WAFER RECONSTRUCTION PROCESS – A BREAKTHROUGH TECHNOLOGY SOLUTIONS EMPLOYED TO TECHNICAL DIFFUSER WAFER PREPARATORY MANUFACTURING

FLORENDO, Jhanet R.
ABAD, Reinadd Jan B.
MANEJERO, Judioz M.

Process Engineering – B2F2 Wafer Test & AOI
STMicroelectronics Incorporated
#9 Mt. Drive, LISP2, Brgy. La Mesa, Calamba City, Laguna
jhanet.florendo@st.com, reinaddjan.abad@st.com,jude.manejero@st.com

ABSTRACT

With the introduction of a new optical diffuser product at Operations 2 and support important customer requirement, an immediate challenge to be able to develop a Wafer Reconstruction process and on top of this we are required to qualify a new machine to support reconstructed wafer manufacturing and meet product quality for end customer. This is the 1st Wafer Reconstruction Process in ST Microelectronics and ST Calamba will be the center of Optical Diffuse Wafer Manufacturing of ST. Successful release of new products and process will bring more advantageous ventures to the Organization and opportunities to the people as well.

This customer request is a challenge to Operations 2 as this is the first time we have processed a reconstructed wafer and requires maintaining an accurate die placement. During the qualification we must consider different factors which includes the qualification of new machine, its capability and limitation, qualification of new process, new operation, and resources. At the onset of the initial phase of the qualification we have qualified a conceptualized die attach with Optical System using an 18-Picker-Turret type handler for 2mm dice size. This new process not only affects the yield at the current step but also resulted with product RTV brought by singulation issue, placement issue and not optimal vision system. There is a need to improve overall Yield 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 review pick up tool design, ejector design, process parameters and machine maintenance. With detailed process analysis and systematic problem-solving methodology, the existing tooling and parameters will be modified and fine-tuned for an efficient and effective wafer reconstruction process with good quality of products but also the manufacturability towards high volume production.

To address the quality issues of this new process, a new technology was instituted to resolve these issues with the **conceptualization of tooling and automatic die aligner** specifically for this purpose and was evaluated thoroughly before integration on the wafer reconstruction process flow. Results showed that the issues pertaining to reconstruction issues like backside tool mark, **rotated dice were eliminated from 14% rotated dice loss and 4% singulation tool mark** This literature discusses the breakthrough solution for quality improvement and manufacturing process & technology at Optical diffuser wafer manufacturing and wafer reconstruction process. 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 die placement and cosmetic defect. This provides the best solution in wafer reconstruction process and ensuring perfect compliance to customer requirements and product quality.

1.0 INTRODUCTION

The electronics industry is making a tremendous investment in Optical Diffuser Wafer Manufacturing. The reasons for this investment include product flexibility in semiconductor manufacturing.

Today's Wafer Reconstruction process has Optical system and have accurate die placement capability and can produce thousands of units per hour. To achieve this performance, the Wafer Reconstruction system must be highly capable of dice singulation at high speeds and consistent efficiency, positively with Vision system that can accurately detect cosmetic and placement non-conformity. The product must be free from damage and foreign material during processing, with dice placement within the specified tolerances.

1.1 Wafer Reconstruction Process

The Wafer Reconstruction process typically refers to the techniques used in semiconductor manufacturing to reconstruct the structure of a silicon wafer. For Operations 2 12-in UV-cured sawn wafer are being reconstructed to 8-in mounted tape

Fig1. Wafer Reconstruction Flow

1.2 Wafer Reconstruction Platform

The Wafer Reconstruction platform is MIT Optimus MR3. The MIT MR3 was designed for 12in wafer to 8in wafer reconstruction, Machine SUPH is up to 15k, capable on 2mm die sorting (0.5 to 15mm machine capability) , placement accuracy of +/-30um , with vision system up to 6 sides inspection capability. The machine capability is appropriate to new product for Operations 2

Fig2. Wafer Reconstruction Platform

This machine is designed for use as an automatic die transfer machine for 8-inch and 12-inch wafer film frames. It can pick the singulated die from a populated, mapped and sawed wafer. The selected bin category from this input frame is placed into the output frame of pre-selected pattern which are all defined early in the recipe.

Vision Systems are installed on top of Input & Output wafer tables and Theta Inspection Station. Input camera and Output camera are used for die verification, inspection of surface defects and aid the wafer until die level alignment. Theta Vision is used for orientation inspection. Identification of the wafer ID, lot information and mapping request by using a Bar Code Scanner at Input Wafer Handler is also available.

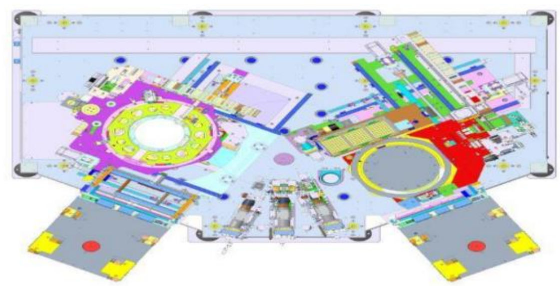


Fig3. Machine Layout

1.3 Wafer Reconstruction Process Details

The Wafer Reconstruction process typically refers to the techniques used in semiconductor manufacturing to reconstruct the structure of a silicon wafer. For Operations 2 12-in UV-cured sawn wafer are being reconstructed to 8-in mounted tape. Other indirect materials includes ejector needle and Die pick-up tool (PUT)

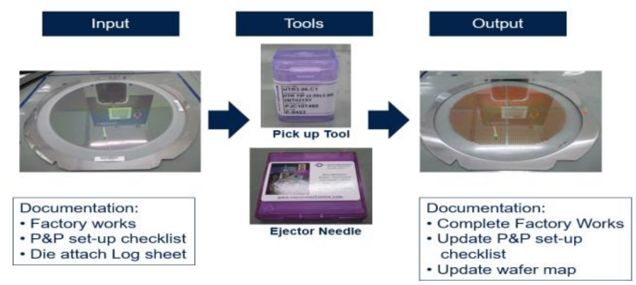


Fig4. Process Direct and Indirect Materials

The process starts in loading the 12in- UV cured-sawn wafer to the Load Station. Dice will undergo 100% dice inspection; Dice PASS the cosmetic inspection will be pick and undergo 100% Bottom Inspection through uplook camera. Dice PASS Inspection will be placed 8-in recon wafer. Output station have 100% dice inspection. Wafer map will be updated after lot completion. FAIL dice on Input and Output Station will be inked reject on wafer map, FAIL dice on bottom inspection will be thrown to REJECT bin.

Pick and Place Process

Fig4. Wafer Reconstruction Machine Macro Flow

1.4 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 foreign material both Frontside and Backside of the wafer.

Table 1. Defect size criteria per Region of Interest

ROI	Defect size
1.Frontt and Backside Edge/Corner 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	Foreign material >30um , between dice and tape
7. Backside non datum area	Foreign material >50um , between dice and tape

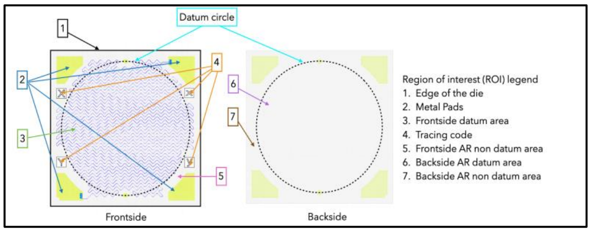


Figure 5. Die Region of Interest, with defects and contamination requirements delineated on Table1.

1.5 Wafer Reconstruction Output Response

The reconstructed wafer should maintain placement with the ring, die spacing and die alignment on the 8in frame.

Table 2. Output response specification.

DESCRIPTION	NOM	TOL	LSL	USL	LCL	UCL
X-Spacing	0.300	±0.05	0.250	0.350	0.265	0.335
Y-Spacing	0.300	± 0.05	0.250	0.350	0.265	0.335
Die Rotation	0.000	± 3	-3.000	3.000	-2.100	2.100
Die Array Rotation (X)	0.000	±2	-2.000	2.000	-1.400	1.400
Die Array Rotation (Y)	0.000	±2	-2.000	2.000	-1.400	1.400
Array Placement within Ring (X)	0.000	±0.1	-0.100	0.100	-0.100	0.100
Array Placement within Ring (Y)	0.000	±0.8	-0.800	0.100	-0.560	0.560

The reconstructed wafer placement within the ring should be +/- 0.1mm horizontal measurement and =/-0.8mm vertical measurement from the reference center of the frame.

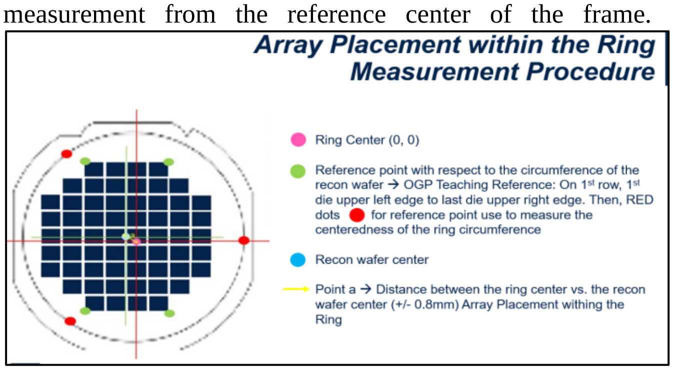


Figure 6. Placement within the ring measurement

The die placement on tape should comply with X and Y spacing tolerance of 0.25 – 0.35mm and die rotation should be less than 3degress , die array rotation should be with 2 degrees specification.

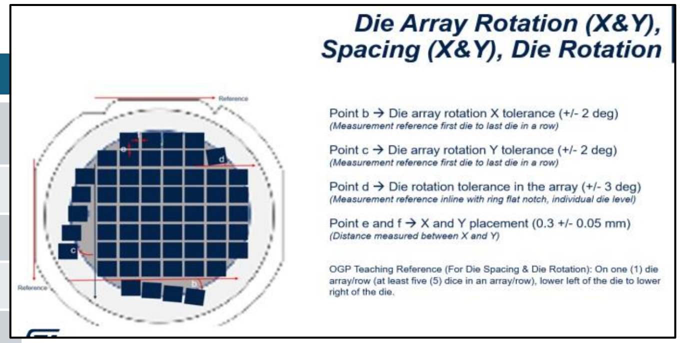


Figure 7. Die Placement measurement.

1.6 Wafer Reconstruction Process Issues

On the early stage of the Engineering phase.
Wafer reconstruction yield is at 80% level.
Not to mention the machine low speed brought by high defect rate. **The rotated die (exceeding theta) yield loss is at 14% and the tape residue defect is at 3.3%.**

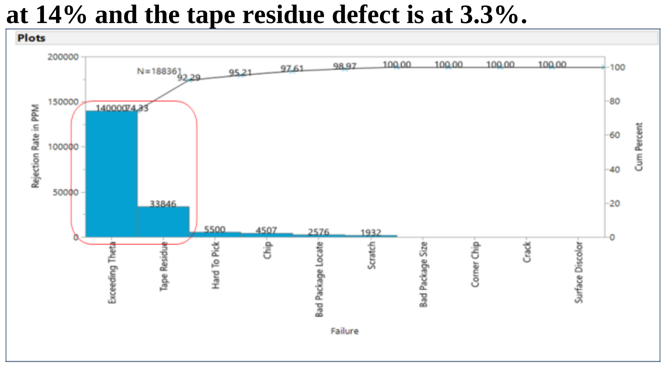


Figure 8. Pareto of Defects in ppm.

1.6.1 Rotated Die Reject

Rotated Die rejects are units failing the 3degrees rotation, this is detected and measured through Bottom inspection and measurement.

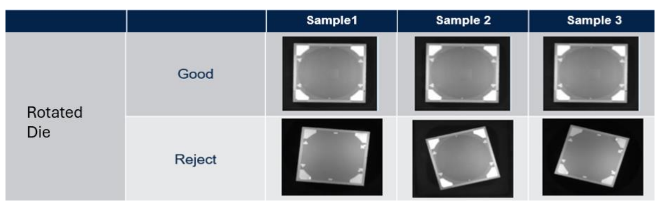


Figure 9. Bottom side AOI Image of Good alignment vs Rotated Die

1.6.2 Tape residue defect

Dice detected with cosmetic defect on backside of die during 100% Bottom Inspection. The location of the defect and optical image confirms that the defect is tape residue and coinciding with ejector contact.

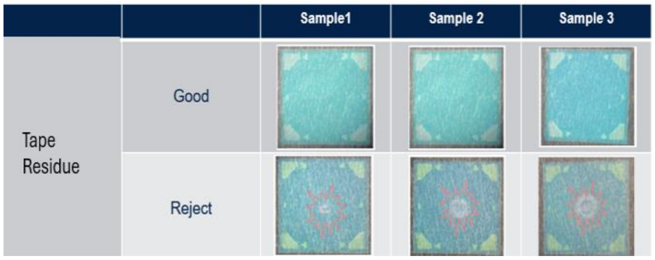


Figure 9. Bottom side Optical Image of Good Die vs Die with Tape Residue

1.7 Bottom Side Inspection Capability Check

To ensure that the Measurement system can effectively discriminate a good vs a non-conforming die. An Attribute MSA was conducted. Likewise, to check the measurement integrity of die rotation a Stability Test was performed.

1.7.1 Attribute Measurement System Analysis

In standard Measurement System Analysis. Known good and Fail samples were provided and tested thrice on machine under qualification (BWR01 MIT Wafer Recon.Machine auto run with AOI enabled and inspects the parts in different order and the results are recorded on a datasheet. Analysis noted; 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 (Miss) is a serious type of error since a non- conforming part is accepted 3. 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.

Table3: 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

Table3: MSA Attribute Matrix

1.7.2 Stability Test

A stability test was performed, this is to assess if the measurement system can be used anytime without compromising the integrity of the Data. Sample standards will be measuring 3 to 5 times in a short period of time to obtain one group of data. Should they be performed on a regular basis such as hourly, daily, or weekly. Initially, 25 groups of data should be gathered.

On Statistical Analysis, we will look for possible out of control points, point outside the control limits, 7 consecutive points above/below the center line and 7 consecutive points upward/downward trend

1.7.3 Wafer Recon Bottom Inspection MSA result

The Bottom side inspection of MIT Wafer recon has high effectiveness at 92% vs 90% requirement. The agreements vs standard is 100% with 0% miss and 0% false alarm.

With the statistical analysis concluded, that the machine is highly capable to detect Tape residue defect on backside and therefore high rejection rate confirms dive have valid defect.

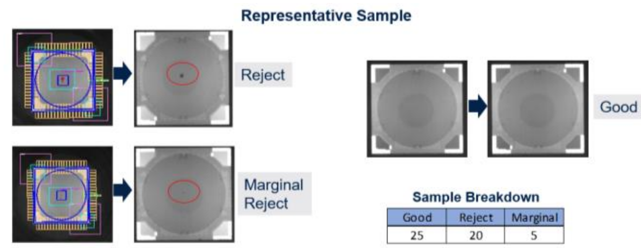
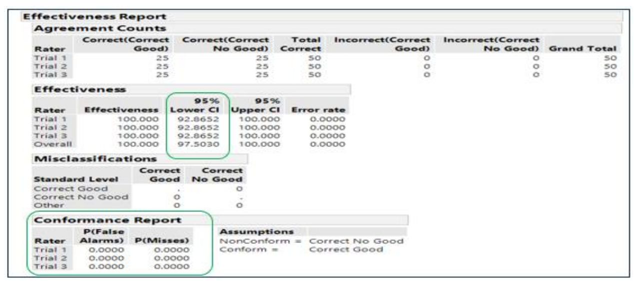


Figure 10: AOI image of detected FAIL and PASS dice



Effectiveness Report

Agreement Counts

Rater	Correct(Correct Good)	Correct(Correct No Good)	Total Correct	Incorrect(Correct Good)	Incorrect(Correct No Good)	Grand Total
Trial 1	25	25	50	0	0	50
Trial 2	25	25	50	0	0	50
Trial 3	25	25	50	0	0	50

Effectiveness

Rater	Effectiveness	95% Lower CI	95% Upper CI	Error rate
Trial 1	100.000	92.8652	100.000	0.0000
Trial 2	100.000	92.8652	100.000	0.0000
Trial 3	100.000	92.8652	100.000	0.0000
Overall	100.000	97.5030	100.000	0.0000

Misclassifications

Standard Level	Correct Good	Correct No Good
Correct Good	.	0
Correct No Good	0	.
Other	0	0

Conformance Report

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

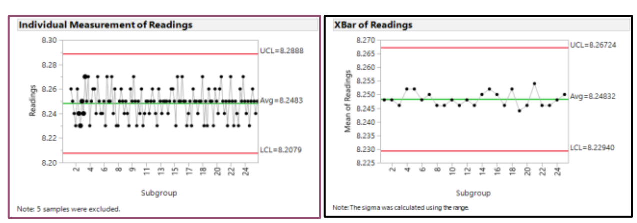
Assumptions	
NonConform =	Correct No Good
Conform =	Correct Good

Figure 11: Statistical Analysis of Bottom side inspection

1.7.3 Wafer Recon Die Rotation Stability Test

On the stability test, Die was pick and rotated intentionally; it was inspected for 5 times repeatedly with an interval of 1hour for 25 times and record the angle measurement did by the machine look up camera.

Statistical Analysis shows a stable measurement system with not out of control points. Therefore, the die bottom measurement is stable and high rejection of rotated die is valid reject.



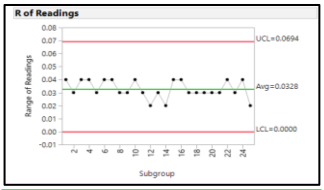


Figure 12: Statistical Analysis of Die Rotation Measurement

2.0 REVIEW OF RELATED WORK

Wafer reconstruction process has been widely used in the manufacturing process as a technique to reconstruct a silicon wafer form. Wafer Reconstruction machines have an integrated optical system to ensure product conformance both cosmetic and die measurement.

The motivation of this study is to bring up a new process and new product successfully to high volume production. The new process, the Wafer reconstruction process yield will be improved for mass production. Successful release of new products and process of Operations1 will bring advantageous ventures to the Organization and opportunities to the people.

3.0 METHODOLOGY

3.1 Rotated Die rejection analysis

3.1.1 Understanding the die pick and place behavior

With the use of high-speed camera during actual pick and place. Die movement was observed on dice with gap during pick.

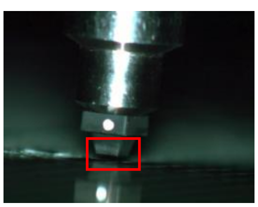


Figure 13: High speed camera image during pick

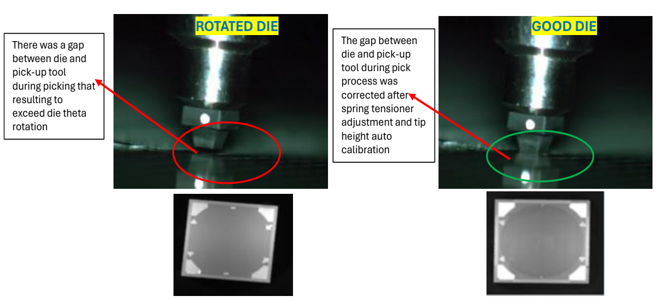


Figure 14: High speed camera image during pick of Rotated vs Good Die

This phenomenon can be corrected through PUT tip calibration.

3.1.2 Auto Die aligner

Integrate on the Wafer Reconstruction machine a station that would auto align the module exceeding the die rotation specification before placing to the 8in wafer tape.
Rotated die rejected on bottom inspection station will be recovered using the new aligner module by correcting the die rotation previously rejected by backside camera.

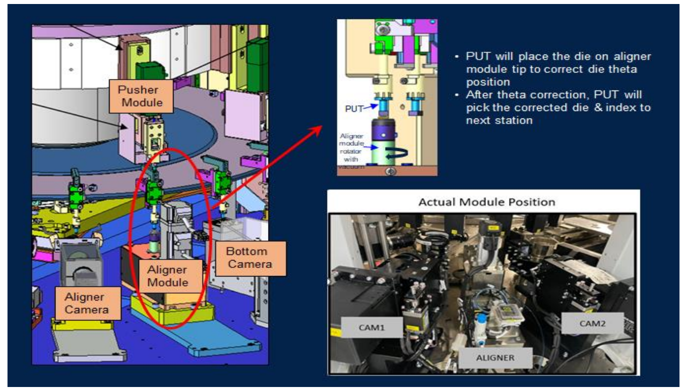


Figure 14: Die Rotation Aligner Module Overview Figure 14: Die Rotation Aligner Module Overview

- Aligner Camera ➔ To check die theta position after pick from input wafer table
- Aligner Module ➔ To correct die theta position before place in output wafer table
- Bottom Camera ➔ To check again the die theta position after aligner module correction & to inspect backside surface.

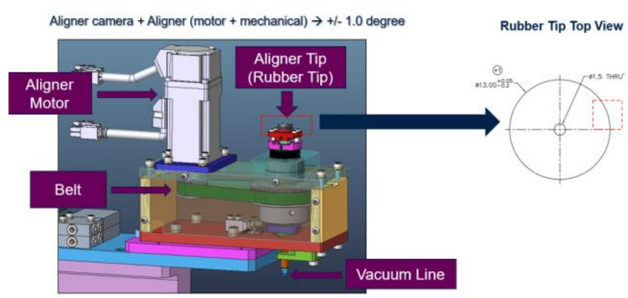


Figure 15: Illustration of Die aligner and Pick up tool

- The Material of aligner is soft HTR (Hardness: Shore A55-A60)
- Size range appropriate for 2.6x2.6mm
- Rubber tip to tip holder thickness 2.1mm
- Recommended, rubber tip will last 150K place/pick depending on the die surface.

3.2 Root cause Analysis for Tape residue defect

To further increase the process yield, the 2nd challenge is understanding the cause and factors for improvement to cutdown the tape residue defect through systematic problem-solving methodology.

3.2.1 Fishbone Analysis of Tape residue defect

The Team identified 16 key process variables as potential factors of the tape residue defect. (See Appendix1- Fishbone Diagram). Under Method process variables are no proper set-up procedure, wrong UV cure setting, wrong wafer staging post cure. Mother nature is out of specs wafer storage. Under Machine variables are uncalibrated machine, not optimized ejector height settings, not optimized ejection speed, not optimized pick force, not optimized pick press down, not optimized pick dwell time and not fine tined look up inspection. Variables under Material are not suitable tip design, not appropriate wafer tape, not suitable needle design, not appropriate ejector pepper pot. For Man, considered variable is the lacking expertise on machine set up.

3.2.2 Cause and Effect Matrix

Out of the identified process variables, 6 factors are identified critical for validation : Ejector needle design , Pick up tool material/design , Ejector height, Ejector speed, Pick and Place force, Pick and Place press down and Dwell time. Refer to Appendix2 – Cause and Effect Matrix.

3.2.3 Validation Plan

The Statistical Analysis Plan was abstracted to consider sample size, nature of data and appropriate method for analysis of responses on tape residue. On ejector needle design compared 150um vs 100um flat tip design. For Pick up tool compared plastic and rubber tip. Pick and place parameters will be evaluated on low to high side. Refer to Appendix3 – Statistical validation plan.

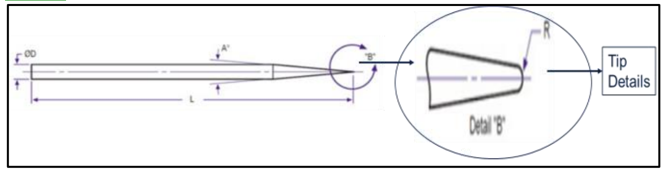
Y (or mini Y)	Unit of Measure	Y data type	X	X data type	Levels of X
Tape Residue	Reject PPM	Discrete	Ejector needle design	Discrete	150um pointed ejector needle and 100um flat tip ejector needle
	Reject PPM	Discrete	Pick up tool material type	Discrete	Rubber Tip and ESD plastic tip
	Reject PPM	Discrete	Ejector height	Discrete	0.4mm -0.75mm
	Reject PPM	Discrete	Ejector Speed	Discrete	40ms -100ms
	Reject PPM	Discrete	PnP Pick Force	Discrete	90 -150g
	Reject PPM	Discrete	PnP Pick Press Down	Discrete	0mm -0.6mm
	Reject PPM	Discrete	PnP Pick Dwell Time	Discrete	50ms -110ms

Figure 16. Evaluation Plan for identified factors vs response on tape residue.

3.2.3.1 Ejector Design

The current set up uses 0.2mm diameter and rounded tip. The study aims to know if diameter and tip shape is a significant factor to tape residue defect occurrence.

POR:



For study:

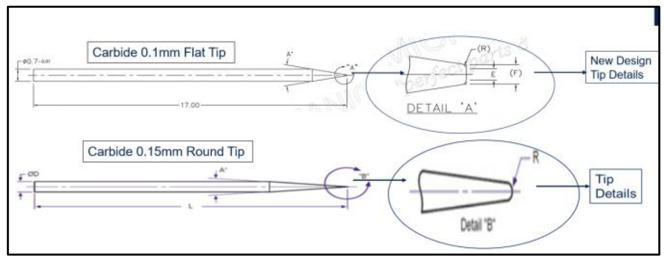


Figure 17: Illustration of Needle tip and dimensions

3.2.3.1 Pick-up tool design

The current set up uses a rubber tip design with 2mmx2mm outer diameter and rounded tip.
The study aims to know if new design have significant factor to tape reside defect.

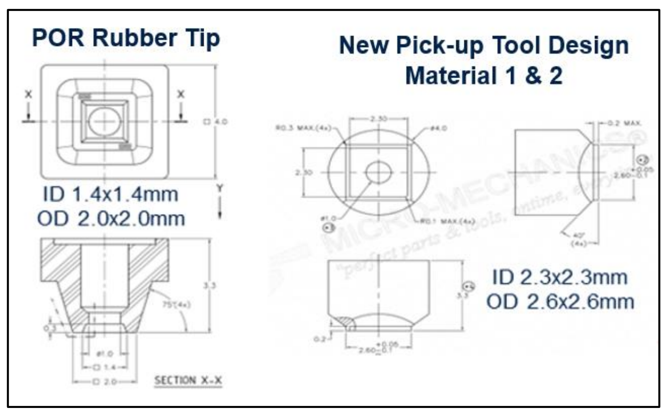


Figure 18: Illustration of PUT design and dimensions.

4.0 RESULTS AND DISCUSSION

4.1 Pick-up tool tip calibration.

Perform and Enable tip heigh calibration every lot start, every intervention on PUT (Pick up tool). To ensure that the PUT was properly inserted, centered position and within the reference line.

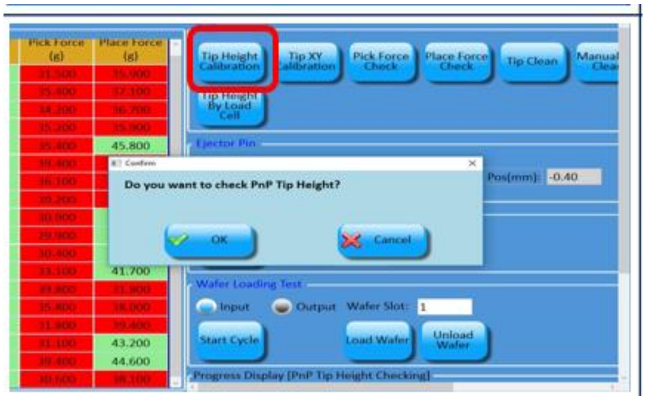


Figure 19: Tip height calibration function.

Figure 20: PUT Pass and FAIL during calibration check

The result shows Rotated dice rejection was cut down to 1.6% from 14% yield loss after performing the correct calibration of Pick up tool.

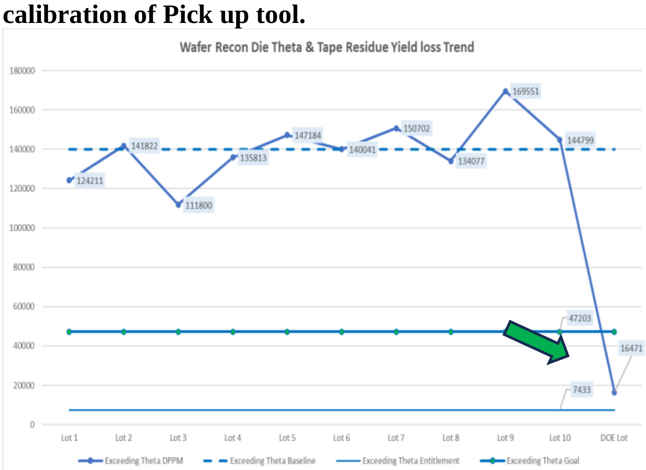


Figure 21: Die Rotation Yield Loss trend

4.2 Qualification of Auto Module Aligner

Integrated the Aoto aligner module on the wafer reconstruction process. Rejected dice with >0.5 degrees will proceed to die aligner for rotation correction. On charts below show that the die failing the 1st bottom inspection maintained the alignment near 0 to 0.5 degrees.

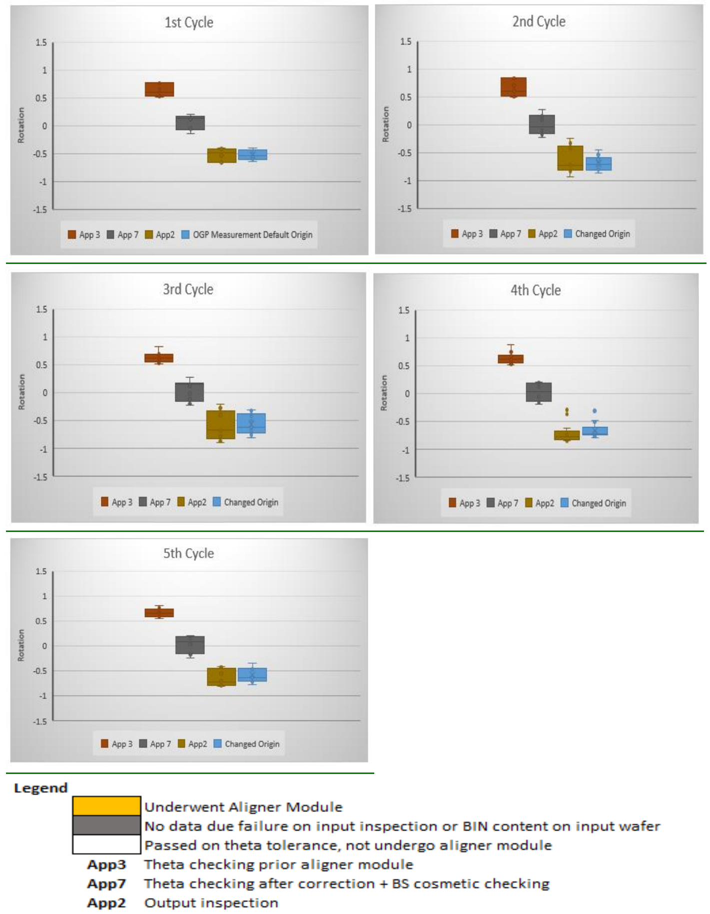


Figure 22: Die Rotation Measurement

Risk assessments were done, and results confirmed:

- Particle count inside the machine is passing the specification.
- No particles induced/observed on tape of the dice undergone die aligner station.
- No cosmetic defect induced on die wafer surface.
- No DRC failure on dice undergone auto aligner.

The Rotated dice rejection was eliminated to 0% from as high of 14% loss during Engineering Phase.

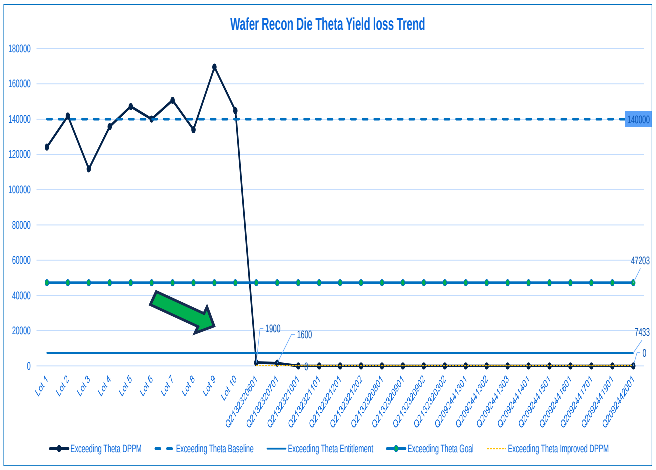


Figure 23: Die Rotation Yield Loss trend

4.3 Summary of Statistical Validation for Tape residue defect

Statistical Analysis confirmed significant difference on tape residue yield loss on different tip and shape.
It was recommended to use a flat tip with a smaller diameter.

All other factors are not significant. Except the ejector height set to optimal settings.

Factors	Levels of Factors	Remarks
Pick Up Tool Design	POR Rubber Tip (1.4mm X 1.4mm)	Select New Design Plastic Tip (2.6mm X 2.6mm)
	New Design Rubber Tip (2.6mm X 2.6mm	
	New Design Plastic Tip (2.6mm X 2.6mm	
POR Ejector Needle Round Tip Size	POR Ejector Needle Round Tip (0.10mm)	Select POR Ejector Needle Tip (0.15mm)
	POR Ejector Needle Round Tip (0.15mm)	
	POR Ejector Needle Round Tip (0.25mm)	
New Ejector Needle Flat Tip Size	New Ejector Needle Flat Tip (0.05mm)	Select New Ejector Needle Flat Tip (0.10mm)
	New Ejector Needle Flat Tip (0.10mm)	
Ejector Needle Design	POR Ejector Needle Round Tip (0.15mm)	Select New Ejector Needle Flat Tip (0.10mm)
	New Ejector Needle Flat Tip (0.10mm)	
Ejector Needle Height	New Ejector Needle Flat Tip Height (0.25mm)	Select New Ejector Needle Flat Tip Height (0.45mm) as reference going to DOE
	New Ejector Needle Flat Tip Height (0.45mm)	
	New Ejector Needle Flat Tip Height (0.75mm)	
Ejection Speed	Ejection Speed (040%)	Select Ejection Speed (70%) as reference going to DOE, nominal value
	Ejection Speed (070%)	
	Ejection Speed (100%)	
Pick Force	PnP Pick Force (090g)	Select Pick Force (150g) as reference going to DOE, nominal value
	PnP Pick Force (150g)	
	PnP Pick Force (200g)	
Pick Press Down	PnP Pick Press Down (0)	Select Pick Press Down 0.3mm) as reference going to DOE, nominal value
	PnP Pick Press Down (0.3mm)	
	PnP Pick Press Down (0.6mm)	
Pick Dwell Time	PnP Pick Dwell Time (050ms)	Select Pick Dwell Time (080ms) as reference going to DOE
	PnP Pick Dwell Time (080ms)	
	PnP Pick Dwell Time (110ms)	

Figure 25: Statistical Validation

4.3 1 Statistical Analysis on Ejector Tip and Dimension

Statistical Analysis (see Appendix 4- Statistical Testing Result) on varying ejector tip and dimension shows that:

1. The quantity of rejects related to exceeding die theta vary on ejector needle tip size used.
2. The best ejector needle tip size to be used is 0.15mm based on the result of the validation. Not the best in terms of exceed die theta rejection reduction but the effect on tape residue and toolmark issue was minimal compared to other ejector needle used.
3. The new ejector needle design tip size does not affect tape residue related reject.
4. New ejector needle design tip size has significant effect on toolmark related reject.
5. The best ejector needle tip size to be used is 0.1mm flat tip since tape residue and exceed die theta was reduced without inducing other defects.

Figure 26: New ejector design for Wafer Reconstruction process

Evaluation concludes the best design is flat tip with 0.1mm diameter considering tape residue and other potential defects.

Line stress confirms that the defect rate was cut down from 3% to 0.3% defect rate.

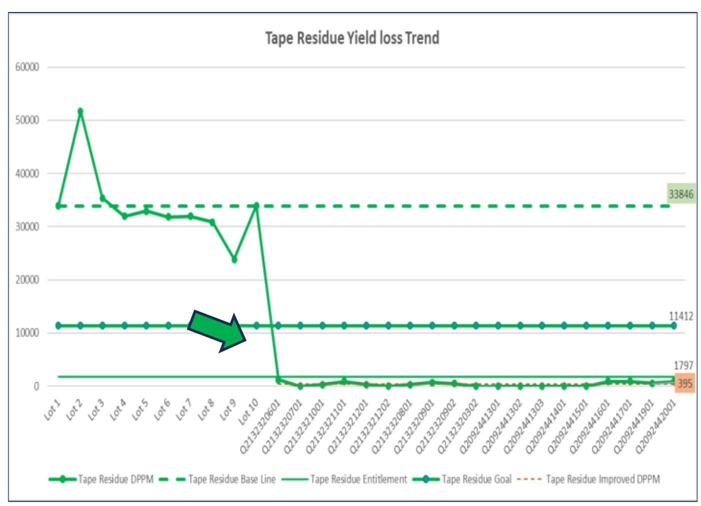


Figure 27: Yield loss trend of tape residue

4.4 Process parameters validation

Statistical Analysis confirms that Combined parameters had no significant effect on exceeding die theta rotation. The result was zero in all runs.

P-Value for ejector needle height response on tape residue was less than 0.05 indicating significant effect on tape residue related issue.
P-Value for ejector needle height response on hard to pick was less than 0.05 indicating significant effect on hard to pick related issue.

The optimum parameter conditions given by the prediction profiler are Ejector Height =0.56mm and Ejection Speed = 70% for UPH consideration. At these levels, the expected PPM rejection for Hard to Pick and Tape Residue is less than 2%.
From the plot, the tolerances for Ejector Height are: Ejector Height: 0.52 – 0.6mm. See Appendix 5 – DOE result.

5.0 CONCLUSION

Based on the machine assessment and qualifications, it was proven that the machine Optical System have high defect detection effectiveness that the high rejection brought by rotated dice at 14% and tape residue at 3.3% are valid process rejection.

This has led to the introduction of machine calibration and auto die aligner that eliminated die rotation to 0%.

With the challenge to further improve the Process Yield. Tape residue defect was also studied and lead to modification of tooling. Smaller tip and flat design have led to lower defect rate from 3.3% to 0.3% loss.

Process parameters were checked and set optimal settings of ejector height to consider singulation and other pick and place defects.

Having deployed this project at the start of the L4 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 for improved wafer reconstruction process. With the integration of auto die aligner, tooling modification, machine maintenance and optimized parameters 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

The authors would like to acknowledge the management of STMicroelectronics Calamba who continuously inspire their technical staff to create innovative solutions in our changing technology landscape. We recognize the support of our department sponsor and Operations 2 Director, Ms Aileen Gonzales , NPDI Director Sherwin Celestino , Management Team Joseph Pambid , Peter Escarro, Shakesy Magbojos, Pedro Peralta. Jeffrey Sartillo and Engineering Support Marlon Naynes, Marvin Mayores and Romeo Vibas.

8.0 REFERENCES

1. Optimus MR3 Die Sorter Wafer to Wafer, MIT Semiconductor PTE Ltd
2. MIT MR3 Manual, Optimus-MR3-OM2-Overview

9.0 ABOUT THE AUTHORS

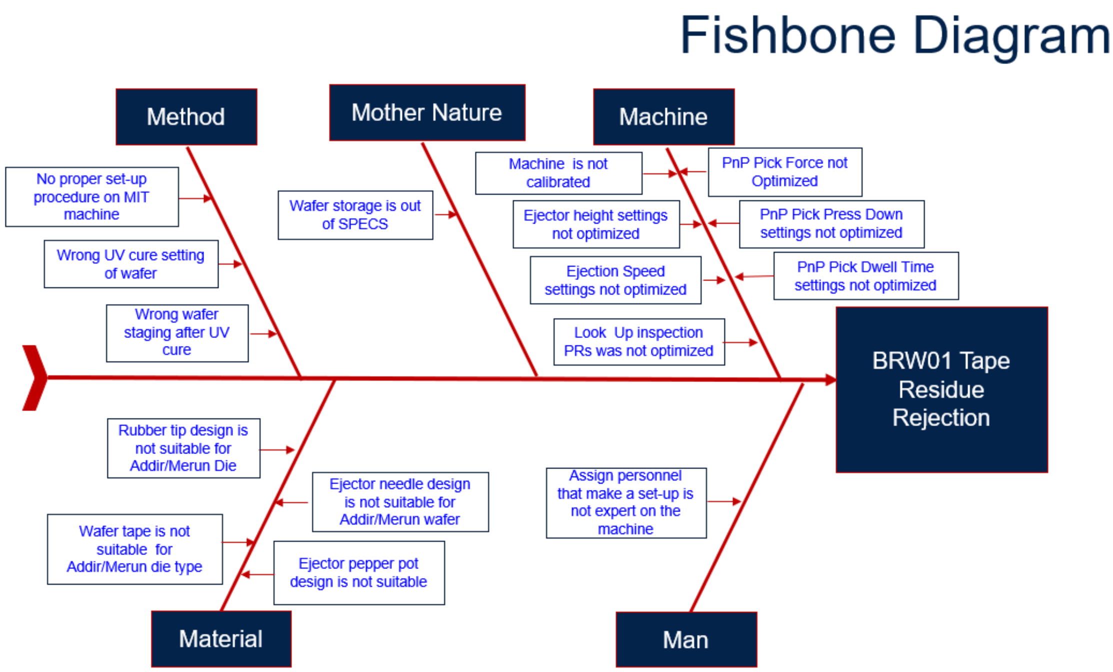
Jhanet R. Florendo is currently a Senior Assembly Process Engineer in STMicroelectronics and is assigned to Wafer AOI and Reconstruction process. She is a registered Electrical Engineer from the University of Perpetual Help Laguna.

Reinadd Jan B. Abad is currently a Senior Test and Finish Process Engineer in STMicroelectronics and is assigned at Test and Finish department for Operations 2. He received his B.S Degree in Electronics and Communications Engineering from University of the Cordilleras in Baguio City.

Judioz M. Manejero is currently a Test Process Manager in STMicroelectronics and is managing the Test and Finish department for Operations 2. He received his B.S Degree in Electronics and Communications Engineering from Mapua University in Intramuros, Manila.

10. APPENDICES

APPENDIX 1: FISHBONE DIAGRAM



APPENDIX 2: CAUSE AND EFFECT MATRIX

S.No	Process Step	Input	Characteristic of Input (KPIV / X)							Total	Is X Continuous / Discrete?	Operating Range (for X)	Unit of Measure (UOM)	Count 3's	Count 9's	X Selected / Discarded?
1	Set-Up	No proper set-up procedure on MIT machine	Wrong machine set-up	1	1					20	Discrete	Correct and proper set-up		0	0	Discard the X
2	Material Preparation	Wrong UV cure setting of wafer	Hard to pick die	1	1					20	Continuous	Correct wafer UV cure setting		0	0	Discard the X
3	Material Preparation	Wafer tape is not suitable for Addir/Merun die type	Hard to pick die	1	1					20	Discrete	Suitable UV tape		0	0	Discard the X
4	Pick & Place	Rubber tip design is not suitable for Addir/Merun Die	Unable to pick die properly	9	9					180	Discrete	Suitable rubber tip design		0	2	Select the X
5	Pick & Place	Ejector needle design is not suitable for Addir/Merun wafer	Unable to pick die properly/Can induced tape residue	9	9					180	Discrete	Suitable ejector needle tip design		0	2	Select the X
6	Pick & Place	Ejector pepper pot design is not suitable	Unable to pick die properly	1	1					20	Discrete	Suitable ejector pepper pot design		0	0	Discard the X
7	Set-Up	Assign personnel that make a set-up is not expert on the machine	Wrong machine set-up	1	1					20	Discrete	Machine expertise to have proper machine set-up		0	0	Discard the X
8	Material Preparation	Wafer storage humidity is out of SPECS	Can cause hard to pick	1	1					20	Continuous	Correct wafer storage humidity base on SPECS		0	0	Discard the X

S.No	Process Step	Input	Characteristic of Input (KPIV / X)							Total	Is X Continuous / Discrete?	Operating Range (for X)	Unit of Measure (UOM)	Count 3's	Count 9's	X Selected / Discarded?
1	Set-Up	No proper set-up procedure on MIT machine	Wrong machine set-up	1	1					20	Discrete	Correct and proper set-up		0	0	Discard the X
2	Material Preparation	Wrong UV cure setting of wafer	Hard to pick die	1	1					20	Continuous	Correct wafer UV cure setting		0	0	Discard the X
3	Material Preparation	Wafer tape is not suitable for Addir/Merun die type	Hard to pick die	1	1					20	Discrete	Suitable UV tape		0	0	Discard the X
4	Pick & Place	Rubber tip design is not suitable for Addir/Merun Die	Unable to pick die properly	9	9					180	Discrete	Suitable rubber tip design		0	2	Select the X
5	Pick & Place	Ejector needle design is not suitable for Addir/Merun wafer	Unable to pick die properly/Can induced tape residue	9	9					180	Discrete	Suitable ejector needle tip design		0	2	Select the X
6	Pick & Place	Ejector pepper pot design is not suitable	Unable to pick die properly	1	1					20	Discrete	Suitable ejector pepper pot design		0	0	Discard the X
7	Set-Up	Assign personnel that make a set-up is not expert on the machine	Wrong machine set-up	1	1					20	Discrete	Machine expertise to have proper machine set-up		0	0	Discard the X
8	Material Preparation	Wafer storage humidity is out of SPECS	Can cause hard to pick	1	1					20	Continuous	Correct wafer storage humidity base on SPECS		0	0	Discard the X

APPENDIX 3: STATISTICAL VALIDATION PLAN

Statistical Test Plan

Statistical Test Plan and Results

Y (or mini Y)	Unit of Measure	Y data type	X	X data type	Levels of X	Hypothesis Statement		Statistical Test	Beta	Alpha	Delta	Sample Size
						Null Hypothesis	Alternative Hypothesis					
Tape Residue	Reject PPM	Discrete	Ejector needle design	Discrete	150um pointed ejector needle and 100um flat tip ejector needle	Ho: $P_{Round} = P_{Flat}$	Ha: $P_{Round} \neq P_{Flat}$	2 Proportion Test	0.1	0.05	2.2%	704
	Reject PPM	Discrete	Pick up tool material type	Discrete	Rubber Tip and ESD plastic tip	Ho: $P_{Rubber} = P_{Plastic}$	Ha: $P_{Rubber} \neq P_{Plastic}$	2 Proportion Test	0.1	0.05	2.2%	704
	Reject PPM	Discrete	Ejector height	Discrete	0.4mm -0.75mm	Ho: $P_{0.4} = P_{0.55} = P_{0.7}$	Ha: $P_{0.4} \neq P_{0.55} \neq P_{0.7}$	2 Proportion Test	0.1	0.05	2.2%	704
	Reject PPM	Discrete	Ejector Speed	Discrete	40ms -100ms	Ho: $P_{40} = P_{70} = P_{100}$	Ha: $P_{40} \neq P_{70} \neq P_{100}$	2 Proportion Test	0.1	0.05	2.2%	704
	Reject PPM	Discrete	PnP Pick Force	Discrete	90 -150g	Ho: $P_{90} = P_{150} = P_{200}$	Ha: $P_{90} \neq P_{150} \neq P_{200}$	2 Proportion Test	0.1	0.05	2.2%	704
	Reject PPM	Discrete	PnP Pick Press Down	Discrete	0mm -0.6mm	Ho: $P_{0} = P_{0.3} = P_{0.6}$	Ha: $P_{0} \neq P_{0.3} \neq P_{0.6}$	2 Proportion Test	0.1	0.05	2.2%	704
	Reject PPM	Discrete	PnP Pick Dwell Time	Discrete	50ms -110ms	Ho: $P_{50} = P_{80} = P_{110}$	Ha: $P_{50} \neq P_{80} \neq P_{110}$	2 Proportion Test	0.1	0.05	2.2%	704

APPENDIX 4: STATISTICAL TESTING RESULT:

Statistical Testing (POR Ejector Needle Tip Size Validation)

Process Function	Process Step	Practical Problem	Test Plan	Hypothesis Statement	Conclusion
Pick Process	Wafer Recon	Does POR ejector needle tip size affect exceed die theta rotation related rejects?	2-proportion test	Ho : $P_{0.10} = P_{0.15} = P_{0.25}$ Ha : $P_{0.10} \neq P_{0.15} \neq P_{0.25}$	Reject Ho P value is less than 0.05 indicates significant difference on die rotation rejection using different needle size.

Two Props	Inputs	Comments
α	0.05	Typically .05
β	0.10	Typically .10 or .20
p_2	0.14	$0 < p_1 < p_2 < 1$
p_1	0.047203	$0 < p_1 < p_2 < 1$
N	159	Sample N from each population

Mosaic Plot

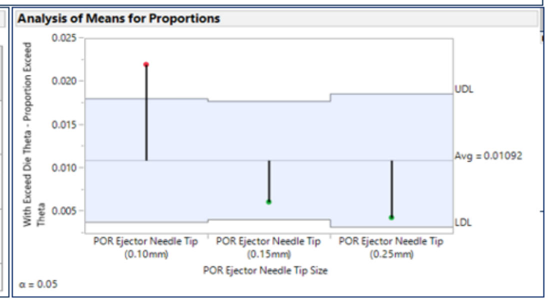
Methodology:
1.) Prepare 850 dice for test for each POR ejector needle tip size.
2.) Process each set of samples using 3 different POR needle tip sizes (0.10mm, 0.15mm and 0.25mm.
Quantify the processed exceed die theta rotation reject and good units

Contingency Table

With Exceed Die Theta

Count / Total % / Col % / Row %	Exceed Theta	Yield	Total
POR Ejector Needle Tip (0.10mm)	17	757	774
	0.74	33.07	33.81
	68.00	33.44	
	2.20	97.80	
POR Ejector Needle Tip (0.15mm)	5	813	818
	0.22	35.52	35.74
	20.00	35.91	
	0.61	99.39	
POR Ejector Needle Tip (0.25mm)	3	694	697
	0.13	30.32	30.45
	12.00	30.65	
	0.43	99.57	
Total	25	2264	2289
	1.09	98.91	

Analysis of Means for Proportions



Tests

N	DF	-LogLike	RSquare (U)
2289	2	6.2539561	0.0454

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	12.508	0.0019*
Pearson	13.313	0.0013*

Practical Conclusion:

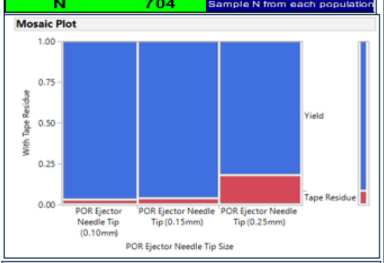
1. **The quantity of rejects related to exceed die theta vary on ejector needle tip size used.**
2. **Best ejector needle tip size to be use is 0.15mm based on the result of the validation. Not the best in terms of exceed die theta rejection reduction but the effect on tape residue and toolmark issue was minimal compared to other ejector needle used.**

Statistical Testing (POR Ejector Needle Tip Size Validation)

Process Function	Process Step	Practical Problem	Test Plan	Hypothesis Statement	Conclusion
Pick Process	Wafer Recon	Does POR ejector needle tip size affect tape residue related rejects?	2-proportion test	Ho : $P_{0.10} = P_{0.15} = P_{0.25}$ Ha : $P_{0.10} \neq P_{0.15} \neq P_{0.25}$	Reject Ho P value is less than 0.05 indicates significant difference on die rotation rejection using different needle size.

Two Props	Inputs	Comments
α	0.05	Typically .05
β	0.10	Typically .10 or .20
p_2	0.033846	$0 < p_1 < p_2 < 1$
p_1	0.011412	$0 < p_1 < p_2 < 1$
N	704	Sample N from each population

Mosaic Plot



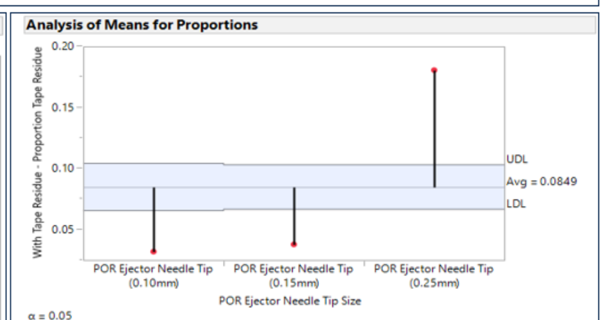
Methodology:
1.) Prepare 850 dice for test for each ejector needle tip size.
2.) Process each set of samples using 3 different needle tip sizes (0.10mm, 0.15mm and 0.25mm.
Quantify the processed with tape residue and good units

Contingency Table

With Tape Residue

Count / Total % / Col % / Row %	Tape Residue	Yield	Total
POR Ejector Needle Tip (0.10mm)	25	757	782
	1.01	30.60	31.61
	11.90	33.44	
	3.20	96.80	
POR Ejector Needle Tip (0.15mm)	32	813	845
	1.29	32.86	34.16
	15.24	35.91	
	3.79	96.21	
POR Ejector Needle Tip (0.25mm)	153	694	847
	6.18	28.05	34.24
	72.86	30.65	
	18.06	81.94	
Total	210	2264	2474
	8.49	91.51	

Analysis of Means for Proportions



Tests

N	DF	-LogLike	RSquare (U)
2474	2	71.885510	0.1000

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	143.771	<.0001*
Pearson	152.209	<.0001*

Practical Conclusion:

1. **The quantity of rejects related to tape residue vary on ejector needle tip size used.**
2. ***Best POR ejector needle tip size to be use is 0.15mm based on the result of the validation. Not the best in terms of tape residue rejection reduction but the effect on exceed die theta rotation and toolmark issue was minimal compared to other ejector needle used.***

CONT'

APPENDIX 4: STATISTICAL TESTING RESULT:

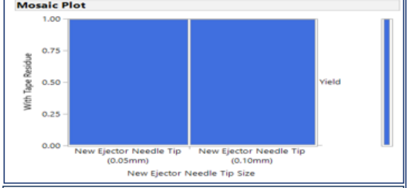
Statistical Testing (New Ejector Needle Tip Size Validation)

Process Function	Process Step	Practical Problem	Test Plan	Hypothesis Statement	Conclusion
Pick Process	Wafer Recon	Does new ejector needle flat tip size affect tape residue related rejects?	2-proportion test	Ho : $P_{0.05} = P_{0.10}$ Ha : $P_{0.05} \neq P_{0.10}$	Accept Ho P-value is greater than 0.05 indicating that there is no significant difference in using different tip size of new ejector needle.

Two Props	Inputs	Comments
α	0.05	Typically .05
β	0.10	Typically .10 or .20
p_2	0.033846	$0 < p_1 < p_2 < 1$
p_1	0.011412	$0 < p_1 < p_2 < 1$
N	704	Sample N from each population

Methodology:
1.) Prepare 850 dice for test for each new ejector needle tip size.
2.) Process each set of samples using 2 different needle tip sizes (0.05mm and 0.10mm).
Quantify the processed with exceed die theta and good units

Mosaic Plot

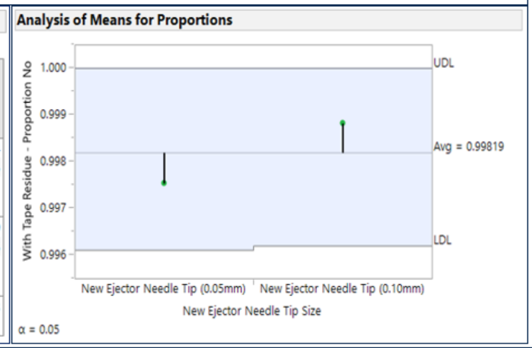


Contingency Table

With Tape Residue

New Ejector Needle Tip Size	Count / Total % / Col % / Row %	Tape Residue	Yield	Total
New Ejector Needle Tip (0.05mm)	Count	3	811	814
	Total %	0.18	48.77	48.95
	Col %	75.00	48.88	
	Row %	0.37	99.63	
New Ejector Needle Tip (0.10mm)	Count	1	848	849
	Total %	0.06	50.99	51.05
	Col %	25.00	51.12	
	Row %	0.12	99.88	
Total	Count	4	1659	1663
	Total %	0.24	99.76	

Analysis of Means for Proportions



Tests

N	DF	-LogLike	RSquare (U)
1663	1	0.56754283	0.0202

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	1.135	0.2867
Pearson	1.089	0.2967

Fisher's Exact Test	Prob	Alternative Hypothesis
Left	0.9428	Prob(With Tape Residue=Yield) is greater for New Ejector Needle Tip Size=New
Right	0.2966	Prob(With Tape Residue=Yield) is greater for New Ejector Needle Tip Size=New
2-Tail	0.3643	Prob(With Tape Residue=Yield) is different across New Ejector Needle Tip Size

Practical Conclusion:
New ejector needle design tip size does not affect tape residue related reject

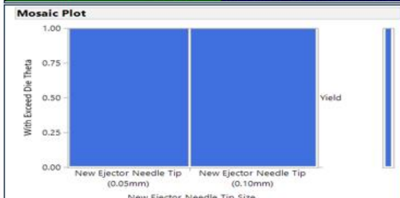
Statistical Testing (New Ejector Needle Tip Size Validation)

Process Function	Process Step	Practical Problem	Test Plan	Hypothesis Statement	Conclusion
Pick Process	Wafer Recon	Does new ejector needle flat tip size affect exceed die theta related rejects?	2-proportion test	Ho : $P_{0.05} = P_{0.10}$ Ha : $P_{0.05} \neq P_{0.10}$	Accept Ho P-value is greater than 0.05 indicating that there is no significant difference in using different tip size of new ejector needle.

Two Props	Inputs	Comments
α	0.05	Typically .05
β	0.10	Typically .10 or .20
p_2	0.14	$0 < p_1 < p_2 < 1$
p_1	0.047203	$0 < p_1 < p_2 < 1$
N	159	Sample N from each population

Methodology:
1.) Prepare 850 dice for test for each new ejector needle tip size.
2.) Process each set of samples using 2 different needle tip sizes (0.05mm and 0.10mm).
Quantify the processed with exceed die theta and good units

Mosaic Plot

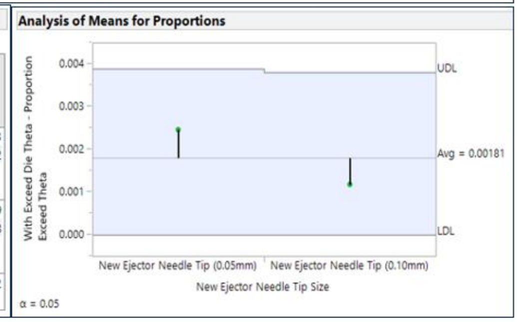


Contingency Table

With Exceed Die Theta

New Ejector Needle Tip Size	Count / Total % / Col % / Row %	Exceed Theta	Yield	Total
New Ejector Needle Tip (0.05mm)	Count	2	811	813
	Total %	0.12	48.80	48.92
	Col %	66.67	48.88	
	Row %	0.25	99.75	
New Ejector Needle Tip (0.10mm)	Count	1	848	849
	Total %	0.06	51.02	51.08
	Col %	33.33	51.12	
	Row %	0.12	99.88	
Total	Count	3	1659	1662
	Total %	0.18	99.82	

Analysis of Means for Proportions



Tests

N	DF	-LogLike	RSquare (U)
1662	1	0.19260901	0.0088

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	0.385	0.5348
Pearson	0.379	0.5382

Fisher's Exact Test	Prob	Alternative Hypothesis
Left	0.8832	Prob(With Exceed Die Theta=Yield) is greater fo
Right	0.4837	Prob(With Exceed Die Theta=Yield) is greater fo
2-Tail	0.6168	Prob(With Exceed Die Theta=Yield) is different a

Practical Conclusion:
New ejector needle design tip size does not affect exceed die theta rotation related issue

APPENDIX :
DESIGN OF EXPERIMENT
DOE RESULT:

DOE

Response Exceed Die Theta

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Pick Force(90,200)	1	1	0	.	.
Pick Press Down(0,0.6)	1	1	0	.	.
Pick Dwell Time(50,110)	1	1	0	.	.
Ejector Height(0.4,0.7)	1	1	0	.	.
Ejection Speed(40,100)	1	1	0	.	.
Pick Force*Pick Press Down	1	1	0	.	.
Pick Force*Pick Dwell Time	1	1	0	.	.
Pick Force*Ejector Height	1	1	0	.	.
Pick Force*Ejection Speed	1	1	0	.	.
Pick Press Down*Pick Dwell Time	1	1	0	.	.
Pick Press Down*Ejector Height	1	1	0	.	.
Pick Press Down*Ejection Speed	1	1	0	.	.
Pick Dwell Time*Ejector Height	1	1	0	.	.
Pick Dwell Time*Ejection Speed	1	1	0	.	.
Ejector Height*Ejection Speed	1	1	0	.	.

Response Tape Residue

Effect Tests

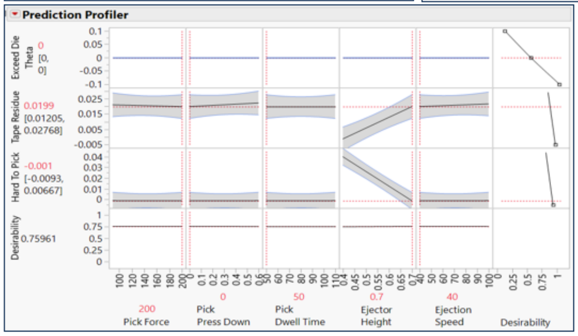
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Pick Force(90,200)	1	1	0.00000968	0.3047	0.5871
Pick Press Down(0,0.6)	1	1	0.00000220	0.0694	0.7949
Pick Dwell Time(50,110)	1	1	0.00000722	0.2273	0.6387
Ejector Height(0.4,0.7)	1	1	0.00435244	137.0104	<.0001*
Ejection Speed(40,100)	1	1	0.00000968	0.3047	0.5871
Pick Force*Pick Press Down	1	1	0.00000113	0.0354	0.8526
Pick Force*Pick Dwell Time	1	1	4.5e-8	0.0014	0.9704
Pick Force*Ejector Height	1	1	0.00000968	0.3047	0.5871
Pick Force*Ejection Speed	1	1	0.00000512	0.1612	0.6923
Pick Press Down*Pick Dwell Time	1	1	0.00000512	0.1612	0.6923
Pick Press Down*Ejector Height	1	1	0.00000220	0.0694	0.7949
Pick Press Down*Ejection Speed	1	1	4.5e-8	0.0014	0.9704
Pick Dwell Time*Ejector Height	1	1	0.00000722	0.2273	0.6387
Pick Dwell Time*Ejection Speed	1	1	0.00000112	0.0354	0.8526
Ejector Height*Ejection Speed	1	1	0.00000968	0.3047	0.5871

Response Hard To Pick

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Pick Force(90,200)	1	1	0.00000358	0.1217	0.7308
Pick Press Down(0,0.6)	1	1	0.00000520	0.1769	0.6785
Pick Dwell Time(50,110)	1	1	0.00000215	0.0732	0.7895
Ejector Height(0.4,0.7)	1	1	0.01361663	463.2266	<.0001*
Ejection Speed(40,100)	1	1	0.00000371	0.1263	0.7260
Pick Force*Pick Press Down	1	1	0.00000345	0.1172	0.7357
Pick Force*Pick Dwell Time	1	1	3.78125e-8	0.0013	0.9717
Pick Force*Ejector Height	1	1	0.00000358	0.1217	0.7308
Pick Force*Ejection Speed	1	1	0.00000520	0.1769	0.6785
Pick Press Down*Pick Dwell Time	1	1	0.00000520	0.1769	0.6785
Pick Press Down*Ejector Height	1	1	0.00000520	0.1769	0.6785
Pick Press Down*Ejection Speed	1	1	3.78125e-8	0.0013	0.9717
Pick Dwell Time*Ejector Height	1	1	0.00000215	0.0732	0.7895
Pick Dwell Time*Ejection Speed	1	1	0.00000345	0.1172	0.7357
Ejector Height*Ejection Speed	1	1	0.00000371	0.1263	0.7260

Prediction Profiler



Remarks:

- ***Combined parameters had no significant effect on exceed die theta rotation. Results was zero in all runs.***
- ***P-Value for ejector needle height response on tape residue was less than 0.05 indicating significant effect on tape residue related issue.***
- ***P-Value for ejector needle height response on hard to pick was less than 0.05 indicating significant effect on hard to pick related issue.***

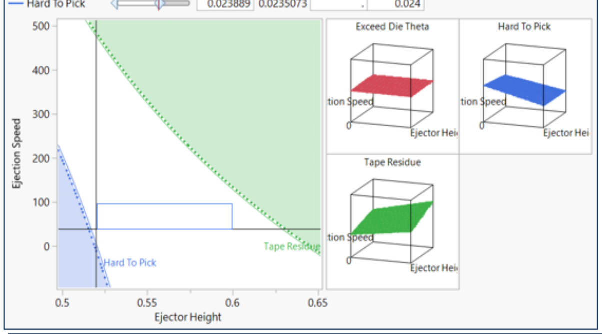
DOE

Minimum Ejector Height

Contour Profiler

Horiz	Vert	Factor	Current X
○	○	Pick Force	200
○	○	Pick Press Down	0
○	○	Pick Dwell Time	50
●	○	Ejector Height	0.5197842
○	●	Ejection Speed	39.647058

Response	Contour	Current Y	Lo Limit	Hi Limit
Exceed Die Theta	0	0	.	0.047
Tape Residue	0.014833	0.0071292	.	0.015
Hard To Pick	0.023889	0.0235073	.	0.024

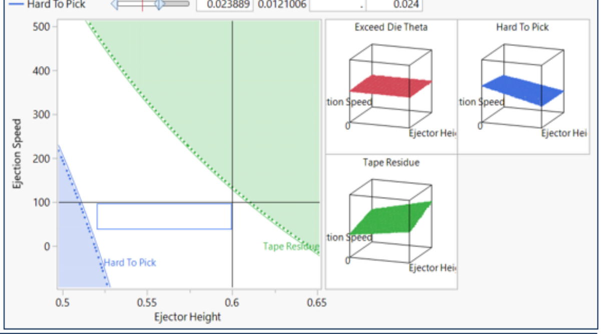


Maximum Ejector Height

Contour Profiler

Horiz	Vert	Factor	Current X
○	○	Pick Force	200
○	○	Pick Press Down	0
○	○	Pick Dwell Time	50
●	○	Ejector Height	0.599907
○	●	Ejection Speed	100.60671

Response	Contour	Current Y	Lo Limit	Hi Limit
Exceed Die Theta	0	0	.	0.047
Tape Residue	0.014833	0.0141785	.	0.015
Hard To Pick	0.023889	0.0121006	.	0.024



Practical Conclusion:

The optimum parameter conditions given by the prediction profiler are: Ejector Height =0.56mm and Ejection Speed = 70% for UPH consideration. At these levels, the expected PPM rejection for Hard To Pick and Tape Residue is less than 2%.

From the plot, the tolerances for Ejector Height are : Ejector Height : 0.52 – 0.6mm