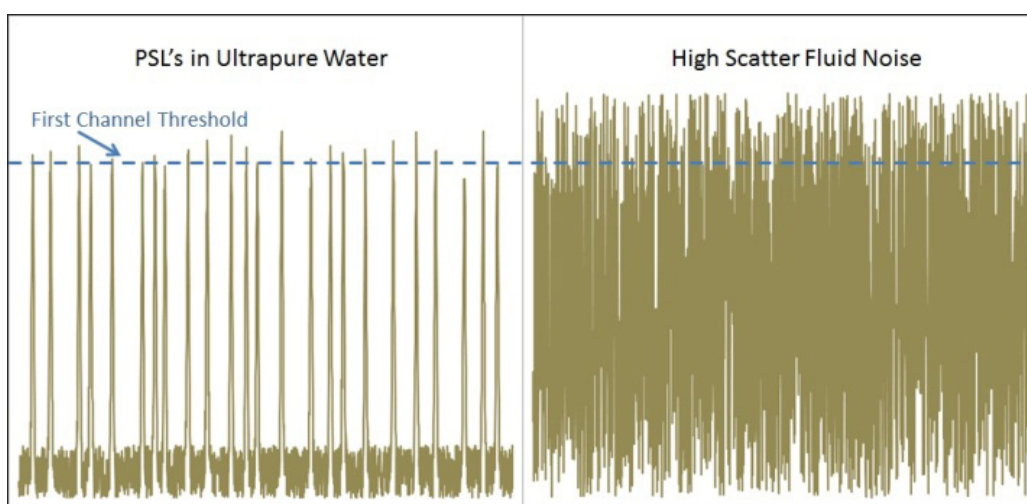


Figure 2 High molecular scatter impacting the first size threshold on a conventional OPC (Oscilloscope Data)

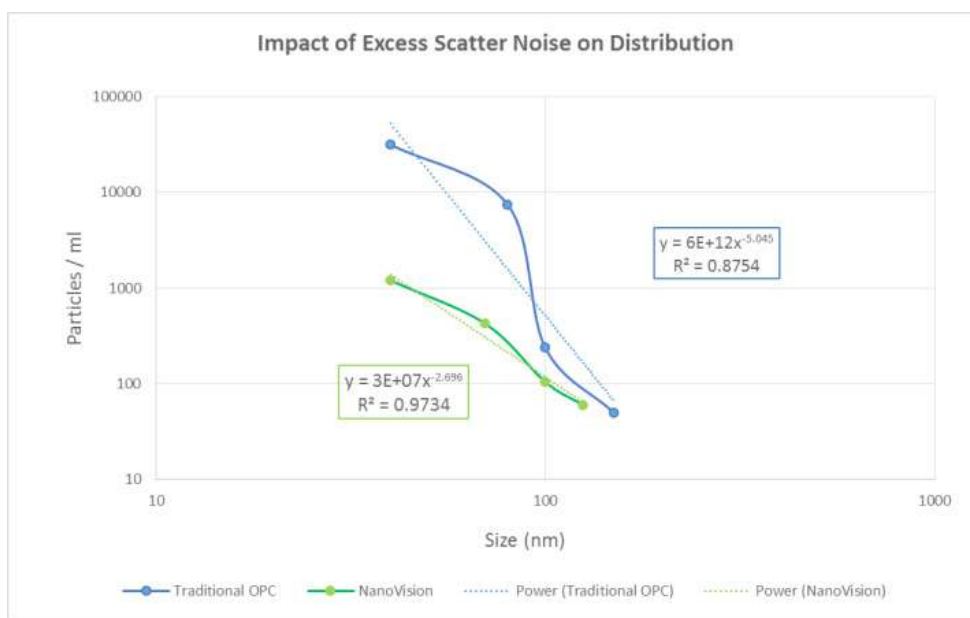


Figure 3 Molecular scatter noise impacting 1st and 2nd channel of traditional OPC (specialty developer chemical TMAH)

A Novel Approach

NanoVision Technology, integrated into the UltraChem family of products, provides a novel approach to measuring high molecular scatter fluids by utilizing a patented high-resolution multidimensional detector. Like the simple array detector in use over the past 25 years, this high resolution detector reduces the impact of molecular scatter on the sample measurement by a factor of > 1000. In addition, the digital processor in the NanoVision Technology products supports a real-time background subtraction mechanism that can also compensate for minor variations in individual pixel performance (**Figure 4**). Like a precision space telescope, NanoVision products are able to update and subtract reference frames from the measured image creating a clear view of the low intensity localized events (particulates) in low and high molecular scatter fluids.

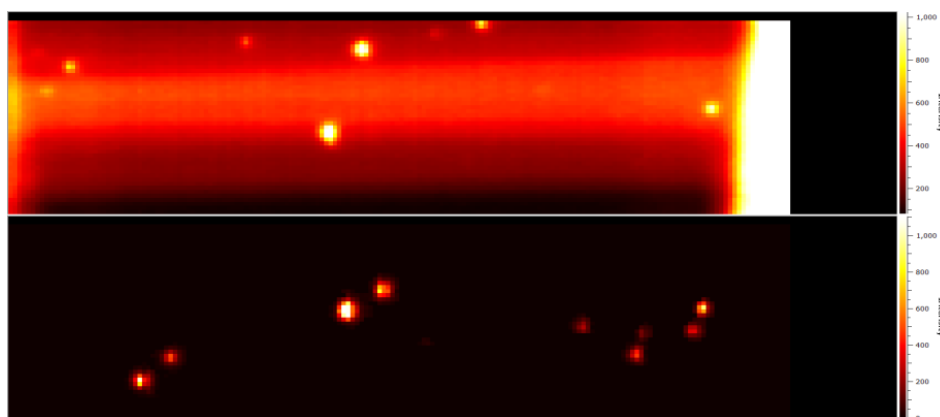


Figure 4 Raw sample image vs. background corrected image

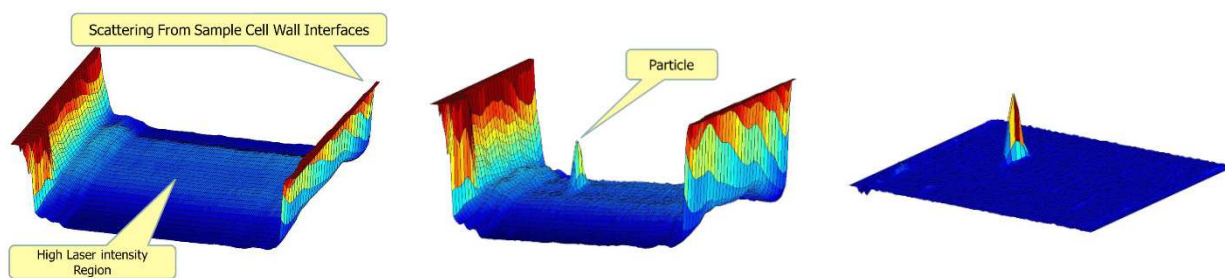


Figure 5 Background image → Image with particle → Image of isolated particle

A sequential illustration of the process is provided in **Figure 5**. Expanding upon this fundamental noise elimination technique, NanoVision Technology products include an adjustable sample view mode to narrow their focus within the beam. This further reduces the effect of molecular scatter in extreme cases. In combination, these techniques allow NanoVision Technology products to characterize particulate contaminants in chemicals previously unmeasurable.

Flexible Metrology Solution

UltraChem products are available in both in-line and discrete sampler configurations (Figures 6 and 7) to provide a flexible metrology solution in the varied applications within the semiconductor production environment. Syringe-based systems such as the SLS-1040 or SLS-1100 provide a convenient means of performing incoming quality assurance on delivered chemicals in both small and large volume containers. This same system can be used within the fabrication facility to spot check process chemistries at point-of-use or point-of-process. Point-of-use monitoring helps provide data-driven optimization of process settings by accurately measuring cleanliness recovery rates. Real-time measurement supports implementation of data driven maintenance intervals and helps identify upstream failures or gradual performance degradation before yield impact occurs.

In-line continuous sampling versions are ideal for bulk chemical delivery within the manufacturing environment and for incoming quality checks of bulk tankers delivering to a large distribution system. These systems may also be used for point-of-use applications providing continuous flow or chemical polishing.

Unprecedented Visibility and Control

NanoVision Technology offers distinct advantages over traditional optical particle counters for specialty chemical characterization. The new measurement techniques effectively reduce the impact of molecular scatter and provide a much more accurate and repeatable characterization of particulate levels. With in-line and sampler configurations, UltraChem products provide a flexible platform for continuous and discrete sample measurement in all stages of the manufacturing process. The combination of data quality and process adaptability provides the most accurate measure of process chemical quality throughout today's semiconductor manufacturing process.

References

1. I.L. Fabelinskii, *Theory of Light Scattering in Liquids and Solids*, Adv. Phys. Sci., 1957, (USSR), 63:474.
2. Boon, J.P. and Fleary, P.A., eds., *The Spectrum of Light Scattered by Fluids*, Adv. Chem. Phys., XXIV.



Figure 6 UltraChem 40 in-line particle counter



Figure 7 SLS-1040 syringe particle counter