IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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Probing Assessment on Fine Pitch Copper Pillar Solder Bumps

June 6 to 9, 2010
San Diego, CA USA

Presentation Overview

- Introduction
- Objectives
- Experimental Methodology
- Fine Pitch Array Probing Technology
- Results of Eutectic Bumps
- Results of Lead-Free Bumps
- Results of Cu Pillar Bumps
- Summary & Conclusions
- Future Work

Introduction

- **Wafer bumping technology is changing as flip-chip devices shrink from 150um to ultra-fine pitch 35um bump arrays**

- **Fine-pitch bumps typically have Cu pillar base with solder cap top**
  - This structure offers a solution to the electro-migration challenges faced by conventional solder balls, with better thermal & electrical conductivity
  - Copper pillar bumps also allow for easy under-fill & flux removal compared to other solder options

- **As the metallurgy of the bump structure changes from eutectic to lead-free on copper pillars with varying contact geometries, probing very fine-pitch bumps presents new test, process & precision challenges**

- **We would like to understand the test challenges on these tiny structures by investigating probe-bump contacts**

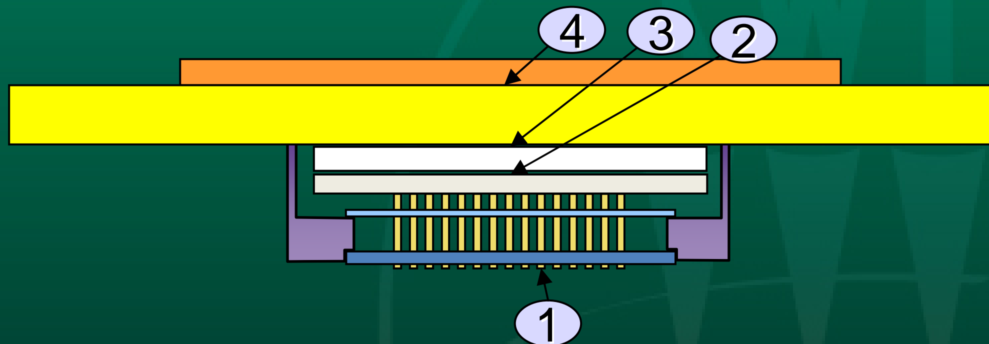
Objectives

- Investigate scrub, contact resistance behavior on cu-pillar bumps as a function of probing conditions for contact reliability.
  - Scrub Marks Study
  - Contact Resistance as a Function of Over-travel, Tip Size
- Study contact behavior of Cu-pillar bumps at 60µm pitch with various solder cap materials:
  - Cu pillar with Eutectic Solder Cap
  - Cu pillar with Lead-free Solder Cap
  - Cu Pillars

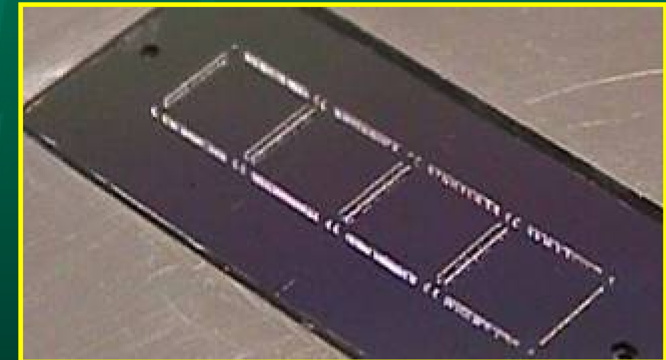
Test Equipment

- **Test Systems for Scrub Mark & Contact Resistance Characterization**
    - Prober: TEL P12 XLn
    - Keithley Tester & Source Meter
    - LEO Scanning Electron Microscope
    - Veeco Profilometer
    - Nikon Optical Inspection System
    - Test Wafers: Al, Au, Cu pillar, Cu-pillar with Pb-Sn cap, Cu-pillar with Sn-Ag cap
    - Probing Technology: MEMS-Fine Pitch Vertical Technology (LogicTouch™)

LogicTouch™ Vertical Probing Technology



1. Probes
2. Space Transformer (MLC)
3. Interposer
4. PCB



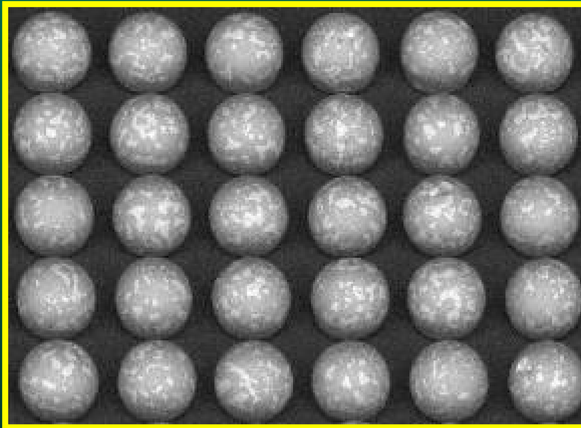
Probes

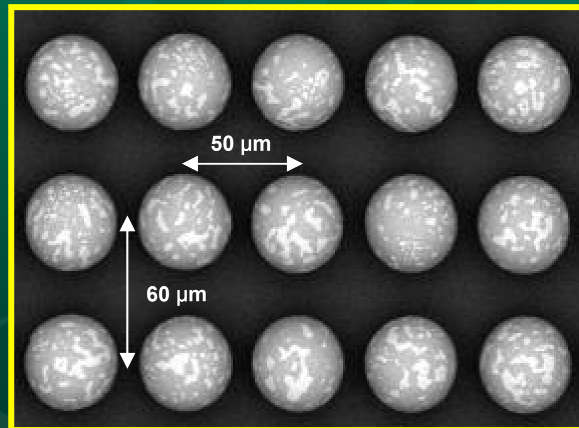
- **Example Layout: 60/30µm Peripheral Layout is Shown**
- **Technology Capable of Probing 60µm Arrays**
- **Technology Scalable to 40µm Pitch**

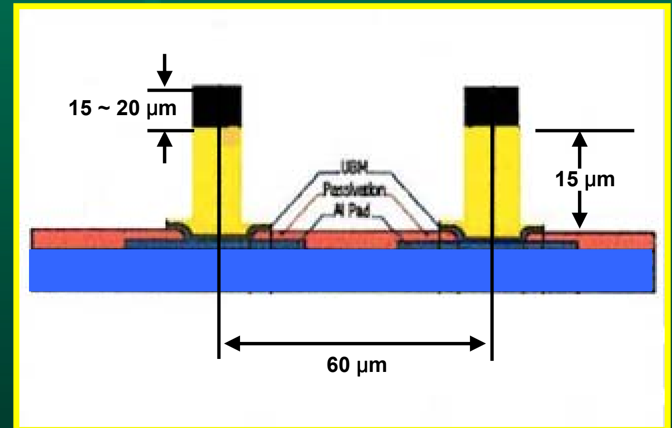
1. Eutectic Solder Bumps

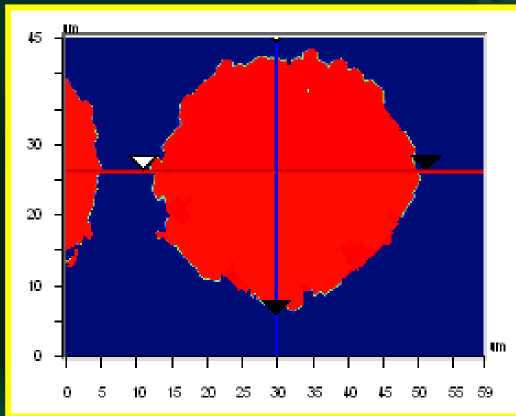
Eutectic Solder Bump Wafer

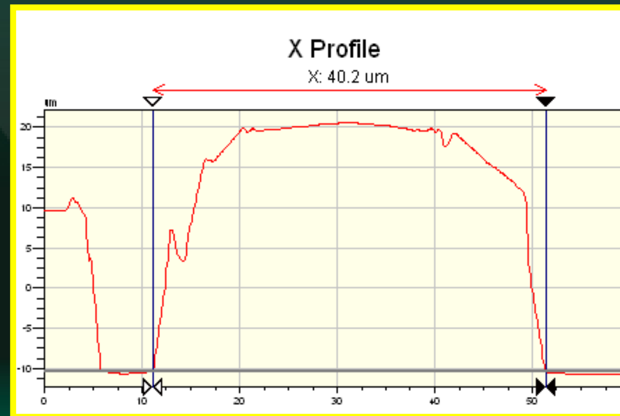
Electroplated Solder Bumps: Cu-pillar with Pb-Sn Cap, after Reflow

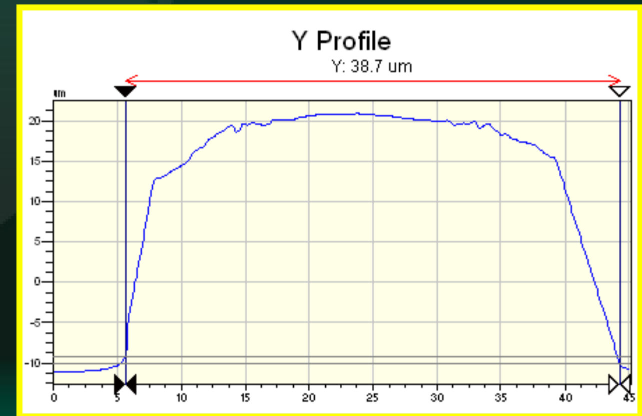




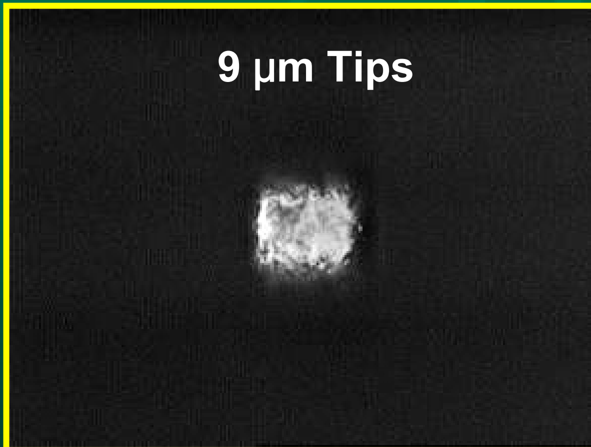


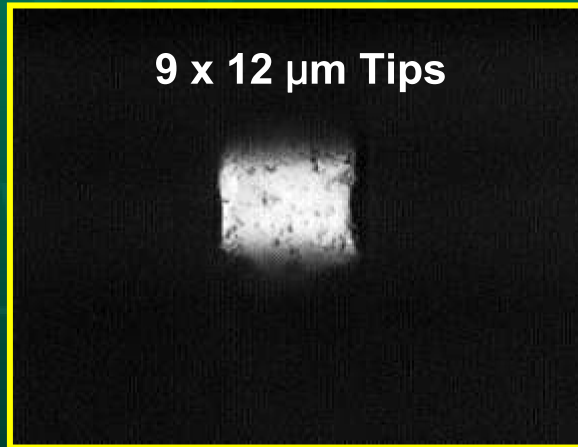


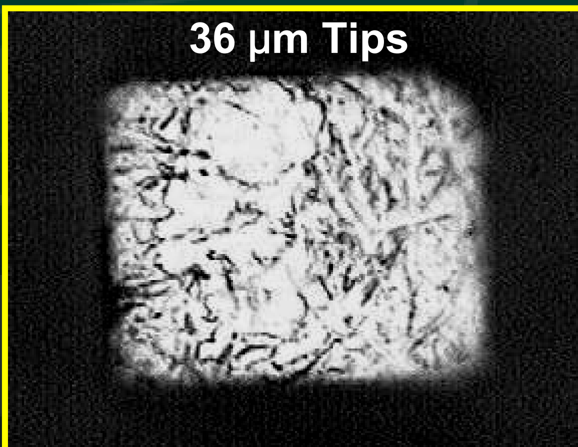




Probe Tips







Eutectic Bump Resistance

cres (Ω)

2.5
2.0
1.5
1.0
0.5
0.0

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

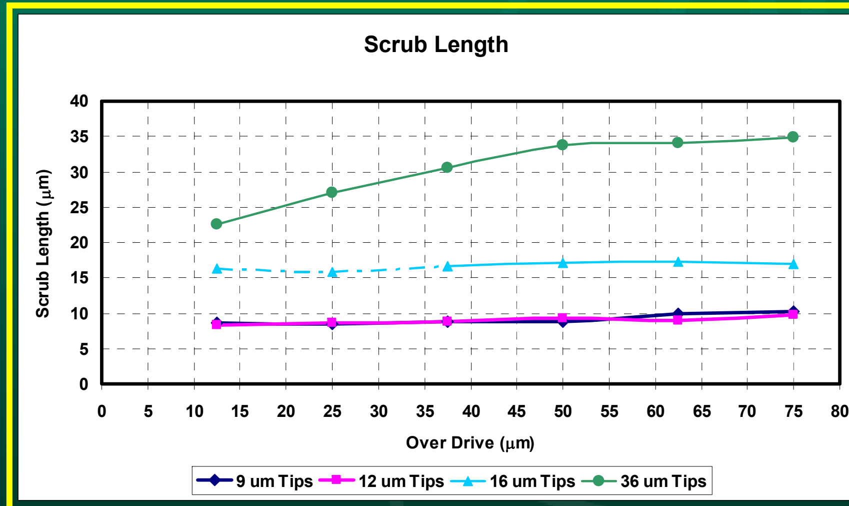
Over Drive (μm)

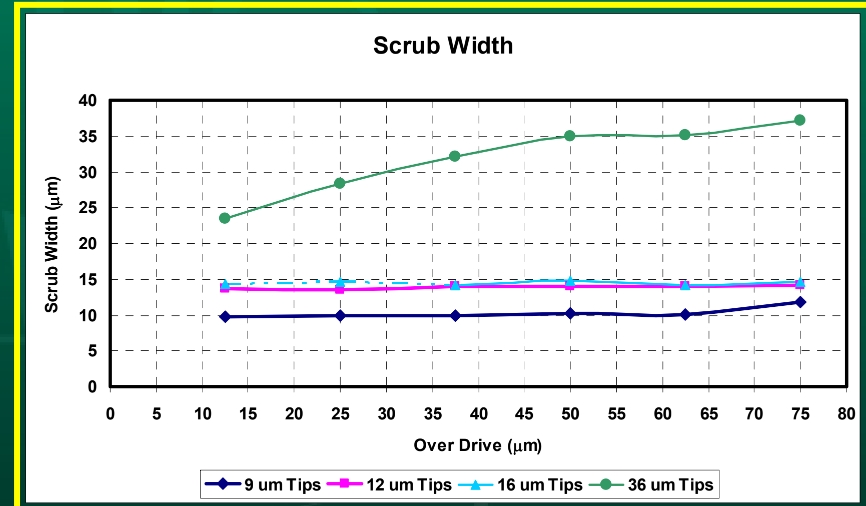
9 um Tips 12 um Tips 16 um Tips 36 um Tips

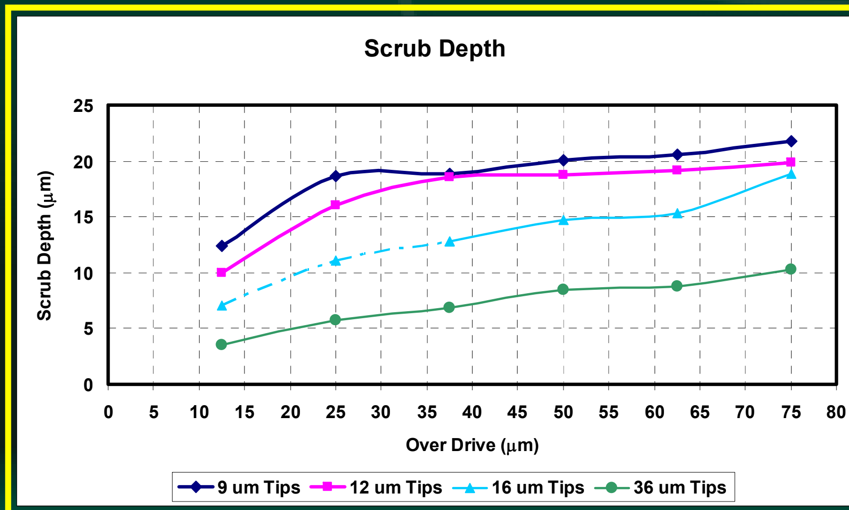
Cres Stable at 25μm OT (~ 3 gf) for All Tip Sizes

Cres is the path resistance including connections from tester to the probe tip.

Scrubs on Eutectic Bumps

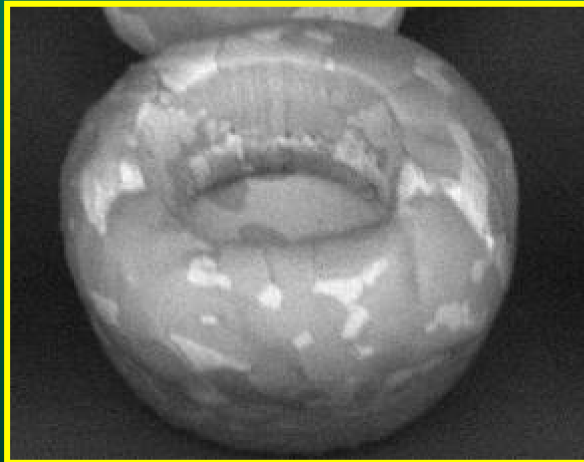


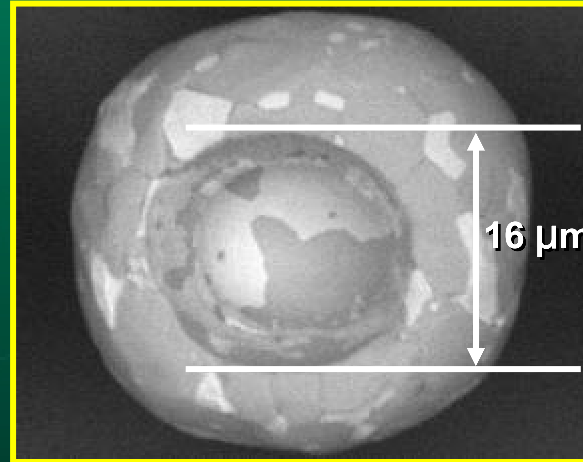




- **16 µm Tips + 50 µm OT**
  - Scrub Mark ~ 17 x 15 µm
  - Scrub Depth ~ 15 µm
- **36 um Tips + 50 µm OT**
  - Scrub Length is 33 x 35 µm
  - Scrub Depth is 8 µm

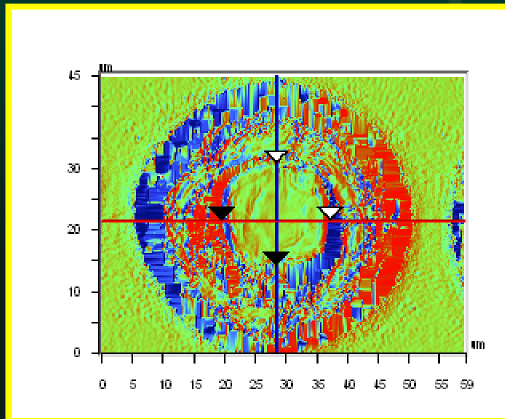
Scrub Marks with 16 µm Tips at 50 µm OT

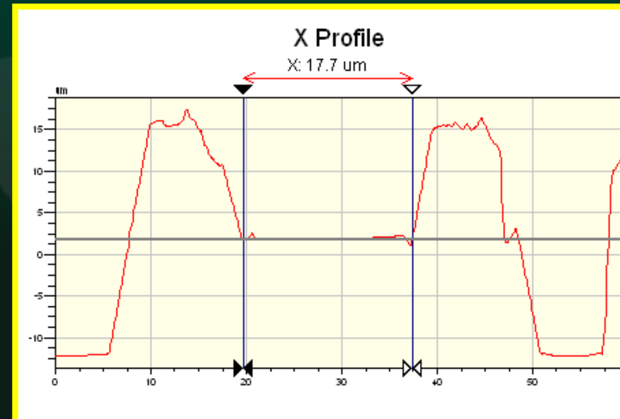


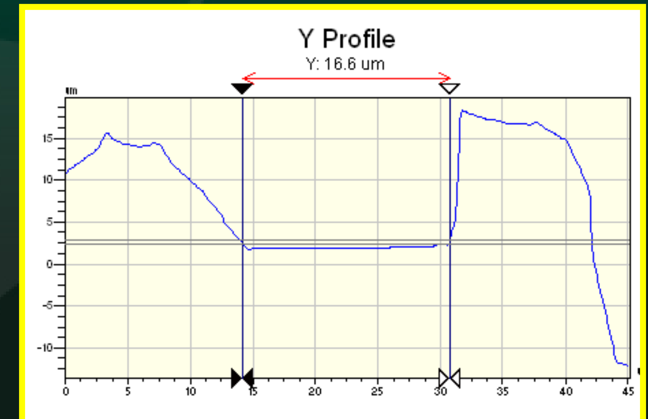


Scrub Mark ~ 18 x 17 µm

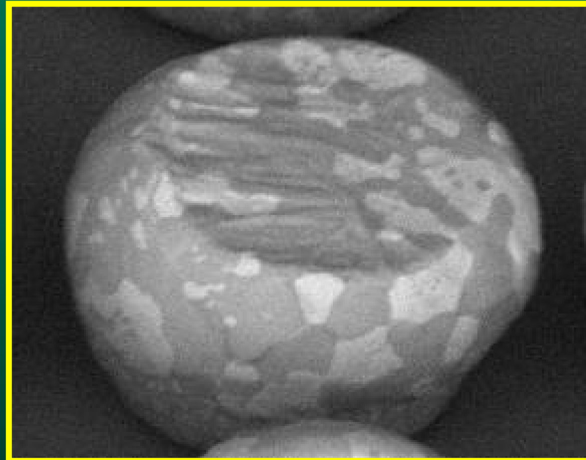
Scrub Depth ~ 15 µm

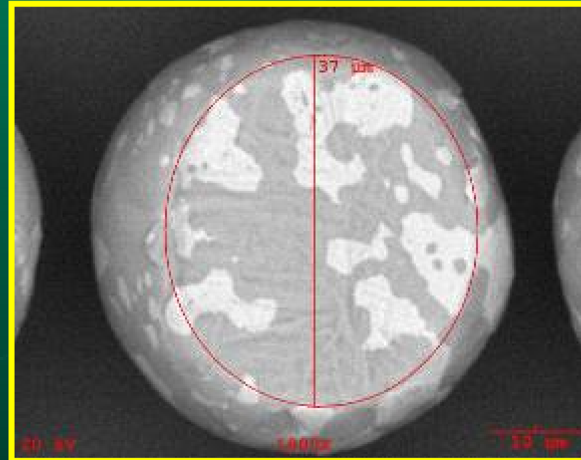






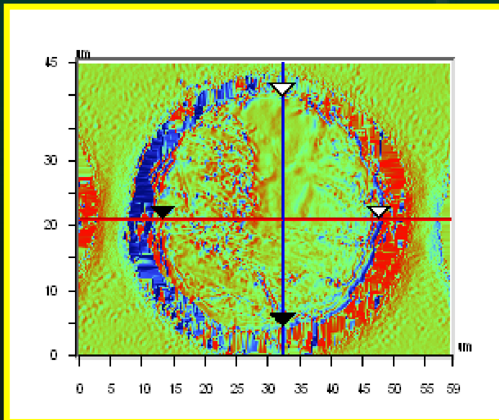
Scrub Marks with 36 µm Tips at 50 µm OT

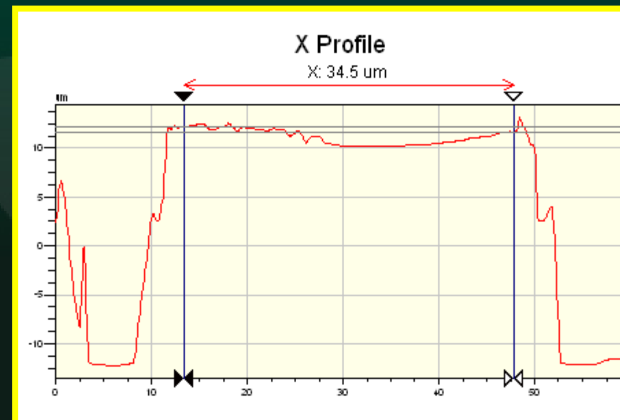


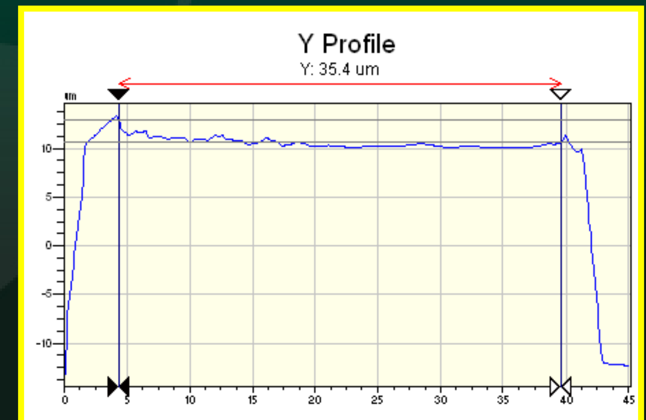


Scrub Mark ~ 35 x 36 µm

Scrub Depth ~ 8 µm



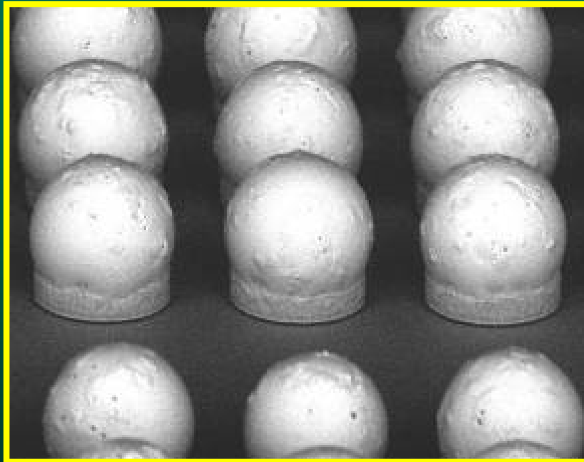


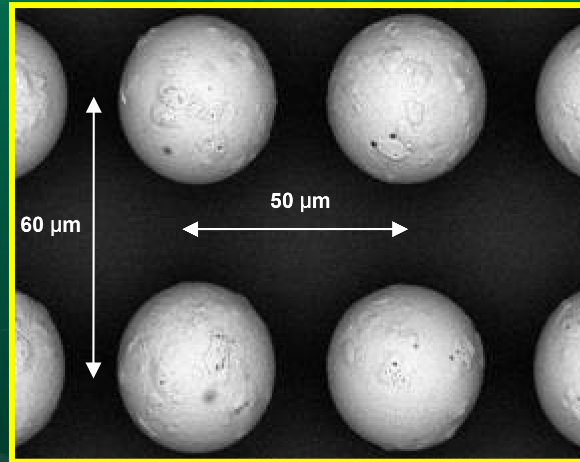


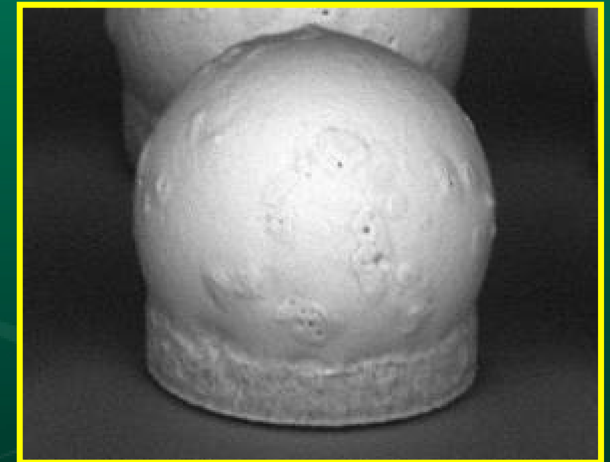
2. Sn-Ag (Lead Free) Solder Bumps

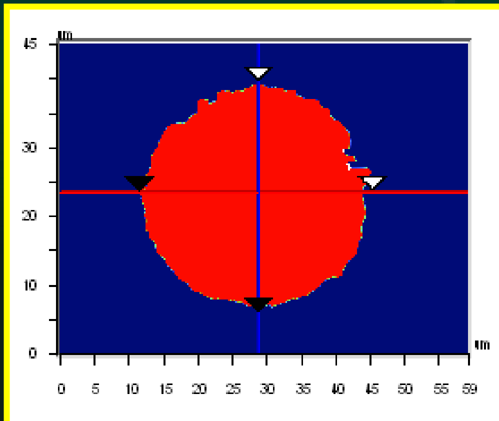
Sn-Ag Solder Bump Wafer

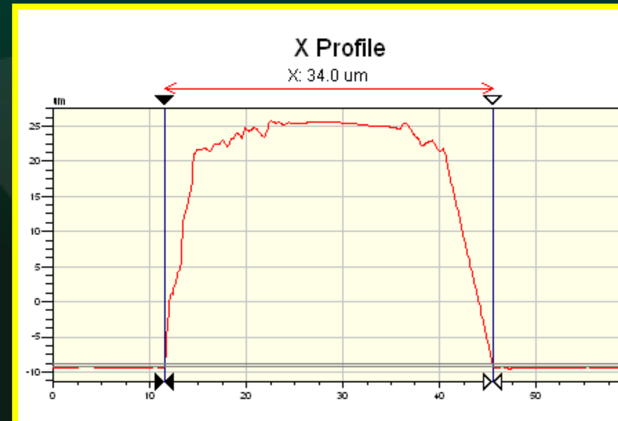
Electroplated Solder Bumps: Cu-pillar with Sn-Ag Cap, after Reflow

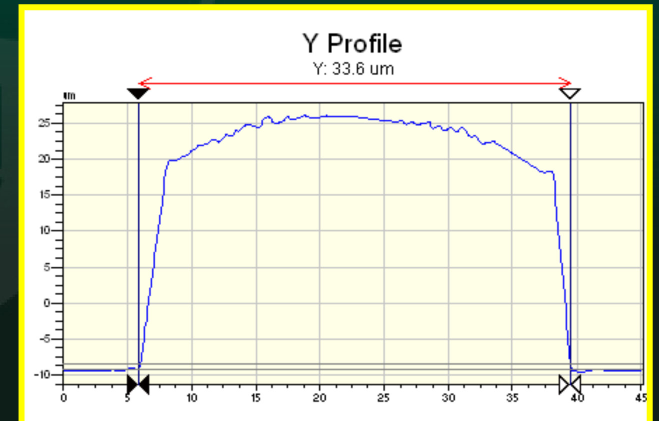












Sn-Ag Bump Resistance

cres (Ω)

2.5
2.0
1.5
1.0
0.5
0.0

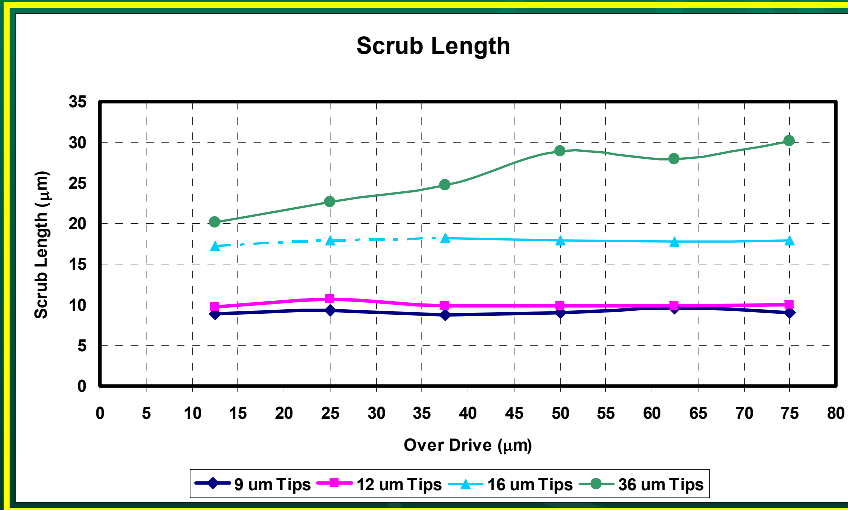
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

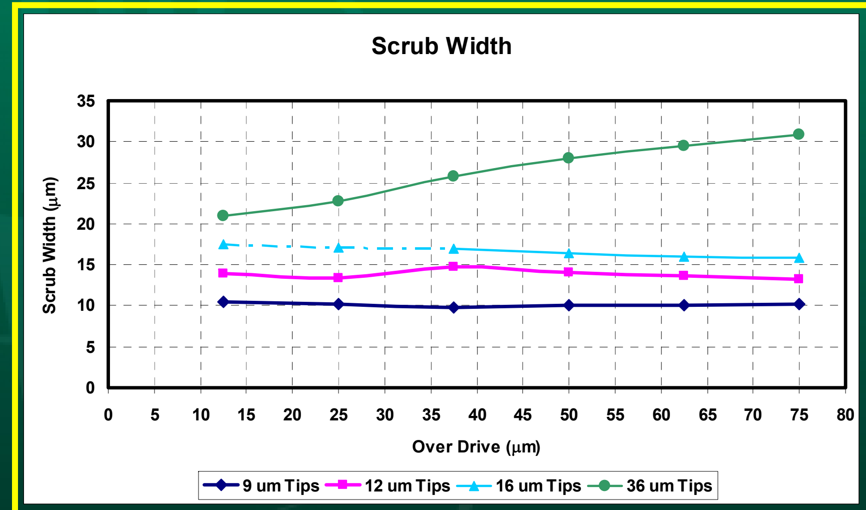
Over Drive (µm)

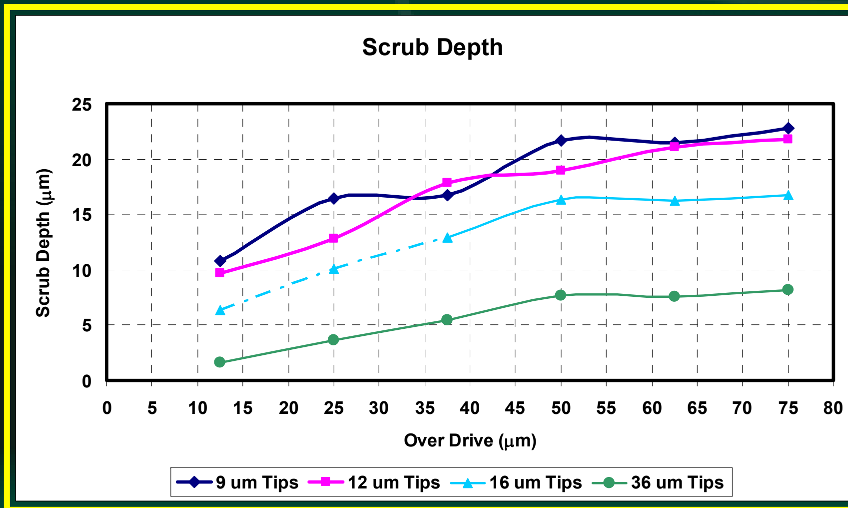
9 um Tips — 12 um Tips — 16 um Tips — 36 um Tips

Cres stable at 25 µm OT (~ 3 gf) for All Tip Sizes

Scrubs on Sn-Ag Bumps

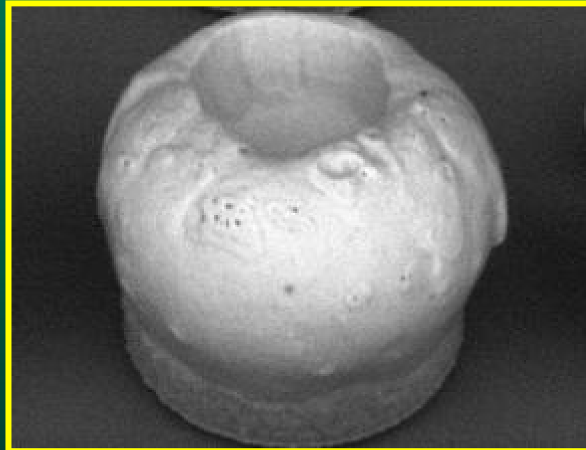






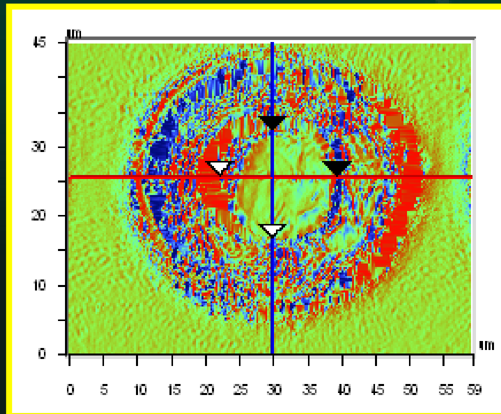
- **16 µm Tips + 50 µm OT**
  - Scrub Mark ~ 17 x 16 µm
  - Scrub Depth ~ 16 µm
- **36 µm Tips + 50 µm OT**
  - Scrub Mark ~ 29 x 28 µm
  - Scrub Depth is 7.5 µm

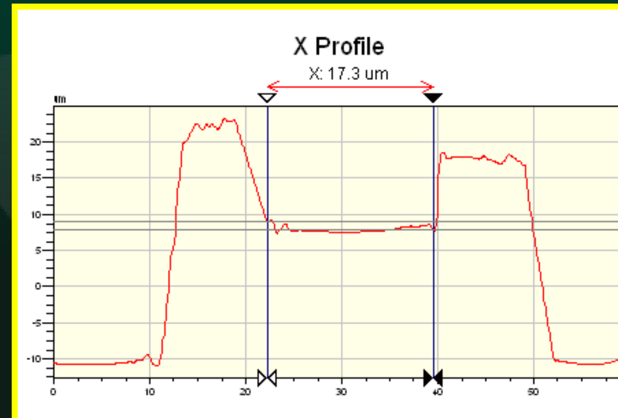
Scrub Marks with 16 µm Tips at 50 µm OT

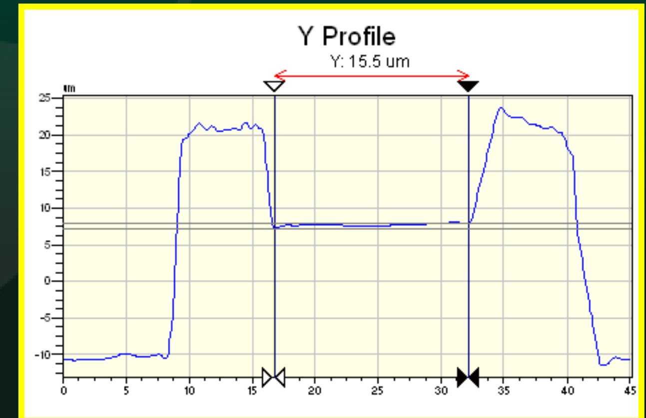


Scrub Mark ~ 17 x 16 µm

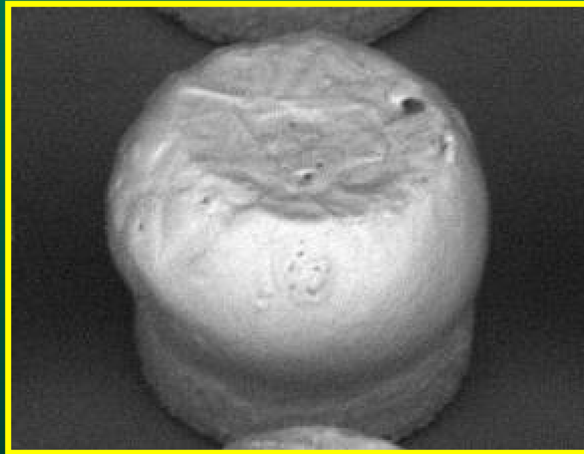
Scrub Depth ~ 16 µm

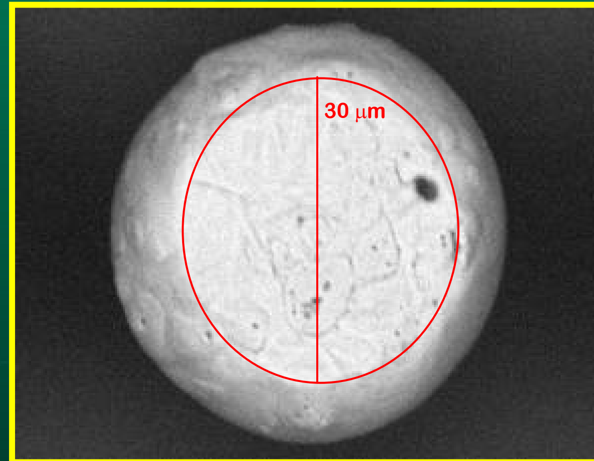






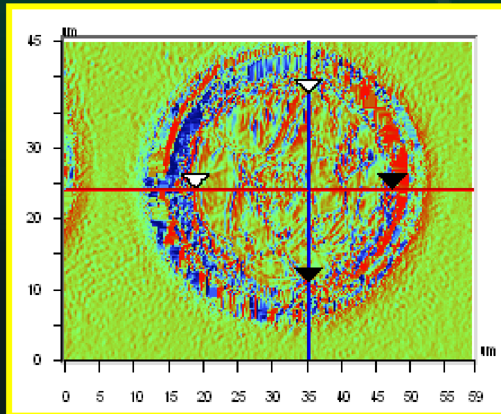
Scrub Marks with 36 μm Tips at 50 μm OT

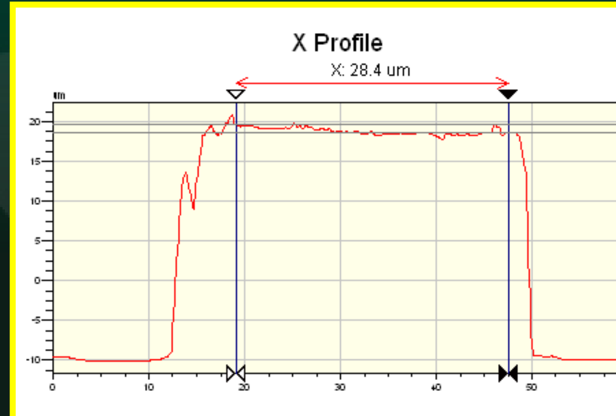


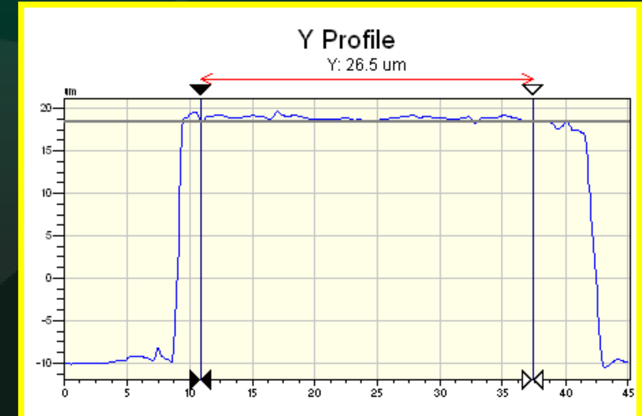


Scrub Mark ~ 29 x 27 μm

Scrub Depth ~ 7.5 μm

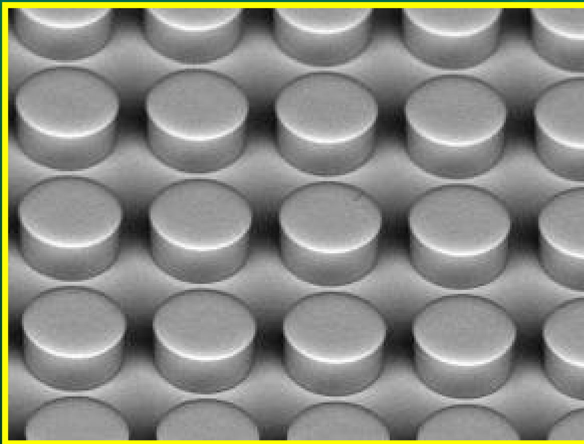


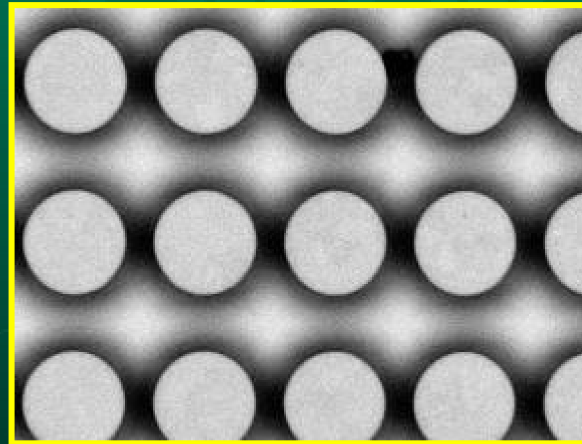


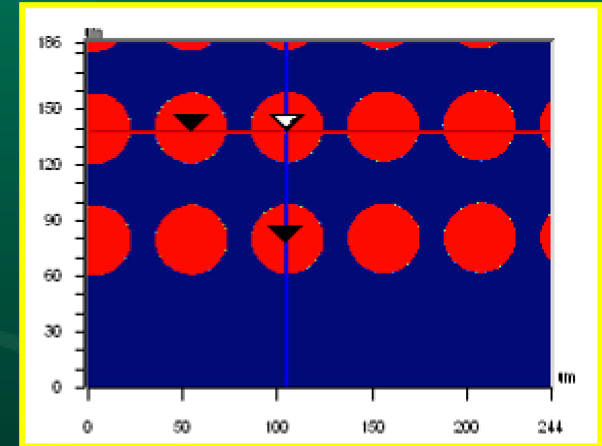


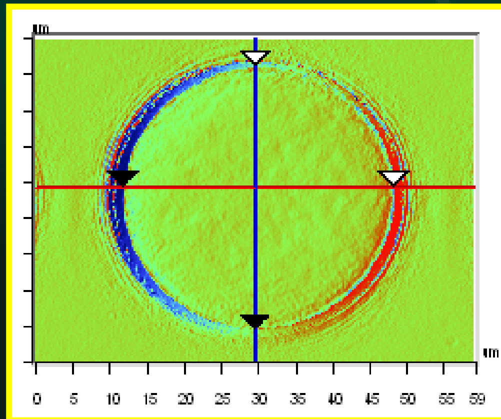
3. Copper Pillar

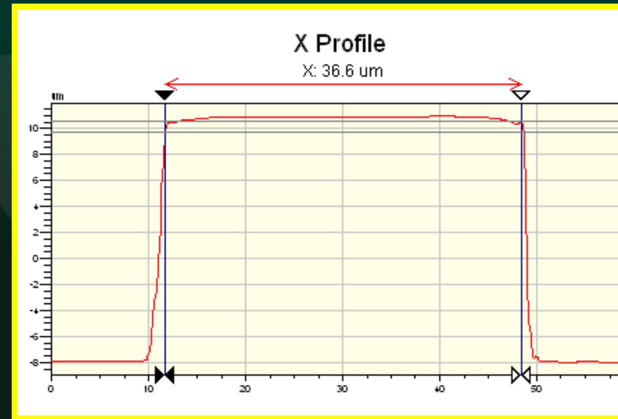
Cu-Pillar Wafer

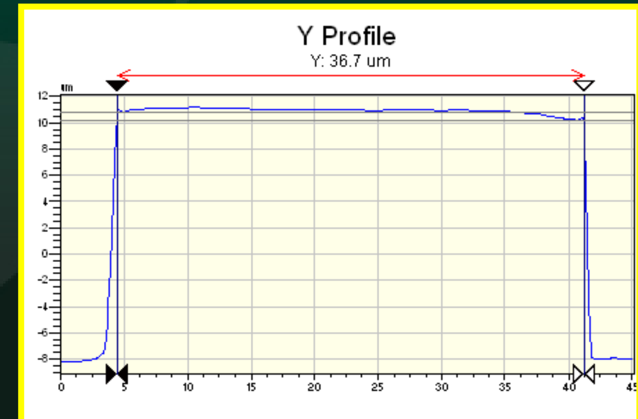












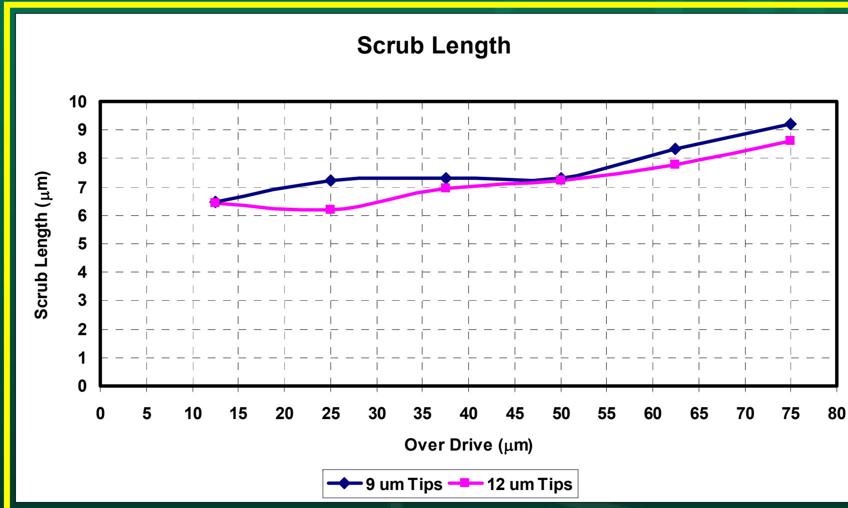
Copper Pillar Resistance

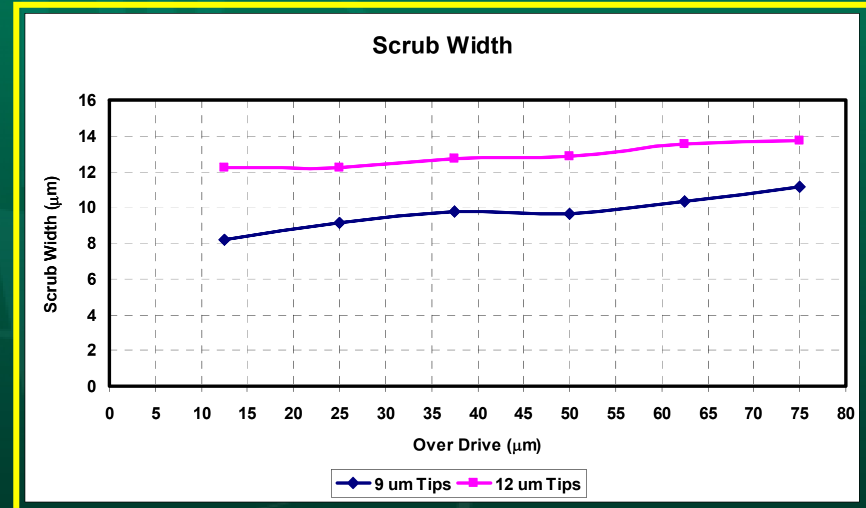
Chart: cres (Ω) vs. Over Drive (μm)

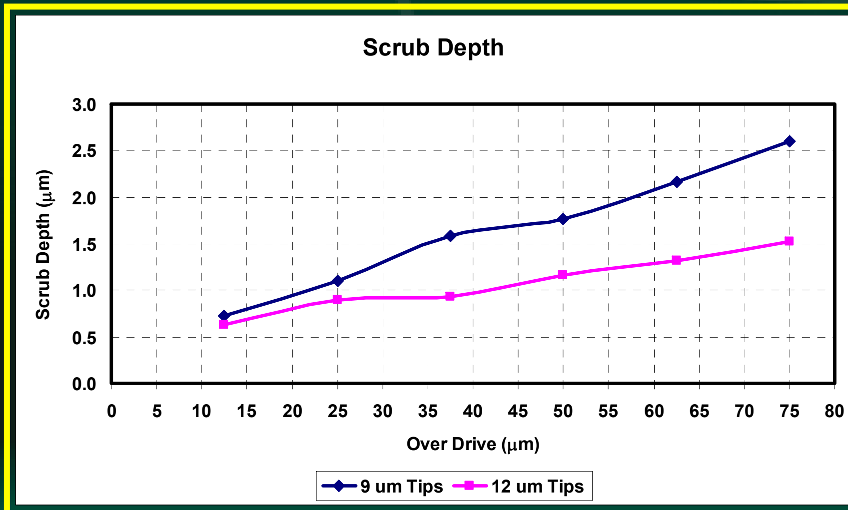
Over Drive (μm)	9 um Tips	12 um Tips
(chart axes: y 0–10, x 0–75)		

- Cres with 12 μm Tips >> 9 μm Tips
- For 9 μm Tips, Cres Stable at 50 μm OT (5~6 gf)

Scrubs on Copper Pillars

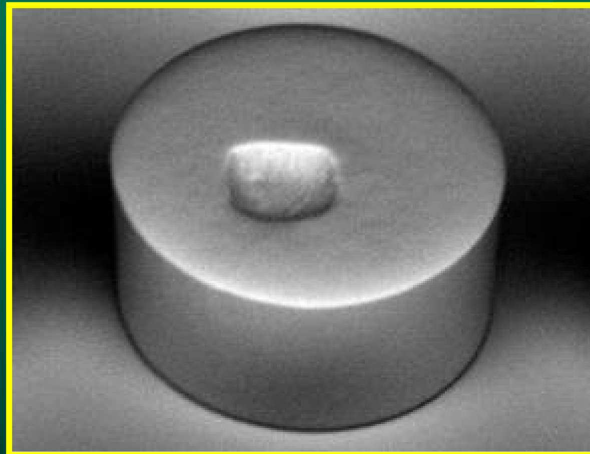


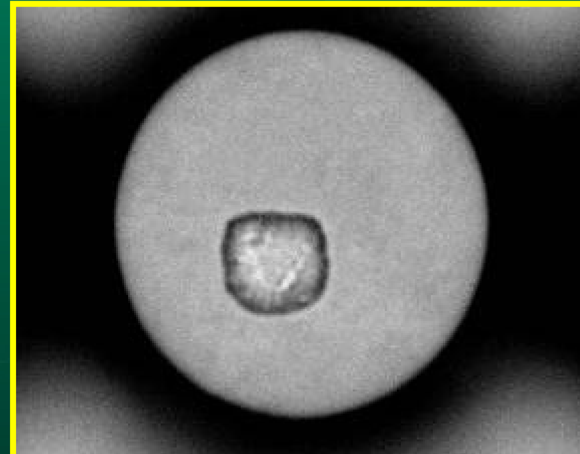




- **9 μm Tips + 50 μm OT**
  - Scrub Mark ~ 7 x 9 μm
  - Scrub Depth is 1.75 μm
- **12 μm Tips + 50 μm OT**
  - Scrub Mark ~ 7 x 12 μm
  - Scrub Depth is 1.15 μm

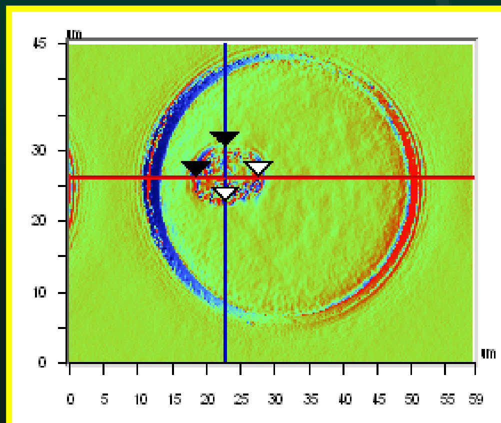
Scrub Marks with 9 µm Tips at 50 µm OT

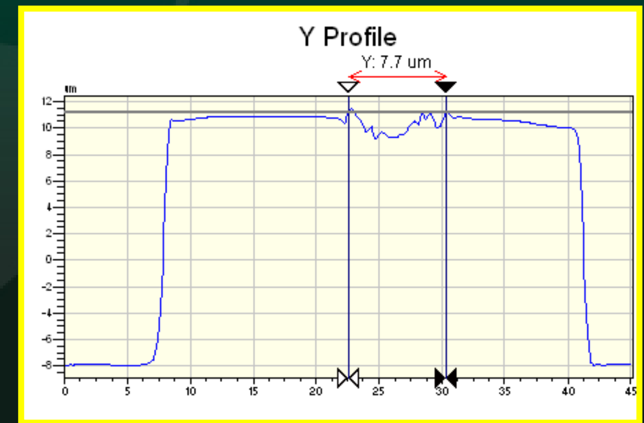




Scrub Mark ~ 8 x 9 µm

Scrub Depth ~ 1.75 µm





Summary & Conclusions

- **We have demonstrated probing fine-pitch solder bumps at 60um pitch arrays using LogicTouch™ technology.**
- **Larger tips (> 16 μm) were effective for solder bump probing while smaller tips were recommended (< 9 μm) for copper pillar probing. Since copper pillar surface is harder to penetrate, a sharper tip is required for effective probing.**
- **Contact behavior of Copper Pillar bumps with solder caps were studied with four different tip sizes.**
  - The Cres behavior on eutectic or lead-free bumps were very similar for all four tip sizes as a function of overtravel. However, the scrub signature of 36um-tip was distinctly different than the rest. We have not observed any appreciable difference in probing performance between eutectic solder & lead-free bumps.
  - Copper pillar probing shows a parallel to copper pad probing. Cres stabilizes at higher OT compared to solder bumps.
  - No damage was observed after multiple probing on all bump types studied.

Future Work

- **Cres Behavior on Contacts on Different Locations on Solder Bumps**
- **Life Test on all Three Bump Materials including the Bump Height Variation vs. Probing Performance**
- **Effect of Current on Scrub, Cres & Cleaning**

Acknowledgements

- Authors gratefully acknowledge the support from Son Dang, Joseph Martin, & Ivan Pipps