EFFICIENT MES LOT-MOVEMENT VIA INTELLIGENT SYSTEM

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ABSTRACT

Automating non-value-added (NVA) activities is a stepping stone towards achieving ideal automation, where human intervention and errors are minimized. This report presents a successful implementation of an automated wait time window process in photolithography using already available technologies, yielding two key benefits: human intervention elimination by moving the lots automatically based on pre-determined rules, and this in turn leads to a more accurate and reliable movement from wait time window resulting in almost 0 unnecessary cycle time

This was also able to improve chemical usage by reducing the rework caused by over ageing lots which translates to further cost reduction for the factory

1. 0 INTRODUCTION

In advanced semiconductor manufacturing, process efficiency and cycle time reduction are critical to maintaining competitiveness, yield performance, and cost control. A significant bottleneck in the production flow arises from wait time requirements in certain process steps such as photolithography, where wafers or lots must remain idle for a predefined duration to ensure material or process stability. Traditionally, managing these wait times has involved manual tracking and movement within the Manufacturing Execution System (MES). Operators are required to monitor wait windows and manually move lots when the time condition is met. However, this manual approach often leads to delays, either from premature movement — violating process constraints — or late movement. It can also lead into unnecessary rework of the process directly impacting cycle time, cost and downstream scheduling.

These inefficiencies are aggravated in high-volume manufacturing environments where human error or workforce limitations can prevent timely lot transitions. The mismatch between actual wait time completion and the operator's availability or attention causes unnecessary dwell time, extending the overall cycle time and reducing equipment utilization.

1.1 Photolitography and Wait Time

Photolithography is a process used in semiconductor manufacturing to transfer patterns onto a silicon wafer. It involves coating the wafer with a light-sensitive material called photoresist, then exposing it to ultraviolet (UV) light through a patterned mask. The exposed areas of the photoresist are developed to reveal specific parts of the wafer for etching or doping. This technique allows the precise creation of tiny circuit patterns needed for microchips and other electronic devices.

Photolithography has a step where it needed to wait for the photoresist to settle. Wait time window helps promote proper chemical adhesion, improves uniformity and chemical stabilization. Wait time window for photoresist usually last for 30 mins to 4 hours depending on what type of chemical used and the thickness applied into the substrate.

If the process were to proceed with in adequate wait time, edge beading would be present on the wafer, this edge bead will often result in poor resolution, wrong dimensions and unintentionally low sidewall angle, and uneven coating heights [2]

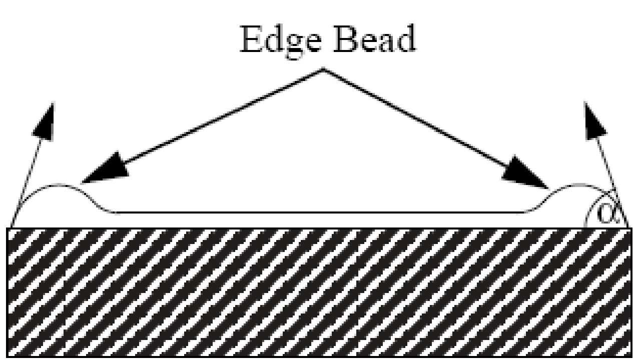


Fig 1. Graphical description of bead effect

On the other end of the spectrum, exceeding the recommended wait time will have negative effect of the deposited coating, this includes Loss of the photo initiator in positive resists, Cross-linking reactions in negative resists, Discoloration, poor resist adhesion and particle formation

Strong dilution of DNQ-based positive and image reversal resists promotes particle formation during coating. Post-coating inspection reveals an initially irregular resist surface that degrades further with time, resulting in pronounced ripples and crack propagation behind the larger particles. As shown on Fig 2, as larger and larger particles as formed over time. [1]

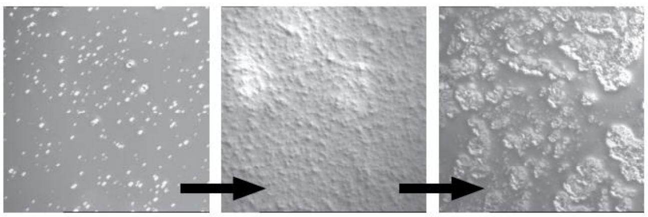


Fig 2. Appearance of more and more (from left to right) aged photoresist coated on a substrate: With increasing concentration and size, particles conglomerate to clusters (each picture 500 x 500 µm)[1]

To avoid long term problems, it advised to remove the over-aged coating and apply a fresh coating. This process is also known as rework.

1.2 Impact of Wait Time Window

Manual tracking of wait time window may vary depending on the type of photo resist, resist thickness and viscosity. In the current factory, it uses 4 types of chemicals which uses different wait time window requirements. The type of bumping technology is also considered in determining the correct wait time window used by the operator.

The intricate combination of production requirements has been found to significantly impact operator decision-making processes. As a direct consequence, a noticeable lapse in wait time windows occurs, averaging approximately 5,000 lots per month. This deviation from optimal wait times results in substantial cycle time repercussions.

Cycle Time Impact: Specifically, the analysis reveals that the average additional cycle time is approximately 2 hours. However, in extreme cases, this impact can be as pronounced as a staggering 27-hour increase (refer to Fig 3 and Fig 4).

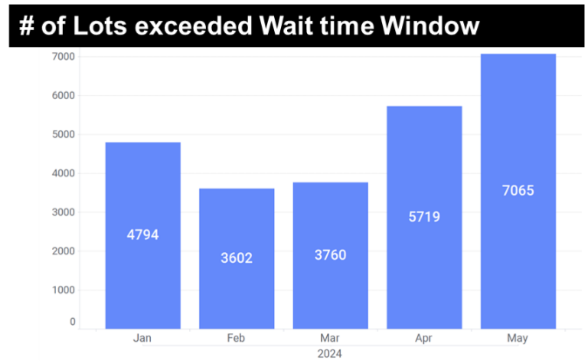
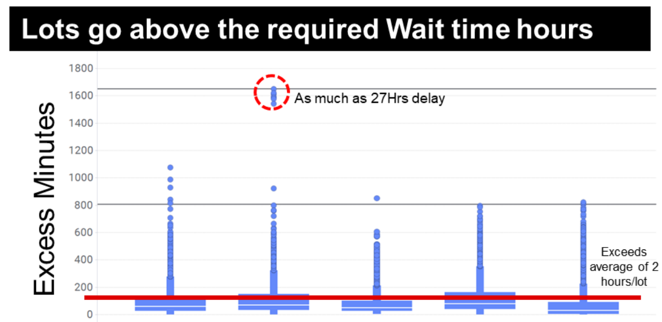


Fig 3. Number of lots exceeded wait time window from Jan to May 2024.



	2024				
	Jan	Feb	Mar	Apr	May
Count	4794	3602	3760	5719	7065
Outliers	370	176	377	296	544
Avg	99.02	113.51	79.8777	119.364	67.4845

Fig 4. Data of number of minutes lots exceeded window time from Jan to May 2024.

2. 0 REVIEW OF RELATED WORK

Refer to 1.0 Introduction.

3.0 METHODOLOGY

To address this issue, an automated solution was developed that integrates MES functionality with programmable logic or scripting. The system monitors each lot's status and wait time requirements in real-time, checks against the predefined time windows, and automatically triggers lot movement or notifies the MES for the next process step—eliminating the need for manual intervention. This automation ensures that process constraints are strictly adhered to, while simultaneously reducing idle time and improving cycle time.

To enable precise and reliable automation of lot movements, the foundational requirement is access to accurate, real-time wait time data from the Manufacturing Execution System (MES). MES is supported by an Oracle database, which stores timestamps of each lot's movement history and required hold or wait conditions per process step. These data points include key fields such as lot ID, operation name, timestamp of wait start, and minimum required wait duration.

To extract and utilize this data efficiently, a custom script was developed using Python scripting, which query the Oracle MES database through secure, read-only SQL access. These scripts perform the following core functions:

Query wait time records: Identify lots currently in a wait state, along with their respective start times and required wait durations.

Calculate elapsed wait time: Compare the current system time against the wait start timestamp to determine if the required window has been satisfied.

Trigger MES actions: Automatically move the lot to the next step by interfacing with MES APIs and command-line tools.

Table 1 was used in determining the exact time based on the chemicals and technology of the devices. This will be used as a lookup table by the script.

Wait Time Window Requirements			
Resist	**Chemical**	**Technology**	**Minimum WTW**
Thermoplastic	Chemical 1	Tech 1,Tech 2, Tech 3, Tech 4	1
Thermoplastic	Chemical 1	Tech 1,Tech 2, Tech 3, Tech 4	4
Thermoplastic	Chemical 1	Tech 1,Tech 2, Tech 3, Tech 4	4
Photo Resist	Chemical 2, Chemical3, Chemical4	Tech 1,Tech 2, Tech 3, Tech 4	0.9
Photo Resist	Chemical3, Chemical4	Tech 4,Tech 5, Tech 6	0.5
Thermoplastic	Chemical 1	Tech 6	0.5
Photo Resist	Chemical 2, Chemical4	Tech 6	2

Table 1. Resist type and wait time window requirements per technology.

By integrating MES database access with lightweight automation scripts, the system ensures that lots are moved as soon as the required wait condition is fulfilled, eliminating manual delays. This method also allows for scalability, as new steps or wait rules can be incorporated by updating the query logic and configuration parameters within the scripts.

This data-driven approach forms the backbone of the automation framework, enabling real-time decision-making and driving measurable reductions in cycle time and operator workload.

4.0 RESULTS AND DISCUSSION

Through this method we were able to stabilize the wait time window Excess time to from hours to only minutes giving and overall Cycle time improvement of 97.6%

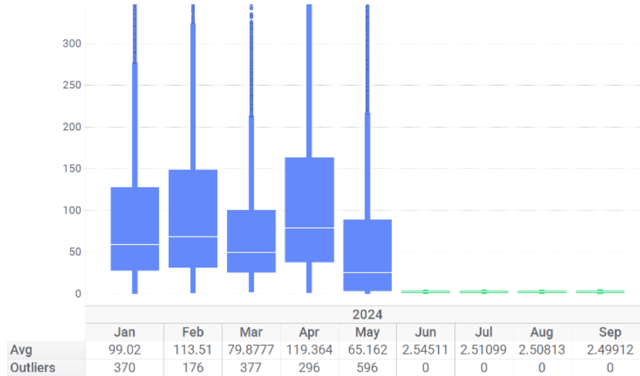


Fig 5. Data of number of minutes lots exceeded window time from Jan to Sept 2024. Green data shows the where the automation was activated

All processes in Wait time window are now done automatically without human intervention. This resulted in approximately 127 man hours per months

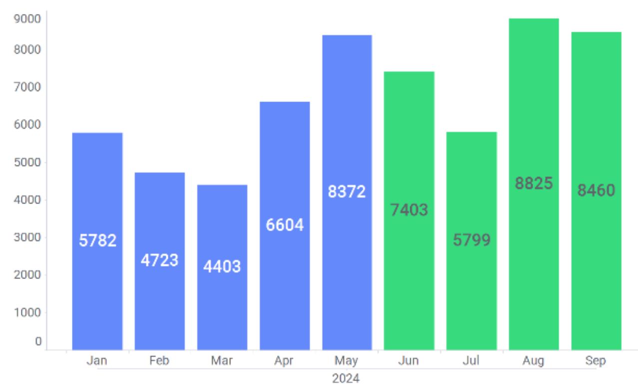


Fig 6. Number of lots moved from wait time window, from Jan to Sept 2024. Green data shows the where the automation was activated

Significant reductions were observed in wafer over-ageing due to improved wait time management, resulting in corresponding decreases in chemical usage required for reworking over-aged wafers. Specifically, the rework caused by over-aging of coated wafers was reduced from 33% to only 4%, as evident from Figure 7.
Overall this improved the rework cost due to over-aged coating by 94.1%

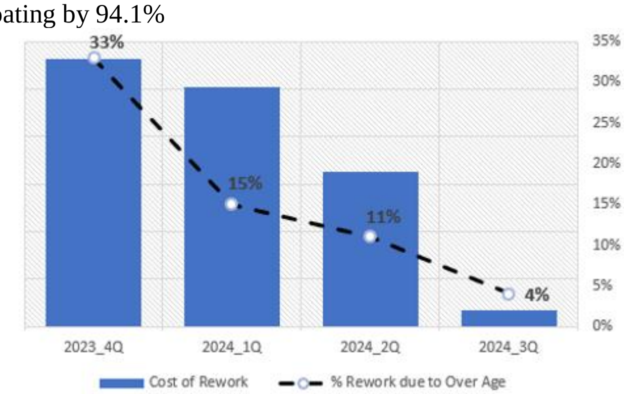


Fig 7. Data of Cost improvement due to rework reductio

5.0 CONCLUSION

A thorough analysis and optimization approach achieved a significant improvement in cycle time, reducing wait times from hours to mere minutes, resulting in an impressive 97.6% Cycle Time Improvement.

By automating all processes within the stabilized wait time window, we have eliminated the need for human intervention, freeing up approximately 127 man-hours per month. Furthermore, our results indicate a substantial reduction (from 33% to 4%) in wafer over-ageing, leading to corresponding decreases in chemical usage required for reworking over-aged wafers, which ultimately resulted in a remarkable 94.1% improvement in rework cost savings. These findings demonstrate the effectiveness of this method in optimizing wait time management and paving the way for future process enhancements in similar contexts.

6.0 RECOMMENDATIONS

The lot movement method presented in this work has broad applicability across various processes that necessitate precise timing requirements. We therefore propose to investigate and evaluate other processes within the organization that can leverage this concept, and implement it as necessary to optimize their execution. By doing so, similar improvements in efficiency and productivity are anticipated, allowing for further optimizations and enhancements to be achieved.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

1. MicroChemicals GmbH. (2023). Storage, ageing, refilling, and dilution of photoresists Retrieved from MicroChemicals website.
2. MicroChemicals GmbH. (2023). Spin Coating from MicroChemicals website.

9.0 ABOUT THE AUTHORS

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10.0 APPENDIX