STRATEGIC DEPLOYMENT OF EFFECTIVE AND EFFICIENT METHODOLOGICAL CONTROLS OF FOREIGN MATERIAL INTERFERENCE IN WAFER-LEVEL 1K MANUFACTURING CLEANROOM ENVIRONMENT

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ABSTRACT

Controlling Foreign Material (FM) interference is essential for maintaining product quality and yield in semiconductor production, especially during wafer testing. To reduce FM interference in a Class 1K cleanroom setting, this study offers a strategic framework for the implementation of practical and efficient methodological measures. This research study highlights important areas for intervention, such as cleanroom design, material handling procedures, methodology, and staff training, through a comprehensive analysis of current best practices and established techniques.

This paper further explores the role of technological advancements, such as real-time particle monitoring systems and automated cleaning resources, in enhancing the efficiency of FM control. The effectiveness of various strategies is evaluated based on their impact on reducing particle count and improving wafer yield. Findings suggest that a holistic approach, combining severe procedural controls, offers a proper solution for minimizing FM interference. The strategic framework proposed in this paper not only addresses current challenges but also provides a scalable model that can adapt to future advancements in Wafer Test and Wafer Preparation in assembly manufacturing processes.

1. 0 INTRODUCTION

Combating FM in such a rigorous setting requires a comprehensive approach, combining advanced filtration systems, demanding cleaning protocols, and strict personnel behavior guidelines. Moreover, the dynamic nature of contamination sources demands continuous monitoring and adaptive strategies to address new challenges as they arise. [2]

Through an inclusive examination of these elements, the research seeks to underscore the principal importance of contamination control and propose innovative solutions that can enhance the effectiveness of existing protocols. Ultimately, the relentless search for precision in cleanroom management not only serves to support the integrity of manufacturing processes but also covers the way for radical developments in FM elimination [3].

1.1 Background of the Study

This study investigates the surge in Return-to-Vendor (RTV) cases observed in the Engineering build of Product A and Product B. The Customer facility reported an unusual increase in defects, particularly concerning top-side contamination on pads in the Engineering build, which significantly contrasts with previous production outcomes and existing benchmarks established by a comparative analysis with STC's defect management strategies.

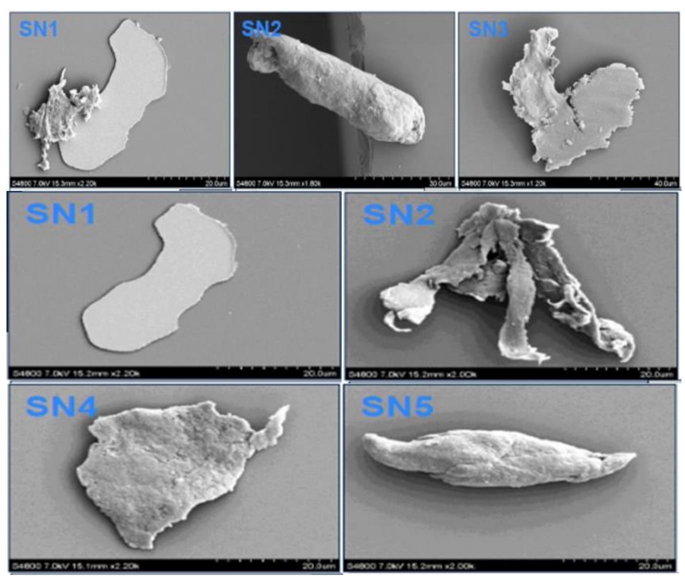


Figure 1: Sample FM found on Top-side and Bottom Side of Product A and Product B

Through this background, the study aims to provide a comprehensive overview of the comprehensive challenges encountered in maintaining product integrity and quality control in high-precision manufacturing environments. It seeks to explore the interplay between technological integration, defect detection, and operational protocols in mitigating the risk of product contamination and defects. By examining the specific case of increased RTV cases linked to pad contamination and other related defects, this research endeavors to uncover actionable insights and develop strategic recommendations to enhance quality control measures, optimize defect detection methodologies, and ultimately improve overall production efficacy.

1.2 Problem of the Study

The study addresses the problem of an increase in RTV during Engineering build of Product A and Product B related to FM attributed to rise in Top and Backside portion of the die. With the Customer’s introduction of AOI at L4 build phase potentially leading to a higher sensitivity in defect identification. With this, it highlights significant challenges in maintaining product integrity and quality.

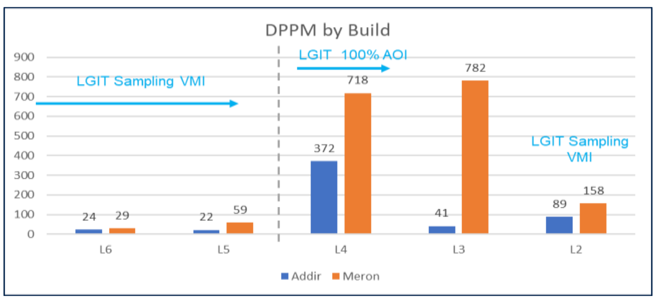


Figure 2: DPPM rate per build of Product A and Product B

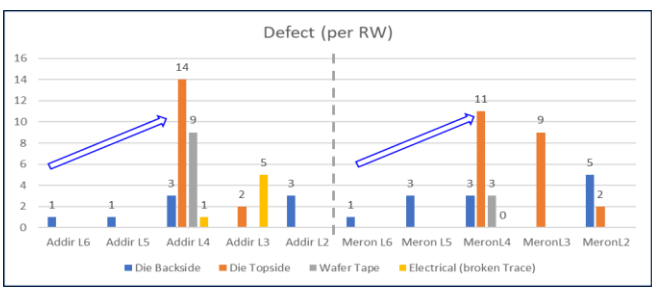


Figure 3: Defect distribution per build of Product A and Product B

Defect Description	Product A Different Builds					Product B Different Builds				
Pad Scratch			4	1				3		
Pad contam			2	1				6	7	
Top side Particle			2						1	
Corner chipping			5		1			1	1	2
Edge chipping			1							
Over pad Metallization Defect			1					1		
Back side Contam	1					1				1
Back side Particle		1	2				3	3		2
Particle on Tape								3		
Tape Wrinkles			9							
Broken Trace			1	5						

Table 1: Count of Feedback related to FM

1.3 Objective of the Study

This study's main goal is to methodically examine and comprehend the underlying causes of the rise in RTV in comparison to the Engineering builds of Product A and Product B relative to FM. By doing this, the research will include a thorough analysis of FM's contribution and develop a framework where FM could be eliminated, and process yield would increase.

2. 0 REVIEW OF RELATED WORK

The foundational aspect of controlling FM interference involves the design and operational protocols of the cleanroom itself. According to ISO 14644-1, the classification of air cleanliness is vital, necessitating sophisticated HVAC systems and HEPA filters to maintain the required particle-free environment. The importance of airflow patterns, pressure differentials, and temperature and humidity control in minimizing particle deposition on wafer surfaces has been extensively documented [1].

The introduction of materials and personnel into the cleanroom presents significant risks for FM contamination. Studies have highlighted the effectiveness of rigorous gowning protocols, material decontamination procedures, and behavioral training in reducing these risks. The use of sticky mats, air showers, and gowning rooms, PPE’s are standard practices to physically remove particles from individuals and objects entering the clean space.

In terms of technological advancement, the evolution of real-time monitoring systems has greatly enhanced the ability to detect and quantify FM presence in cleanrooms. Technologies such as airborne particle counters, surface particle detectors, and molecular contamination monitors provide critical data for assessing cleanroom cleanliness and identifying contamination sources promptly.

Human interaction within the cleanroom is identified as a significant source of FM. Implementing best practices for personnel behavior, along with optimizing manufacturing processes to minimize manual handling of wafers, can reduce contamination risks.

Future research directions include the development of more advanced materials for cleanroom construction, enhancements in personal protective equipment, and the integration of artificial intelligence in monitoring systems to predict contamination events before they occur. This holistic approach ensures not only the strategic deployment of controls but also adapts to the evolving landscape of semiconductor manufacturing, where minimizing FM interference is critical to maintaining high standards of product quality and manufacturing efficiency.

3.0 METHODOLOGY

To address FM resolution in a Class 1K manufacturing environment effectively, a strategic framework can be used focusing on prevention, detection, and response mechanisms. This framework is designed to minimize the intrusion and impact of particulate contamination, thereby ensuring the integrity of the manufacturing process and the quality of the final products in water level.

3.1 Design, Material and People Flow:

3.1.1 Cleanroom Design and Airflow Management:
Optimize the layout and airflow within the cleanroom to minimize particle accumulation. Implement high-efficiency particulate air (HEPA) filtration systems to continuously remove contaminants from the air.

3.1.2 Material and Equipment Control:
Establish strict protocols for the introduction of materials and equipment into the cleanroom. This includes using proper cleaning and decontamination procedures before entry.

3.1.3 Personnel Training and Gowning Procedures:
Conduct comprehensive training programs for all personnel regarding cleanroom behavior and contamination control practices. Implement rigorous gowning procedures, including the use of appropriate cleanroom garments and adherence to proper gowning techniques.

3.1.4 Regular Monitoring and Sampling:
Employ monitoring equipment to continuously assess particulate levels and air quality within the cleanroom.

3.1.5 Methodological Environmental Control
Employ monitoring equipment to continuously assess particulate levels and air quality within the cleanroom.

3.2 Response and Mitigation:

3.2.1 Rapid Response Protocols:
Develop and implement rapid response protocols for contamination events, including immediate containment measures and the initiation of clean-up procedures.

3.2.2 Root Cause Analysis:
Conduct thorough investigations of contamination incidents to identify the root cause. Apply lessons learned to prevent recurrence.

3.2.3 Continuous Improvement:
Leverage data from monitoring and incident investigations to continuously improve contamination control practices. Regularly review and update cleanroom protocols to adapt to new challenges and technological advancements.

3.3 Documentation:

3.3.1 Record-Keeping:
Maintain detailed records of contamination control efforts, including monitoring data, incident reports, and corrective actions. This documentation is essential for regulatory compliance and continuous improvement efforts as shown in Appendix – A.

By focusing on prevention, detection, and rapid response, organizations can effectively manage FM contamination in Class 1K manufacturing environments, thus protecting product quality, and enhancing operational efficiency.

4.0 RESULTS AND DISCUSSION

4.1 Machine Considerations

4.1.1 Installation of HEPA Filter and Exhaust
HEPA filters play a crucial role in maintaining the strict cleanliness standards of a cleanroom environment by trapping particles as small as 0.3 to 0.5 microns [3], ensuring that the air circulating within the machine remains free of contaminants. Their use not only safeguards the production environment against pollution but also significantly enhances product reliability and reduces the risk of product failures due to contamination as shown in Appendix – B.

Through the introduction of HEPA filter and Exhaust, it is observed that 3% of the surface defect was removed after installation.

4.1.2 Enclose Laminar Flow Hood
An enclosed Laminar hood offers an additional layer of protection by isolating the work environment from the broader cleanroom space. This type of hood minimizes turbulence, effectively preventing settled particles from becoming airborne and ensuring that any potential contaminants are swept away from the critical work area as shown in Appendix – C.

4.1.3 Suck and Blow implementation
Suck & Blow feature is a dual-purpose spot type ionizer that blows air directly on the wafer during Pick and place and is also equipped with a vacuum that effectively removes airborne particles on the wafer as shown in Appendix – D.

4.1.4 Use of Fan type ionizer and install air sweeper at MIT

Air sweepers are designed to enhance air circulation and filtration within the cleanroom machinery [5]. This helps the continuous movement of air, ensuring that particles are efficiently guided towards the filtration systems, through HEPA filters, for removal. The effectiveness of air sweepers in reducing particle accumulation on critical components of the machine has been observed, to contribute significantly to maintaining the integrity of the cleanroom environment. This direct contribution to minimizing particulate contamination is vital for processes that are highly sensitive to such pollutants, thus enhancing product reliability and yield.

Fan-type ionizers play a pivotal role in neutralizing charged particles and surfaces within the machinery. In a Class 1000 cleanroom, where electronic components and sensitive materials are often handled, the accumulation of static electricity can attract particles and lead to electrostatic discharge, potentially damaging products and disrupting sensitive processes. The use of fan-type ionizers has shown a marked decrease in ESD events, highlighting their importance not just in maintaining cleanliness but also in protecting the integrity of the manufacturing process and its outputs.

Figure 4: Fan type ionizer and sir sweeper installation

Yield results in using this type of air sweeper and fan-type ionizers are linked with the results indicated in Figures 10 and 11.

4.1.5 MIT FM Trend

With the enhancements at MIT, there has been a noticeable downward trend in the FM trend across different builds, specifically Product A and Product B. This trend was particularly evident when comparing data from the Engineering build to the Production build, where a significant reduction in the overall FM yield loss within the input yield, marked by a 2.15% change. Furthermore, the loss in output yield was minimized to 0.06%, while the yield on the backside had a minor reduction of 0.05%. These figures highlight the efficacy of the enhancements introduced by MIT, indicating a successful outcome.

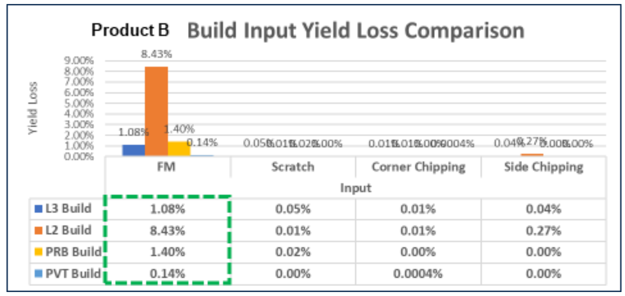


Figure 5: Product B FM Trend at Input Yield Loss

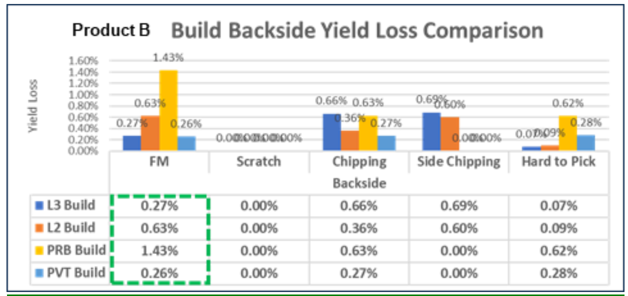


Figure 6: Product B FM Trend at Backside Yield Loss

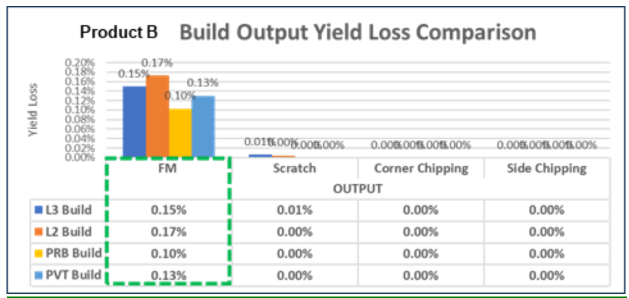


Figure 7: Product B FM Trend at Output Yield Loss

Category	Issue	Failure Rate	Defect Details	Expected Gain
Vision	Backside FM	0.26%	Reject when L and W is >50um	0.00%
Vision	Input FM	0.14%	FM Criteria Accept if <30um or <700um2 (AR) or Accept if <50um or <2,000um2 (Non-AR)	0.00%
Vision	Output FM	0.13%	FM Criteria Accept if <30um or <700um2 (AR) or Accept if <50um or <2,000um2 (Non-AR)	0.00%

Table 2: Defect Criteria of Backside, Input and Output FM for Product B

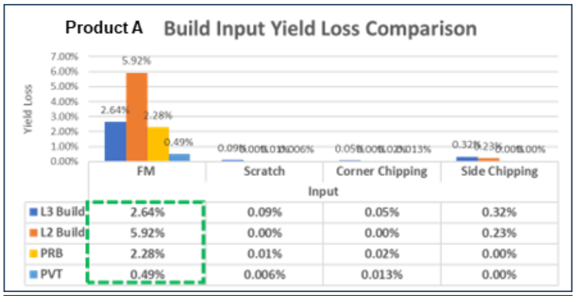


Figure 8: Product A FM Trend at Input Yield Loss

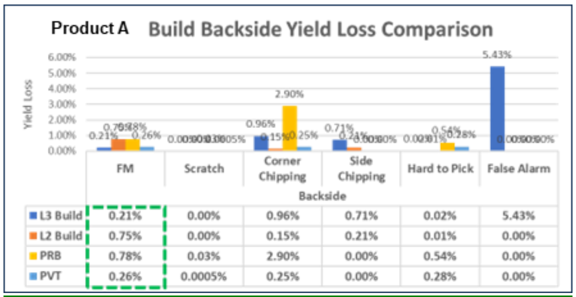


Figure 9: Product A FM Trend at Backside Yield Loss

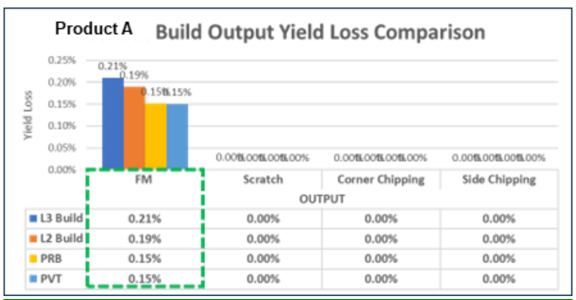


Figure 10: Product A FM Trend at Output Yield Loss

Category	Issue	Failure Rate	Defect Details	Expected Gain
Vision	Input FM	0.49%	FM Criteria Accept if <30um or <700um2 (AR) or Accept if <50um or <2,000um2 (Non-AR)	0.20%
Vision	Backside FM	0.26%	FM Criteria Accept if <30um or <700um2 (AR) or Accept if <50um or <2,000um2 (Non-AR)	0.00%
Vision	Output FM	0.15%	FM Criteria Accept if <30um or <700um2 (AR) or Accept if <50um or <2,000um2 (Non-AR)	0.00%

Table 3: Defect Criteria of Backside, Input and Output FM for Product B

4.1.6 <u>Auto Inhibit Function</u>

When the operator is present at the station, an IR sensor detects his/her presence; (a) the system will have a timer (one minute – subject to evaluation or no delay) (b) the operator does not plug in the wrist strap, an audible alarm and a tower light will trigger see flow chart in Appendix – E.

1. If not plugged in or failing, the alarm and the machine will prompt error – not start.
2. If plugged in and ok, the machine will proceed to production.
   - If the operator unplugs, the machine will alarm and will not process the next wafer.

<u>4.2 Logistics Segment</u>

<u>4.2.1 N2 Cabinets</u>

<u>4.2.1.1 DOE 1.0 – Comprehensive Dust Particle Counting in N2 Cabinet Layers of Production Line</u>

Tracking dust particle counts over time allows us to identify trends and patterns that help to predict when contamination levels increase and enable proactive measures to be taken.

A significant increase in dust particle concentrations was noted, particularly at Layer 4.

The bottom layer (Layer 4) of the N2 cabinet serves as the entrance point for N2 supply. The blow of N2 begins at the bottom surface and circulates to the top layer, where it continues to circulate shown in Appendix – F.

Dust particles from the top layers (Layers 1-3) settle down to Layer 4 due to the circulation of N2 air inside the cabinet.

Dust trails could be coming from the N2 vent/diffusers.

<u>4.2.1.1.1 No usage of the 4th layer (bottom layer of N2 Cabinet, Racks and other staging station)</u>

With this DOE, the N2 cabinet's 4th or bottom layer was not used to prevent the accumulation or settlement of dust particles on direct materials such as reconstructed wafers considered as finished products.

<u>4.2.1.2 DOE 2.0 – Continuing Comprehensive Dust Particle Assessment in N2 Cabinet Layers of Production and Test Production Line</u>

Installation of filters can help to lessen/remove particulate contaminants from the N2 entry/source.

There is a strong correlation between DOE 1 and DOE 2, which indicates that even if the cabinet is empty or contains materials, dust particles are still present and are typically found close to the Layer 4 N2 supply vent.

4.2.1.2.1 N2 Cabinet Filter Installation

The installation of air particulate filters can lead to improved operational efficiency by minimizing the need for frequent equipment maintenance and cleaning [6]. This also removes airborne particles from the environment surrounding the direct material, in this case, reconstructed wafers.

Figure 11: Particulate filter with 0.01um filter size installed in each N2 cabinet.

4.2.1.3 DOE 3.0 – Performance of initial N2 Cabinets installed with Particle Filter and cleaning

Results correlated to DOE's 1 & 2 where higher particle concentration is at the bottom entry point of N2.

Assessing the effectiveness of cleaning procedures and the cleanliness of the environment allows for the optimization of processes and procedures to minimize contamination risks could lead the N2 cabinet into a more airborne-free environment as shown in Appendix - G.

After installation of the particulate filter onto new N2 cabinets inside the Production line, it is significantly observed that the particles have declined showing the effectiveness of the installation.

4.2.1.3.1 N2 Cabinet Weekly Cleaning Procedure

An additional procedure was made by properly giving the shop floor a more holistic way of cleaning the N2 cabinets, inside and outside portions of the N2 cabinet as shown in Appendix – H.

The procedure on N2 cabinet (Cleaning and Particle measurement) is defined at specs DM00644344 (N2 Cabinet with RH Controllers)

Note: Cleaning frequency and particle measurement of N2 cabinet is once a week

4.2.1.4 DOE 3.1 – Investigating the Impact of RH Reading Direction on Top-to-Bottom and Vice Versa

There is no notable difference between the two Production cabinets while reading from bottom to top or top to bottom layer shown in Appendix – I.

It makes no difference if the RH reading is taken from top to bottom. The RH reading is still steady.

4.2.1.5 DOE 4.0 – Progressive DOE for additional N2 Cabinets post Particle Filter Installation

Dust Count Particle for additional N2 Cabinets shows low count for the past 4 days of continuous monitoring. A notable increase of particles on T2 was observed - for further action points to understand the failed particle count. RH is still stable between 40-65% as shown in Appendix J.

4.2.1.6 DOE 5.0 – DOE for N2 Purging Practices

Layer 4 of the N2 cabinet contains dust particles, which can be decreased by completing a 5-minute purge. Purging the N2 Cabinet before actual usage reduces the dust particle count, helping to preserve the cabinet's cleanliness.

Layer 4 of the N2 cabinet contains dust particles, which can be decreased by completing a 5-minute purge. Said purging would entail flushing the N2 cabinet to eliminate the dust particles. This reduces the dust particle count, which helps to preserve the cabinet's cleanliness and efficiency shown in Appendix – K.

4.2.1.7 Dedicated N2 Cabinet

With a dedicated N2 Cabinet for Product A and Product B, dust particles can be trapped while also providing an additional layer of protection against FM that could damage the integrity and performance of reconstructed wafers.

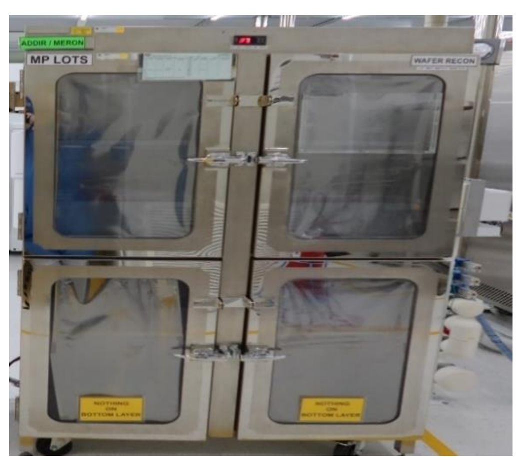


Figure 12: Dedicated N2 Cabinet for Product A and Product B

4.2.1.8 Paperless monitoring of N2 flow rate and RH monitoring of N2 cabinet

Since log sheets made of paper can contribute to the accumulation of FM, a move to a systematical approach of listing information through system-based application is observed.

Monitoring of Relative Humidity, Relative temperature, and Dust particle count were considered in the application generation.

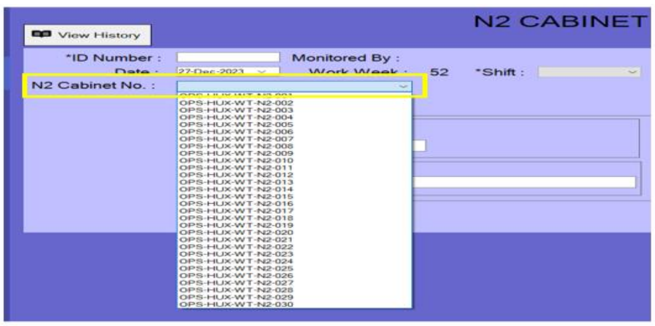


Figure 13: N2 Cabinet Checklist Online Monitoring

4.2.1.9 Airborne Particle Count and Measurement on Different Areas of N2 Cabinet

Daily monitoring of Dust Particle Count was also placed to ensure the monitoring of Airborne FM presence on the shop floor specifically in the critical stations shown in Appendix – L.

4.2.2 Used of Enclosed Pushcart

The enclosed pushcart plays a vital role in transferring direct material from one place to another. This enclosure provides a protective barrier that shields the material from airborne particles and contaminants that could otherwise adhere to or infiltrate the products during movement between processes.

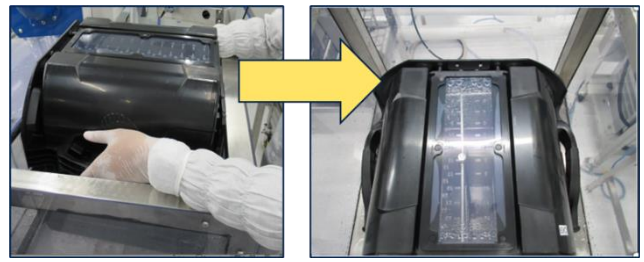
Figure 14: Enclosed Pushcart used for Product A and Product B

The procedure for cleaning the enclosed pushcart is defined at DM00****** specs. The frequency of cleaning is Daily.

4.2.3 IDM Cleaning Procedure

4.2.3.1 FOUP Cleaning Procedure

FOUP (Front Opening Unified Pod) is required to be replenished in one cycle run. After usage, FOUP should be placed in the cleaning rack and needs to be endorsed in the



cleaning area designated for FOUP.

Figure 15: Proper FOUP Cleaning Procedure

4.2.3.2 Qualification and Cleaning Procedure on 8-inch Unified Cassette

Qualifying a new material specific to a Unified cassette involves strong testing and evaluation as this ensures the newly introduced material does not contribute additional FM or contaminants that could compromise the cleanliness of the cleanroom and should maintain the high yield performance of the product as referred to Appendix – M.

After the evaluation, data shows increased FM occurrence on previous process flow with frequent wafer transferring to cassettes, yield loss increase of 0.28%.

Simulation using a unified cassette with no cassette-to-cassette transferring has lower FM occurrence at 0.09%, projected 0.2% yield impact on the new wafer transfer method.

BASELINE					EVALUATION				
Wafer	T0	Wafer Transfer (T1)	T0	Wafer Transfer (T1)	Wafer	T0	Wafer Transfer (T1)	T0	Wafer Transferr (T1)
3	89.00%	88.86%			1	94.65%	94.53%		
4	91.97%	91.55%			2	88.86%	88.79%		
Yield loss	90.49%	90.21%			Yield loss	91.76%	91.66%		
LOSS	0.28%				LOSS	0.09%			

Table 4: Response of yield after using the Unified 8-inch cassette

4.2.3.3 8-inch and 12-inch Metal Cassette/Metal Ring

With the proper introduction of procedures for cleaning both 8 and 12-inch Metal Cassettes and Rings, FM accumulation can be prevented. Using the Ultrasonic Machine with enhanced parameters, FM will not be a problem as this is easily removed by the machine.

Figure 16: Proper way of Cleaning of Metal cassette with Metal Ring

The procedure of cassette cleaning is defined at DM****** (Test and Finish Ultrasonic Cleaning Process)
Note: Cleaning is every day, the cassette is being cleaned every cycle only, including checking of cover condition.

4.3 Methodological Aspect

4.3.1 Ground strap operator re-awareness

Static electricity can cause surfaces to attract and hold onto airborne particles, including dust, fabric fibers, and other particulates. By grounding personnel and equipment, ground straps reduce the static charge, thereby decreasing the likelihood that these surfaces will attract and retain airborne contaminants. Ground straps prevent these discharges, thereby reducing the creation of new particulates that could compromise the cleanroom's-controlled environment.

Figure 17: Wrist strap awareness label to the operator

4.3.2 Dry Clean OCAP

Introducing a Dry Clean OCAP (as shown in Appendix - N) specifically aimed at reducing FM accumulation on top of wafer surfaces in a cleanroom environment. This strategy involves identifying deviations from standard cleaning procedures and promptly implementing corrective actions without introducing moisture or chemicals that could potentially harm the wafer surfaces.

Process Details							BASELINE (T0)					DRY CLEAN EVALUATION (T1)					Overall Yield Gain
DOE	ADI-C	Saw	Saw Parameters: Saw Condition	Saw Parameters: Dry time (sec)	Saw Parameters: RPM	Material	Wafer Yield	FM Yield loss	Dice Fly Off	Broken/Crack	Die Misalignment	Wafer Yield	FM Yield loss	Dice Fly Off	Broken/Crack	Die Misalignment	
DOE1	BTI01	BWS21	POR	270	1500	Q316035-1895	96.70%	3.8%	0%	0%	0%	98.50%	1.80%	0%	0%	0%	1.80%
DOE2	BTI01	BWS21	Lower than POR	135	1500	Q316035-1990	98.60%	1.3%	0%	0%	0%	99.60%	0.30%	0%	0%	0%	1.00%
DOE3	BTI01	BWS21	Higher than POR	540	1500	Q316035-2095	96.20%	3.3%	0%	0%	0%	98.20%	1.85%	0%	0%	0%	2.00%

Process Details							BASELINE (T0)					DRY CLEAN EVALUATION (T1)				
DOE	ADI-C	Saw	Saw Parameters: Saw Condition	Saw Parameters: Dry time (sec)	Saw Parameters: RPM	Material	INPUT (QTY)	FM Qty	Dice Fly Off	Broken/Crack	Die Misalignment	INPUT	FM	Dice Fly Off	Broken/Crack	Die Misalignment
DOE1	BTI01	BWS21	POR	270	1500	Q316035-1895	7764	292	0	0	0	7764	140	0	0	0
DOE2	BTI01	BWS21	Lower than POR	135	1500	Q316035-1990	7774	100	0	0	0	7774	23	0	0	0
DOE3	BTI01	BWS21	Higher than POR	540	1500	Q316035-2095	7797	258	0	0	0	7797	144	0	0	0

Table 5: Qualification and Data Results using Dry Clean OCAP

Data shows FM defect rate reduced after DRY clean with 1.0% to 2.0% yield gain.

4.3.3 Transfer jig from cassette to shipper box

Eliminating manual handling in a process within a cleanroom environment mainly affects the accumulation of FM because humans are significant sources of contaminants, including skin flakes, hair, and clothing fibers. Automated processes reduce the direct interaction between workers and the sensitive products or components being manufactured, significantly decreasing the likelihood of introducing particulates and other contaminants into the clean area. Introducing the Transfer Jig would greatly affect the overall efficacy of the process as this separate's human intervention from direct material handling.

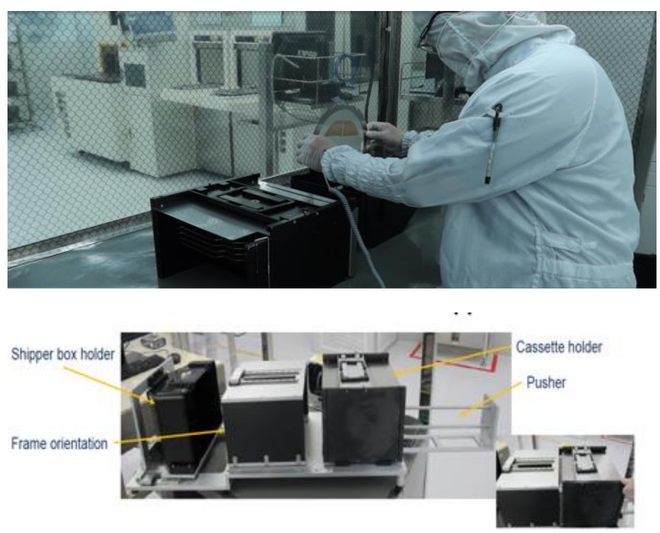


Figure 18: Current process of reconstructed wafer transfer to shipper box.

4.4 Environment Check, people movement, and re-layout on Critical Stations

4.4.1 Change of entrance at Production Line

Changing the entrance configuration and regulating people's traffic in a cleanroom environment are strategic measures that can significantly affect the accumulation of FM inside such controlled spaces. By optimizing entrance locations and the flow of personnel, facilities can minimize the number of contaminants brought in from outside areas, as each entry and movement within the cleanroom can introduce airborne particles, fibers from clothing, and other pollutants. New layout shown in Appendix - O.

4.4.2 Qualification of Shoe Cleaner

Reducing the amount of particulate matter and contaminants introduced from outside is the main role of the installation of shoe cleaners before entry into a clean environment. By effectively cleaning the shoes of personnel and visitors, this measure helps maintain the stringent cleanliness standards required in cleanroom settings, crucial for the manufacturing of sensitive components such as the final product – reconstructed wafers. This proactive approach to contamination control directly contributes to minimizing defect rates and improving the overall reliability and integrity of products produced within the cleanroom.

Figure 19: Shoe cleaner installation at the entrance of Production line

4.4.3 Reduction/Removal of working table/chairs

With fewer working tables or items, the cleanroom benefits from improved airflow and easier cleaning protocols, leading to a decrease in the overall particle count in the environment. This streamlined setup not only enhances the cleanliness of the cleanroom but also reduces the risk of product defects associated with particulate contamination, thereby improving the reliability and performance of the products manufactured in such a controlled setting. Layout shown in Appendix – P.

5.0 CONCLUSION

The implementation of methodological controls to prevent FM interference in the tough environment of a Class 1K cleanroom—which is essential for wafer-level semiconductor manufacturing—has been thoroughly studied in this study. The study's key findings show that modern air filtering systems, real-time particle monitoring, and improved access controls considerably lower the incidence of FM, improving yield rates and product quality in the process. Furthermore, the adoption of innovative materials and surface treatments has shown promise in creating environments that inherently prevent contamination.

This research highlights the importance of a proactive view towards FM control. By integrating different methodologies and assisting in analysis of spikes of FM through continuous measurement – facilities can anticipate contamination events and implement preventive measures before production is affected. Significant figures were shown at MIT showing enhancement a successful piece of FM reduction in machine assembly. Moreover, the study emphasizes the critical role of human factors in FM management, advocating for comprehensive training programs that reinforce best practices in cleanroom conduct. These controls – outlined in this paper not only mitigate the risks associated with FM interference but also contribute to operational efficiency and sustainability.

In conclusion, the research provides a robust foundation for addressing FM interference in wafer-level manufacturing. It emphasizes an integrated approach that leverages continuous improvement and human factors engineering to maintain the integrity of cleanroom environments. As the semiconductor industry continues to advance, with ever-decreasing feature sizes and increased complexity, the principles and strategies discussed herein will remain pivotal in ensuring the reliability and quality of semiconductor devices.

6.0 RECOMMENDATIONS

The recommendations below aim to further enhance the field's understanding and management of FM in Wafer-level manufacturing:

1. **Advanced Detection Techniques:** Future research should explore the development and integration of more sophisticated FM detection technologies. This includes nanoscale sensors and machine-learning algorithms capable of predicting contamination events before they impact the wafer production line.

2. **Material Science Innovations:** Research into self-cleaning surfaces or materials that can neutralize contaminants on contact would be particularly valuable.

3. **Cross-Industry Benchmarking:** Examining FM control strategies in industries beyond wafer-level manufacturing, such as pharmaceuticals or aerospace, could yield cross-applicable insights. This research opportunity might reveal innovative practices or technologies that could be adapted to the wafer-level testing context.

7.0 ACKNOWLEDGMENT

With the help and contributions of numerous people and organizations, the research project "Strategic Deployment of Effective and Efficient Methodological Controls of Foreign Material Interference in Wafer-Level 1K Manufacturing Cleanroom Environment" was able to be completed. We would like to express our sincere gratitude to everyone who helped make this work possible.

The researchers would like to thank the support coming from the Management Team, especially Aileen Gonzales, Ana Liza Ferraris, Marco Chavez and Peter Escarro for their unwavering support and guidance. Their belief in our capabilities has been a source of motivation and resilience during the demanding phases of this project.

This research is a testament to the power of collaboration and support across different spectrums of the academic and industrial community. We are grateful for the opportunity to contribute to the field of manufacturing and testing and look forward to the potential applications and future developments arising from this work.

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9.0 ABOUT THE AUTHORS

Bryan M. Delos Santos holds a degree in Electronics Engineering with extensive practical knowledge in the Wafer Probing Industry. He's been with STMicroelectronics for 2 years as Test Process Engineer 2 which continues to enhance analysis and interpretation and provides a comprehensive, well-rounded perspective.

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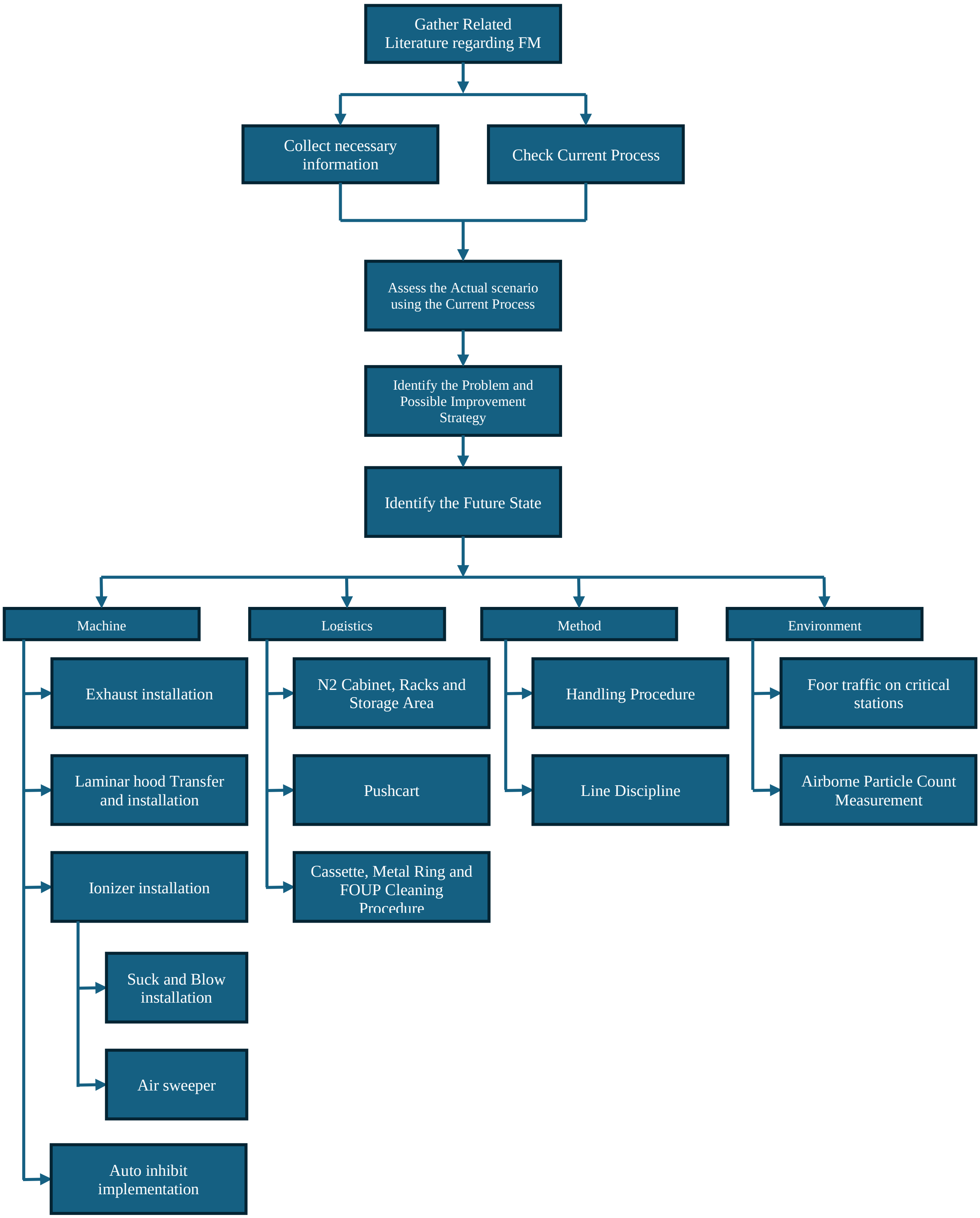
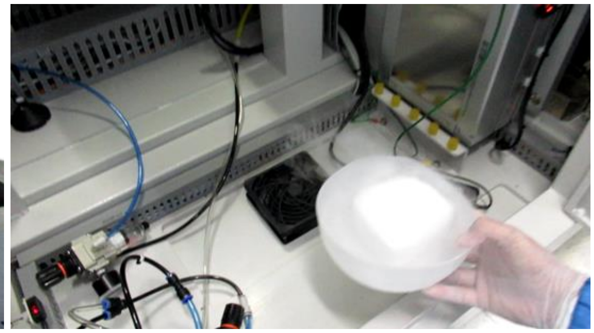
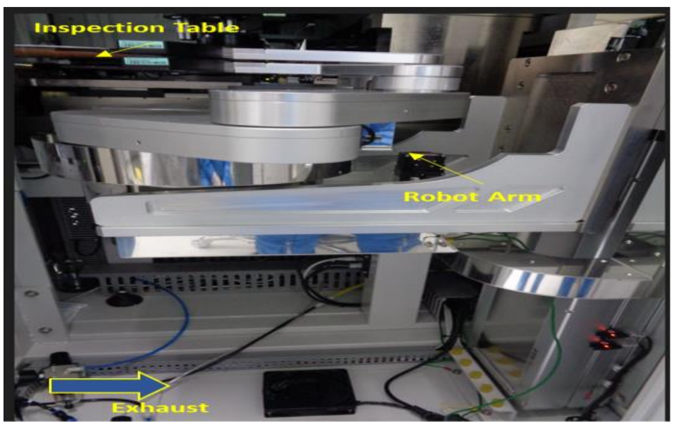
10.0 APPENDICES

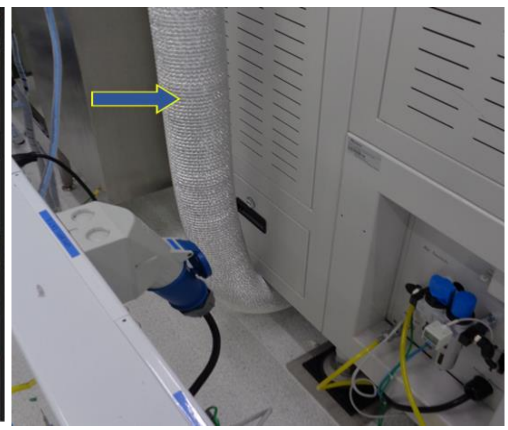
Appendix – A: Framework of FM DOE and Activity

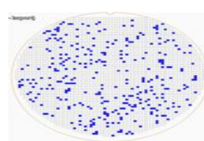
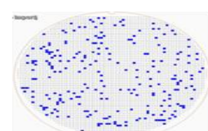
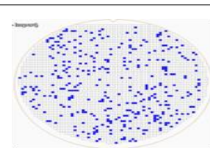
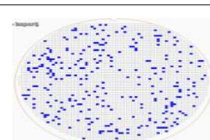


Appendix – B: HEPA Filter and Exhaust Installation at Choma 1

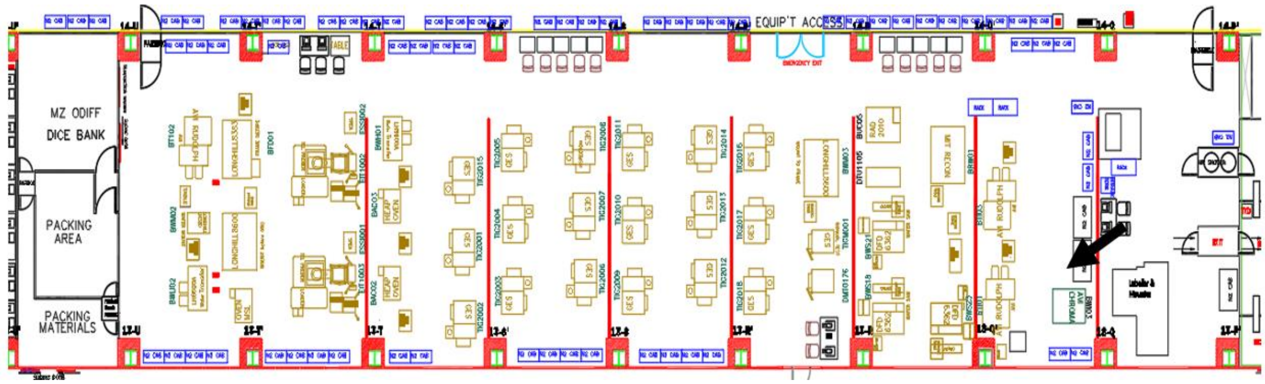


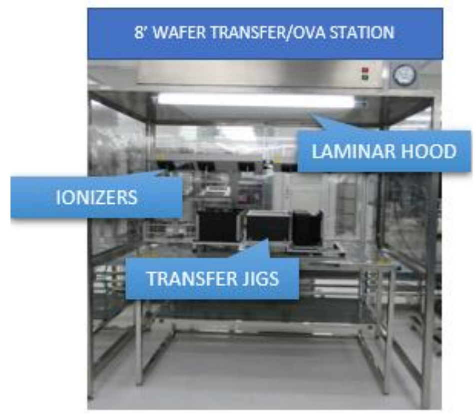




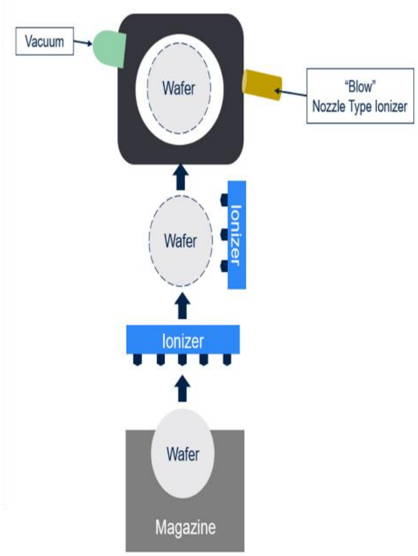
Wafer	Yield		Top Side Reject	
	TO	Add IONIZER	TO - No Exahust	With Exahust
1	85.37%	88.30%		
2	84.63%	87.01%		
Yield Ave	85.00%	87.66%		
Impact/GAIN		2.65%		
Remarks		2.65% Yield gain Equivalent of 3% of the defect was removed		

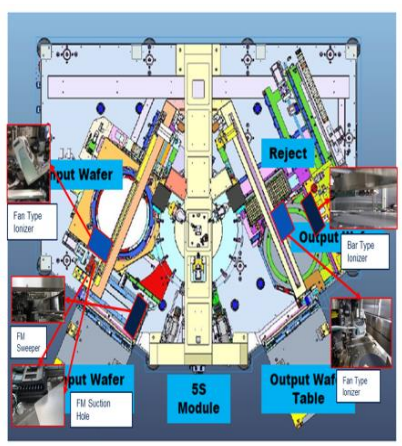
Appendix – C: Layout of Transfer for Enclosed Laminar hood



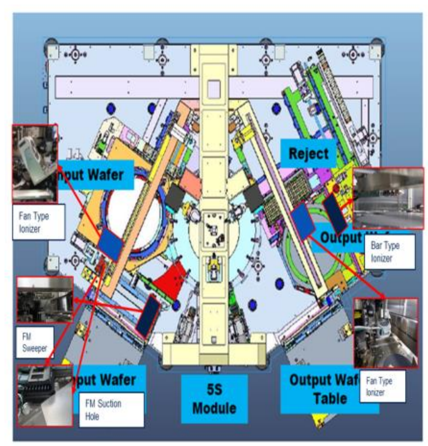


Appendix – D: Suck and Blow Mechanism



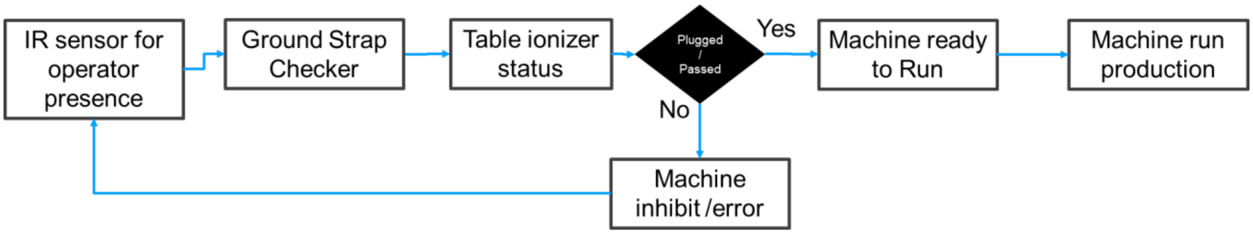


Input – Fan Type + Bar Type Ionizer	
Output – Fan Type + Bar Type Ionizer	
Yield:	*Addir: 93.28%*

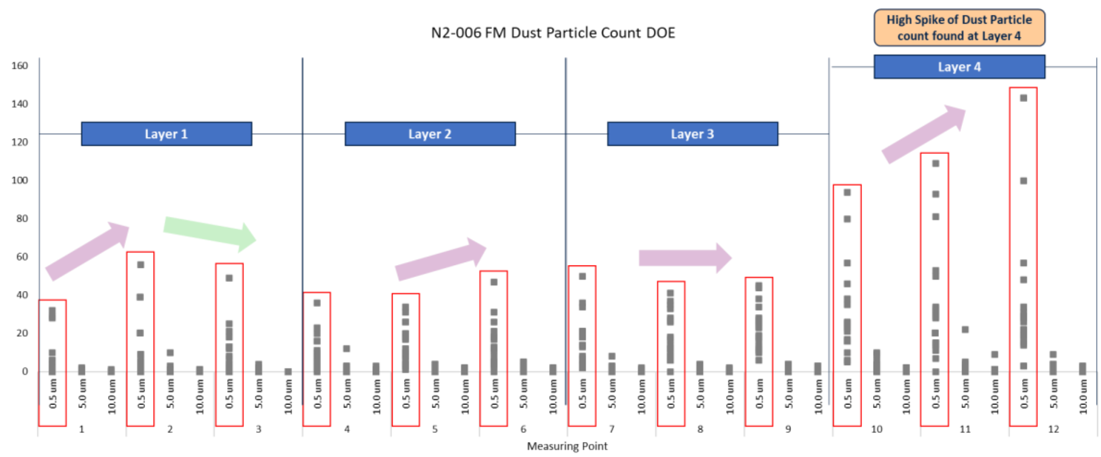


Input: Fan Type + 2 Bar Type Ionizer + Suck and Blow	
Output – Fan Type + Bar Type Ionizer	
Yield:	*Addir: 97.98%*

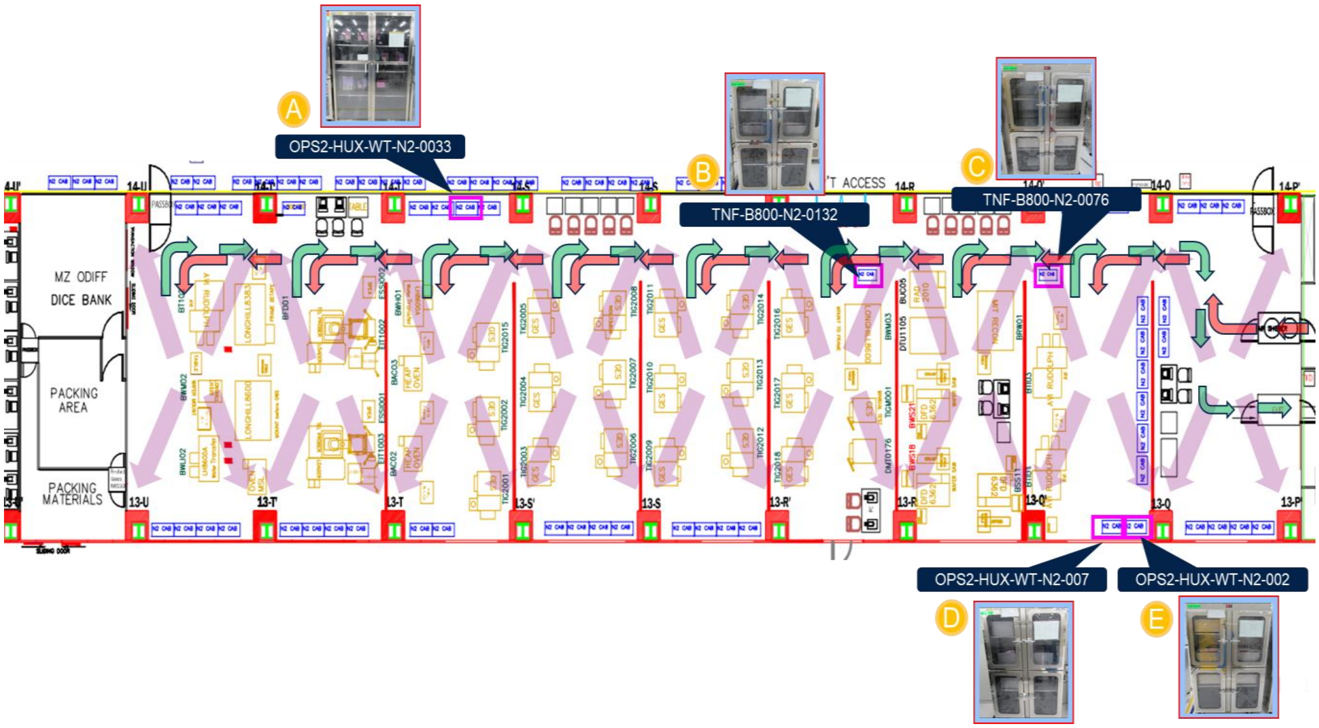
Appendix – E: Auto-inhibit Flow Chart



Appendix – F: Layer 4 with a high concentration of FM

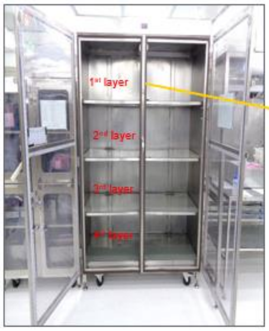


Appendix – G: Particle measurement in each N2 cabinet with installed filters



N2 CABINET			Before Filter Installation		T0 - After Filter Installation		T1 – After Additional Cleaning (With Filter)		T2 – After Additional Cleaning (With Filter)		T3 – After Additional Cleaning (With Filter)		T4 – After Additional Cleaning (With Filter)		T5 – After Additional Cleaning (With Filter)		T6 – After Additional Cleaning (With Filter)		T7 – After Additional Cleaning (With Filter)		T8 – After Additional Cleaning (With Filter)		T9 – After Additional Cleaning (With Filter)		T10 – After Additional Cleaning (With Filter)		T11 – After Additional Cleaning (With Filter)		T12 – After Additional Cleaning (With Filter)	
			FACILITIES		FACILITIES		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS		PROCESS	
			10/24/2023 6AM		10/24/2023 8AM		11/03/2023 8PM		11/04/2023 2AM		11/04/2023 8AM		11/04/2023 2PM		11/04/2023 8PM		11/05/2023 2AM		11/05/2023 8AM		11/05/2023 2PM		11/05/2023 8PM		11/06/2023 2AM		11/06/2023 8AM		11/06/2023 2PM	
			0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron	0.5 Micron	5.0 Micron
A OPS2- HUX-WT-N2-033	W	OUTSIDE TOP OF CABINET	340	4	0	0	10	1	0	0	10	0	0	0	0	0	0	0	0	0	60	1	10	0	0	0	60	2	20	1
	X	INSIDE TOP SHELF	300	0	130	0	80	0	20	0	20	0	30	0	0	0	40	0	0	0	10	0	30	1	20	0	10	0	10	0
	Y	INSIDE BOTTOM SHELF	1030	2	1650	2	320	0	30	0	40	0	70	1	300	1	120	0	80	1	0	0	20	0	10	0	20	0	0	0
	Z	OUTSIDE BOTTOM OF CABINET	-	-	130	2	10	1	0	0	10	2	0	0	0	0	0	0	30	0	0	0	10	0	0	0	60	0	0	0
B TNF-B800-N2-0132	W	OUTSIDE TOP OF CABINET	180	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	110	0	0	0
	X	INSIDE TOP SHELF	550	1	340	0	70	0	20	0	10	3	30	0	10	0	0	0	0	0	70	0	30	1	10	0	160	1	10	1
	Y	INSIDE BOTTOM SHELF	1210	2	870	2	120	0	150	0	130	1	120	0	110	0	40	0	140	0	40	0	50	1	10	1	190	3	30	1
	Z	OUTSIDE BOTTOM OF CABINET	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	10	0	70	0	20	0
C TNF-B800-N2-0076	W	OUTSIDE TOP OF CABINET	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	20	0	10	0	0	0
	X	INSIDE TOP SHELF	170	0	350	0	60	0	20	0	0	0	0	0	0	0	10	0	0	0	0	0	30	0	10	0	0	0	0	0
	Y	INSIDE BOTTOM SHELF	5560	11	1950	6	110	1	60	0	70	0	70	0	170	2	60	0	50	0	20	0	20	0	40	0	120	0	50	1
	Z	OUTSIDE BOTTOM OF CABINET	-	-	20	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	30	0	30	0	30	0	20	0
D OPS2-HUX-WT-N2-007	W	OUTSIDE TOP OF CABINET	160	2	40	1	20	0	0	0	0	0	0	0	20	0	20	0	0	0	0	0	30	0	20	0	60	1	30	0
	X	INSIDE TOP SHELF	480	2	480	0	10	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	20	0	10	0
	Y	INSIDE BOTTOM SHELF	4420	12	3030	9	160	2	80	0	70	1	50	0	50	0	80	0	100	0	20	0	70	0	40	1	180	0	60	1
	Z	OUTSIDE BOTTOM OF CABINET	-	-	70	2	10	0	0	0	0	0	0	0	10	1	10	0	0	0	0	0	50	1	10	0	0	0	10	0
E OPS2-HUX-WT-N2-002	W	OUTSIDE TOP OF CABINET	220	1	20	1	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
	X	INSIDE TOP SHELF	180	0	120	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	10	0	10	0	50	1	10	0	30	0
	Y	INSIDE BOTTOM SHELF	2430	3	470	6	170	0	90	1	100	6	70	2	160	0	130	0	120	0	120	2	10	0	100	0	160	0	80	1
	Z	OUTSIDE BOTTOM OF CABINET	-	-	15	3	40	0	10	0	10	2	0	0	30	1	30	0	20	0	0	0	10	0	30	0	0	0	0	0

Appendix – H: Proper cleaning of N2 Cabinets using manual lint- free cloth application



Appendix – I: RH reading from Layer 4 upward and downward

ECAP N2 CABINET

ECAP	T0		T1		T2		T3	
	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN
Layer 1	56.03	57.65	55.77	57.07	56.3	58.38	55.49	58.36
Layer 2	55.96	58.74	56.43	58.56	56.71	58.34	55.64	58.38
Layer 3	56.91	58.63	56.15	58.53	57.17	58.45	55.77	58.86
Layer 4	53.81	59.1	57.48	59.04	56.32	58.78	58.24	60.21

ACAP N2 CABINET

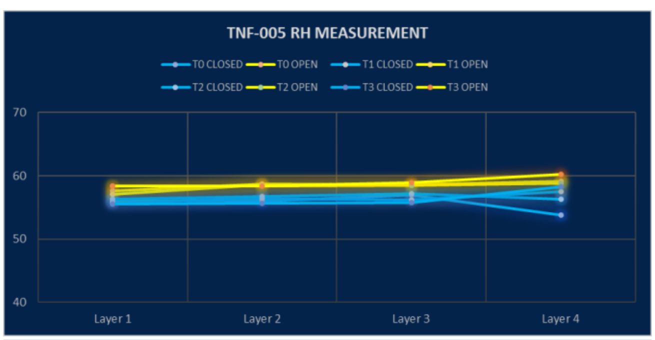
ACAP	T0		T1		T2		T3	
	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN
Layer 1	41.8	55.56	41.38	52.88	50.36	53.67	49.75	52.58
Layer 2	49.04	54.49	50.01	54.35	53.94	55.92	50.81	52.62
Layer 3	50.18	55.14	50.10	53.82	48.66	55.81	52.87	54.78
Layer 4	43.94	53.34	52.73	54.93	55.20	58.90	49.11	51.21

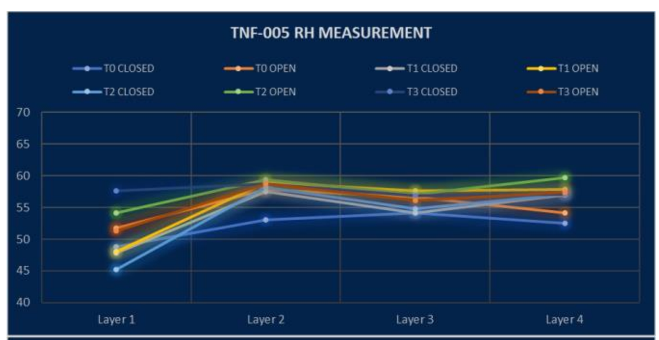
ECAP N2 CABINET

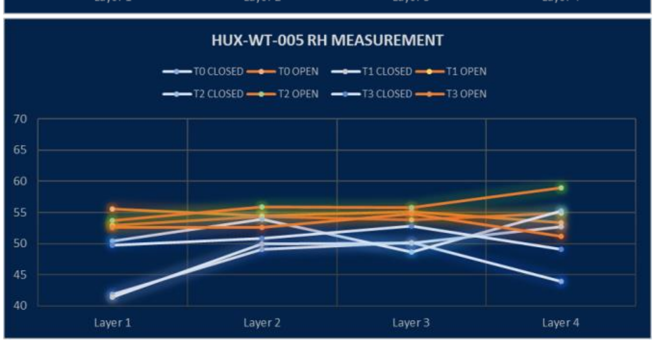
ECAP	T0		T1		T2		T3	
	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN
Layer 1	48.81	51.73	47.80	48.06	45.24	54.19	57.60	51.30
Layer 2	53.09	57.83	57.47	58.90	58.19	59.42	58.67	58.67
Layer 3	54.13	56.60	54.15	57.63	54.84	57.10	56.86	56.11
Layer 4	52.52	54.14	56.92	57.89	57.12	59.70	57.06	57.40

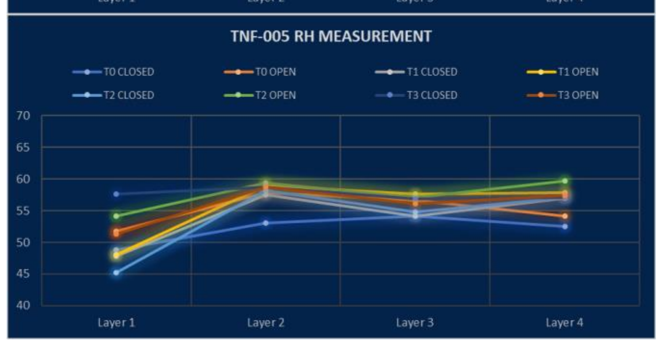
ACAP N2 CABINET

ACAP	T0		T1		T2		T3	
	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN	CLOSED	OPEN
Layer 1	47.97	51.26	42.67	45.48	48.62	51.70	50.20	53.32
Layer 2	52.34	55.60	50.23	54.10	51.18	54.36	49.83	51.60
Layer 3	50.16	54.09	49.53	53.32	47.26	51.45	53.00	54.36
Layer 4	52.19	55.81	51.28	55.03	42.86	50.73	47.27	50.83

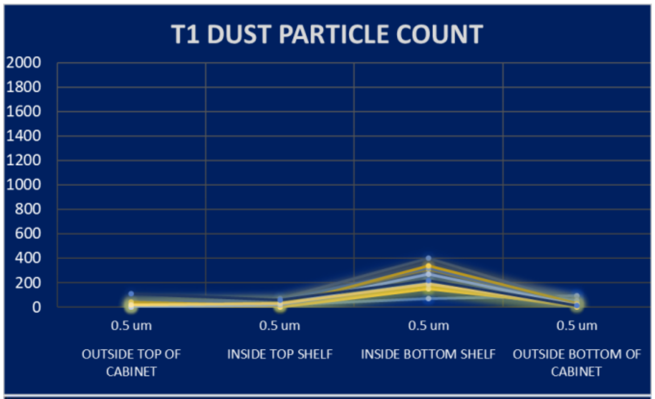


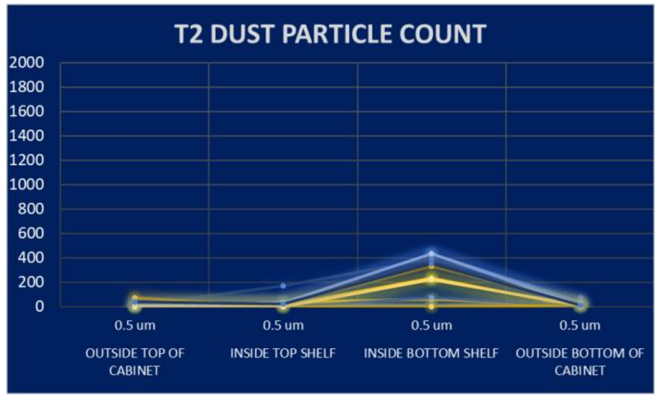


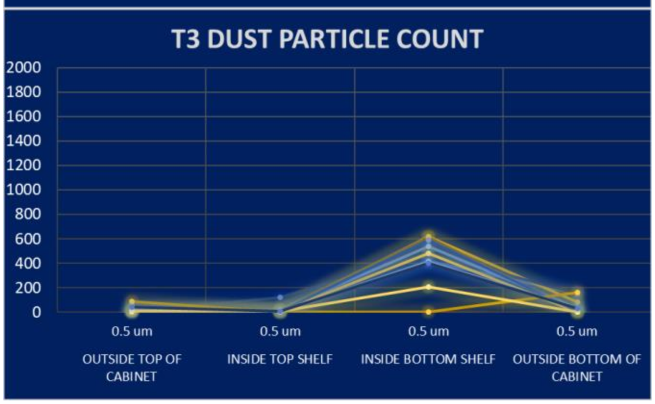


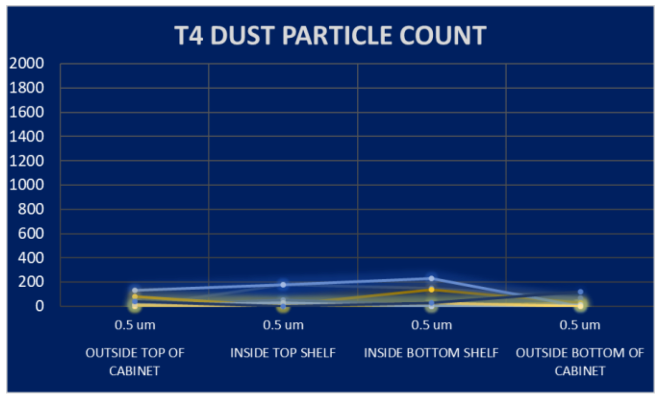


Appendix – J: Additional measurement of dust particle to newly installed particulate filter



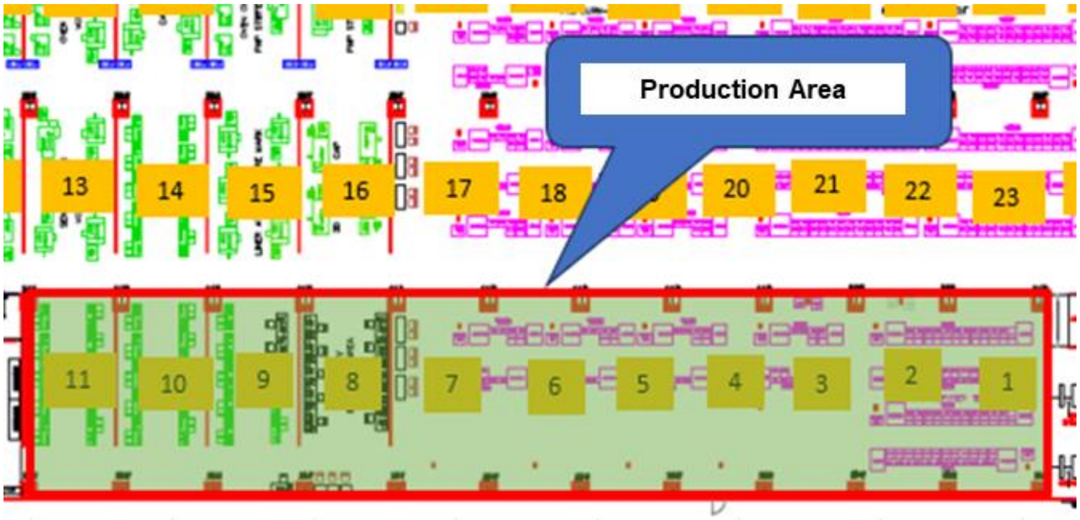




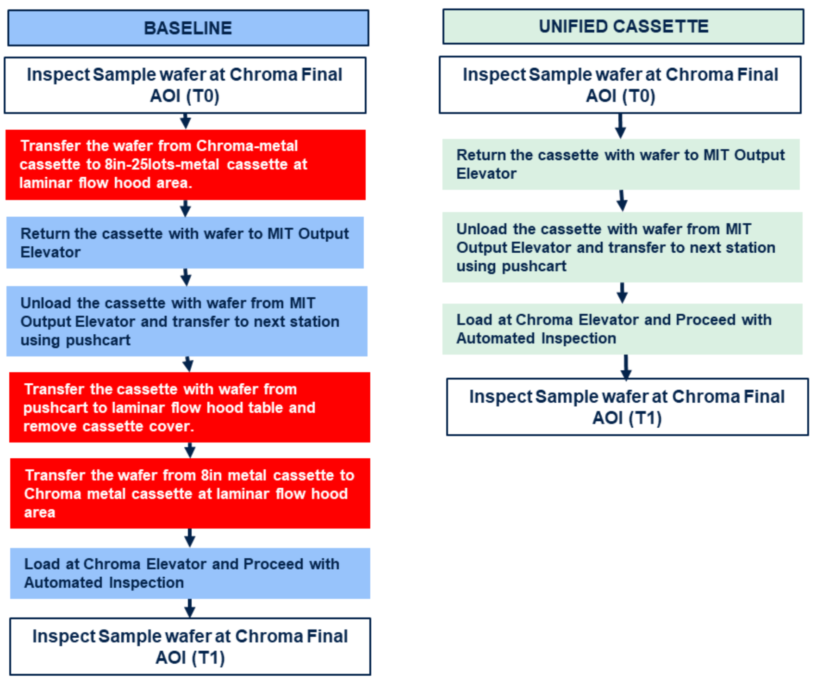


Appendix – K: Proper way of N2 cabinet with 5-minute purging daily

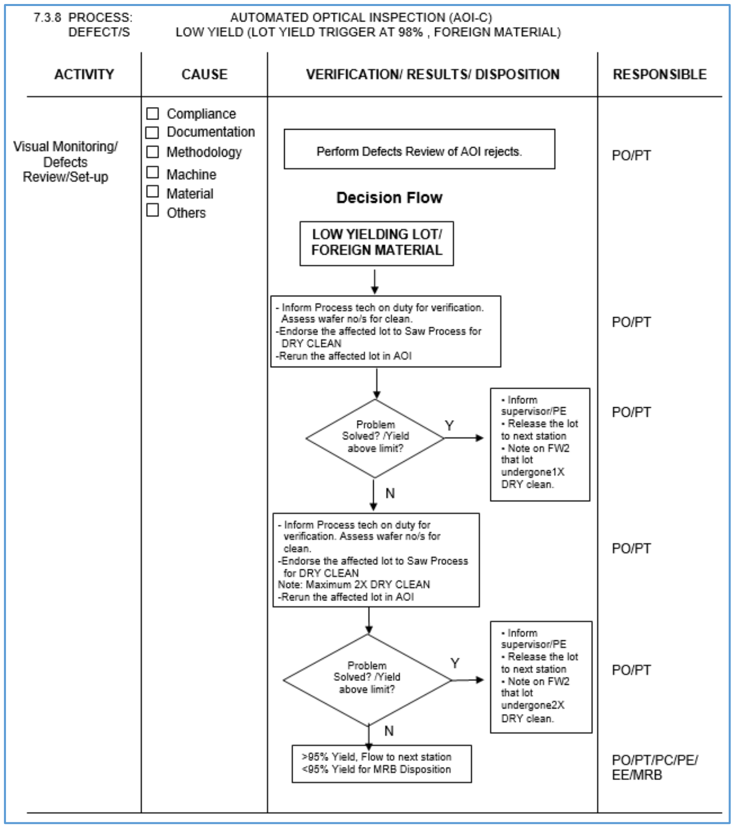
Appendix – L: Measurement of Dust particle Count in Critical Stations



Appendix – M: Current and Future State of Unified Cassette Enhancement



Appendix – N: Detailed Dry Clean OCAP for Low yielding lot caused by FM

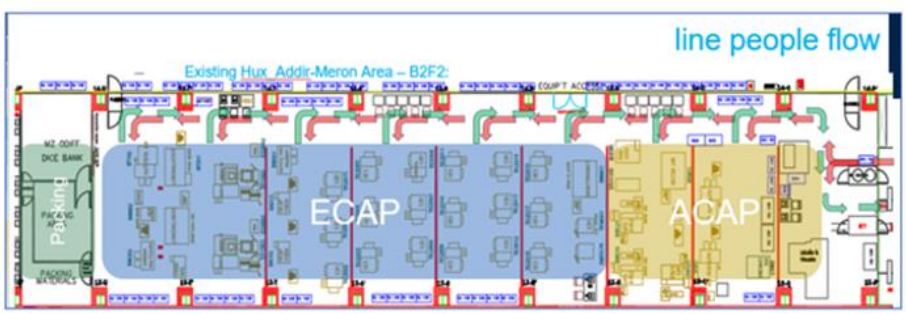


7.3.8 PROCESS: AUTOMATED OPTICAL INSPECTION (AOI-C)
DEFECT/S LOW YIELD (LOT YIELD TRIGGER AT 98% , FOREIGN MATERIAL)

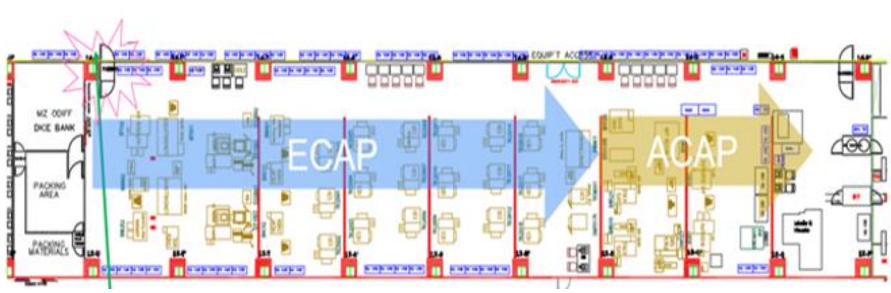
ACTIVITY	CAUSE	VERIFICATION/ RESULTS/ DISPOSITION	RESPONSIBLE
Visual Monitoring/ Defects Review/Set-up	☐ Compliance ☐ Documentation ☐ Methodology ☐ Machine ☐ Material ☐ Others	Perform Defects Review of AOI rejects.	PO/PT
		Decision Flow **LOW YIELDING LOT/ FOREIGN MATERIAL** - Inform Process tech on duty for verification. Assess wafer no/s for clean. -Endorse the affected lot to Saw Process for DRY CLEAN -Rerun the affected lot in AOI	PO/PT
		Problem Solved? /Yield above limit? Y: • Inform supervisor/PE • Release the lot to next station • Note on FW2 that lot undergone1X DRY clean.	PO/PT
		N: - Inform Process tech on duty for verification. Assess wafer no/s for clean. -Endorse the affected lot to Saw Process for DRY CLEAN Note: Maximum 2X DRY CLEAN -Rerun the affected lot in AOI	PO/PT
		Problem Solved? /Yield above limit? Y: • Inform supervisor/PE • Release the lot to next station • Note on FW2 that lot undergone2X DRY clean.	PO/PT
		N: >95% Yield, Flow to next station <95% Yield for MRB Disposition	PO/PT/PC/PE/ EE/MRB

Appendix – O: Transfer of Entrance/Exit Door

FROM

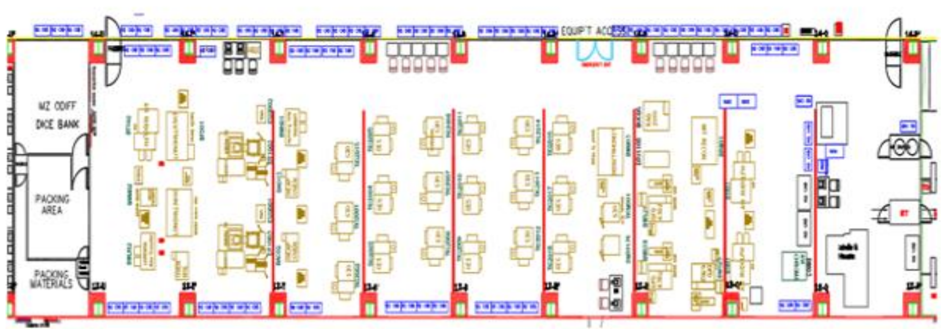


TO



Appendix – P:
Reduction of working tables and chairs inside Production Line

FROM



TO