CHALLENGE TO ERROR PROOFING AUTOMATED INSPECTION SOLUTIONS TO EMBEDDED COSMETIC DEFECTS ON OPTICAL DIFFUSER WAFER USING HIGH RESOLUTION CHROMA EQUIPMENT

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ABSTRACT

With the increasing volume of optical diffuser wafer manufacturing, we need to think of solutions to streamline the process flow and introduce an effective system of quality control. With the introduction of a new optical diffuser product at Operations 2 and support important customer requirement, an immediate challenge to be able to conceptualize an Optical system for embedded defects with mounted tape, not to mention the challenge of the low line capacity. On top of this we are required to qualify a new process to support reconstructed wafer manufacturing and meet product quality for end customer.

This customer request is a challenge to Operations 2 as this is the first time we are processing a reconstructed wafer and requires Front surface and Backside surface wafer cosmetic quality compliance. During the qualification we must consider different factors which includes the appropriate machine and its capability and limitation, qualification of new process, new operation, and resources. At the onset of the initial phase of the qualification we have been doing manual inspection of wafer at Front side, with wafer flipping and manual inspection of Back side using a high magnification scope for 2mm dice size. These issues not only affect the yield at the current step brought by manual intervention but also resulting to lot cycle time loss with 2hrs inspection time on 1 (one) reconstructed wafer of about 3000 dice. To improve overall productivity and ensure product quality as these are key factors at the start of engineering milestone and must be effective prior mass production. This requires further efforts to eliminate manual intervention. With detailed process mapping and strategic qualification, the existing method will be automated using an efficient optical system supporting not only the quality of products but also the manufacturability towards high volume production.

To address the manual handling resulting to different quality issues, a new technology was instituted to resolve these issues with the introduction of the Automated Backside and Frontside Wafer Inspection The proposed machine was designed specifically for this purpose and was evaluated thoroughly before integration on the Optical diffuser process flow. Results showed that the issues pertaining to manual inspection were eliminated after the implementation of Automated Backside and Frontside Inspection. Finally, the method shows increased productivity from 2hrs wafer inspection to 25mins wafer inspection. Not to mention the avoidance on additional manpower head count and elimination of customer complaints on defect embedded between dice and mounted tape and Frontside defects. This literature discusses the breakthrough solution for quality improvement and manufacturing process & technology at Optical diffuser wafer manufacturing and removal of the manual visual inspection and improved product quality control. Realization of proposed solution and automation aided during the engineering phase and eliminated non-value-added activity. By introduction of new process and challenge to process yield improvement further machine improvements were introduced to eliminate cosmetic defect and any cosmetic issues on wafer surface though avoidance of wafer transferring and provision of unified cassette, elimination of Foreign Material (FM) on surface through installation of exhaust & filter system. This provides the best solution in wafer inspection not requiring manual intervention and ensuring perfect compliance to customer requirements and product quality.

1.0 INTRODUCTION

The electronics industry is making a tremendous investment in Optical System Inspection. The reasons for this investment include productivity and product quality control.

Today's Automated Optical machines can effectively discriminate good vs fail units thousands per hour with a very high degree of accuracy. To achieve this performance, the Optical Inspection system must be highly capable of screening defective parts at high speeds and consistent efficiency, positively eliminating introduction of other defects after optical inspection. The product must be free from damage and FM during processing, handling, and placement.

The preferred Optical inspection system for this demand is a Chroma Frontside and Backside Wafer Inspection. The

Chroma Automated Inspection is fully capable on effective defect screening with high resolution image analysis with improved machine design / system to remove or avoid FM interference on wafer surface and defect on tape backside,

In the previous state prior introduction of an Optical system. There was an RTV of dice with FM sandwiched between dice and tape feedback by our Important Customer.

As interim action we deployed manpower to so manual visual inspection on Backside at high magnification scope using 187x to effectively screen the defect, the wafer was then flipped to inspect Frontside brought by manual intervention. This activity takes 2hrs to inspect 1 (one) full recon wafer with 3442 dice 1 (one) lot completion cycle time is more than 24hrs.

The wafer map will be manually updated through map edit that consumes additional 2 to 4hrs activities.

Not to mention an additional tape inspection injected on mounting tape prior utilization at wafer reconstruction vision system consumes 2.25hrs to 3hrs activity for 1 lot processing requirements.

Consequently, the need for the provision of an AOI driven to support High Volume Production, improve productivity, avoid manpower cost, avoid manual wafer intervention and automate map update.

The Optical system concept introduces an innovative solution with an Automated and highly effective defect detection of Backside and Frontside Wafer defects with high-speed processing with introduced process and machine improvement for High product quality and Machine Efficiency.

1.1 Automated Optical Inspection (AOI)

AOI (AOI) performs visual inspection of dice/object during manufacturing using camera with adjusted light settings and image analysis technology.

The light source illuminates from different angles and the camera takes pictures to create a comprehensive image for assessment. Comparing the captured image to a reference good dice image and asses' measurements according to thresholds or tolerances or against the stored data of a flawless dice/object. The comparison allows the optical system to pinpoint any discrepancies or defects on actual dice or object.

AOI has been widely used in the manufacturing process because it is a non-contact inspection or test method. This is because the AOI process is automated, meaning it saves time and costs for both the manufacturer and the customer.

Advantages of automated inspection increased production efficiency. Improved accuracy and consistency. It inspects items quickly and precisely while reducing the possibility of human error and guaranteeing repeatable results. This results in shorter inspection times. More uniformity, accuracy, and lower costs.

On current manufacturing system, once the dice/wafer has passed inspection, it would update the wafer map with traceable identity of PASS vs FAIL dice and update, with saved images and other required information.

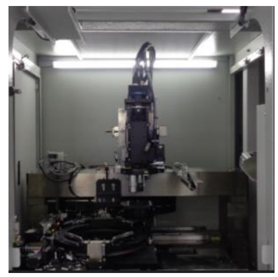


Fig1. Automated Inspection Equipment

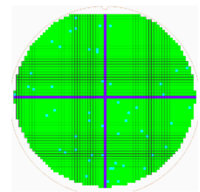


Fig2 Wafer Map

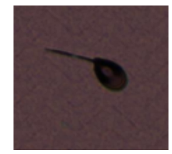


Fig.3 Defect Image

1.2 Frontside and Backside Wafer Inspection Requirement

With the new product introduction and customer requirement. We are required to check accordingly the defects per region of interest and FM both Frontside and Backside of the wafer (defect in between dice and tape).

Table 1. Defect size criteria per Region of Interest

ROI	Defect size
1. Edge of die	Chipped >50um
2. Metal Pad	Scratches >340um, Other defects >50um size
3. Frontside datum area	Defect >30um size
4. Tracing code	Missing Trace
5. Frontside non datum area	Defect >50um
6. Backside datum area	FM >30um , between dice and tape
7. Backside non datum area	FM >50um , between dice and tape

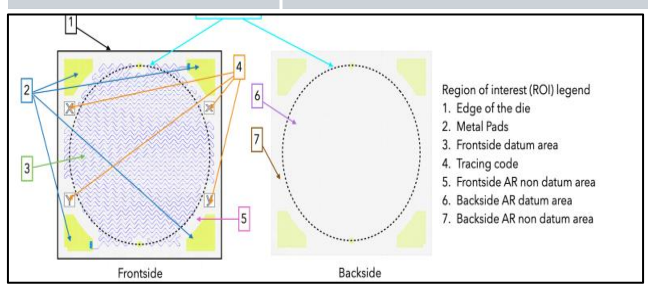
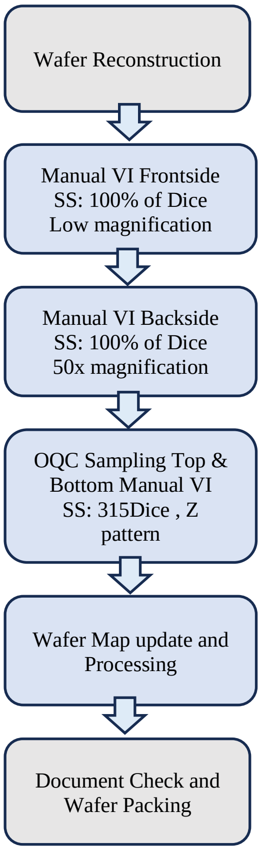


Figure 4. Die Region of Interest, with defects and contamination requirements delineated on Table1.

1.3 Recon Process Output Response

During Engineering Phase to inspect cosmetic defects on Frontside and Backside of the wafer including FM in between dice and tape, after reconstruction process there is a manual intervention. Manual intervention can be subjective depending on the operator. Manual wafer flipping and recording of dice coordinated on printed wafer map need to be performed. Process Control Outgoing Quality Inspection is done through Manual Visual Inspection Sampling.

Flow for Manual VMI After Reconstruction Process:



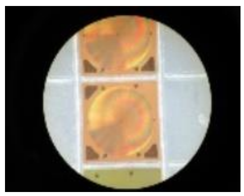


Figure 5. Frontside Inspection Focus on Surface Defects

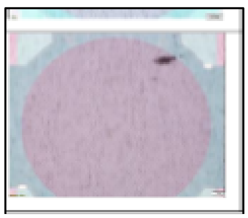


Figure 6. Backside Inspection Focus on Embedded defects in between dice and tape

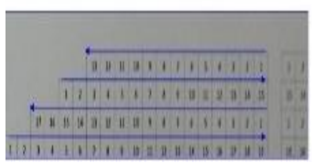


Figure 7. Inspection Record on printed map

Table 2. Process Time consumed on Manual Inspection

Production Activity	Average Process Time
1. Pre-Operations (Set up and Material Preparation) at Low Magnification Scope	8.2 mins
2. Frontside Inspection w/ printed map update (3442u)	66.4 mins per recon wafer 617.3mins 1 lot of 12 recon wafers
3. Pre-Operations (Set up and Material Preparation) at High Magnification Scope	9.9 mins
4. Backside Inspection w/ printed map update (3442u)	90.8 mins per recon wafer 844.2 mins 1 lot of 12 recon wafers
5. Post Operations (Records update and Lot preparation for next step)	6.5mins
Process Control Activity	**Average Process Time**
1. Wafer Map edit and update	57.3mins for 3% loss of 1 lot w/ 12 recon wafers
2. Backside and Frontside Visual Inspection	12.1 mins 1 representative wafer per lot
***Total Process time to complete 1 lot with 32000 dice is 1555.4mins (25.9 hrs)** ***2 Visual operators per day to complete 1 lot inspection**	

Moreover, the existing procedure during Engineering phase consumes more than 24hrs activities to complete processing of 1(one) lot with 32000 dice. With the manpower resources needed; 2 (two)Visual operators, 1 (one) technician for Map edit and 1 (one) technician for Outgoing Control Inspection.

The efficiency and effectiveness of Manual Visual Inspection is not guaranteed. During Engineering Phase there were Returned wafers and confirmed escape on our inspection or induced during the manual intervention process.

Table 3. Returned wafer remnants from our Customer with confirmed defects.

Wafer#	Reject Criteria	Remarks
Q2150121902	Reject if >340 µm	Pad scratch is confirmed
Q2150122202	Ø > 50 µm & > 2000 µm^2	Pad contam is confirmed
Q2150122303	Ø > 30 µm & > 700 µm^2	Optical contam is confirmed
	Ø > 30 µm & > 700 µm^2	Optical contam is confirmed
	L and W is >50um	Corner chipping is confirmed
Q2150122304	Ø > 50 µm & > 2000 µm^2	Pad contam is confirmed
Q2421150602	Reject if >340 µm	Pad scratch is confirmed
	Reject if >340 µm	Pad scratch <340um, but failed as pad contam
	Reject if >340 µm	Pad scratch is confirmed
	Reject if >340 µm	Pad scratch <340um (scratch faded on other edge)
	Reject if >340 µm	Pad scratch is confirmed
	Reject if >340 µm	Pad scratch is confirmed

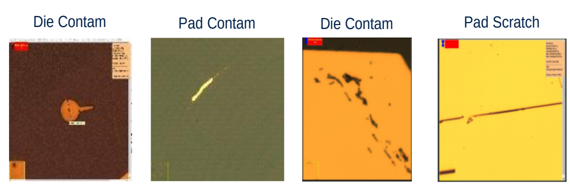


Figure 8. Frontside defects escaped Manual Visual Inspection

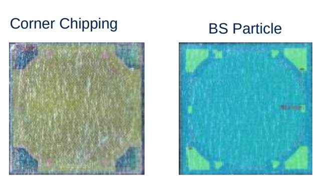


Figure 9. Backside defects escaped Manual Visual Inspection

1.4 Semi-Auto Tape Only-Inspection

With the customer feedback of units with FM defect sandwiched between dice and tape, Interim action was Tape inspection before dice placement on MIT wafer recon vision system.

Inspection of tape only on 5 zones that consumed 5mins inspection per wafer. This activity will entail 1 (one) hour material preparation per lot with 12 recon wafers, Not to mention the additional preparation time in the event of rejected tape with FM/cosmetic defect.

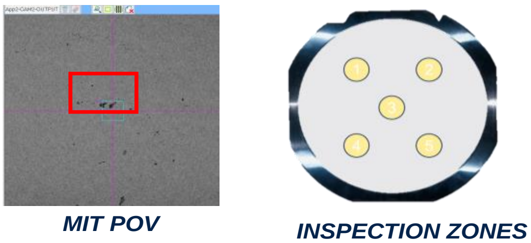
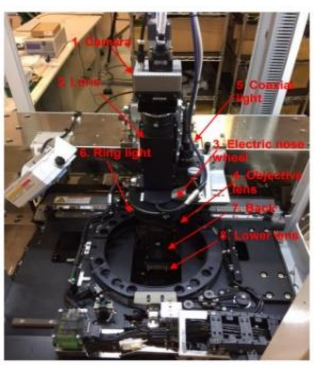


Figure 10. Tape-Inspection zone and sample defect on tape.

1.5 Automated Optical Frontside & Backside Inspection Machine

With the issues encountered at the early engineering stage of this this project. The team have utilized an available machine which could help with this function without compromising the product quality and sustainability.

Chroma Inspection System has top and bottom side color inspection. Capable tor 8inch wafer inspection area. With customer specification per region of interest, the chroma machine has appropriate defect detection algorithms, versatile defect criteria definitions, complete defect classification. Ready for wafer mapping up/down stream operation.



No.	Components
1	Camera
2	Lens
3	Electric nose wheel
4	Objective lens
5	Coaxial light (white)
6	Upper, lower right light
7	Back light
8	Lower lens

Figure. 11. AOI Machine Optical System

Chroma Optical System has high speed camera with autofocus compensation and the machine have a precise wafer handler. Besides Pass and Fail function and bin data, all raw data and dice images may be recorded for further analysis. It has a database for image analysis thus providing advanced feedback for process controls.

2.0 REVIEW OF RELATED WORK

Based on studies, AOI process has been widely used on manufacturing process because of non-contact inspection method and can be used on many stages of manufacturing process at high efficiency. Aside from AO Function, machines can be integrated with improvements to perform various manufacturing tasks.

The motivation of this study is to eliminate manual intervention on wafer inspection, tape inspection, manual map update, OQC visual sampling. By introduction of highly effective AOI at high scan speed and integrate machine improvements to prevent additional defects on product.

3.0 METHODOLOGY

3.1 Process Flow with AOI

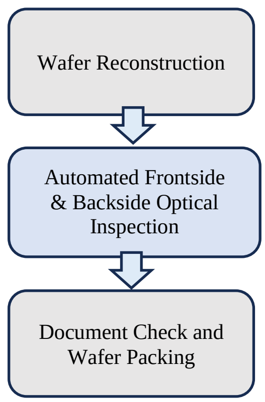


Figure 12. ODIFF Endline Process Flow.
*Need to transfer from Recon cassettes (21 slots) to Chroma AOI cassettes (13 slots)
*Simultaneous inspection of Frontside and Backside
*Auto map update post processing

3.1.1 Frontside and Backside Inspection Qualification

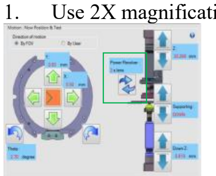
Table 4. Machine Qualification Timeline

Qualification Timeline
Machine Transfer to ODIFF line / production lay out
Installation of facilities
Internal and External Qual plan discussion
Machine set-up/Power Up/Utilities connection/Micro terminal/Network link/Malware scan Anti-virus (Power/Air/Vacuum)
Machine Handler Set-up/Onset debug/Qualification
Equipment Qualification Report/ESH Form
IEDB Enrollment and Set-up / EMCS Enrollment
Process Plan/Process Group inclusion of new process step (Final AOI process) - Non-Critical Station
Yield and Scrap code set-up for new Process
Onsite machine debug and Training to ST Engineers/Techs (Equipment/Operations/Maintenance Training) + Training Material
Set-up Parameter/Process Parameter Check (Critical parameter)
AOI Capability and Inspection Buy-off (FS and Backside)

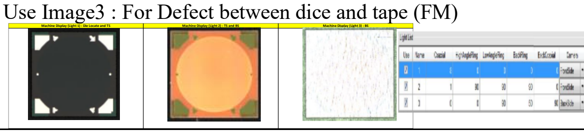
3.1.2 Automated Inspection Concept

Inspection Concept

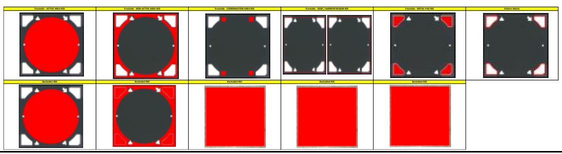
1. Use 2X magnification for 2x2mm dice size:



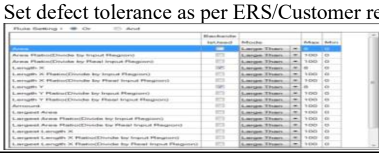
2. Light set adjustment to create images with significant defect contrast:
Use Image 1 for Frontside defect and die locate
Use Image2 For Embedded defects both Front and Backside
Use Image3 : For Defect between dice and tape (FM)



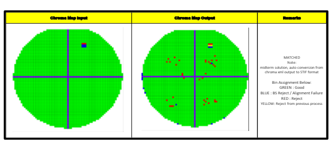
3. Set Region of Interest/Inspection as per ERS/Customer requirements:



4. Set defect tolerance as per ERS/Customer requirements:



5. Set Bin reject codes and integrate on Map wizard system:



3.1.3 Detection Effectiveness through Performing Statistical Analysis Attribute MSA

The measure of metrology effectiveness can be determined through a statistical analysis and MSA, known good and reject samples were prepared and processed three times on machine for qualification.

3.1.4 Attribute R&R Result

• P(FA) This type of error is not as serious as a miss since a conforming part is rejected. However, rejecting a conforming part causes rework and re-inspection to be performed when it is not necessary.

• P(Miss) is a serious type of error since a non- conforming part is accepted.

• Also check the Kappa results. A general rule of thumb is that the values of kappa greater than 0.75 indicate good to excellent agreement (with maximum kappa =1); values less than 0.40 indicate poor agreement.

Table5: MSA Attribute Matrix

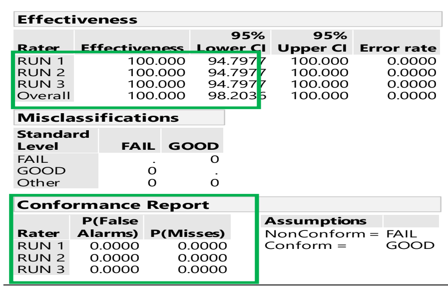
Standard	Effectiveness (95% LCI)	P(FA)	P(Miss)	Kappa
Good	≥90%	≤5%	≤2%	≥0.75
Marginally Acceptable – need improvement	≥80%	≤10%	≤5%	< 0.75
Unacceptable – need improvement	<80%	>10%	>5%	≤0.40

3.1.5 Statistical Analysis – Attribute MSA Result

Statistical Analysis shows that the Optical System and Set up Vision Recipe PASS the standard Measurement System Analysis with **94% detection effectiveness , 0% miss with 100% correlation to reference**.

Tabke6. MSA Result of Chroma Final AOI BWI03

Final AOI_AddirWholeOQC-2xRecon-8Inch		
E (95% LCI)	P (FA)	P (MISS)
≥90%	≤5%	≤2%
94.00%	0%	0%



Effectiveness

Rater	Effectiveness	95% Lower CI	95% Upper CI	Error rate
RUN 1	100.000	94.7977	100.000	0.0000
RUN 2	100.000	94.7977	100.000	0.0000
RUN 3	100.000	94.7977	100.000	0.0000
Overall	100.000	98.2035	100.000	0.0000

Misclassifications

Standard Level	FAIL	GOOD
FAIL	.	0
GOOD	0	.
Other	0	0

Conformance Report

Rater	P(False Alarms)	P(Misses)
RUN 1	0.0000	0.0000
RUN 2	0.0000	0.0000
RUN 3	0.0000	0.0000

Assumptions
NonConform = FAIL
Conform = GOOD

Figure 13. MSA Statistcial result

Verification shows the Vision system is highly capable to detect defects on Frontside and embedded defects between dice and tape

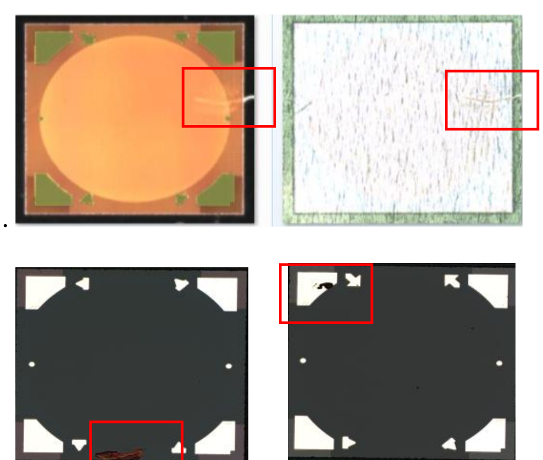


Figure 14. AOI Images of detected rejects

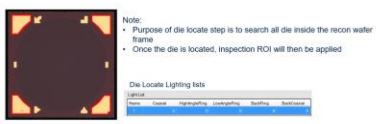
3.2 Increasing Machine Scan speed.

On the original machine set up the UPH is at **1.28K only**, With the set up, we will be needing an additional 2 (two) machines to support mass production of 100k/d target capacity.

To increase Machine speed, we selected optimal reference for Die locate and use 4 FOV for Backside and Frontside Inspection.IE UPH validation on new version recipe is at **8.3K (2x the required 3K UPH).** 1x CHROMA setup for new Products at 147k/d (V5) will be enough to support the 100k/d target Capacity

Dice Inspection Concept

1,. Die locate reference on 4 pads only:



2. Use 4 FOV both on Frontside and Backside Inspection

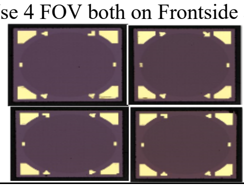


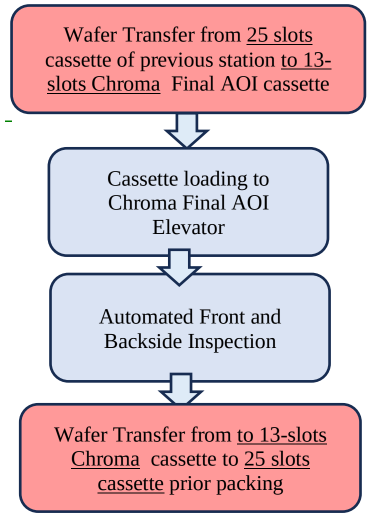
Table 7. Calculated UPH before and after Recipe improvement

Description	Old Version Recipe	New Version Recipe
PGDW	3442	3442
Hours per wafer	2.685	0.414
Wafer per Hour	0.372	2.414
UPH	**1281.8**	**8310.7**
Machine EFF%	85%	85%
Capacity (k/d)	**25**	**164**
Parameters	100% Inspection, 100% Image saving of Good and Reject	100% Inspection, 100% Image saving of Good and Reject
Remarks	Single Pass Die locate+Inspect+Image Save	1st Pass Die locate+Improve PR, 2nd Pass Inspection+Improve FOV+Image Save

3.3 Machine operation of Chroma 7940 AOI

3,3.1 Manual Wafer Transfer Flow with the introduction of new process

With the introduction of a new process, there is a manual wafer transferring from previous step (MIT wafer Recon) to Final AOI (Chroma AOI). Chroma AOI is using a 13-slots cassette (1pc dedicated cassette) while Mounter and Recon is using 25-slots cassette.



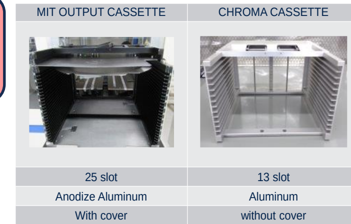


Figure 15. Illustration of cassettes per process and wafer transfer flow.

3,3.2 Introduction of unified cassettes and eliminating manual wafer transfer.

Conceptualized a unified cassette ;13-slots and Teflon material. The objective is to eliminate manual wafer transferring by using modified cassette for MIT Recon output and Final AOI Input/Output.

BEFORE		AFTER
MIT OUTPUT CASSETTE	CHROMA CASSETTE	MODIFIED CASSETTE
		
25 slot	13 slot	13 slot
Anodize Aluminum	Aluminum	Teflon Engineering Plastic
With cover	without cover	With cover

Figure16. Illustration of Different cassettes per process and the Unified cassette to be use from Tape Mounter to Final AOI.

To utilize unified cassette for production use, there were adjustments done on chuck table , cassette elevator and sensor pitching at Final AOI.
Assessment done on MIT Recon process, recipe was created for 13-slots-cassette with pitch and slots positioning adjustments.

With the utilization of unified cassettes. Mounted tape will be transferred to 13-slots cassette, Same cassette will be used for MIT Wafer Reconstruction and same cassette will be used for loading and unloading at Chroma Final AOI. Thus, eliminate manual intervention and risk of wafer transfer quality and productivity wise.

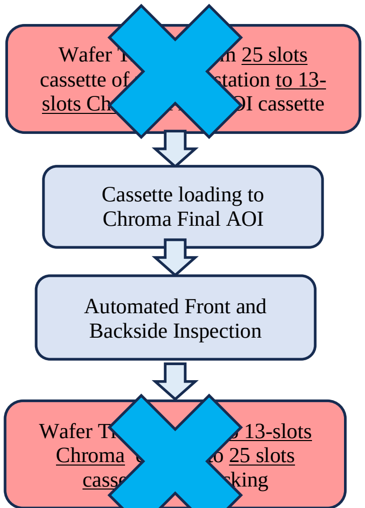


Figure 17. Illustration of streamline process

3.4 Final AOI Reject verification and Defect Reduction Solutions

3,4.1 Final AOI Yield Reject Verification during Engineering Phase

During the Engineering Phase the Final AOI Yield is below the MP target of 98.5%. Yield is averaging 93%. Top detractor is defect on Front side of wafer and FM ranging 4 to 6% defect rate.

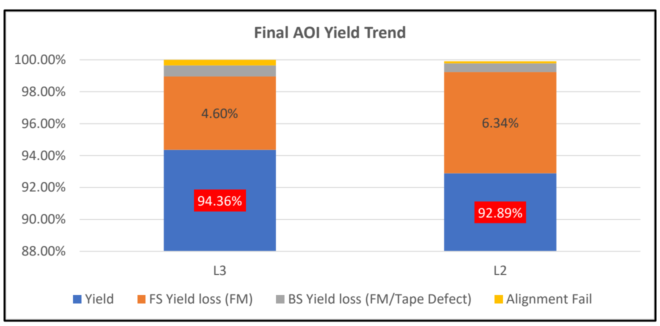


Figure 18. Yield and Top detractor chart.

As per verification the defect on wafer surface is a removable FM. Removed during blowing and picking using gel stick. Failure Analysis confirmed FM from environment and production materials like dust, labels, tape.

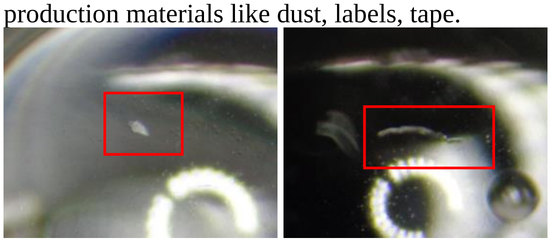


Figure 18. Optical photo of defects and verification confirmed removable FM

3,4.2 Installation of FM Sweeper at Final AOI

Solution was the Installed bar-type ionizer at Input area to remove FM prior Inspection and Packing.

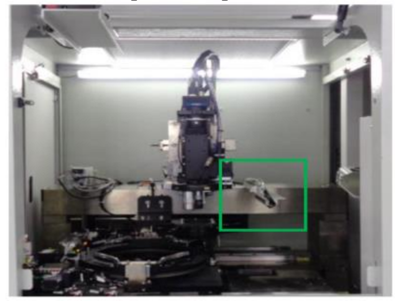


Figure 18. Photo of ionizer installed.

An exhaust system was installed to reduce/exhaust FM inside the machine.

Figure 19. Illustration of exhaust installed.

Hepa filter was installed to maintain cleanliness inside the machine and aid on reducing mobile FM from wafer surface.

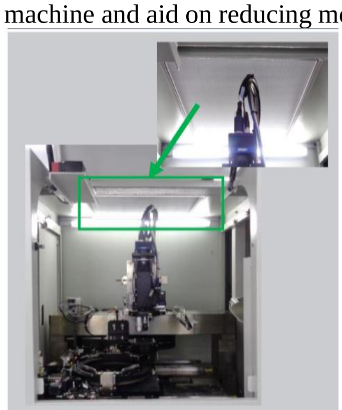


Figure 20 . Photo of hepa filter installed.

4.0 RESULTS AND DISCUSSION

4.1 Chroma Final AOI Process Buy Off

After the setup of Vision and Handler for 8in reconstructed wafer. Machine and Process Buy Off were accomplished that includes MSA for Frontside and Backside defects, ESD checking of Ionizer , Wafer Map generation validation and AOI correlation with other Wafer AOI.

4.1.1 Measurement System Analysis

Measurement System Analysis **PASS both on Product A and Product B with satisfactory results passing >90% detection effectiveness with 0 miss and 0 false alarm.**

	Final AOI_MeronSamplingV1-2xRecon-8Inch		
Parameter	E (95% LCI)	P (FA)	P (MISS)
Acceptable for the appraiser	≥90%	≤5%	≤2%
Actual	94.80%	0%	0%

	Final AOI_AddirWholeOQC-2xRecon-8Inch		
Parameter	E (95% LCI)	P (FA)	P (MISS)
Acceptable for the appraiser	≥90%	≤5%	≤2%
Actual	94.79%	0%	0%

Effectiveness Report

Agreement Counts

Rater	Correct(FAIL)	Correct(GOOD)	Total Correct	Incorrect(FAIL)	Incorrect(GOOD)	Grand Total
RUN 1	45	25	70	0	0	70
RUN 2	45	25	70	0	0	70
RUN 3	45	25	70	0	0	70

Effectiveness

Rater	Effectiveness	95% Lower CI	95% Upper CI	Error rate
RUN 1	100.000	94.7977	100.000	0.0000
RUN 2	100.000	94.7977	100.000	0.0000
RUN 3	100.000	94.7977	100.000	0.0000
Overall	100.000	98.2036	100.000	0.0000

Misclassifications

Standard Level	FAIL	GOOD
FAIL	.	0
GOOD	0	.
Other	0	0

Conformance Report

Rater	P(False Alarms)	P(Misses)
RUN 1	0.0000	0.0000
RUN 2	0.0000	0.0000
RUN 3	0.0000	0.0000

Assumptions	
NonConform =	FAIL
Conform =	GOOD

Figure 21. Attribute MSA result and statistical Analysis.

4.1.2 ESD Checking of Ionizers

Ionizer **PASS** Ionizing decay time of Less Than10 sec both positive and negative, Ion balance is Less Than 15 Volts.

4.1.3 Map generation and validation

Successful integration of machine to Input Wafer map and Auto generation of Output map post AOI processing. Assigned colors for good dice and reject dice per category for traceability.

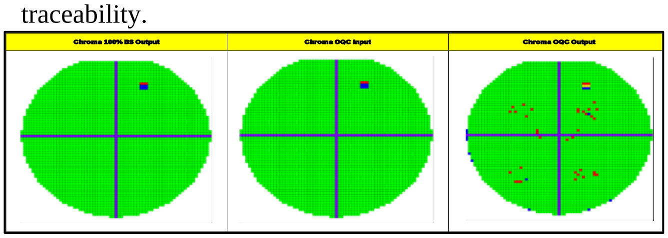


Figure 22. Final AOI Wafer Map image, good bins (green) , previous process rejects (blue) , Final AOI reject (red)

4.1.4 Chroma 7940 Final AOI Correlation to MIT Recon AOI and Rudolph NSX330 AOI post Saw

Chroma Final AOI Pass Correlation test, Identified reject samples was successfully detected FAIL on Final AOI and Identified good dice PASS inspection Statistical Analysis result shows Agreement at 100% with Kappa score of 1.0 comparing result vs standard and comparing result per test.No misclassification 0% moss and 0% false alarm and Defect detection score of 96%

Effectiveness Report

Agreement Counts

Rater	Correct(FAIL)	Correct(PASS)	Total Correct	Incorrect(FAIL)	Incorrect(PASS)	Grand Total
RUN 1	73	27	100	0	0	100
RUN 2	73	27	100	0	0	100
RUN 3	73	27	100	0	0	100

Effectiveness

Rater	Effectiveness	95% Lower CI	95% Upper CI	Error rate
RUN 1	100.000	96.3007	100.000	0.0000
RUN 2	100.000	96.3007	100.000	0.0000
RUN 3	100.000	96.3007	100.000	0.0000
Overall	100.000	98.7357	100.000	0.0000

Misclassifications

Standard Level	FAIL	PASS
FAIL	.	0
PASS	0	.
Other	0	0

Conformance Report

Rater	P(False Alarms)	P(Misses)
RUN 1	0.0000	0.0000
RUN 2	0.0000	0.0000
RUN 3	0.0000	0.0000

Assumptions	
NonConform =	FAIL
Conform =	PASS

Figure 23. Statistical Analysis report of Final AOI on Correlation wafers

Coordinates	MIT Output	Chroma TOP	Remarks
33,1			Defect on Pad confirmed Detected on MIT & Chroma
36,0			Defect on Active area confirmed Detected on MIT & Chroma

Figure 24. Representative AOI Image of defects detected at Final AOI vs MIT Recon AOI.

4.2 Chroma Final AOI UPH and Capacity Validation

IE Calculated AOI UPH at 8,310.
79% productivity improvement, comparing 25.9hrs process time on manual inspection to complete 1 lot with 32000 dice vs AOI of 5hrs per lot.

The calculated capacity is at 164K per day which is sufficient to support 100k per day requirement on Mass production.

Table8. Process tine and Capacity calculation.

No of Machine	UPH	Efficiency	Capacity /day
1	8,310.70	85%	164452.1316

4.3 Unified Cassette Qualification

4.3.1 Qualification at Chroma Final AOI

After elevator fine tuning for unified cassette. Qualification was executed to assess risk on quality and machine efficiency.

Resulted shows PASSED the Qualification characteristics,. PASSED the ESD requirement and Line stress resulted to no damaged wafer and no machine error occurrence.

#	Characteristic	Qualification	Result
1	Broken Wafer	0 occurrence	PASS
2	Dropped Wafer	0 occurrence	PASS
3	Misaligned wafer on chuck table	0 occurrence	PASS
4	Elevator error	0 occurrence	PASS

Modified Cassette	DATA	Result
	P1 : 44 P2 : 46 P3 : 45 P4 : 38 P5 : 40 P6 : 40 P7 : 41 P8: 39 P9 : 43	PASS

Figure 25. Unified cassette qualification result on line stress and ESD Check

4.3.2 Qualification at MIT Recon process

After recipe generation and fine tuning for unified cassette. Qualification was executed to assess risk on quality and machine efficiency. Results noted on below table showing PASS Qualification characteristics.

Table9. Unified cassette qualification result at MIT Recon.

#	Characteristic	Qualification	Validation	REMARKS
1	Broken Wafer	N/A	0 broken wafer	PASS
2	Dropped Wafer	0 occurrence	0 dropped wafer	PASS
3	Misaligned wafer on Output table	0 occurrence	0 occurrence	PASS
4	Elevator error	0 occurrence	0 occurrence	PASS

4.4 FM reduction on Wafer Surface

FM comparison of AOI system with and without the installed FM sweeper, exhaust and Hepa filter. Observed 63% reduction of FM defect.

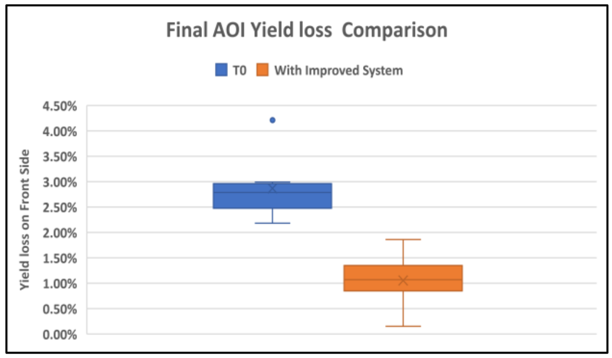


Figure 26. FM Yield loss before and after improvement actions

Yield Trend shows significant improvement compared with L3/L2/PRB Engineering Phase. Mass production yield exceeded 98.5% MP target. Implemented unified cassette, FM sweeper on PRB build. Implemented exhaust and hepa filter on PVT-MP phase.**5.2% Improved Yield** after implementation of improvement actions to remove FM on wafer surface.

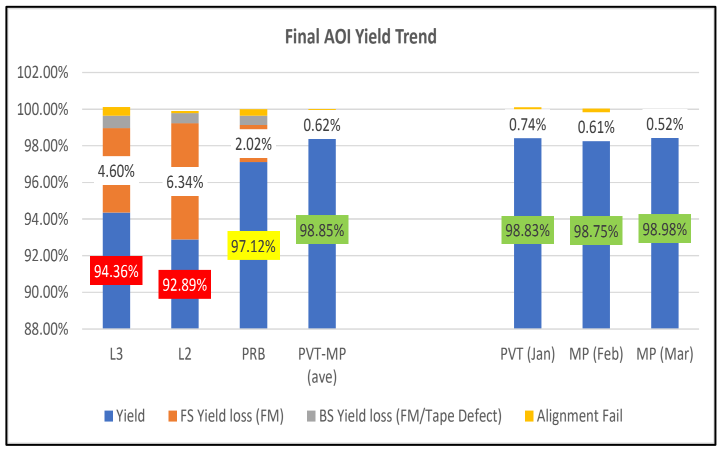


Figure 27. Final AOI Yield Trend chart

4.5 Customer IQC monitoring

No Customer complaint after implementation of Final AOI July 2023 to May -td 2024.

❑Customer IQC Result

No	LGIT Incoming Date	Inspection Date	LGIT P/N	Incoming Q'ty	Material	Dimension Inspection	Dimension fail	Cosmetic Inspection	Cosmetic Fail	Lot Result	Remarks
1	1/20/2024	1/21/2024	3ODI00012A	65,355	Addir	32	0	500	0	Pass	
2	1/20/2024	1/20/2024	3ODI00010A	30,145	Meron	32	0	315	0	Pass	
3	1/23/2024	1/24/2024	3ODI00012A	29,155	Addir	32	0	315	0	Pass	
4	1/23/2024	1/24/2024	3ODI00010A	26,453	Meron	32	0	315	0	Pass	
5	1/24/2024	1/26/2024	3ODI00012A	29,674	Addir	32	0	315	0	Pass	
6	1/24/2024	1/26/2024	3ODI00010A	61,751	Meron	32	0	500	0	Pass	
7	1/25/2024	1/26/2024	3ODI00012A	55,583	Addir	32	0	500	0	Pass	
8	1/25/2024	1/27/2024	3ODI00010A	59,801	Meron	32	0	500	0	Pass	
9	1/26/2024	1/29/2024	3ODI00012A	59,253	Addir	32	0	500	1	Pass	Back side corner chipping
10	1/29/2024	1/31/2024	3ODI00012A	51,616	Addir	32	0	500	0	Pass	
11	1/30/2024	1/31/2024	3ODI00012A	59,244	Addir	32	0	500	0	Pass	
12	1/30/2024	1/31/2024	3ODI00010A	120,117	Meron	32	0	500	0	Pass	

Background:
- LGIT IQC result on 12 lots ST-Calamba shipped (total of 648K) , 100% PASS IQC.
- 1 lot with 1u cosmetic observation with corner chipping at backside , confirmed passing MIT measurement

Figure 28. IQC Customer report showing 0ppm during inspection.

5.0 CONCLUSION

The previous set up of manual visual inspection to address customer complaint on defect embedded in between dice and tape was a major concern of this project, not only it could be a quality problem and but could be a potential shipment blocker for mass production brought by long process time.

Based on the machine assessment and qualifications, it was proven that Optical system using Chroma AOI has high defect detection effectiveness for both Frontside and embedded defect between dice and tape Backside inspection.

This has led to the introduction of a new process for production use of technology via automation inspection. An innovative solution on vision system with map update and optimal field of view coverage have increased scan speed to exceed machine capacity. The introduction of unified cassette and FM reduction on wafer surface during the qualification and engineering stage have shown quality improvement.

Having deployed this project at the start of the L3 milestone, no quality issues have been recorded during the engineering run up to mass production. With these, the new machine and process was established and finalized as part of the optical diffuser wafer process towards the mass production of the latest proximity device at Operations 2 and the project's deployment is successful and has supported the manufacturability of the new product.

6.0 RECOMMENDATIONS

The current study can be interpreted as the ultimate solution with the replacement of manual visual inspection of front and backside defects to fully automated technology which addressed certain manufacturing problems. With the integration of unified cassettes and FM sweeper and exhaust system have positive result of the study, we can implement this change towards the mass production of the latest device and can also be sustained to other future devices with the same customer requirement.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

1. Wafer Chip Inspection System Model 7940 by Chroma ATE inc and Chroma US.com
2. EN_7940_MaintenanceManual_20200106

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