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Solving Semiconductor Equipment Leveling Problems and Establishing Process Uniformity Standards

In order for semiconductor process equipment to operate efficiently, very precise leveling standards are needed for all wafer process and transfer locations. However, when asked about the leveling standard at their fab most process or equipment maintenance engineers responded, "we have no leveling standards." It is inherently difficult to measure the inclination of semiconductor process equipment as access to the equipment may be limited and traditional leveling methods including, eyeballing and bubble levels do not have the precision or repeatability required to establish leveling standards.

The risks of insufficient inclination measurement and nonconformity across the wafer production process include:

- Wafer damage - as a result of vibration, slippage, scratching
- Particle contamination
- Increased equipment downtime
- Increased maintenance burden
- Wafer non-uniformity
- Process nonconformity
- Increased defects and reduced yield

This paper describes case studies illuminating the challenges and limitations of current leveling methods and the experience of one maintenance team in a Korean fab using a new inclination measurement technique (WaferSense ALS), which is a wireless, leveling wafer that can be handled by the automation and moved anywhere throughout the equipment.

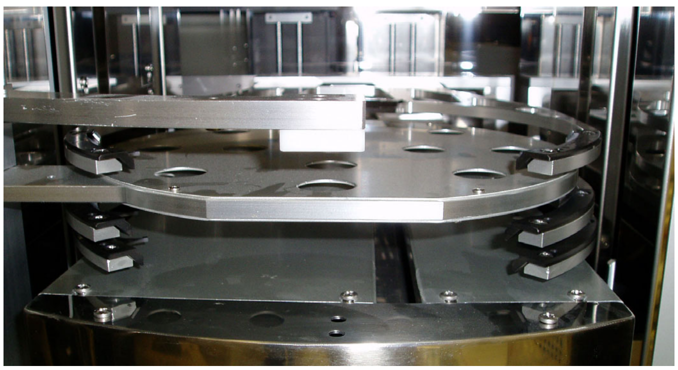
Case Studies: The Limitations Of Traditional Leveling Techniques

The following case studies describe some of the limitations presented by the traditional leveling devices and techniques as introduced above.

Case Study 1: Many important wafer transfer and process locations are not leveled due to inaccessibility

General purpose in nature, bubble levels are typically not easily accommodated by wafer handling equipment making their use time consuming or sometimes impossible. Figure 1 provides a front side view of a robot arm with multiple paddles that is impossible to level with most bubble levels.

In cases where bubble levels were used to level semiconductor process equipment, fab maintenance teams still reported their use to be time consuming and uniformity issues were hard to troubleshoot because of the lack of objective data being collected. Figure 2 provides a side view of a bubble level inside a process chamber; assessing this station's levelness is difficult and it requires a dentist-style mirror.



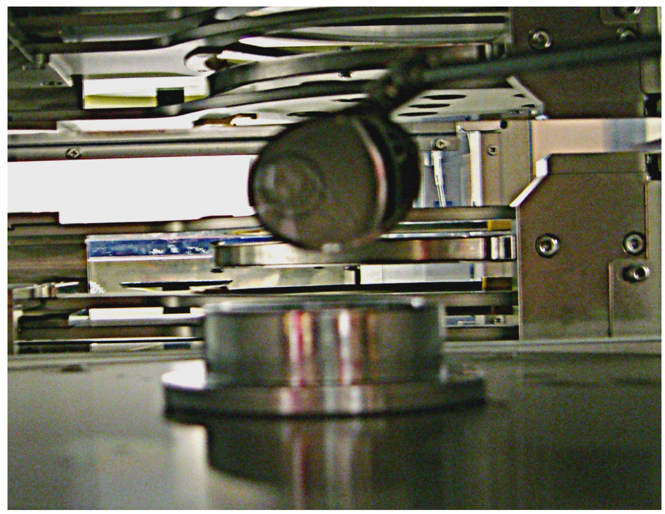


Figure 1 (above): Front side view of robot arm with multiple paddles.

Figure 2 (right): Bubble level inside process chamber; dentist-style mirror used to view bubble level from above.

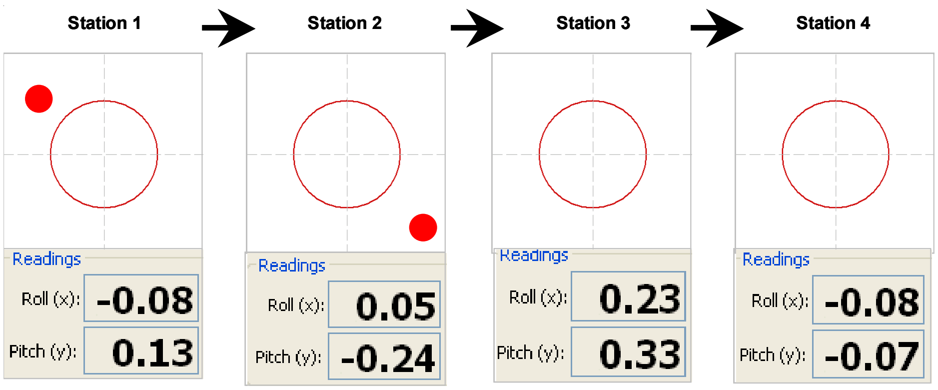
In these applications a routine check of equipment inclination was either not performed or required multiple engineers the better part of a shift to complete and still did not provide an accurate, numeric output from which process uniformity standards can be established. Wafer process uniformity and leveling standards can only be established based on accurate, repeatable, and objective leveling data. Since traditional leveling devices, including bubble levels, do not provide numeric output that can be recorded on a station-by-station, tool-by-tool, and PM–by-PM (preventative maintenance) basis, wafer uniformity performance tracking does not exist. Electronic levels output real data, but recording and tracking this information is an intensive additional manual procedure, which accordingly is often omitted in the push to get the tool back in production as soon as possible.

Bubble and electronic levels also only permit leveling measurements to be taken referenced to earth's gravity. For some equipment and/or processes it is preferred that a station's inclination be set referenced to another plane, or for the two to be coplanar, and not necessarily to earth's gravity. When the two surfaces are not coplanar there is an increased risk of wafer slippage or scratching and particle generation. Fab maintenance engineers report they have had no means to adjust equipment to be coplanar to a preferred set plane point.

Case Study 2: Imprecise and inconsistent leveling across stations compound errors and increases risk of wafer damage

Often overlooked during routine semiconductor equipment preventative maintenance is the fact that the adverse effects of faulty inclination settings have a cumulative effect. For instance, each time a wafer is transferred between two stations of different inclinations this inclination variance increases the chance for particle generation through wafer scratching, slipping, misplacement, or vibration. In most extreme cases such wafer mishandling could result in wafer breakage.

Additionally, slight process variance caused by poorly controlled wafer inclination during transfer might be minimal for an isolated process or transfer step, but it can accumulate over the wafer manufacturing process and ultimately impact wafer uniformity. In Example A, the variance in inclination for a number of transfer stations compounds over the path of travel through equipment, such that during a handoff at Station 4 the wafer has encountered significantly different inclinations from that at Station 1. The compounded variance reflects that the wafer's inclination has changed by more than the allowed tolerance (of ±0.1°) over these few handoffs.



Example A: The compounding effect of faulty wafer inclination – by Station 4 the wafer has encountered significantly different inclinations from that it had at Station 1.

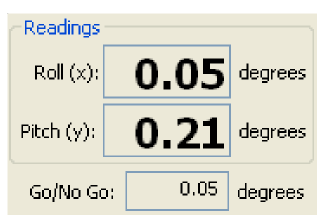
With different semiconductor equipment, due to specific mechanical configurations, the adverse effects of faulty inclination magnify within the same station.

In Example B, the analysis performed on a semiconductor diffusion furnace during PM, demonstrates how a seemingly slight deviation in the inclination of the wafer boat could result in a significant deviation at the top (1.3 mm in roll, 5.6 mm in pitch).

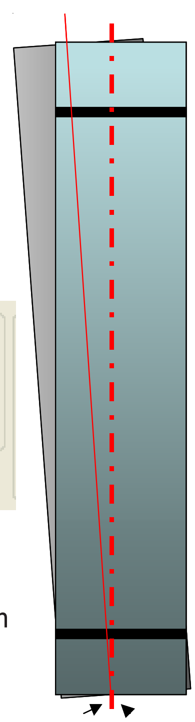
A 5.6 mm wafer placement deviation between the bottom and the top of the wafer carrier is certain to result in both wafer damage and wafer process non-uniformity. The fab maintenance team in charge of this equipment explained that their leveling tools (i.e., bubble levels) did not provide the accuracy and form factor needed to correctly characterize and service their equipment, making it impossible to determine and resolve magnified inclination errors.

Example B: Seemingly slight inclination deviation at the bottom of the furnace boat magnifies to dangerous proportions at the top.

Actual ALS measurements



ALS200 placed in bottom slot of 150-wafer boat



Boat center at (0,0) position

Potential misalignment at top of boat:

X = 1.3 mm top is out of alignment with bottom*

Y = 5.6 mm top is out of alignment with bottom*

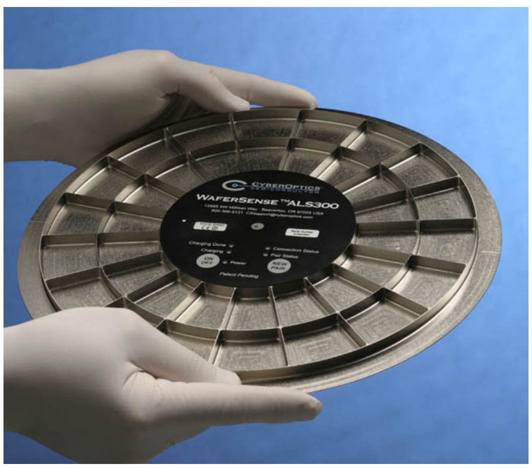
* When center of boat at bottom is compared with center of boat at top. Center of boat is determined when both roll and pitch equal 0.

Case Study 3: Traditional leveling techniques tested against WaferSense ALS

The maintenance team in a 200 mm Korean fab recently implemented use of WaferSense ALS to measure the inclination of a furnace originally thought to be level to acceptable standards.

The WaferSense Auto Leveling System (ALS) was designed to meet the specific requirements of leveling semiconductor equipment in an accurate and objective way so that uniformity standards could be improved. Implementing ALS as part of routine semiconductor equipment preventative maintenance offers maintenance teams the following benefits:

- Wafer-like form factor to facilitate access to all stations for optimal equipment characterization and setup without the need to disassemble equipment (Figure 3 presents a top side view of ALS300; Figure 4 presents a front side view of special, multi-paddle robot easily leveled with ALS).
- Objective and reproducible level adjustments for better PM-to-PM and tool-to-tool process uniformity.
- Reduced equipment adjusting time through live feedback.
- Full equipment characterization over time based on data recorded during every preventative maintenance cycle.



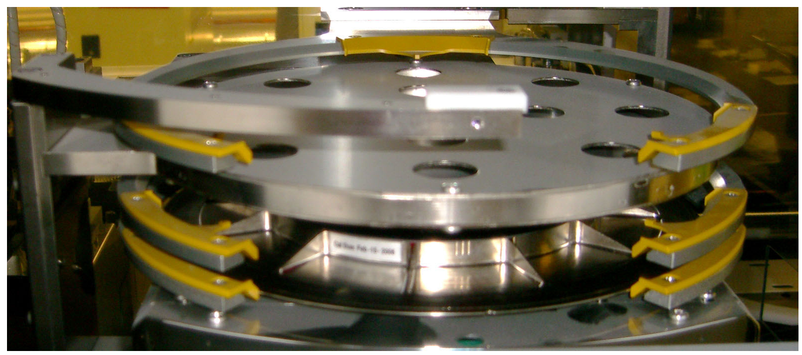


Figure 3 (left): ALS300 from CyberOptics Semiconductor.

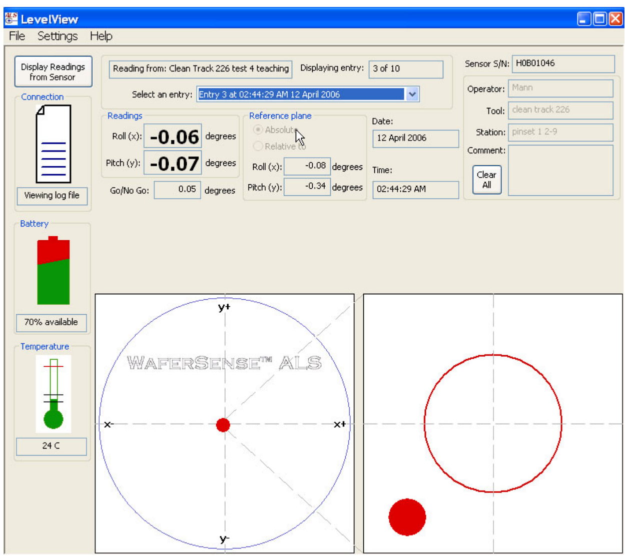
Figure 4 (above): Using ALS200 to level robot arm with multiple paddles.

Case Study 3 continued

The furnace had been previously leveled with traditional leveling techniques that included bubble levels, rulers, and eye balling techniques. Then each station was checked using the WaferSense leveling wafer.

Results:

- When using ALS it was discovered that the average wafer handling inclination deviation between the equipment's end-effectors and the wafer boat was 0.122º (or 0.4 mm) in the roll (X) plane and 0.13º (or 0.5 mm) in the pitch (Y) plane.
- The standard tolerance (±0.1º or ±0.3 mm) was used to characterize the equipment; all critical wafer transfer positions – previously thought to be level, were found to be out of conformity (see Figure 5 a & b.).
- LevelView's numeric pitch and roll output made it possible to quickly determine the furnace boat's misalignment in pitch and roll see Example B in case study 2.).
- Based on the interaction with ALS, the maintenance team estimated potential for 75% time savings in leveling all critical furnace transfer and process locations. The traditional leveling methods averaged 8 hours per furnace while ALS made it possible to characterize the equipment in just two hours.
- Using ALS the team estimated potential to improve leveling accuracy by 60% over previous methods.
- The new data tracking functionality built into the WaferSense ALS has been incorporated into the semiconductor process tool preventative maintenance procedures and is expected to improve setup reproducibility and monitor any degradation in the equipment over time..



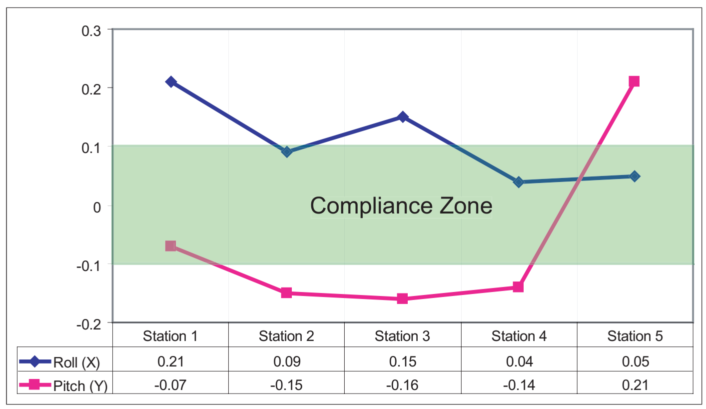


Figure 5a (left): Diffusion furnace station previously leveled with bubble levels proves to be out of tolerance.

Figure 5b (above): Multiple stations in diffusion furnace do not comply with desired tolerance of ±0.1°.

Conclusion

Semiconductor equipment leveling is an important maintenance task for all wafer processing tools. Establishing and implementing leveling standards is impossible with traditional devices, as they were not developed with semiconductor equipment needs in mind. WaferSense ALS provided an alternative to traditional leveling methods that allowed the fab maintenance team to make more accurate inclination measurements and to change preventative maintenance and setup procedures that will save them time and improve process uniformity.

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