LED Wafer Probe Test

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Overview

- Introduction
- Objectives / Goals
- Methods / Materials
- Results / Relevant Findings / Key Data
- Discussion of Results / Strengths / Weaknesses, etc.
- Summary / Conclusion
- Follow-On Work

LED Wafer Device Introduction

- **Focus on Small LED Die Size Probe Test**
  - Die Size < 50um
- **Small Bump Size**
  - Gold Bump Size < 10um
- **Tight Bump Pitch**
  - Bump Pitch < 40um
- **Wafer**
  - Warpage > 50um
  - Million Die per Wafer

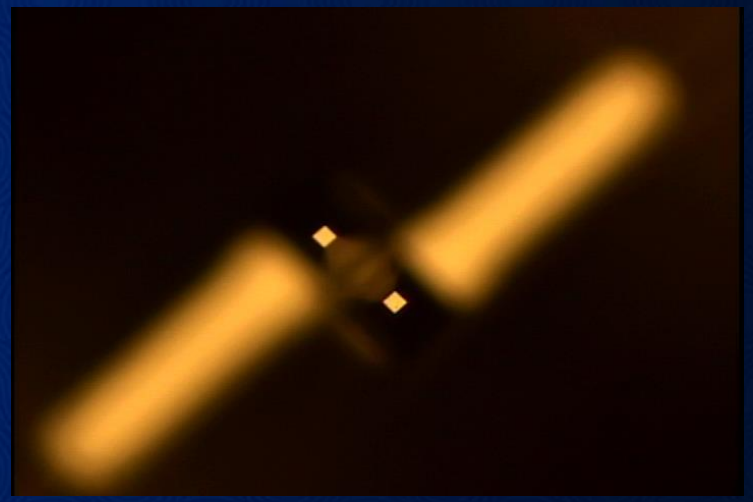
LED Wafer Probe Test Challenge

Item	LED Device Under Test	Probe Card	Prober
1	Gold Bump Pitch < 40um	Tight Pitch < 40um Probe	XY Chuck Stage Accuracy Probe to Tip Alignment Accuracy
2	Gold Bump Size < 10um	XY Tip Position Accuracy Low Scrub Ratio Contact Resistance	XY Chuck Stage Accuracy Probe to Tip Alignment Accuracy
3	Wafer Warpage > 50um	Over Drive Operating Margin Planarity	Contact Z Position Profile
4	Million Die per Wafer	Parallelism by Multi – DUT Probe Life Time	XYZ Contact Position Control Fast Indexing Speed
		Total Probing System XYZ Position Accuracy Probe to Pad Alignment Method	

Total Electrical Test Cost by Parallelism

Objectives

- **Develop Probing System for micro LED**
  - Probe Card Development and Evaluation
  - Total XY Position Accuracy +/- 4.5 um
    - Total = Probe Card and Prober
    - Probe Card and Prober Stage XY Accuracy
    - Probe to Pad Alignment Method
  - Actual Over Drive Control
    - Wafer Warpage > 50um
    - Actual OD Change by Temperature

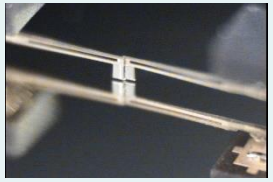
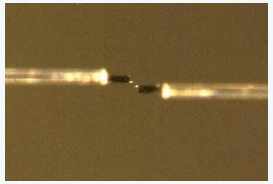
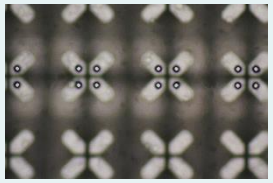
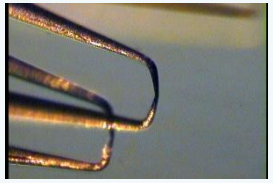


37um Pitch Probe

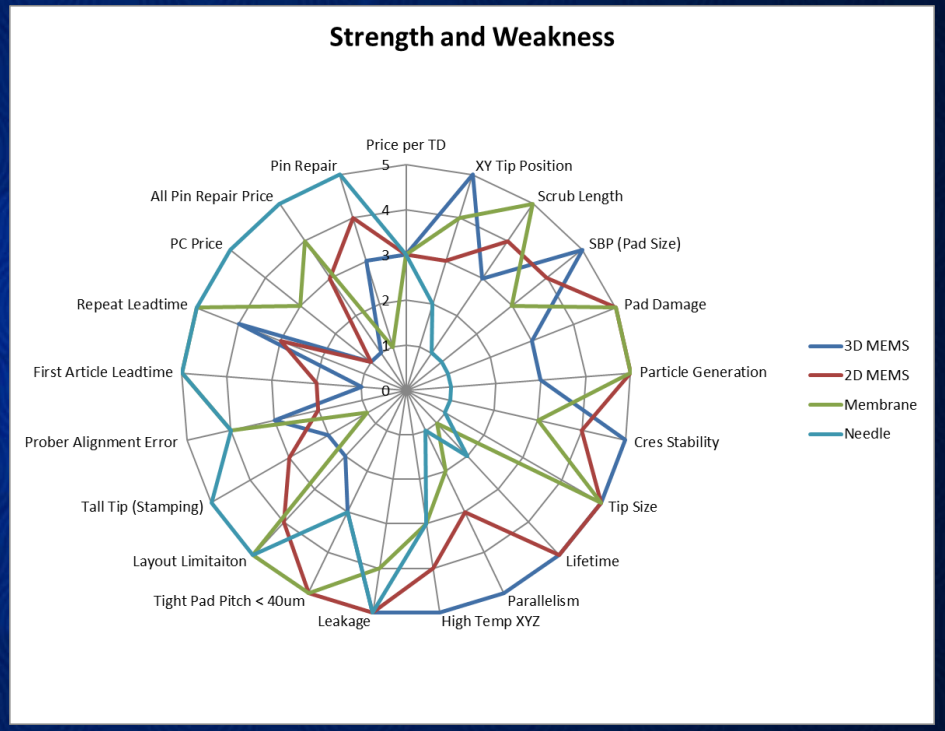
Total Probing System XYZ Position Accuracy Evaluation Methods / Materials

- **Probe Type**
  - 3D MEMS, 2D MEMS, Membrane, Needle
- **Probe Card**
  - 2DUT Intentionally Large Skip DUT Layout for Future Multi - DUT
- **Prober**
  - Probe to Pad Alignment Method
    - Probe to Pad Alignment Software Development
- **Wafer**
  - Customer Bump Pattern Wafer with Electrical Connection
    - Gold Bump Size < 3um for XY Position Accuracy Target +/- 4.5 um
- **Electrical Test**
  - Open / Short
  - 100,000 TD / Wafer

Probe Type Evaluation

Option		Probe Type
1		3D MEMS Cantilever
2		2D MEMS Cantilever
3		Membrane RBI
4		Needle

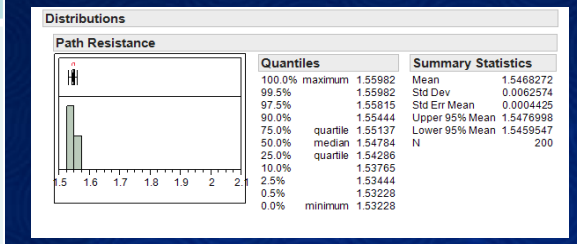
Advantage / Disadvantage

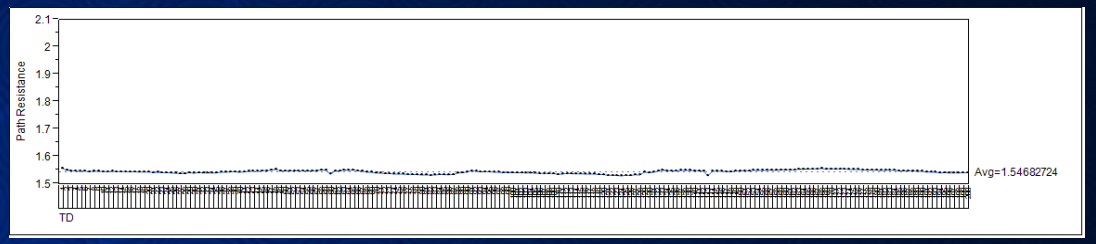


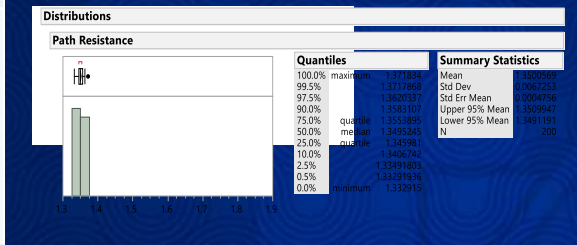
There is no perfect probe.

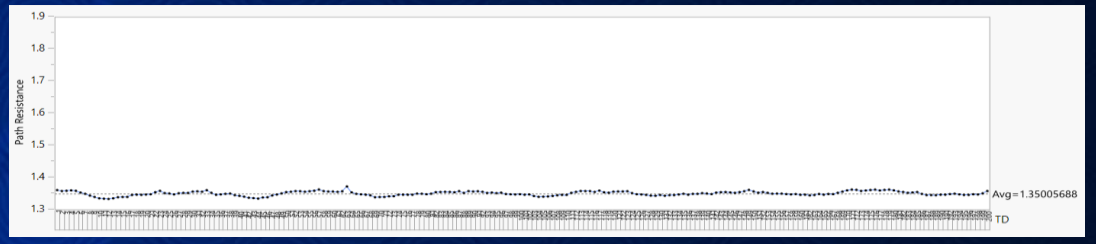
2Pin Path Resistance on Gold Wafer 200TD

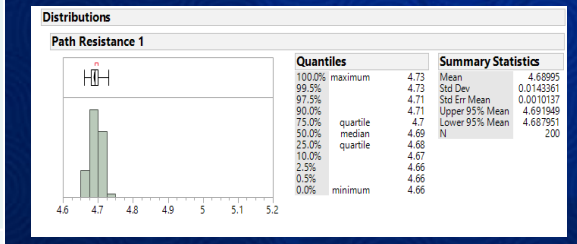
Option	Probe Type	Resistance Standard Deviation (Ohm)
1	3D MEMS Cantilever	0.006
2	2D MEMS Cantilever	0.007
3	Membrane RBI	0.014
4	Needle	0.064

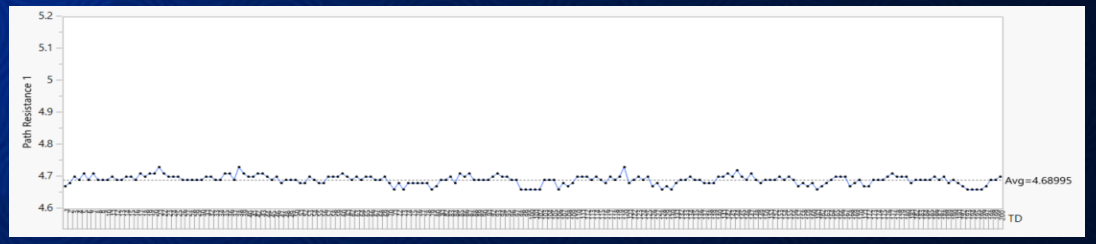


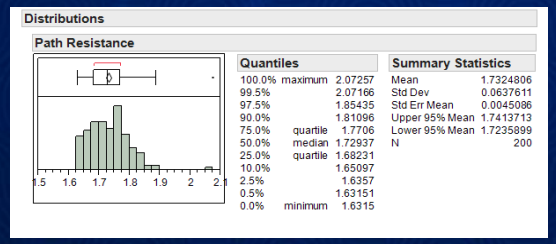


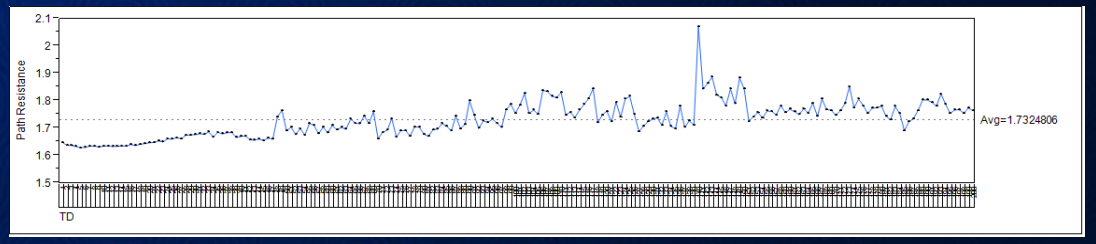




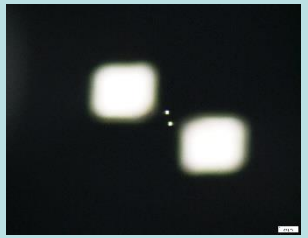
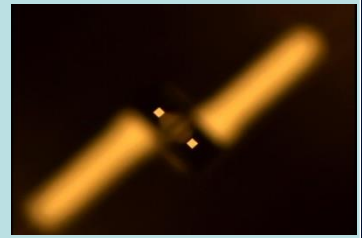




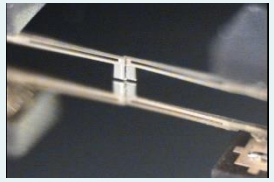
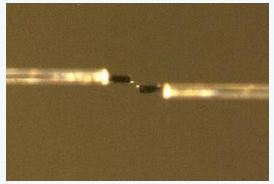
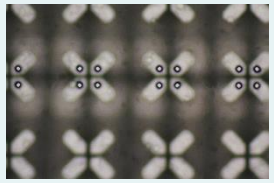
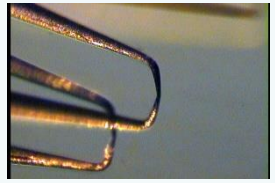




2D and 3D MEMS Cantilever Probe Card Tip Position

	2D MEMS Probe Card 	3D MEMS Probe Card 
Spring Fabrication Process	Lithography Lateral Direction Probe	Lithography Vertical Direction Probe
Tip Position	Spring and Ceramic Attach Process	Spring Fabrication Process
Typical XYZ Tip Position Accuracy 32DUT LED Probe Card	+/- 5um	+/- 1um
Card to Card XYZ Tip Position Error 32DUT LED Probe Card	+/- 5um	+/- 1um

Probe Type Evaluation

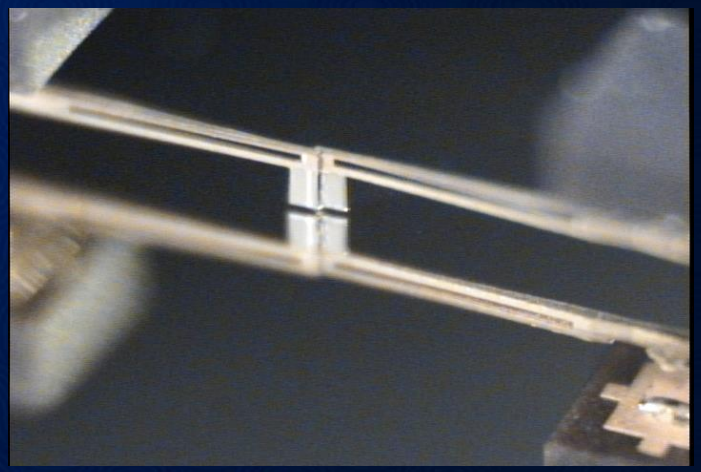
Option		Probe Type	Contact Resistance STD Deviation (Ohm)	XYZ Tip Position Accuracy	Card to Card XYZ Tip Position Error for Production	Probe Tip Alignment from Top Side
1		3D MEMS Cantilever	0.006	Typical +/-1um Excellent	Card #1 - #10 Same XY Tip Position	Need Development
2		2D MEMS Cantilever	0.007	Typical +/-5um	Different XY Tip Position for Card #1 - #10	Easy to Align
3		Membrane RBI	0.014	Typical +/-3um	Good XY Tip Position for Card #1 - #10	Difficult
4		Needle	0.064	Typical +/-5um	Large Variation	Easy to Align

3D MEMS Vertical Tip Probe to Pad Alignment

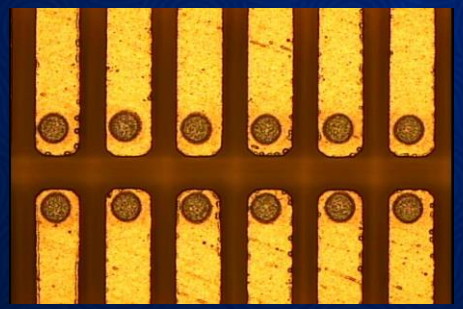
- **Prober**
  - No Upper Looking Chuck Camera
- **3D MEMS Cantilever Probe**
  - Tip Position at bottom of Beam
  - Beam Top Laser Mark XY Position Accuracy +/-5um
    - Not Acceptable for Total System XY Accuracy +/- 4.5um

Top View

Side View

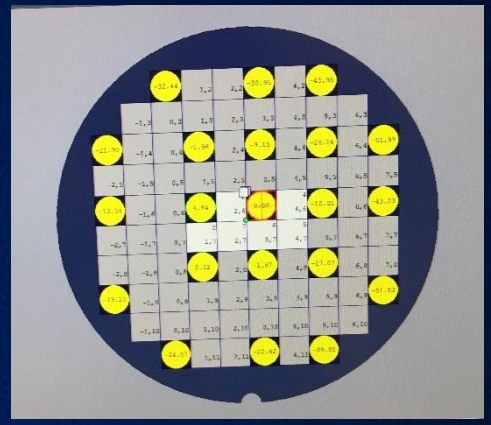


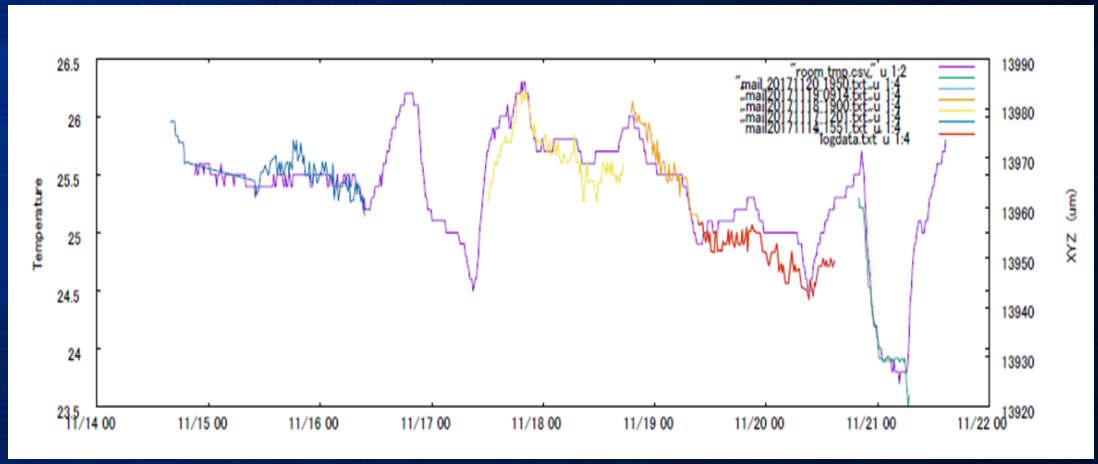
Laser Mark on Beam



Z Direction Probe to Pad Alignment Method 1

- **Optical Alignment**
  - Wafer Z Profile
    - > 21 Points Measurement for 50um Warp Wafer
    - 30 minutes!
  - Camera Position Move by Room Temperature Change
    - Aluminum (Camera Stage) : 23 ppm / deg C
    - FR4 (PCB) : 16 ppm / deg C
    - Ceramic (Probe Head) : 6 ppm / deg C



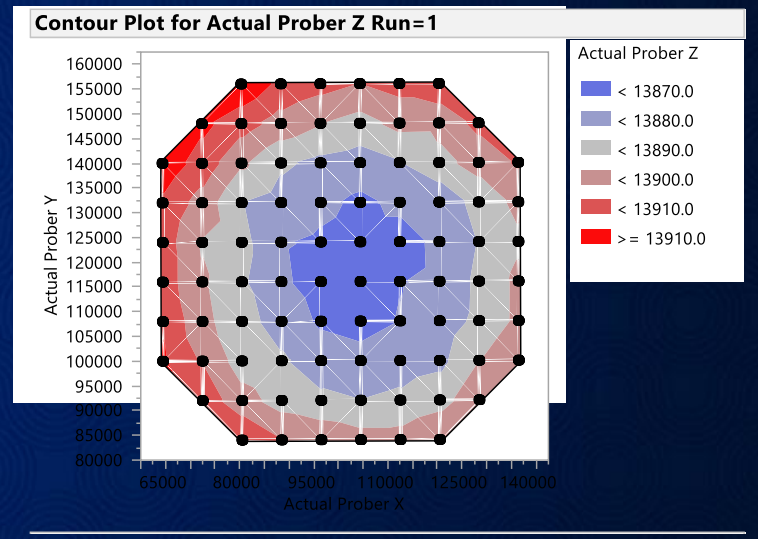


Temperature Changed 2 degree C in 7 days
Contact Z Position Changed 60um

Z Direction Probe to Pad Alignment Method 2

- **Electrical Alignment**
  - Accurate First Electrical Contact Z Position
    - Accurate Probe Tip Z and Wafer Z Position
  - 88 Location / Wafer
    - Do not require optical wafer Z profile
  - Need Electrical Tester
    - Need to control arcing

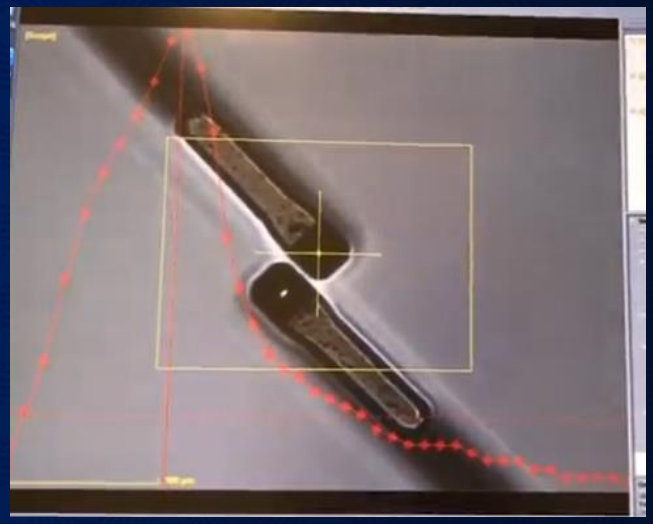
First Electrical Z Position Contour Plot



XY Direction Probe to Pad Alignment Method 1

- **Optical Alignment**
  - Use Chuck Mirror to Align 3D MEMS Probe
  - Alignment Accuracy Depends on Tip Condition
    - Tip Size
    - Clean / Dirty Tip by Particle
    - Smooth / Rough Tip Surface
  - Fast Alignment Time (Need to Focus Z)

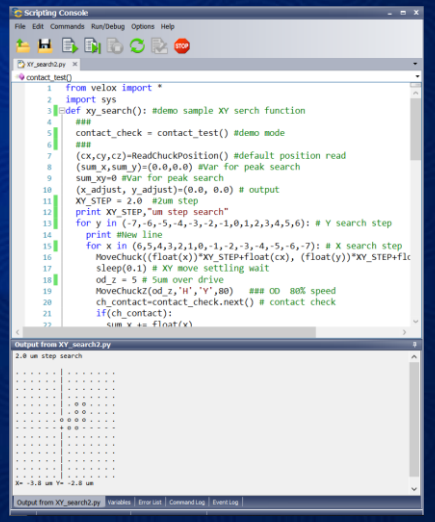
Top Side Microscope View using Chuck Mirror



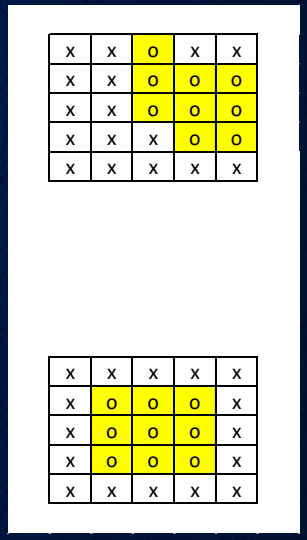
XY Direction Probe to Pad Alignment Method 2

- **Electrical Alignment**
  - 2 or 3um Stepping Electrical Contact
    - Python Script Development to Control Stage and SMU
  - Accurate XY Position Alignment

Python Script



3um Step Electrical Contact Position



Probe Type Evaluation

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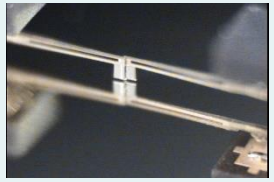
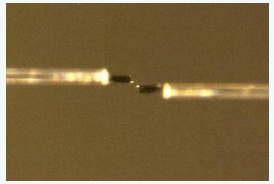
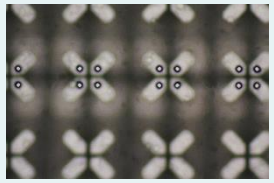
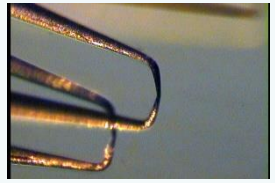
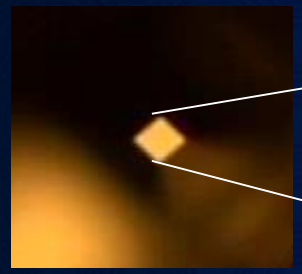
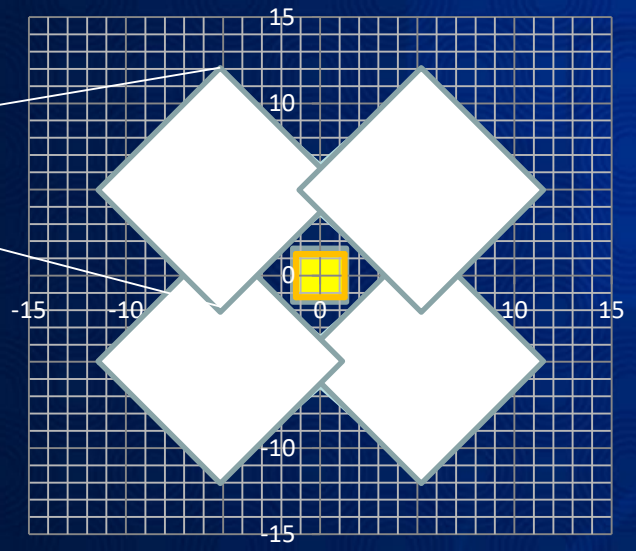
1		3D MEMS Cantilever	0.006	Typical +/-1um Excellent	Card #1 - #10 Same XY Tip Position	Developed XYZ Electrical Alignment
2		2D MEMS Cantilever	0.007	Typical +/-5um	Different XY Tip Position for Card #1 - #10	Easy to Align
3		Membrane RBI	0.014	Typical +/-3um	Good XY Tip Position for Card #1 - #10	Difficult
4		Needle	0.064	Typical +/-5um	Large Variation	Easy to Align

XY Tip Position Error and Contact Test Wafer Bump Size

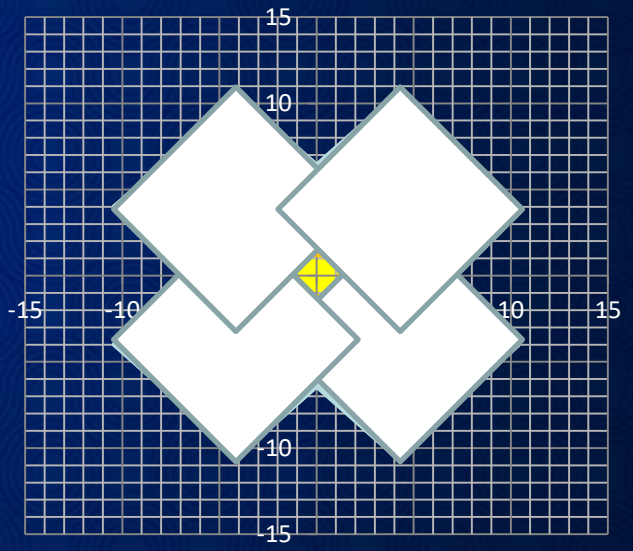
- **XY Error +/- 5um : Open**





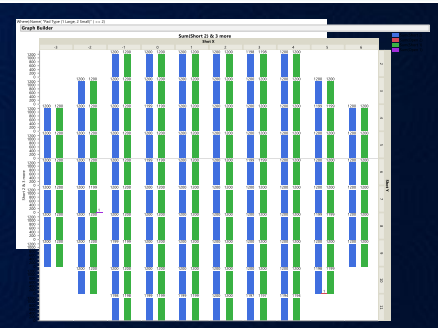
Gold Bump Size < 3um

XY Error +/- 4um : Short



XYZ Probe to Pad Alignment and 100,000TD Contact Test Result

Method	Z Probe to Pad Alignment	Actual OD Control Result	XY Probe to Pad Alignment	XY Probe to Pad Alignment Result
1	Optical Z Profile 18 Location / Wafer	Open Failure Contact Z Point Changed by Temperature	Optical	Alignment Error by Tip Condition
2	Electrical First Z Contact 88 Location / Wafer	Pass 100,000 TD	Electrical 3um Step Search	Pass 100,000 TD



Findings : Alignment Error and Cleaning

- **Optical Alignment**
  - Probe Tip Location Error by Particle and Tip Condition
  - Need Cleaning to Avoid Alignment Error

- **Electrical Alignment**
  - No XYZ Tip Position Error by Tip Condition
  - No Cleaning Required

Conclusion

- **Successfully Developed Total Probing System for Micro LED Wafer Test.**
- **Developed New 3D MEMS Cantilever Probe to Pad Alignment Method. Electrical XYZ Alignment Method Pass 100,000TD Contact Test on <3um Gold Bump.**
- **Engineering Prober is very Flexible to Develop New Alignment Algorithm.**

Follow on Work

- **Increase Probe Card Parallelism to > 32DUT and Release for Production**
- **Develop < 20um Pitch Probe Card**

Acknowledgements

- **FormFactor Team Member**
  - Masahiro Sameshima
  - Dong-Thuc Knobbe
  - Takuya Yoshida
  - Susumu Noguchi
  - Masanori Watanabe
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