PREDICTIVE TESTING FOR LONGEVITY: EXTENDING SHELF LIFE OF PROTECTIVE LINERS THROUGH ACCELERATED AGING

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ABSTRACT

This STMicroelectronics Calamba project aims to evaluate the feasibility of extending the shelf-life of B201 Protective liners to 36 months to meet the growing demand from Customer.

The shelf life of protective liners is a critical factor in ensuring their effectiveness and reliability across various industrial applications, including automotive, construction, and packaging. This study explores strategies for extending the shelf life of protective liners through accelerated aging tests.

By simulating long-term environmental exposure in a controlled, accelerated manner, these tests provide valuable insights into the material degradation processes and help predict the lifespan of liners under real-world conditions. The research focuses on key factors influencing shelf life, such as material composition, environmental conditions, and storage practices. Findings suggest that selecting durable materials, optimizing storage environments, and employing rigorous quality control measures can significantly enhance the longevity of protective liners.

The evaluation involves a detailed analysis of the B201 Protective liner's material properties, focusing on enhancing durability and longevity. Techniques such as involves a thorough inspection of the raw materials to identify any signs of degradation or compromised performance over aged conditions are tested. Accelerated aging experiments are conducted to simulate extended materials shelf-life.

Initial findings suggest that with the application of targeted preservation methods, the B201 liners can achieve the desired shelf-life extension while maintaining quality standards.
Extending the shelf-life of B201 liners is achievable and essential for supporting Customer care demand, ensuring product reliability and supply chain efficiency.

Additionally, the study highlights the importance of integrating accelerated aging tests into the product development cycle to identify potential weaknesses and improve material formulations. This approach not only ensures product reliability but also contributes to cost savings and environmental sustainability by reducing waste and the need for frequent replacements.

1. 0 INTRODUCTION

As the liner materials have surpassed their recommended shelf-life, it is crucial to evaluate their current condition and determine their suitability for continued use. The introduction outlines the need for a comprehensive assessment of the expired liners, identifying potential risks and degradation that may impact manufacturing efficiency and compliance with industry standards. By understanding the challenges posed by expired materials, we can develop strategic solutions to mitigate risks, ensure quality assurance, and optimize resource management.

Due to B201 expired liner materials, ST Calamba decrease in demand for B201 from Customer and outlines the strategic approach to align future supply with the projected Customer Care demand of 1.8 million units for 2025. The unexpected demand drop presents challenges in maintaining efficient inventory and production planning. With the next loading scheduled between March and April, it is imperative to reassess our supply chain strategies to ensure readiness for the anticipated demand. Also taking into account the MOQ from raw material supplier which will incur additional cost.

The challenge is need for a thorough examination of the materials to identify any degradation or loss of performance that may affect product quality and compliance with industry standards. By understanding the implications of the extended shelf life, we can make informed decisions regarding reconditioning, replacement, or continued use to maintain operational efficiency and product integrity.

Expired Liner Material cost high impact and significant cost implications associated with expired materials and their impact on operational efficiency and financial performance. As materials surpass their shelf life, they may lead to increased waste, reduced product quality, and potential disruptions in the production process.

To avoid high-cost problem, this project addresses these challenges to minimize financial losses and maintain supply chain integrity. By analyzing the factors contributing to high costs, such as disposal expenses and the need for replacement materials, we can develop strategies to mitigate risks and optimize resource management. Understanding the cost impact of expired materials is crucial for making informed decisions that support long-term sustainability and profitability.

1.1 Protective Liner/Film

Protective liners are materials used to safeguard surfaces or products from damage, contamination, or wear. They are commonly used in various industries, including manufacturing, semiconductor, automotive, construction, packaging, and electronics. In Figure 1 shows the 3M Protective Liner material used to protect B201 Optical device lens during High temperature processes.

3M Heat Resistive Polyimide Tape is a heat resistive polyimide process tape with electrostatic discharge (ESD) properties on the polyimide backing layer. The adhesive is a thermally cross-linkable acrylic copolymer that provides good initial adhesion and has less adhesion build-up even after high temperature.

Figure. 1. B201 Module with Protective Liner

1.2 Expired Liner Materials

Expired liner materials refer to those that have surpassed their recommended shelf life, typically set by manufacturers to ensure optimal performance and reliability. For B201 Protective liners, expired materials can affect the peel test performance once it reaches the guaranteed shelf life, referring to below Figure. 1.

Over time, expired liners may lose their structural integrity, leading to compromised performance. Using expired materials can result in product defects or failures, impacting customer satisfaction. Managing expired materials can incur additional costs, including disposal, replacement, and potential production delays.

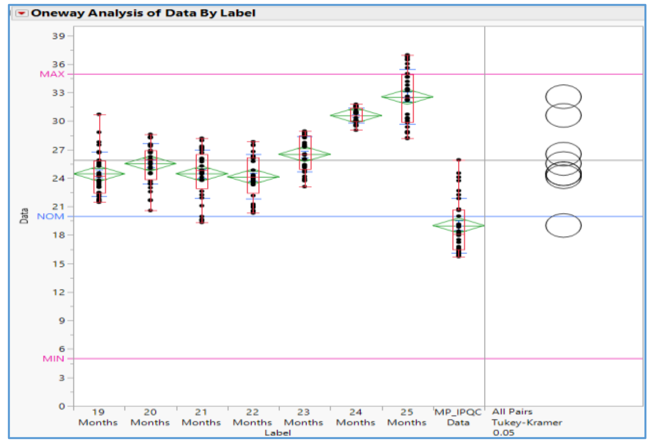

Figure. 2. Anova plot for B201 Expired Liner Materials more than 24 months

1.3 Liner Attach Process

A liner attach machine is a specialized piece of equipment designed to automate the process of attaching liners to various surfaces or products. These machines are commonly used in manufacturing and packaging industries to improve efficiency, consistency, and precision in liner application.

Figure. 3. MIT LB800 Final Liner Attach Machine

2. 0 REVIEW OF RELATED WORK

The Arrhenius equation is commonly used to relate the rate of aging to temperature. It assumes that the chemical reactions responsible for aging follow a predictable pattern.

The Arrhenius-Peck relationship is a model used in accelerated aging tests to predict the life of a product under different temperature and humidity conditions. This model combines the Arrhenius equation (for temperature acceleration) with the Peck model (for humidity acceleration) to calculate an overall acceleration factor. This factor helps determine how much faster a product will age under accelerated test conditions compared to real-world use conditions.

For this project, Calculated lifetime is 1.13-1.14 years using the Arrhenius-Peck Model (considering no observed failure at 65 deg C/90% RH at 400 hrs and activation energy used is polymer thermal aging = 0.1 – 0.23eV) which is also aligned with Customer specification in Table 1 below.

Table. 1. Core Tech Optical Sensing Commodity Quality Requirements

Accelerated storage temperature (°C)	40	65	85
Accelerated storage temperature (K)	313.15	338.15	358.15
Number of hours in accelerated storage tests	Number of years that the accelerated storage tests are simulating		
100	0.04	0.29	1.10
200	0.08	0.59	2.19
300	0.13	0.88	3.29
400	0.17	1.18	4.38
500	0.21	1.47	5.48
600	0.25	1.76	6.58
700	0.29	2.06	7.67
800	0.34	2.35	8.77
900	0.38	2.64	9.86
1000	0.42	2.94	10.96
1100	0.46	3.23	12.06
1200	0.51	3.53	13.15

3.0 METHODOLOGY

3.1 DOE Methodology Legs

Perform Liner shelf-life extension study using ST Material Engineering Plan. Conducting a linear shelf-life extension study using the ST Material Engineering Plan involves systematically evaluating the longevity and stability of a product under specific conditions. The process begins with defining the study's objectives, such as extending the shelf life by a certain period. Key materials are selected to ensure they represent typical production batches. See Figure 4.

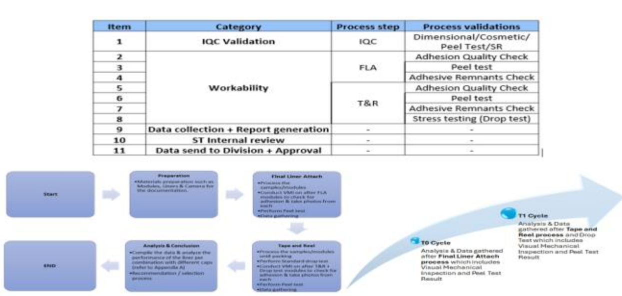

Figure. 4. DOE Methodology

3.2 Accelerated Ageing Test Methodology

Accelerated aging tests are a valuable method for predicting the shelf life of protective liners and other materials. These tests simulate the effects of time on a product by exposing it to elevated conditions such as temperature, humidity, and light, thereby accelerating the aging process. Accelerated aging tests aim to estimate the long-term effects of environmental factors on materials in a shorter time frame. This helps in predicting the shelf life and ensuring the reliability and safety of the product.

Accelerated aging tests are a powerful tool for predicting the shelf life of protective liners. By carefully designing and conducting these tests, manufacturers can ensure product reliability and extend shelf life, ultimately leading to cost savings and improved customer satisfaction. Here's a comprehensive guide on how to conduct accelerated aging tests to extend the shelf life of protective liners. See Fig. 5.

Steps for Conducting Accelerated Aging Tests

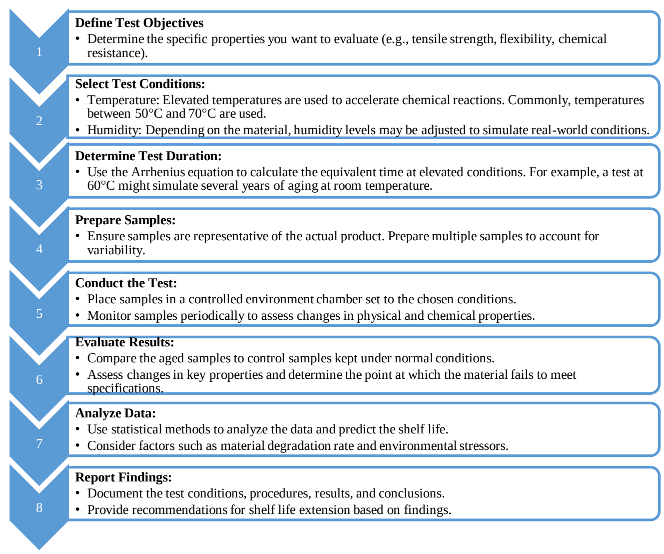

Figure. 5. Procedure on Accelerated Aging Tests

3.2.1 Evaluation of Existing Material (Normal aging) + REL at module level

- Use existing material with T0 qualification.
- Perform REL at module level - Proposal is to use Customer Spec "CoreTech Optical Sensing Commodity Quality Requirements (099-28157-B)" for accelerated aging. Bake at 65 deg C / 90% RH for 400 hrs. Equivalent to 1.18 Year shelf life
- Perform Shipping Combo in reference to 099-28157-B
- The test will provide assessment for 12 months condition at Module level.

Table. 2. Evaluation of Existing Material Project timing

	Activity	Projected Timing - WK 2	3	4	5	6	7	8	9	10
1	REL Test - Accelerated aging at module level for the available material (25th month old with passing T0 Evaluation) Proposal - Use Customer Spec - CoreTech Optical Sensing Commodity Quality Requirements (099-28157-B) for accelerated aging - 65 deg C / 90% RH for 400 hrs - this is equivalent to 1.18 Year shelf life - Conduct Module level peel test before and after bake									
2	Shipping Combo - 099-28157-B									
3	Do Engineering evaluation on existing material (28th month old) – upon production usage based on loading plane to guarantee T0 usage									

3.2.2 Evaluation of Material with Accelerated aging at Raw Material level + REL at module level

- Do accelerated aging at raw material (supplier side) to consider +12 months in shelf life (= 36 months).
- Build material on baked material and ship to STC for evaluation.
- REL at module level - Proposal is to use Customer Spec "CoreTech Optical Sensing Commodity Quality Requirements (099-28157-B)" for accelerated aging. Bake at 65 deg C / 90% RH for 400 hrs. Equivalent to 1.18 Year shelf life
- Perform Shipping Combo - The test will provide assessment for 36 months old material at T0 + 12 months condition at Module level.

Table. 3. Evaluation of Material with Accelerated aging at Raw Material level + Rel at module level Project timing

	Activity		Projected Timing - WK 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	CCL - Raw material Accelerated Aging for 4 weeks @ 60 deg C, this is equivalent to 1 year storage at 25deg C. - Supplier to conduct Peel test evaluation before and after accelerated aging - Do accelerated aging on raw material good to produce 1 reel = 10k units.	Leg 1 2 weeks condition			Jan-20 completion													
		Leg 2 4 weeks condition				CNY - Plant shut down Jan-28 to Feb-8		Feb-10 start										
2	CCL Production Sample Build (1 reel from accelerated aging material) Ship to Calamba																	
3	STC Qual (IQC - Dale / Engineering Qual - Reinadd)																	
4	REL Test - Accelerated test at module level Proposal - Use Customer Spec - CoreTech Optical Sensing Commodity Quality Requirements (099-28157-B) for accelerated aging - 65 deg C / 90% RH for 400 hrs - this is equivalent to 1.18 Year shelf life - Conduct Module level peel test before and after bake																	
5	Shipping Combo - 099-28157-B																	

3.2.3 Evaluation Plan and Qualification Criteria

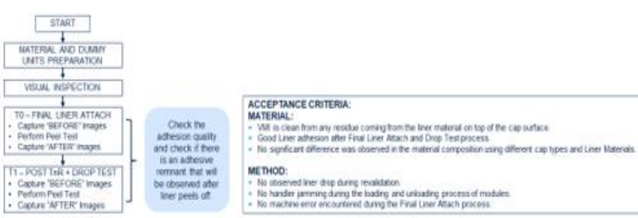

Figure. 6. DOE Plan

Table. 4. Qualification Criteria

Step	Cycle	Station	Samples	Before Peel test VMI criteria	Peel Test Criteria	After Peel test VMI criteria	TOF-SIMS Criteria
1	T0	FLA	32u	Pass on liner adhesion check (No sign of bulging or potential liner drop)	Peel Force response must be within specifications	No visible adhesive remnants (low power microscope)	N/A
2	T2	Tape & Reel + Drop Test	32u	Pass on liner adhesion check (No sign of bulging or potential liner drop)	Peel Force response must be within specifications	No visible adhesive remnants (low power microscope)	N/A

Materials and methods for the evaluation plan and qualification criteria from T0 cycle – Final Liner Attach process up to T2 cycle – Tape and Reel + Drop Test.

3.2.4 Module Reliability Test Requirement for Shipping Combo

Table. 5. Module Reliability Test Requirement

Stress Name [Abbreviation] (Reference)	Test Parameters	Spec	Failure Mode	Allowable Fail Rate (Design)	Allowable Fail Rate (Config)
Package Vibration (080-5443)	• UUT's must be placed in shipping container during stress application • Vibration profile: Truck followed by Air • Orientation: X, Y, Z • Duration: 30min per axis per vibration spectrum (total 180min) • Read points: after truck, after air	180 min	All failure modes called out per ERS	0F/90	0F/22
Package Storage (080-1653)	• UUT's must be placed in shipping container during stress application • Temp and humidity profile: 3 cycles extreme, followed by 10 cycles normal • Read points: after extreme profile (3 cycles), after normal profile (10 cycles)	10 cycles	All failure modes called out per ERS	0F/90	0F/22
Package Drop (062-0087)	• UUT's must be placed in shipping container during stress application • Impact surface: 0.75in thick particle board, durometer 75±5 durometer shore D • Drop order/orientation: refer to section 8.03.3 in 062-0087 • Drop height: refer to section 8.03.4 in 062-0087 • Read points: after 6th, 10th drop	10 drops	All failure modes called out per ERS	0F/90	0F/22

Stress Test or Reliability Test requirement for shipping combo such as:

- Package Vibration for 10 minutes
- 3 cycles of extremes temperature and humidity profile, followed by 10 normal cycles for Package Storage.
- 10X drops of Package Drop Test.

4.0 RESULTS AND DISCUSSION

4.1 IQC Test Data of Expired Liner

ST CALAMBA IQC / INSPECTION REPORT

MATERIAL CODE	SUPPLIER / FAB / EWS	SUPPLIER SITE	MATERIAL DESCRIPTION		IQC SPEC.# / REV.		DRAWING # / REV.	
55X20072	CCL	CHINA	8201 LINER		DM00319257	5.0	DM00824029	4.0
GR No.	INVOICE NO.	INVOICE QTY.	SUPPLIER LOT NO.	MATERIAL TYPE			DATE RECEIVED	DATE INSPECTION COMPLETED
N/A	WM2024121301	1 ROLL	2925620	8201 LINER			20-Dec-2024	26-Dec-2024
C of C Available	DMR No. (as Applicable)		REMARKS		INSPECTOR		FINAL DISPOSITION (ACCEPT/REJECT)	
N/A	N/A	N/A	VISUAL: PASSED DIMENSION: PASSED PEEL TEST: PASSED		295342		ACCEPT	
PURPOSE								

1. Dimensional Inspection: **ACCEPTED**

IQC Inspection Items	Tape width	CD1_Liner Pitch	CD2	A	B	C	D	E	F	G
	4	5	6	7	8	9	10	11	12	13
Nominal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tolerance (-)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tolerance (+)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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USL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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RESULT	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
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CPK	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

2. Mechanical Inspection:Peel Test/Surface Resistance Check

IQC Inspection Items	MaxPeak @ Peel interval	MinForce @ Peel interval	AvgForce @ Peel interval	Converted Test results	Tolerance
Spec.					
LSL					
USL					
1	3.09	2.82	2.98	1.192	
2	3.08	2.57	2.72	1.088	
3	2.83	2.59	2.66	1.064	
4	3.04	2.64	2.88	1.152	
5	2.79	2.56	2.67	1.068	
MIN	3.09	2.82	2.98	1.192	
MAX	2.79	2.56	2.66	1.064	
Mean	2.966	2.636	2.782	1.113	0.9~2.3N/cm
SDEV	0.144	0.107	0.141	0.057	

SURFACE RESISTANCE CHECK	
TOP	BOTTOM
1.55×10^9	3.60×10^9
1.44×10^9	5.54×10^9
8.97×10^8	3.66×10^9
8.66×10^8	4.55×10^9
8.32×10^8	3.51×10^9

Figure. 7. Liner IQC Data of Expired Materials

- Dimensional and Visual Cosmetic Inspection Passed
- Mechanical peel test at coupon level Passed
- Surface Resistance Measurement Passed

4.2 Supplier Accelerated Aging Test Result

Table. 6 & 7. Stokvis and CCL Accelerated Aging Test Result

Supplier: **STOKVIS**

Raw Material	3M 7418E
3M Batch No	02Y22Y19
Raw Mfg Date	12/5/2022
Material Expired date	12/4/2024

Activity:	Accelerated Aging @ 4 weeks (672 hrs)
Age of material from time of test	26 months
Peel Test	Strip sample @ 25mm*300mm using SUS plate

Peel test @ T0

Lot No. :	02Y22Y19	Report Date:	2025. 1. 14
Part No.	3M7418E	Sample Type	tape
Supplier	3M	Material Width	25mm
Tester	LWL	Test standard	GB/T 2792
Test speed	300mm/min	Storage period	20MIN
Rolling times	3times	Weight	2KG
Test No.	section-max load (N)	section-min load (N)	section-average load (N)
3M7418E-1	3.54	3.41	3.46
3M7418E-2	3.33	3.2	3.26
3M7418E-3	3.63	2.81	3.51
Max	3.63	3.41	3.51
Min	3.33	2.81	3.26
Average	3.5	3.14	3.41
Criterion:0.9-2.3N/cm	TEST Result 3.41N/25mm=1.364N/cm	Result	1.36N/cm

Peel test after Accelerated Aging

Lot No. :02Y22Y19 Baking		Report Date:	2025. 02. 12
Part No.	3M7418E	Sample Type	tape
Supplier	3M	Material Width	25mm
Tester	LWL	Test standard	GB/T 2792
Test speed	300mm/min	Storage period	65℃-4weeks
Rolling times	3times	Weight	2KG
Test No.	section-max load (N)	section-min load (N)	section-average load (N)
3M7418E-1	3.53	3.26	3.37
3M7418E-2	3.47	3.34	3.43
3M7418E-3	3.5	2.84	3.23
Max	3.53	3.34	3.43
Min	3.47	2.84	3.23
Average	3.5	3.15	3.34
Criterion:0.9-2.3N/cm	TEST Result 3.34N/25mm=1.34N/cm	Result	1.34N/cm
Remark:No glue residue on SUS plate			
Test methed: 1reel 3M7418E material→Baking 65°C for 4weeks (672hrs) →slitting on Strip test 25mm*300mm 3pcs sample pasted on SUS plate→20Min→ Peel test			

Conclusion: Peel test after aging is at 1.34N/cm passing the spec criteria of 0.9-2.3N/cm.

Supplier: **CCL**

Raw Material	3M 7418E
3M Batch No	01X22X16
Raw Mfg Date	11/2/2022
Material Expired date	11/1/2024

Activity:	Accelerated Aging @ 4 weeks (672 hrs)
Age of material from time of test	27 months
Peel Test	Strip sample @ 25mm*300mm using SUS plate

Peel test @ T0

No	最大剥离强度max peeling strength (N/cm)	最小剥 离强度 min	平均剥离强度 Average peeling strength (N/cm)
1	1.704	1.616	1.657
2	1.647	1.56	1.605
3	1.654	1.525	1.583
4	1.647	1.542	1.576
5	1.6876	1.536	1.69
最大值MAX	1.704	1.616	1.69
最小值MIN	1.647	1.525	1.576
平均值Average	1.66792	1.5558	1.6222

Peel test after Accelerated Aging

No.	最大剥离强度max peeling strength	最小剥离强度min peeling strength	平均剥离强度Average peeling strength
1	(N/cm)	(N/cm)	(N/cm)
2	1.605	1.517	1.55
3	1.315	1.098	1.141
4	1.697	1.635	1.658
5	1.884	1.619	1.734
最大值MAX	1.895	1.815	1.837
最小值MIN	1.315	1.098	1.141
平均值AVERAGE	1.679	1.537	1.584

Conclusion: Peel test after aging is at 1.58N/cm passing the spec criteria of 0.9-2.3N/cm.

Summary:
Stokvis: 26-month-old material
Passed Peel test after 4 weeks accelerated aging.

- T0: 1.36N/cm
- After aging: 1.34N/cm
- Spec: 0.9-2.3N/cm

CCL: 27-month-old material
Passed Peel test after 4 weeks accelerated aging.

- T0: 1.62N/cm
- After aging: 1.58N/cm
- Spec: 0.9-2.3N/cm

Raw Material supplier advice - accelerated aging is equivalent to +12 months. With passing peel test data, 3M B201 liner material is guaranteed for additional 1 year from current material age.

4.3 Peel Force Summary Data

Table. 8. Peel Test Results

PRODUCT	CAP TYPE	CONVERTER	MATERIAL	SAMPLE	PROCESS CHECK	MIN Peel Force (g-f)	MAX Peel Force (g-f)	MEAN Peel Force (g-f)	Std Dev Peel Force (g-f)	CPK Initial Limit
B201 Atlantis	IGT	CCL	3M7418E	32	T0 (Post FLA)	21.32	28.76	24.93	2.478	1.353
				32	T1 (Post Tnr + Drop Test)	24.89	29.99	27.51	1.823	1.368
	XPT	CCL	3M7418E	32	T0 (Post FLA)	23.03	28.17	24.85	1.449	2.333
				32	T1 (Post Tnr + Drop Test)	27.21	30.93	29.15	1.102	1.438

Based on the Summary of Peel test result, both IGT and XPT Cap PASSED Target CPK (>1.33) and ALL Peel test data are within specs tolerance subjected at different cycles (T0 vs T1) using CCL_3M7418E material.

4.4 Variability Chart for Peel Force

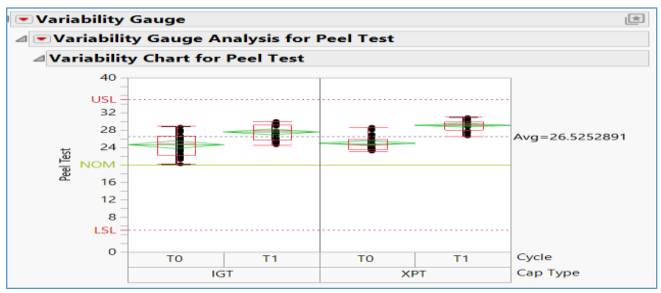


Figure. 8. Variability Chart for Peel Force (gF):

- Both Cap (IGT and XPT) using 3M7418E Liner shows stable readings at different cycles and PASSED on defined specification limits from 5 to 35 gF but slightly above nominal target of 20gf (Avg=26.52gf).
- Liner material 3M7418E on both IGT and XPT cap shows stable performance and normal adhesion response from T0 to T1 cycles.

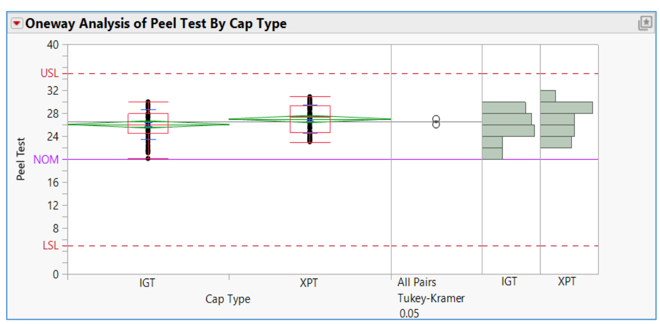


Figure. 9. One way analysis for Peel Force (gF):

Correlation data from interaction plots showed that mean from liner material 3M7418E on both cap (IGT and XPT) is BOTH within Peel Test specs limit and almost have the same performance. Both CAP type is correlated based on Tukey-Kramer analysis.

4.5 Adhesion Quality Inspection and Remnant Inspection

Table. 9. Adhesion Quality Inspection

SAMPLE IMAGES after FINAL LINER ATTACH		RESULTS
IGIANT		Adhesion quality PASSED after Final Liner Attach
XPT		Adhesion quality PASSED after Final Liner Attach

Table. 10. Adhesion Remnant Inspection

ADHESION QUALITY INSPECTION - AFTER PEEL OFF						
CCL						
PRODUCT	CAP TYPE	CONVERTER	MATERIAL	T0 (Post FLA)	T1 (Post TnR + Drop Test)	REMARKS
B201 Atlantis	IGIANT	CCL	3M7418E			There is no adhesive remnant observed after the liner peel off – PASSED Sample Qty: 32 samples/cycle/cap
	XPT	CCL	3M7418E			There is no adhesive remnant observed after the liner peel off – PASSED Sample Qty: 32 samples/cycle/cap

Both Cap (IGT and XPT) using 3M7418E Liner shows passed adhesion quality inspection check and adhesion remnant inspection on different test stages after FLA, Tape and Reel and Drop Test. Refer to Table 9 and 10.

4.6 Peel Test Response after Reliability Test

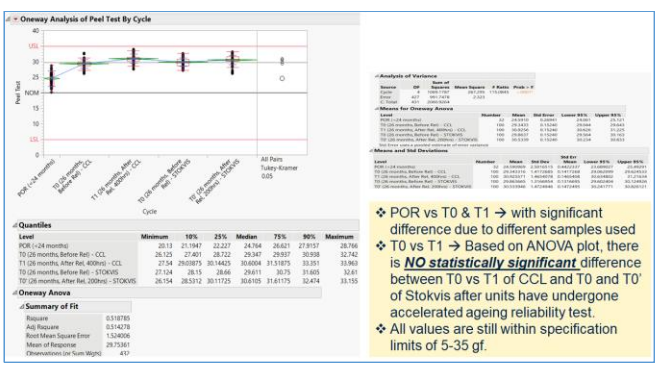


Figure. 10. REL Test Peel Test Results

- T0 vs T1, based on ANOVA plot, there is NO statistically significant difference between T0 vs T1 of CCL and T0 and T1 of Stokvis after units have undergone accelerated ageing reliability test.
- All values are still within specification limit of 5-35gf.

4.7 Module Sticky Test after Reliability Test

Table. 11. Module Sticky Test Results

CTST (Cover Tape Sticky Test) and USCT (Unit Stuck on Carrier Tape) Checking							
CCL							
PRODUCT	CAP TYPE	CONVERTER	MATERIAL	100% Visual Mechanical Inspection	CTST (Cover Tape Sticky Test)	USCT (Unit Stuck on Carrier Tape)	REMARKS
B201 Atlantis	IGIANT	CCL	3M7418E				• No modules sticking on the cover tape - PASSED • No modules stuck on carrier tape – PASSED • Sample Qty: 2 strips/50 pcs/cap
	XPT	CCL	3M7418E				• No modules sticking on the cover tape - PASSED • No modules stuck on carrier tape – PASSED • Sample Qty: 2 strips/50 pcs/cap

On Both IGT and XPT, Cover Tape Sticky Test and Unit Stuck on Carrier Tape Test results – PASSED which shows no ESD build up after REL

- No modules sticking on cover tape.
- No modules stuck on carrier tape.

4.8 Electrical/Functional Testing and Drift Analysis After Reliability Test

4.8.1 Module Accelerated Test

Table. 12. Accelerated Test Results

Test Parameters	T0 (Before Rel)	T1 (After Rel)	Remarks
Electrical/Functional Testing	 90/90 units Passed	 90/90 units Passed	All sample units passed (Bin 1)
Drift Analysis	Passing defined limits on Test parameters	Passing defined limits on Test parameters	No observed drifting on critical parameters (as per Reliability Test Specifications) ATLANTIS_LIV-SPEA_T0_vs_T1.pptx

All units passed (BIN 1) at Electrical/Functioning Test.
No observed drifting on critical parameters and passing defined limits on test parameters based on reliability test specifications.

4.8.2 LIV Test

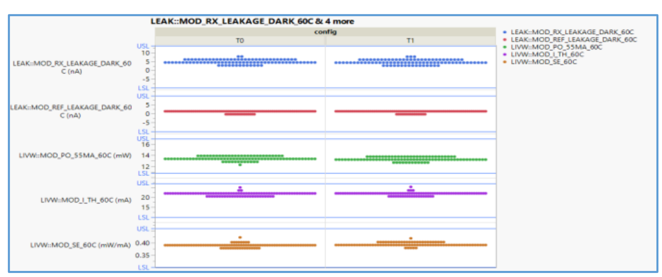


Figure. 11. LIV Test Plot

- All units passed (BIN 1) at Electrical/Functional/Optical Test at LIV Test stage.
- Statistical plot shows all units passed (BIN 1) after SPEA Drift test and no drift from T0 to T1 After Rel

4.8.3 SPEA Test

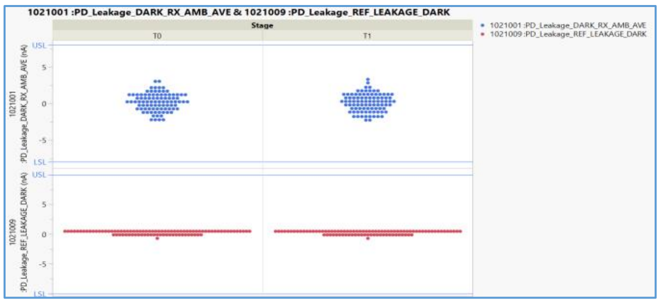
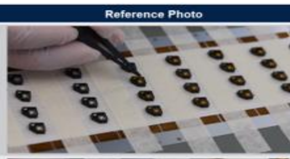


Figure. 12. SPEA Test Plot

- All units passed (BIN 1) at Electrical/Functional/Optical Test at SPEA Final Module Test stage.
- Statistical plot shows all units passed (BIN 1) after SPEA Drift test and no drift from T0 to T1 After Rel

4.9 Manual Liner Removal Simulation on T0 and T1 Samples (Replicate End customer process)

Table. 13. T0 and T1 Manual Liner Removal Result

Condition	Reference Photo	Result
T0 – Before Rel (After Liner attach)		20/20 samples passed and successfully removed liner manually (see also video as separately shared)
T1 – Post Reliability		20/20 samples passed and successfully removed liner manually (see also video as separately shared)

Procedure:

1. Sample preparation: Place samples with liner on adhesive tape to simulate condition with FATP or Final Assembly and Test Package (module is already soldered within the system).
2. using an ESD plastic tweezer, manually peel-off liner on B201 modules starting from the tab toward the opposite side.
3. Conduct visual inspection for adhesive residue (magnification: 30X).

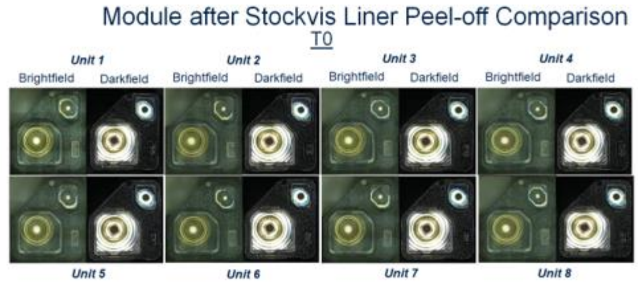


Figure. 13. Manual Liner Removal FA Result (100% Optical Inspection)

Result:
No adhesive residue observed on the cap surface on all inspected samples during 100% VMI.

4.10 Control Run (CR) Samples at Customer level

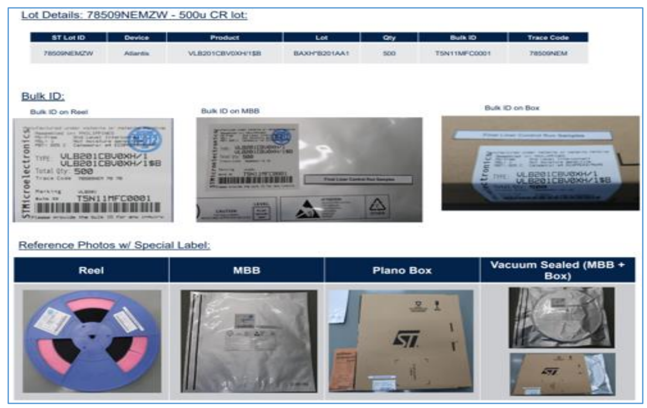


Figure. 14. Control Run Samples

ST Calamba to prepare Control run samples to FATP (1 Reel/500 units) using the aged Stokvis/CCL material to check the response during manual liner removal process at customer side.

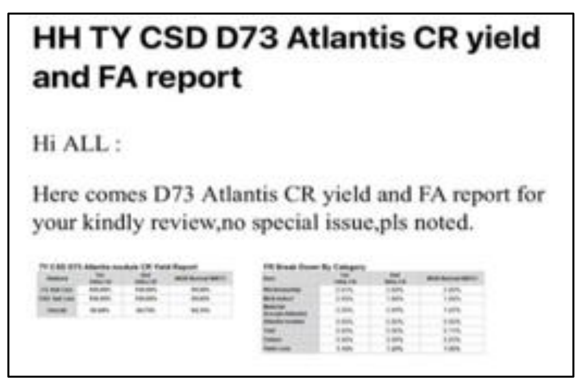


Figure. 15. FATP Result

No issues encountered at FATP downstream customer during processing of CR samples as confirmed in Figure. 15.

4.11 Project Cost Savings (Liner Raw Materials Cost Impact):

Existing Liner Raw material at supplier already reached 24 months old shelf life

- 6.5Mpcs equivalent at CCL
- 4.3Mpcs equivalent at Stokvis

Liner Raw Material cost impact:

- 85.2K$ on CCL
- 73.6K$ on Stokvis

Note: In case of Fresh material build, MOQ requirement is 26 rolls equivalent to 6.5Mpcs.

Total Cost Savings: 161.5K$

5.0 CONCLUSION

The successful implementation of accelerated aging tests for protective liners has proven to be an invaluable tool in predicting and extending their shelf life. Through careful simulation of environmental conditions such as temperature, humidity, these tests provide critical insights into the long-term performance and durability of liner materials. The study confirms that accelerated aging tests can effectively identify potential degradation pathways and material weaknesses, allowing for targeted improvements in material formulations and manufacturing processes.

Key findings indicate that selecting materials with inherent resistance to environmental stressors, optimizing storage conditions, and implementing robust quality control measures are essential strategies for enhancing the longevity of protective liners. By accurately predicting the lifespan of liners, manufacturers can ensure product reliability, reduce waste, and achieve significant cost savings.

Furthermore, the integration of accelerated aging tests into the product development cycle enables proactive identification of potential issues, facilitating continuous improvement and innovation. This approach not only supports the development of high-quality, durable liners but also contributes to sustainability efforts by minimizing the frequency of replacements and reducing environmental impact. Overall, the success of accelerated aging tests underscores their importance as a standard practice in the development and quality assurance of protective liners.

With the result and based on the findings after different simulations and experiments have been performed, it was proven that shelf-life extension of Protective liner material passed Engineering evaluation both for Raw Material Accelerated ageing test and Module Reliability test which guarantees additional 12 months from the expiration date.

With the provision of the extended Shelf life of Protective liners through Accelerated Aging and Predictive testing, we have successfully consumed expired stocks without any customer quality issues and achieved significant cost savings, manufacturing sustainability and significant impact on operational efficiency and financial performance.

6.0 RECOMMENDATIONS

The current study can be interpreted as a successful predictive testing solution by extending the Shelf life up to its maximum life span by using accelerated aging test. With the positive result of the study, STMicroelectronics Calamba recommends extending the shelf life of B201 Liner to 36 months to support Customer demand and we can implement this change and consume for mass production and can also be sustained to other future devices using the same liner material.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

1. **MIT Semiconductor Pte Ltd**
   https://mit.com.sg/consumer/

2. **3M™ Heat Resistive Polyimide Tape** 7418E
Electronics Materials Solutions Division
www.3M.com/electronics

3. **DESIGN for RELIABILITY Concepts in Accelerated Testing**
DfRSoft.com

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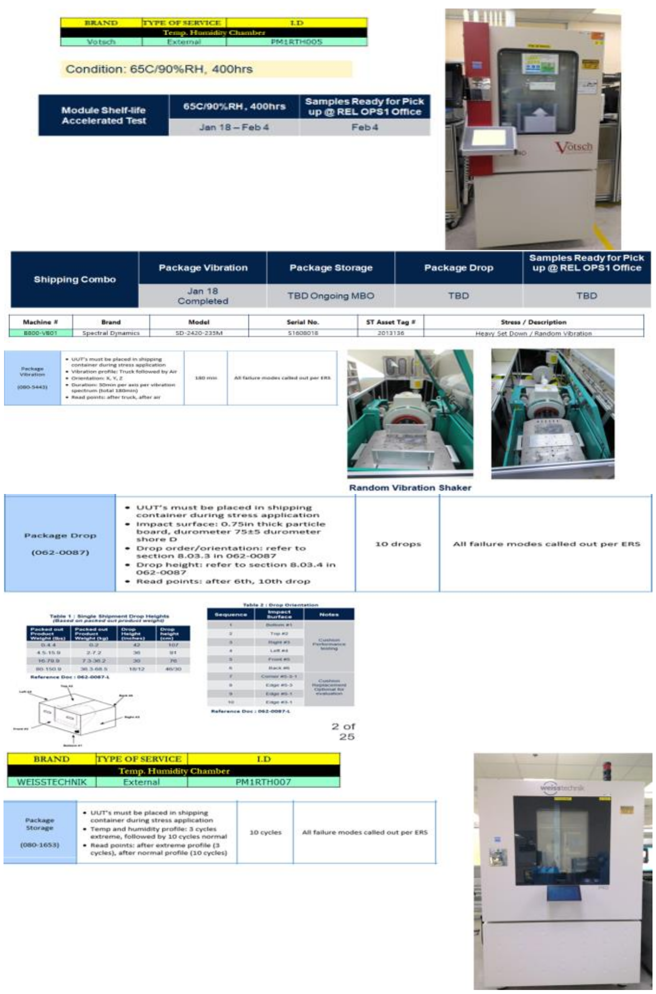
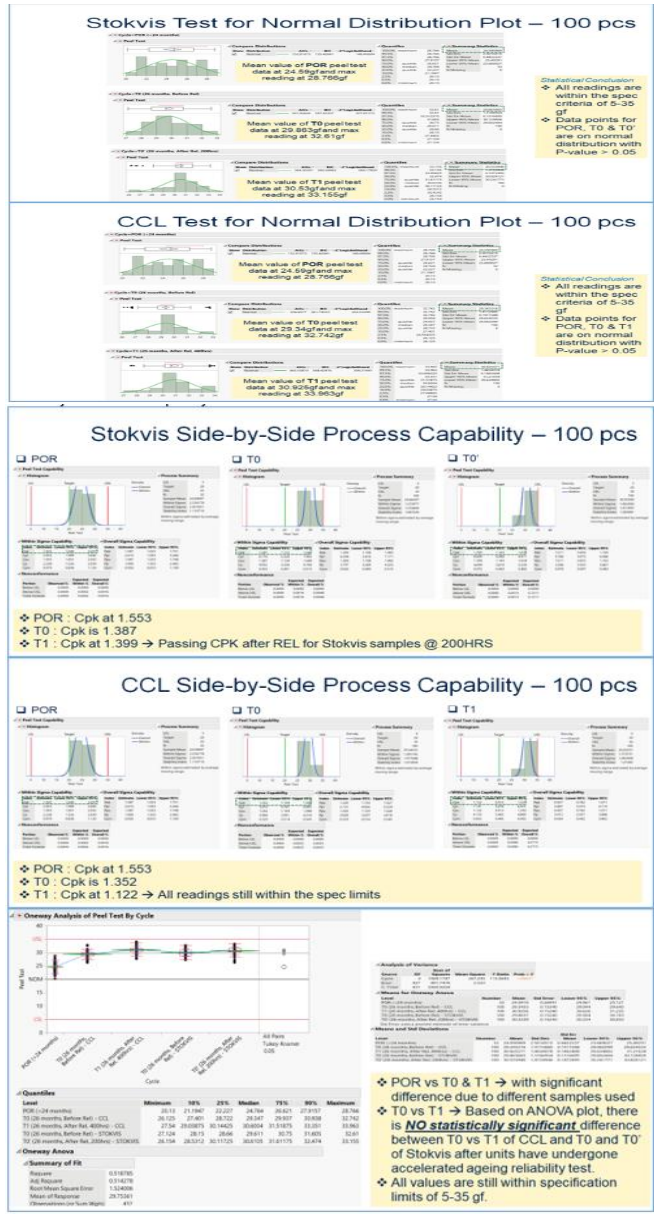
10.0 APPENDIX

Appendix A – Reliability Test Equipment and Specifications



Appendix B – Peel Test Response after REL Testing



Appendix C – Liner Adhesion Test after REL Testing