HARD STAIN PPM REDUCTION IN POTTING STATION THROUGH EFFECTIVE AND ROBUST DESIGN OF TAPE TRACK COVER

Irish Jan T. Beltran
Eric G. Espino
Bernard R. Zamora

Assembly Operations 1
STMicroelectronics, Inc.
9 Mountain Drive, LISP 2, Calamba 4027 Laguna, Philippines,
irish-jan.beltran@st.com, *eric.espino@st.com*, *bernard.zamora1@st.com*

ABSTRACT

In today's ever-changing technology, in an industry where competition is neck and neck among companies, Cost saving serves an important role in staying competitive in the industry. This technical paper will discuss how cost savings were achieved through elimination of one of the top defect contributors during manufacturing. Hard Stain was solved using DMAIC approach.

1. 0 INTRODUCTION

Micromodule package is one of our company's high volume production lines. The volume ramp-up on Q3 of 2021 presented challenges that need to be addressed and corrective and preventive actions should be put in place immediately.

One of the main defect contributors for Micromodule devices is the high ppm level of scrapped units due to hard stain. This device is being monitored by the top management which drives the authors to further improve the yield. PPM reduction for this defect will contribute to yield improvement. This will be the main goal of this paper. The PPM rate of scrapped units due to hard stain is averaging 22477 PPM from MAR to JUN 2021. The target is to reduce the hard stain PPM level to 15734 ppm before the end of Q1 2021. PPM reduction for this defect will contribute to yield improvement.

Fig. 1. CME3010D Potting System and Inline Curing Oven

2.0 METHODOLOGY

2.1 DEFINE PHASE

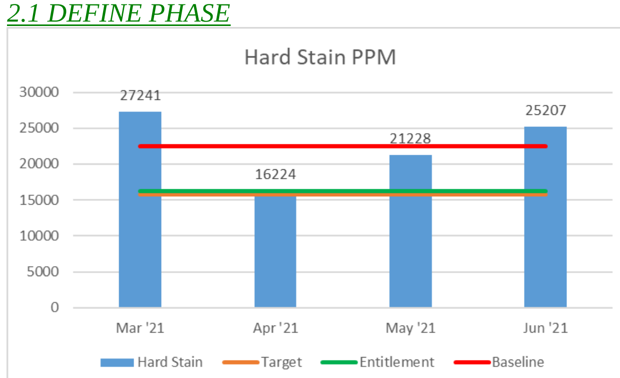


Fig. 2. Micromodule Hard Stain PPM from March to June 2021

The figure above shows the high PPM rate of scrapped units due to hard stain averaging 22477 PPM for Micromodule devices from MAR to JUN 2021. The target is to reduce the hard stain PPM level to 15734 ppm only.

2.1.1 Potting Process Description

The potting process uses a 2-head dispense system; each head utilizes a 12-fold nozzle for faster resin encapsulation process. In-line curing is linked to the potting machine to instantly cure the dispensed resin. The 1st dispense head encapsulates the even rows while the 2nd head encapsulates the odd rows.

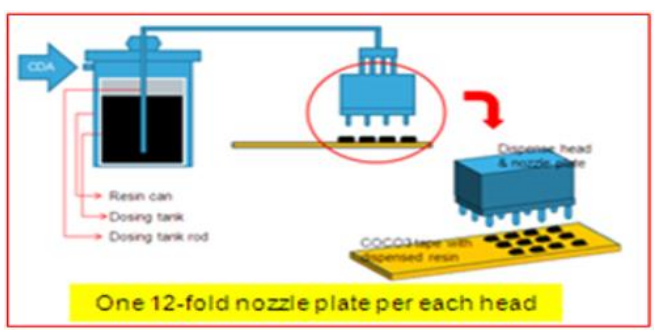


Fig. 3. Potting Head Dispense System

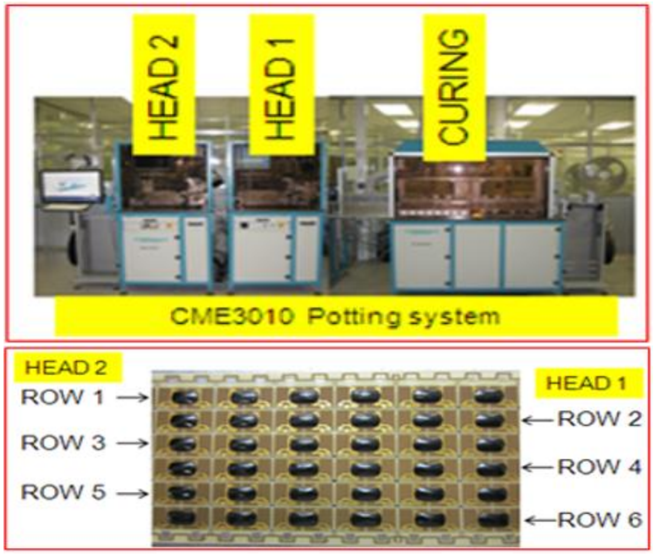


Fig. 4. Head 1 encapsulates the even rows while Head 2 encapsulates the odd rows.

2.1.2 What is Hard Stain?

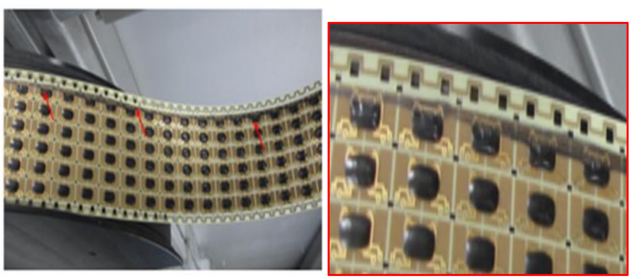


Fig. 5. Hard Stain Defect Signature

The figure above shows the defect signature of Hard Stain. It is a defect wherein the resin scattered on the lead frame surface. This defect is detected after potting station. It is usually seen at the 1st and last Row of the Lead frame tape. These units are rejected thus contributing to yield loss (yielded off in Visual Mechanical Inspection/VMI Station)

2.2 MEASURE PHASE

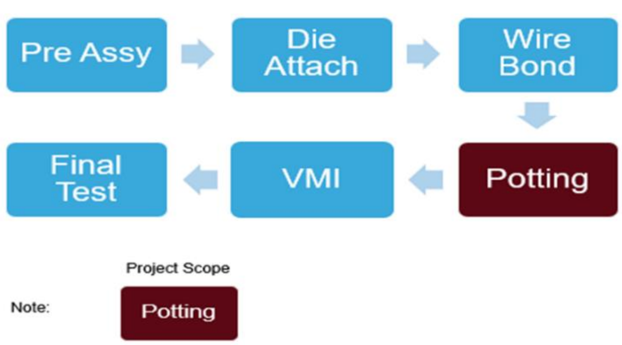


Fig. 6. Micromodule Process Macro Map

Figure 6 illustrated that from Assembly manufacturing department, the authors focused on one major step in assembly, the Potting Station.

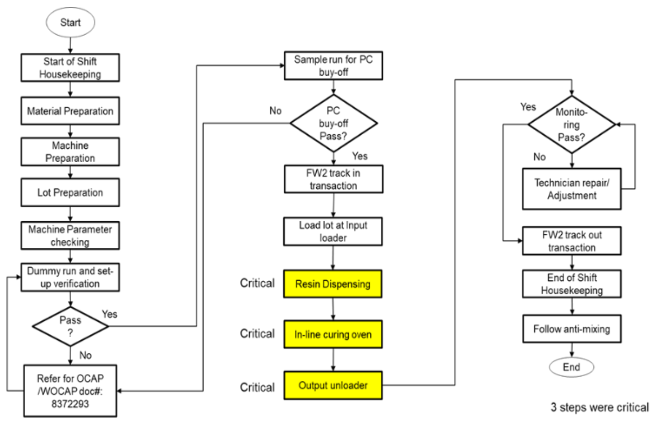


Fig. 7. Detailed Process Flow

The figure above shows that the Process flow has 3 critical steps. These 3 Critical steps were validated on the Key Process Input Variables (KPIV) table.

Table 1. KPIV table

	Process Inputs (KPIVs)				
Process Step	Type of Input	Input	Characteristic of Input (KPIV / X)	C/N	Specification
Resin Dispensing	Equipment / Infrastructure	Head 2 Resin Dispense	Able to dispense Resin	Controllable	Tape guide should not touch or scratch Lead frame surface
	Equipment / Infrastructure	Head 1 Resin Dispense	Able to dispense Resin	Controllable	Tape guide should not touch or scratch Lead frame surface
In-line Curing Oven	Equipment / Infrastructure	Pre-Cure track	Able to transfer tape from Dispense area to In-line Curing Oven	Controllable	Tape guide should not touch or scratch Lead frame surface
	Equipment / Infrastructure	In-line curing oven	Able to cure tape	Controllable	Tape guide should not touch or scratch Lead frame surface
Output unloader	Equipment / Infrastructure	Output track cover	Able to transfer tape from In-line	Controllable	Track cover should not touch or scratch Lead frame surface

There are 5 Key Process Input Variables identified as potential x's. For the first step, Head 1 and 2 should be able to dispense resin without the tape guide touching or scratching the leadframe surface. For the second step, Pre-Cure track should be able to transfer the tape from the dispensing area to the in-line curing Oven without the tape guide touching or scratching the leadframe surface. And for the last step, the output track should be able to transfer the tape from the in-line cure to the output unloader without the tape guide touching or scratching the leadframe surface. These 5x's will be fed into Identifying input variables on the next table.

Table 2. Cause and Effect Matrix

Cause and Effect Matrix

S.No	Process Step	Input	Characteristic of Input (KPIV / X)	1	Total	Is X Continuous / Discrete?	Operating Range (for X)	Unit of Measure (UOM)	Count 3's	Count 9's	X Selected / Discarded?
				Hard Stain							
			Is Y Continuous / Discrete?	Discrete							
			Customer Priority	10							
1	Resin Dispensing	Head 2 Resin Dispense	Able to dispense Resin	9	90	Discrete			0	1	Select the X
		Head 1 Resin Dispense	Able to dispense Resin	9	90	Discrete			0	1	Select the X
2	In-line Curing Oven	Pre Cure track	Able to transfer tape from Dispense area to In-line Curing Oven	9	90	Discrete			0	1	Select the X
		In-line curing oven	Able to cure tape	9	90	Discrete			0	1	Select the X
3	Output unloader	Output track cover	Able to transfer tape from In-line	1	10	Discrete			0	0	Discard the x

The table above shows that from the initial 5 x's, the team agreed that the remaining 1 x's with a score of 1 have a minor contribution and minor impact on the PPM reduction. The 4x's were given a score of 9 each.

2.3 ANALYZE PHASE

The authors proceeded in validating the 4 remaining x's. The first potential root cause to be validated is the Dosing Head track and the process step is from Dosing Head 2 to Dosing Head 1.

Fig. 8. Dosing Head 2 to Dosing Head 1 process step validation

Table 3. First Potential Root Cause Validation

Potential Root cause	Process Step	Practical Problem	Method of Validation	Results	Conclusion
1. Dosing Head Track	Dosing Head 2 to Dosing Head 1	Is the Dosing Head 2 able to transfer the leadframe tape to Dosing Head 1 without causing Hard Stain?	Observe the leadframe tape indexing from Dosing Head 2 to Dosing Head 1 through potting and indexing simulation.	Based on observation, there is no occurrence of Hard Stain while simulating the leadframe tape transfer from Dosing Head 2 to Dosing Head 1.	Not Valid Root Cause

Validation result shows that there is no occurrence of Hard Stain while simulating the leadframe tape transfer from Dosing Head 2 to Dosing Head 1 and therefore, the team concluded that this is not a valid root cause.

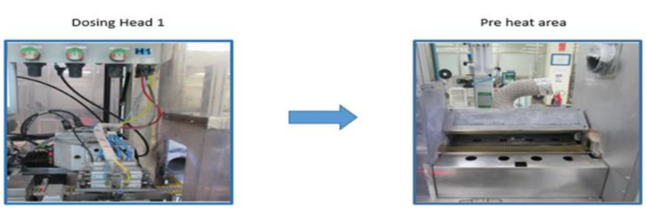


Fig. 9. Dosing Head 1 to Pre-heat process step validation

Table 4. Second Potential Root Cause Validation

Potential Root cause	Process Step	Practical Problem	Method of Validation	Results	Conclusion
2. Dosing to Pre Heating	Dosing Head 1 to Pre Heat Area	Is the Dosing Head 1 able to transfer the leadframe tape to Pre Heat Area without causing Hard Stain?	Observe the leadframe tape indexing from Dosing Head 1 to Pre Heat Area through potting and indexing simulation.	Based on observation, there is no occurrence of Hard Stain while simulating the leadframe tape transfer from Dosing Head 1 to Pre Heat Area.	Not Valid Root Cause

Validation result shows that there is no occurrence of Hard Stain while simulating the leadframe tape transfer from Dosing Head 1 to Pre-Heat Area. Therefore, the team concluded that this is not a valid root cause.

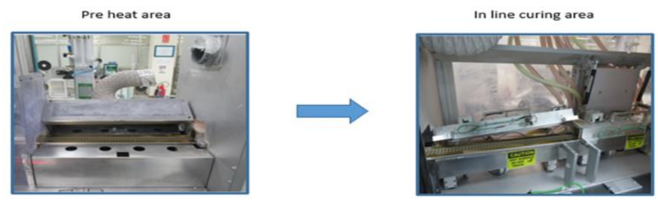


Fig. 10. Pre-heat process step validation

Table 5. Third Potential Root Cause Validation

Potential Root cause	Process Step	Practical Problem	Method of Validation	Results	Conclusion
3. Pre-Heating to Curing	Pre Heat Area To Inline Oven cure	Is the Pre Heat Area able to transfer the leadframe tape to Inline Oven Cure without causing Hard Stain?	Observe the leadframe tape indexing from Pre Heat Area To Inline Oven cure through indexing simulation.	Based on observation, there are traces of Hard Stain during leadframe tape transfer from Pre Heat Area To Inline Oven cure.	Valid Root Cause

Based on validation performed, there are traces of Hard Stain during leadframe tape transfer from Pre Heat Area to Inline Oven cure. Therefore, the team concluded that this is a valid root cause.

Fig. 11. In-line Curing Area to Output Area

Table 6. Fourth Potential Root Cause Validation

Potential Root cause	Process Step	Practical Problem	Method of Validation	Results	Conclusion
4. Curing to Output	Inline Oven cure to Output Reel	Is the Inline Cure Oven able to transfer the leadframe tape to Output Reel without causing Hard Stain?	Observe the leadframe tape indexing from Inline Oven cure to Output Reel indexing simulation.	Based on observation, there is no occurrence of Hard Stain while simulating the leadframe tape transfer from Inline Oven cure to Output Reel.	Not Valid Root Cause

Validation result shows that there is no occurrence of Hard Stain while simulating the leadframe tape transfer from In-line Curing Area to Output Area. Therefore, the team concluded that this is not a valid root cause.

Table 7. Summary of Potential Root Cause Validation

Potential Root cause	Process Step	Conclusion
1. Dosing Head Track	Dosing Head 2 to Dosing Head 1	**Not Valid Root Cause**
2. Dosing to Pre-Heating	Dosing Head 1 to Pre Heat Area	**Not Valid Root Cause**
3. Pre-Heating to Curing	Pre Heat Area To Inline Oven cure	**Valid Root Cause**
4. Curing to Output	Inline Oven cure to Output Reel	**Not Valid Root Cause**

The team summarized the Potential Root Causes Validation and verified that only the Pre-Heat Area to In-Line Cure as the process step where the Hard Stain occurs. The team closely monitors and made an in-depth analysis on how hard stain occurs during leadframe tape transfer.

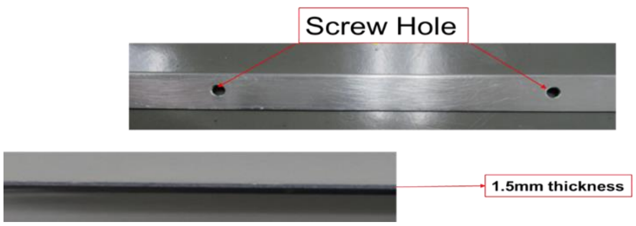


Fig. 12. OEM Tape Track Cover

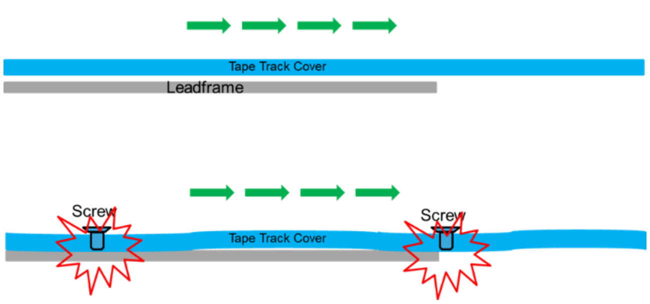


Fig. 13. Valid Root Cause illustration

It was found out that the Tape track cover was already worn out and bent. And the thickness of the Aluminum Tape Track Cover was only 1.5mm. When the screw holding the tape track cover was placed, it creates a slight bent on the cover. The slight bent causes a portion of the tape track cover to protrude thus causing Hard stain on Leadframe tape while indexing from Pre Heat to Cure area.

2.4 IMPROVE PHASE

Instead of buying from the same tape track cover from OEM. The team came up with the solution to redesign the tape track cover. The Redesigned Track Cover is made with Thicker Stainless Steel with 2.5mm thickness which is the maximum thickness that can be used without obstruction.

Table 8 Tape Track Cover Validation

Thickness	Material	Availability	Test Run	Cost	Remarks
1.5mm	Aluminum	Yes	Performed	874 USD	Existing
2 mm	Aluminum	no	-	-	Not available in supplier A and B
2.5 mm	Aluminum	no	-	-	-
3 mm	Aluminum	Yes	Not performed	-	Does not fit machine leadframe guide
1.5mm	Stainless Steel	Yes	Not performed	412 USD	Available in Supplier A
2 mm	Stainless Steel	no	-	-	Not available in supplier A and B
2.5 mm	Stainless Steel	Yes	Performed	302 USD	Available in Supplier B
3 mm	Stainless Steel	Yes	Not performed	-	Does not fit machine leadframe guide

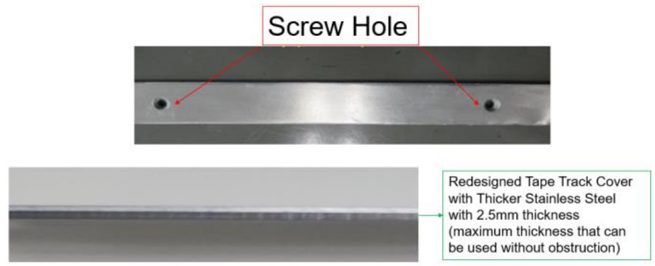


Fig. 14. Redesigned Tape Track Cover

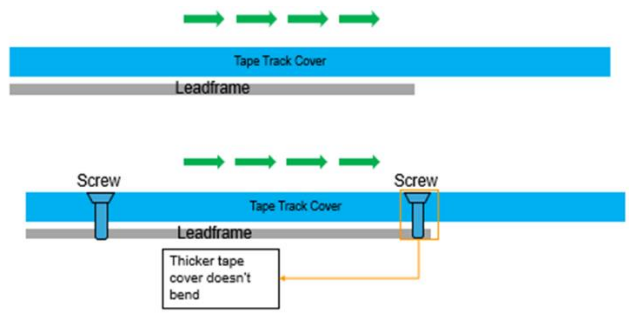


Fig. 15. Valid Root Cause illustration

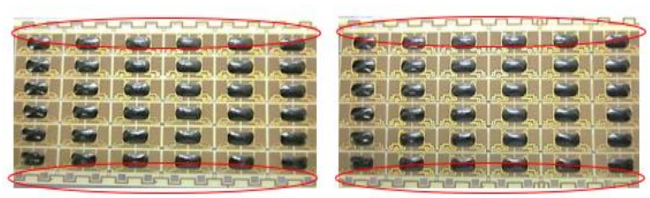


Fig. 16. Sample Micromodule tape without Hard Stain

To verify the effectiveness of Redesigned Tape Track cover, a Statistical test using 2 proportion test in potting process was performed. Focused Process step is from Pre Heat Area to Inline Oven Cure and the practical Problem statement is “Is the new tape track cover better the old design?”. Using 7005 samples for each run, the practical conclusions were observed, run results are different between designs and at better than 95% confidence level, old tape track cover will result to higher hard stain occurrence.

Table 7. Hypothesis Table

Process Function	Process Step	Practical Problem	Test Plan	Hypothesis Statement	Conclusion
Potting	Pre Heat Area To Inline Oven cure	Is the new Tape Track cover better than the Old design?	2-proportion	Ho: PNew design = POld design Ha: PNew design > POld design	P value< 0.05 Reject Ho

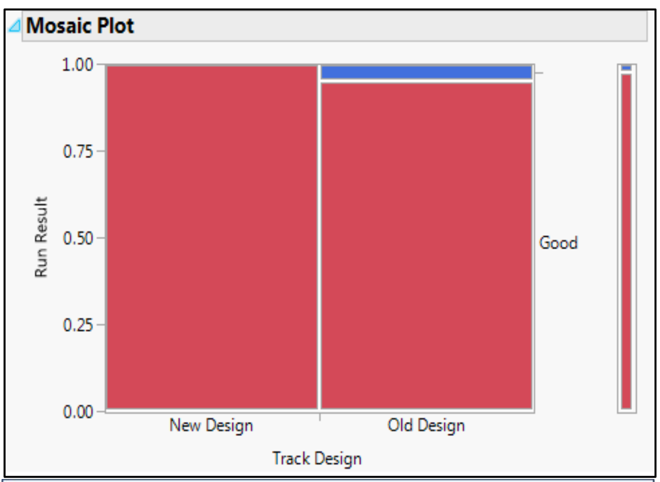
Table 8. Sample Size computation

Two Props	Inputs	Comments
α	0.05	Typically .05
β	0.10	Typically .10 or .20
P_2	0.01573	$0 < p_1 < p_2 < 1$
P_1	0.02248	$0 < p_1 < p_2 < 1$
N	7005	Sample N from each population

Table 9. Run Results

Cover Design	Run Result	Data
Old Design	Good	6662
Old Design	Hard Stain	343
New Design	Good	7005
New Design	Hard Stain	0

Table 10. Statistical Analysis



Fisher's Exact Test	Prob	Alternative Hypothesis
Left	1.0000	Prob(Run Result=Hard Stain) is greater for Tape Track Design=New Design than Old Design
Right	<.0001*	Prob(Run Result=Hard Stain) is greater for Tape Track Design=Old Design than New Design
2-Tail	<.0001*	Prob(Run Result=Hard Stain) is different across Tape Track Design

Practical Conclusion:

- ✓ Run Results are different between the designs.
- ✓ At better than 95% confidence level, Old tape track design will result to higher hard stain occurrence for micromodule devices.

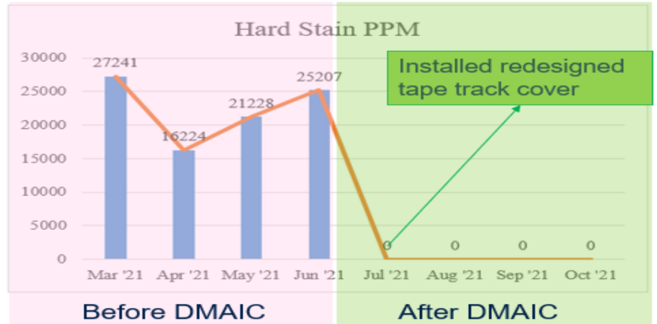


Fig. 17. Hard Stain PPM After DMAIC

The timeline for Hard Stain Reject PPM shows that Hard Stain Reject was eliminated starting July of 2021. This is with the installation of the redesigned tape track cover.

Table 11. Annualized Cost Savings

Input Volume (K)	1,244	1,558	1,947	3,684	2,077	1,086	1,005	484	1,849	2,668	3,097	2,262	22,962
Defect rate (%)													
Baseline	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	
Actual/Target	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	
Improvement	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	2.2477%	
Scrap qty reduced (K)	27.97	35.02	43.76	82.80	46.68	24.42	22.60	10.88	41.57	59.97	69.61	50.84	516
Device Cost ($)	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	
Savings (K$)													
Monthly	1.66	2.08	2.60	4.92	2.78	1.45	1.34	0.65	2.47	3.57	4.14	3.02	30.69
Cumulative	1.66	3.75	6.35	11.27	14.05	15.50	16.84	17.49	19.96	23.53	27.66	30.69	

RESPONSIBILITY MATRIX	IE	Project Owner
CCRP Release #	n/a	I Beltran
Actual Savings (K$)	30.69	

30.69K IE Certified

The IE Certified Annualized cost saving from Sep 2021 to Aug 2022 was calculated at 30.69KUSD for all Micromodule devices.

2.5 CONTROL PHASE

To sustain the improvements, applicable documents and systems were updated. Then a successful deployment to the shopfloor personnel followed by a preventive maintenance schedule to ensure all activities were executed according to plan. Table 12 shows the summary of the documents and systems that have been updated.

Table 12. Documentation

Item	Action Item	Due Date	Responsible	Doc # / Rev	Remarks
1	PCMS - To document the design change for tape track cover for Coco3	WWK2137	Irish Jan Beltran	PTM_CAL_060293	Done
2	DMS - To create Material Purchasing Specification (MPS) and upload to DMS	WWK2132	Irish Jan Beltran	DM00639530	Done
3	MRB - To document Nonstandard Lot used for Line Stressing	WWK2127	Bernard Zamora	P1C7-FW2-191115-5527	Done

3.0 CONCLUSION

After installing the redesigned tape track cover, the following conclusions were obtained:

- There is a significant difference between the old and new tape track cover design
- 2-Proportion Test results states that Old tape track design will result to higher hard stain occurrence

Micromodule devices Hard Stain PPM was reduced from 22477 PPM to zero PPM before the start of Q2 '21.

3.0 RECOMMENDATIONS

It is recommended to fan-out these learnings to other machines. Future studies are recommended for plans to zero-out the occurrences of hard stain.

4.0 ACKNOWLEDGMENT

We would like to thank Mr. Leonel Jay Manuel and all the Integrated Lines Team for their sincerest appreciation and full extended support.

To our colleagues for providing us with the tools necessary to complete this project.

To our beloved family, friends, and colleagues who wholeheartedly supported them to make this project fruitful and successful.

5.0 REFERENCES

1. Mhuelbauer CME 301D Potting System Maintenance Manual

6.0 ABOUT THE AUTHORS

Irish Jan T. Beltran received his engineering degree (B.S. Electronics and Communications Engineering) in Manuel S. Enverga University Foundation in Lucena City. He has 20 years of experience in Semiconductor Manufacturing focusing on Equipment Line sustaining, Preventive Maintenance and Project Management. He is currently a Sr. Equipment Engineer in Assembly Integrated Lines at STMicroelectronics, Inc.

Eric G. Espino is a Sr. Equipment Test Engineer in the Integrated Lines. He earned his Engineering degree in BS Electronics and Communications Engineering from the Computronix College Dagupan. He is a certified Six-Sigma Green Belt practitioner currently employed at STMicroelectronics, Inc. He is currently in the Semiconductor Industry for 22 years.

Bernard R. Zamora graduated B.S. in Industrial Engineering at University of Batangas and graduate of B.S. in Information technology at Laguna State Polytechnic University. He has 15 years of experience in Semiconductor and Solar manufacturing focusing on Process Engineering. He is currently a Sr. Process Engineering Technician at Finish Integrated Lines at STMicroelectronics, Inc.