Innovative Quartz Cassette Design for Minimizing Wafer Breakage and Quartz Cassette Damage

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ABSTRACT

In semiconductor manufacturing, wafer handling is a critical process that directly affects yield, product quality, and operational efficiency. Manual wafer transfer, particularly between process tools such as the Vertical Transfer and Oven machines, remains a common practice in many facilities.

In AMPI Probe production, quartz cassettes are utilized during the oven bake process to handle wafers. These quartz cassettes, made of high tensile glass, are picked up and loaded using a fork. The asymmetrical support provided by the current fork design has resulted in several incidents of broken wafers and damaged quartz.

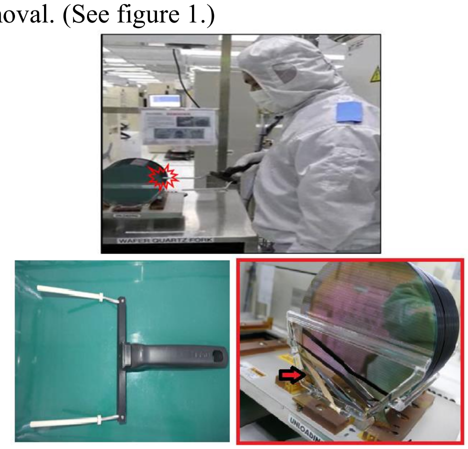
To address the identified handling challenges, the team proposes a redesigned quartz cassette featuring an integrated, user-friendly mechanism that enables direct and secure wafer transfer without the need for external tools. This design aims to enhance operational reliability and reduce the likelihood of damage to both wafers and quartz components during movement between process tools. By improving handling precision and minimizing contact risks, the new cassette design is expected to preserve material integrity and contribute to greater efficiency and consistency in the oven bake process within AMPI Probe production.

1. 0 INTRODUCTION

1.1 Background of study

Mostly, semiconductor companies have adopted metal cassettes for their durability and ease of handling, these are known to accumulate particles over time, which can lead to contamination and further yield degradation. But in contrast, quartz cassette offers cleaner handling but present ergonomic and mechanical challenges due to their design.

The AMPI Probe has experienced two incidents of broken wafers attributed to the operator mishandling with a fork. These incidents resulted in the scraping of two wafers, leading to a significant yield loss. The process involves the manual transfer of wafers loaded in quartz cassettes using a fork, moving them from the Vertical Transfer machine to the Oven machine. This procedure requires the insertion of the fork into the quartz cassette holder, a task complicated by the small-diameter hole. The minimal gap between the quartz cassette handle and the wafer increases the risk of mishandling and subsequent wafer damage during insertion and removal. (See figure 1.)



- Recent 2 cases of fork mishandling at bake oven process resulting in broken wafers.
- The incident resulted in a scrap cost of US$2,259
- Delayed shipment due to additional inspection and verification process done on affected lot.

Item	Hold Date	Lot	Wafer QTY	Remarks	Wafer Cost
919333	10/24/2024	234205QDAA	1	Broken wafer 25 accidentally hit by fork	$1,034 US Dollar
169012	12/17/2023	2349683QDAB	1	Broken wafer 21 accidentally hit by fork	$1,225 US Dollar

Table 1. *Scrapped wafers due to previous quartz design*

From FY20 to FY24, the oven bake process has most frequently encountered the issue of damaged quartz. This recurring problem is primarily due to the mechanical stress exerted on the fork hole during the loading and unloading of quartz cassettes using a fork. Over time, this stress leads to the formation of dents and subsequent damage to the quartz cassettes. (See Figure 2.)

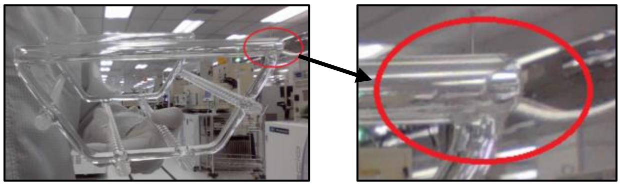


Figure 2. *Damage quartz due to misuse of fork*

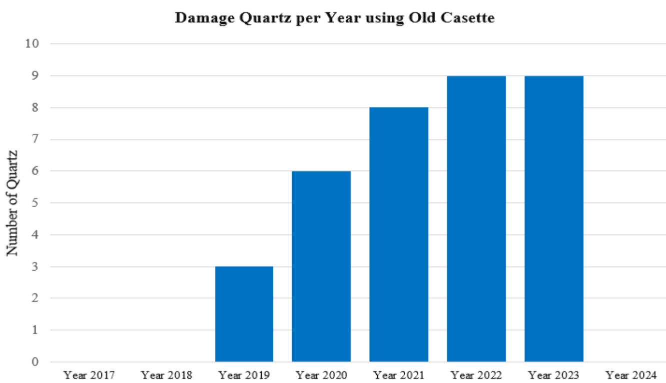


Figure 3. *Damage quartz per year due to mishandling tool*

Damage Quartz Cassette	Cost per piece	Total Cost
35	$331 US Dollar	$11,585 US Dollar

Table 2. *Total Scrapped Quartz due to misused of Fork*

Scrapped Quartz:

- 35 pieces of the quartz used in production were damaged due to the use of fork during transfer process.
- The incident resulted in scrappage of quartz amounting to 11,585 USD for the last 5 years.

1.2 Statement of the Problem

The primary issue in the oven bake process is the incidence of wafer breakage, which can occur due to several factors, including improper handling and flaws in the quartz cassette design.

This breakage results in multiple adverse outcomes:
Quality Control Issues: Broken wafers lead to yield loss.

Material Waste: Broken wafers and damaged cassettes cannot be used in the production process, resulting in a direct loss of valuable materials.

Production Delays: The need to replace broken wafers causes delays in the manufacturing timeline.

Increased Costs: Direct costs are incurred due to damage to quartz cassettes and wafer breakage.

1.3 Objective

These objectives are designed to develop a more reliable and efficient quartz cassette that greatly minimizes the occurrence of wafer breakage, resulting in enhanced yield and cost savings for the company.

Enhance Usability:

- Develop a cassette design that is user-friendly, enabling safe and efficient wafer loading and unloading with minimal risk of damage.
- Simplify the wafer transfer process between the Vertical Transfer Machine and the Oven Machine to improve workflow efficiency.

Reduce Mechanical Stress:

- Introduce design features that distribute weight and pressure more evenly, helping to prevent localized stress that can lead to damage of quartz components.
- Eliminate the need for external tools such as forks by integrating a more intuitive and secure handling mechanism.

Cost-effectiveness:

- Reduce wafer breakage incidents caused by improper manual handling techniques.
- Prevent physical damage such as dents on quartz cassette handles, which often result in scrappage and increased replacement costs.

2. 0 REVIEW OF RELATED WORK – NOT APPLICABLE

3.0 METHODOLOGY

The old design of quartz carriers lacked handles and required the use of a fork for loading and unloading, which led to several issues. Designing a new quartz cassette involves several steps and considerations to ensure it meets the necessary requirements for its intended application:

1. **Define Requirement**: Develop a design that minimizes the need for manual handling tools during the loading and unloading of quartz cassettes.
2. **Design Specifications**: Dimensions. Define the size and thickness based on the application.
3. **Prototyping**: Create a prototype to test the design.

Phase 1: In the initial design revision, the quartz cassette was equipped with horizontally oriented handles on both sides to facilitate manual handling. However, too much space was consumed once loaded and increased risk of touching other wafers during unloading process.
(See Figure 4)

Phase 2: The final design was modified to feature vertically positioned handles on both sides. This adjustment was made to enhance ergonomic handling while maintaining the full loading capacity of the oven chamber, ensuring that operational efficiency was not compromised. (See Figure 5)

4. **Testing and Simulation**: Conduct simulation to validate the new design.

- Assessment of the redesigned quartz cassette within the chamber to verify its effectiveness in maximizing capacity. (See Figure 5)
- A comparative analysis of post-bake yield outcomes using the original versus the redesigned quartz cassette design. (See Figure 6)

5. **Optimization**: Based on simulation results, refine the design to address any issues.

6. **Final Production**: Proceed to purchase final revision design.

Figure 4. *Redesigned quartz cassette (Revision 1)*

Figure 5. *New quartz cassette design inside the oven chamber.*

Figure 6. *There is no significant change in the median yields between the Old Quartz Design and the New Quartz Design*

The development of a new quartz design involves a comprehensive methodology to ensure the final product meets the desired standards of performance, aesthetics, and cost-effectiveness. This methodology typically includes several key criteria:

1. **Cost Management:** Ensure that the new quartz design stays within the base price of the original design to manage expenditure effectively.
2. **Design Optimization:** Maintaining the oven chamber's loading capacity while ensuring sufficient spacing between each quartz cassette to ensure efficient operation. (See Figure 7)
3. **Mechanical Stress Reduction:** Implement design features that minimize mechanical stress on the quartz, thereby enhancing durability and reducing the risk of damage during handling.

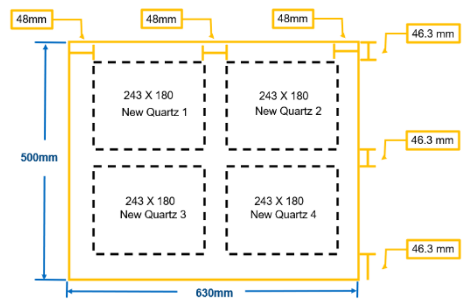


Figure 7. *New quartz cassette layout inside the oven chamber.*

3.1 Root Cause Analysis

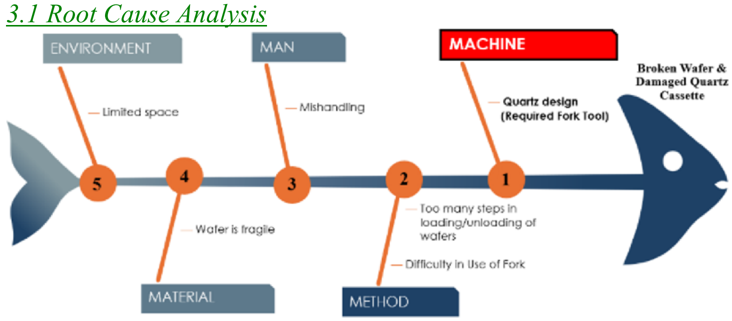


Figure 8. *Fishbone diagram*

By identifying and analyzing these possible causes, the team developed strategies and brainstormed to mitigate the problem. Data analysis established that the main contributor was:

1. Machine: Quartz Design (Required external tool)
2. Method: The existing wafer handling process involved multiple manual steps, which contributed to inefficiencies and increased the risk of wafer & cassette damage.

4.0 RESULTS AND DISCUSSION

The team developed and evaluated two design revisions of the quartz cassette. Each revision was assessed based on its impact on handling efficiency, wafer safety, and compatibility with existing equipment. The results of these evaluations are summarized below, highlighting the improvements and limitations observed in each design iteration.

Criteria	Original Design Quartz	Revision 1 Design Quartz	Final Design Quartz
Base Cost (US$ 331)	PASSED	PASSED	PASSED
Conformity (4 quartz/chamber)	PASSED	FAILED	PASSED
Reduced mechanical stress on quartz	FAILED	PASSED	PASSED

***Table 3**. Design quartz cassette simulation result.*

The new quartz design is both effective and reliable, removing the necessity for any additional tools. Furthermore, the design features have proven to significantly lower the risk of wafer breakage and distribute weight and pressure more evenly when both hands of the operator are utilized. The batches processed in the oven bake procedure, as shown in figure 10, experienced no issues during the operation

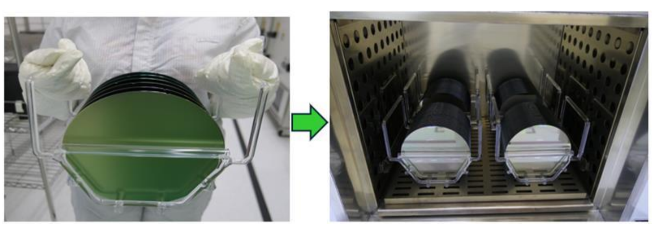


***Figure 9.** New quartz cassette design*

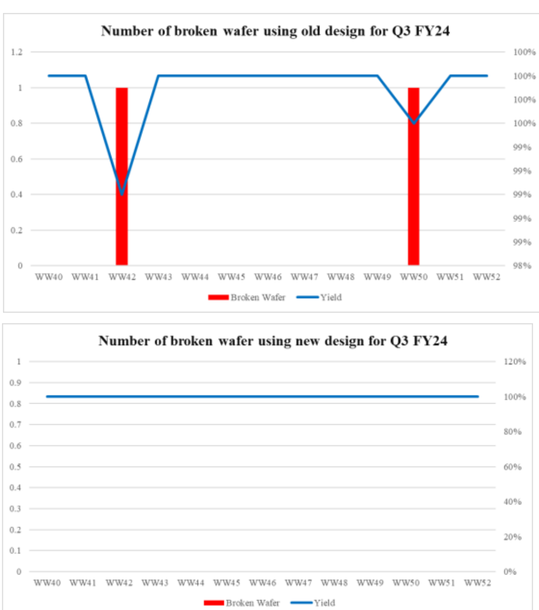


***Figure 10.** Number of broken wafers encountered using old and new quartz cassette.*

5.0 CONCLUSION

Prior to the full implementation of the initial designed quartz cassette, the team conducted a thorough assessment to identify any potential impacts on downstream processes.

During simulation of the initial design revision, it was observed that the oven chamber's loading capacity was not fully utilized. Had this issue not been identified during the evaluation phase, proceeding with the procurement of Revision 1 cassettes would have resulted in reduced capacity and operational inefficiencies. This proactive assessment ensured that the final design maintained both functional improvements and production capacity.

6.0 RECOMMENDATIONS

The team recommended considering the use of quartz materials, which are 70% cheaper compared to metal cassettes. Additionally, it has been noted that metal cassettes can cause contamination during the manufacturing process. Therefore, transitioning to quartz materials not only offers significant cost savings but also reduces the risk of contamination, thereby improving the overall quality and reliability of the product.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES – NOT APPLICABLE

9.0 ABOUT THE AUTHORS

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