Vertical MEMS for Pre-Bump Probe

• **Introduction: eWLP and Pre-Bump Probing Requirements**

• **Experiment Objectives & Details**
  – Accurate Probing on Small Pads at Fine Pitch
  – Low Scrub Depth on Pre-Bump Pads
  – Wafers Probed & Measurements Taken

• **Observed Probe Results & Conclusions**
  – Accuracy & Repeatability Across Wafer
  – Measured Scrub Depth Results
  – Reliable Enabling of Pre-Bump Probing for Improved eWLP Yields

• **Follow-On Work**
  – Production Characterization in Large Volume

• **Summary**
MicroProbe: A Leading Supplier of Logic/RF/SoC Probe Card Solutions

Innovation and Growth

• **Technology Leadership**
  – >1000 MEMS probe cards delivered
• **Market Share Growth**
  – #1 supplier of Advanced SoC Probe Cards
• **Customer Collaboration**
  – 35-year history of delivering results

Breadth and Stability

• **Broad Product Portfolio**
  – Cantilever, Vertical, and MEMS
• **Global Presence**
  – Major facilities in China, Taiwan, US
• **Strong Institutional Investors**
  – Flywheel Ventures, Gemini Investors, Intel Capital
eWLP Resurrects Pre-Bump Array Probing

• While pre-bump probing has been largely eliminated from mature BGA Flip-Chip packaging flows, the workflow and cost considerations of eWLP are re-introducing need for effective pre-bump probing on arrays of aluminum pads.

• Today’s designs challenge probing on multiple fronts:
  – Full-grid array layout at ~100um pitches $\rightarrow$ Vertical Architecture
  – Small pads and pad openings $\rightarrow$ Small Scrub
  – Low-k dielectrics and under-pad circuitry $\rightarrow$ Low Force

• Experimental work demonstrates that MicroProbe’s MEMS Vertical probe solution addresses today’s pre-bump probe requirements, enabling cost-effective implementation of newly developed eWLP-based packaging flows.
What is eWLP?

- eWLP = “Embedded Wafer Level Packaging”
- eWLP is an evolution of BGA-type packaging that uses molded carriers and fan-out RDLs. The original die are singulated, embedded into molded carriers, and then reconstituted onto artificial wafers. Wafer-level processes then add redistribution layers (RDLs) and solder balls.
- This approach enables both a higher level of interconnects per die area (due to the fan-out RDL) and enables greatly simplified multi-chip integration.
- Also known as eWLB (Wafer-Level BGA) and FO-WLP (Fan-Our WLP)
eWLP and Pre-Bump Probe

• Packaging bad die into molded carriers, and subsequently attaching them to reconstituted wafers, causes very expensive yield loss for the final eWLP wafer.

• For multi-die eWLP packages, the cost impact is even worse – the problem is directly analogous to test escapes finding their way into a multi-chip module.

• Because of these considerations, effective test of the target die prior to singulation is imperative to ensure good yield at final test.
Example eWLP Test Flow

- Die A Wafer Sort
- Die B Wafer Sort
- Die C Wafer Sort

Dice Wafer / Singulation → Integration of Good Die Into Molded Carrier

- Reconstitution Into Artificial Wafer
- Redistribution Layers (RDL) Printed
- Solder Ball / Cu Pillar Attach
- Final Test

June 12 to 15, 2011
Pre-Bump Probe Challenges

- **Fine Pitch in Full Grid Arrays**
  - RDL fan-out permits increasingly fine pitch across high pincount arrays. Today’s arrays are 130um – 180um. Next generation arrays will be < 100um.

- **Small Pads**
  - Bond pad openings are getting smaller: 50um octagonal pads are migrating towards 40um

- **Low Force**
  - CUP and Low-K require very low force contact on the pad material to ensure there is no IC damage
MicroProbe Vertical MEMS “Mx” Probe Architecture

- Composite MEMS structure allows optimization of mechanical and electrical design
  - Multiple materials & Layers
  - Photolithographically Defined Shape

- Resulting material & geometry flexibility provides optimal contact performance and pitch scalability
Customer Experiments with Mx for Pre-Bump Probing

- Customer A: Focus on low force contact to minimize pressure applied to circuit under pad
- Customer B: Focus on good contact with minimal scrub depth into pad material
- Customer C: Focus on probe tip accuracy for contacting small pads with high precision and repeatability

Example Mx Probe Head with > 10K MEMS Probes
Customer A: Low Force Experiment

• Wafer Setup for Experiment
  – 300mm wafer at 40nm process
  – eWLP pre-bump pads probing
  – 60um octagonal pads

• Evaluation Criteria
  – Cres must be within acceptable range for device
  – Probe force over active area and low-k ILD must be minimal
  – Scrub mark must be small and repeatable
Mx Probe Contact Force at Overtravel

![Diagram showing Probe Contact Force vs Overtravel](image)

- Recommended OT = 65um
Mx Low-Force Design & Modeling

• MEMS Geometry & Metallurgy
  – Proprietary Mx MEMS process enables multi-layer probe design with lithographically defines shapes
  – Focused on low-force mechanical design while maintaining excellent Cres characteristics

• Design & Modeling
  – Detailed FEA models are developed to predict scrub stress behavior
  – Model predictions are continually refined based on real-world observation
Customer A: Low Force Findings

- Mx scrub mark ranges 8um – 15um
- Maximum scrub depth of 0.55um
  - (After 8 touchdowns)
- No ILD cracking found with 60um over-drive
Customer B: Small Pads Experiment

- Test Setup for Experiment
  - \( \approx 180 \) Die Per Wafer
  - \( \approx 7,500 \) Pads Contacted per Die
  - 55um Pads in 180um Array
  - TEL P12Ln Prober with Test Temperature of 40degC
Scrub Mark Size & Accuracy

- Customer Findings on Scrub Mark Placement
  - Typical accuracy to pad center: +/- 9um
  - Worst-case accuracy observed: +20um
  - (Mx Typical Spec = +/-13um)

- Customer Findings on Scrub Mark Size
  - 20um OD → 7um Scrub
  - 30um OD → 10um Scrub
  - 50um OD → 11um Scrub
  - 65um OD → 15um Scrub
  - (Mx Recommended OD = 65um)
Accuracy & Repeatability Across Wafer

Die = -5, 0

Die = -1, 0

Die = 0, -6

Die = 0, 5

Die = 6, 0
Customer B: Small Pads Findings

- Mx solution delivers highly-accurate and repeatable scrub marks that are suitable for pre-bump probing small pads
  - Overall planarity of a large array was very good (< 24um)
  - Probe mark placement was very accurate, consistently placing the scrub center within +/- 13um. (One outlier was observed.)
  - Placement across 300mm wafer was extremely repeatable
  - Tip recognition, cleaning requirements, etc., are production-worthy
Customer C: Scrub Depth Experiment

- **Wafer Setup for Experiment**
  - 300mm qual wafer selected in Engineering lab
  - Entire wafer probed with 4 touchdowns on every die
  - Lower 2/3 probed with a 5th touchdown
  - Lower 1/3 probed with a 6th touchdown

- **Scrub Mark Review Techniques**
  - Center and edge samples collected from each zone
  - Angled photos taken to profile scrub mark shape
  - Passivation cap added to enable FIB cross-sectioning
  - Scrub depth into Aluminum directly measured
Customer C: Scrub Depth Findings

- Pad Scrub Findings
  - Starting aluminum depth of 1.20um
  - Worst-case image: 6 touchdowns at wafer center
  - Aluminum depth of 0.64um shows maximum scrub depth of 0.56um
  - Low scrub was very repeatable across all wafer zones
Conclusions & Use Benefits

• Conclusion
  – The Mx MEMS vertical probe solution addresses key requirements for today’s pre-bump probing: low-force, high-accuracy contact, repeatability, and low force. These characteristics can enable effective pre-bump probe for the next generation of pads testing.

• Use Benefits
  – Flows such as eWLP can significantly reduce packaging costs by ensuring only known good die are put into molded carriers & reconstituted wafers
  – Yield learning & improvement can be accelerated by bringing “first look” closer to the wafer fab – no need to wait for bumping to see low yield
  – Long-term quality & reliability of pads-tested devices can be improved by reducing the risk that under-pad circuitry is stressed or damaged
Follow-On Work / Q&A

• Follow-On Work
  – Lifetime testing on accuracy and scrub would be beneficial to understand MEMS stability and repeatability versus legacy solutions
  – Copper pads testing should be conducted – these studies were all done using Aluminum pads
  – Additional hot-temp testing would be useful, as would a cold-temp study

• Questions?