Material Variance Reduction Through Six Sigma Approach

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Abstract

Bill of Materials (BOM) is what makes the final product of a semiconductor manufacturing company producing high value RF power devices. Any waste in materials will be translated in material variance that will be reflected in unfavorable financial results. From data gathered in overconsumption of bulk material report, one of the contributors of material variance is AuSn preform used in one of high value products of RF Power device for Mobile Broadband application. The goal of this paper is to reduce the material over consumption as per six sigma approach and that is baseline – 70% (baseline-entitlement). This quantitative approach for the goal of this project will be the basis for waste reduction initiative. The approach or methodology that will be used to reduce material overconsumption will be through Six Sigma DMAIC approach. This will cover Define, Measure, Analyze, Improve and Control phases necessary to set clear project goal (Define) until determination of potential X's or potential causes of over consumption (Measure) until validation (Analyze) going to Improve phase and Control. The expected results after probing all sources of contributors of waste is to provide actions based on each potential causes and monitor the over consumption on weekly and monthly basis. This paper also aims to provide structural approach to prevent material wastage through appropriate controls.

Keywords
Bill of Materials, Six Sigma, AuSn preform, DMAIC approach, Diebond

1. Introduction
Companies worldwide compete against each other to become the choice of the customers. Companies that fail to attract customers will undoubtedly disappear. The price setting of the products is an important factor. From the companies' perspective the price should be set so that an acceptable profit margin can be achieved, preferably it should be set higher. Many manufacturing companies find that it might not always be possible to increase the price in order to increase the profit. Instead, a method could be to increase the profit margin by lowering the cost of manufacturing. One of the more famous concepts for making the production more cost effective is Lean Production. Lean originates from Toyota production system (TPS). One of the creators of TPS, Taiichi Ohno says that the goal with it is to decrease

cost in the production. Taiichi Ohno believes that to increase profit a company should lower the costs through different actions, rather than increasing the price for the customer (Tony Sorensen, Niclas Freijd, 2012).

One part of Lean manufacturing that makes an organization more cost effective is elimination or decreasing waste in the production. In Lean, waste is categorized in to 7 different areas. An example for how the engineers looked at waste at Toyota is that they originally used a mass production system where machines were designed to work only on one product. Toyota engineers saw that when the machine was waiting for parts to process it was just idle. They considered this to be a waste of resources to have machines idling. The Toyota production system developed at Toyota was designed to eliminate waste like this. Other companies also benefit from having this point of view when looking at their production to save resources and become more effective (Tony Sorensen, Niclas Freijd, 2012).

According to NI Business Info.Co.UK, reduce your business waste to save money with the following advantages of reducing waste. Waste is a resource which can lead to greater business productivity if managed correctly. Advantages of waste reduction in your business include shifting from methods of waste disposal to processes of waste reduction can bring a range of key benefits: You can save money through more efficient use of raw materials, packaging and technology. .It allows you to cut your waste disposal costs. Compliance with environmental legislation becomes cheaper and more straight forward. You can improve your reputation among customers, suppliers, potential employees and insurers, who may want to be sure that you take your environmental responsibilities seriously. You may also boost the morale of existing staff. The amount of money you can save by managing waste depends on the nature of your work. For example, a manufacturer will probably be able to save more than an office-based business by reducing the number of raw materials and wastewater in production processes (nibusinessinfo.co.uk)

There are many tools that can be used to reduce manufacturing waste and one of which is Six Sigma initiative. “A Six Sigma initiative is a customer focused problem-solving approach with reactive and proactive improvements of a process leading to sustainable business practices. The sustainable business practices include innovation, improvement, competition, environmental compliance, customer satisfaction, and growth of the organization.” The above definition entails organization to undergo structured problem-solving approach through proper data collection and deliver the expected customer satisfaction. The growth of the organization may be valued in terms of its financial gain, stakeholder confidence, employee retention, productivity, and resource utilization. This definition also warrants the importance and necessity of dedicated people who can improve a process with zero variation and sustain the improvements for a long period of time ensuring the success of a Six Sigma initiative. (K. Muralidharan)

1.1 Objectives

One of the sources of unfavorable factory financial results is material variance and over consumption which led to material planning uncertainty if losses are uncontrolled and even higher factory selling cost (FSC) especially when dealing with high value materials such as AuSn (80% gold and 20% tin) preforms used as die attach material in one of the products in RF Power manufacturing company. The AuSn die attach material is a very important bill of materials in RF Power product and it is coming from single source supplier in the US. Also, the volume is low for this material with no leverage for lower material price negotiation from the supplier which leaves improvement in the consumption in the factory to support cost reduction initiatives considering that RF power devices using AuSn preform is ramping up. In fact, die attach machine was only two (2) upon release in 2019 and became ten (10) by end of 2022 and will become twelve (12) in the middle of Q2 2022 indicating higher volume and higher consumption of AuSn preform material. All sources of waste and over consumption of AuSn preform will be tackled in this paper using DMAIC approach leaving no stones unturned to find all potential causes of material overconsumption with corresponding validation and actions towards improvement and control.

Top 10 items of overconsumption of bulk materials in the factory were taken from recent data from Q4 2021 to Q1 2022. Top 1 was not considered as it has known yield loss issue starting Q4 2021 and with 8D team already setup to address issues related to plating quality of wafer. With this reason, top 2 material was considered for improvement in this paper taking into account all AuSn preform overconsumption and waste. The factory has different types of AuSn preforms that will cater to different die dimension as die attach material. The generic sources of waste and overconsumption can be from yield, component scrap allocation in the system, kitting and material handling, and finally during die attach process itself. These sources will be probed intensively in this paper to come up with related improvements and control. It is therefore the goal of this study to reduce overconsumption on AuSn preform material according to quantitative goal setting from six sigma which is baseline minus 70% of baseline minus entitlement where entitlement is the lowest achieved over consumption of raw materials.

The significance of this material overconsumption reduction project is to contribute to material variance reduction due to high amount per piece of this AuSn preforms amounting to $0.53 to $0.68 which is a significant amount to justify its importance for the factory.

2. Literature Review

Similar study from Hasaan, Mohamed (2013) on Applying Lean Six Sigma for Waste Reduction in a Manufacturing Environment where it also applied Lean Six Siga methodology or DMAIC phases. The five phases of the LSS methodology DMAIC process were implemented in the welding wire manufacturing company. The tools of the LSS methodology enriched the efforts towards waste reduction. Linking AHP for prioritizing the influence of causes on the waste generation and to determine their countermeasures to cure the root causes of the problems. As one of the industrial engineering tools, AHP integration was also a contribution of the current work to increase the effectiveness of such a methodology of LSS. The AHP questionnaires were conducted by the welding wire manufacturing company key persons and their feedback was analyzed to categorize the priorities of the causes of waste. Cause and effect study using the fishbone diagram was used to address the main causes of the waste in the welding wire manufacturing. The 80/20 rule of the Pareto analysis was used to identify the most important causes of waste to deal with.The objective of the company's management was to reduce the waste ratio to be below 4%, which could not be achieved without following a systematic methodology like Lean Six Sigma. LSS was proved to be a valuable tool in the case of systematic waste reduction objectives. Integrating LSS with other statistical tools could extend its effectiveness and sustain the improvements obtained as in the case of applying the quality plan tool.

Another study from Pandey Abhishek, Jain, K.K(2016), Implementation of Six Sigma and Other Cost Reduction Techniques for Improving Quality in Selected Manufacturing Industries found that In the manufacturing industries the major concern is to optimize the quality of product and production cost. This problem can be reduced by using various techniques. The Six Sigma technique is mostly used to enhance the quality of product, reduce cost and process improvement for the manufacturing industries. This paper identifies the different quality and cost reduction techniques used in selected industries and also find out various processes which reduces source of variation and improves quality and productivity, results increase in customer satisfaction.

From Desale, Sunil, Deodhar, Sharad (2013), Identification and Eliminating Waste in Construction by Using Lean and Six Sigma Principles, explored the principle of lean and six sigma for identification and illumination of waste in construction organization. Efficient material management is essential in managing a productive and cost-effective site. In this working career, the author has been observing inefficient labour productivity practices, resulting from poor site material management, and handling. In this paper, therefore an attempt has been made to rectify these activities and construction organization. Primary objective of the study is to derive the reasons contributing to the amount of material wasted on residential building sites, which needs to bring down substantially by devising suitable method. A case study follows that demonstrates, how lean thinking and six sigma principles, tools and techniques be applied to a public and semi government authorities.

From Asgar et.al (2013), Six Sigma was a technique developed in 1985 by Bill Smith of Motorola. Six Sigma is a business improvement methodology that increases profits and delivers value to customers by focusing on the reduction of variation and elimination of defects with the help of various statistical, data-based tools and techniques. Whereas, Lean methodology is a business transformation technique which was derived from the Toyota Production System (TPS) which focuses on increasing customer value by reducing the cycle time of product and service delivery through the elimination of all forms of waste and unevenness in the workflow. The concept of Lean Six Sigma is a combination of both the Lean and Six Sigma. The aim of the authros is to define the meaning and basic principles of Process Improvement Techniques. For this purpose, Process Improvement Techniques focuses on Lean, Six Sigma and combined approach as Lean Six Sigma. These techniques have been used in various sectors like private sector, manufacturing and service organizations for many years.

From Bhaskar, et al (2020), Lean Six Sigma is a combination of two powerful process improvement methods: Lean and Six Sigma. It decreases organization's costs by removing "Waste" from a process and solving the problems caused by a process. Lean Six Sigma (LSS) is an emerging extremely powerful technology which is used to identifying and eliminating waste, improving the performance, efficiency and customer satisfaction to sustain in competitive manufacturing and nonmanufacturing environment. The identified lean six sigma tools and techniques, methodologies, frameworks, success and failure factors and strategies can be effectively used as a roadmap in manufacturing sector. This is also identified that the LSS has been implemented worldwide and in all type of manufacturing organizations for achieving the excellence. They have been successfully achieved their LSS objectives.

3. Methods

The framework of this study is anchored on Input, Process, Output (IPO) described in Figure 1 where input is the data on over consumption of AuSn preform from Q4 2021 to Q1 2022 while processes involved Define, Measure, Analyze, Improve and Control and output is data on overconsumption of AuSn preform after undergoing six sigma methodology to reduce over consumption.

INPUT	PROCESS					OUTPUT
	SIX SIGMA METHODOLOGY					
	Define (1)	Measure (2)	Analyze (3)	Improve (4)	Control (5)	
Consumption of AuSn preform (Q4 2021 to Q1 2022)	Business Case	Macro Map	FMEA	Summary of Critical X's	Updated FMEA	Reduction on consumption of AuSn preform (after)
	Project Selection	PFD	Validation Plan	Plan for DoE	Control Plan	
	Project Description	IO Worksheet	Graphical Analysis	DOE	PTAP	
	Project Scoping	C&E Analysis	Correlation & Regression	Metrics Tracker	Metrics Update	
	Project Charter	Quick Wins	Hypptheis Test		Financial Calcualtion	
	Cost Savings	MSA	Metrics Tracker			
		Process Capability				

Figure 1. Input-Output-Process (IPO)

Six Sigma Methodology is summarized and illustrated in Figure 1 under Process with detailed steps under each phase. Methodologies used in this paper is clear cut from Six Sigma which is DMAIC approach. D for Define, M for Measure, A for Analyze, I for Improve and C for Control.

Define Phase starts with high level determination of issues that contributed to material losses where 2nd highest contributor from Q4 2021 to Q1 20222 was considered in the selection of the project, until clear scope and problem statement and goal was identified. Define phase identified business case, project selection, project scope, project impact and project metric.

Measure Phase includes process mapping (macro and micro), input and output matrix, cause and effect analysis, potential X’s prioritization, quick wins, Measurement System Analysis (MSA), determine process capability and review objective statement.

Analyze phase includes detailed Failure Mode and Effect Analysis (FMEA) on potential X’s, providing validation plan on critical X’s filtered from FMEA then provide metrics tracker.

Improve phase include validation of impact of critical X’s and improvement plans while Control phase includes making sure that actions are documented, deployed to all stakeholders and process owners are empowered to monitor improvement actions identified and provide savings calculation.

According to study published by Abhishek Pandey, Dr. K. K. Jain (2016) in Figure 2 to further explain DMAIC approach. Define Phase includes definition of goals and objectives, customer critical requirements, define team roles and responsibilities and define process mapping and business flow. Measure Phase includes measurement of opportunity for improvement and performance and analyze and compare data to determine issue and shortfalls. Analyze phase includes determination of the variation in the process and analyze cause and defect of source of variation. Improve phase includes process to eliminate variation and develop creative and enhanced plan. Finally, Control phase includes control process variation to satisfy customer requirements and develop strategy to monitor and control the improvement process.

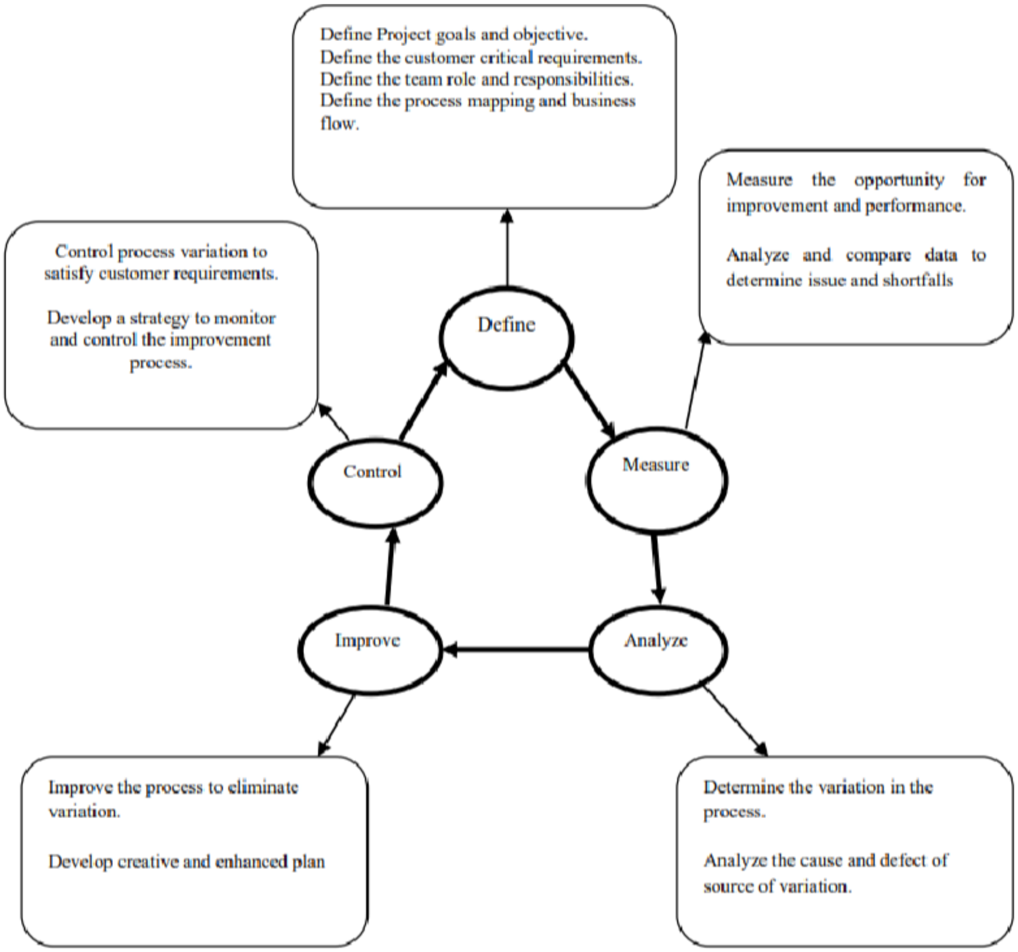


Figure 2. DMAIC Approach

As per Banuelas, et al (2005), The main focus of Six Sigma is to reduce potential variability from processes and products by using a continuous improvement methodology, which follows the phases: define, measure, analyze, improve and control. This approach is known as DMAIC methodology and is employed in tackling problems associated with existing processes/products.

3.1 Data Collection

Source of data coming from actual material overconsumption data of a company manufacturing RF and RF power products. It is summarized in from data on Table 1, top 2 contributor of higher cost of over consumption is Preform AuSn and when added with top 10 contributor will result to 89.6KUSD only for 6 months of production from October 2021 to March 2022.

Table 1. Top Contributors of Material Overconsumption

	Top 10 Items - Overconsumption Cost			
	Material	**Material Description**	**Total Bulk Materials**	
1/	332296304181	ACP3+ SOT125X flange	$	(156,806)
2/	339921090362	Preform AuSn 5.735 x 0.985 x 0.012	$	(68,405)
3/	332202997231	DIE ATTACH FILM CDF515P8C8	$	(58,237)
4/	332296303571	RF SOT1275 SW0800-6V6 RJR	$	(53,894)
5/	342213600060	Cover Tape PUA0495-300 (56mm)	$	(49,552)
6/	342213500652	CT,PS,SOT1120B3,W44P28L40,RLSR	$	(47,133)
7/	342213600059	COVER TAPE PUA0375-300 PSA	$	(36,964)
8/	340010001282	CAR TAPE OMP V2 CT W44 P28 30.51x21.3	$	(34,493)
9/	342213500505	BAG 483X400(SMD)	$	(23,965)
10/	339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	$	(21,238)
	Total - (Top 10)		**$**	**(550,687)**
	Top 10 as % of Total Overconsumption			**68.35%**
	Total - YTD Overconsumption		**$**	**(805,657)**

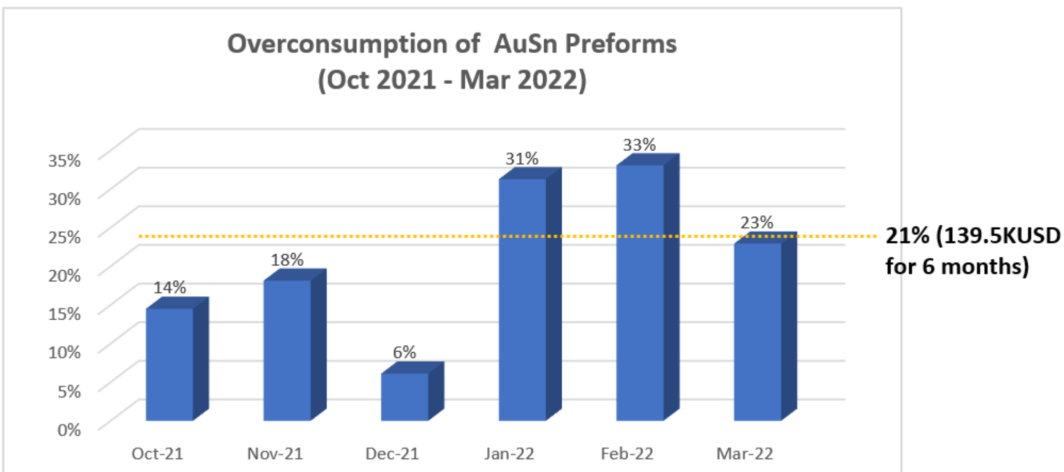


Figure 3. 4 Types AuSn Preforms Overconsumption

All the rest of four (4) AuSn preform types were combined in Figure 3 to come up with 139.5KUSD overconsumption or financial losses for 6 months from October 2021 to March 2022. If not reduced, the losses will continue even during production ramp up.

4. Results and Discussion

Starting with Define (D) Phase, AuSn preform was already selected based on financial result on material over consumption, further digging of data in SAP system was done to get all AuSn preforms and included to over consumption where each preform has target quantity derived from the calculated quantity to be issued to production while actual quantity is the actual consumption. By comparing target quantity with actual consumption can result to over or under consumption in percentage (%). In the case of October 2021 to March 2022 in Figure 4, overconsumption of AuSn preform was from as low as 6% to arrive at the entitlement, while 21% as the average or baseline overconsumption. For the goal, it is computed as in Equation 1, where calculated goal is 11% so improvement will be from 21% to 11% with 10% improvement on AuSn preform material over consumption.

Goal = Baseline – 70% (Baseline – Entitlement) (Equation 1)

Goal = 21% - ((70% (21% - 6%)) = 11%

Therefore, the goal of this paper is to reduce over consumption of AuSn preform to 11% and below through Six Sigma methodologies.

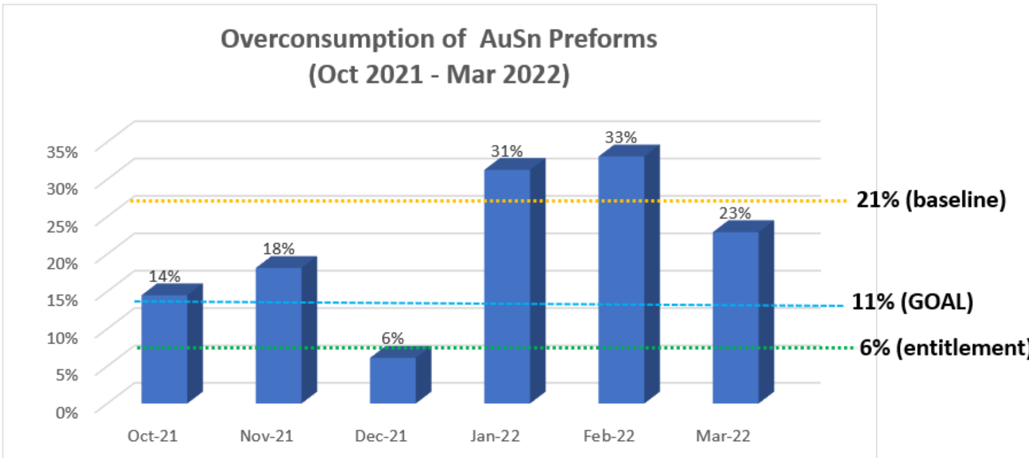


Figure 4, Baseline, Entitlement and Goal

Under Define Phase, project scope is defined from Planning of materials, Material Kitting from issuance of AuSn preform until Diebond process only as AuSn preform is already consumed at Diebond process used as die attach interface to bond active dice to heatsink or flange. Define phase is summarized in a project charter from Figure 5. It started with a business case where material over consumption report included AuSn preform in top 10 contributing to 139KUSD for 6 months as also stated in the Problem Statement. Objective Statement is to reduce over consumption of AuSn preform from October 2021 to March 2022 by 10% (21% to 11%) by end of May 2022 and that there will be no consequences on die attach or diebond quality and yield. Estimated cost savings is at 10% reduction valued at 152.5KUSD as validated by Finance Controller.

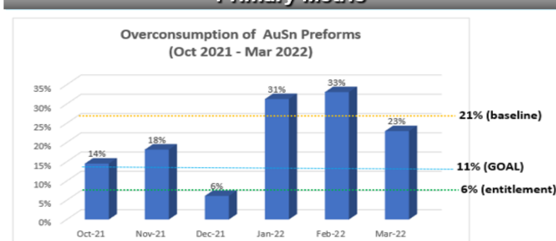
Business Case

From Q4 2021 to Q1 2022, top 10 raw materials with over consumption have both AuSn preforms on top 2 and top 10

Problem Statement

There was 21% over consumption on 4 types of AuSn preform material found at Diebond station from October 2021 to March 2022

Primary Metric



Objective Statement

Reduce over consumption of AuSn preform die attach material at Diebond station from October 2021 to March 2022 from 21% to 11% by wk2228.

Project Scope

The project will cover activities related to planning of materials, withdrawal and issuance of AuSn preform until actual usage at Diebond.

Project Schedule

Phase	Define	Measure	Analyze	Improve	Control
WK	WW2215	Wk2216	wk2218	Wk2219	wk2222

Consequential Metric

No effect on die attach quality, yield

Project Benefit

Calculated cost savings at 10% reduction at 152.5KUSD

Team

- Marilou Agapay-Project Owner
- DB Assembly Process Engineer
- Kitting Supervisor/Process Owner
- Equipment Maintenance Engineer
- Production Supervisor
- Process Systems
- Material Planner

Approvers

Project Champion
Operations Head

Finance Rep
Finance Controller

Coach
Master Blackbelt

Process Owners
Engineers, Supervisors

Figure 5. Project Charter under Define Phase

Measure Phase starts with Macro Map in Figure 6, where process starts at Material Planning, Incoming Quality Inspection, Material Kitting and Diebond.

Figure 6. Macro map

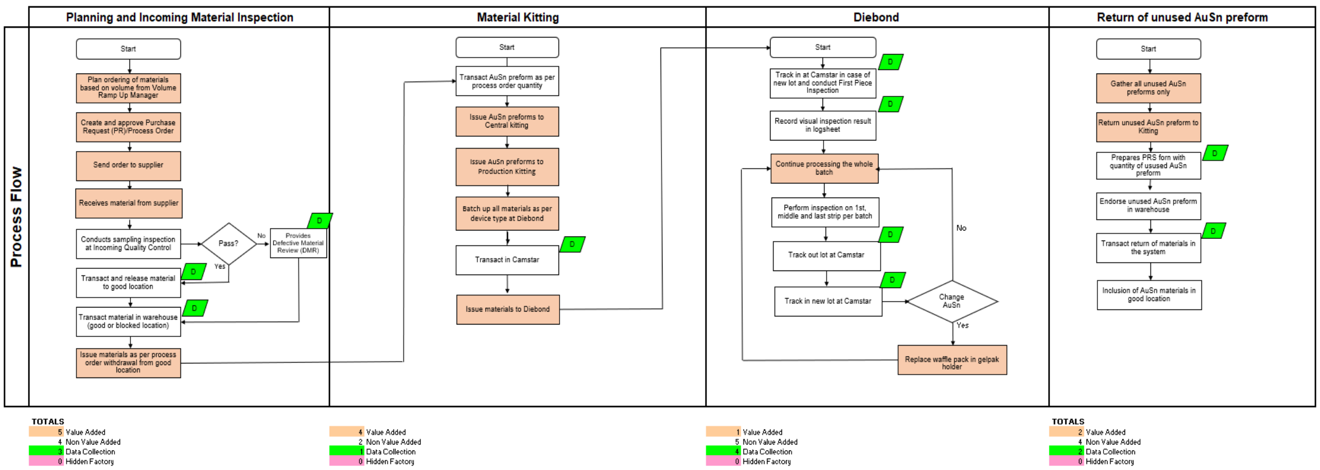


Figure 7. Process Flow Diagram (PFD)

Next step is to provide detailed Process Flow Diagram (PFD) per macro step as shown in Figure 7. Under Planning of Material, it starts with plan to order materials based on volume from Volume Ramp Up Manager followed by completion of Purchase Request (PR) and Purchase Order (PO) until order is sent to supplier and finally material is received in the factory. Upon receipt of material, Incoming Quality Control (IQC) Inspector conducts sampling inspection followed by transaction and release of material to good location in the system and in warehouse followed by transaction of material in warehouse both in good and blocked location for material lots that did not pass IQC criteria. Last step is to issue materials as per process order withdrawal from good location only. Under Material Kitting, first step is to transact AuSn preform as per process order quantity, followed by issuance of AuSn preform to Central Kitting, issuance of AuSn preforms to Production Kitting, followed by batch up all materials as per device type at Diebond, followed by transaction in Camstar (Manufacturing Execution System) and last step is to issue materials at Diebond.

At Diebond process with continuous production, track in at Camstar in case of new lot and conduct First Piece Inspection, records visual inspection result in logsheet, then whole batch or lot will continue processing, perform inspection on first, middle and last strip per batch, followed by track out lot at Camstar. If need to change waffle pack of AuSn preform, it will be replaced every 108 pieces per waffle pack.

New process which started only this year 2022 is to return unused AuSn preforms starting with gathering all unused AuSn preform only, return unused AuSn preform to Kitting, prepares Production Return Slip (PRS) form with quantity of unused AuSn preform, endorse unused AuSn preform in warehouse, followed by transaction of returned materials in the system and last step is inclusion of AuSn materials in good location.

After process flow diagram (PFD), value stream mapping is also included where value added activities were identified and these are activities where customers are willing to pay for while non-non-value-added activities are those activities where customers are not willing to pay for. Data collection was also identified in the PFD including hidden factory where activities are not documented in the process. Next activity is to provide the Input/Output (I/O) worksheet from detailed process flow including identification if value or nonvalue added, reference documents per step, type of input, name of input, characteristics of inputs, specifications or detailed requirements and any error or deviation from specifications that can contribute to problem. At the end of this exercise, factors will be determined that can contribute to over consumption of AuSn preform as shown in Table 2. For the major process on planning of material and incoming material inspection, process steps such as plan ordering of AuSn materials based on volume from Volume Ramp Up Manager qualified as Value Added. Reference is Work Instruction (WI) for Material Planning, type of input is Man, name of Input is Material Planner, characteristics of input is correct material planning, specifications is as per volume and material requirements. Factor that can contribute to the problem or any error or deviation from specifications that can contribute to problem is that more orders of AuSn may be placed versus available wafers. Other steps under Material Planning and Incoming Quality Control (IQC) inspection are in Table 2. One of the steps under Material Kitting is to issue materials to Die attach or Diebond with bill of materials (BOM) issued such as flanges, dice and AuSn preforms to complete die attach process. This is considered as value added activity guided by Work Instruction (WI) for Material Kitting with type of input under Man specific to Material Kitting personnel. Characteristics of input is correct issuance of materials and quantity where specification is according to correct quantity and material type. Factor that can contribute to the problem is wrong material and batch quantity issued. Next major process is died attach or die bond where bill of materials is used to attach die into the flange using AuSn preform as die attach material using an automatic die attach equipment with pulse heating stage. The pulse heating stage enables curing of AuSn preform to form an interconnect on backside of die. AuSn preform with specific dimension is placed in waffle pack and packed in a moisture barrier bag (MBB) with argon and will be opened right before using it. Also, there will be excess AuSn preforms since packing quantity (PQ) is not matched with the quantity of dice in gopak and the batch quantity which is at 96 pieces due to ring frame attach with 16 units in a strip with total 6 strips in one lot or batch. In the flow, return of excess AuSn preform materials was included though not done religiously. This will be further elaborated in Analyze phase. AuSn materials to be returned should still be in the original packing material since opening the package will already create oxidation in the material.

Fishbone or Ishikawa diagram is included as another methodology to find potential factors or potential Xs to leave no stones unturned as shown in Figure 8. Some of the factors identified were expired preforms, damaged preforms as received, IQC rejects, no concession of expired preforms, high component scrap, and dislodged preforms after opening of waffle pack under Material. Missing AuSn preform or spit out and frequent SCAT failed under Machine. Mishandling of AuSn preforms, no manpower to collect unused preforms and unused AuSn preforms not returned under Man while low yield under Method and wrong measurement causing low yield under Measurement.

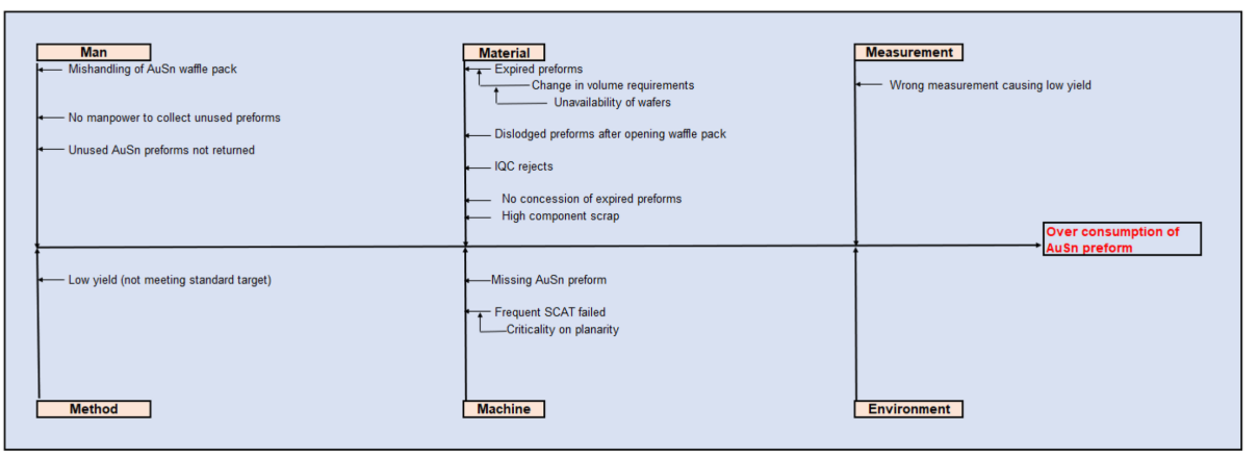


Figure 8. Ishikawa Diagram

Table 2. Input/Output Worksheet

Major Process	PROCESS STEP	VA/NVA	REFERENCE	TYPE OF INPUT	NAME OF INPUT	CHARACTERISTICS OF INPUT	SPECIFICATIONS	FACTOR THAT CAN CONTRIBUTE TO THE PROBLEM
		Value Add activity is an activity that the customer is willing to pay for	Reference document MWI, Vital Points, Specification Manual	Things necessary to perform the activity to produce the output	Please specify e.g. jig name, etc.	Features of the Input to ensure that the process will have the desired output	Detailed requirement e.g. dimension, etc.	any error or deviation from specifications that can contribute to problem
Planning of Material and Incoming Quality Control IIQC)	Plan ordering of materials based on volume from Volume Ramp Uo Manager	VA	WI for Material Planning	Man	Material Planner	correct material planning	As per volume and material requirements	More orders of AuSn vs. available wafers
	Create and approve Purchase Request (PR)/Process Order (PO)	VA	WI for Material Planning	Man	Material Planner	correct material planning	As per volume and material requirements	More orders of AuSn vs. available wafers
	Send order to supplier	VA	WI Procurement	Man	Purchasing	correct material descritpion and qty,	As per volume and material requirements	More orders of AuSn vs. available wafers
	Receives material from supplier	VA	WI Warehouse	Man	Warehouse personnel	correct material descritpion and qty,	As per volume and material requirements	More orders of AuSn vs. available wafers
	Conducts sampling inspection at Incoming Quality Control	NVA	WI IQC	Man	IQC Inspector	Pass quality requirements	As per visual and dimensional requirements	Over rejection or under rejection from IQC
	Transact and release material to good location	NVA	WI IQC	Man	IQC Inspector	Correct transaction	As per transaction requirements	Wrong transaction going to blocked location
	Transact material in warehouse (good or blocked location)	NVA	WI IQC		Warehouse personnel	Correct transaction	As per transaction requirements	Wrong transaction going to good or blocked location
	Issue materials as per process order withdrawal from good location	VA	WI Warehouse	Man	Warehouse personnel	Correct issuance of materials	As per material and qty requirements	Wrong issuance of materials
	Provides Defective Material Review (DMR)	NVA	WI Warehouse	Man	IQC Inspector	Correct transaction of defective materials	As per IQC criteria	Wrong transaction of materials
Material Kitting	Transact AuSn preform as per process order quantity	NVA	WI for material withdrawal-Generic	Man	Warehouse personnel	Correct transaction	As per correct qty and material type	Wrong quantity of materials
	Issue AuSn preforms to Central kitting	VA	WI for material withdrawal-Generic	Man	Warehouse personnel	correct materia issuance	As per correct qty and material type	Wrong issuance of materials
	Issue AuSn preforms to Production Kitting	VA	WI for material withdrawal-Generic	Man	Central Kitting	correct materia issuance	As per correct qty and material type	Wrong issuance of materials
	Batch up all materials as per device type at Diebond	VA	WI for material withdrawal-Generic	Man	Production Kitting	Correct material and batch qty	As per correct qty and material type	Wrong material and batch quantity
	Transact in Camstar	NVA	WI for material withdrawal-Generic	Man	Production Kitting	Correct material and batch qty	As per correct qty and material type	Wrong material and batch quantity
	Issue materials to Diebond	VA	WI for material withdrawal-Generic	Man	Production Kitting	Correct issuance of materials and qty	As per correct qty and material type	Wrong material and batch quantity
Production-Diebond	Track in at Camstar in case of new lot and conduct First Piece Inspection	NVA	WI MRSI for GaN ACP2	Man	Operator	Correct transaction in MES	As per reuirement in MES	Wrong FPI causing low yield
	Record visual inspection result in logsheet	NVA	WI MRSI for GaN ACP2	Man	Operator	Correct recording of visual rejects	As per visual inspection criteria (Diebond related)	Wrong recording of visual rejects
	Continue processing the whole batch	VA	WI MRSI for GaN ACP2	Man	Operator	Correct processing of lot	As per WI and product requirement	Low yield
	Perform inspection on 1st, middle and last strip per batch	NVA	WI MRSI for GaN ACP2	Man	Operator	Meet visual criteria	As per WI and product requirement	Wrong recording of visual rejects
	Track out lot at Camstar	NVA	WI MRSI for GaN ACP2	Man	Operator	Correct transaction in MES	Track in and out at Camstar per lot	Failure to record lot at Camstar
	Track in new lot at Camstar	NVA	WI MRSI for GaN ACP2	Man	Operator	Correct transaction in MES	Track in and out at Camstar per lot	Failure to record lot at Camstar
	Replace waffle pack in gelpak holder	VA	WI MRSI for GaN ACP2	Man	Operator	Correct AuSn material	As per WI and product requirement	Mishandling of AuSn preform
Return unused preforms	Gather all unused AuSn preforms only	VA	No WI yet	Man	Team Lead/Supervisor	Correct quantity usage	As per agreement on return of materials	Failure to gather unused AuSn preforms
	Return unused AuSn preform to Kitting	VA	No WI yet	Man	Team Lead/Supervisor	Correct quantity usage	As per agreement on return of materials	Failure to return unused AuSn preforms
	Prepares PRS forn with quantity of unused AuSn preform	NVA	No WI yet	Man	Production Kitting	Correct quantity usage	As per agreement on return of materials	Failure to prepare PRS form
	Endorse unused AuSn preform in warehouse	NVA	No WI yet	Man	Production Kitting	Correct quantity usage	As per agreement on return of materials	Failure to endorse materials in the system
	Transact return of materials in the system	NVA	No WI yet	Man	Warehouse personnel	Correct transaction	As per agreement on return of materials	Failure to return materials in the system
	Inclusion of AuSn materials in good location	NVA	No WI yet	Man	Warehouse personnel	Correct location at warehouse	As per agreement on return of materials	Failure to include unused AuSn preform in good location

Cause and Effect (C&E) matrix in Table 3 was also provided to include all factors from Input and Output (IO) matrix with scoring criteria to be considered as potential factors or potential X's. Scoring criteria used is zero (0) as no impact, 1 as mild or negligible impact, 3 moderate impact and 9 as major or severe impact. Each item is rated by the team in order to filter the potential factors which will be further filtered in the Analyze phase. C&E matrix is further summarized in Table 4.

Table 3. Cause and Effect Matrix

Scoring:
0 no impact
1 mild/negligible impact
3 moderate impact
9 major/severe impact

Outputs related to the problem: Over consumption (1)
Priority: 10

PROCESS STEP	Type of Input	Name of Input	Characteristic of Input (G)	Specifications	Over consumption	Total	Status
Plan ordering of materials based on volume from Volume Ramp Up Manager	Man	Material Planner	correct material planning	As per volume and material requirements	9	90	selected
Create and approve Purchase Request (PR)/Process Order (PO)	Man	Material Planner	correct material planning	As per volume and material requirements	0	0	discard
Send order to supplier	Man	Purchasing	correct material descritpion and qty,	As per volume and material requirements	0	0	discard
Receives material from supplier	Man	Warehouse personnel	correct material descritpion and qty,	As per volume and material requirements	0	0	discard
Conducts sampling inspection at Incoming Quality Control	Man	IQC Inspector	Pass quality requirements	As per visual and dimensional requirements	1	10	discard
Transact and release material to good location	Man	IQC Inspector	Correct transaction	As per transaction requirements	0	0	discard
Transact material in warehouse (good or blocked location)		Warehouse personnel	Correct transaction	As per transaction requirements	0	0	discard
Issue materials as per process order withdrawal from good location	Man	Warehouse personnel	Correct issuance of materials	As per material and qty requirements	0	0	discard
Provides Defective Material Review (DMR)	Man	IQC Inspector	Correct transaction of defective materials	As per IQC criteria	0	0	discard
Transact AuSn preform as per process order quantity	Man	Warehouse personnel	Correct transaction	As per correct qty and material type	0	0	discard
Issue AuSn preforms to Central kitting	Man	Warehouse personnel	correct materia issuance	As per correct qty and material type	0	0	discard
Issue AuSn preforms to Production Kitting	Man	Central Kitting	correct materia issuance	As per correct qty and material type	0	0	discard
Batch up all materials as per device type at Diebond	Man	Production Kitting	Correct material and batch qty	As per correct qty and material type	9	90	selected
Transact in Camstar	Man	Production Kitting	Correct material and batch qty	As per correct qty and material type	0	0	discard
Issue materials to Diebond	Man	Production Kitting	Correct issuance of materials and qty	As per correct qty and material type	0	0	discard
Track in at Camstar in case of new lot and conduct First Piece Inspection	Man	Operator	Correct transaction in MES	As per reuirement in MES	0	0	discard
Record visual inspection result in logsheet	Man	Operator	Correct recording of visual rejects	As per visual inspection criteria (Diebond related)	0	0	discard
Continue processing the whole batch	Man	Operator	Correct processing of lot	As per WI and product requirement	0	0	discard
Perform inspection on 1st, middle and last strip per batch	Man	Operator	Meet visual criteria	As per WI and product requirement	0	0	discard
Track out lot at Camstar	Man	Operator	Correct transaction in MES	Track in and out at Camstar per lot	0	0	discard
Track in new lot at Camstar	Man	Operator	Correct transaction in MES	Track in and out at Camstar per lot	0	0	discard

Table 4. Selected from C&E Matrix

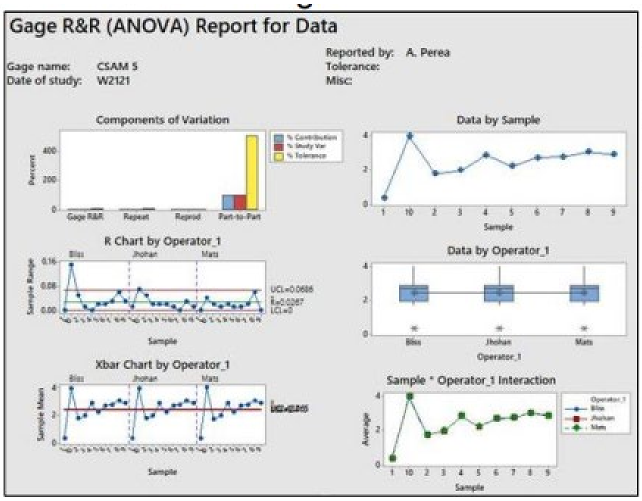
Scoring:
0 no impact
1 mild/negligible impact
3 moderate impact
9 major/severe impact

Outputs related to the problem: Over consumption (1)
Priority: 10

PROCESS STEP	Type of Input	Name of Input	Characteristic of Input (G)	Specifications	Over consumption	Total	Status
Plan ordering of materials based on volume from Volume Ramp Up Manager	Man	Material Planner	correct material planning	As per volume and material requirements	9	90	selected
Batch up all materials as per device type at Diebond	Man	Production Kitting	Correct material and batch qty	As per correct qty and material type	9	90	selected
Replace waffle pack in gelpak holder	Man	Operator	Correct AuSn material	As per WI and product requirement	9	90	selected
No manpower to collect unused preforms	Man	Team Lead/Supervisor	Correct handling of preforms	As per material return	9	90	selected
Unused AuSn preforms not returned	Man	Team Lead/Supervisor	Correct handling of preforms	As per material return	9	90	selected
Low yield (not meeting standard target)	Method	Production	Meeting yield target	As per yield target	9	90	selected
Expired preforms	Material	Material Planner	Correct planning	As per volume and material requirements	9	90	selected
Dislodged preforms after opening waffle pack	Material	Kitting	Correct material	As per QDS	9	90	selected
High component scrap	Material	Material Planner	Correct component scrap	As per system requirements	9	90	selected
Missing AuSn preform (spit out)	Machine	Diebond machine	Correct pickup	As per WI and product requirement	9	90	selected

Table 4 from C&E matrix has selected ten (10) out of 39 items 4) as potential factors or potential X's. These are plan ordering of materials, batch up of materials as per device type for Diebond or Die attach, replace AuSn waffle pack with new one, no manpower to collect unused AuSn preforms, unused AuSn preforms not returned, low yield or not meeting standard target yield for 2022, expired preforms, dislodged preforms after opening waffle pack, high component scrap factor and missing AuSn preform or spit out or sometimes called poor pick up. As some of the potential X's may be duplicates, this will be filtered in next steps under Analyze phase. Next step is to provide Measurement System Analysis (MSA) where applicable. In this case, there is no direct measurement system but overconsumption of AuSn preform is affected by Scanning Acoustic Tomography (SCAT) since it has major impact on yield which will then affect consumption of AuSn preforms. Figure 9 showed MSA of both SCAT machine and disposition for pass and fail criteria of voids percentage through Attribute MSA.

Under Measure Phase, Measurement System Analysis was done on the measurement system to measure voids percentage. Result of %SV of CSAM and SCAT is 2.28 with 61 ndc which suggests that CSAM or SCAT can be used for screening die attach voids in Figure 9.



Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.021893	0.13136	2.28	11.67
Repeatability	0.021678	0.13007	2.26	11.56
Reproducibility	0.003062	0.01837	0.32	1.63
Operator_1	0.003062	0.01837	0.32	1.63
Part-To-Part	0.960875	5.76525	99.97	512.42
Total Variation	0.961124	5.76675	100.00	512.55

Number of Distinct Categories = 61

Figure 9. Measurement System Analysis (SCAT Machine)

For Measurement System Analysis or Attribute MSA, showed that there is 95% confidence interval on all appraisers versus standard. It matched all appraisers' assessment and agreed with each other in Figure 10.

Attribute Agreement Analysis

Attribute Agreement Analysis for 1, 2, 3, 4, 5, 6, 7, 8, 9

Date of study: 20 Aug 2021
Reported by: Rey Lucanas
Name of product: ACP2 Gan
Misc: Voids Visual Check

Within Appraisers

Assessment Agreement

Appraiser	# Inspected	# Matched	Percent	95% CI
1	30	30	100.00	(90.50, 100.00)
2	30	30	100.00	(90.50, 100.00)
3	30	30	100.00	(90.50, 100.00)

Matched: Appraiser agrees with him/herself across trials.

Fleiss' Kappa Statistics

Appraiser	Response	Kappa	SE Kappa	Z	P(vs > 0)
1	F	1	0.105409	9.48683	0.0000
	P	1	0.105409	9.48683	0.0000
2	F	1	0.105409	9.48683	0.0000
	P	1	0.105409	9.48683	0.0000
3	F	1	0.105409	9.48683	0.0000
	P	1	0.105409	9.48683	0.0000

Each Appraiser vs Standard

Assessment Agreement

Appraiser	# Inspected	# Matched	Percent	95% CI
1	30	30	100.00	(90.50, 100.00)
2	30	30	100.00	(90.50, 100.00)
3	30	30	100.00	(90.50, 100.00)

Matched: Appraiser's assessment across trials agrees with the known standard.

Between Appraisers

Assessment Agreement

# Inspected	# Matched	Percent	95% CI
30	30	100.00	(90.50, 100.00)

Matched: All appraisers' assessments agree with each other.

Fleiss' Kappa Statistics

Response	Kappa	SE Kappa	Z	P(vs > 0)
F	1	0.0304290	32.8634	0.0000
P	1	0.0304290	32.8634	0.0000

All Appraisers vs Standard

Assessment Agreement

# Inspected	# Matched	Percent	95% CI
30	30	100.00	(90.50, 100.00)

Matched: All appraisers' assessments agree with the known standard.

Fleiss' Kappa Statistics

Response	Kappa	SE Kappa	Z	P(vs > 0)
F	1	0.0608581	16.4317	0.0000
P	1	0.0608581	16.4317	0.0000

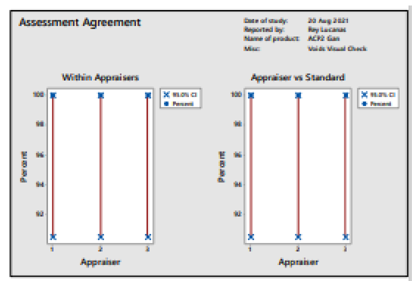


Figure 10. Attribute MSA for Operators

Another MSA was done as Data Quality Audit or Drill Down for the overconsumption data of AuSn preform. First is data of overconsumption came from SAP system provided by Finance and Accounting team. Next, data is collected from target quantity of batch up based on process order and actual issuance of AuSn preform per process order. AuSn preform is batched up or kitted together with other other materials such as flanges or heatsink, dice or wafer. In some weeks, data from SAP can see reversal or return of preforms. Material Kitting team is doing the batch up and with Camstar (Manufacturing Execution System) transaction per process order quantity of AuSn preforms, Old definition of end of use of AuSn preform is that it is scrapped or thrown away after end of process order but in every process order, there is 72 pieces of AuSn preform excess due to mismatch packing quantity with batch up quantity for the finished product as can be seen in Table 5.

Table 5. Material Batch up per Process Order

Process Order	Net Qty	Materials	Material Desc	Consumpt	COSL	OPSL	Additional For COSL	NeT+ COSI	Additional For OPSL	Final Qty	SAP computation	Yield	Actual AuSn (1st PrO)	Excess AuSn (per PrO)
DBX4G04CL-77A	400	HDR-FLANGE		1	1	11.36	4.00	404.00	45.89	449.89	450	89.80%		
		CEGP		1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%		
		CEGP		1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%		
		CESF		2	5	11.36	40.00	840.00	95.42	935.42	936	89.80%		
		CESF		2	5	11.36	40.00	840.00	95.42	935.42	936	89.80%		
		RING FRAME		1	1.36	11.36	5.44	405.44	46.06	451.50	452	89.80%		
		CAP		1	1.36	11.36	5.44	405.44	46.06	451.50	452	89.80%		
		DIEATTACH	Preform AuSn 4.267 x 1.1176 x 0.0127	1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	540	72
		DIEATTACH	Preform AuSn 6.1722 x 1.2192 x 0.0127	1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	540	72

During Measure Phase, there were quick wins identified which was implemented in the production line as shown on Table 6. No change on way of working on batch up by Kitting together with GaN die (though AuSn is considered as bulk material) and do not open AuSn preform when not in use since it is purged by Argon gas to prevent oxidation done by Diebond Operators. Change is to continue to use AuSn preforms for the next process order instead of taking out and scrap remaining AuSn preforms after just one process order. Also, in old way of working with no specific frequency to return AuSn preform matrial back to Kitting, it was deployed to implement to gather unused AuSn preforms after 2 process orders or approximately after 2 days and return to Kitting to be used for new process order. Other change is to transfer AuSn preforms to next machine processing same device or product to deplete AuSn preforms instead of scrapping remaining AuSn preforms.

Table 6. Quick Wins Implemented

OLD WoW	NEW WoW
Batch up by Kitting together with GaN die (though AuSn is considered as bulk material)	Batch up by Kitting together with GaN die (though AuSn considered as bulk material) – no change
Do not open AuSn preform when not in use	Do not open AuSn preform when not in use (no change)
Take out and scrap remaining AuSn preforms after 1 process order (72 pcs)	Continue to use AuSn preforms for the next process order
No specific frequency for return of AuSn preform material	Gather unused AuSn preforms after 2 process orders (~2 days) and return to Kitting to be used for new process order
Take out and scrap remaining AuSn preforms during conversion from one device to the next device	Transfer AuSn preform to next machine to deplete AuSn preforms since conversion is one machine at a time

For the Analyze phase, Failure Mode and Effect Analysis (FMEA) was used to further filter out potential X's to be considered as critical Xs in Table 7.

Table 7. Failure Mode and Effect Analysis

RPN Rating Scale		Action to be taken
Lower	Upper	
1	125	Move the X to Control Plan and record existing controls for X
126	300	Take immediate action on X to reduce RPN to less than 125
301	1000	Take X for Graphical and Statistical Analysis

Note: The above cut-off values are used as a thumb rule. Should you want to use different cut-offs, please change the above values

Process / Product
Failure Modes and Effects Analysis
(FMEA)

Process or Product Name: Kitting and Diebond

Responsible: Dennis Cruz, Rochelle Mujar, Angie Alinea

Prepared by: M. Bigcas

Page _1___ of _1___

FMEA Date (Orig) ______________ **(Rev)** ______________

Process Function	Input	Characteristic of Input (KPIV / X)	Potential Failure Mode (How the X fails?)	Potential Effects of Failure	SEV	Potential Cause(s)/ Mechanism(s) of Failure (Sub X's)	OCC	Current Process Controls	DET	RPN	Recommended Action(s)	Responsibility	Completion Date	Action Results				
														Actions Taken	SEV	OCC	DET	RPN
The highest value process steps from the C&E matrix.	Shortlisted inputs of the process step mentioned in Column A	The shortlisted X's from the C-E Matrix	In what ways might the process potentially fail to meet the process requirements and/or design intent?	What is the effect of each failure mode on the outputs and/or customer requirements? The customer could be the next operation, subsequent operations, another division or the end	How Severe is the effect to the customer?	How can the failure occur? Describe in terms of something that can be corrected or controlled. Be specific. Try identify the causes that directly impacts the failure mode, i.e., root causes.	How often does the cause or failure mode occur?	What are the existing controls and procedures (inspection and test) that either prevent failure mode from occurring or detect the failure should it occur? **Should include an SOP number.**	How well can you detect cause or FM?	SEV x OCC x DET	What are the actions for reducing the occurrence, or improving detection, or for identifying the root cause if it is unknown?	Who is responsible for the recommended action?	What is the completion date for the recommended action?	List the completed actions that are included in the recalculated RPN. Include the implementation date for any changes.	What is the new severity?	What is the new process capability?	Are the detection limits improved?	Recompute RPN after actions are complete
Planning of Material	Material Planner	Plan ordering of materials	AuSn material orders higher than available wafers	Expired AuSn preform	7	AuSn material order not aligned with actual production volume	6	Volume forecast and die supply	7	294	Study extension of shelf life for AuSn preform based on previous data	M. Bigcas	wk2226					
Material Kitting	Kitting Personnel	Batch up materials per device type	Mismatched quantity of AuSn preform vs. batch quantity	Over consumption	7	MOQ of AuSN waffle pack at 108 pcs vs. 96 pcs batch quantity	4	As per MOQ setting	6	168	Review to optimize batch up quantity. If not, create WoW on return or AuSn preforms	R. Mujar/ M. Bigcas	wk2226					
					6	High component scrap	4	AOP budget for COSL	5	120	Review appropriate COSL	R. Mujar/ M. Bigcas	wk2224	Reviewed COSL, 0% component scrap still has excess AuSn prforms issued	6	4	4	96
Diebond	Diebond Operator	Replace waffle pack in gelpak holder	Mishandling of preform during replacement	Over consumption	7	Dislodged preforms after opening waffle pack	6	WI to arrange first to make preforms in place	6	252	Propose to supplier to provide paper cover that will hold AuSn preform in place	A. Panganiban/ M. Bigcas	wk2228					
Diebond	Diebond Operator			Over consumption	6	Missing AuSn preform (spit-out)	3	WI on setup of pick up AuSn preforms	5	90	Revisit machine improvement on spit out	A. Novestera	wk2226					
Diebond	Diebond Operator		Unused AuSn preforms not returned	Over consumption	7	No procedure and manpower to collect unused preforms	6	None	6	252	Provide Way of Working for the return of preforms	R. Mujar/ M. Bigcas	wk2222					
Assembly and Test Process	Production	Not meeting standard or budget overall yield for 2022	Low overall yield	Over consumption	6	Critical stations not meeting target yields (Diebond, SCAT and Test)	5	With targets set per station	5	150	Continue yield improvement on GaN ACP2	R. Lucanas	wk2224					
					6		5		5	150	Test rejects reduction (P3dB)	E. Orij	TBD					

Under planning of materials, potential effect is expired AuSn preform because material is not aligned with actual production volume. Data from Table 7a showed actual expired preforms from year 2021. Table showed number of days expired, quantity, price per unit and amount in USD.

Table 7a. Expired Preforms Accumulated in 2021

Material Description	Batch	No. of days [TPT]	WEEKCODE	Qty in PCS	Price per Unit in USD	Amount in USD	Material Issue
Preform AuSn 5.735 x 0.985 x 0.012	C293104	447	2021-03	128	0.53	$67.20	EXPIRED
Preform AuSn 4.155 x 0.935 x 0.012	C295239-1	409	2021-08	208	0.54	$111.34	EXPIRED
Preform AuSn 4.267 x 1.1176 x 0.0127	C298591	157	2021-44	21364	0.6	$12,852.58	EXPIRED
Preform AuSn 6.1722 x 1.2192 x 0.0127	C298727	191	2021-39	55396	0.66	$36,710.93	EXPIRED
Preform AuSn 5.735 x 0.985 x 0.012	C298782-1	342	2021-18	352	0.53	$184.80	EXPIRED
Preform AuSn 4.155 x 0.935 x 0.012	C298783-1	45	2022-08	2,976	0.54	$1,593.05	Expired Material
Preform AuSn 4.155 x 0.935 x 0.012	C298783-1	157	2021-44	3232	0.54	$1,730.09	EXPIRED
Preform AuSn 4.155 x 0.935 x 0.012	C298783-1	342	2021-20	640	0.54	$342.59	Expired
Preform AuSn 4.155 x 0.935 x 0.012	C308434	148	2021-46	1,024	0.54	$548.15	EXPIRED
				85320		$54,140.73	

Main reason of expiration of preforms in blocked stocks in raw materials warehouse was due to die supply requirement did not materialize from wafer supplier. Factory is dependent on the wafer supply from supplier of die in China. Leadtime for ordering AuSn preform is 8-12 weeks or almost three (3) months. If volume will not materialize, preform will exceed its shelf life and will be expired as system also indicate until when material can be used. Total quantity of AuSn preform expired is 85.3Kpcs amounting to 54.140KUSD which is valid as critical X's. Second potential critical X's is that there is mismatch in the quantity of AuSn preforms due to Minimum Order Quantity (MOQ) in its packing quantity with the batch up quantity to arrive at net quantity of finished product. Third potential critical X's is dislodged preforms after opening of waffle pack while fourth potential critical X's is not all unused AuSn preforms are returned since only sealed parts can be returned. AuSn preforms are packed in waffle packed with Argon purged in its moisture barrier bag (MBB). In Table 8, total excess AuSn preforms that should be returned at 74,240 pieces from February to

May 2022, but production only returned 41,118 pieces or with disparity of 33,122 pieces amounting to 16.56KUSD. This is second item with highest cost.

Table 8. Quantity of Excess Preforms

RETURNED PREFORMS (PRS'ed)		
12nc	**Description**	**Total**
339921090259	Preform AuSn 4.267 x 1.1176 x 0.0127	3,234
339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	15,660
339921090361	Preform AuSn 4.155 x 0.935 x 0.012	12,288
339921090362	Preform AuSn 5.735 x 0.985 x 0.012	9,936
Grand Total		**41,118**

PEP	Device Name	Material	Material Description	Total Qty (Issuance)	Excess Issuance
934960267518	DBX4G74CL-67AV	339921090361	Preform AuSn 4.155 x 0.935 x 0.012	134,656	12,845
		339921090362	Preform AuSn 5.735 x 0.985 x 0.012	141,912	20,101
934960348518	DBX4G24CL-77A	339921090362	Preform AuSn 5.735 x 0.985 x 0.012	117,612	17,076
934960137518	DBX4G04CL-77A	339921090259	Preform AuSn 4.267 x 1.1176 x 0.0127	101,038	6,530
		339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	111,348	16,840
934960485518	C4H27W400AV	339921090361	Preform AuSn 4.155 x 0.935 x 0.012	1,536	144
		339921090362	Preform AuSn 5.735 x 0.985 x 0.012	1,620	228
934960484518	C4H22W500A	339921090362	Preform AuSn 5.735 x 0.985 x 0.012	1,080	152
934960486518	C4H18W500A	339921090361	Preform AuSn 4.155 x 0.935 x 0.012	1,024	80
		339921090362	Preform AuSn 5.735 x 0.985 x 0.012	1,188	244
TOTAL				**613,014**	**74,240**
				33,122	**$ 16,561.00**

For the validation plan of potential critical X's, it is indicated in Table 9 with four (4) items namely planning of materials where AuSn material order is not aligned with actual production volume and availability of dice or wafers causing expired preforms. In practical theory, in case of expired preforms, this can still be used based on previous qualification where additional 5.5 months can be added to initial 12 months shelf life with impact to metric at 6% since there were accumulated 85Kpcs out of 1425Kpcs of AuSn performs in 2021. Validation plan is to compare the SCAT yield of expired and non expired preforms used in production. Validation plan for mismatched MOQ of AuSN preforms waffle pack at 108 pieces versus 96 pieces batch up quantity is to compare batch up of AuSn performs with different component scrap if it will not result to excess preforms while validation plan for dislodged AuSn preform during opening of waffle pack is to compare dislodge preforms on first and second section or small versus large preforms and finally for no procedure and manpower to collect unused preforms, validation will compare new way of working on handling AuSn performs at diebond and return of excess AuSn preforms.

Table 9. Validation Plan

No.	Process	Potential Critical X's	Practical Theory	Decision	Impact to Metric	Validation Plan
1	Planning of Material	AuSn material order not aligned with actual production volume causing expired preforms	In case of expired preforms will be used due to planning issue, is the SCAT yield of expired and non expired preforms comparable ?	Valid	85Kpcs expired in 2021 vs. total qty of preforms (target) in 2021 - (85Kpcs/1425Kpcs or 6%)	Compare yield of expired vs. non expired preforms
2	Material Kitting	MOQ of AuSN waffle pack at 108 pcs vs. 96 pcs batch quantity	Will different or lower component scrap result to lower issuance of AuSn preform ?	Valid	15% (72 pcs excess every process order), items 2 & 4 have same impact	Compare batch up of AuSn preforms with different component scrap %
3	Diebond	Dislodged AuSn preforms during opening of waffle pack	Is dislodged preform related to small or large preform ? Use data from data gathering in wk2224	Valid	3.6% based on data gathering (but arranged by shaking waffle pack)	Compare dislodged preforms on first and second section or small vs. large preforms
4	Diebond	No procedure and manpower to collect unused preforms	Is the returned qty of AuSn preform in May comparable with June (after new WoW) ?	Valid	15% (72 pcs excess every process order), items 2 & 4 have same impact	Compare new WoW of AuSn preform returns vs. old WoW

First validation plan in Table 10 and Figure 11, it is related to comparison of SCAT yield using expired and non expired preforms in production using two (2) proportions test with aim of validating if indeed additional shelf life on AuSn preforms will still have acceptable yield but it is not intended to change shelf life in Quality Description Sheet (QDS) since 12 months is the guaranteed shelf life of supplier but extension of shelf life is as per application. Result from proportion test with pvalue of 0.000 showed even expired preforms has better SCAT yield result compared with production using non expired preforms. This is because expired preforms were inserted in mostly running machine while production still has factor of setup and conversion with known lower SCAT yield after setup or change device.

Table 10. Validation 1

Items	Details
Practical Problem	In case of expired preforms will be used due to planning issue, is the SCAT yield of expired and non expired preforms comparable ?
Null Hypothesis	Ho: $P1_{expired} = P2_{non\ expired}$
Alternative Hypothesis	Ha: $P1_{expired} \neq P2_{non\ expired}$
P-Value	Pvalue at 0.000
Practical Conclusion	Reject Ho, SCAT yield of expired preforms (additional 5.5 months) has significant difference with SCAT yield of non expired preforms at 95% confidence level

2 Proportions Test

Estimation for Difference

Difference	95% CI for Difference
-0.0096549	(-0.012712, -0.006598)

CI based on normal approximation

Test

Null hypothesis $H_0: p_1 - p_2 = 0$
Alternative hypothesis $H_1: p_1 - p_2 \neq 0$

Method	Z-Value	P-Value
Normal approximation	-5.58	0.000
Fisher's exact		0.000

The test based on the normal approximation uses the pooled estimate of the proportion (0.0248839).

Graphical result

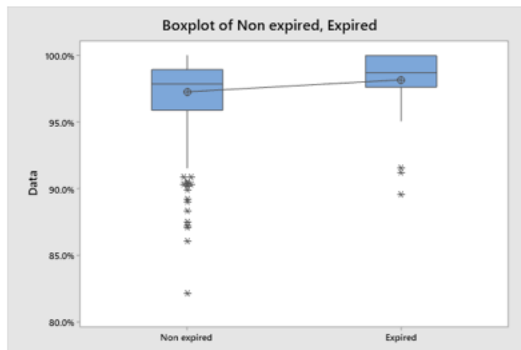


Figure 11. 2 Proportions Test (Validation 1)

For the second validation, practical problem is will different or lower component scrap result to lower issuance of AuSn preform was validated by doing batch up exercise on the spreadsheet of Material Kitting team where changing the component scrap from 5% to 0% will still yield to excess preforms and even higher since there is still operational scrap included in the gross quantity for batch up so validation proved that nothing can be done on the component scrap as shown in Table 11 to reduce excess AuSn preforms but other improvement can be considered. Impact to metric of second and fourth potential critical Xs under validation is 15% since in every process order, there is 72 pieces excess preforms out of 468 pieces issued gross quantity for the finished product.

Table 11. Validation 2 with Component Scrap Reduction

Process Order	Net	Materials	12NC	Material Desc	Consumpt	COSL	OPSL	Additional For COSL	NeT+ COS	Additional For OPSL	Final Qty	SAP computation	Yield	Actual - Issued in SAP	Waffle Pack Requirement	Qty of AuSn Preforms	Excess AuSn preforms
DBX4G04CL-77A	400	HDR-FLANGE	332235580401		1	0	11.36	0.00	400.00	45.44	445.44	446	89.80%	464			
		CEGP	340010001558		1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	499			
		CEGP	340010001559		1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	561			
		CESF	340010001560		2	5	11.36	40.00	840.00	95.42	935.42	936	89.80%				
		CESF	340010001562		2	5	11.36	40.00	840.00	95.42	935.42	936	89.80%				
		RING FRAME	332296303591		1	1.36	11.36	5.44	405.44	46.06	451.50	452	89.80%	470			
		CAP	332296303401		1	1.36	11.36	5.44	405.44	46.06	451.50	452	89.80%				
		DIEATTACH	339921090259	Preform AuSn 4.267 x 1.1176 x 0.0127	1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	468	4.33	540	72
		DIEATTACH	339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	468	4.33	540	72

Process Order	Net	Materials	12NC	Material Desc	Consumpt	COSL	OPSL	Additional For COSL	NeT+ COS	Additional For OPSL	Final Qty	SAP computation	Yield	Actual - Issued in SAP	Waffle Pack Requirement	Qty of AuSn Preforms	Excess AuSn preforms
DBX4G04CL-77A	400	HDR-FLANGE	332235580401		1	0	11.36	0.00	400.00	45.44	445.44	446	89.80%	464			
		CEGP	340010001558		1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	499			
		CEGP	340010001559		1	5	11.36	20.00	420.00	47.71	467.71	468	89.80%	561			
		CESF	340010001560		2	5	11.36	40.00	840.00	95.42	935.42	936	89.80%				
		CESF	340010001562		2	5	11.36	40.00	840.00	95.42	935.42	936	89.80%				
		RING FRAME	332296303591		1	1.36	11.36	5.44	405.44	46.06	451.50	452	89.80%	470			
		CAP	332296303401		1	1.36	11.36	5.44	405.44	46.06	451.50	452	89.80%				
		DIEATTACH	339921090259	Preform AuSn 4.267 x 1.1176 x 0.0127	1	0	11.36	0.00	400.00	45.44	445.44	446	89.80%	446	4.13	540	94
		DIEATTACH	339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	1	0	11.36	0.00	400.00	45.44	445.44	446	89.80%	446	4.13	540	94

For the third validation on dislodged preform, there was quick data gathering on whether small or large preforms has the most occurrence, but result showed that p value of 0.053 validates that all preforms encounter dislodged preforms while in waffle pack and even proven by sample Xray on still unopened pouch of AuSn preforms. The validation is in Table 12 and Figure 12.

Table 12. Validation 3

Items	Details
Practical Problem	Is dislodged preform related to small or large preform ?
Null Hypothesis	Ho: $P1_{\text{large preform}} = P2_{\text{small preform}}$
Alternative Hypothesis	Ha: $P1_{\text{large preform}} \neq P2_{\text{small preform}}$
P-Value	Pvalue at 0.053
Practical Conclusion	Accept Ho, Dislodged on small preform after opening of waffle pack has no significant difference with large preform at 95% confidence level

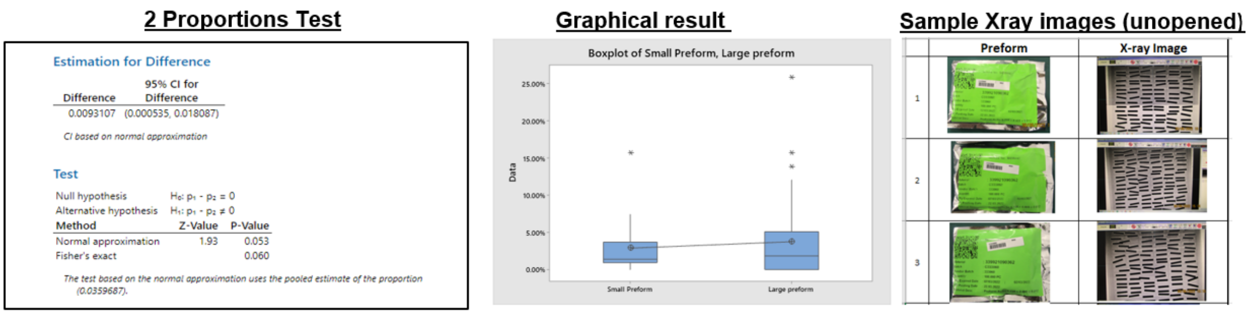


Figure 12. Validation 3 (Proportions Test and Sample Xray dislodged Preforms)

For the fourth validation, it is intended to validate if the new way of working on continuous use of AuSn performs at diebond and returns of excess preforms after 2 process orders will have differences in terms of excess AuSn preforms returned to Kitting in Table 13 where result on data comparison on returned quantity on AuSn preforms between old way of working in May 2022 compared with new way of working. Gap of excess AuSn preforms returned in May is 75% while gap of return in a week after implementation of new way of working, gap has dropped significantly to 2%.

Table 13. Validation 4

MAY - MONITORING OF EXCESS GAN PREFORMS							
Material	Material Description	Total Qty (Issued)	Target Issuance	Excess Issuance	Total Price (excess)	Returned from Prod'n (PRS'ed)	Total Price (PRS'ed)
339921090259	Preform AuSn 4.267 x 1.1176 x 0.0127	80,850	76,200	4,650	$ 654.54	-	$ -
339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	88,844	76,200	12,644	$ 8,894.74	2,700	$ 3,411.06
339921090361	Preform AuSn 4.155 x 0.935 x 0.012	6,656	5,568	1,088	$ 2,489.15	-	$ -
339921090362	Preform AuSn 5.735 x 0.985 x 0.012	91,260	77,836	13,424	$ 6,638.10	5,148	$ 1,417.50
TOTAL		**267,610**	**235,804**	**31,806**	**$18,676.53**	**7,848**	**$ 4,828.56**

MONITORING OF GAN PREFORMS (wk2223)									
PEP	Device Name	Material	Material Description	Total Qty (Issued)	Target Issuance	Excess Issuance	Total Price (excess)	Returned from Prod'n (PRS'ed)	Total Price (PRS'ed)
934960137518	DBX4G04CL-77A	339921090259	Preform AuSn 4.267 x 1.1176 x 0.0127	24,500	22,096	2,404	$ 1,446.25	1,012	$ 608.82
		339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	27,000	22,096	4,904	$ 3,249.39	5,292	$ 3,506.48
934960348518	DBX4G24CL-77A	339921090362	Preform AuSn 5.735 x 0.985 x 0.012	15,660	14,000	1,660	$ 871.50	2,484	$ 1,304.10
934960484518	C4H22W500A	339921090362	Preform AuSn 5.735 x 0.985 x 0.012	864	864	-	$ -		
TOTAL				**68,024**	**59,056**	**8,968**	**$ 5,567.14**	**8,788**	**$ 5,419.40**

Summary for the Analyze phase is that after further filtering out of potential X's using Failure Mode and Effect Analysis, potential critical X's became four (4) items that were validated and will have its corresponding improvement actions in Improve Phase as shown in Table 14 with corresponding owners.

Table 14. Improvement Actions

No.	Process	Critical X's	Impact to Metric	Improvement Actions	Owner
1	Planning of Material	AuSn material order not aligned with actual production volume causing expired preforms	85Kpcs expired in 2021 vs. total qty of preforms (target) in 2021 - (85Kpcs/1425Kpcs or 6%)	In case of expired AuSn preforms, +5.5 months can be utilized	M. Bigcas/ M. Esturas
				Evaluate expired preforms by 12 months if 2 years shelf life is still good based on application	D. Locana
2	Material Kitting	MOQ of AuSN waffle pack at 108 pcs vs. 96 pcs batch quantity	15% (72 pcs excess every process order), items 2 & 4 have same impact	Same as item 4 Implement new WoW of AuSn preform continuous use at diebond returns with update on Diebond and Kitting documents	R. Mujar/ D. Locana
3	Diebond	Dislodged AuSn preforms	3.6% based on data gathering (but arranged by shaking waffle pack)	Continue current WoW on arranging and shaking waffle pack to make AuSn preforms in place	D. Locana/ A. Alinea
				Propose new waffle pack cover to supplier in order to hold AuSn preform in place inside waffle pack	M. Bigcas/ A. Panganiban
4	Diebond	No procedure and manpower to collect unused preforms	15% (72 pcs excess every process order), items 2 & 4 have same impact	Implement new WoW of AuSn preforms continuous use at diebond and returns with update on Diebond and Kitting documents	R. Mujar/ D. Locana

For the improvement on material planning, heuristic plan was done in 2022 to align volume and AuSn preform materials to be ordered as seen in Table 15.

Table 15. Heuristic Planning

Heuristic Plan

Product ID	Product Desc	Category	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
934960137518	DBX4G04CL-77A	ACP2 GAN	88,300	143,000	169,800	63,700	93,300	75,500	56,700	98,400
934960267518	DBX4G74CL-67AV	ACP2 GAN	79,500	66,400	34,600	103,100	49,800	90,500	50,900	10,000
934960348518	DBX4G24CL-77A	ACP2 GAN	68,910	158,650	159,900	72,600	107,700	90,700	49,900	26,200

needed preforms

Where used	Material 12NC	Matl. Description	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	open P.O	SOH
DBX4G04CL-77A	339921090259	Preform AuSn 4.267 x 1.1176 x 0.0127	103,882	168,235	199,820	75,747	111,126	91,157	69,234	119,015	125,000	303,708
DBX4G04CL-77A	339921090260	Preform AuSn 6.1722 x 1.2192 x 0.0127	103,882	168,235	199,820	75,747	111,126	91,157	69,234	119,015	145,000	245,710
DBX4G74CL-67AV; C4H27W400AV	339921090361	Preform AuSn 4.155 x 0.935 x 0.012	89,326	74,607	39,438	115,843	58,200	102,852	59,274	13,319	92,000	211,410
DBX4G74CL-67AV; DBX4G24CL-77A	339921090362	Preform AuSn 5.735 x 0.985 x 0.012	244,458	431,484	399,703	281,322	301,322	308,239	173,631	74,940	400000	730,139

For the extension of shelf life, there was already study in year 2021 where additional 5 months after original expiration date or 17.5 months from manufacturing date for AuSn preform. Proposed change is on usage of expired AuSn preforms for GaN products. This was due to shortage in the supply of AuSn preforms due to supplier's capacity limitations in 2021. There was no previous evaluation done for expired AuSn preforms for GaN. The result of this evaluation is only applicable to all AuSn preforms for GaN.

Risk assessment or change FMEA was done to determine risks and recommended actions to mitigate risks. In Table 16, one of potential failure mode such as voids and die attach delamination due to change in AuSn preform melting point or oxidation of Sn component of the preform using expired preform where action is for die attach machine to be in good condition and must pass speed lot before running qualification lot using same die diffusion and flange lot for all lots to eliminate variability and focus will only be on control (non-expired) and evaluation lots (expired) AuSn preforms. Risk table was used as inputs for the qualification plan at 0 hour and reliability testing as shown in Table 17.

Table 16. Risk Assessment on Use of Expired Preforms

Risk Assessment / CFMEA

Affected Process Step / Design Function	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s) of Failure	OCC	Current Controls: Prevention	Current Controls: Detection	DET	RPN	Recommended Actions	Owner
Diebond (active)	Voids, die attach delamination, change in wetting quality (poor or dry wetting)	Assembly and test yield loss, material downtime	7	- Change in the AuSn preform melting point - Oxidation of the Sn component of the preform	3	- Proper storage of the preforms - B2B approach in setting up MRSI	100% SCAT at midline	6	126	- PID/Temp profile check at start of control lot - MRSI to be used must pass the speedlot. **- Use same die diffusion and flange lot for all lots**	A. Novesteras
100% CSAM	Voids, die attach delamination	Yield loss, material downtime	7	- Change in the AuSn preform melting point - Oxidation of the Sn component of the preform	5	- Proper storage of the preforms - B2B approach in setting up MRSI	100% SCAT at midline	2	70	- Yield comparison vs. control lots and historical 04CL-77A performance	F. Custodio
DC test	Test parametric shift (esp. Dvm), change in product performance level	Yield loss	6	- Voids, delamination in the die attach region	3	- Proper storage of the preforms - B2B approach in setting up MRSI	100% SCAT at midline, 100% final test	2	36	- Yield monitoring & comparison after DC test - Comparative analysis of parametric distrbution of control vs. evaluation lots	E. Mendoza, A. Perea
Reliability test	Change in product performance after reliability testing, test parametric shift	Decreased product performance, product failure, customer complaint	5	- Propagation of die attach voids - Delamination between the AuSn/die or AuSn/flange interface	3	None	Final testing at each reliability readpoint during evaeluation	5	75	- Yield monitoring & comparison after DC test at each readpoint - Comparative analysis of parametric distrbution of control vs. evaluation lots	B. Angeles, M. Maalat, F. Custodio
	Degradation of die attach quality	Decreased product performance, product failure, customer complaint	7	- Propagation of die attach voids - Delamination between the AuSn/die or AuSn/flange interface - Reduced strength of the AuSn preform	4	None	100% SCAT at each readpoint during evaluation	5	140	- 100% SCAT at each readpoint - Comparison with historical SCAT performance of 04CL-77A after reliability testing	B. Angeles, M. Maalat, K. Jardin

Table 17. Qualification Plan on Use of Expired Preforms

Qualification Plan

Process	Test / Quality Characteristic	Acceptance Criteria	Measurement method	Sample size	# of lots	Remarks
Assembly & Test						
Diebond (active)	Voids, delamination	- Voids: ≤ 3 % for single void and ≤ 10% for accumulated void *Mouse bites not allowed on shortside of die	PVA-TEPLASAM300 MACHINE	Control - 5 pcs Eval - 1 pc / lot	1 control, 3 eval	- 5 pcs from control will be part of the buy-off - 1 pc / eval lot will not be part of buy-off; this will only be for monitoring
	Visual attribute	- Refer to visual criteria - Must be comparable with unexpired material	Low power microscope	30 pcs / lot	1 control, 3 eval	Take photos of 5 units per lot to compare the wetting appearance
	Die placement	Refer to assembly diagram	Smartscope	3 pcs / lot	1 control, 3 eval	This will serve as a reference
100% CSAM	Voids, delamination	- Voids: ≤ 3 % for single void and ≤ 10% for accumulated void (mouse bites not allowed on shortside of die) - Yield must be comparable with unexpired material	PVA-TEPLASAM300 MACHINE	100% (whole lot/ batch)	1 control, 3 eval	- Sample rejects to be subjected to cross-section
RF	Test parametric shift, change in product performance level	- Must pass spec limits - Must be comparable to the control	SiliconDash	100%	1 control, 3 eval	Review the Efficiency test parameter and its test distribution
DC	Test parametric shift, change in product performance level	- Must pass spec limits - Must be comparable to the control	SiliconDash	100%	1 control, 3 eval	Check the Dvm/Dvm_B2 shift and its test distribution. Safekeep 3 units / lot as reference for the succeeding electrical tests after reliability loading.
Reliability Testing						
TMCL (-65/150degC) w/ MSL3+3x reflow 245degC Readpoints: 500C (decision point), 1000C (FIO)	RF, SPAR, DC	- Must pass spec limits - Must pass allowable parametric shift - Must be comparable to control	SiliconDash	77 units/lot	1 control, 3 eval	Include 3 reference samples / lot from 0-hr as basis of comparison (test it along with the lots after each rel. test readpoint; review the efficiency/Dvm2/DvmB2 test parameters and its test distribution)
	Voids, delamination	- Voids: ≤ 3 % for single void and ≤ 10% for accumulated void (mouse bites not allowed on shortside of die) - Yield must be comparable with control	PVA-TEPLASAM300 MACHINE	77 units/lot	1 control, 3 eval	

Evaluation was conducted using control and expired preforms and was processed at assembly and test including reliability testing as summarized in Table 18. Recommendation from the expired AuSn preform study is to use remaining stocks of expired preforms until 17 months based on 0 hour and reliability results of the evaluation, no significant impact was seen on the package and product performance both as assembly and test or product performance. Original shelf life of AuSn preform in its sealed bag is only 12 months but can be extended according to its application. In this case, 5 months extension is justified through risk assessment done. Also result of production lots using expired preform after approval in change control board has comparable result with non expired preform in mass production run in production. Solder preforms and ribbon Solder preforms, and ribbon should be stored in their original unopened container in a nitrogen dry box to optimize their shelf life. This inhibits growth of oxides that can compromise the wetting performance. Stored properly, performs can have a shelf life of up to five years. Since leadcontaining alloys are more prone to oxidation, they should be used within six months of the manufacture date. However, by following proper storage conditions, they can be used up to two years after the date of manufacture.

Table 18. Summary of Qualification Results

	Check items	Control	Lot 1	Lot 2	Lot 3
0-hr	Diebond (actives)	No workability issues encountered during diebonding.	No workability issues encountered during diebonding.	No workability issues encountered during diebonding.	No workability issues encountered during diebonding.
	100% CSAM	• 100% Yield	• 98.936% Yield • Void rejects have the same signature as production rejects	• 100% Yield	• 98.936% Yield • Void rejects have the same signature as production rejects
	Test Performance	• Acceptable DC1/SPAR/RF/DC2 performance. • Median shift and delta sigma analysis generally passed for majority of the parameters. Parameters not meeting the required limits have either a high Cpk or are comparable to the control lot. • DC2 rejects such as Vgso, Igso, and Igdo are test parameters not related to the expired AuSn preform being evaluated. Additionally, these are typical rejects seen in the reject pareto of production lots. • Majority of Dvm parameters passed the median shift criteria. Dvm_2 did not pass the median shift criteria; however, the distribution was comparable to that of the 50 production lots from August 2021.			
TMCL 500C	100% CSAM	• Normal occurrence of edge voiding observed.	• Normal occurrence of edge voiding observed.	• Normal occurrence of edge voiding observed.	• Normal occurrence of edge voiding observed.
	Test Performance	• Acceptable SPAR/RF/DC2 performance. • Median shift and delta sigma analysis generally passed for majority of the parameters. Parameters not meeting the required limits have either a high Cpk or are comparable to the control lot. • DC2 rejects such as Igsv and Yfs are test parameters not related to the expired AuSn preform being evaluated. • All DvM parameters are meeting the delta sigma criteria. Outlier identified is also a reject on other parameter.			

For the improvement on unused preforms not returned by production, action is to provide procedure and schedule per week to gather excess AuSn preforms to enforce regular return which is every end of 2 process orders or every 2 days per machine. Procedure will include form or return slip and deployment to all die attach Operators and Material Kitting team with new way of working flowchart shown in Figure 13 where it starts from allocation of AuSn preform in process order followed by receipt of process order followed by processing of process order at die attach machine where collection is done every end of second process order where collected AuSn preforms are returned to Kitting and PRS or system transaction and recording is done before using the collected AuSn preforms back to new process order and the cycle continues. For the conversion of machine to other product or device, AuSn preform will be transferred to other machine to continue its consumption so that there will be no excess preforms or scrapped preforms along the process.

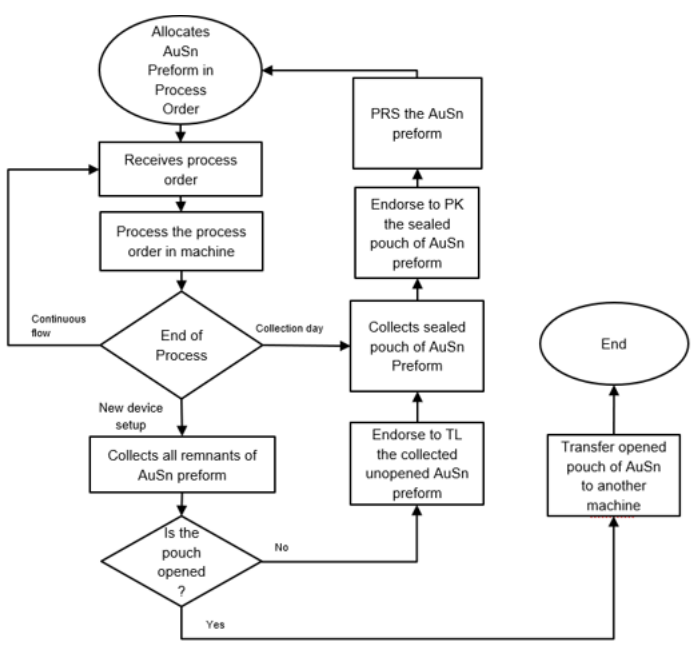


Figure 13. New Way of Working on Use and Return of Excess Preforms

For the calculation on expected AuSn preforms to be returned. For one process order, net quantity required is 400 pcs. Actual gross quantity to be kitted is 444 pcs considering yield and component scrap. AuSn preforms to be issued at 5 packs with 108 pieces of AuSn preforms. Total AuSn preforms issued at 540 pieces since AuSn preform are issued on per bag basis, any excess should be returned but only sealed bag should be returned. Expected AuSn preform to be returned is 7 waffle pack of specific AuSn preform per machine per day. This is summarized in Table 19. After two (2) process orders, there will be twice 96 pieces or 192 pieces or with 108 pcs unopened pack and open pack with 84 pcs which will be continuously used in succeeding process orders.

Table 19. Computed Excess AuSn Preforms per Process order

	in pieces	**Remarks**
1 Process order	400	Net quantity (100 pcs per packing quantity (PQ)
Gross quantity	444	90% yield factor
Issue 5 waffle packs	540	108 pcs of AuSn preform per pack
Excess preforms	96	opened already

For the dislodged preforms as inherently seen in actual and in Xray right before opening the pouch or packaging is because there is nothing to hold the preforms in place while inside the packaging unable to restrict its movement. It is important that no dislodged preforms and they are in place since it will result to poor pick up and misplaced preforms during die attach process. This led to communication with supplier to improve their preform case or cover as shown in Figure 14.

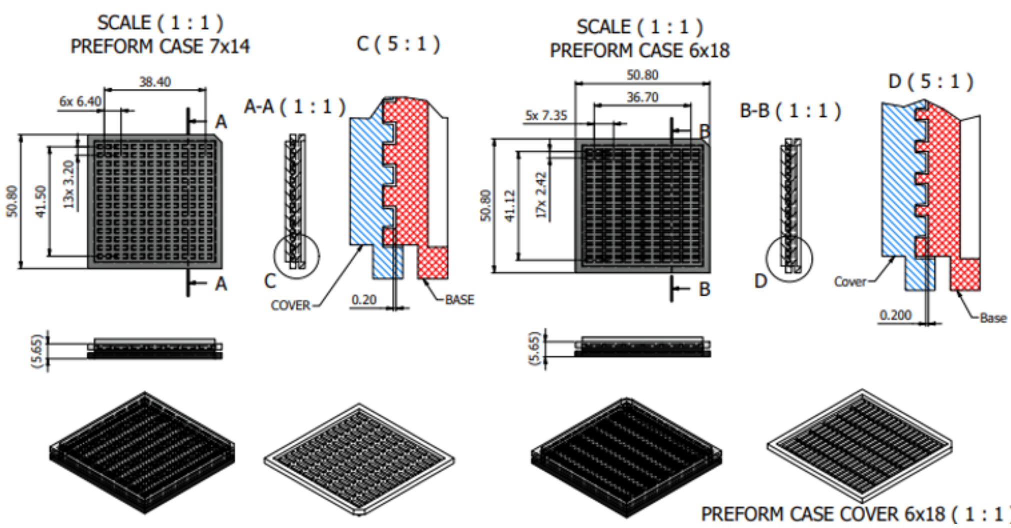


Figure 14. Proposal to Improve Preform Case

At die attach process, Operators will continue their current way of working as shown in Figure 15 to recover the preforms without dislodged by arranging them and placing them back to their proper position before placing at die attach machine for pick and place to be used as die attach material between heatsink and dice.

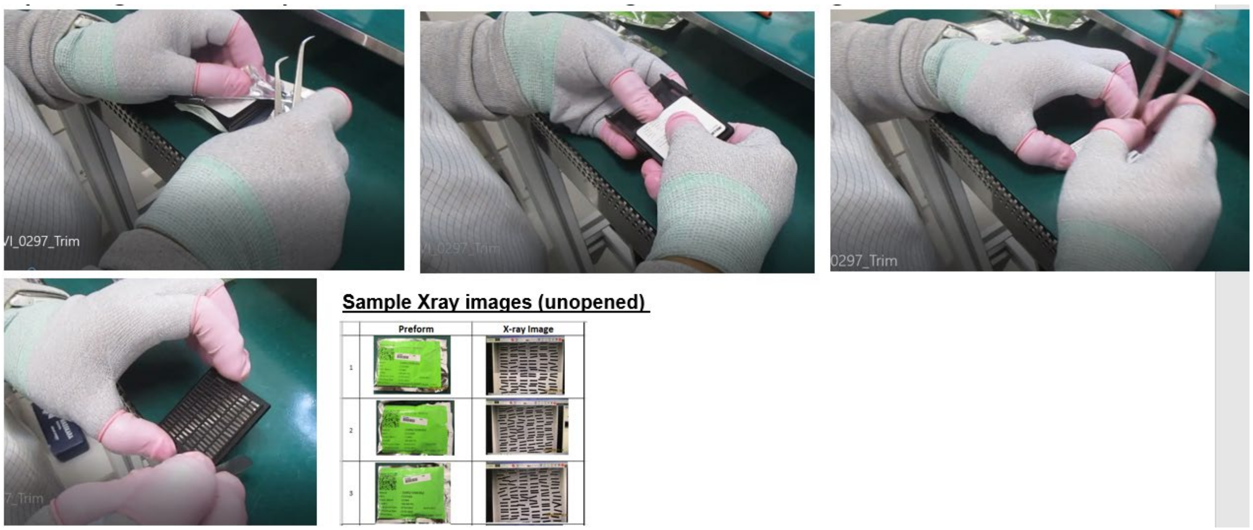


Figure 15. Procedure on How to Recover Dislodged Preforms

For the Control phase, planning of AuSn materials with respect to volume will be continuously monitored to avoid expiration of preforms and from study on actual use of expired AuSn preforms, shelf life can be extended to 17 months with update in the system. For the unused preforms to be returned due to mismatch packing quantity of AuSn preform per process order, new way of working will be documented in Material Kitting document as well as Diebond or Die attach process to document the improvement. Also, FMEA was updated to show reduction of RPN after improvement actions were implemented. The metric was also shown where improvement was seen in June as taken from SAP data in Figure 16.

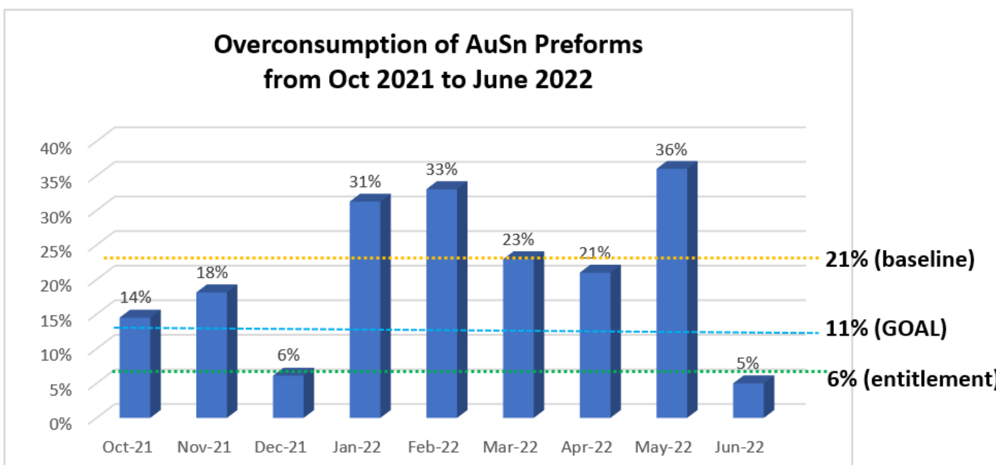


Figure 16. Result After Improvement in June 2022

This is also back up by separate monitoring done by Material Kitting for the returns in June where AuSn preforms almost similar with calculated expected returns of AuSn preforms and these returned preforms were used right away in the next process orders.

6. Conclusion

This actual study on material variance reduction of AuSn preform through DMAIC approach led to a quantitative goal from Define Phase, identification of focused process and potential X's in Measure phase, Analyze phase led to further filtering out on critical X's through Failure Mode and Effect Analysis (FMEA) and addressed through action to reduce AuSn preform over consumption.

For the Define Phase, goal is coming from improvement from 21% to 11% % or 10% reduction on AuSn preform material over consumption. Project scope is defined from Material Planning, Material Kitting from withdrawal and issuance of AuSn preform until Diebond process only as AuSn preform is already consumed at Diebond process used as die attach interface to bond active dice to heatsink or flange. Define phase is summarized in a project charter started with a business case where material over consumption report included AuSn preform in top 10 contributing to 139KUSD for 6 months as also stated in the Problem Statement. Objective Statement is to reduce over consumption of AuSn preform from October 2021 to March 2022 by 10% (21% to 11%) by end of May 2022 and that there will be no consequences on die attach or diebond quality and yield. Estimated cost savings is at 10% reduction valued at 152.5KUSD projected annual savings.

For the Measure phase, project scope defined from macro map at Material Planning, Material Kitting to Diebond or Die attach while detailed Process Flow Diagram (PFD) was done together with Input Output (IO) worksheet and Ishikawa, or Fishbone diagram summarized in Cause and Effect (C&E) matrix to get potential X's from rating provided if it will be discarded or considered for next step in the Analyze phase.

For the Analyze phase, Failure Mode and Effect Analysis (FMEA) filtered out the highest risk priority number (RPN) for validation. Critical X's derived from FMEA were planning of AuSn preform versus volume that will be realized to prevent expired AuSn preform but if expired preforms will be encountered, extension of 5.5 months was already validated from what happened in 2021 with no impact on SCAT yield. Another critical X's is the way of working and consistent return of unused AuSn preform in its original packing content. Third is on dislodged preforms since the waffle case is unable to hold the preforms in place.

Improvement actions were provided in Improve and Control phase to address critical X's. One of these improvements aside from consistent monitoring of AuSn preform material planning aligned with realized volume is the qualification and evaluation of expired AuSn preform to extend shelf life from 12 to 17 months which can be used right away without impact on SCAT yield, but the Quality Description Sheet (QDS) will not be changed as suppler guarantees 12 months shelf life and extension varies depending on its application. Consistent return of excess AuSn preform in production also implemented according to the new way of working at diebond by continuously using the preforms and collection will be at the end of two (2) process orders and collected preforms will be used on new process orders thus SAP will not see new withdrawals of AuSn preforms as it is fed back to next process orders leaving no unused or scrap preforms in production line. Control Phase has documented the new way of working on handling AuSn preforms while improvement in packing material to address dislodged preforms will be carried out by the Process Owner and Purchasing team as it will still take time to implement the change. Finally, last important item in this study is whether change can be seen in the metric of over consumption and indeed there was big improvement seen in June 2022 data where over consumption already dropped to 5%.

New opportunities seen in other materials used in production line of RF Power manufacturing company as they are of high value and no more reduction in price forcing reduction of wastages in various stages in manufacturing company. One of which is the over consumption of GaN dice or wafer as it is also showing up in the unfavorable factory variance.

References

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Biography

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