A SIX SIGMA APPROACH TO ADDRESS HIGH PPM AT DIE ATTACH DUE TO EPOXY RELATED REJECTS

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ABSTRACT

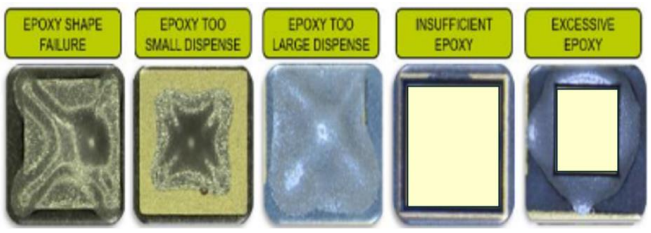
This project is about DPPM Reduction of Epoxy Related Defects in Die Attach Process. By assessing the possible Key Process Input Variable (KPIV) and applying DMAIC methodology, three inputs were validated as true causes. Pressure Level, Dispensing Nozzle Design, and Epoxy Viscosity Level.

After thorough optimization, implementation of strict viscosity control on the incoming materials and improvement on tool design, the team were able to reduce the PPM Level of Epoxy related defects by 66% with cost saving of 419K USD.

1. 0 INTRODUCTION

Die Attach is using a conductive glue to attach the die on the substrate. A 100% glue coverage is required as the glue will serve as heat sink and electrical connection from the substrate to the die. Units not conforming to the required glue coverage will be rejected due to Electrical Failure in Test.

Epoxy Related defect is categorized as Epoxy Shape Failure, Too Small Dispense, Too Large Dispense, Insufficient Epoxy and Excessive Epoxy as shown in Figure 1. These defects occur in post dispense and post bond processes. Rejected units are being detected by the machine using Post Epoxy, Pre-bond and Epoxy Bridging Inspection.



2. 0 REVIEW OF RELATED WORK

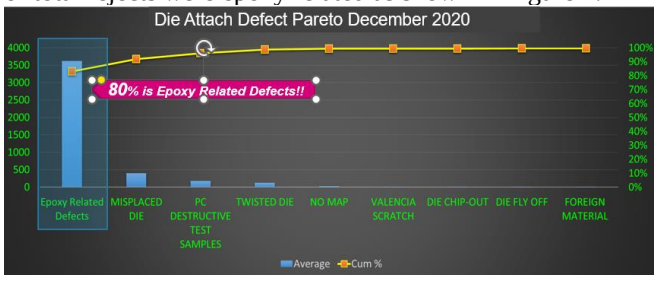
As other Semicon industries have been implementing, epoxy is commonly use as the adhesive agent. Many have already made improvements to eliminate and/or reduce problems related to epoxy. Many studies have already been published and benchmarked by them.

Study related to jetting have been noticed and discussed, the advantage and disadvantage, "According to the relative position between the nozzle and the substrate, it can be categorized as contact dispensing and jetting dispensing. The disadvantages of traditional contact dispensing, such as low efficiency, great workspace, large size and poor consistency, has been unable to meet the production demands, and is gradually replaced by jetting dispensing. Jetting dispensing technology separates the fluid by applying pressure in the nozzle, forming the droplets on the substrate. In the process of product packaging, it can reduce the contact between the needle and products and effectively avoid the disadvantages such as drawings and scratches. Besides, the dispenser has no vertical displacement, which greatly improves the distribution efficiency and the uniformity of droplets".

3.0 METHODOLOGY

3.1 Define Phase

Epoxy related defects have the highest defect rate in all Assembly processes. Looking into the Defect Pareto for October to November 2020, alone in Die Attach Process 80% of total rejects were epoxy related as shown in Figure 2.



3.1.1 Problem Statement

The rejection rate of Epoxy Related Defects averaging 1941 PPM from October to November 2020 results to Low Yield Output in Die Attach Process.

Fig.3. Die Attach Yield Trend

3.1.2 Objective Statement

The objective of this project is to reduce the high PPM Level of Epoxy Related defects by the end of Q2'19 to achieve the Die Attach Target Yield. As shown in Figure 4, DPPM trend shows that the current rejection rate at Die Attach is much higher than the computed target goal. Thus, indicates that these rejects have big contribution on the process Yield Loss.

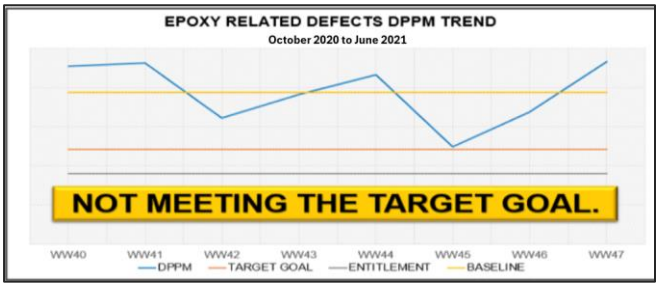


Fig.4. Die Attach DPPM Trend

3.2 Measure Phase

3.2.1 Identifying Potential Causes

The team used Input / Output matrix to identify the KPIVs associated with epoxy related defects. The team were able to identify 13x KPIVs as potential causes.

Please refer on Appendix A – Input and Output Matrix, for detailed list of identified KPIVs.

3.2.2 Cause and Effect Prioritization

Assessing the list using the Cause and Effect Prioritization Matrix and rating according to its impact to epoxy related defects, potential critical X's were narrowed down from 13 to 7 X's.

After checking the currently controlled documents, the team narrowed down the critical X's that will proceed with Measure Phase to 4 X's; (1) Pressure Level, (2) Dispensing Height, (3) Nozzle Design and (4) Epoxy Viscosity Level.

Please refer on Appendix B – Cause and Effect Prioritization Matrix, for the assessment details on identified KPIVs.

3.2.3 Feedback of Issue

During the realization period of this project, consistent feedback regarding Epoxy related defects from the succeeding stations were received.

3.2.4 Measurement Capability

Considering the feedback, the team checked the current machine detection control using Measurement System Analysis (MSA) and found to have weak inspection performance, revealing that not all defective units are being rejected. Thus, indicates that the current control is not effective.

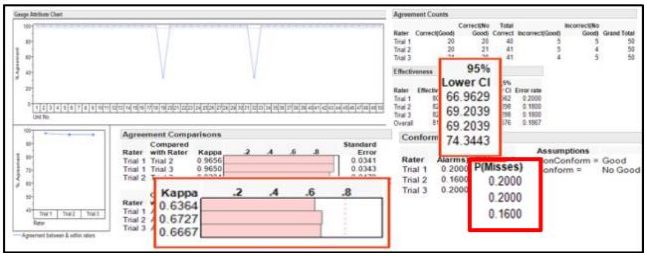
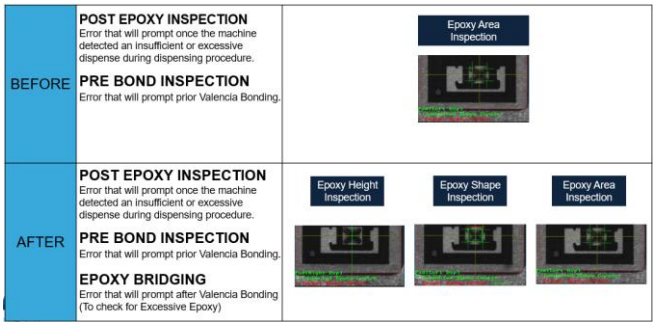


Fig.5. Equipment Attribute MSA

Due to not effective machine detection control, implementation of tighter machine inspection was fan out in all Die Attach machine.



Machine judgement shows good performance as no rejected units are being accepted and low percentage of good units being rejected after detection improvement. Showing that the improve detection is effective.

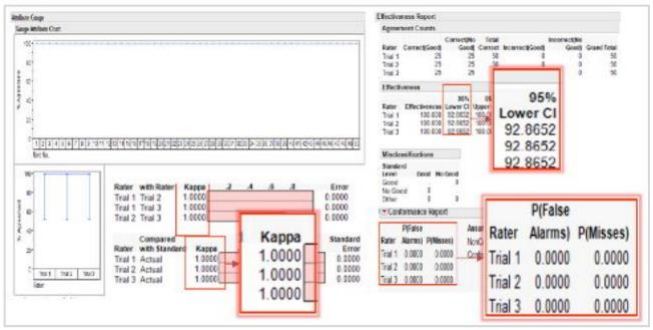


Fig.6. Operator Inspection Judgment

Die Attach operator judgement in improved machine inspection also shows good response as no rejected units are being accepted and low percentage of good units being rejected. Therefore, indicates that the current judgement of operator is good and effective.

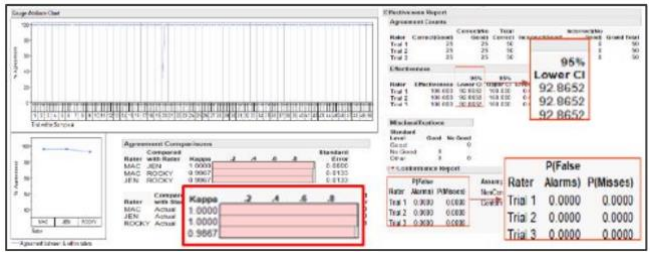


Fig.7. Operator Inspection Judgment

The implementation of tighter machine inspection leads the team to realization of the real rate of Epoxy related defects. At WW48, after the pull implementation of improve detection, the defect rate increases by 43%.

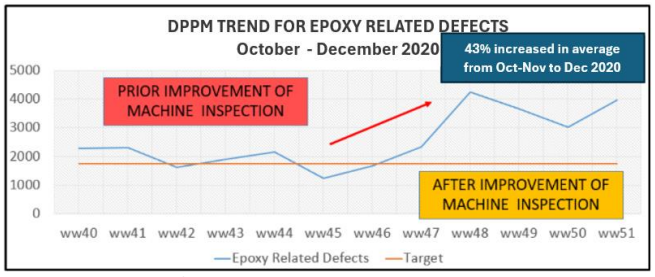


Fig.8. DPPM Trend for Epoxy Related Rejects

After realizing the true rejection rate, the team performed another baseline review of epoxy related defects at Die Attach process. At WW48, the actual DPPM Level increases by 43% as shown in Figure 9, with final goal of decreasing the DPPM level from 3619PPM to less than 1746PPM.

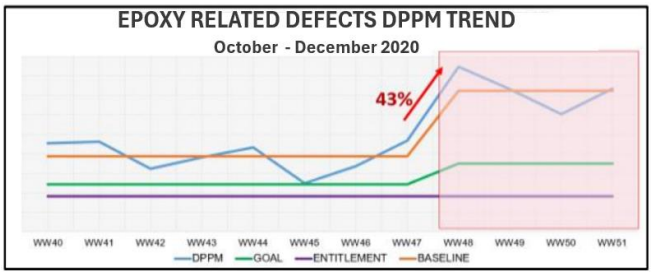


Fig.9. DPPM Trend (October to December 2020)

3.3 Analyze Phase

3.3.1 Validation Plan

The validation plan is the guide that the team used for analysis and test to validate the identified 4 Critical X's from the Cause and Effect diagram.

Please refer on Appendix C– Validation Plan, for the detailed plan details.

3.3.2 Pressure Level

Die Attach was using Manual Dispenser Module. It is being manually adjusted by the attending personnel if they were alerted by the machine or if they noticed that there is an abnormality on the glue dispense during run.

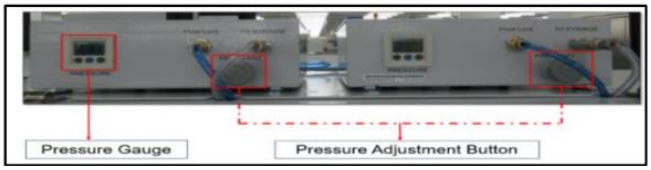


Fig.10. Die Attach Manual Dispenser Module

To check the relationship between epoxy floor life and pressure level the team use correlation test. Result shows that Pressure Level vary through time of epoxy usage, the longer the epoxy is being use the lower the pressure is needed. Given this result, it is difficult to monitor the pressure in all machines as it is needed a constant adjustment as the epoxy life progress. Therefore, Pressure level is a true cause.

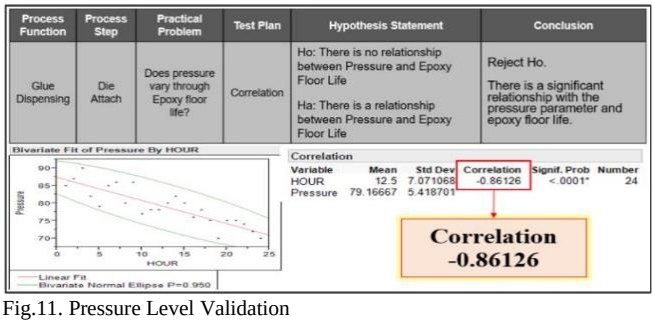


Fig.11. Pressure Level Validation

3.3.3 Dispensing Height

To check if the dispensing height affects the rejected unit regards to epoxy related, we use 2 Proportion test as shown in Figure 12. Result shows that there is no significant difference on the rejected units indicating that Dispensing Height is found to be invalid.

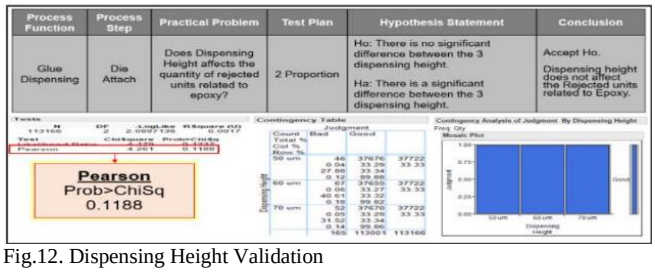


Fig.12. Dispensing Height Validation

3.3.4 Nozzle Design

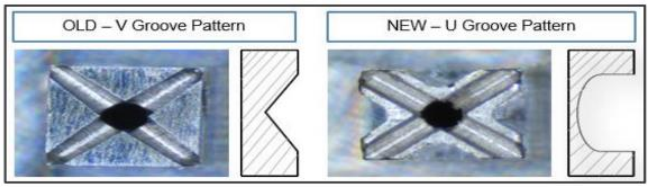


Fig.13. Nozzle Design

In this validation, we are going to validate the existing nozzle design, having V-Groove pattern, and the new nozzle design, having a U-Groove pattern, using 2-Proportion Test.

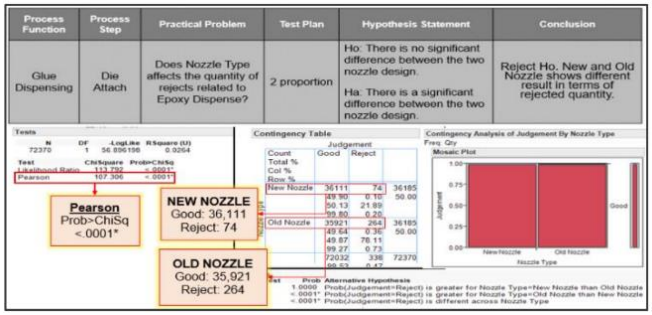


Fig.14. Nozzle Design Validation – Quantity

As part of the quality characteristic, the team run test on the die responses that have a relationship on the two sets of variables. Since the data was non normally distributed, we used 2 median test. Data shows low p-value indicating that there is a significant difference between the two nozzle. New nozzle data result moves nearer the target with less variation than the Old nozzle design.

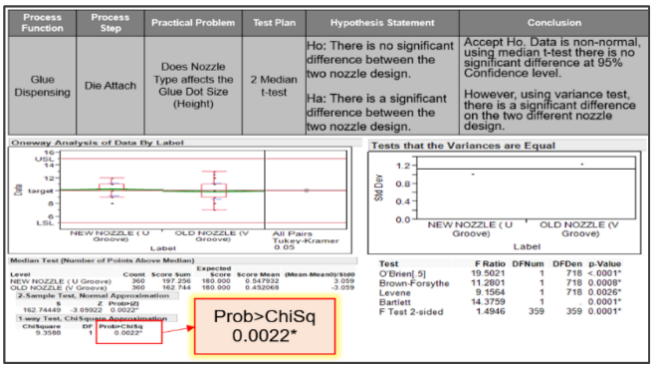


Fig.15. Nozzle Design Validation – Quality

The teamused same test on other quality characteristic as all data were non normally distributed. Result shows that data moves nearer the target and has a lesser variation using the new nozzle than the old design, indicating that new nozzle design is better.

Please refer on Appendix D – Nozzle Design Quality Characteristics Validation, for the detailed result.

3.3.5 Epoxy Viscosity Level

The team use Correlation test to check the relationship between Epoxy Floor Life and Epoxy Viscosity Level. Result shows that Viscosity Level of epoxy vary through time of usage. The longer the usage of epoxy the lower the viscosity it become, showing that Viscosity Level is a true cause.

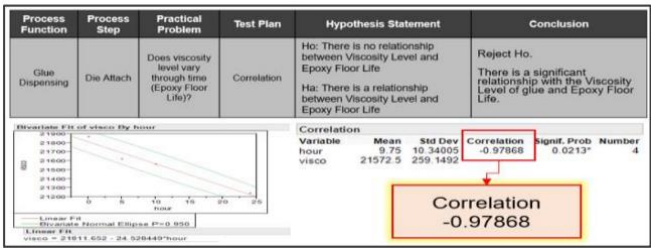


Fig.16. Epoxy Viscosity Level Validation

3.3.6 Go-No-Go Table

After series of evaluations and analysis, the team found that 3 out 4 identified Critical X's were valid and will proceed to Improve Phase.

Table 2. GO-NO-GO Table

INPUT	CHARACTERISTIC INPUT	OPERATION RANGE	REMARKS	GO / NO GO
Dispensing Pressure	Pressure Level	70 -90 Kpa	VALID	GO
Epoxy	Viscosity Level	20400 -27000 cps	VALID	GO
Dispensing Height	Parameter	50-70 um	INVALID	NO GO
Nozzle Tip	Design	Cross Pattern V groove	VALID	GO

3.4 Improve Phase

3.4.1 Pressure Level

To address the concerns regarding manual dispensing module, the team implemented the use of Archerfish Dispensing module, which have auto-compensate feature in terms of pressure and time. It automatically adjusts the epoxy dispense based on the average of the previous dispense. Automatic adjustment is done the software feedback control and no manual adjustment was involved.
Note: Prior the trial of Archerfish module, the team have option to choose other model that can be applicable to the process such as the Vermes Dispensing, but considering the cost and the function addressing the problem, the team decided to pick the Archerfish module.

Fig.17.Archerfish Dispenser Module

After implementation of the auto-compensating dispenser, no occurrence of Insufficient and Excessive Epoxy was received from the succeeding stations. Machine downtime related to epoxy dispense error also improved by 52% as shown in Figure 18.

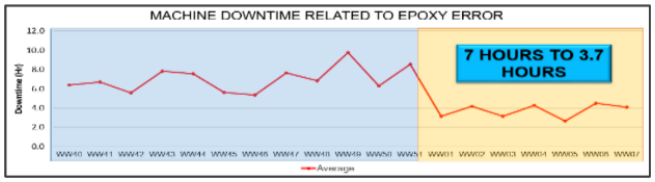


Fig.18. Machine Downtime

The team came up with one potential problem of the Archerfish module. Its auto-compensating feature depends on the average of previous dispensed units. If the lighting is not optimized, false auto-compensation may occur. To address this problem, installation of polarized camera was fan-out in all machines to eliminate glare or reflection cause by external light.

3.4.2 Nozzle Design

Addressing the nozzle design, the team came up to re-design the nozzle tip from V-Groove to U-Groove to correct the insufficient and excessive dispense issue. Dispensing using the new design has more control on the 4 sides of the coverage and extended coverage on the 4 corners of the dispense epoxy, as shown in Figure 19.

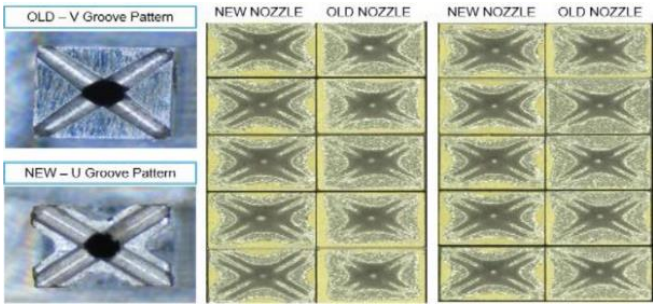


Fig.19. Epoxy Dispense Comparison

3.4.3 Viscosity Level

Addressing the Viscosity Level problem, the team used Regression test to determine if there is a significant relationship between the quantity of rejected units and epoxy viscosity level. As per result, there is a 99.8% change on the quantity of rejects as the level of viscosity decreases. It shows that while the level is increasing the number of quantity rejected is decreasing or vice versa.

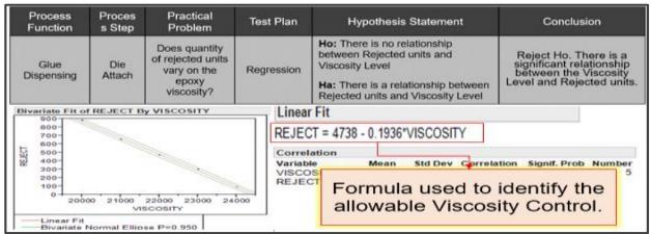


Fig.20. Regression Test – Viscosity Validation

3.5 Control Phase

All corrective actions were documented through PCMS and PCN. For the new tool and material controls, Work Instruction for Die Attach and FMEA were updated and implemented. Deployment to all involved personnel was conducted prior full implementation of new standards. Old nozzle design was also pulled out in Kitting after implementation of new design.

Please refer on Appendix E – Project Documentation, for detailed information on above item.

4.0 RESULTS AND DISCUSSION

As for the result, target PPM was achieved after full implementation of new tool and material control at IQC. As shown in Figure 21, the team were able to achieve30% PPM Level lesser than the set target goal of 1217 PPM. No epoxy related feedback from the succeeding stations was also noted.

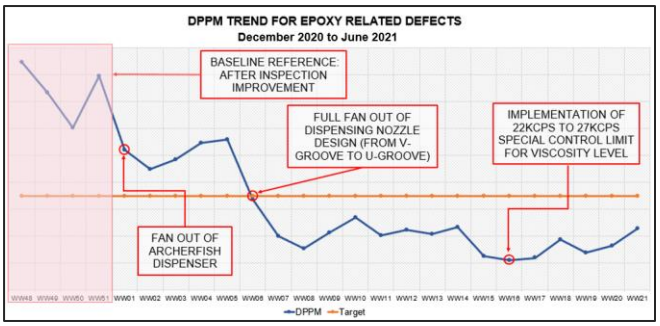


Fig.21. DPPM Trend December 2020 – June 2021

As for actual cost savings for 12 months, the team saved up to 419K USD.

YIELD IMPROVEMENT / SCRAP REDUCTION PROJECT

Reference

CCRP Volume	30-Apr-2021

Monthly Forecasting Savings	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Total
Input Volume (K)													
Defect Rate (%)													
Baseline	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	
Actual/Target	0.10%	0.12%	0.07%	0.16%	0.20%	0.13%	0.14%	0.11%	0.09%	0.06%	0.17%	0.17%	
Improvement	0.20%	0.18%	0.23%	0.14%	0.10%	0.17%	0.16%	0.19%	0.21%	0.24%	0.13%	0.13%	
Scrap qty reduced (K)	20	3	15	16	16	34	39	46	51	29	65	82	415
Device Cost													
Calculation Constant (To be filled by IE when necessary)											COST SAVINGS: 419K USD		
Savings ($)													
Monthly	20	3	15	16	17	34	39	47	52	29	65	83	
Cumulative	20	23	38	54	71	104	143	190	242	271	336	419	

Cost Saving Table

5.0 CONCLUSION

Using the appropriate tools and DMAIC principle, it was concluded that the auto-compensating dispense module, that automatically adjust the epoxy dispense with real time monitoring and measurement, significantly improved the machine downtime related to Epoxy Related Defects by 47%.

After analyzing the material behavior using Correlation test, it shows that the viscosity level varies through time. The implementation of strict epoxy viscosity control helped to improve the rejection rate of epoxy related defects along with the implementation of new nozzle design, that gives control on the spread of epoxy on the 4 sides.

These actions results to 66% improvement on the PPM Level of Epoxy Related defects and helps Die Attach Process to achieve the 99.8% target yield.

6.0 RECOMMENDATIONS

The authors recommended that the learnings and result for the Epoxy evaluations such as special control of viscosity level, transit temperature control and improvement on shipment packaging will be shared to New Product Development Team to be applied on the new products that will be using the same epoxy.

7.0 ACKNOWLEDGMENT

The authors would like to extend their sincerest appreciation to the OPS2 Die Attach Team for the full support on accomplishing this milestone.

OPS2 Production, PC, Equipment and Process Engineering Team forthe support on achieving the goal of this project.

8.0 REFERENCES

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9.0 ABOUT THE AUTHORS

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10.0 APPENDIX

Appendix A – Input and Output Matrix

Characteristics of Process Outputs (KPOVs)				
Key Output	**Characteristic of Output (KPOV / Y / Mini Y)**	**Specification**	**MSA**	**Z-Score (Short Term)**
DIE BONDED UNITS	100% coverage of glue and not touching the gold metallization	100% coverage of glue and not touching the gold metallization		

			Process Inputs (KPIVs)				
Process Step	**VA/NVA**	**SOP**	**Type of Input**	**Input**	**Characteristic of Input (KPIV / X)**	**C/N**	**Specification**
Material Preparation	VA	DM00383818	Raw Material / Information	Stiffener	Strip Planarity	Controllable	Not crumpled, no damage
			Raw Material / Information	Epoxy	Type of Material	Controllable	Correct Lot Number
			Raw Material / Information	Epoxy	Condition	Controllable	No appearance abnormality
			Raw Material / Information	Epoxy	Viscosity Level	Controllable	20.4 - 27 kcps
			Raw Material / Information	Epoxy Expiration Sticker	Date and Time of Expiration	Controllable	Not Expired
			Raw Material / Information	Die Wafer Water	Wafer Label	Controllable	Correct Die wafer water
			Raw Material / Information	Die Wafer Water	Wafer ID	Controllable	Match with Lot Traveller
			Raw Material / Information	Die Wafer Water	Wafer Condition	Controllable	No Damage
Dispensing	VA	DM00383818	Process Control / Method / Policy	Dispenser Nozzle	Type of Nozzle	Controllable	Nozzle Carbide Tip
			Process Control / Method / Policy	Pressure	Level	Controllable	70 - 90 Kpa
			Process Control / Method / Policy	Dispensing Height	Height	Controllable	50 -70 um
			Process Control / Method / Policy	Needle Tip	Design	Controllable	V Groove Nozzle Tip
			Process Control / Method / Policy	Nozzle	Life Span	Controllable	24 Hrs

Appendix B – Cause and Effect Prioritization Matrix

Characteristics of Process Outputs (KPOVs)				
Key Output	**Characteristic of Output (KPOV / Y / Mini Y)**	**Specification**	**MSA**	**Z-Score (Short Term)**
DIE BONDED UNITS	100% coverage of glue and not touching the gold metallization	100% coverage of glue and not touching the gold metallization		

Rating Criteria	
0	No Impact on Y
1	Minor Impact on Y
3	Moderste Impact on Y
9	Major Impact on Y

Process Step		**Characteristic of Input (KPIV / X)**	Epoxy Shape Failure	Too small dispense	Too Large dispense	Insufficient Epoxy	Excessive Epoxy	**Total**	**Is X Continuous / Discrete?**	**Operating Range (for X)**	**Unit of Measure (UOM)**	**X Selected / Discarded?**
Material Preparation	Stiffener	Strip Planarity	3	0	0	3	0	60	Discrete	No warpage, no damage		Select the X
	Epoxy	Type of Material	0	0	0	0	0	0	Discrete	Correct lot Number		Discard the X
	Epoxy	Condition	9	9	9	9	9	450	Discrete	No Freee Thaw Voids		Select the X
	Epoxy	Viscosity Level	9	9	9	9	9	450	Continuous	20.8-27 kcps		Select the X
	Epoxy Expiration Sticker	Date and Time of Expiration	3	3	3	3	3	150	Continuous	Not Expired		Select the X
	Die Wafer Water	Wafer Label	0	0	0	0	0	0	Discrete	Correct Wafer Water		Discard the X
	Die Wafer Water	Wafer ID	0	0	0	0	0	0	Discrete	Match with Lot traveller		Discard the X
	Die Wafer Water	Wafer Condition	0	0	0	0	0	0	Discrete	No Damage		Discard the X
Dispensing	Dispenser Nozzle	Type of Nozzle	0	0	0	0	0	0	Discrete	Stamping		Discard the X
	Pressure	Level	3	9	9	9	9	390	Continuous	70 - 90	Kpa	Select the X
	Dispensing Height	Height	0	0	0	3	3	50	Continuous	50 - 70 um	um	Select the X
	Needle Tip	Design	3	0	3	0	3	90	Continuous	cross pattern dispense nozzle v groove	mm	Select the X
	Nozzle	Life Span	0	0	0	0	0	0	Continuous	24 hrs	hrs	Discard the X

Appendix C – Validation Plan

Validation Plan												
Y (or min Y)	**Unit of Measure**	**Y treated as**	**X**	**True Nature of X**	**Levels of X**	**Hypothesis Statement**		**Statistical Test**	**Beta**	**Alpha**	**Delta**	**Sample Size**
						Null Hypothesis	**Alternative Hypothesis**					
Epoxy Viscosity Level	Hour	Continuous	Time	Continuous	Epoxy Viscosity Level, 24hrs floor life	There is no relationship between the Viscosity Level and Epoxy Floor Life	There is a relationship between the Viscosity Level and Epoxy Floor Life	Correlation	1.0	0.05	0.1	24
Machine Pressure Parameter	Hour	Continuous	Time	Continuous	Pressure Parameter, 24 hours	There is no relationship between Pressure and Time	There is a relationship between Pressure and Time	Correlation	1.0	0.05	0.1	24
Epoxy Dispense Rejection	PPM	Discrete	Dispensing Height	Discrete	50-70 um	Ho : $P_{50um} = P_{60um} = P_{70um}$	Ha : $P_{50um} < P_{60um} < P_{70um}$	2 Proportion	1.0	0.05	0.1	24
Epoxy Dispense Rejection	PPM	Discrete	Nozzle Design	Discrete	U Groove and V Groove	Ho : $P_{old\ nozzle} = P_{new\ nozzle}$	Ho : $P_{old\ nozzle} \neq P_{new\ nozzle}$	2 Proportion	1.0	0.05	0.1	24
Glue Dot Size Length		Continuous	Nozzle Design	Discrete	U Groove and V Groove	Ho : $P_{old\ nozzle} = P_{new\ nozzle}$	Ho : $P_{old\ nozzle} \neq P_{new\ nozzle}$	2-Sample T-test	1.0	0.05	0.1	24
Glue Dot Size Height		Continuous	Nozzle Design	Discrete	U Groove and V Groove	Ho : $P_{old\ nozzle} = P_{new\ nozzle}$	Ho : $P_{old\ nozzle} \neq P_{new\ nozzle}$	2-Sample T-test	1.0	0.05	0.1	24
Glue Dot Size Width		Continuous	Nozzle Design	Discrete	U Groove and V Groove	Ho : $P_{old\ nozzle} = P_{new\ nozzle}$	Ho : $P_{old\ nozzle} \neq P_{new\ nozzle}$	2-Sample T-test	1.0	0.05	0.1	24
Gllue BLT		Continuous	Nozzle Design	Discrete	U Groove and V Groove	Ho : $P_{old\ nozzle} = P_{new\ nozzle}$	Ho : $P_{old\ nozzle} \neq P_{new\ nozzle}$	2-Sample T-test	1.0	0.05	0.1	24

Appendix D- Nozzle Design Quality Characteristic Validation Table

CHARACTERISTIC	NORMALITY TEST	P-Value (Median Test)	VARIANCE TEST	REMARKS
Dot Size (Height)	Non Normal	0.201	0.0001	Data moves nearer the target and has a lesser variation using the New Nozzle. New Nozzle is Better.
Dot Size (Length)	Non Normal	0.0057	0.0008	
Dot Size (Width)	Non Normal	0.925	0.0001	
Glue BLT	Non Normal	0.0022	0.0022	

Appendix E – Project Documentation

ITEM	ACTION ITEM	DUE DATE	RESPONSIBLE	DOC#/REV	REMARKS	STATUS
1	PCMS • B80X IR Flood Attach New Dispensing Nozzle Design	7-Feb	Jessa May Cantos	PTM_CAL_049540	Fully implemented and Fan out in all BIA machines	DONE
2	PCN •18110720 - Change of ASM 838P Dispenser Module from Standard to Archerfish	20-Nov	Jessa May Cantos	18110720	Fully implemented and Fan out in all BIA machines	DONE
3	FMEA •F00010935 - IR Flood Attach Include the Archerfish Dispenser under Insufficient and Escessive Epoxy	WW11	Jessa May Cantos	F00010935	Validated	DONE
4	Work Instruction DM0325516 - IR Flood Attach Change the 8NC number for New Nozzle	WW07	Jessa May Cantos	DM00325516	Revised and Released	DONE