PROBE CONTACT FORCE: SIGNIFICANT FACTOR IN REDUCING CONTACT RELATED ISSUE AT WAFER PROBE

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ABSTRACT

Probe testing contributes a significant role in ensuring the functionality and reliability of electronic devices. However, one of the challenges that can lead to inefficiencies in testing procedures is the probe contact issue. Poor probe contact would result to intermittent failures causing low equipment utilization. The unstable contact resistance is known as poor probe contact which results from the Probecard needle's inability to pierce the wafer bond pad.

Equipment Utilization is defined as the amount of time a piece of equipment, machinery, or asset is used and as computed as shown below:

Equipment Utilization = Actual operating time / Available time.

To address these issues, a thorough study was conducted focusing on factors that influence probe contact. Using the root cause analysis tools, such ISHIKAWA diagram/Fishbone Diagram, Gemba Walk, Process Mapping and other useful quality tools, the cause of contact related issue leading to probe hardware downtime were identified, validated and solutions were developed.

Wafers have different pad thickness structures depending on product design/bond pad structure. The thicker the material, the more gram force is needed on needle to fully penetrate the wafer bond pad. Compatibility of wafer bond pad structure is important to avoid poor contact.

1. 0 INTRODUCTION

Probe wafer testing is a process in semiconductor manufacturing where a semiconductor wafer is tested before the individual integrated circuits are diced and packaged. This testing is being done using a system, program, test equipment, device, and hardware The probe card serves as a tester's hand, contacting bond pads on a wafer's surface, establishing an electrical connection between the tester and IC and enabling signal flow. A well-designed probing system should ensure low and stable contact resistance between each needle-like probe and the IC chip-bonding pad during electrical signal transmission and reception.

In AMPI (Allegro Microsystems Philippines) the actual probe setup, consists of Tester with Test head where the PIB (Probe Interface Board) is docked; pogotower that enables the connection between PIB and Probecard; and lastly, a wafer which is vacuums by the prober chuck. (Fig. 1)

At AMPI, automotive products and motor application devices undergo testing and processing in a cold environment (-40 degrees Celsius) with 2um wafer pad thickness material.

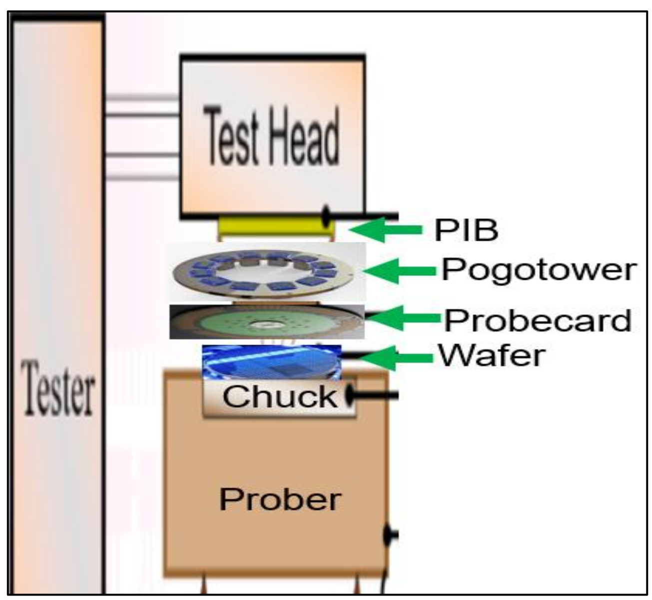

Fig.1. Actual Probe Setup showing complete Tester,Testhead PIB, Pogotower Probecard, wafer and prober.

The printed circuit board known as the Probecard is equipped with needle pins that are positioned to make contact with the wafer pad and route signals from the load board to the tester.

A healthy probe card will provide reliable and accurate testing resulting in good equipment utilization. However, a problematic Probecard will result in inconsistent testing which may affect the utilization.

This project's scope will be concentrated on the probecard, which has needle pins inserted in the probehead to contact the wafer bond pad during probing. (Fig. 2)

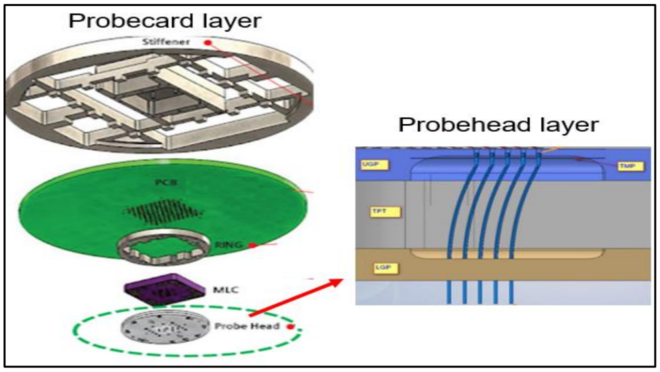

Fig. 2. Exploded view of Probecard showing layered components: stiffener, PCB, ring, MLC and Probehead with needle.

According to data gathered from 2023, Hardware is the top contributor of unplanned downtime with 60% which affects the utilization. (Fig. 3).

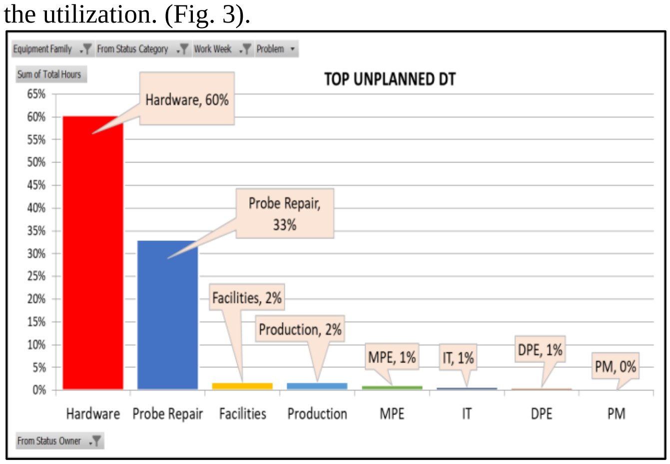

Fig. 3. Probe Unplanned Downtime showing Hardware as the top downtime contributor.

Second level analysis shows that missing/light marks are the biggest contributor of Hardware downtime with an overall prevalence of 38%, while bin7 failure is the second contributor with 37%. Both bin7 and missing/light marks can be associated as contact related issue. (Fig. 3)

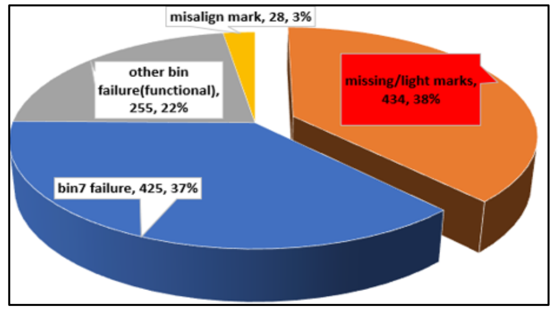

Fig. 3. Top Hardware Problem showing missing/light marks and bin7failure as top2 contributor.

The scope of this project has been examined in a Kaizen event held in AMPI to define process improvement and root cause determination of contact problem resulting to light/missing marks and bin7 failure. The team investigated and analyzed the issue and developed a comprehensive approach to the resolution of contact problems.

The Team revisited the needle design and revalidated it with the wafer bond pad structure. Based on data using the historical downtime of the devices/products having a contact issue using the existing needle, the 3mils needle shows poor penetration to the bond pad which resulted to poor contact that leads to light/missing probe mark and bin7. (Fig. 4). This led the Team to revisit and revalidate the needle gram force if compatible with the bond pad thickness. It was validated that a maximum 100um overdrive setup requirement will only have a gram force of 7 grams which is not enough to penetrate the wafer bond pad. (Fig.5)

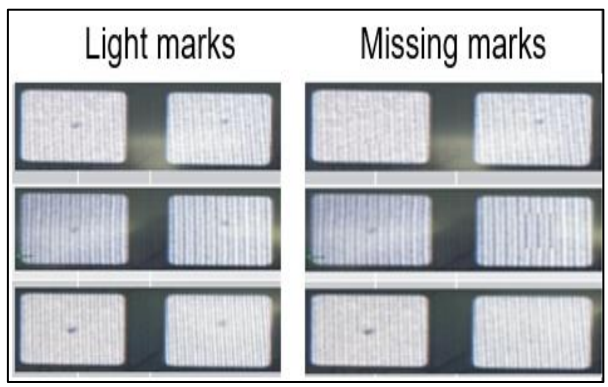

Fig. 4. Probemark impression showing light and missing marks.

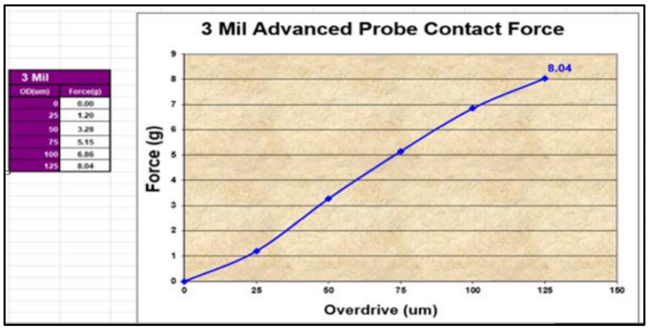

Fig. 5. 3mils needle gram force vs. overdrive showing 7 grams force for a maximum 100um overdrive.

To increase gram force, the Team recommended converting the needle from 3.0mils to 3.5 mils (Fig. 6) with hypothesis of thicker needle have higher gram force which will result to a good penetration to wafer bond pads. Using 3.5mils at 100um overdrive will result to 9 grams vs 7 grams when using 3mils. (Fig. 7) With this strategic approach, electrical testing is now stable; downtime was significantly reduced which resulted to an improved utilization.

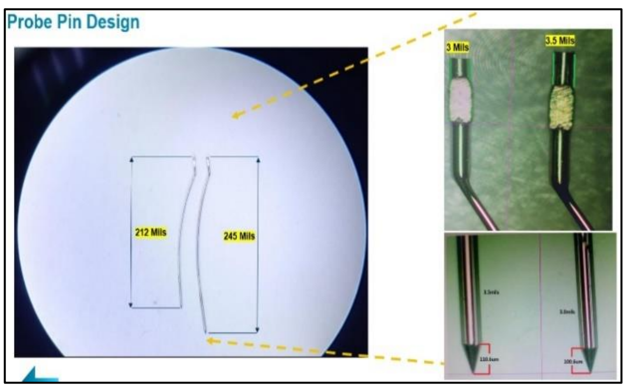

Fig. 6. Needle pin design 3mils and 3.5mils comparison.

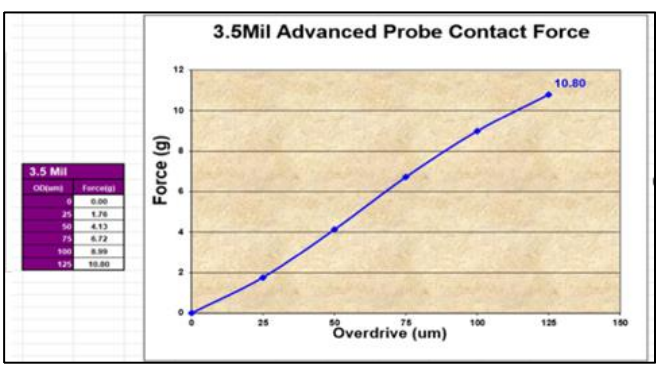

Fig. 7. 3.5mils needle gram force vs. overdrive showing 9 grams force for a maximum 100um overdrive.

2. 0 REVIEW OF RELATED WORK

Refer to 1.0 Introduction.

3.0 METHODOLOGY

Lean Tools & Techniques such as ISHIKAWA diagram/Fishbone Diagram, Is/Is Not Analysis, Gemba Walk and Process Mapping are applied to determine the cause of the problem and the effectiveness.

Using the ISHIKAWA Diagram/Fishbone Diagram, under Material Category is the significant factor that contributes the cause of the problem that will lead to Light/Missing Probe marks Defect. (Fig. 7)

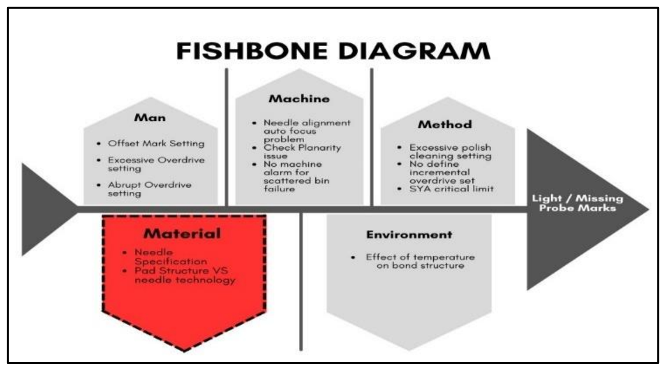

Fig. 7. Fishbone Analysis showing Material as the significant factor.

Using the Is/Is Not Analysis, using the 3mils needle during cold probe testing of wafer with pad thickness of > 2um will result to poor penetration causing intermittent contact failure. (Fig. 8)

PROBLEM: INTERMITTENT CONTACT FAILURE (IS / IS NOT ANALYSIS)		
	IS	IS NOT
WHAT?	3 MILS VERTICAL COBRA PIN TECHNOLOGY CAUSING LIGHT MARKS	MEMS TECHNOLOGY
WHERE?	PROBE Testing using COLD Temp probing	Ambient/HOT Temp probing
WHEN?	Existing design of Probecard pin cobra technology since start of PROBE	New pin cobra technology for new product
WHY?	Pad thickness structure (> 2um)	Pad thickness structure (< 2um)
HOW?	3mils needle does not fully penetrate the bond pad structure with pad thickness of >2um	3mils needle can fully penetrate the bond pad structure with pad thickness of < 2um

Fig. 8. Is/Is Not Analysis showing the cause of poor contact failure.

Using GEMBA Walk (Fig. 9) and Process Mapping (Fig. 10) the actual place where the problem was identified in the process. It was identified that the light/missing mark happens when setting the probemarks in wafer pad and will lead to failing electrical test, over rejection and bin7 failure.

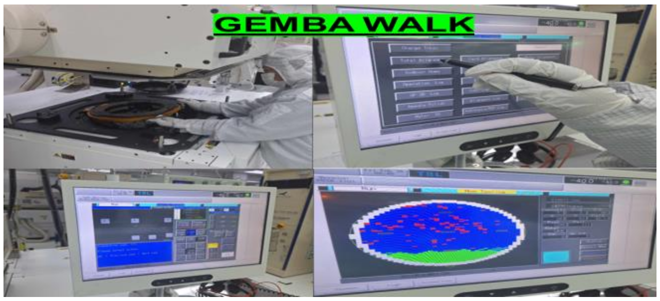

Fig. 9. GEMBA Walk identifying where the problem will occur.

Fig. 10. Process Mapping identifying where in process the problem will occur.

4.0 RESULTS AND DISCUSSION

After completing the validation and applying Lean Tools & Techniques, the results show significant improvement and reduction of contact issues.

Converting the current needle design from 3mils to 3.5mils has increased the gram force of needle resulting to a good penetration on the bond pad. (Fig. 11)

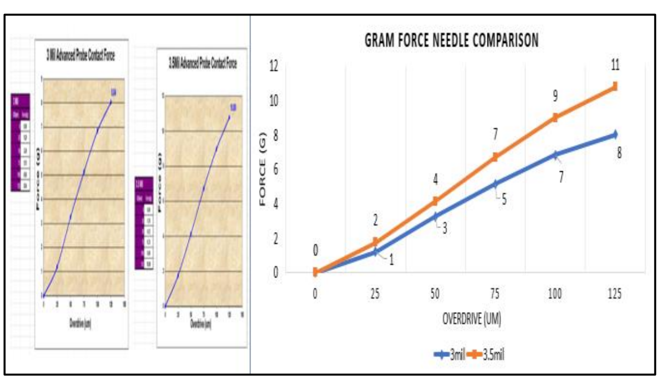

Fig. 11. Gram force needle comparison of 3mils vs 3.5mils

Mechanical validation shows that using 3.5mils at 100um overdrive will not induce exposed Metal Oxide. (Fig. 12)

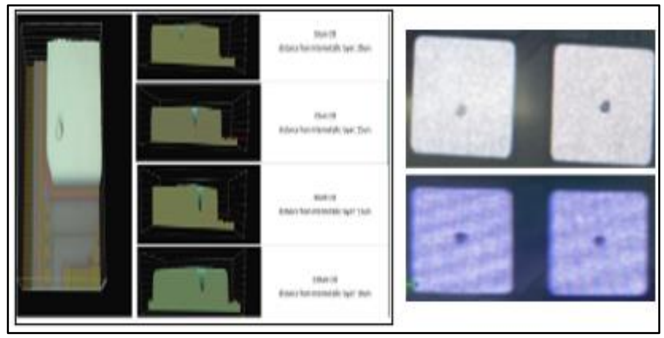

Fig. 12. Mechanical pin penetration and probemark results showing no Exposed Metal Oxide.

The electrical test result of the 3.5mils shows nominal distribution of contact resistance which is within nominal measurement, while the 3.0mils is marginal on lower limit. (Fig. 13)

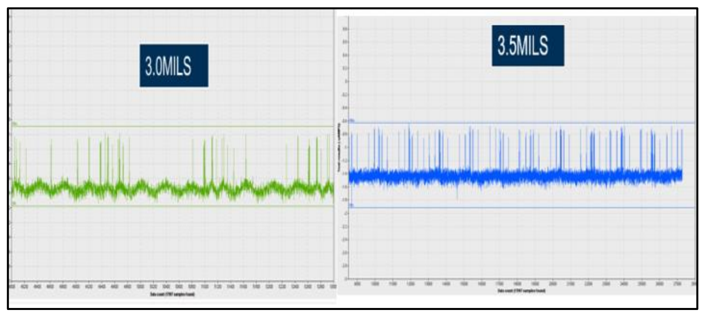

Fig. 13. Electrical test distribution of contact resistance test.

Statistical analysis using t-test was used to compare and check if there is significant difference between the 3mils vs 3.5mils First Pass Yield (FPY) performance. (Fig. 14)

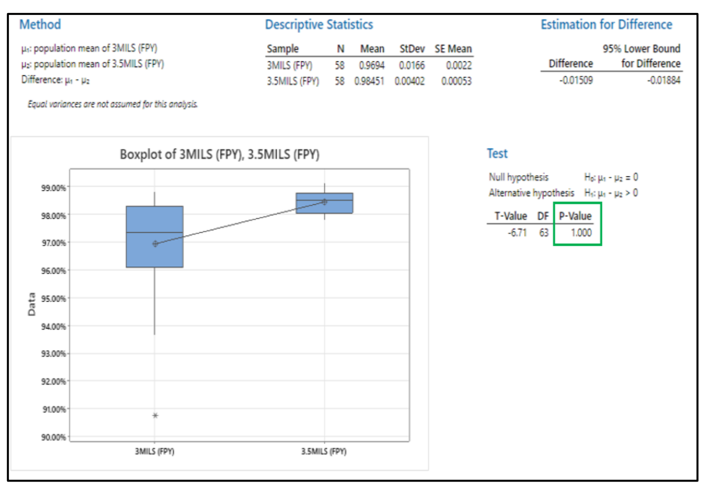

Fig. 14. The data shows that there is a significant improvement on First Pass Yield using 3.5mils vs 3mils.

Hardware downtime was reduced by 39%, from 60% to 21% reduction. (Fig. 14)

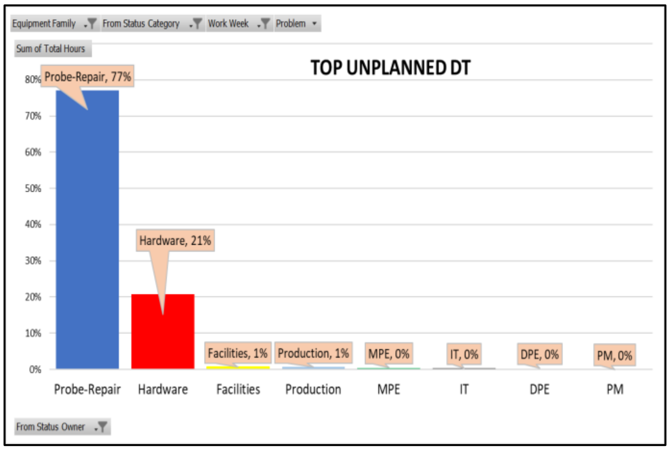

Fig. 14. Top Probe Unplanned Downtime is shows reduced to 21%.

Light/missing marks occurrence was reduced by 14%, from 38% to 24% reduction (Fig. 15)

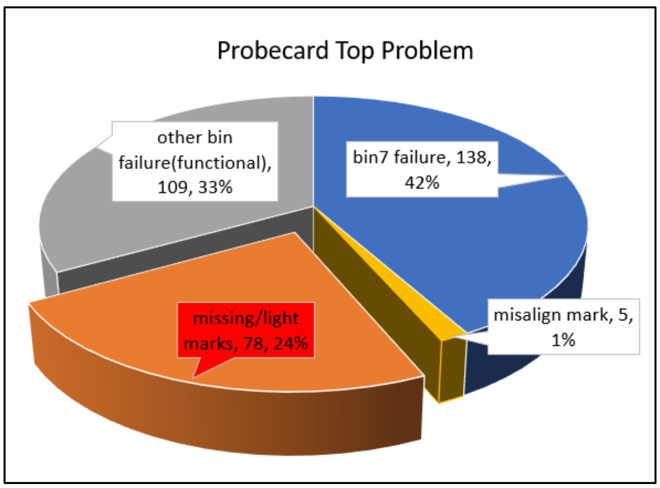

Fig. 15. Probecard Top Problem is shows reduced to 24%.

The 3.5mils has an average improvement to 1.93% vs target of 3% and continues to drop compared when using 3mils with an average downtime of 4.41%. (Fig. 14)

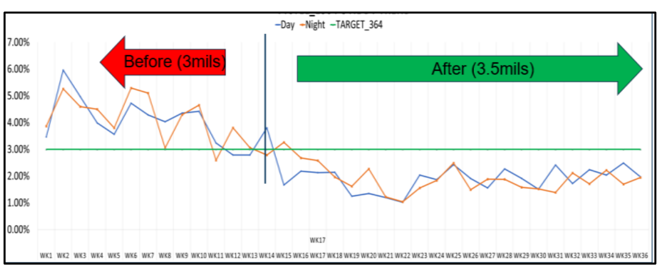

Fig. 14. Hardware downtime Utilization Trend showing improvement after using 3.5mils.

5.0 CONCLUSION

The Team was able to validate that missing/ light marks which cause poor electrical and mechanical contact will lead to frequent missing and light marks failure is due to low gram force which is the characteristic of a 3.0mils pin.

Using 3.5mils the pin was able to penetrate the bond pad which will help in reducing light/missing marks. The gram force increases resulting in a good pin mark. This significantly good impact on probe marks impression.

6.0 RECOMMENDATIONS

The probe contact force is an important factor in determining good contact during wafer testing. Gram force compatibility to bond pad structure should be considered in determining the correct needle that will be used during wafer testing.

Using LEAN Tools such as ISHIKAWA diagram/Fishbone Diagram, Is/Is Not Analysis, Gemba Walk and Process Mapping will help in determining the root cause of the problem for easier analysis and determining the appropriate corrective actions.

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8.0 REFERENCES

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