Maximize uptime and optimize maintenance with AMS

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CyberOptics' new WaferSense® sensor, Auto Multi Sensor™ (AMS), combines an Auto Leveling Sensor (ALS), Auto Vibration Sensor (AVS), and a humidity sensor in a thin, light, all-in-one multi sensor. The ALS and AVS have well-established records of success, garnering praise from both users in the fab and equipment manufacturers for their ease-of-use, robust performance and convenient form factor. The addition of the humidity sensing (to tilt and vibration) in the AMS lets engineers also check for air leaks in the chamber and evaluate the efficiency of dry air purging procedures.

AMS applications

CyberOptics developed its first leveling sensor more than 10 years ago to provide accurate measurements of wafer tilt under vacuum in thin film process chambers. Accurate tilt measurements are essential to ensure parallelism and film uniformity. At sea level, atmospheric pressure exerts a force of about 10 N/cm^2 (15 lb/in^2)—potentially more than 7000 N (> 1500 lb) on a surface the size of a 300 mm (12 in) wafer. In practice, that much force is never exerted on an unsupported wafer, but enough force is present to cause significant differences between measurements made at atmosphere and those made under vacuum for supporting parts like susceptors, heating stages, pedestals, and electrodes. The AMS can operate in vacuums as low as 10^{-9} Torr.

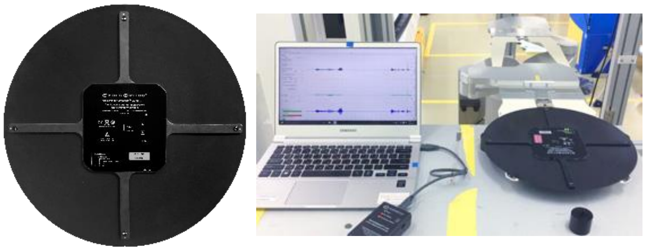


Figure 1 AMS sensor (left) and sensor with associated communications module and laptop computer (right) providing data acquisition and analysis.

Like the ALS and AVS, the AMS has a thin wafer-like shape and communicates wirelessly. It can simultaneously measure tilt, vibration, and humidity inside a sealed, evacuated chamber. Tilt measurements reference only the constant direction of the earths gravitational field, allowing it to establish a reference plane in one position and use it to measure relative tilt at another position. For example, the AMS can be placed on and upper electrode at atmospheric pressure to set the referential plane, and then on the lower electrode inside the chamber under vacuum in relative mode to adjust parallelism and improve process uniformity.

The AMS's ability to travel through the system just like a wafer, making measurements at all stages of the transport path, can make inspection and maintenance operations more efficient. Conventional open-chamber measurements require repeated N$_2$ purges to avoid exposing personnel to noxious process gases and by-products. Purging is expensive and time-consuming. With the AMS, engineers can acquire highly repeatable measurements of tilt, vibration and humidity without venting the chamber. If measurements are within specification, chamber venting may be avoided altogether. If not, adjustment of supporting parts like lifter pins, clamp ring, end-effector for levelling and parallelism can be performed quickly to improve alignment, reduce cross-contamination and particle generation, and generally smooth wafer transport. The net result is a significant reduction in downtime and the cost of purge gas.

Leveling pedestal and heater stage to smooth transport and improve uptime

Poor leveling and lack of parallelism between the pedestal, the heater stage and the wafer may cause vibration during movements of the lifter pins, shifting the wafer position and degrading uniformity. The shifted wafer may be “hooked” within the chamber, and the resulting stress, combined with the effects of high temperatures, a plasma, or a strong electrostatic field, may cause the wafer to crack. The numerical data provided by the AMS vibration sensor gives engineers a quantitative basis for detecting and evaluating wafer transport problems.

Lift pins are typically made of ceramic, a hard material that easily transfers vibration to the wafer. They sometimes vary in length and may not be adjustable for leveling purposes. It is good practice to have replacements on hand when adjusting tilt and parallelism. These are not frequent adjustments (perhaps once a year or less) but monitoring vibration can alert engineers to the need for attention or allow them to confidently postpone unnecessary maintenance, and associated downtime, for a healthy system.

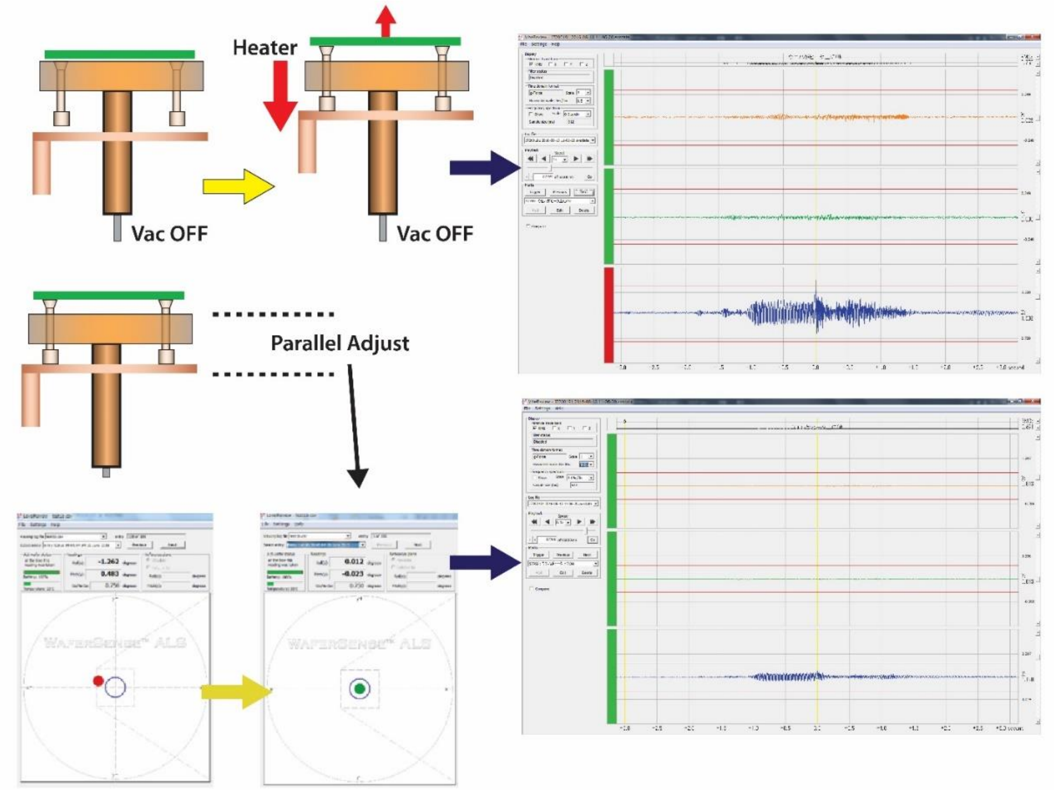


Figure 2 Leveling the pedestal and heating stage to improve parallelism significantly reduces vibration, leading to improved yields and reduced downtime.

Adjusting end-effector droop and twist and monitoring robot vibration

Robots used in semiconductor processing tools play a major role in transporting wafers through the manufacturing process. They must handle a wafer with high speed and accuracy and without adding particles.

They include consumable parts, such as the end-effector, that must be replaced with some frequency. Other parts, such as the geared motors that control their translation and rotation movements also wear out and must be replaced in less frequent major overhauls. A run-until-fail approach to maintenance carries high cost, since a robot failure usually results in significant process downtime. At the same time, periodic maintenance, scheduled with sufficient frequency to reduce the likelihood of failure to an acceptable level, carries its own cost since maintenance is performed more frequently than is actually required. Accumulating wear causes increased vibration in back-lash motions when the gears reverse directions. Measuring these vibrations with an AMS on an ongoing basis provides a quantitative wear indicator that allows engineers to maximize uptime by anticipating problems and scheduling maintenance only when needed and in coordination with other planned process downtime.

Figure 3 shows the vibrations measured before and after an overhaul on a robot that had been in use for 4 years. In this case, the retract motion is driven by a timing belt, and there is 55Hz vibration in X, Y and Z direction. AMS includes an FFT function to analyze the frequencies contained in the signal, and a filtering function (figure 4) to facilitate the detection of abnormal vibrations. These functions can be used to set up easy-to-use go/no go qualification and to help evaluate the need for maintenance.

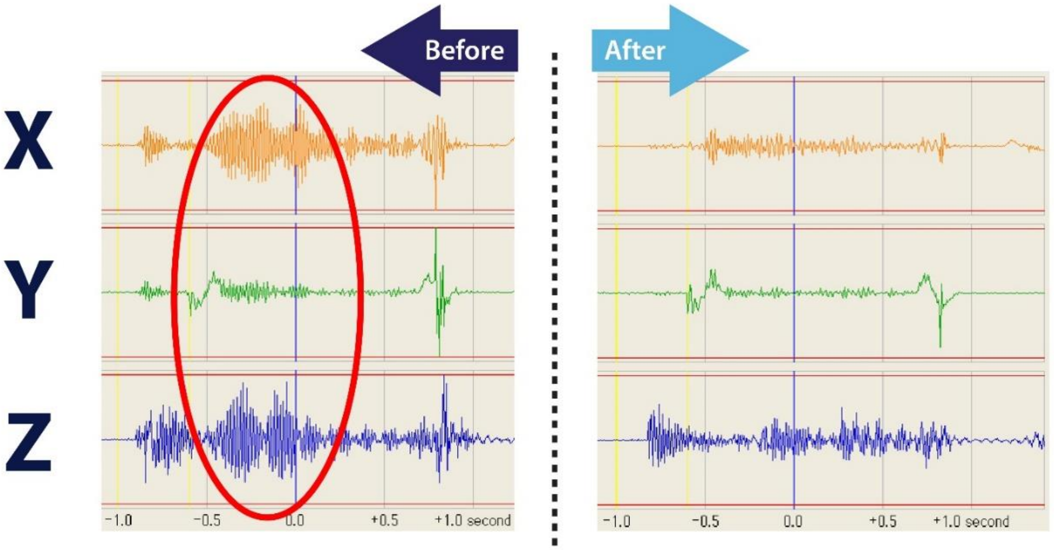
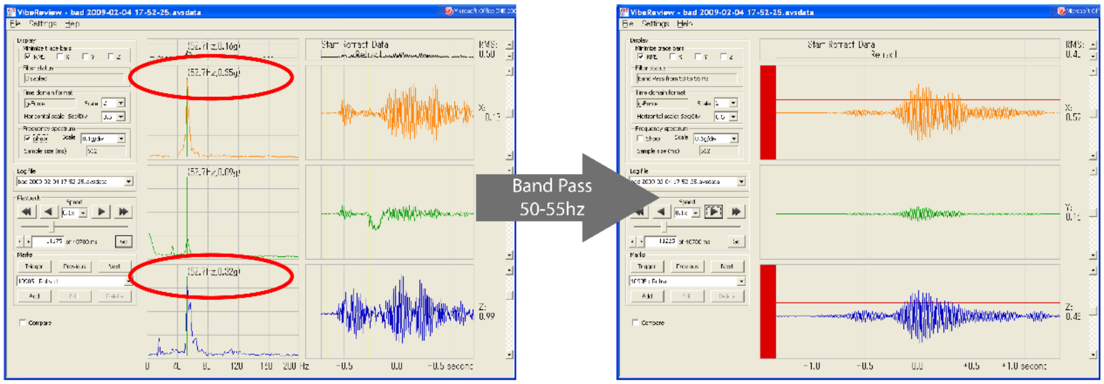


Figure 3 Before and after overhaul of robot which had been used for four years and had particle issue.



FFT Function

Set the Criteria with 0.3g

Figure 4 Filtering out the robot motion acceleration to see the filtered vibration around 55Hz, and set a simple criteria of 0.3g for GO/NOGO.

The AMS can be used to adjust robot blade (end-effector) droop and twist in the stretch and retract motion. When the blade of a pantograph type arm is replaced, the balance of both side arms must be adjusted to make the blade horizontal. The blade must have access to several chambers and parallelism with the lift pins requires the utmost care and precision.

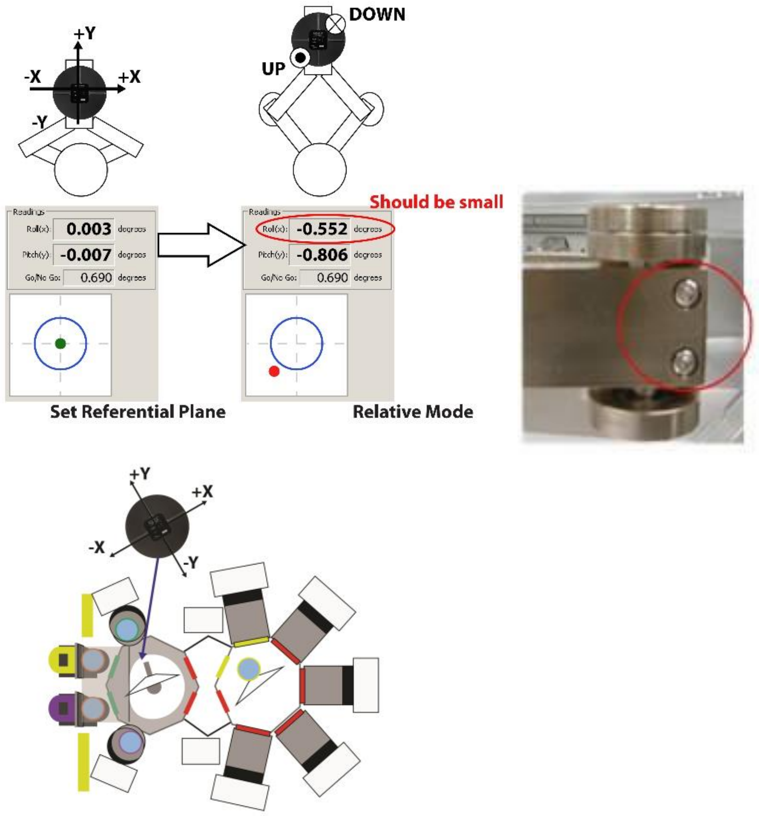


Figure 5 The AMS makes it easy to adjust droop and twist of a robot and effector.

Adjustment proceeds in four steps:

1. Properly load the AMS on the blade, manually or from the load port.
2. Choose the arm stretch position (load lock, orientator or cooling chamber) with the most convenient access the adjustment.
3. Measure the tilt at retract and stretched locations to level the robot arm.
4. Adjust the arm's elbow and lift screws and shoulder (DD Motor) positions to level.

Best known method

AMS's wafer-like form factor and wireless communication allow it to be used inside an evacuated process chamber. These same attributes make it easy to use without any special training or skill, and this makes the data it generates highly reproducible across multiple users and over extended periods of time. Its quantitative, numeric results give engineers an objective basis for comparisons and analysis, and the readily shareable PDF data format facilitates cooperation within engineering teams and collaboration with equipment manufacturers and field service personnel when diagnosing and solving equipment problems. Users consistently cite vacuum compatibility, ease-of-use, and highly accurate, numerical data to justify their designation of AMS as BKM (best-known-method).

ROI

Given the value of a typical wafer relative to the cost of the AMS, even small improvements in uptime or yield can generate a large rate of return on investment.

Summary of benefits

- Minimize downtime – avoid costly shut-downs.
- Maximize uniformity – and process yield.
- Optimize maintenance – only as needed and coordinated with other maintenance activities.
- Establish go/no go qualification – easy to establish and enforce.
- Diagnose and solve problems faster – trace root causes with accurate measurements.
- Encourage team cooperation – with evidence-based equipment performance evaluation.
- Facilitate communications with OEM and field service – document problems with quantitative data.
- Motivate improvement – easy-to-use criteria for performance comparisons.
- Inspire confidence and efficiency – minimize uncertainty with objective measurements.