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Applying 8D Methodology to Improve the Quality of the MEMS Probe Card

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Abstract

This study aims to explore the effectiveness and practical operation of applying 8D methodology to MEMS probe card quality management. Through an analysis of three quality incident cases, the research investigates methods for effectively addressing product defects resulting from human error in semiconductor manufacturing processes. The findings indicate that the 8D methodology is a valuable tool for identifying root causes and formulating long-term corrective measures, including the development of standardized operating procedures, targeted re-education training, mentorship programs, and tool improvement initiatives. These interventions have proven effective in reducing the recurrence of defects and enhancing customer satisfaction. Moreover, this study emphasizes the importance of establishing a learning organization and implementing comprehensive knowledge management systems as critical strategies for fostering an organizational culture centered on continuous quality improvement. The research further recommends integrating human factors engineering principles and digital management systems to optimize maintenance operations and improve overall production quality. Such advancements are projected to strengthen the company's competitive position within the high-precision industry by enhancing operational accuracy and reliability.

Keywords: 8D methodology, human factors engineering design, MEMS probe card, mentoring system

1. Introduction

Due to limitations in manufacturing technology, traditional probe cards can no longer keep up with the trend of shrinking line widths, leading to the gradual replacement by MEMS (Micro-Electro-Mechanical Systems) probe cards. MEMS probe cards, which utilize MEMS technology to create micro-scale probe structures, can precisely contact test pads on wafers and enable high-efficiency, high-accuracy testing when integrated with automated test equipment (ATE).

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With advancements in semiconductor processes and the expansion of electronic applications, MEMS probe cards have demonstrated significant advantages in testing highly complex components such as memory, microprocessors, and system-on-chip (SoC) devices. As these components continue to shrink in size and increase in stacking density, traditional probe cards fail to meet the demands. In contrast, MEMS probe cards, with their superior precision and performance, are progressively replacing conventional technologies. The evolution of probe card technology is illustrated in Figure 1.

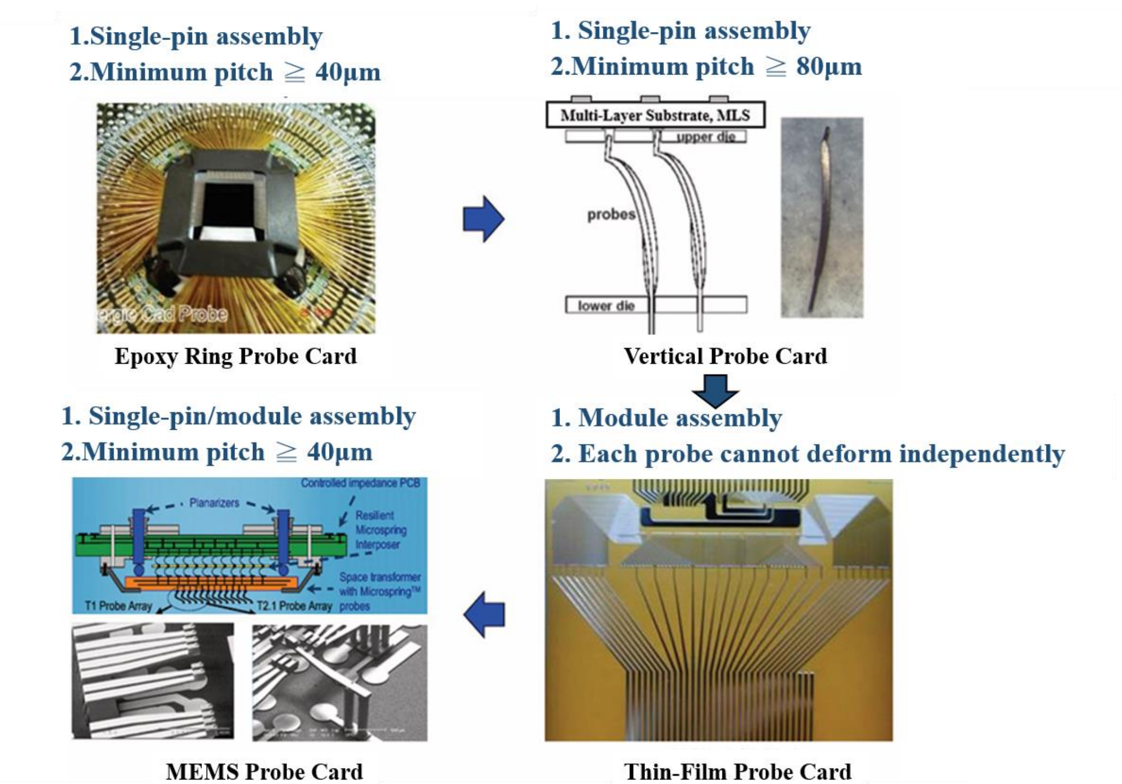

Figure 1. Evolution of Probe Card Technology (Chou et al., 2021)

With the rising demand for smartphones, electric vehicles, and the Internet of Things (IoT), the precision requirements for semiconductor testing have become increasingly stringent. MEMS probe cards, featuring miniaturized structures and optimized contact designs, can reliably transmit signals within extremely limited areas, thereby enhancing testing accuracy and production efficiency.

According to Verified Market Research, the global MEMS probe card market is valued at approximately USD 3 billion in 2024 and is projected to reach nearly USD 6 billion by 2030, with a compound annual growth rate (CAGR) of around 10.7%. The global development of the probe card market is illustrated in Figure 2.

Figure 2. Global Development of the Probe Card Market

IC packaging and testing represent the back-end processes of semiconductor manufacturing, which must be carried out according to customer specifications under strict quality control. If the final products fail to meet requirements, customer complaints may arise. Quality management should prioritize prevention, focusing on identifying critical influencing factors and responding promptly to reduce the risks of returns and compensation. However, production often suffers from incomplete data and human variability, making root cause analysis challenging. Therefore, efficient issue handling relies heavily on teamwork and knowledge management.

In the manufacturing of MEMS probe cards, extremely high precision is required—minor deviations can lead to rework and quality issues. Although certain processes have been automated, assembly and maintenance still depend on manual operations. Human error thus becomes a key challenge, directly impacting production yield and efficiency.

This study aims to apply the 8D (Eight Disciplines Problem Solving) methodology to improve the quality of MEMS probe cards. Through case study analysis, this research identifies root causes of product defects, formulates corrective actions, and incorporates employee training and process optimization to enhance quality management effectiveness. The objectives of this study are as follows.

（1） Apply the 8D report methodology for quality improvement of MEMS probe cards.

（2） Identify and analyze the primary causes of MEMS probe card failures.

（3） Improve operational and management processes in order to reduce defect rates.

（4） Cultivate a disciplined and productivity-oriented work culture among personnel.

2. Literature Review

The core of quality improvement lies in continuous monitoring and evaluation. When a product, service, or system fails to meet standards, it is essential to promptly implement both "corrective actions" and "preventive actions." Corrective actions focus on short-term resolution, while preventive actions emphasize in-depth analysis of root causes to prevent recurrence of the problem. According to Lai (2021), common quality management tools such as Root Cause Analysis, 8D Methodology, 5W Analysis, Failure Mode and Effects Analysis (FMEA), and Cause-and-Effect Diagrams are all effective in identifying and resolving quality issues.

This section begins with a review of IC probe cards and the practical application of the 8D methodology. Fang (2017) states that the 8D problem-solving method, widely used in the IC industry, is a systematic tool comprising eight steps—from forming a problem-solving team and identifying root causes to implementing permanent corrective actions. It helps employees address quality issues in an organized manner while ensuring transparency and consistency throughout the process. The article also emphasizes the use of knowledge management to integrate experience and data, which helps enhance the organization's problem-solving capabilities.

Chou et al. (2021, 2022) explored the probe card design and manufacturing processes required for mass production of advanced IC products, outlining the technological evolution from epoxy probe cards to vertical, film-type, and ultimately to the mainstream MEMS probe cards. As IC complexity increases, the number of probe pins, precision, and testing speed have become key competitive factors. MEMS probe cards utilize photolithography and electroforming techniques to fabricate high-hardness micro-probes, combined with 3D ceramic substrates to enhance signal transmission efficiency and probe density. These features enable MEMS probe cards to meet high-frequency and high-density IC testing demands, offering potential for improved efficiency and reduced costs. The study also proposes concrete recommendations to enhance the competitiveness of Taiwan's semiconductor testing industry.

In the field of IC and semiconductor industries, Shih and Chen (2007) demonstrate that the 8D problem-solving methodology has been practically applied in the IC packaging industry to maintain product quality stability in a highly competitive market. On the other hand, a number of empirical studies in manufacturing contexts show that applying the 8D methodology leads to significant defect reduction and improved problem resolution. Arriaga-Vargas & González-Araya (2020) improved a manufacturing process in a cable-assembly, the study found that defects dropped from 67 to 16 (76% reduction) after applying 8D. Similarly, a case study by Mahmood (2023) in production of temperature sensors and power-supply units used 8D with a cross-functional team and “5 Whys” root-cause analysis to address leakage-current issues; the study provided an 8D template for practitioners.

Furthermore, Ionescu et al. (2022) proposed a model for monitoring the interdependence of 8D and FMEA tools in the era of Industry 4.0, equipment-communication and business-flow integration. Cirtina et al. (2025) employed the 8D analysis method and demonstrated its effectiveness in identifying and solving engineering problems in the automotive industry.

3. Research Methods

This study utilizes a qualitative research methodology, emphasizing an in-depth exploration of phenomena through the analysis of non-numeric data sources such as textual documents, visual materials, and observational records. The research aims to investigate the background, causative factors, and broader implications associated with product quality issues. The study incorporates a comprehensive literature review alongside case study analysis, focusing on 8D reports pertaining to product defects within a MEMS probe card manufacturing company. Throughout the research process, the application of seven quality tools is integrated to facilitate the thorough completion and analysis of the 8D reports, thereby enhancing the robustness of the problem-solving framework. The study is structured into three primary sections: the first describes the scope of the research, the second provides a detailed exposition of the 8D methodology, and the third introduces and elaborates on the seven quality tools employed in the analysis.

3.1 Research Scope

This study centers on Company A, a manufacturer of MEMS probe cards, with the primary case study material consisting of 8D quality reports. The scope of the research is delineated by a specific timeframe and the selection of 8D quality reports associated with product defects and issue resolution within the context of MEMS probe card manufacturing.

3.1.1 Time Scope

The study period begins from October 2019, when Company A was established, with the implementation of the 8D method as the main quality improvement tool starting in October 2021. The primary research timeframe spans from October 2021 to June 2024.

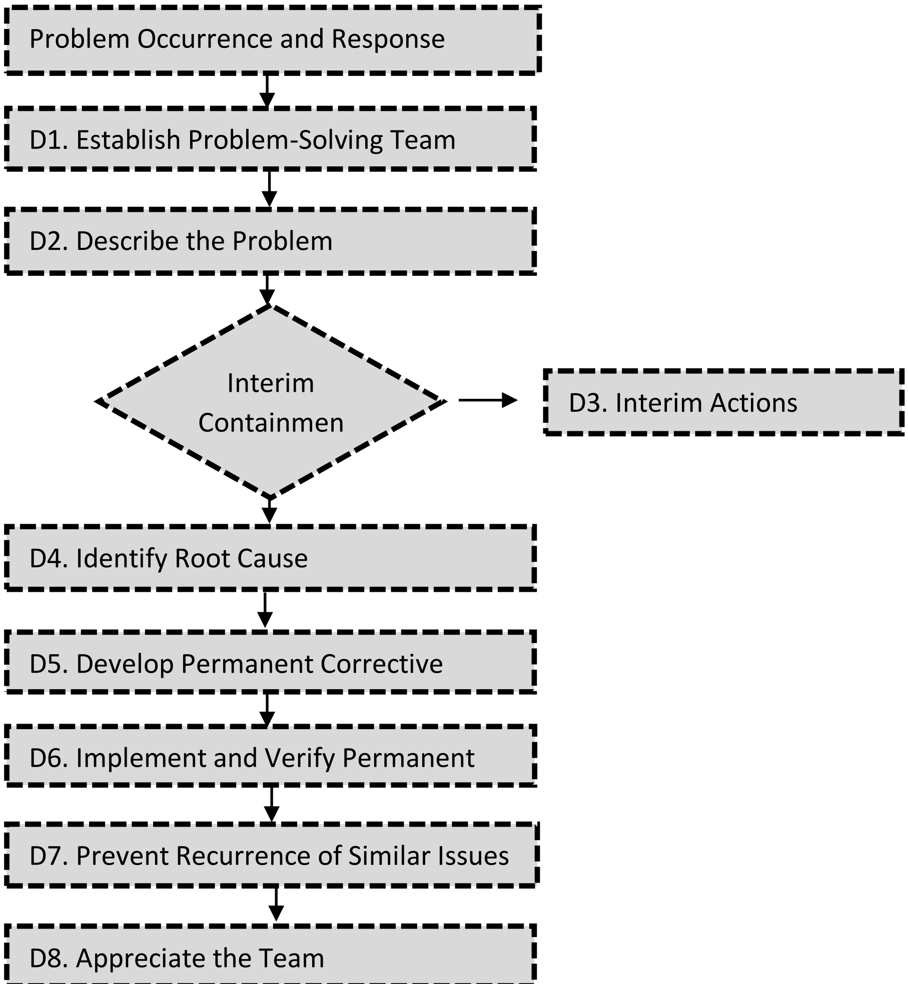

Figure 3. Ford 8D Steps

3.1.2 Case Scope of MEMS Probe Card 8D Quality Reports

The analysis covers Company A's operations from October 2019 to June 2024. Three quality anomaly cases from both internal and customer-side service engineers are selected for 8D report case analysis. This aims to explore the advantages and effectiveness of 8D application, serving as a foundation for promoting company-wide quality improvement, increasing market share, and enhancing customer satisfaction.

3.2 8D Methodology

8D (Eight Disciplines) is a systematic problem-solving tool developed by Ford Motor Company, widely applied across various industries. Its core lies in team collaboration and systematic analysis to identify root causes, develop solutions, and prevent recurrence, emphasizing process efficiency and error prevention. Mastering the 8D approach enhances problem-solving skills while strengthening team cooperation and leadership. The 8D process includes eight key steps: D1: Forming the team; D2: Describing the problem; D3: Implementing interim containment actions; D4: Identifying the root cause; D5: Developing permanent corrective actions; D6: Implementing and verifying improvements; D7: Preventing recurrence; D8: Recognizing team contributions. The relationships among these steps are illustrated in Figure 3. The specific procedures are detailed as follows.

Establish the Team (D1): Form a cross-functional team with the necessary skills and motivation. Members can come from internal departments, suppliers, or customers, possessing product, process, and management knowledge, along with required resources and authority. Clearly explain the reason for their selection and assign a sense of mission to ensure active participation.
Describe the Problem (D2): Provide a detailed problem description before taking action to avoid misunderstandings. Use the 5W1H approach (Who, When, Where, What, Why, How) and quantitative data to focus on key issues and help clarify the root cause.

Implement Interim Containment Actions (D3): Apply temporary controls to mitigate the problem’s impact, not the root cause. Examples include recalling defective products, emergency shutdowns, comprehensive inspections, 100% inline inspection, and temporary protections to control the scope, severity, and duration of the issue.

Identify Root Cause (D4): Determine the true cause of the problem by listing all possible causes, identifying the most probable ones, and confirming the key root cause to provide a basis for corrective actions.

Develop Permanent Corrective Actions (D5): Select the best permanent solutions either to eliminate the root cause or to control its effects.

Implement and Verify Permanent Actions (D6): Develop a detailed plan including objectives, methods, steps, deadlines, responsible personnel, and required resources (including budget) to ensure effective execution.

Prevent Recurrence (D7): Prevent future occurrences by revising processes, policies, operational methods, monitoring systems, and roles and responsibilities. Standardize effective countermeasures as future operating guidelines to avoid repeated or similar issues.
Recognize Team and Individual Contributions (D8): After successful problem resolution, publicly acknowledge the team and individuals’ contributions to express gratitude, reinforcing their sense of accomplishment and value.

3.3 Quality Control Seven Tools

When applying 8D, the 7 Quality Control Tools (7 QC Tools) are often used. These tools are primarily for identifying, analyzing, and solving quality issues in processes. They are widely applied across manufacturing, service industries, and other fields to help companies improve quality and increase efficiency. A brief introduction to the 7 QC Tools is as follows:

(1) Check Sheet
A simple data collection tool used to record and organize occurrences of problems. It helps track defect frequency and patterns and is commonly used for process anomaly records. Its features include ease of use and providing a basis for subsequent statistical analysis.

(2) Fishbone Diagram (Ishikawa Diagram / Cause-and-Effect Diagram)
Used to identify the root causes of problems. The problem is placed at the "head" of the diagram, with possible causes branching out as "bones." It systematically organizes potential factors, aiding in finding the root cause of quality defects.

(3) Control Chart
A statistical tool for monitoring process variation and determining if a process is within control limits. It helps distinguish between random and systematic variations, prevents process loss of control, visualizes monitoring, and detects abnormalities early to prevent quality issues from escalating.

(4) Pareto Chart
Based on the 80/20 rule, it identifies the few critical problems causing most defects. By ranking problems by frequency or impact, it helps focus resources on the most important issues, improving problem-solving efficiency.

(5) Histogram
A statistical tool that displays data distribution, especially showing patterns of process variation. It visualizes frequency distributions to help identify abnormalities or trends in the process.

(6) Scatter Diagram
Used to examine the relationship between two variables, determining if there is correlation and identifying factors affecting process outcomes. It visually analyzes positive, negative, or no correlation between variables, helping uncover potential quality problem causes.

(7) Flow Chart
Depicts the steps of a process or system graphically, showing the sequence and relationships of each step. It helps identify bottlenecks or non-value-added activities, clearly presenting the process flow to spot improvement opportunities and optimize processes.

4. Introduction to the Case Study

This section explores the case company used in this study, hereafter referred to as Company A. It is divided into five sections: The first section briefly outlines Company A's development history, main products, and market expansion; the second section introduces the parent company's background and growth; the third analyzes the main products and their application areas; the fourth focuses on the probe card maintenance process, detailing required resources and equipment; and the fifth presents an 8D case analysis, examining problem context, causes, and implications through qualitative data (text, images, observations). This section also combines

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literature review and case study methods to analyze and discuss quality issues in the MEMS probe card company, using the seven quality tools to support the 8D report completion.

4.1 History of Company A

Company A, a subsidiary of an Italian foreign enterprise, was established in Taiwan in 2019. It is responsible for the repair, after-sales service, and promotion of probe cards in the Greater China region. The parent company is a global leader in probe card manufacturing, with operations across Asia, Europe, and America, serving the entire semiconductor industry. Company A is located in the Taiyuan Technology Park, Hsinchu, adjacent to major wafer foundries and IC design firms, providing geographical and service advantages.

The company focuses on the manufacturing and repair of probe cards, which are used in system-level chip testing for mobile communications, automotive electronics, display, and logic chips. It also engages in wholesale of machinery and electronic materials, equipment manufacturing, and repair services, offering diversified solutions. With growing demand for AI and high-performance computing (HPC) chips, the company continuously enhances technological innovation and quality to meet the high-end probe card market and deepen customer collaboration.

4.2 History of the Parent Company

The parent company is a key global player in semiconductor testing equipment, specializing in the design, manufacture, and sale of MEMS probe cards widely used in chip testing. Founded in 1996 with headquarters in Italy, it serves wafer foundries, IDM, fabless IC design companies, and packaging and testing firms. Leveraging technological innovation and customized services, it is one of the global duopolies alongside US-based Form Factor. It went public on the Milan Stock Exchange in February 2022, expanding its international influence.

The first factory was established in 1997 with about 10 employees, and in 2000 launched the first vertical probe card using COBRA technology, featuring 960 pins and 240-micron spacing.

As business expanded, the company began global deployment starting in 2001 with offices in France, Singapore (2003), and San Jose, USA (2007). It entered the Taiwan market via distributors in 2006. The core products, probe cards, are advanced testing equipment used across IT, 5G, IoT, automotive, and aerospace chip manufacturing.

The company boasts a comprehensive technology portfolio, including Cantilever technology, TPEG™ vertical MEMS technology, carrier boards, and final test boards, capable of meeting highly complex testing demands. To serve the Asia-Pacific market, it established Taiwan subsidiary Company A in Hsinchu in 2019, responsible for Greater China operations, with additional offices in Korea, China, Japan, the Philippines, and Singapore, and European service centers in France and Germany.

4.3 Analysis of Main Products

The principal products of the company consist of MEMS-based probe cards, which encompass the following classifications:

1. Vertical Probe Card: Leveraging MEMS technology to achieve probe miniaturization, this type is primarily employed in the testing of central processing units (CPU), graphics processing units (GPU), and application-specific integrated circuits (ASIC). It is characterized by its high durability and precision, rendering it particularly suitable for testing advanced 5G and artificial intelligence (AI) chips.
2. Cantilever Probe Card: Designed for conventional wafer testing applications, this category is utilized for testing power management integrated circuits (PMIC), microcontroller units (MCUs), and radio frequency (RF) chips. It offers high current testing capabilities, facilitating robust performance in such contexts.
3. TPEG™ Technology Probe Card: Developed expressly for high-density chip testing, including dynamic random-access memory (DRAM) and NAND Flash memory, this type of probe card is capable of testing thousands of I/O ports concurrently, thereby significantly improving testing efficiency.
4. System-in-Package (SiP) Probe Card: Mainly employed in wafer-level packaging (WLP) and 2.5D/3D integrated circuit (IC) testing, this category supports high-frequency and high-temperature testing environments, ensuring reliable performance under demanding conditions.
5. RF Probe Card: Utilized for the testing of RF-related chips such as those used in 5G, Wi-Fi 6/7, and millimeter-wave devices, this type features ultra-low loss characteristics vital for accurate RF measurements.

This comprehensive product portfolio exemplifies the company's focus on high-precision, high-performance testing solutions across a broad spectrum of advanced semiconductor applications.

4.4 Introduction to MEMS Probe Card Repair Process

MEMS probe cards are critical semiconductor testing technology, featuring high-density and high-precision designs that ensure stable and accurate wafer testing. However, improper manufacturing or repair can cause test errors, probe wear, or wafer damage, impacting yield and costs. Due to continuous 24-hour chip production, probe cards often require maintenance, with customers commonly demanding local manufacturing and repair services to shorten delivery times and maintain production continuity.

Company A was established to provide timely engineering support and probe card repair services to local customers and assist its parent company with downstream processing and shipment inspections. Since its founding in 2019, it adopted ISO 9001 standards. Initially, quality issues were recorded via "Quality Abnormality Forms," but this simplified process hindered follow-up tracking and analysis. To improve efficiency, in July 2020, the company implemented the 8D quality management method, using the 8D Report as the standard process for handling quality abnormalities.

Probe card repair requires personnel and equipment, including quality control engineers, process engineers, and operators. Equipment includes stereo microscopes for visual inspection, measuring microscopes, probe card grinding machines, PRVX testing equipment, and X-ray inspection devices. The following section describes the equipment and their functions for reference.

（1） PRVX4 Probe Card Physical and Electrical Tester
The PRVX equipment is primarily used for incoming quality control (IQC) after product receipt. It tests the physical and electrical characteristics of probe cards, including probe tip area measurement, coplanarity testing of all probes, and leakage current testing of the probe card.

（2） High-Magnification Measurement Microscope
The high-magnification measurement microscope is primarily used for incoming quality control (IQC) after product receipt. It tests the physical characteristics of probe cards, such as automatic measurement of probe tip area, coplanarity testing of all probes, and individual probe height measurement.

（3） Stereo Microscope
The stereo microscope offers lower magnification and is used by operators for incoming quality control (IQC) after product receipt. It also serves as an auxiliary tool during manual probe card repair work. Operators use this device to visually inspect the probe card's probes under magnification and perform probe replacement tasks.

（4） X-ray Inspection Machine
The X-ray inspection machine is an advanced technology device used in semiconductor test factories for quality control. It can penetrate non-metallic materials to inspect PCB circuits of probe cards and check for bent probes inside the probe heads. Additionally, it is used for quality inspection of PCB re-soldering, providing clear imaging to prevent soldering defects such as cold solder joints.

（5） Probe Polishing Machine
The probe polishing machine is an essential piece of equipment for probe card companies. It is used during the semi-finished stage of probe cards to ensure all probes are ground to the same length (coplanar). Additionally, the polishing machine serves as the primary tool for cleaning the probe tip surfaces.

The MEMS probe card repair process is as follows:

（1） Incoming Quality Control (IQC): After receiving the probe cards, maintenance engineers perform inspections based on customer feedback. Tools used include stereoscopic microscopes, high-magnification microscopes, PRVX probe card testing equipment, and X-ray inspection devices.

（2） Probe Head and PCB Repair: Operators execute repairs according to the maintenance order, including replacing damaged or worn probes, renewing all worn probes, or replacing

PCB components. Tools involved are stereoscopic microscopes and personal hand tools such as tweezers and soldering irons.

（3） Probe Polishing: After replacing probes, assistant engineers use a polishing machine to grind all probes to the same height (coplanar). Tools used are the polishing machine and high-magnification microscopes.

（4） Outgoing Quality Control (OQC): After repairs, testing engineers conduct final inspections using the PRVX equipment to ensure the repaired probe cards meet customer acceptance standards before shipment.

5. D Report Cases Analysis

This section analyzes case studies of quality improvement in MEMS probe card repairs using A Company's 8D quality reports and the Seven Quality Control (7 QC) Tools. The analysis highlights the strengths and weaknesses of each case to guide future quality enhancements, shorten product delivery and repair cycles, meet customer demands, and ensure uninterrupted chip production and shipment. Three 8D case reports are examined in this study.

5.1 Case 1

In October 2022, an incident occurred involving scratches and component detachment on the LG (Lower Guide) ceramic of a probe head (as shown in Figure 4). The event took place during probe card repair operations at the Hsinchu factory, where improper handling by operators and repair engineers caused surface damage to the LG ceramic and parts to fall off.

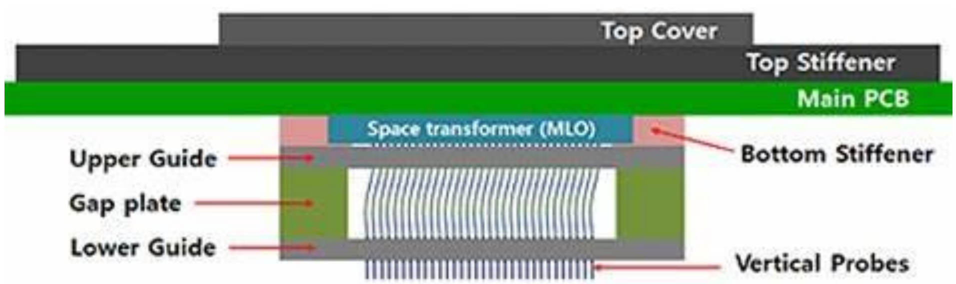

Figure 4. Diagram of Probe Card and Probe Head Components (Case 1)

(1) Team Formation (D1):
Assemble a problem-solving team including the factory maintenance manager, maintenance engineers, and quality control engineers. Assign the factory maintenance manager as the team leader responsible for overseeing overall improvement progress, delegating tasks, holding meetings, and regularly reviewing work items to ensure implementation of corrective actions.
(2) Problem Description (D2):
Using the 5W1H approach (When, Where, Who, What, Why, How), describe the case: On October 23, 2022, a probe card maintenance operator performed maintenance at the Hsinchu

factory. While inspecting the probe card's Upper Guide (UG) and probes, contamination was found on the UG. Under a microscope, the operator attempted to clean the contamination with a brush but applied excessive force. The metal brush holder contacted the UG directly, causing scratches and component detachment on the UG ceramic. This damaged product affected the customer's production, requiring replacement of the UG and components.

(3) Immediate Containment Actions (D3):

After the operator reported the issue, the on-site supervisor immediately ordered suspension of probe card maintenance, inspected and photographed the UG damage, and reported it. Simultaneously, all operators' cleaning procedures using microscopes and brushes were reviewed and corrected to prevent further damage.

(4) Root Cause Verification (D4):

The operator reported the incident details. The team leader held a meeting using fishbone diagram analysis (as shown in Figure 5) and group discussion to identify the main causes:

- The operator failed to notice the brush's metal part height and applied excessive pressure during cleaning, causing the UG ceramic scratches and component detachment.
- The microscope light source position affected the operator's cleaning angle, resulting in a near-vertical brushing motion that increased the risk of direct contact and damage to the UG and its components. Consequently, the entire set of probes and UG needed to be replaced and rebuilt.

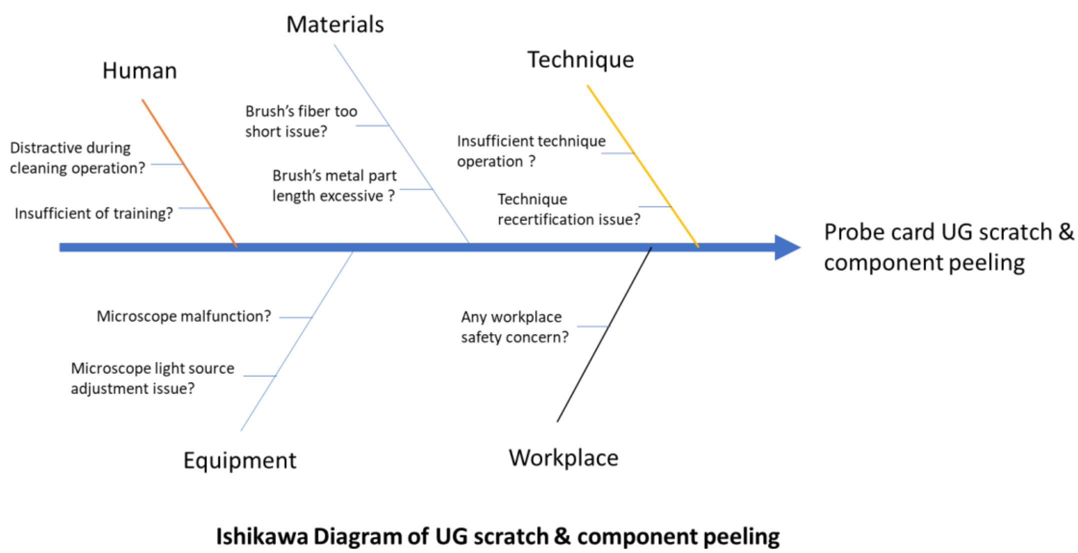

Figure 5. Fishbone Diagram (Case 1)

(5) Select and Verify Permanent Corrective Actions (D5):

Through repeated discussion and validation, the team confirmed that the main cause of the UG (Upper Guide) ceramic damage and part detachment was human error. Therefore, the following three permanent corrective action were adopted:

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- Inspect the probe cleaning brush to ensure bristles are untangled and metal fixtures are secure before starting cleaning.
- Retrain operators on proper cleaning technique using the brush at a 60–75 degree tilt to gently remove contaminants.
- Retrain operators on microscope usage, adjusting the light source direction to avoid interference with brush cleaning motions.

(6) Implement Permanent Corrective Actions (D6):

The main cause being human error, the following were implemented:

- Retrain operators on brush cleaning and microscope operation, ensuring the microscope light does not interfere with brush cleaning.
- Introduce a mentorship system for new operators, with experienced mentors guiding and regularly checking trainees' procedures and methods, plus performance evaluations before independent work.
- Incorporate adjusted microscope light settings and brush inspection methods into the Standard Operating Procedures (SOP). Train all operators accordingly to prevent recurrence.

(7) Implement Preventive Measures (D7):

Preventive measures include:

- Establish standardized operating procedures for consistent training.
- Create a case sharing list for quarterly factory-wide awareness campaigns to prevent recurrence.
- Use weekly factory meetings to reinforce discipline, internal communication, and foster a positive work culture.
- Conduct annual retraining and assessments for factory operators.

(8) Team Recognition (D8):

Thanks to the cooperation of the factory and quality control teams for promptly identifying and resolving the root cause, ensuring product quality.

In October 2022 at the Hsinchu factory, a typical human error occurred during probe card maintenance where improper brush use caused UG (Upper Guide) ceramic scratching and part detachment, impacting quality, delivery, and customer trust. The incident highlighted insufficient standardization, weak human risk control, and poor tool design.

After the event, the operator promptly reported to the supervisor, and similar operations were halted for damage inspection and process review (D3). A cross-department team was convened to initiate problem-solving, demonstrating basic crisis management and clear organizational structure (D1) with horizontal collaboration and responsibility assignment.

During problem analysis (D2, D4), the team used 5W1H and fishbone diagrams to break down the issue, identifying that uncontrolled distance between metal brush parts and ceramic combined with microscope light positioning caused excessive brush pressure, scratching the UG. This showed the problem arose from interactions among personnel, tools, and work environment, evidencing systemic analysis capability.

For corrective actions (D5, D6), three measures were proposed: reinforce brush inspection and usage standards, adjust brush cleaning angle to 60–75 degrees, and optimize microscope light setup with enhanced training. These were institutionalized into SOPs and training. A mentorship and assessment system for new employees was also introduced to strengthen skill application and accountability.

Through manuals, case sharing, routine discussions, and annual retraining, employee risk awareness and problem-solving skills were enhanced, promoting a learning organization.
Although results were positive, three improvement areas remain: adopt human factors engineering to improve lighting and workspace, design error-proof brushes with downward pressure limits, and implement digital traceability systems to enhance process tracking and training effectiveness.

In summary, Case 1 demonstrates how human error combined with tool design impacts quality, but the organization shows mature quality management in response, analysis, improvement, and institutionalization. Continuous implementation of systems, deeper training, and digital tool adoption will improve precision, reduce costs, and strengthen competitiveness and customer trust.

5.2 Case 2

In November 2022, a Lower Guide (LG) ceramic crack incident occurred during probe card maintenance performed by a customer service engineer at a Taichung customer testing facility. The ceramic crack on the LG probe head was caused by improper operation (as shown in Figure 6).

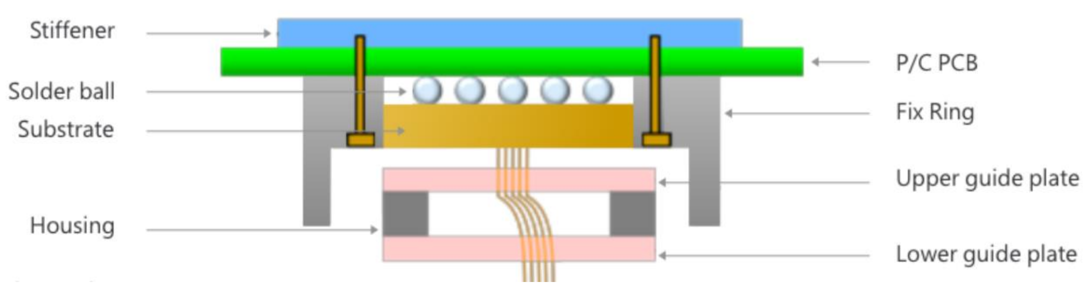

Figure 6. Diagram of Probe Card and Probe Head Components (Case 2)

(1) Establish Team (D1):
Form a problem-solving team including the FAE manager, customer service engineers, and quality control engineers. Assign a leader to oversee overall progress, allocate tasks, hold meetings, and regularly review team members' work to ensure implementation of improvements.
(2) Describe Problem (D2):

Using the 5W1H method, describe the case details: When, Where, Who, What, Why, and How. On November 28, 2022, a customer service engineer at the Taichung customer testing facility operated the probe card polishing machine in the cleanroom. Due to improper machine operation, the Lower Guide (LG) of the probe card cracked, impacting customer production. The probe card had to be returned to the factory for complete remanufacturing.

(3) Implement Immediate Containment Actions (D3):

Immediately instructed onsite customer service engineers to halt all probe card repair work, inspect and report damage extent to supervisors, and review polishing machine operation procedures and parameters to prevent further probe card damage.

(4) Identify and Verify Root Cause (D4):

The onsite engineer reported the incident. The team leader convened a meeting, using fishbone diagram analysis (as shown in Figure 7) and discussions to determine the main cause: operator error in setting the polishing machine height parameter, causing the machine head to strike the LG directly and crack it beyond usability. Full replacement of all probes and LG was necessary.

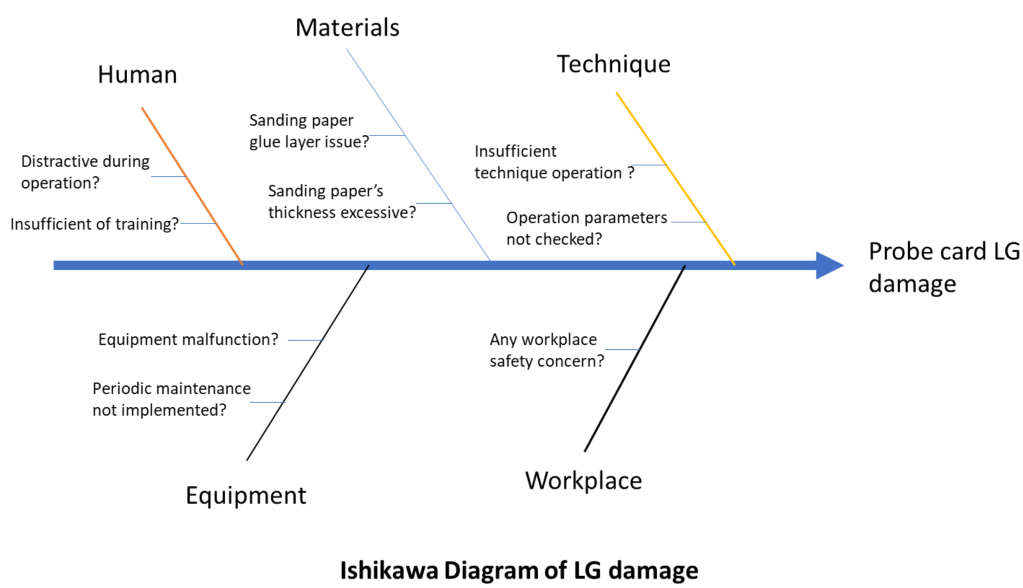

Figure 7. Fishbone Diagram (Case 2)

(5) Select and Verify Permanent Corrective Actions (D5):

After discussion and verification, two permanent corrective actions were adopted:

- Operators must visually confirm the polishing machine height parameter at least three times before proceeding.
- During fine adjustments, operators must visually confirm the setting after every increment before continuing polishing to avoid errors.

(6) Implement Permanent Corrective Actions (D6):

Two measures were implemented:

- From November 28, 2024, all onsite customer service repair engineers must retrain and pass an assessment on probe card polishing machine operation before returning to field work.

- Strengthen onsite training emphasizing focused, careful operation; any doubts must be reported to supervisors immediately to ensure zero-error operation.

(7) Implement Preventive Actions (D7):

Preventive measures include:

- Establish a case-sharing list with annual reviews to prevent recurrence.
- Hold weekly problem discussion meetings to enhance internal communication.
- Conduct annual retraining on troubleshooting for FAE and FSE personnel.

(8) Team Recognition (D8):

Appreciate the FAE team for prompt response ensuring repair quality. The incident occurred in November 2022 at the Taichung customer test site due to operator error during polishing, causing LG ceramic breakage and full probe card remanufacture, impacting customer production.

From a management perspective, the incident revealed insufficient process standardization, lack of onsite supervision, and weak human risk control. However, the response demonstrated a basic crisis management process and continuous improvement culture, providing valuable lessons.

After occurrence, the organization quickly halted operations and inspected damages (D3), convened a cross-department problem-solving team (D1), showing high risk awareness and mobilization capacity.

During problem analysis (D4), 5W1H and fishbone diagrams were used to thoroughly investigate, confirming the main cause as human error in machine parameter setting, with further insight into system and process issues, demonstrating mature problem-solving mindset.

For corrective actions (D5, D6), a dual confirmation system was implemented, including triple visual checks and real-time parameter verification, alongside a retraining and certification program, delegating quality responsibility clearly to field personnel to enhance operational thresholds and risk awareness.

Preventive measures (D7) like case sharing, regular problem meetings, and annual retraining indicate transformation of individual experiences into organizational knowledge, fostering a learning culture and preventing error recurrence, improving team professionalism.

Despite clear and proactive response, three areas remain for improvement:

- Over-reliance on manual repeated visual checks—recommend automating calibration and abnormality alert systems to reduce dependence on experience.
- Clearer performance and accountability mechanisms to boost transparency and responsibility.
- Deepening “Quality at the Source” cultural education to reinforce engineers’ role as quality gatekeepers.

In summary, this case exposes risks of human error in high-precision manufacturing and highlights organizational capabilities in crisis management and continuous improvement. Future adoption of digital monitoring and formalized processes, along with strengthened quality culture, will enhance stability and competitiveness.

5.3 Case 3

In October 2022, at a customer testing facility in Taichung, a probe head screw loosened, causing surface damage to wafers during production (as shown in Figure 8).. A customer service engineer performing probe card maintenance at the customer site failed to properly secure the screw, which protruded and scratched the wafers—an operational error.

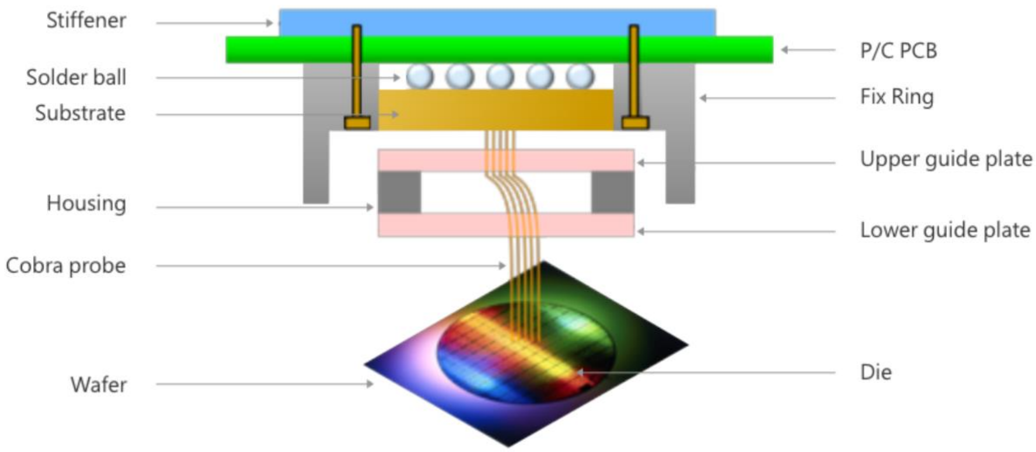

Figure 8. Diagram of Test Probe Card, Probe Head, and Wafer

(1) Establish Team (D1):
Form a problem-solving team including the FAE manager, customer service engineers, and quality control engineers. The FAE manager leads the team, overseeing progress, assigning tasks, convening meetings, and regularly reviewing department execution to ensure repair quality improvement measures are implemented.
(2) Describe Problem (D2):
Using 5W1H, the case is described as follows: On October 22, 2022, a customer service engineer performed probe card maintenance inside the cleanroom at the Taichung customer testing site. During maintenance, the probe head fixing screw was loosened but not re-tightened before returning the card to production, causing wafer surface damage from the protruding screw. The customer counted 4 damaged wafers.
(3) Implement Immediate Containment Actions (D3):
The engineer immediately reported to supervisors, and onsite maintenance was suspended. Supervisors inspected the probe card screw condition with the customer, took photos, and reported the issue. The process was reviewed, requiring that future repairs be double-checked by another engineer for screw tightness to prevent recurrence.
(4) Identify and Verify Root Cause (D4):
The onsite engineer reported this incident. The team leader gathered and discussed potential causes:

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- The repair technician failed to notice the screw was not tightened during reassembly, leading to gradual loosening and wafer damage.
- Comparison of two spare screwdrivers with the incident tool confirmed consistent torque settings—tool malfunction excluded.
- Microscopic measurement showed identical thread spacing between spare and incident screws—excluding screw defect.

Fishbone diagram analysis (as shown in Figure 9).and team discussion concluded the root cause was operator distraction and failure to follow screw-tightening confirmation procedures.

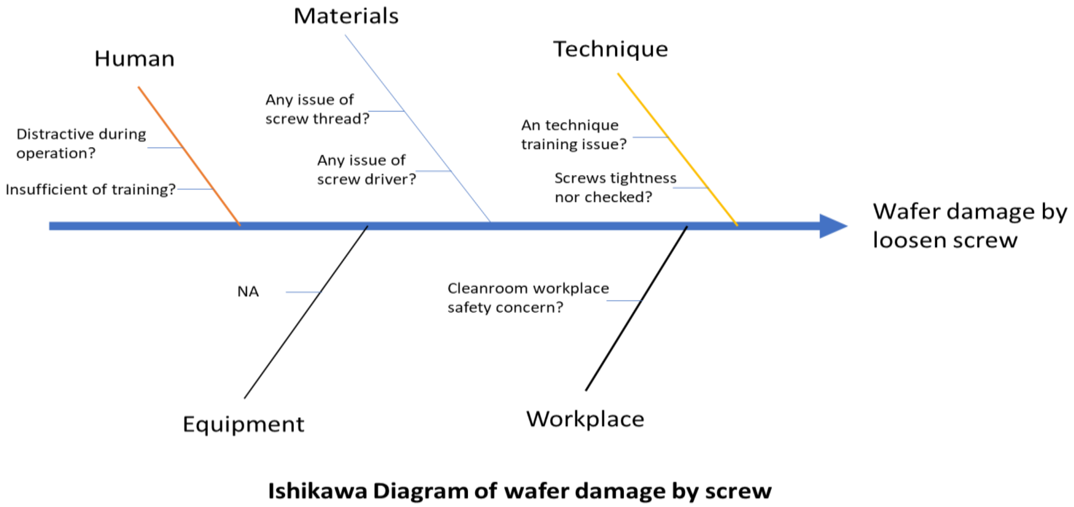

Figure 9. Fishbone Diagram (Case 3)

(5) Select and Verify Permanent Corrective Actions (D5):

After thorough discussion, the team confirmed the root cause as human error and adopted these permanent corrective measures:

- Retrain all onsite customer service engineers following the probe card repair standard operating procedures (SOP).
- Require electronic torque screwdriver re-checks of all screws after repair to ensure tightness and prevent loosening.
- Introduce a double-check system where a second engineer verifies screw tightness with the electronic torque screwdriver.
- Upon handing over repaired cards to the customer, their engineers jointly conduct a final screw tightness check with the torque screwdriver, creating a triple-check defense.

(6) Implement Permanent Corrective Actions (D6):

From November 3, the following actions were implemented:

- Supervisors led retraining of all customer service engineers on the SOP for probe card repairs.
- Included in onsite work management: screws must be re-checked for tightness with electronic torque screwdriver after repair.
- Established double verification by another engineer using the torque screwdriver.
- Per agreement with the customer, the customer's engineer performs the third verification during repair handover.

(7) Implement Preventive Actions (D7):
Preventive measures include:
- Standardize onsite customer service procedures to support consistent training.
- Create a case-sharing list; regularly promote cases in quarterly meetings to prevent recurrence and confirm understanding via two-way communication.
- Weekly meetings reinforce discipline and internal communication; establish proper onsite and customer communication methods and cultivate correct work culture.
- Conduct annual retraining and assessment for all customer service engineering staff; those failing reassessment are prohibited from onsite work.

(8) Team Recognition (D8):
Thanks to the prompt cooperation of customer service and quality control teams, the root cause was quickly identified and properly addressed, ensuring stable repair quality at the customer site.
This incident in October 2022 was caused by human error: failure to properly tighten screws during onsite probe card repair led to four wafers being scratched by protruding screws. Although losses were limited, this posed potential risks to company image and customer trust.
The overall response demonstrated the company's basic crisis response, problem analysis, and improvement system management capability. Immediate containment included halting onsite repair and damage inspection, showing excellent risk awareness and crisis handling—a key performance in quality management.

Subsequent 8D procedures displayed systematic problem-solving. Team formation (D1) led by the FAE manager integrated customer service and quality assurance, enhancing cross-department collaboration. Problem description (D2) used 5W1H to clarify background and occurrence, aiding swift error localization.

Root cause analysis (D4) employed fishbone diagrams and exclusion methods, ruling out tool and material issues, ultimately attributing to operator distraction and incomplete tightening, reflecting mature organizational review beyond individual mistakes.
Corrective actions (D5, D6) implemented a "three-line verification" system: self-check, peer review, and final customer confirmation, forming a closed loop that strengthened onsite error prevention. SOP updates and education training emphasized systematization and talent development.

Preventive actions (D7) centered on institutionalization and cultural building, promoting experience sharing, regular meetings, and annual retraining, fostering a learning organization culture.

Although triggered by individual error, the response showed cross-functional collaboration and PDCA spirit, effectively preventing problem escalation and establishing preventive measures.

Further management improvements recommended:
- Strengthen human factors management by monitoring staff mental state and workload to enhance alertness beyond training.

- Introduce digital inspection workflows with electronic sign-offs and repair history to replace paper checks, improving transparency.
- Implement a reward and penalty system to incentivize error prevention and sanction repeated SOP violations, reinforcing system authority.

In summary, this case demonstrates mature organizational ability in handling quality anomalies, offering an excellent example of problem resolution and improvement. Continued systematization, digital integration, and human risk control will further strengthen corporate reputation, client relations, operational resilience, and sustainable competitiveness.

6. Conclusion

This study explored how the 8D methodology can effectively address quality issues encountered in the production and practical use of MEMS probe cards, enhancing product reliability and customer satisfaction. MEMS probe cards are critical components in semiconductor testing; their quality directly impacts process efficiency and final product yield. Due to their intricate structure and complex manufacturing process, common issues include shorts, opens, contact failures, and insufficient lifespan.

Research indicates that 8D reports, with their structured and practical approach, are particularly suitable for high-precision products like MEMS probe cards. They effectively identify root causes, develop countermeasures, prevent recurrence, and promote cross-department collaboration and knowledge management, establishing sustainable quality improvement mechanisms. As global quality standards rise, the 8D method is a key tool for enterprises to achieve total quality management and operational excellence.

This study applied the 8D process to real abnormal cases, verifying its effectiveness in root cause analysis and error-proofing mechanisms, thus providing a feasible improvement model for probe card quality management.

6.1 Research Findings

Comprehensively, the 8D report is a structured, practical quality resolution tool, especially suited for complex, multi-fault-pattern products like MEMS probe cards. Implementing the 8D process effectively uncovers root causes, formulates corrective actions, prevents recurrence, and fosters interdepartmental cooperation and knowledge management, laying a foundation for long-term quality improvements. Under increasingly stringent global quality demands, the 8D method strengthens problem-solving and management processes, driving enterprises toward total quality management and operational excellence. After case study analysis and validation, the conclusions are as follows:

6.1.1 Probe Repair and Manufacturing Process

Current MEMS probe card repair heavily relies on temporary fixes and empirical approaches, lacking systematic problem-solving tools. Increased defect frequency or customer complaints may harm brand and operational performance. This study validates the practical effectiveness of the 8D method in quality improvement and offers implementation recommendations for enterprises.

6.1.2 Execution and Practical Outcomes of the 8D Method

Through several case studies on quality anomalies in MEMS probe card repair and manufacturing, the 8D steps were systematically applied:

- **D1:** Form cross-functional teams including QA, engineering, process, and customer service to fully understand issues.
- **D2:** Describe problems in detail using 5W1H, documenting event specifics.
- **D3:** Provide interim containment actions for urgent customer needs.
- **D4:** Perform root cause analysis with tools like 5Whys and fishbone diagrams to identify true causes such as tool defects or human errors.
- **D5:** Develop permanent corrective actions including process optimization and SOP updates.
- **D6:** Verify effectiveness through experimental design and long-term monitoring of quality metrics.
- **D7:** Institutionalize improvements with training, audits, and automated checks.
- **D8:** Recognize team contributions publicly to foster collaboration culture.

Post-implementation, quality improvements were significant, with contact failure rates dropping from 2.3% to 0.5%, repair time reduced by 40%, and shipping delays substantially cut, proving 8D's role in stabilizing quality and boosting customer trust.

6.1.3 Application of 8D in MEMS Probe Cards

The study confirms that beyond problem resolution, 8D facilitates organizational learning and knowledge accumulation. Its structured process and team-based approach improve response and prevention capabilities, especially suited for sophisticated products like MEMS probe cards. It enhances transparency, accountability, reduces recurrence risks, and builds traceable records aiding internal knowledge bases and experience sharing.

6.2 Recommendations

Based on the validation with Company A, the study suggests:

1. Expand samples and industry scope to other probe card types or precision electronic components, assessing 8D's versatility and adaptability.
2. Integrate data analytics tools such as AI and machine learning to improve accuracy and efficiency in root cause analysis.
3. Evaluate cost-benefit of 8D implementation from defect rates, labor hours, and customer complaint reduction perspectives to encourage adoption.
4. Establish automated management systems to streamline 8D report recording, tracking, and analysis, enhancing overall quality and efficiency.

6. 3 Limitations

Despite demonstrating 8D's practical value, this study has limitations:

- It mainly analyzes three case studies and may not fully represent all MEMS probe card types or manufacturing quality issues.
- Long-term stability and recurrence control require further monitoring beyond the short-term verification conducted.
- Cases studied are retrospective, limiting real-time interviews with personnel involved at the time of the incidents.

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