Integrated Process Monitoring for Sputter Etch Clean Using a Stiletto IPM Particle Detection System

INFICON

INTRODUCTION

The Stiletto Integrated Process Monitor (IPM) is a particle detection system capable of *in situ* metrology and process control, enabling yield and productivity improvements for the most advanced semiconductor processes. Stiletto is the first *in situ* particle monitoring (ISPM) system to be fully integrated with the process tool. When combined with parametric tool data, particle counts can be overlaid with equipment status to allow engineers to identify the exact time and cause of particle formation. Stiletto's ability to detect particles during every run of every wafer provides unprecedented protection against defect-induced yield loss.

SPUTTER ETCH CLEAN PROCESS

The sputter etch clean process removes native oxide from the bottom of contact and via holes prior to the metal deposition process used in front end semiconductor IC manufacturing. This oxide removal enables good electrical conductivity between the metal and polysilicon levels or between successive metal levels.

Oxide is sputtered from the underlying surface using a low pressure, highly biased Argon plasma. Throughout the process the oxide is re-deposited on the surface of the chamber dome, creating the potential for particle excursions. As the re-deposited oxide grows thicker it will eventually flake off and land on the wafers being processed, causing significant yield loss. Once this flaking occurs, the chamber dome is replaced and a manual cleaning of the process chamber is performed to return the chamber to a baseline, particle-free, condition. By monitoring the chamber condition in real-time it is possible to improve process yields and productivity.

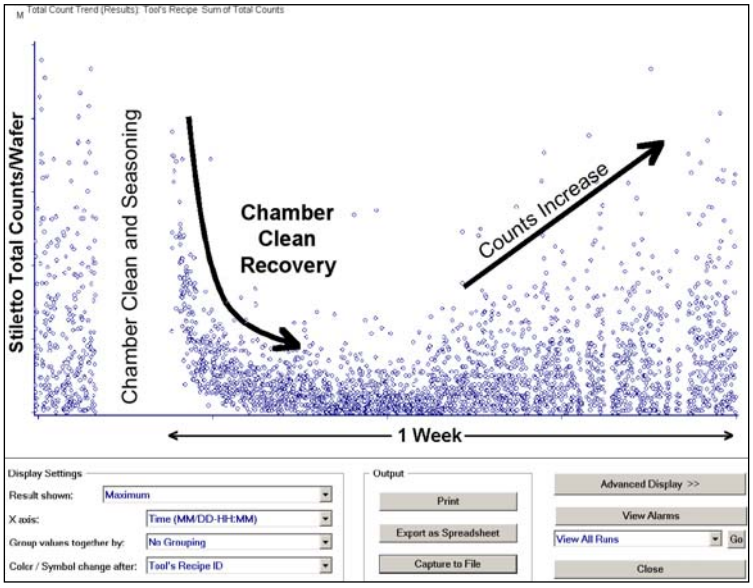

Figure 1. Stiletto data from a single clean cycle on a sputter etch process. Each point is the total particle counts for a single wafer process. Note the increase in counts as the chamber ages.

IPM INSTALLATION

The Stiletto sensor is installed in the transition pump line between the process chamber and the turbo pump on the sputter etch clean chamber. This location is ideal because it is located close to the wafer substrate. The Stiletto IPM integrates with the sputter etch equipment platform and collects tool state information which can be plotted with the particle information. Through this interface it is also possible to track product lot IDs and substrate IDs to enable correlation of wafer-level metrics to the *in situ* sensor data.

PREDICTIVE MONITORING

The Stiletto IPM monitors chamber condition in real-time and can provide an alarm when chamber flaking begins to occur. Catching chamber flaking quickly can significantly reduce its impact on wafer yields.

Chamber Clean Recovery

After a manual chamber clean is performed, particle levels are high due to the disturbance of the vacuum integrity and the physical disturbance of the interior surfaces of the chamber. Typically a chamber seasoning process is performed on non-product wafers to remove any leftover contamination.

Figure 1 shows that high particle levels still exist in the chamber even after a chamber clean and seasoning. Exposing product to this condition can be avoided by monitoring the seasoning process, running product only after the particle levels have returned to baseline. Figure 2 shows Stiletto counts during typical chamber seasoning runs. Alarm levels can be set to ensure that product wafers are run only after the chamber has returned to a low baseline particle level. Notice in Figure 2 that many seasoning wafers are run after the chamber is back to baseline. By using Stiletto it is possible to improve productivity by running product as soon as the particle counts return to baseline, without running too many seasoning wafers.

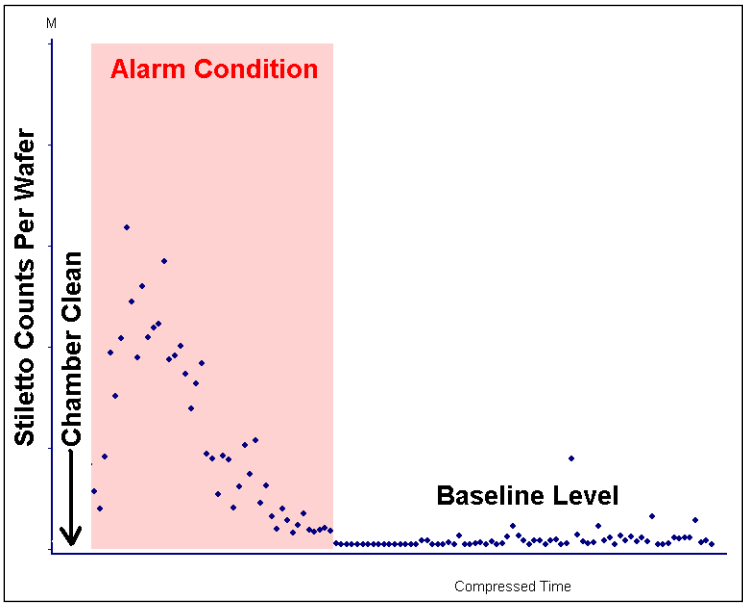

Figure 2. Stiletto data from chamber seasoning process.

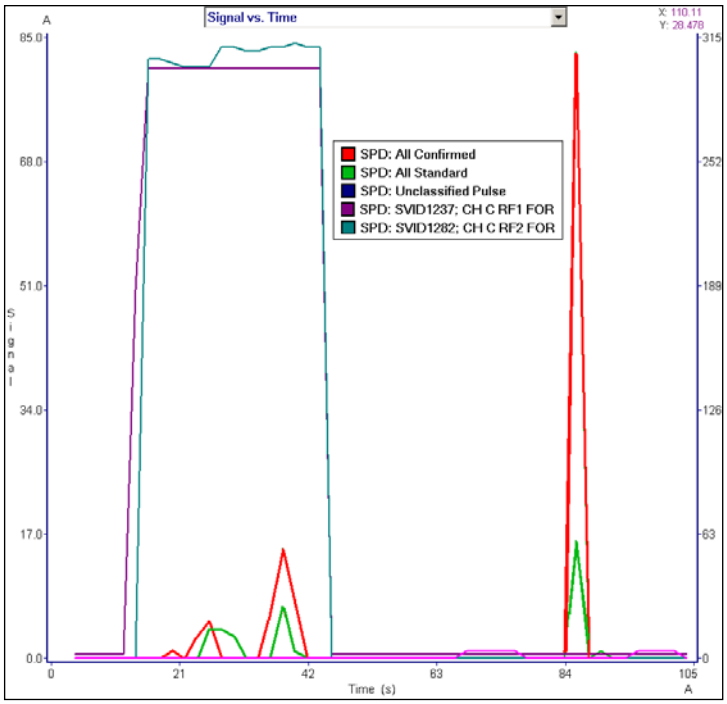

Figure 3. Real-time data collection profile for a wafer with particles generated during wafer transfer.

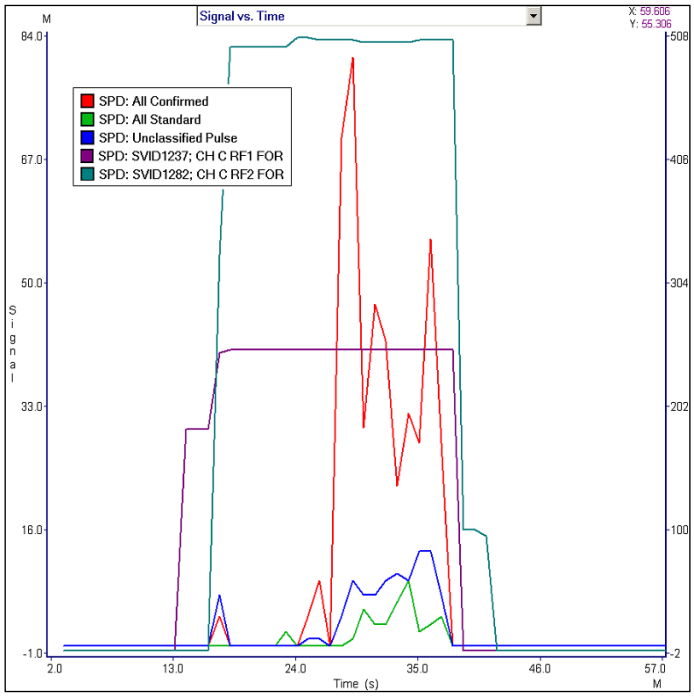

Figure 4. Real-time data collection profile for a wafer with particle flaking detected while the etch plasma is lit.

Chamber Flaking

Figure 1 shows a typical trend of particle levels from the Stiletto IPM on a sputter etch process. Notice the low level of particles following the chamber clean and successive chamber clean recovery. This level gradually increases as the oxide begins to build up on the chamber dome. At some point this particle increase begins to impact yield on product wafers. Using Stiletto to indicate when this level is reached will minimize the impact of chamber flaking on yield.

FAULT DETECTION

The real-time capability of Stiletto provides visibility into particle generation mechanisms within the sputter clean chamber. Figures 3 and 4 show the particle accumulation for two product wafers, and indicates when particles are being generated in the chamber. Using this information to isolate particle sources enables shorter repair times when the chamber goes down due to particle excursions.

Figure 3 shows particles detected after the RF power is turned off, indicating particles created during wafer transfer. Figure 4 illustrates particles that are created during the time that the plasma is on. This profile is observed on wafers processed just prior to a chamber clean, and indicates chamber wall flaking. When the plasma is on, particles are liberated from the chamber walls and detected by Stiletto. Once the plasma turns off, particles are no longer released.

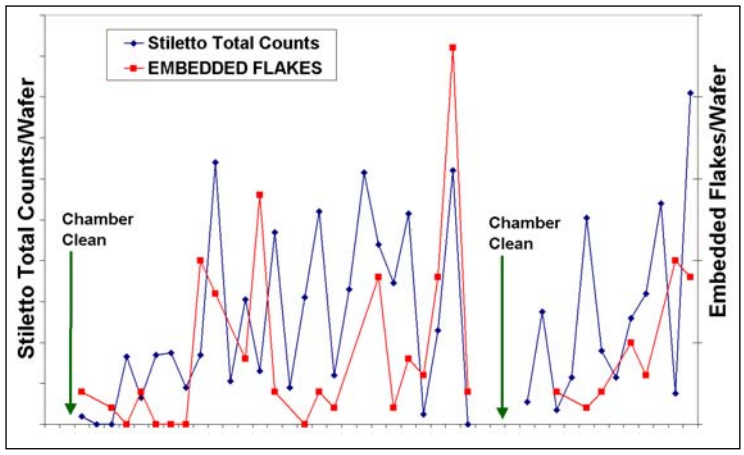

Figure 5. Wafer-by-wafer correlation between Stiletto and *ex situ* particle counts.

CORRELATION

In order to set up proper limits for halting the process, it is necessary to correlate the Stiletto data with on-wafer defects. Particle-on-wafer defect levels can be obtained from *ex situ* metrology tools which measure product wafers and count and classify defects. Measuring wafer defects accurately is time consuming and costly, so typically *ex situ* metrology employs a sampling method. Typical sampling protocols will measure one wafer from a lot, one or two times per day. Usually the wafer is pulled from the same slot of each lot, for ease of tracking. Typically with *ex situ* sampling methods, it is necessary to take corrective action as soon as a single wafer is detected with high particle levels. Figure 5 shows particle data from *ex situ* metrology plotted with Stiletto particle data from the same wafer.

Figure 6 shows all the data from the same two clean cycles, demonstrating the improved resolution provided by Stiletto.

PROCESS CONTROL

Once the correlation between Stiletto and the chamber condition is understood, trend rules can be set up to halt wafer processing. Figure 7 shows alarm limits applied to Stiletto data from a sputter etch process. The red bars indicate when the particle excursion counts were outside of the limit set by the trend rules.

Collecting particle data from every wafer improves the sampling frequency of the measurement and reduces the number of false alarms. By using a trend rule, the failing condition must have several successive wafers with high counts before generating an alarm.

CONCLUSION

The Stiletto IPM provides breakthrough technology to control particle levels in the sputter etch clean process. The Stiletto IPM improves product yields by monitoring particle levels on every wafer and providing real-time fault detection to reduce product exposure when adverse particle conditions exist. Alarm limits can be set to halt processing and initiate maintenance events before product is put at risk. The Stiletto IPM provides time-based particle information throughout the entire wafer process, which enables real-time identification of particle sources.

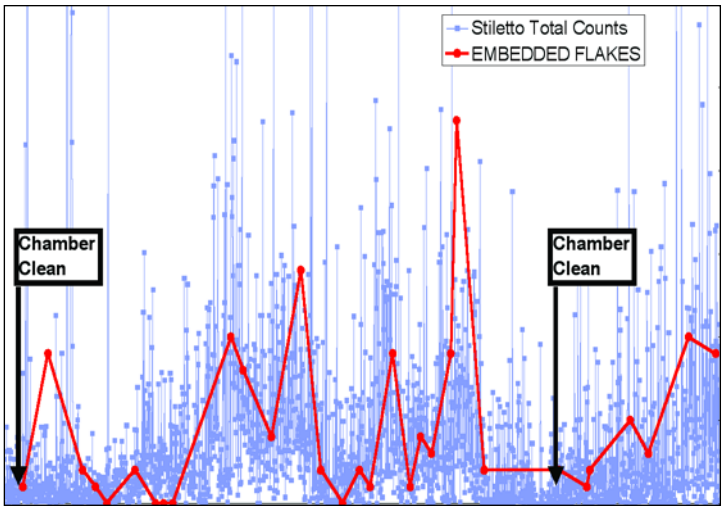

Figure 6. *Ex situ* wafer data plotted with all *in situ* wafer data. *In situ* monitoring provides a higher sampling rate.

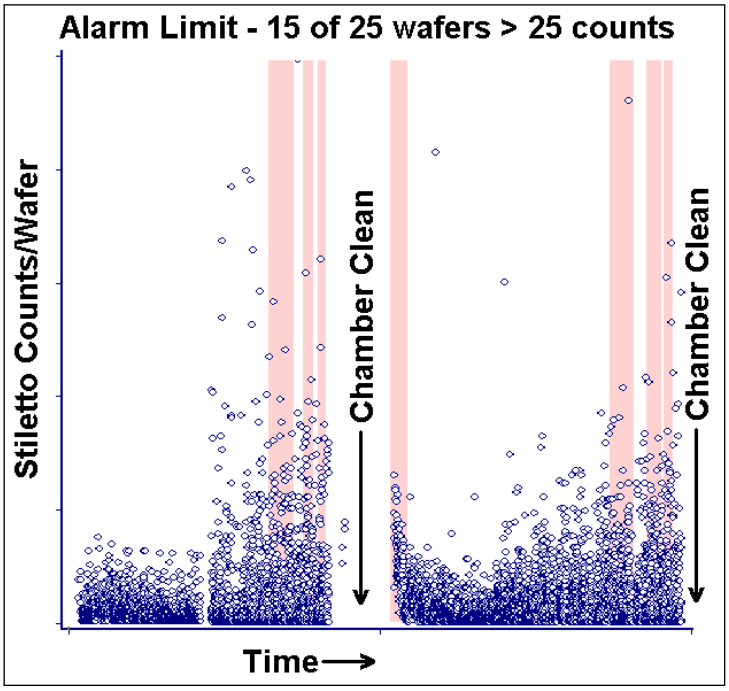

Figure 7. Alarm limits applied to Stiletto data. Trend rule of 15 out of 25 wafers with more than 25 particles was applied. Note how the alarm is active just prior to the pending chamber cleans, and during the PM recovery.

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