INNOVATION AND INCLUSION OF POU DESICCANT DRYER TECHNOLOGY TO ELIMINATE PAD DISCOLORATION CAUSED BY INTERACTION OF CDA MOISTURE TO METALLIC LGA PADS

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ABSTRACT

In 2023 during the new product qualification phase and start of engineering run of BXXX Project, a Proximity Optical sensor, Pad discoloration was prevalent on P2 (Prototype 2) milestone lots processed at Tape and Reel and is the top detractor at Finish process with failure rate of 5.28% during P2 and 5.36% during EVT (Engineering Validation Test) milestone impacting the Yield consequently and not meeting our committed Yield target towards Mass production. During the product introduction, Tape & Reel process performance was equivalent to 53K DPPM defect level due to pad discoloration and has affected the manufacturing bring-up and qualification. Initial validation & simulation shows pad discoloration is induced due to the moisture contamination coming out from CDA (Compressed Dry Air) supply from the Tape and Reel Machine rotary turret during pick and place of module when in contact with the substrate pads. This is a challenge taking into consideration that this new device is processed on Dead bug configuration at Tape and Reel Process to support FATP (Final Assembly and Test Package) at Downstream end customer to support their automation during mounting of this proximity device.

Using Problem Solving & Root Cause Analysis methodology and Process capability check, a task force was formed comprising of cross functional teams and in collaboration with Quality group to validate and replicate the issue to find the root cause resulting to Pad discoloration and subsequently to execute risk assessment on the modules and define the long-term corrective & preventive actions to eliminate moisture on CDA supply.

This resulted in the introduction of the POU (Point-Of-Use) Desiccant Dryer system at Tape and Reel process as a solution for Pad discoloration issue due to CDA moisture hence via acquisition of desiccant dryer at end user. Implementation of POU CDA Dryer system became the ultimate solution to reduce the moisture present on the CDA main supply by maintaining the dew point to its desired level to meet the air dryness requirement prior to supplying to the machine. A POU Desiccant dryer or an adsorption dryer is a piece of industrial equipment that uses desiccant materials to eliminate water from the air channeled through it. A standard desiccant dryer system uses a two-tower set up to ensure a continuous air-drying cycle. This is used to stabilize the dew point or the temperature at which water begins to condense out of the air into a liquid form and to provide a comprehensive dry air quality system.

Inclusion of this innovative equipment solution at Finishing Tape and Reel process has eradicated the CDA moisture and subsequently addressed the chronic Pad discoloration issue. This has reduced the defect rate to 0 DPPM level, eliminating the top Finish Yield loss defect of Pad discoloration as early as engineering phase and resulting to Finishing Overall Yield of 99.85%. This has led to the successful ramp-up towards the mass production of BXXX products. Implementation of this project has prevented potential line down and enabled the full qualification of the new device. This has also prevented potential customer incidents that may arise during production and ensures product requirements & cosmetic quality standards are met along the steep schedule of engineering phase to mass production.

1. 0 INTRODUCTION

All atmospheric air contains some amount of water vapor. Imagine your work environment as a sponge, retaining moisture. If we were to squeeze it out, there'd be excess water. The same happens when air is rapidly pressurized, and why equipment is needed to achieve dry compressed air.

Since rapid temperature changes occur during the high heat compression process, water vapor is created. This level of moisture is called a Pressure Dew Point (PDP), which is further explained in this article. To avoid potential problems, including increased maintenance costs and shutdowns, it's important to dry compressed air with an aftercooler and drying equipment.

Risks from not removing water vapor include corrosion, microorganisms, and increased moisture in humid environments. Not only do these factors affect an air compressor's life cycle, but also overall production quality. Condensate contains more than water. When compressed air is dried, contaminants are removed in the process. If the application requires clean air, using a proper dryer set up is essential.

Referenced above, PDP is used to describe the water content in compressed air. It is the temperature at which water vapor condenses into water. Low PDP values indicate small amounts of water vapor in compressed air. When evaluating different dryers, it's worth noting that atmospheric dew point isn't comparable to PDP. For example, a PDP of +2˚C at 7 bar is equivalent to –23˚C at atmospheric pressure. It's also important to understand that using a filter to remove moisture isn't effective.

This is because further cooling leads to continued precipitation of water condensation. To select the right type of drying equipment, you'll need to understand the PDP. Taking cost into account that the lower the dew point required, the higher the investment. Five techniques exist for achieving dry compressed air. These include, cooling plus separation, over-compression, membranes, absorption, and absorption drying.

CDA stands for Compressed Dry Air or a system which is an essential part of manufacturing industry. In fact, compressed air is common and considered the fourth utility after electricity, natural gas and water. It uses compressed air dryers with special type of filter systems that are specifically designed to remove the water that is inherent in compressed air.

Industrial Sectors which use compressed Air are Semiconductor, Automotive, Food, Manufacturing, Metal Fabrication, Petroleum, Power generation and many more.

Moisture accumulates when the distance of the Point of Use is far from the CDA supply or when the machine is on idle and the CDA have a stagnant flow where that air will saturate, and moisture or airborne water vapor start to build up or the air dryer system is not sufficient to remove excess water from the supply.

Due to the oxidation or possible source of corrosion on Metallic LGA substrate pad. this could cause the following i.e Solderability Issues, Quality Issue or Customer Complaints, Reliability Issues

1.1 Pad Discoloration Phenomenon

Gold plating is one of the common pad surface finishing for area array packages. Nickel immersion Gold provides a uniform coating on copper pads for excellent solderability and enhanced resistance to corrosion. Nickel plays an important role as a diffusion barrier for Cu while the thin immersion gold layer over nickel protects the Ni from oxidation.

This technical paper describes a discoloration related failure mechanism in Gold (Au) LGA pads. The discoloration is caused by severe oxidation of Nickel (Ni), which in extreme severity leads to electrical fails due to increased contact resistance. The root cause for the Au/Ni oxidation is illustrated as due to the porosity of the immersion gold and the synergistic degradation of the pores during the down-stream backend and assembly's processing. Further discussion of this problem mode necessitates to mitigate the degrading impact of the end of line processes on gold surface finish, and eventually elimination of the discoloration related quality issue.

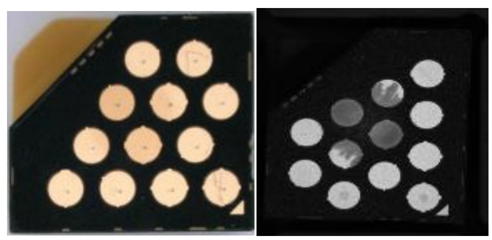


Figure. 1. Pad Discoloration Defect

1.2 Metal Pad composition of Proximity device

The LGA Pads on the Bottom Substrate of the module are composed of Copper Base metal, Nickel (5um min Electrolytic) and Gold (0.3um to 0.8um 99.99%) as finishing layer.

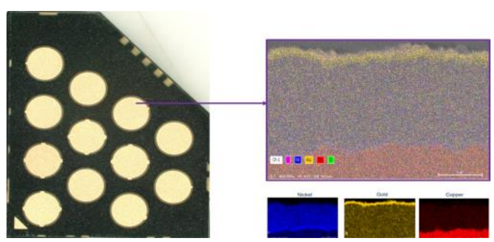


Figure. 2. LGA Pad Composition

Metal Gold Pads are naturally porous material and has high permeability where minute spaces or holes are present and oil, water or air may penetrate.

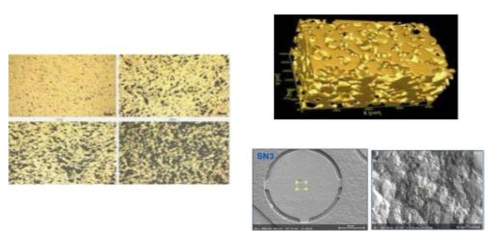


Figure. 3. Metal Gold Pads

1.3 Interaction of CDA moisture on Metallic pads

When metal is exposed to moisture which contains oxygen, this causes reaction where the metal ions bond with the oxygen atoms and creates an oxidation. This can manifest in the Printed Circuit Boards (PCB) or Metallic pads which is usually composed of Au (Gold).

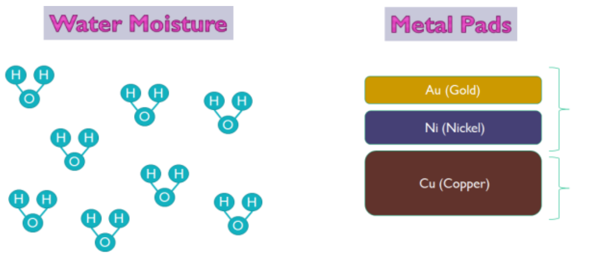


Figure. 4. Water Moisture Interaction to Metals Pads

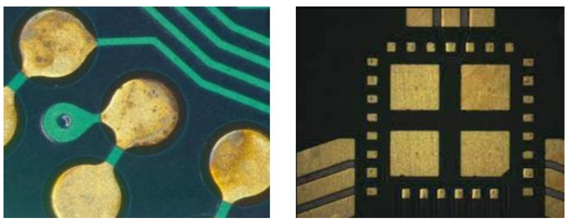


Figure. 5. PCB with Metal Pad Discoloration

2. 0 REVIEW OF RELATED WORK

Some air compressors come with an integrated aftercooler to eliminate up to 70% of moisture. This is ideal for most applications and makes the drying process easy.

However, if you work in an environment that's humid or an application requiring the driest possible air, the process may require additional drying. Deciding on the right equipment depends on the process and application needs and space.

Atmospheric air contains more water vapor at high temperatures and less at lower temperatures. This fluctuation affects water concentration when the air is compressed. For example, a compressor with 7 bar pressure, 200 l/s capacity, and 20˚C temperature with 80% humidity releases 10 l/hour of water. As a result of this precipitation in the pipes and connected equipment, problems can occur. To avoid this, the compressed air must be dried.

In addition to an integrated aftercooler, the process may opt for an integrated or standalone drying equipment. When researching the best solution, it is highly recommended to pay attention to the PDP of the environment.

Choosing the right dryer for the process application and about specific dryers, there are several options for Aftercoolers, Refrigerant dryers, Over compression, Absorption and Adsorption Drying (Desiccant dryers) & Membrane dryers.

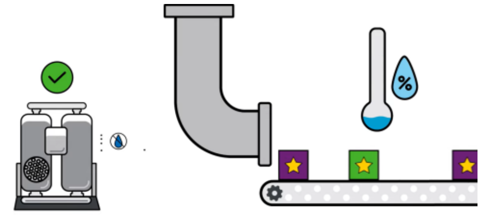


Figure. 6. Desiccant Dryer

When choosing a dryer, there are two types prominently discussed, refrigerant and desiccant. The right one is determined by the required setup, budget, and application.

1. Refrigerant dryers

The more cost-effective option, refrigerant dryers are suitable for most applications requiring high pressure air. As inferred from its name, this equipment works by cooling air down. This drying process occurs through piping connected to an air compressor. They tend to achieve dew point levels of 2ºC to 10ºC and are fairly energy efficient. In addition, refrigerant gases used in newer equipment limit global warming as much as possible.

2. Desiccant dryers

If a more robust dry compressed air solution is desired, desiccant dryer is the best option. While the initial cost of investment is higher than refrigerant dryers, they're more energy efficient and deliver cleaner air.

Desiccant dryers work through a chemical process that binds to moist air, eliminating vapor during production. As a result, desiccant dryers can reach a PDP of -40ºC. Since this equipment requires less electricity than a refrigerant dryer, the operation cost is much lower.

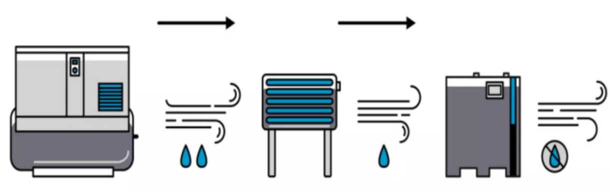


Figure. 7. Desiccant Dryer System to end user

3.0 METHODOLOGY

3.1 Finish Yield Top Detractor – Pad Discoloration

Pad Discoloration was the Top detractor during the EVT phase of the new Proximity device (BXXX) with an impact of 5.36% yield loss at ASTI Tape and Reel process. Other cosmetic rejects are within process capability PPM. This significantly affects the overall target yield performance of the product.

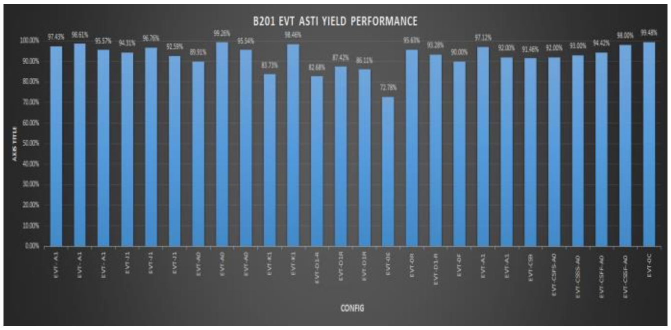


Figure. 8. ASTI Tape and Reel Yield Performance

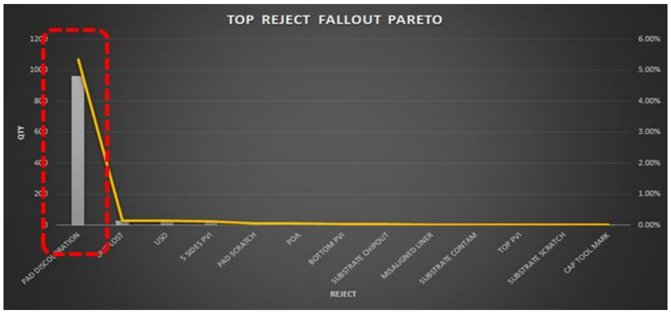


Figure. 9. ASTI Top Reject Pareto

3.2 Pad Discoloration Defect Signature

Sample photos of reject modules after 100% visual inspection showed pad discoloration defect signature which are localized on the center pads of the module. AOI cosmetic validation on affected modules showed visible pad discoloration with difference in light contrast. Affected modules failed at top station during PVI inspection. See Fig. 10 & 11.

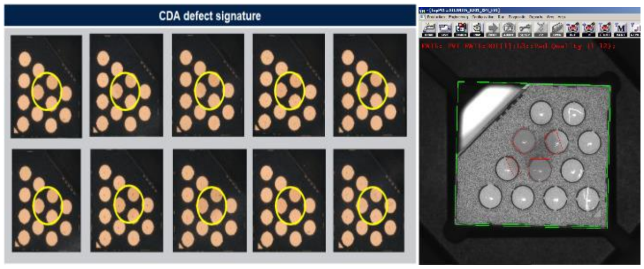


Figure. 10 & 11. CDA Defect Signature

3.3 Pad Discoloration Design of Experiment (DOE)

3.3.1 DOE Methodology Legs:

- DOE 1: Process 14 units to complete 1 gang pick (1 row). Secure before and after images using low/high mag scope. Save the AOI Images of Bottom inspection and check for any pad discoloration.
- DOE 2: Process another 30 units and ensure to complete all 24 turret nozzles. Secure before and after images using low/high mag scope. Save the AOI Images of Bottom inspection and check for any pad discoloration.
- Perform supplementary material experimental comparison thru controlled moisture staging with existing legacy devices (Product A, Product B, Product C) versus BXXX to check output response in terms of pad discoloration.

DOE 1: Gang Pick Simulation

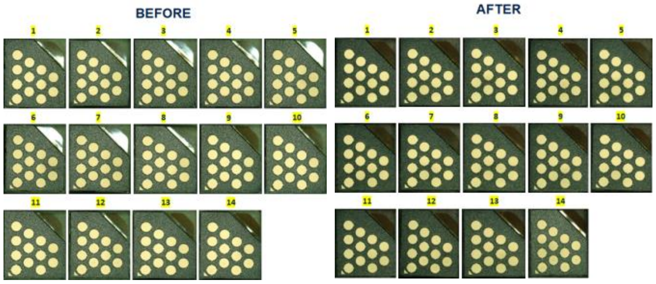


Figure. 12 & 13. Before and After Images after Gang Pick

Remarks: After simulation on Gang pick, there are no signs of Pad Discoloration or any substance on pad.

DOE 2: Turret Nozzle Simulation

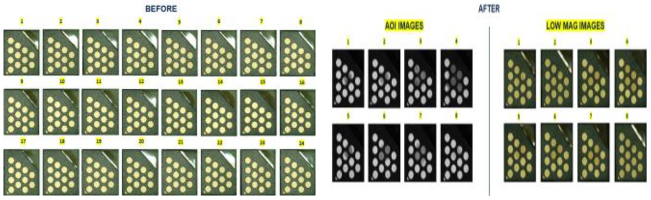


Figure. 14 & 15. Before and After Images after Turret Nozzle Simulation

Remarks: 8 out of 24 units observed with pad discoloration after simulation at turret nozzle.

3.3.2 Turret Nozzle Validation:

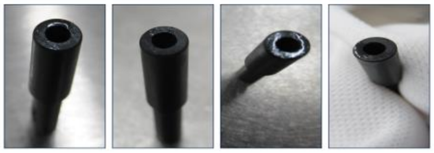


Figure. 16. Turret with liquid substance

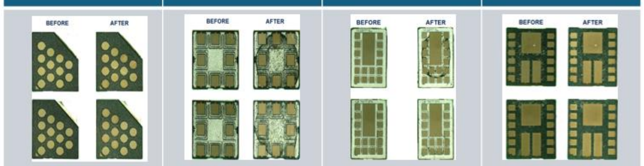
Observed that all Turret Nozzles (Turret 1 to Turret 24) are having liquid substance (water) which is the most probable cause of Pad discoloration on Bottom part of module after the experiment.

On the other hand, no moisture was observed on the Gang pick nozzle possibly due to difference in mechanism (multiple units picked up simultaneously), different material which is metal composition, difference design and not circular and lastly located

3.3.3 Material Pad DOE Comparison

Table 1. LGA Pads Experiment on Different devices

Product A	Product B	Product C	BXXX



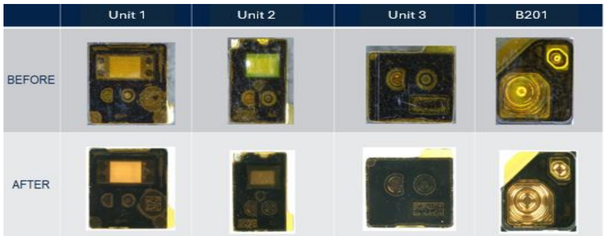
After the experiment shown in Table 1, all Products A,B,C have the same reaction when liquid substance (water) drops on substrate manifesting pad discoloration. Hence, this removes the hypothesis that there is a specific material problem for the BXXX module.

This shows that after all DOE validations and testing, Pad Discoloration is caused by a liquid substance contaminating the substrate pads.

3.4 Simulation on Dead bug vs Live Bug module

Table 2. Liquid substance (Moisture) reaction on top of the liner

	Unit 1	Unit 2	Unit 3	B201



An additional review and validation were also performed to check the reaction of the liquid substance (moisture) when immersed on top of the liner. This is because legacy devices are processed on live bug position and the turret is in contact with the liner whereas BXXX device is processed in dead bug position and turret is contact with the substrate pads, hence, more critical in terms of pad discoloration. Table 2 shows that the water/moisture easily evaporates on top of the liner material (Polyimide) after exposing in less than 1 hour staging.

3.5 CDA Moisture Contact Mapping in ASTI Machine

CDA Supply is directly connected to the ASTI Tape and Reel machine where the air supply goes to the turret tip for pick and place of modules. The liquid substance or moisture observed on the turret tips is directly in contact with the module bottom pads at dead bug orientation. Pad discoloration reject is evident on the contact point between the turret and module part referring to below Figure. 17.

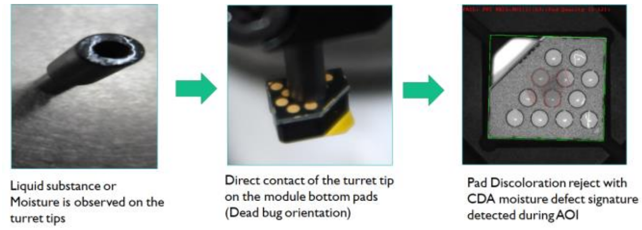


Figure. 17. Pick and Place of Module

3.5.1 Overlay of Turret/Gang Pick vs Module

Overlay photo of the Turret PnP Tip/Gang Pick which is contact on substrate/LGA Pads (Middle part)

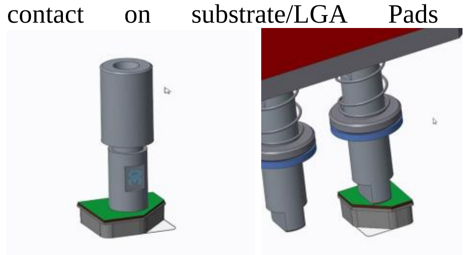


Figure. 18. Turret and Gang Pick Overlay

Superimposed image of the Turret tip and Gang pick shows that the defect location of Pad discoloration is coinciding with the contact points of the pick-up tool head.

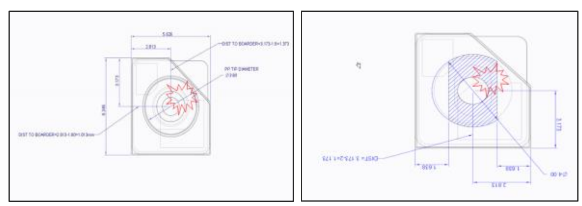


Figure. 19. Superimpose of Turret and Gang Pick vs Defect location

3.5.2 ASTI Tape & Reel Machine Simulation and Mapping

Upon machine checking, all Turret tips (Turret 1 to 24) have liquid substance which causes the pad discoloration. After cleaning all turret tip and performing setup cycle run, another validation activity is performed by checking on the same turret tip every 5mins to confirm if the turret will be having liquid substance again after cleaning. After validation, it is found out that turrets are still having liquid substance every single time which is possibly the main source of pad discoloration. Turret tip is continuously accumulating CDA moisture even after cleaning.

Figure. 20. Turret Tip Checkout after cleaning

3.5.3 Machine Sequence

Possible Contact points on ASTI TnR machine is during Turret Pick up on bottom substrate (LGA Pads). Figure 21 below shows the processing sequence of modules from machine input to output.

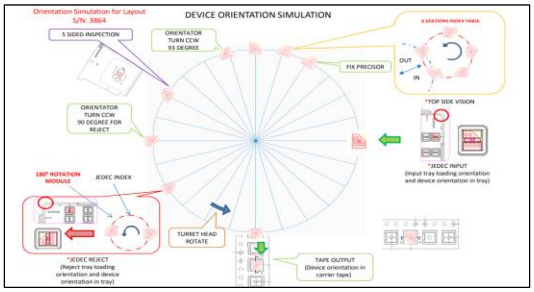


Figure. 21. ASTI Machine Sequence

Contact points on ASTI TnR machine is during Gang pick-up and Turret Pick head on bottom substrate (LGA Pads) which is the possible source of CDA moisture and resulting to Pad discoloration. The machine is equipped with 24 nozzle turret tips which are in contact with the module during production mode.

After bottom pad inspection at TnR AOI (Station 7 Top Side Inspection), still there will be pick and place from this step going to the orientator, five sides inspection and top inspection going to Taper which can still induce pad discoloration due to CDA moisture during pick and place. *Refer to Appendix A – ASTI Machine Stations.*

3.5.4 ASTI Machine Mapping – Contact Points

Table 3. Machine Station Validation

Station No.	Machine Part	Image	Function	Remarks
N/A	Tray Input Loader		Tray with modules are placed in the input loader for the Tape and Reel process. 1st Tray is taken from the bottom part	Trays will be flipped manually prior loading at Tray Input
N/A	Gang Pick		Unit pick up from input tray and transferring the modules to input Shuttle (14x picks at same time)	Modules will be picked and in contact on the substrate pads Possible source of Pad stains/discoloration
2	Input Shuttle 1 & 2		Input shuttle 1 & 2 moves alternately which receieves the units from Gang Pick and transfers to the turret pick head.	Modules are placed on shuttle on substrate up position (dead bug) on shuttle
N/A	Turret Pick Head		Pick and place from machine station to station	Units are held on the substrate part LGA pads of the module Possible source of Pad stains/discoloration
7	Rotary Table 1		The Turret will put down the module to Rotary Table 1 to send it to the Top Inspection.	Modules are placed on the rotary on substrate up position (dead bug)
9	Orientator 2		After the Top Inspection the Turret will pick up the unit and place it to the Orientator 2 to align the module center/position in preparation for the Bottom and 5 Sides Inspection	Modules are placed on the orientator on substrate up position (dead bug)
14	Orientator 3		After Bottom and 5 Sides Inspection, the turret will put down the module to the Orientator 3 to rotate the module accordingly to the Carrier Tape and Reject tray position	Modules are placed on the orientator on substrate up position (dead bug)
16	Rotary Table 2		The Turret will put down the reject unit on the Rotary Table 2 to send to Reject Trays. Good units will not go to the Rotary Table 2	Modules are placed on the rotary on substrate up position (dead bug)
20	Inpocket		Turret will place the module onto the Carrier tape and will undergo Inpocket and Post Seal Inspection	Modules are placed on the carrier tape on substrate up position
N/A	Auto Sort		Turret will pick any reject module from the Inpocket and drop to auto sort bin	Reject units will be sorted out

Modules will be picked up in Gang pick & Turret PnP and in contact with the substrate pads which is the possible source of pad stains and discoloration. There is no direct contact on the module with other stations in the rotary, orientation & precisor area.

3.6 FA Material Analysis

3.6.1 Failure Analysis on Material Samples

Appendix B shows the different material samples submitted to Failure Analysis laboratory for the detection of OH (Oxygen/Hydrogen) presence on the material.

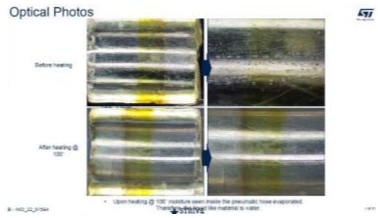


Figure. 22. Moisture present on the CDA hose

Upon heating the CDA hose splice sample @ 100ºC, moisture seen inside the pneumatic hose evaporated. Therefore, the liquid like material is confirmed water.

Analysis conclusion:
Liquid substance inside pneumatic hose is water.

CDA contamination samples of liquid like substance taken from ASTI equipment were submitted also for FTIR & EDX analysis.

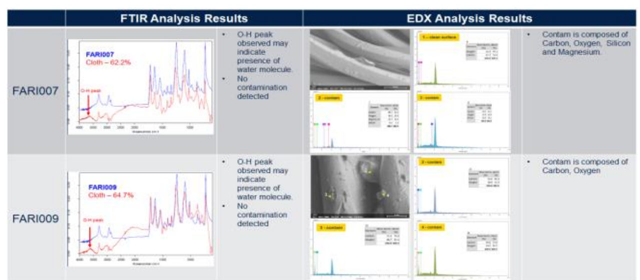


Figure. 23. FA Result of Input to ASTI Machine

Result: OH peak observed are indicative symptoms for presence of water molecules.

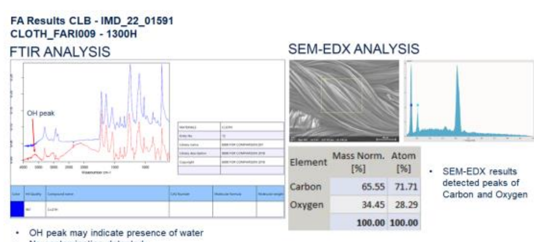


Figure. 24. FA Result of Cloth Samples

Result: OH peak observed may indicate presence of water molecules

3.6.2 Failure Analysis on the Pad discoloration

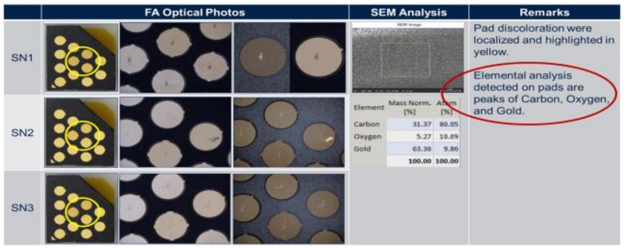


Figure. 25. FA Result of Pad Discoloration

Elemental analysis detected on pads are peaks of Carbon, Oxygen and Gold which signifies oxidation on the affected pads with discoloration.

3.7 POU (Point of Use) Desiccant Dryer Qualification

A POU desiccant dryer or an adsorption dryer is a piece of industrial equipment that utilizes desiccant materials to eliminate water from the air channeled through it. A standard desiccant dryer system uses a two-tower set up to ensure a continuous air-drying cycle.

Below are the composition & main functions of POU Dryer:

- Composed of different particulate and moisture filters to absorb excess moisture in the CDA supply.
- Controls the Dew point at acceptable level of humidity and dryness (<-60ºC)
- Ensures that there will be no excess moisture on the CDA before it enters the ASTI Tape and Reel machine.

Figure 26 shows the actual Desiccant dryer model used (Parker CDAS / OFAS HL 050 – 085) and was qualified for this purpose.

Figure. 26. POU Desiccant Dryer Model (Parker CDAS / OFAS HL 050 – 085)

Refer to *Appendix C* for the POU Desiccant Dryer Actual Installation and POU Displays and Indicators and Column Status Indicators

3.7.1 POU Desiccant Dryer Main Parts

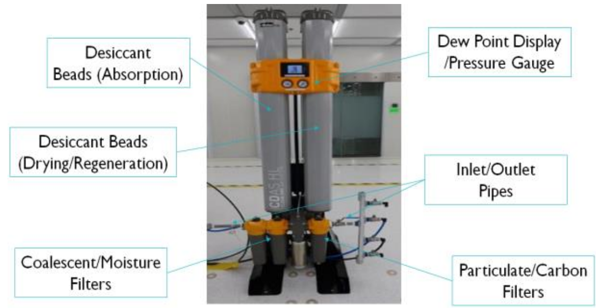


Figure. 27. POU Desiccant Dryer Main Parts

The main parts of the POU desiccant dryer is composed of (1) Desiccant Beads 1st column (2) Desiccant beads 2nd column (3) Coalescent/Moisture Filters (4) Inlet/Outlet Pipes (5) Particulate/Carbon Filters and (6) Dew Point Display/Pressure Gauge

3.7.2 POU Desiccant Dryer Operation

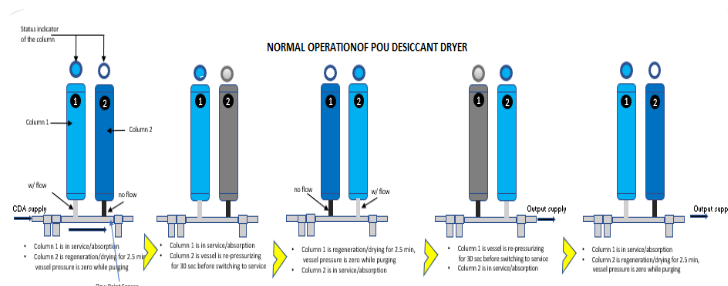


Figure. 28. POU Desiccant Dryer Operation

Adsorption dryers operate on the principle of two drying beds, one to dry the process air whilst the other is being regenerated and readied for use, swapping periodically. CDAS HL dryers operate on the PSA (Pressure Swing Adsorption) principle which uses a proportion of the dry process air to regenerated the off-line bed. The diagram below illustrates the drying / regeneration cycle of a CDAS HL operating at maximum (Full Flow / Minimum Inlet Pressure / Maximum Inlet Temperature)

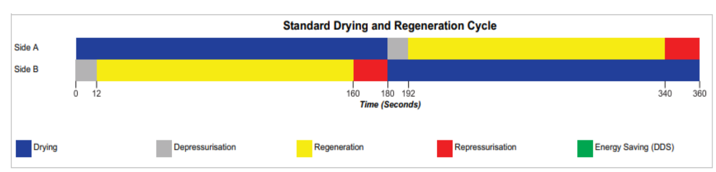


Figure. 29. Standard Drying and Regeneration Cycle

CDAS HL are complete purification systems designed to reduce the major contaminants found in a compressed air system. CDAS HL provides 4 stages of contamination reduction for 7 contaminants (if liquid water or oil is present, the CDAS HL must be protected by an optional OIL-X WS grade Water Separator).

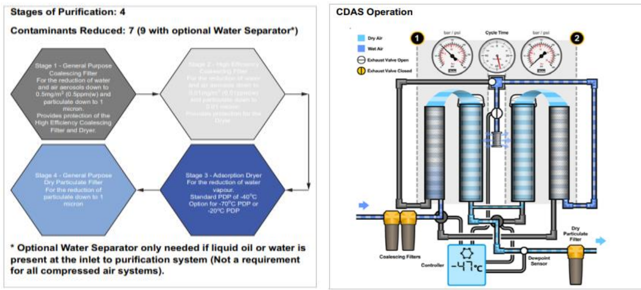


Figure. 30 & 31. Stages of Purification & CDAS Operation

3.7.3 POU Desiccant Dryer Overall System

CDA Overall system starts from the Main Compressor/Dryers located outside the operations area and then transfers through CDA Main loop distributed across different areas inside the plant. Subsequently it will pass through CDA Subloops, or dropline connected directly to the POU desiccant dryers located inside the production area prior reaching to the machine (end user or point of use) which is the ASTI Tape and Reel. See Figures. 32 & 33.

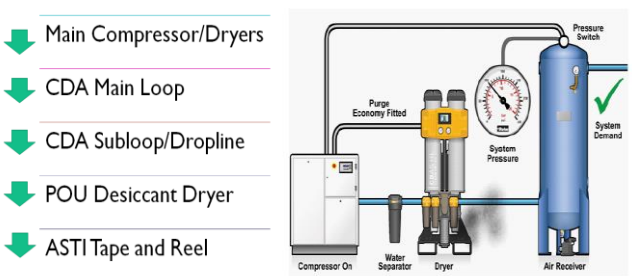


Figure. 32. POU Desiccant Dryer Overall System


Figure. 33. ASTI Tape and Reel Machine (End User or Point of use)

3.8 CDA Purging and Moisture Verification Procedure

- Purging and Moisture Verification frequency @ Main CDA Supply is every 2 hrs
- Purging and Moisture Verification @ Turret is every 4 hours
- Dummy units moisture verification Procedure: Moisture/Discoloration Verification Frequence is every 12 hrs

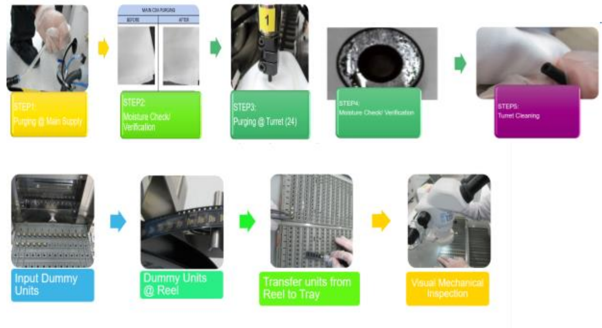


Figure. 34. CDA Purging Procedure

4.0 RESULTS AND DISCUSSION

4.1 Staging of Units with Pad Discoloration

Results of experiment show that the Pad discoloration is still prevalent after 3 hours dry staging under room temperature placed in carrier tape. Based on risk assessment, it was observed that the discoloration on pads remains intact after staging via tray or carrier tape (1hr-->2hrs-->3hrs) when exposed in standard clean room temperature, hence this phenomenon does not disappear after processing which signifies that this defect may reach up to end customer.

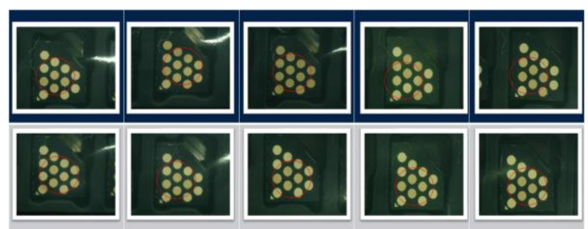


Figure. 35. Pad discoloration still observed after 1 hr staging in room temperature inside carrier tape

Refer to Appendix E – Pad Discoloration after 2hrs and 3 hrs staging

4.2 POU Desiccant Dryer Validation

Perform quick validation to validate the effectiveness of the Desiccant dryer at Tape and Reel station by checking any CDA moisture presence on Turret tips after purge and run dummy units to check any signs of Pad discoloration on modules

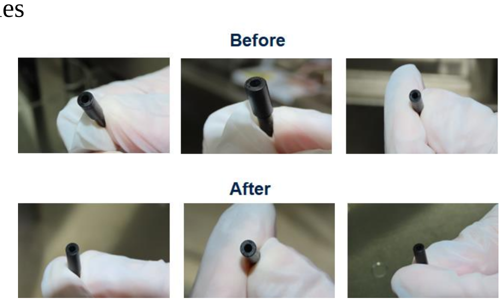


Figure. 36. Turret Tip Checkout

- Turret Tip Checkout:

Table 4. Turret Tip Checkout Result

Item	Activities:	Result:
1	Purging Turret Nozzle	Dry Nozzle Observed
2	Nozzle Check	No significant water marks observed on turret tips compared to previous condition

- VMI after Dummy Run:

Table 5. VMI Evidence Photos

Table 6. VMI Result

Item	Activities:	Result:
1	Run 1 Dummy tray	No signs of any Pad discoloration observed on the units after 100% VMI
2	Do cycle run (2x)	
3	100% VMI (Before and After)	

Process Validation Result:

- No watermarks observed on the Turret tips after the installation of Desiccant dryer at Tape and reel
- No signs of Pad discoloration observed on the modules during dummy/cycle run
- No Pad Discoloration on actual EVT lots (5kpcs)
- Equipment Cycle run with result of zero pad discoloration.

4.3 POU Dewpoint

4.3.1 POU Dew Point Monitoring and Purging

Table 7 shows the POU Dewpoint Monitoring every 12 hrs interval which is reaching up to -65C more than the alarm set of -56C. Air Pressure is also consistent at 5.4 Bars supplying directly to end user. This shows a stabilized dew point or temperature at which water begins to condense out of the air into a liquid form and provides a comprehensive dry air quality system.

Table 7. POU Dew Point Monitoring

Parameter		April 26,2023											
	24-HOUR	2	4	6	8	10	12	14	16	18	20	22	24
POU Dryer (Fill Up By Facilities)	Eco Set Point	-70	-70	-70	-70	-70	-70	-70	-70	-70	-70	-70	-70
	Pressure Monitoring (Bars) Every 4hrs	5.4		5.4		5.4		5.4		5.4		5.4	
	Dew Point Monitoring Every 2hrs (POU)	-65	-65	-65	-65	-65	-64	-65	-65	-65	-65	-65	-65
	Dew Point Monitoring Every 2hrs (Remote Station)	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline	For relocation as it was installed to CDA dropline
	Dew Point Alarm Set Point	-56	-56	-56	-56	-56	-56	-56	-56	-56	-56	-56	-56
Output Response (Fill Up By Operations)	Purging @ CDA Inlet Every 2hrs									0	0	0	0
	Purging @ PnP 1 & 2 Every 24hrs	No Contam/Stains											
	Daily Cycle Run Every 24hrs (5k units)	No Contam seen											

Table 8 shows No Contamination/Stains observed during purging at CDA inlet and turret tips after installation of POU Dryer

Table 8. CDA Inlet Purging Validation

4.3.2 POU Dew Point Monitoring

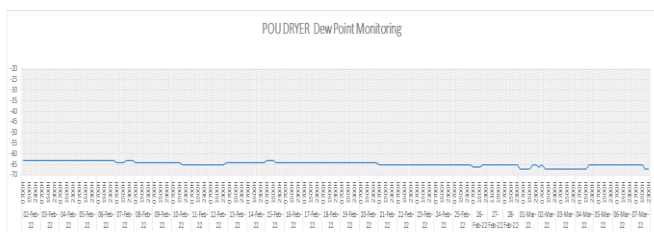


Figure. 37. POU Dew Point Trend

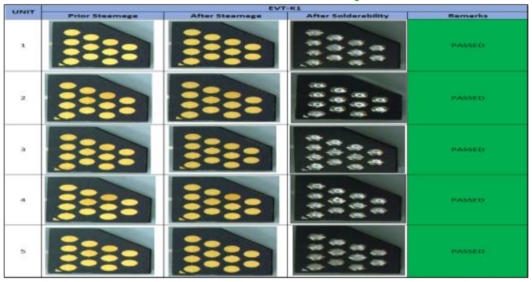
POU Dryer dew point trend consistently meet the target of -60C to ensure dryness of the CDA supply based on the online system monitoring from Facilities team. This also equates to the quality of the CDA supply output and observed no CDA related pad defects observed after stabilizing the POU dryer on engineering lots.

4.4 Solderability Test

Process:

1. Steam Age (pre conditioning) : 8 hrs + 2 hrs staging after steam age
2. Dip and look test

Table 9. Solderability Test



Solderability test shows Passing result which implies good bonding between the solder vs LGA pads on the samples units processed with the POU desiccant dryer.

4.5 Lot Monitoring and Cycle run after POU Installation

Tape & Reel equipment with CDA supply from POU Desiccant Dryer completed 40 cycle run for more than 20 days with 0% failure rate related to pad discoloration and no stain found during purging at main CDA line and turret purging.

Table 10. Lot Monitoring

CYCLE RUN	MACHINE	DATE	TIMEFRAME	QTY	PAD DISCO REJECTS (QTY)	FAILURE RATE	RESULTS	MAIN CDA PURGING (Operations)	TURRET PURGING (Operations)	DEW POINT MONITORING (Facilities)
1	FARI007	20-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-62
2	FARI007	21-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-63
3	FARI007	21-Mar-23	5:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-63
4	FARI007	22-Mar-23	3:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-63
5	FARI007	23-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-64
6	FARI007	24-Mar-23	3:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-64
7	FARI007	24-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-65
8	FARI007	25-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-65
9	FARI007	25-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-65
10	FARI007	26-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-65
11	FARI007	26-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-66
12	FARI007	27-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-66
13	FARI007	27-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-66
14	FARI007	28-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-66
15	FARI007	28-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-66
16	FARI007	29-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-66
17	FARI007	29-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-66
18	FARI007	30-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-66
19	FARI007	30-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-66
20	FARI007	31-Mar-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-67
21	FARI007	31-Mar-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-67
22	FARI007	01-Apr-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-67
23	FARI007	01-Apr-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-67
24	FARI007	02-Apr-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-67
25	FARI007	02-Apr-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-67
26	FARI007	03-Apr-23	7:00 AM	150	0	0.00%	Passed	No Stain	No Stain	-67
27	FARI007	03-Apr-23	7:00 PM	150	0	0.00%	Passed	No Stain	No Stain	-68

4.5.1 Results of Cycle Run Activities

No rejects related to pad discoloration during 100% VMI after continuous cycle run and 1 month of monitoring after installation of the POU Desiccant Dryer.

Table 11. Pad discoloration Checkout

4.5.2 Results of Purging Activities

Purging activities by operations showed zero stain validated using lint free cloth and zero stain was observed at Machine inlet and 24x pcs Turret tips.

Table 12. Purging Result

4.6 ASTI Machine Fan-out

With the positive result of the POU Desiccant dryer after installation, this was proliferated out to 4x other ASTI tape and reel machines in Finish process needed for the set-up of BXXX device to support the production build capacity and volume.

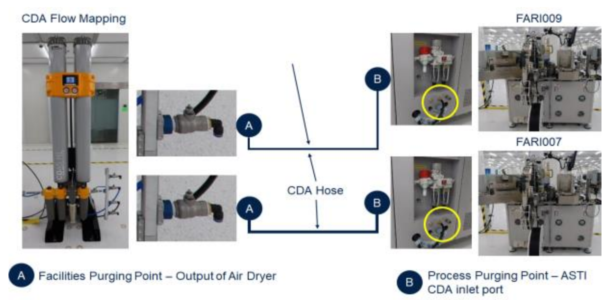


Figure. 38. POU Dryer Fanout to other ASTI T&R Machines

4.7 Elimination of the Pad discoloration defect

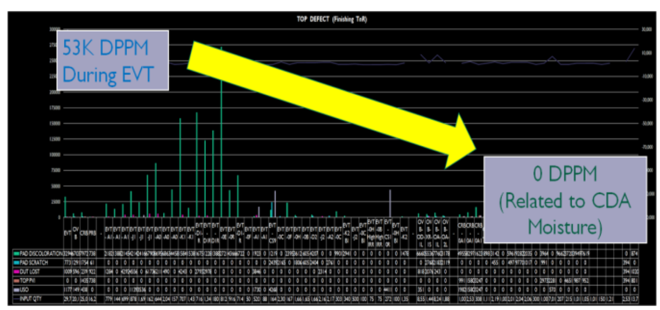


Figure. 39. Pad Discoloration Elimination

From 53k DPPM during EVT stage related to pad discoloration defects, significant reduction of Pad discoloration was observed from OVB to CRB milestone with zero occurrence of Pad discoloration related to CDA moisture. This has significantly improved the overall Yield in preparation for the Mass production.

5.0 CONCLUSION

With the result and based on the findings after different simulations and experiments have been performed, it was proven that the Pad discoloration present on the LGA pads of the proximity device are induced at Tape and Reel process during pick and place due to moisture coming directly from the CDA supply.

CDA moisture accumulates when the distance of the Point of Use is far from the CDA supply or when the machine is on idle and the CDA have a stagnant flow where that air will saturate, and moisture or airborne water vapor start to build up or the air dryer system is not sufficient to remove excess water from the supply.

This has led to the qualification of a new Manufacturing process and technology via the inclusion of POU Desiccant Dryer system at Point of use and installed prior Tape and Reel machine. An innovative solution with the introduction and bring up of CDA Dryer system which was the ultimate breakthrough to reduce the moisture present on the supply by stabilizing the dew point or the temperature at which water begins to condense out of the air into a liquid form and to provide a comprehensive dry air quality system.

With the provision of the POU Desiccant Dryer and integrating this new technology at Finish Process during the Engineering milestone, no quality issues have been recorded during the validation run. Pad discoloration was totally eliminated reaching up to 0 DPPM and meeting the committed Yield target of 99.85% overall.

This has been proven to be effective during the qualification and engineering stage by removing product quality issues. The new machine and system have been established and finalized as part of the Finishing process towards the mass production of the latest proximity device and the project's deployment was successful and has supported the manufacturability of the new product.

6.0 RECOMMENDATIONS

The current study can be interpreted as the ultimate breakthrough solution with the inclusion of POU Desiccant Dryer technology which is a more robust dry compressed air solution. This new system integration is a more energy efficient system and deliver cleaner air to the end user and addressed certain manufacturing problems related to pad discoloration, stains, or corrosion. With the positive result of the study, operations 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 B2F2 Director Ms. Aileen V. Gonzales for the support and encouragement to finish the project, the whole team's support form the Process Engineering group. In addition, we acknowledge the valuable support of Equipment Engineering and Facilities team for the setup and sustaining support they have contributed during the implementation phase and making this project a success.

8.0 REFERENCES

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3. **STI Semiconductor Technologies & Instruments** *https://www.stigp.com/product/at468-turret-based-scan-pack/*

4. **IEEE Xplore** *https://ieeexplore.ieee.org/document/1345605*

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10.0 APPENDIX

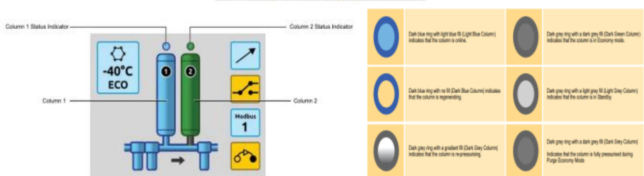
Appendix A – ASTI Machine Stations

Steps	Description	STN	Possible Pad Contact
1	Tray Input Loader	-	NO
2	Gang Pick up	-	YES
3	Input Shuttle	Station 2	NO
4	Turret Pick Head	-	YES
5	Rotary Table 1	Station 7	NO
6	Top Side Inspection	Station 7	NO
7	Orientator 2	Station 9	NO
8	Bottom and 5 Side Inspection	Station 12	NO
9	Orientator 3	Station 14	NO
10	Rotary Table 2	Station 16	NO
11	Inpocket Inspection	Station 20	NO
12	Auto Sort	Station 20	NO
13	Post Seal Inspection	Station 20	NO
14	Reel Spool	-	NO

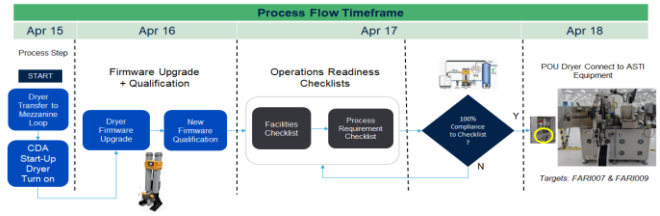
Appendix B – FA Material Samples

Materials	Photos	FA Reference
Point A – Start of POU		Clean. FA not needed
Hose Splice		CLB - IMD_22_01564
Point B – End of POU		CLB - IMD_22_01573
ASTI Filter		CLB - IMD_22_01590
Turret Tip		CLB - IMD_22_01594
CLOTH_FARI009 -1300H 15-Mar		CLB - IMD_22_01591
CLOTH_FARI009 -1500H 15-Mar		CLB - IMD_22_01592
CLOTH_FARI009 -1600H 15-Mar		CLB - IMD_22_01593

Appendix C – POU Desiccant Dryer Actual Installation and POU Displays and Indicators and Column Status Indicators



Appendix D – CDA Start-up Checklist and POU Desiccant Dryer Checklist



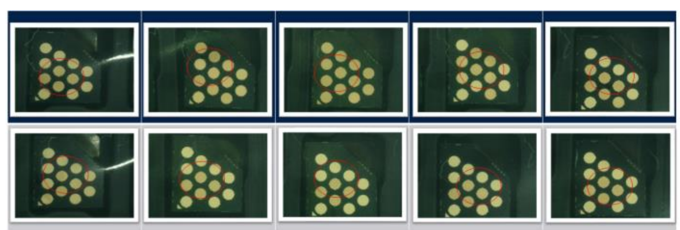
CDA Start Up Checklist

CDA Start up and Checklist Procedure	Item	Activity	Remarks	Accept Y / N
	1	Check and open drain valves of all Air Receiver Tanks	Done	Y
	2	Start Air Compressor, add unit as needed	Done	Y
	3	Check drain of receiver tanks and let it purge continuously until no moisture is coming out, close the drain valve	Done	Y
	4	Start up RAD and DAD, add unit as needed	Done	Y
	5	Continuous purge at CDA main loop until no contamination and moist found while purging	Done	Y
	6	Continuous purge at POU DAD drop line (considering firmware is already upgraded) until no moisture and contamination found while purging	Done	Y
	7	Start hourly monitor pressure and dew point including the purging at Main CDA loop and POU DAD drop line (use the old monitoring logsheet).	Done	Y
	8	Before endorsing to Operation, Dew point should be ≤-60ºC, Pressure ≥5 bar, and no traces of contamination and moisture	Done	Y

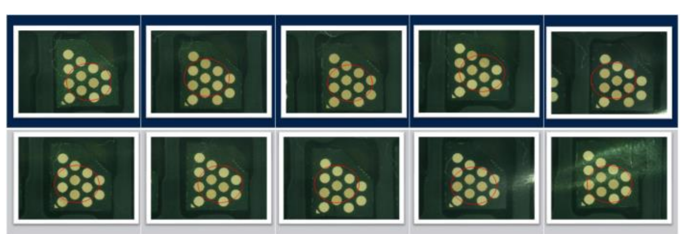
POU Desiccant Dryer Checklist

Desiccant Dryer Equipment	Component	Parameter	Acceptance Criteria	Accept (Y / N)
	Dryer	Check POWER ON and STATUS / FAULT indicators	No fault should be present on the LCD display	Y
	Dryer	Check for air leaks.	No leak	Y
	Dryer	Check the pressure gauges during purging for excessive back pressure.	≥ 5 bars	Y
	Dryer	Check the condition of electrical supply cables and conduits.	No exposed wire, properly terminated	Y
	Dryer	Check for cyclic operation.	Every 3 minutes cycle	Y
	Dryer	Check the exhaust silencers.	No leak	Y
	Dryer	Check the outlet check valves	Complete every 3 minutes cycle	Y
	Dryer	Check the inlet, outlet and control valves	Complete every 3 minutes cycle	Y

Appendix E – Pad Discoloration after 2hrs and 3 hrs staging



Pad discoloration still observed after 2 hrs staging in room temperature inside carrier tape



Pad discoloration still observed after 3 hrs staging in room temperature inside carrier tape