CLEANROOM MONITORING NEWS
ELECTRONICS

PARTICLE MEASURING SYSTEMS

June 9, 2010 - Issue 1, Volume 1

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- **Particle College** August 10-11

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FIXED LOCATION PARTICLE MONITORING STRATEGY

How can I best utilize today's particle monitoring technologies to effectively detect cleanroom contamination events while minimizing labor and equipment resources that are better used elsewhere?

This question gets to the heart of particle monitoring strategy. The best solution would be to monitor continuously for all particle sizes in all locations; unfortunately, that is neither a cost-effective or practical solution. Strategically, it must be decided by contamination control experts how to maximize coverage (both from a particle size standpoint and a physical area covered) while balancing other considerations such as monitoring budgets and labor availability.

Generally, the first priority for ensuring particulate contamination control in cleanrooms is to always detect, reduce, and eliminate large particles. Regardless of industry, large particles kill yields; they don't discriminate because the final product is an integrated circuit, flat panel display, hard disk drive, or a critical aerospace optical component; if large particles are present, consistent and high yield levels are difficult to maintain.

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PRODUCT SPOTLIGHT

Airnet® II Particle Sensor

Continuous low-cost particle counters are available in various styles and with many different features. Featured products include the Airnet 201 and the new Airnet II 301. A quick comparison of the Airnet 201 and the Airnet II 301 shows the capabilities available for low-cost particle detectors. *Read More...page 3*

APPLICATION OF LOW COST FIXED LOCATION PARTICLE MONITORS

Relative to the cost of maintaining a contamination-free cleanroom, the cost of fixed-point monitoring is trivial. Consider the costs incurred in the pursuit of minimizing or preventing particle contamination within a cleanroom:

- Large particulate "bag-filters" are used upstream of make-up air handling systems.
- Fine particulate filters are installed on both make-up and recirculated air handling systems.
- HEPA filtration is installed in the overhead ceiling.
- Laminar flow is maintained to minimize turbulence which may incite particle formation and accumulation.
- Employees, prior to entering cleanrooms, put on smocks or gowns to cover nearly every part of the body. *Read more....page 3*

TESTING VALVES FOR PARTICLE GENERATION

Industry standards continue to push toward cleaner processes, and valves have always been notorious for generating particles. Over the years, Particle Measuring Systems (PMS) has been asked to recommend a particle-free valve for specific processes. PMS has not defined a specific valve or manufacturer that meets particle-free operation, but we have developed guidelines for testing particle contamination generated by valves. This paper will discuss those guidelines. *Read more....page 4*

FIXED LOCATION PARTICLE MONITORING STRATEGY

Problem Statement:

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Particle Monitoring Strategy

This question gets to the heart of particle monitoring strategy. The best solution would be to monitor continuously for all particle sizes in all locations; unfortunately, that is neither a cost-effective or practical solution. Strategically, it must be decided by contamination control experts how to maximize coverage (both from a particle size standpoint and a physical area covered) while balancing other considerations such as monitoring budgets and labor availability.

Generally, the first priority for ensuring particulate contamination control in cleanrooms is to always detect, reduce, and eliminate large particles. Regardless of industry, large particles kill yields; they don't discriminate because the final product is an integrated circuit, flat panel display, hard disk drive, or a critical aerospace optical component; if large particles are present, consistent and high yield levels are difficult to maintain.

This implied requirement to detect all large particles in advanced technology manufacturing works in the favor of those same manufacturers, considering the spectrum of particle counting equipment available today. Simple laser-diode based instruments are available for detecting large particles (≥ 0.3 µm) which are extremely small and can be deployed in nearly any location. These particle counters operate continuously and due to their low-cost, can be implemented in significant quantities throughout the cleanroom or manufacturing facility and within process tools. On the opposite end of the spectrum, however, are more advanced particle counters which detect extremely small particles sizes (≤ 0.1 µm), are much larger (which limits locations they can be placed), generally don't run continuously, and may take a more sophisticated user to operate.

Recently, advanced technology manufacturers have been adopting particle detection strategies which incorporate large numbers of low-cost continuous aerosol particle counters in fixed locations in cleanroom process bays or within process specific tools in order to immediately detect any large particle event. Benefits from this strategy include:

Low cost	Given a fixed budget, more units can be installed allowing for greater area coverage with minimal capital investment.
Continuous	These fixed aerosol monitors will immediately identify those particles which are guaranteed killers, namely large particles greater than 0.3 µm.
Footprint	A compact size allows for placement in nearly any location.
Predictive	It is well known that environmental particles tend to follow a nearly 1/r2 distribution (r = particle radius). Detecting larger particles in the immediate environment also provides an extrapolative mechanism to estimate the concentration of smaller particles within the same environment.

The requirement for monitoring smaller particles is not eliminated; small particle detection still remains essential as part of an effective overall particle monitoring strategy. However, ensuring detection of large particles as a "first line of defense" is proving a reliable means for ensuring processes, equipment, and cleanrooms are well controlled.

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PRODUCT SPOTLIGHT - AIRNET II

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	Airnet 201	Airnet II 301
Size (l, w, h)	17 x 12 x 14 cm	14 x 9 x 10 cm
1st Channel Size	0.2 µm	0.3 µm
2nd Channel Size	0.3, 0.5, or 1.0 µm	0.5 µm
Max. Particle Concentration	1,000,000 / ft^3	5,100,000 / ft^3
Communication	Ethernet, RS-232, 4-20mA	Ethernet, RS-232, 4-20mA (opt.), OPC (opt.)

APPLICATION OF LOW COST FIXED LOCATION PARTICLE MONITORS

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- Large particulate "bag-filters" are used upstream of make-up air handling systems.
- Fine particulate filters are installed on both make-up and recirculated air handling systems.
- HEPA filtration is installed in the overhead ceiling.
- Process tools include specific particle filtration with some tools having their own air recirculation systems.
- Laminar flow is maintained to minimize turbulence which may incite particle formation and accumulation.
- Employees, prior to entering cleanrooms, put on smocks or gowns to cover nearly every part of the body. In addition, the process in which that clothing is donned is systematically chosen to minimize particle transfer. Particles are blown off of the smocks and gowns using forced air immediately before employees can enter a cleanroom.
- Equipment entering cleanrooms receives multiple stages of wipe-downs in order to remove particles that may remain from the assembly and/or shipping process.
- Products and some support equipment are transported and stored in enclosed containers (FOUP's, FOSB's, Reticle pods, wafer stockers, etc.) designed to prevent particulate contamination from reaching the critical components inside of the enclosure.

Low-cost, fixed-point particle counters that are pervasively distributed throughout the cleanroom protect the products that the above investments are designed for. If a HEPA filter seal within a process tool develops a small pinhole leak that goes undetected due to a lack of particle monitoring, not only is the investment of that protection system lost, but the

APPLICATION OF LOW COST FIXED LOCATION PARTICLE MONITORS *CONTINUED*

exposure of additional losses due to product yield loss from such a defect will far exceed the HEPA filter investment costs.

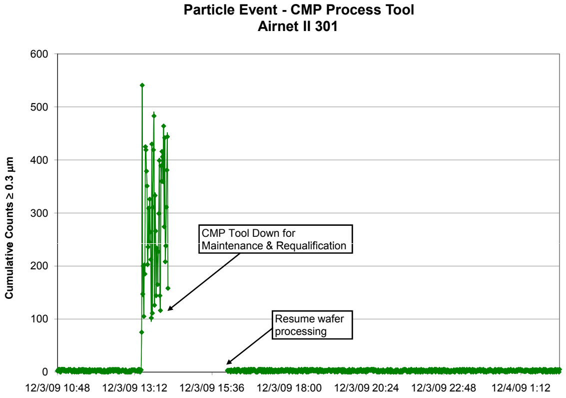
The benefits from such a strategy are exhibited in Figures 1 and 2. In a CMP process bay, particle monitoring is normally covered by a single 0.1µm particle counter placed in the center of the room. However, product risk or exposure largely occurs only when the wafers are inside of the mini-environment or within the process tool. To supplement the primary particle monitoring strategy, six low cost Airnet II 301 (≥ 0.3 µm) particle counters were installed within each CMP process tool to detect large particles suspected of causing micro-scratches, dishing, and digs in an oxide planarization process. Subsequent via formation and deposition processes can fill these defects with metal which cause die loss at electrical test with failures attributed to "opens" or shorting of the circuit by unintended metal bridging between neighboring vias.

Figure 1. Metal Bridge Caused by CMP Dishing

The 0.1µm particle counter, and a 0.3 µm particle counter that was placed beside it within the center of the process bay did not indicate any significant particle events in the process bay. However, data from the Airnet II 301 within one specific CMP tool CP-XXX detected a significant increase in large particle counts; the rapid increase indicated that the cause was very sudden and should be traceable to a specific action or condition that changed in the immediate environment.

This particle source was identified and corrected, however, wafers processed during this time were required to process through additional defect detection and electrical testing (100% inspection vs. random sampling), and additional equipment downtime was incurred as a result of servicing this process tool.

Figure 2. 0.3 µm Particle Counts (CP-XXX)



Summary

Low-cost, fixed point monitors are increasing in popularity for wide area particle monitoring coverage of cleanrooms, as well as individual coverage of process tools. The Airnet and Airnet II products are an important initial technique when defining and executing an effective monitoring strategy for contamination control of aerosol particulates. When combined with specific technologies such as high sensitivity portable aerosol particle counters, manifold monitors and process gas particle detectors, a comprehensive particle monitoring program is achieved that protects critical products as well as the investments intended to ensure maximum yields.

In the next few issues, we will continue to look at additional aerosol particle monitoring strategies and techniques that complement low-cost fixed point monitoring.

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Testing Valves for Particle Generation

Industry standards continue to push toward cleaner processes, and valves have always been notorious for generating particles. Over many years, Particle Measuring Systems (PMS) has been asked to recommend a particle-free valve for specific processes. PMS has not defined a specific valve or manufacturer that meets particle-free operation, but we have developed guidelines for testing particle contamination generated by valves. This paper will discuss those guidelines.

Standards and Suggested Practices

The Semiconductor Manufacturing Technology (SEMATECH) task force wrote guidelines for testing valves, which was later adopted by the American Society for Testing and Materials (ASTM). These guidelines are very comprehensive, so PMS was asked to develop a document that is more streamlined and easy to understand. Still, if you would like to reference the documents mentioned above, here are the specific titles:

> SEMASPEC *Test Method for Determination of Particle Contribution by Valves in Gas Distribution Systems*
>
> ASTM F1394 - 92(2005) *Standard Test Method for Determination of Particle Contribution from Gas Distribution System Valves*

Particle Traps

Commonly, valves are referred to as *particle traps* and for good reason. When the valve is closed, the media (liquid or air) carrying particles can deposit those particles on the valve's closed gate. Then, when the valve opens, these trapped particles will release into the media stream and create a large spike in the particle contamination.

The simple movement of a valve includes frictional components that add particles to the media. Rotating ball valves, pivoting butterfly valves, rising gate valves, and common globe valves all contribute particles to the process. Globe valves (*Figure 1*) are the most common, and as shown in the cutaway view below, particles can stick to any surface that comes into contact with the media. Additionally, the rotating stem creates friction within the threads and this friction creates particles.

Different valve materials, like Teflon®, reduce the frictional component but do not *eliminate* particle generation. Still, Teflon valves are a better choice than most other materials. The tubing connected to the valves often contributes more particles than the valve, so selecting the proper tubing can provide significant particle reduction.

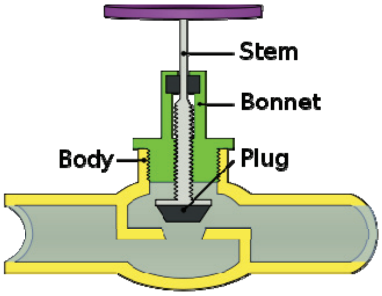

Figure 1: Globe Valve

Particle Tubing

The testing plan should consider the tubing material because it will connect directly to the valves. Then, a well-defined layout for the tubing installation should maximize particle transport. These two factors strongly affect the reliability of valve testing data.

The tubing material is critical, along with the length, diameter, and bends. PMS has performed numerous tests and written several documents that describe tubing for particle transportation. Some tubing materials are not always available or affordable. Table 1 lists the preferred materials for successful particle transport while minimizing particle generation (with the most preferred tubing material listed first).

Stainless steel
Conductive polymer
Polyester
Vinyl (if plasticizer does not interfere)
Polyethylene
Copper
Glass
Teflon
Aluminum

Table 1: Tubing Materials

Bev-A-Line® conductive polymer 3/8" ID tubing is commonly installed with aerosol manifold systems, while Teflon Galtek PFA tubing is commonly installed with liquid particle counter systems. Teflon is used instead of conductive tubing because when sampling polar liquids the electrostatic losses are minimal. Both materials offer superior particle transport, for their respective application, and can be purchase at a reasonable cost.

When planning the tubing installation, the test facility should consider the length, diameter, and bends. Air flow velocity inside the tubing is sharply influenced by the sample tubing and particle transportation will greatly improve with proper tubing selection and installation.

To minimize particle loss in tubing, the tubing should always lie flat (if possible) with minimal bends. If tubing bends are required, the bend radius (measured to the inside curvature) should not be less than 6 inches. Also, the tubing diameter and materials should be conducive to particle transport.

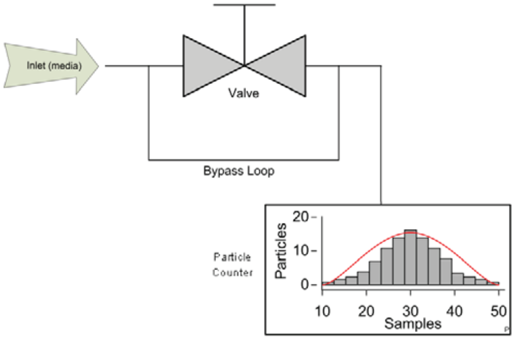

Figure 2: Valve Testing Diagram

Figure 2 illustrates a basic valve-testing platform. The inlet is open to the *media*, either unfiltered or filtered. The media is simply defined as air or liquid that passes through the valve. If using unfiltered media, the background particle counts must be subtracted from the particle counts contributed by the valve. If using filtered media, the background counts should be negligible, so any particle counts should have been contributed by the valve.

Next, the valve is installed in parallel to the bypass loop. The bypass loop provides constant flow to the particle counter; otherwise, low flow conditions will cause the particle counter to stop sampling. Both the bypass loop and the exhaust line from the valve connect to a T-fitting.

The particle counter connects to the other side of the T-fitting. The particle counter's pump or vacuum supply pulls media through the system. As particles are drawn into the particle counter, they will be sized and counted.

Test Procedure

Preparation

1. Verify the particle counter's calibration.
2. Prepare the particle counter's software by entering the test recipe as described below in the ***Testing*** section below.

Testing

Once the system has been prepared for testing, follow the procedure described below. Unless otherwise specified, the same procedure is followed for each test.

1. ***Background Particulate Testing***
   a. Configure the system as shown in *Figure 2*, with the exception of the valve. In place of the valve is a length of tubing (known as a *spool piece*). The particle counter's sample interval is set to 10 minutes, with continuous sampling.
      - Specifically, after finishing one sample interval, the particle counter will reset the data then start the next sample interval.

   b. The particle count data is analyzed at the *smallest particle channel.*
      - The smallest particle channel is defined by the user or process, and meets the valve's purity specifications.

   c. Continuous sampling is taken until a sample interval provides very few particle counts.
      - In air, extremely clean valves produce < 30 particles/m^3 (cumulative counts).
      - In liquids, extremely clean valves produce < 10 particles/mL (cumulative counts).

   d. After successfully performing this test, the data provides the background level of particulate contamination.
2. ***Static Particulate Testing***
   a. Once the background count has been determined, the valve is plumbed into the system in an OPEN position.
   b. The particle counter begins sampling the media for 10 minutes at the flow rate specified by the particle counter.
      - This sample removes any loosely-attached particles in the valve.

   c. The particle counter or software should collect and store all data.
3. ***Dynamic Particulate Testing***
   a. Next, set the particle counter to 20-second sample intervals, continuously, until stopped by the operator.
   b. Close the valve, leave it closed for a 5-second period, then reopen the valve.
      - The particle counter should be continuously recording the data, in 20-second sample intervals.

   c. The particle counter continues to sample particle data until the system returns to the baseline level achieved in Step **3.b**.
   d. Steps **3.b** and **3.c** are repeated twice, for a total of three open/close cycles.

Once the data has been collected and recorded, testing is complete. Remove the valve from the testing platform and begin testing the next valve (if applicable).

Data Analysis

When testing valves, the data will often show a peak as the valve opens. This peak occurs when the particles trapped on the valve are freed into the system. Afterward, the particles reach an equilibrium state and the particle counts may start to gradually decrease.

Figure 3 illustrates data from a 3-port valve, and there are three defined peaks. The first peak occurred when the valve port A was opened. The initial particle surge was followed by a gradual decrease in particle activity.

Near sample 46 in *Figure 3*, the valve was closed, then, quickly re-opened. This created a second peak as the particle surge appeared, then started to diminish until the valve was closed again. When both valves were closed the particle counts were nearly zero.

The third peak occurred when both valve ports open. Since the pressure drop was more gradual, the particle counts slowly increased until they reached equilibrium. Eventually, after enough time passes, we would expect particle counts to fall, but this could take some time.

The third peak clearly illustrates that even when open, valves can add particles to a system. Also, it is important to remember that these particles were not coming from an outside source, as the entire valve was sitting in a HEPA-filtered enclosure. These particle counts were being emitted by the valve assembly.

Summary

The procedures listed in this paper provide a quick method for measuring particle counts contributed by valves. The data from the tests can be used to compare different types of valves or compare similar valves from different manufacturers. Either way, knowing the purity of valves before installation could lead to process improvements and reduce particle contamination in the final product.

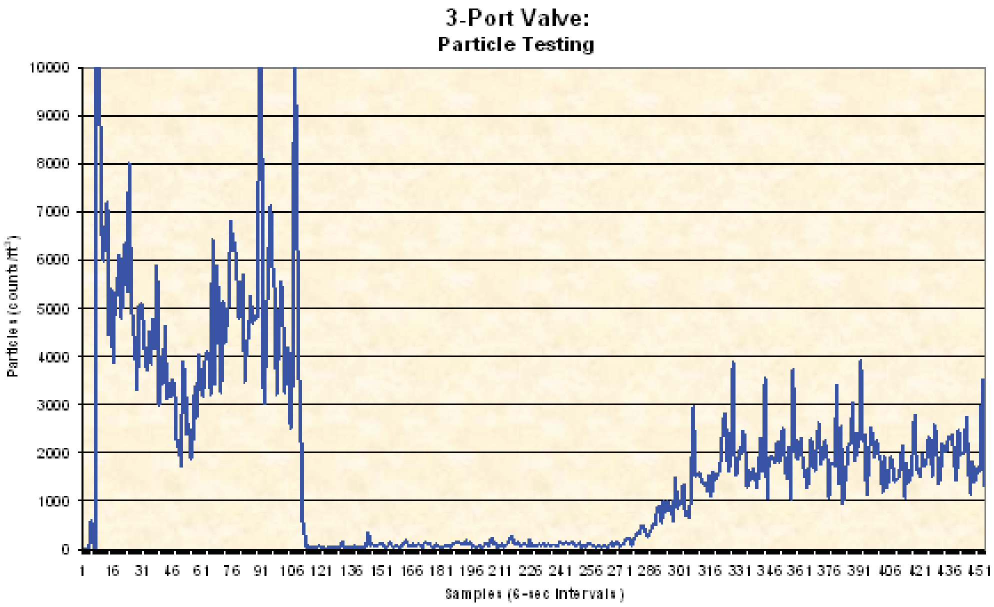

Figure 3: Valve Testing Data

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