LEADING INDICATOR DETECTION THROUGH SPC INPUT VARIABLES

Sebastian D.P. Novio
Kate Drew G. Heromiano
Leo E. Cada
Central Plating Sustaining Engineering Department
Nexperia Philippines Inc., Philips Avenue, LISP 1
sebastian.novio@nexperia.com; kate.drew.heromiano@nexperia.com; leo.cada@nexperia.com

ABSTRACT

Nexperia Assembly and Test Cabuyao is a major assembly and test center that provides more than 5,000 different semiconductor products around the world. Recently ATCB achieved another milestone of getting 1ppb (Parts Per Billion) defect rate, results of having a balanced productivity and product quality.

To achieve an excellent product quality while producing billions of products, a good foresight is needed to see and prevent things before it can happen. This paper will discuss the different items ATCB plating team conducted to establish leading indicators on Machine, Chemicals and Process Parameters.

This paper guides us on how to establish Plating Process' leading indicators and signals such as Plating Belt Thickness, Pb ppm measurement on product and chemical bath, High Pressure Waterjet pump load, and rectifier voltages to provide good quality products while minimizing production downtime impacts.

Routine monitoring of the machine conditions is done to ensure smooth production and detect any possible root causes of downtime or product defects. The authors showed how the process is monitored, how each defect is related to the parameters, and the effects of SPC monitoring on the overall performance of the production. Identified process characteristics such as pump load, belt thickness, Pb ppm and rectifier voltages will be included on FMEA as critical factors with "S" classification. The SPC input variable system monitors all facets of production such as mechanical, electrical, chemical and product variables.

This resulted to a drastic decrease on Plating Lagging OCAP such as Chipped package with 0 lagging OCAP hits, zero peel-off OCAP hits since implementation. Flakes test hits were reduced from 0.218% to 0.136% lagging OCAP. And a cumulative cost savings of $866,649 to date of writing

1. 0 INTRODUCTION

1.1 Process Control

Having good manufacturability means having a good balance between product quality, process control and manufacturing cost. The first step in establishing the critical parameters on the plating line is to monitor each input variable. Sustaining Engineering team conducts regular inspection of the machine's condition prior to production or if a defect was detected during processing.

1.1.1 Failure Mode and Effects Analysis (FMEA)

Failure Mode and Effects Analysis is an effective tool for evaluating a process to identify risks. FMEA is a "living document" in which engineers follow in terms of risk assessment. At ATCB critical parameters such as plating thickness was identified with an "S" characteristic, such parameters are deemed critical and controlled with an SPC (statistical process control) system.

This paper identified the top defects, provided deeper causes on input parameters, and established SPC controls on input variables that contributes to plating process' top defects.

1.1.2. Current Variables with SPC System

Plating thickness defines the quality of a Leadfinish, dictates the solderability properties, intermetallic layer formation, electrical resistance, and Tin (Sn) coverage. Looking at the FMEA Sn Plating Thickness is one of the critical parameters with Severity rating of 7 with "S" classification. Thus, an SPC control is required. The standard thickness specification requirement for all plated packages is 7 to 15 microns. Plating thickness is measured using X-ray fluorescence (XRF) equipment. Sampling frequency, sampling size, and location are defined in the control plan.

Plating thickness is currently the only variable monitored using SPC. Plating Thickness Cpk for ATCB is at 2.1781 (Fig. 1).

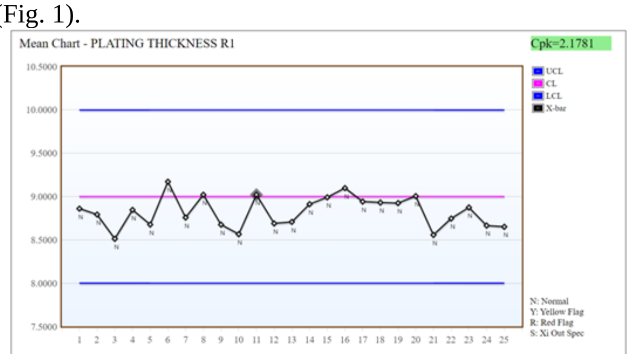


Figure1. SPC charts for Plating thickness measurement of SOT669.

1.2. Top Defects

The top contributors of OCAP hits in Central Plating are Chipped package with Plating seepage on the back surface (CHPSB), Flashes (MFB) and Flakes (FLK) as shown in Figure 2. Detection of the top OCAP hits are at downstream visual and machine inspections.

In the FMEA Peel-off plating and Pb ppm have high RPN number requiring SPC even though they are not included on the top OCAP hits.

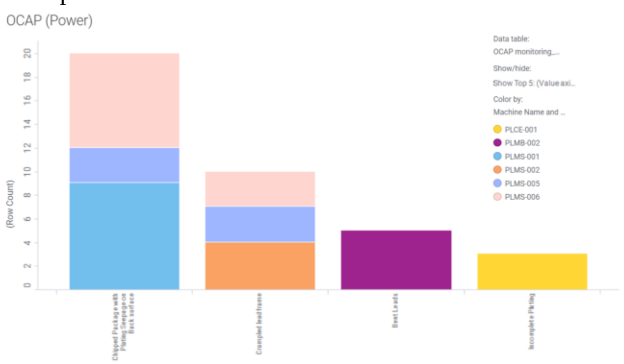


Figure2. Pareto of Plating Top Defects

1.2.1. Input Variable Check

Input variables are machine parameters, input materials and other factors with functions that can provide early signals before a failure. These are identified individually and are being monitored daily. Machine health checks (see Fig. 3) are done in a specific routine to inspect specific parts or parameters of each process at the start of the shift. This is to ensure that the machine is in good operating condition. Any abnormalities in the parts or parameter settings will be captured during this activity.

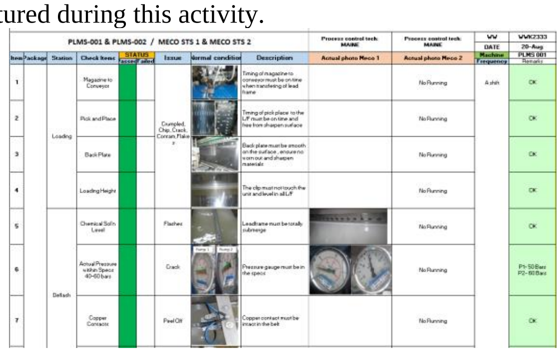


Figure3. Sample image of Machine Health checklist

1.2.2. Chipped package on Back Surface and flashes

High Pressure Water Jet of a deflash-plating machine is one of the critical modules on the equipment due to little variations on the working pressure may result to CHPSB (High Pressure) or MFB (Low Pressure). Pressure fluctuations are a key factor in the generation of excess flashes (Fig. 4). In a continuous production line, pressure fluctuations are too late as a detection point. The team define other factors that can detect possible pressure fluctuation points before they occur.

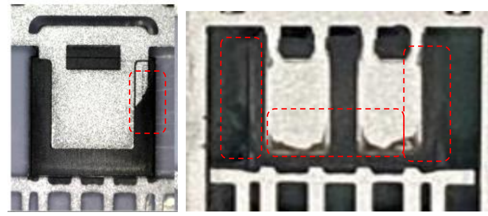


Figure4. CHPSB (Left); Excess flashes (Right)

1.2.3. Flakes and their Effects

Flakes (Fig. 5) are excess tin metal on the surface of the metal substrate. There is a tendency for the excess tin metal to detach and transfer to other parts of the unit such as leads, when this occurs, electrical shorting can occur. The longer the excess metal, the more it is prone to short with the adjacent leads.

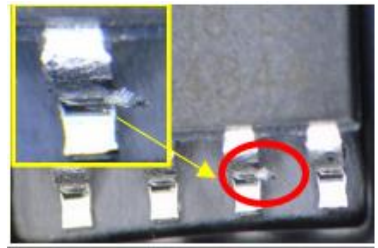


Figure5. FLK sample defect signature

1.3.4. Peel-Off Plating

One of the rare but critical defects encountered at plating is the peel-off plate (Fig. 6). The signature of this defect is the poor adhesion of the plating layer with the base metal.

One factor the team identified is the quality of the belt. This will be discussed further in the paper on how the belt quality impacts the peeling of plating.

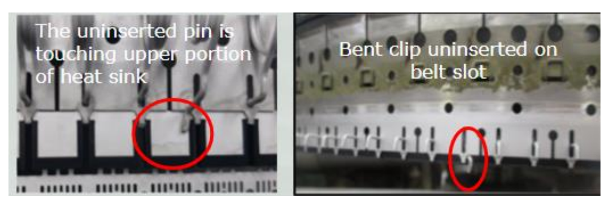


Figure6. Effects of uninserted bent clips

1.3.5. Plating Thickness Out of Specs (PTOS)

Plating thickness is defined as directly proportional to the rectifier current setting. While voltage effects will determine whether the electrodeposition will occur. During machine stoppages, the voltage of an electrolytic system tends to fluctuate, since the current setting is fixed on our plating lines, voltage fluctuations is more appropriate parameter to monitor rectifier condition.

1.3.6. Lead (Pb) PPM control.

Since 2003, EU laws have restricted the use of hazardous substances in electrical and electronic equipment through the RoHS Directive. Restriction of Hazardous Substances in Electrical and Electronic Equipment or RoHS restricts chemicals such as lead, mercury, and cadmium which may be released during the use, collection, treatment, and disposal of electrical and electronic wastes. For lead (Pb), the concentration should not exceed 1000 ppm.

Figure7. Exposed Pb from the Clipbonding process contaminates the Plating Bath.

Lead content on the plating bath is coming from DACA Lead solder (95%) used in the clipbonding process. An external Pb joint is exposed which would eventually undergo chemical etching upon submerging in the plating chemicals (see Fig. 7).

2.0 REVIEW OF RELATED WORK

2.1 Electrodeposition principles

In an electrochemical reaction, an electrolytic cell requires both electrodes in the same container immersed in an electrolyte solution while requiring an external supply of electrical energy for a reaction to take place. Electroplating is an example of an electrolytic process. As electrical energy flows through the two electrodes (cathode and anode), it will result in a reduction and oxidation reaction (redox). Different metals have different reaction potentials. The more negative the value, the greater the tendency of the metal to oxidize [1]. The more positive the value of the potential, the greater the likelihood of a metal undergoing reduction. The driving force behind the redox reaction is the standard cell potential commonly represented in Volts (V) [4].

2.2. Importance of Voltage Output

During electrolytic processes, when the surface of the leadframe is exposed to a fluid, it creates an Electrical Double layer (EDL), as shown in Figure 8. This is composed of two parallel layers of charges (whether positive or negative).
The first layer consists of ions adsorbed in the surface of the material due to chemical interactions while the second layer is composed of ions loosely attracted to the surface via electrostatic force or Coulomb force. The attractive or repulsive force between the two charges electrically screens the first layer.
Chemical reactions require a certain amount of activation energy. In this case, the EDL acts as the activation energy barrier of the chemical reaction and the voltage as the driving force to push the chemical reaction forward. Uncontrolled or unmonitored voltage output could affect certain parts of the equipment/machine and possibly the final product.

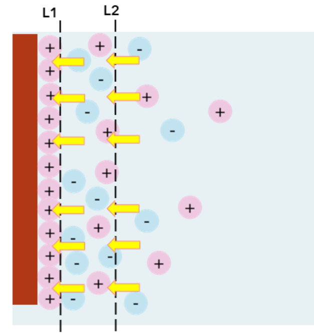


Figure8. Schematic of Electrical Double layer in the solution.

2.3. Galvanic Corrosion

Majority of the process in Central Plating uses electrical input to assist in chemical reactions. Processes including Electrolytic Deflash, Degreaser, Pre-Dip, Electroplating, and Belt stripping require electrical input from rectifiers to assist in the chemical reactions to produce the intended results. These processes also involve liquid solutions as their medium to transfer one ion to another.

Galvanic corrosion occurs when two different metals are immersed in a conductive solution and are electrically connected. Another metal corrodes instead of the metal in contact with the electrolyte. When electrical current is supplied, one metal becomes the anode and corrodes faster while the other becomes a cathode and corrodes slower. The driving force of corrosion is the potential difference between the two different materials.

The conveyor belt of a plating line is the major part affected with galvanic corrosion. Corrosion (Fig. 9) on the belt thickness reduces its thickness overtime.

Figure9. Discolored belt due to Galvanic Corrosion

2.4. Isolation Tank

The isolation tank corresponds to the 1st plating cell, while the main tank corresponds to the supply of plating solution on the 2nd to 5th plating cell. Fig 10 shows the typical plating tank configuration.
Previous studies demonstrated that Pb on the leadframe dissolves on the bath during the 1st 12 seconds only or on the 1st process cell.

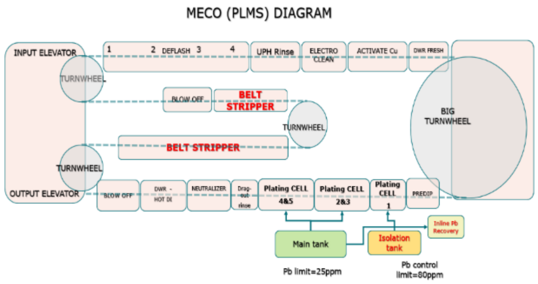


Figure10. Plating Tank Configuration.

Separation of the 1st process cell and the rest of the plating bath is a good innovation by the plating team to minimize the effects of this dissolution. Due to this, Pb contamination are measured on both the isolation and the main tanks. In the initial stage of data gathering, for over a month on 2 separate Plating line machines, a sample of Sn deposit from plated product was collected and analyzed through AAS (Atomic Absorption Spectrophotometer) method. Method used was based in reference to RoHS guidance of analyzing lead (Pb).

3.0 METHODOLOGY

3.1. Define Phase

Independent characteristics are parameters, values or variables that can be adjusted and not affected by other factors in the machine. This paper will show us how we are able to identify different input variables through data correlation, root cause analysis and understanding of machine mechanisms.

3.1.1 Out of Control (OCAP) Occurrences

Whenever abnormalities are detected in the machine, an investigation is conducted to analyze the problem and to provide corrective actions. Based on the OCAP trend (see Fig. 11), machine stoppage is the leading contributor to OCAP hits followed by Plating Thickness OOS.

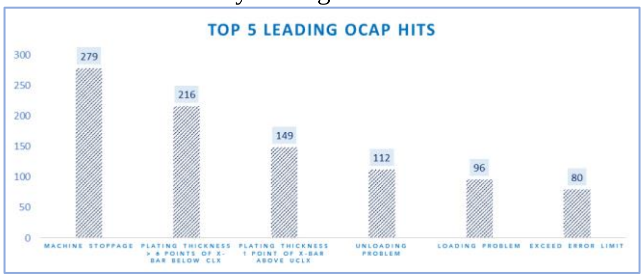


Figure11. Leading OCAP Hits

3.1.2. CHP and MFB Occurrences

Defects like Chip packages and Mold Flashes are commonly detected in various machines. This can be a result of the multiple occurrences of out-of-specs pressure output in a high-pressure water jet pump. The excessive force introduced in the leadframe could potentially chipped out portions of the mold package upon contact. As well as lower pressure fails to remove mold flashes.

3.1.3 Belt Condition

The conveyor belt serves as the connection between the machine and the product during processing in all of the process cells. The quality of the belt dictates many of the interactions between the product and the machine.

3.1.4. Rectifier Current/Voltage Readings

The rectifier supplies the voltage and distributes the current to multiple electrolytic process cells from the pre-treatment to the electroplating process. Disturbances in the rectifier electrical output could result in several defects in the products like flakes, peel-off, or thick/thin plating thickness. One of the top defects caused by an abnormal rectifier output is Peel-off Plating (POPL). Fig. 12 demonstrates rectifier output monitoring.

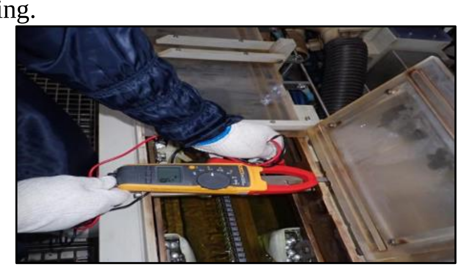


Figure 12. Measurement of rectifier output

3.1.5. Lead (Pb) ppm

Lead ppm is the amount of lead concentration in the plating solution measured daily. This gives a signal when to replace the plating bath. Lead analysis is done at every start of the shift by taking samples of plating solution from the Isolation and Main plating process cells. The current specification limit 250 ppm with a control limit of 200ppm for the Isolation tank and 45 and 50ppm for control and specification limits respectively on the main tank.

Feed and Bleed activity is done when the lead ppm has reached the control limit. This procedure is done by disposing the plating solution in the Isolation tank and replacing it with the plating chemical from the Main tank. The equivalent volume removed from the Main tank will be replenished with new make-up chemicals. Fig. 13 shows the feed the bleed procedure.

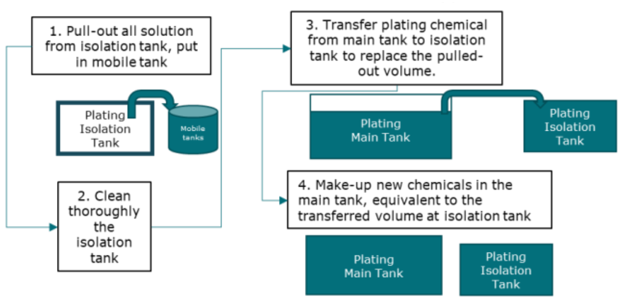


Figure13. Feed and Bleed Procedure Diagram.

3.2. Measure Phase

3.2.1 Water Jet Pressure Reading

The conventional way to monitor HPWJ response is to get the actual pressure output and check the actual output vs. display output to check variations.

“Percent Pump-load” is a feedback display parameter available on a MECO STS machine. This parameter displays how much power is needed by the pump to provide the required pressure. However, it is observed that this pump load can be used as a leading indicator for pressure fluctuations. For example, in Fig. 15, pressure fluctuations is observed on machine with >75% pump load.

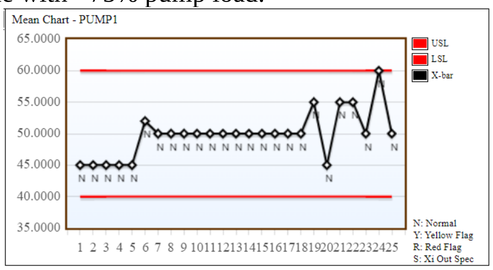


Figure15. High-pressure fluctuations on machine log taken at >75% pumpload

Aside from the pressure fluctuations, it was also identified that higher pump loads will result in the wearing of nozzle diameters (bigger diameter) as shown later in Figure 22.

3.2.2 Belt Width Thickness

Flakes are easily detected upon unloading of leadframes from the machine. These are located on the leadframe pinholes that are clipped in the belt (see Figure 21). This defect could occur when the tin coating does not properly adhere to the surface of the metal. A dirty conveyor belt or incomplete stripping of the belt could cause this defect as the residual tin deposits accumulate over time as they pass through the process cells. These tin deposits are oxidized or contaminated during the Pre-treatment processes. Upon entering the Plating process cells, the plated tin deposits will have poor adhesion with the oxidized tin deposits. When the leadframe is unloaded from the belt, the excess metal adheres to the leadframe producing flakes.

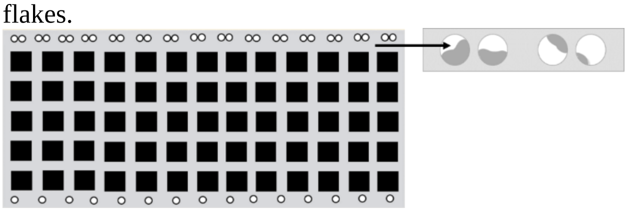


Figure16. Schematic Diagram of flakes on leadframe.

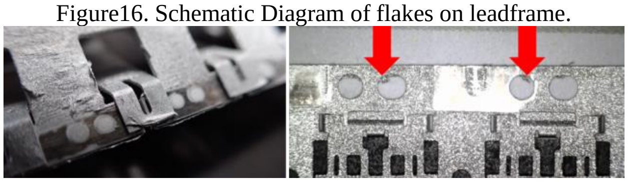


Figure17. Actual image of belt simulated with flakes.

3.2.2.1 Peel-off Plating

Aside from belt flaking, another critical defect associated with the belt thickness is Peel-Off plating. Abnormal thinning of the conveyor belt is a signal of accelerated Galvanic corrosion (see Fig. 18). This can come from stripper process cell shorting. Eventually these micro galvanic corrosion results to a higher surface area of the belt increasing corrosion rate exponentially. Ultimately result to peel-off plating defect will be described later.

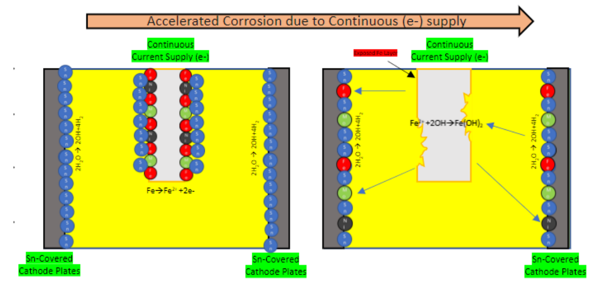


Figure18. schematic diagram of accelerated galvanic corrosion.

3.2.3 Rectifier Voltage and Current

One of the top contributors to Plating Machine downtime was rectifier breakdown. There is little to no signals when these downtimes will occur. Aside from the machine downtime and production delays, rectifier errors would often result in partial lot scrappages due to PTOS.

Most of the time, rectifier breakdowns would start from build-up of corrosion resulting to poor wiring connections and dirty contacts (see Figure 19).

Figure19. Rectifier breakdowns caused by corrosion (Left) vs. No Corrosion (Right)

Looking at the science of electrodeposition, the team used a mathematical expression that identify leading indicators on this problem, these will be further explained in Sec. 3.3.5.

3.2.4 Pb ppm control

The analysis of Pb content on plated products using EDXRF-RoHS is done in parallel with the daily analysis on plating bath using AAS.

Based on the data gathered in Figure 20, with a Pb content of 25 ppm at the Main tank and 120 ppm at the Isolation tank, the Pb deposit on tin-plated products is only around 200 ppm. Third-party analysis also confirmed that the Pb content of the plated leadframe is only around 15% of the RoHS requirement.

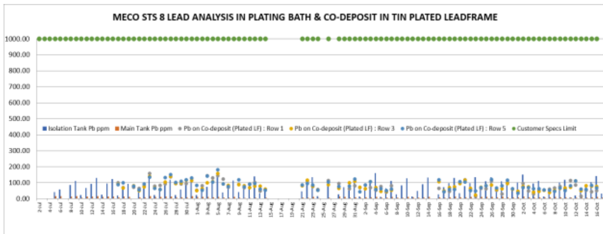


Figure20. Lead Analysis Correlation in Plating Bath vs. Plated Leadframe

This means that the established controls are still far from the RoHS limit of 1000ppm of Pb content.

The objective is to identify correlations of Pb ppm on bath and eventually on the final product. This would improve the efficiency, quality, and cost of producing ATCB parts.

3.3. Analyze Phase

3.3.1. Correlation between Deflash abnormality and pump load

Production line monitoring observed that CHPSB is already observed at >75% pump load, this is because of the ramp-up time of the machine, during these pump load values. The ramp-up time of the deflash allows the packages to be immersed on continuous waterjet bombardment for more than 15 seconds. Pump load correlation data (Fig. 21) suggest that it should be controlled at 75% pump load.

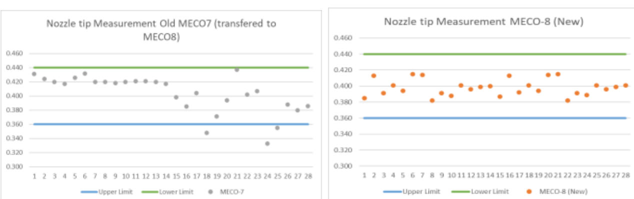


Figure21. Pump load at 78% (Left) vs. Pump load at 62% (right).

Box plot pump load on the above graph identified a clear correlation between the pump load and any deflash abnormality such as clogged nozzles, pump oil issues, and nozzle diameter issues.

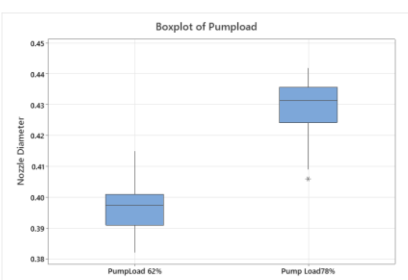


Figure22. Correlation between pump load and Nozzle Diameter

The plating team measured two different set of nozzles new and old. New nozzles with average diameter of 0.4mm resulted to a pump load of 62% while old nozzles with average diameter of 0.45mm exhibits pump load of 78% (Fig. 22). Standard specification of nozzle diameters supplied by FSE should not exceed 10% of the part drawing of 0.40mm.

Control of pump load at less than 75% ensures that the nozzle diameter would not exceed the 10% value of 0.40um. From this correlation of pump load and nozzle diameter, prediction of deflash related rejects is established.

3.3.2. Belt condition

The overall process in Central Plating uses chemicals that are either acidic or basic. In addition, most processes undergo electrolytic chemical reactions that could affect the quality of the belt. The metal surface of the belt is etched by the chemicals over time. The belt experiences fatigue with repeated cycles reducing the integrity of the metal [1]. The current replacement of the belt is scheduled periodically (around 6 months).

Monitoring the belt condition is crucial in the Plating process. If the belt is not properly cleaned or maintained, overtime flakes formation would occur. Accumulated layers of Sn on the belt can also result to a peel-off plating, this is due to oxidized Sn retained on the belt during cycle.

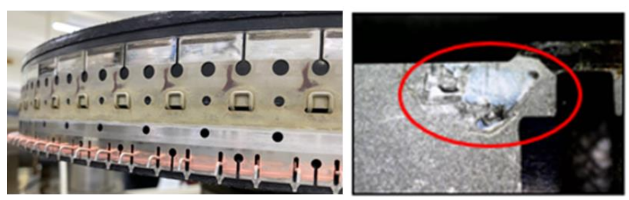


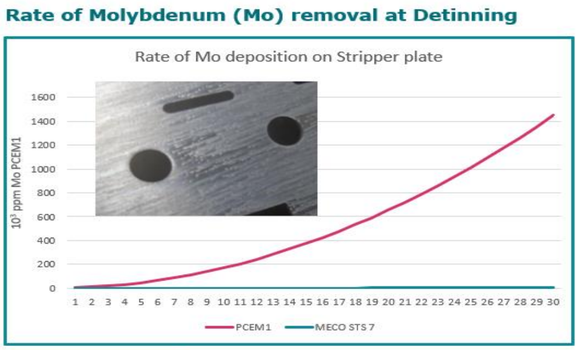
Figure23. Sn Peel-off case in PLCE-001

From the previous cases of Sn peel-off, one of the abnormalities found was the corroded belt due to galvanic corrosion (see Figure 18). The corrosion was caused by current leakage at the Belt Stripper rectifier. A residual current of around 200 mA was detected at the rectifier while the machine was in standby mode, normally current output should be zero (0) at this mode.

Further analysis shows that the amount of Molybdenum stripped from the belt is significantly higher compared to the machine without rectifier leakage current (see Fig. 23). Removal of Molybdenum reduced the corrosion resistance of the belt.

For plating applications, SS316 is used as these are known to have higher chemical resistance compared to SS304. The addition of molybdenum to SS316's chemical makeup improves its resistance to harmful acids and alkalis.

To validate the Mo removal rate, stripper plates was checked for Mo deposition. The high Mo content on the stripper plates, the higher degradation of Mo on the Belt is occurring.



MACHINE	Mo (ppm)	Accumulation Time Hrs	Accumulation Time Days	Rate of accumulation ppm/day	Rate of accumulation ppm/hrs
PCEM1	2200	17	0.708	3105.882	129.412
MECO STS 7	500	720	30	16.667	0.694

Figure24. Rate of Molybdenum deposition at Stripper Plates

In Figure 24, Molybdenum deposition rate on normal conditions is around 16.667 ppm/day. On affected machine (PCEM1) is at 3105.882 ppm Mo/day. This confirms the belt degradation, which removes the chemical resistant properties of the belt.

3.3.3 Pb ppm analysis

Plating bath life determines the trigger in which we change chemicals; these are based on either time of use or particle impurities such as carbon, Sn^{4+}, Pb or other foreign heavy metals present on the plating bath.

Current ATCB capability is to control that Pb content of the Plating bath via Atomic Absorption Spectrometer (AAS).

Figure 25. PG-500 AAS(Left); RoHS XRF (Right).

Pb content on the plating bath is monitored daily. Previous controls were at 25ppm on the main tank and 80ppm on the isolation tank. Once the Pb content reach 25ppm on the main tank and 80ppm on the isolation tank, Bleed & Feed activity is performed to bring down the Pb content on the solution.

Second step of our Pb contamination control will be the implementation of the use of our RoHS X-Ray Fluorescence Spectrometer (XRF) (see Fig. 25). RoHS X-Ray can measure the Pb co-deposition on the product. RoHS limit on co-deposited Pb is < 1000 ppm.

To set a new control limit for lead control, multiple concentrations of lead in the plating bath (100, 150, 200, 250, and 300 ppm) are prepared to determine the effect of Pb deposition on the material. Solder (Pb) from DACA was dissolved to create various Pb concentrations in the plating solution. The results from leg validations as shown in Table 1 is that the isolation tank with a plating solution of 250 ppm is optimum concentration that will deposit an average of 894.7 ppm on plated Leadframes meeting the RoHS requirement.

Batch No.	Pb ppm (Main Tank)	Pb ppm (Iso Tank)	Current Applied	Pb ppm (Product)
MLEC05006100	50	100	175	23.7
MLEC05006300	50	150	250	20.07
MLEC05006400	50	200	175	40.83
MLEC05006500	50	200	350	76.6
MLEC05006600	50	250	250	894.7
MLEC05006700	50	300	350	2451.36

Table1. ETR Run on High Pb Plating solution.

3.3.5 Rectifier monitoring

Electrodeposition Potential or Cell Voltages is the energy required for the plating process to proceed and is stated as:

$$E_D = E_{Rev} + E_{Electrolyte} + E_{Contact} + E_{Irrev}$$

Where:
E_D = Electrodeposition Potential
E_{Rev} = Reversible Potential or Enthalpy
$E_{Electrolyte}$ = Electrolyte Potential
$E_{Contact}$ = Contact Potential
E_{Irrev} = Irreversible Potential or Entropy

Equation1. Electrodeposition Potential

Voltage fluctuations on an electrolytic system can predict variations of each Potentials stated on Eq1. Particularly on the Contact potential. Too high voltage may indicate corrosion on the wires, disconnected copper contacts or possible rectifier life issues. Therefore, monitoring of the voltage is a good leading indicator to predict rectifier abnormalities.

With all of the input variables identified on the Analyze phase, the team implemented monitoring of these variables: (1.) Lead content on Chemical bath and Product (in ppm), (2) Rectifier Voltage and Current actual readout, (3) Deflash pressure and pump load and (4) Belt Thickness.

Item	Parameter	Source	Method/Equipment	Data
Lead Control	Lead content (ppm)	Plating Bath	AAS	Laboratory Analysis
		Plated leadframe	EDXRF-RoHS	
Rectifier Output	Current	Actual readout vs. UI Display	Ammeter / Voltmeter	Machine Health Check
	Voltage			
HPWJ	Pump Pressure	Pressure gauge	Manual checking	
	Pump Load	Machine UI	Manual checking	
Belt Condition	Belt Thickness	Conveyor Belt	Digital Caliper	

Table2. Critical Input Variables

For Lead control, the team implemented measurements on both Pb ppm on Plating Bath using Atomic Absorption Spectrophotometer (AAS) and on the plated product using EDXRF-RoHS machine.

Rectifier voltage and current output are also measured using handheld Ammeter and Voltmeter.

On High Pressure Waterjet, pump load is also implemented. this is measured using machine user interface and actual pressure is monitored using handheld pressure gauges.

Belt thickness is also monitored using a digital caliper.

The defined critical input variables are all monitored through SPC systems with a set of control limits that will trigger a response prior a failure (see Fig. 26).

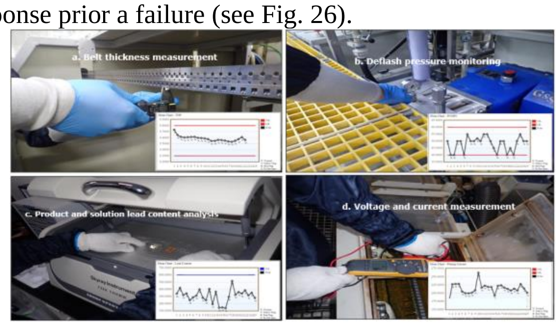


Figure26. Input Variable control monitoring.

3.5. Control Phase

3.5.1 Out-of-Spec or Out-of-Control Notification

Proper specification and control limits were established for the parameters from Table 2. If there are any parameters with out-of-spec (OOS) or out-of-control (OOC), the system generates real-time feedback via alert e-mails (Fig. 27) to concerned personnel for immediate action. Batches processed during the alerts are checked for any defects that are potentially starting to occur.

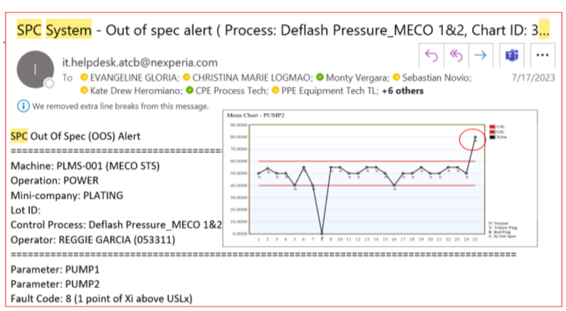


Fig. 27. SPC OOS Auto-alert e-mail

3.5.2 Documentation

To ensure changes and improvement will be sustained, following procedures will be updated; (a). JOV-2G2-40H/2007 Control Plan of Power Leadfinish to reflect special characteristics class (S) and new control method via SPC, (b). JOV-2G1-040/2024 PFMEA of Power Tin Plating MECO STS to include new process control detection and lower risk priority number or RPN, (c). JOV-2G0-99D/3003 WI of Power for Machine Health Check to document proper procedure on checking of defined input variable SPC, and (d). JOV-2G3-040/2088 OCAP of Power Deflash Plating PBO for the new identified controls.

4.0 RESULTS AND DISCUSSION

In SPC control implementation for belt thickness, Peel-off occurrence already zero-out in PLCE-001 from October 2022 to the present (Fig. 28).

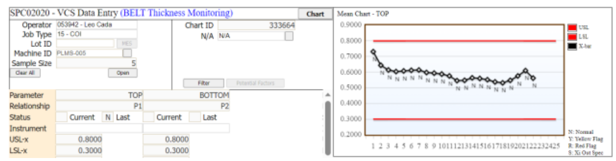


Figure28. Belt Thickness SPC

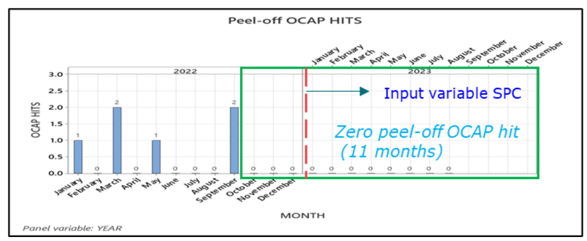


Figure29. PLCE-001 Peel-Off OCAP Monitoring

In the pump load SPC controls implementation of high-pressure pumps, were able to detect 3 occurrences of out-of-spec (OOS) preventing chipped packages (CHP) (Fig. 30).

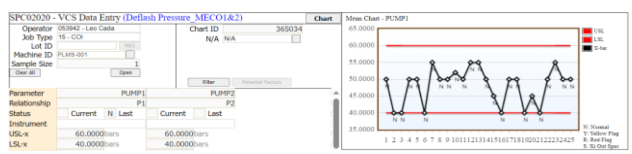


Figure30. Pump load - SPC monitoring chart.

Since the start of SPC monitoring the team observed a significant decrease in CHPSB and deflash related rejects as these are now prevented through pump load monitoring.

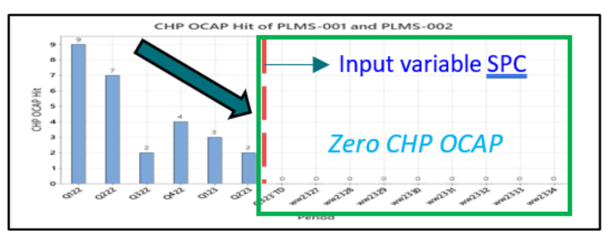


Figure31. OCAP trend for CHPSB

The voltage SPC monitoring for rectifiers can detect rectifier abnormalities, like loose contact and corroded wirings to prevent defects such as flakes from occurring (Fig. 32).

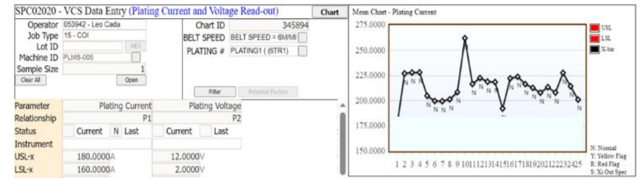


Figure32. SPC monitoring for voltage.

Flake rejects is significantly reduced from 0.218% to 0.136% (Fig. 33).

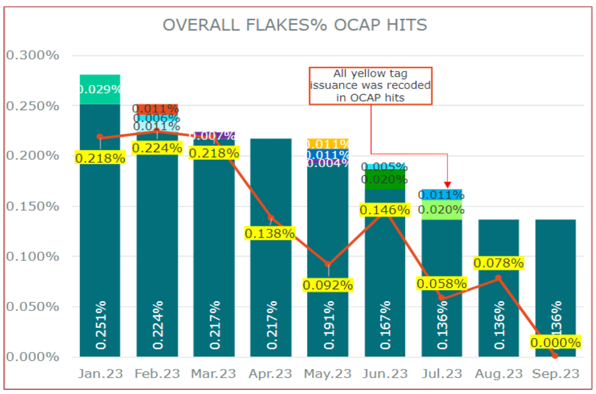


Figure33. Lagging OCAP for Flakes (Test OCAP)

The new control limits set for Lead analysis in plated products and plating baths greatly reduced the Feed and Bleed activities and prevent wastages of chemicals while maintaining the RoHS requirement of <1000 Pb ppm (Fig. 34).

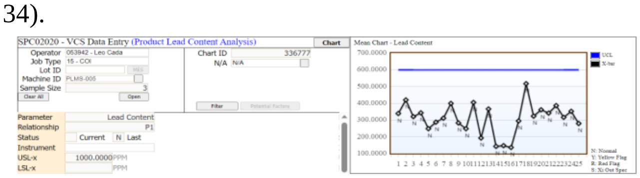


Figure34. SPC monitoring Pb ppm on product.

The monthly cost for chemical consumption is reduced from 47k to 34k USD.

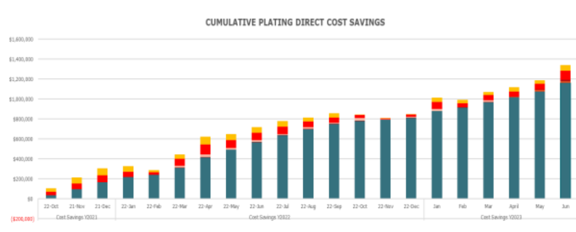


Figure35. Cumulative savings due to Pb control

Cumulative cost savings for ATCB due to the control of Pb control initiative is about $866,649 this is from Oct2021 until 2023, with on-going cost savings initiative up date (Fig. 35).

5.0 CONCLUSION

The inclusion of input variables in the SPC system is an effective approach to detecting leading indicators of process abnormalities. SPC monitoring of lead ppm on product and solution resulted to a significant cost saving in chemical consumption.

SPC can be considered as an additional detection method in the FMEA and improve RPN (risk priority number) rating. Real-time data like EDXRF lead content results and deflash pump load can be automatically encoded to the SPC database.

6.0 RECOMMENDATIONS

The team recommends that the identified input variables such as pump load, belt thickness, Pb ppm measurement and rectifier voltages should be included on FMEA as a critical (S) classification.

Other input variable SPC like chemical concentration, solution temperature, belt speed, nozzle distance, and nozzle tip diameter are to be considered in the next phase of implementation.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

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9.0 ABOUT THE AUTHORS

Sebastian D. Novio is a Senior Process Engineer at Nexperia ATCB. He is one of the first batch of cadet engineers produced by ATCB who had been in plating for 6 years. A certified six sigma green belter. His agility & diligence significantly contributed to overall plating improvement.

He is a BS Chemical Engineering graduate from University of Santo Tomas (España, Manila).

Kate Drew G. Heromiano is a Junior Process Engineer in-charge of the plating laboratory. She supports plating projects for process improvement and cost reduction. An author and co- leader in the success of improving the SPC Plating Thickness Cpk attainment for Clipbonded packages. She is a BS Chemical Engineering graduate from Mapua Malayan Colleges of Laguna (Cabuyao, Laguna)

Leo E. Cada is a Senior Process Engineer at Nexperia ATCB in-charge of process tooling and chemical management. He has 11 years' experience in semiconductor industry seasoned for wet processes, electroplating and plasma etching. Leader in implementing SPC for input variables and machine health checks thus achieving a robust plating process. Also one of the co-lead in reducing chemical waste through plating solution recovery. He is an Electronics and Communications Engineering graduate from Southern Luzon State University (Lucban, Quezon).