BiTS 2010 Session 3

ARCHIVE 2010

CONTACT TECHNOLOGY ART AND SCIENCE

New Development in High Temperature Spring Probes

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A Comparison of New Probe Materials Against Pb Free Solder

Nick Langston—Yamaichi Electronics USA
Hideyuki Ichinosawa—Koshin Kogaku Co., Ltd.

Pb Free BGA Contactor - FA & Solutions

Jiachun (Frank) Zhou, Kevin Deford—Interconnect Devices Inc.

New Probe Architecture in High Volume Production

Tony DeRosa—Multitest

New Development in High Temperature Spring Probes

John Winter – Rika Denshi America Inc.
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Eiji Masaoka – Rika Denshi Co., Ltd.

2010 BiTS Workshop
March 7 - 10, 2010

Outline

- Background
- Problem & Solutions
- Test Summary
- Conclusion

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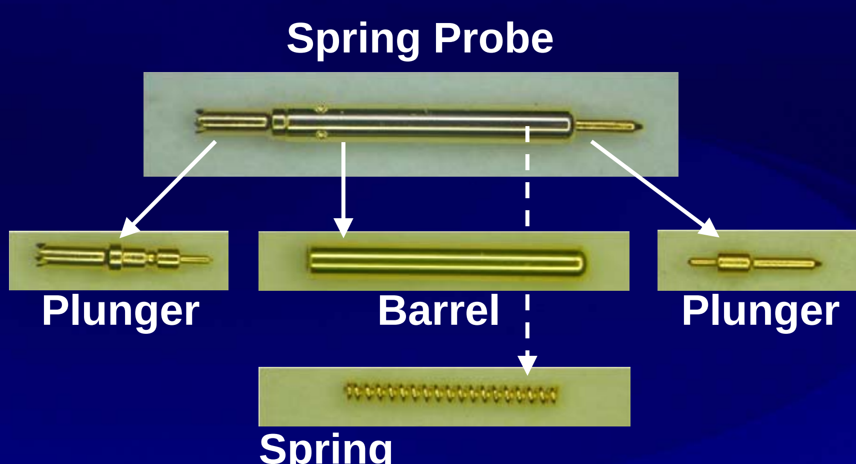
Background

- Increased demand for reliable high temperature probes.
- ITRS2007 & AEC-Q100 specify 175º C test requirements.
- Current standard probes typically have a test limit of 150º C.
- Design objective was to develop a probe that eliminated or decreased the degradation high resistance failures at temperatures over 150º C.

Typical spring probe construction



Problem & Solutions

Problem

Increased contact resistance at temperatures above 150º C, due to surface oxides defusing from the base material and the nickel plating layer.

Solutions

Plunger : K3-Gold™ plating

Barrel : e-barrel™ or Pre-clad barrel

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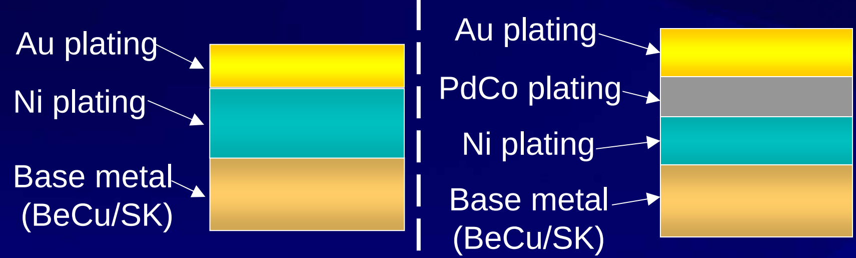
Plating comparison

Conventional Au-plating | **K3-Gold™ plating**



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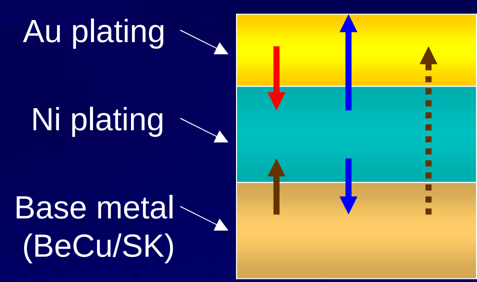
Diffusion in conventional Au plating



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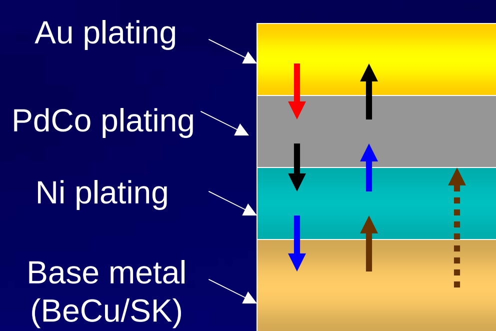
Diffusion in K3-Gold™ plating



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K3-Gold™ after high temperature exposure

Conventional Au plating

K3-Gold™

Before baking at high temperature

After baking at high temperature

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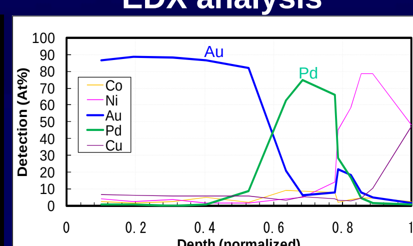
K3-Gold™ plating cross-section

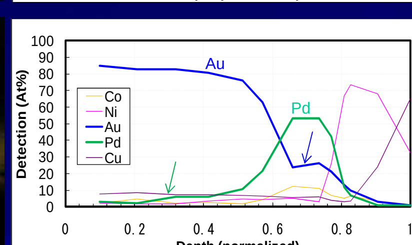
Cross-section

EDX analysis

Before heat treatment



After heat treatment



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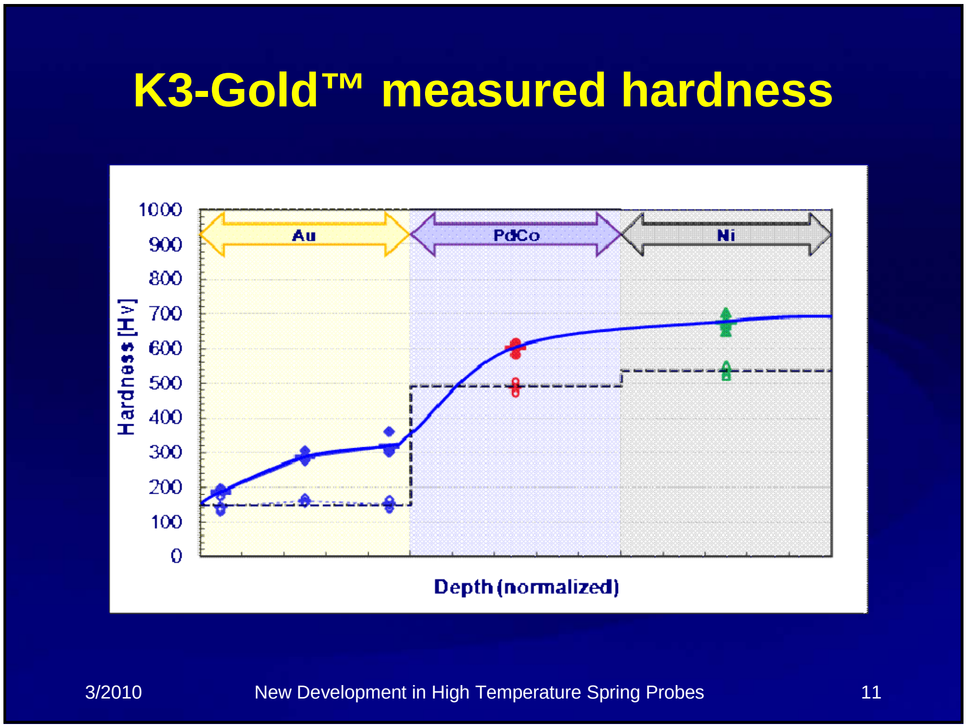
K3-Gold™ measured hardness
Au
PdCo
Ni
Hardness [Hv]
1000
900
800
700
600
500
400
300
200
100
0
Depth (normalized)
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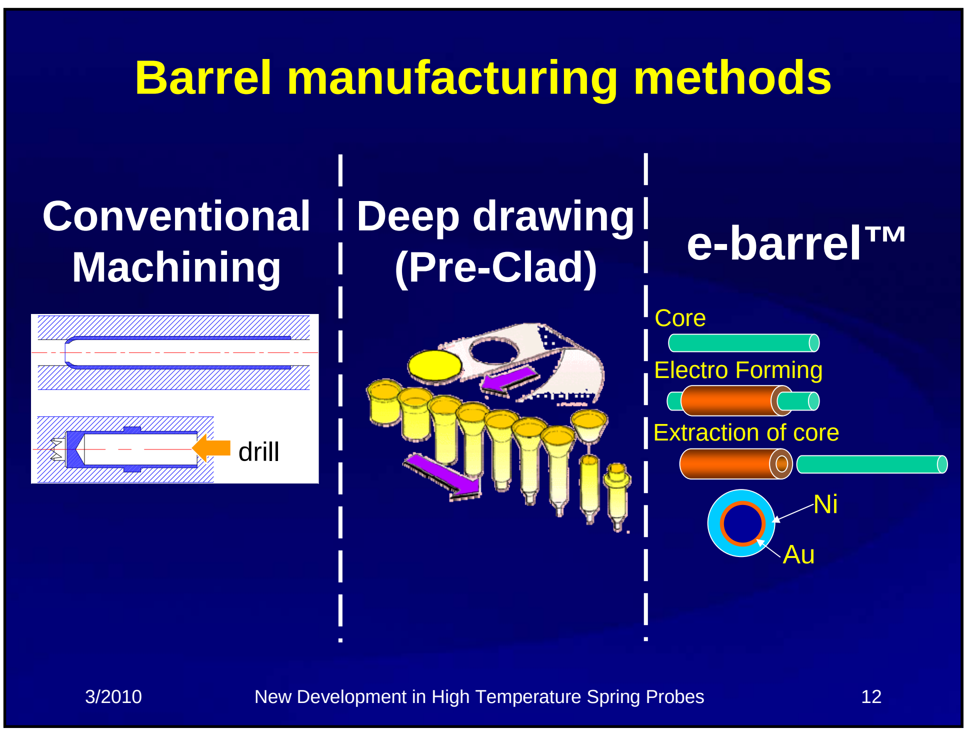
Barrel manufacturing methods
Conventional Machining
drill
Deep drawing (Pre-Clad)
e-barrel™
Core
Electro Forming
Extraction of core
Ni
Au
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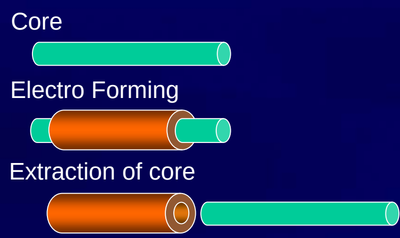
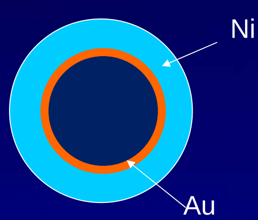
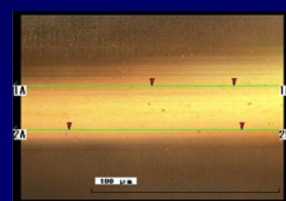
e-barrel™





SEM photo of e-barrel™

Barrel I.D. Surface finish



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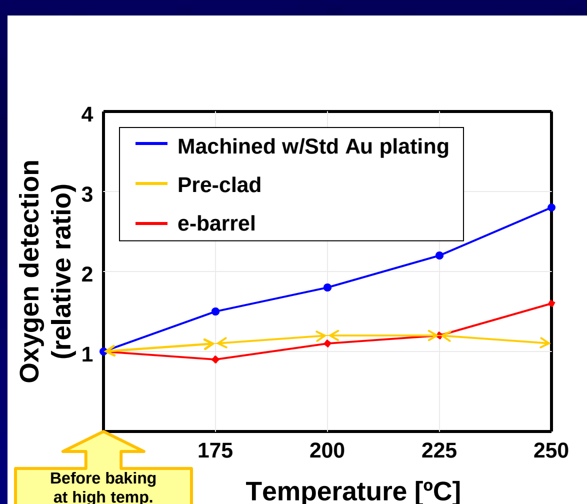
Oxidation comparison



Machined
⇒ Oxidation of Ni

e-barrel
⇒ Oxidation of Ni

Pre-Clad
⇒ Non-oxidation up to 250º C

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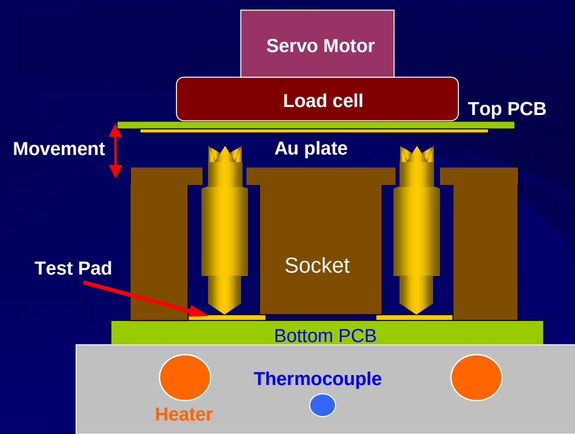
Cycle Tester



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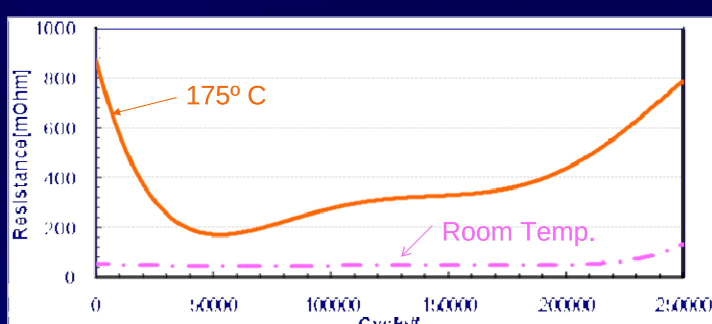
Durability Test Result - Standard Probe



Baking 20 hours at 175º C ⇒ Life Test at 175º C — Average 320.6 mOhm, Std.Dev. 699.4 mOhm

Life Test at Room Temperature — Average 54.6 mOhm, Std.Dev. 46.4 mOhm

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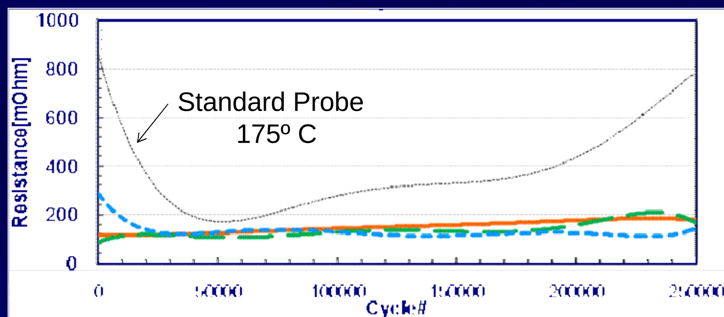
Durability Test Result - Clad & K3-Gold™



Baking 20 hours at 175º C ⇒ Life Test at 175º C — Average 150.2 mOhm, Std.Dev. 54.9 mOhm

Baking 20 hours at 200º C ⇒ Life Test at 175º C — Average 136.6 mOhm, Std.Dev. 77.6 mOhm

Baking 20 hours at 225º C ⇒ Life Test at 175º C — Average 129.1 mOhm, Std.Dev. 98.2 mOhm

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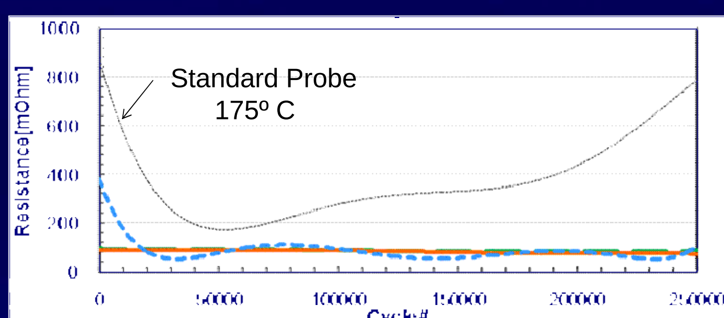
Durability Test Result - e-barrel™ & K3-Gold™



Baking 20 hours at 175º C ⇒ Life Test at 175º C — Average 81.4 mOhm, Std.Dev. 13.7 mOhm

Baking 20 hours at 200º C ⇒ Life Test at 175º C — Average 86.6 mOhm, Std.Dev. 11.4 mOhm

Baking 20 hours at 225º C ⇒ Life Test at 175º C — Average 84.8 mOhm, Std.Dev. 103.0 mOhm

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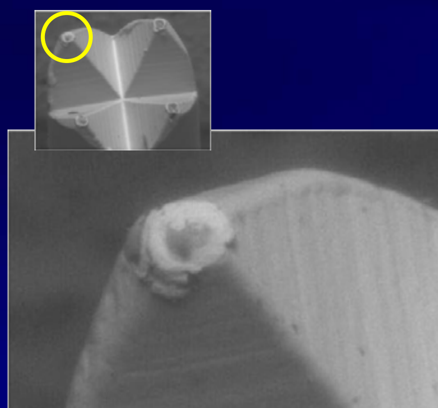
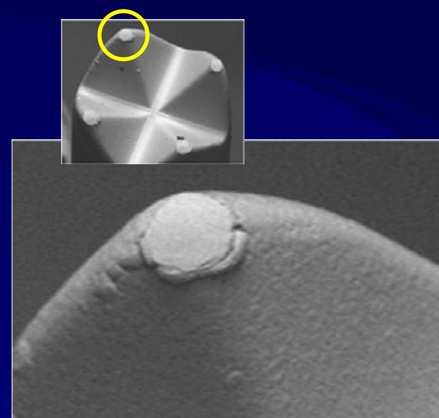
SEM observation after durability test

Conventional Au-plating



K3-Gold™ plating



Evaluation results

		Barrel		
		Machining	Pre-Clad	e-barrel
Plunger	Conventional Plating	Up To 150º C		
Plunger	K3-Gold™		Up To 200º C	Up To 200º C

Conclusion

Successfully designed and developed a spring probe that will meet our current customer’s high temperature test demands.

Probe Features

- Excellent CRES performance at high temperature
- Improved current carrying capability
- Can easily be added to most probe designs

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A Comparison Of New Probe Materials Against Pb Free Solder

Nick Langston Jr.
Yamaichi Electronics, USA.
Hideyuki Ichinosawa
Koshin Kogaku Co., Ltd

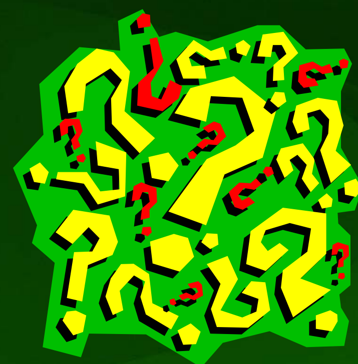
2010 BiTS Workshop
March 7 - 10, 2010

Agenda

- Problem Statement
- Probe Material Options
- Test Design
- Test Results
- Next Steps / Further Research
- Conclusion

The Legend of the Million Cycle Pin

- **Material:**
  - Un
- **Cleaning:**
  - Almost none
- **Price:**
  - $10 ea



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Problem Statement

- **Standard Au plated probe's effectiveness is diminishing**
  - Shorter overall lifetime
  - Decreased first pass yield
  - Increased cleaning frequency

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Characteristics to Improve

- Durability
  - Increase probe lifetime under all conditions.
- Stability
  - Improve consistency of measurements across cycles.
- Surface Finish
  - Decrease solder adhesion / contamination.

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Characteristic: Durability

- Base Materials:
  - Beryllium Copper
  - Hardened Steel
- Palladium Alloys
- Au Alloys

	Hardness (Vickers)	Resistivity (μΩ / cm)
BeCu	400	8.0
SK	600	15.0
Pd Alloy	420	31.5
Au Alloy	330	12.5

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Characteristics: Stability

- **Platings:**
  - Nickel / Gold
    - Chemical etching
  - Palladium Cobalt
- **Coatings:**
  - Diamond-Like Carbon
    - Conductive Super Hard coating (CSH™)

	Hardness (Vickers)	Resistivity (μΩ / cm)
Ni/Au	450 / 200	8.5 / 2.0
PdCo	630	4.0
DLC	800	500

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Diamond Like Carbon

- Coating, not plating
  - Vacuum deposition
- Insulative
- Typical applications:
  - Automotive parts
  - Drill bits
  - Medical devices
- Very smooth
  - Low affinity with Sn

	Coefficient of Friction
Ni/Au	.267
CSH	.133

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Probe Details

- Probe CT3164
  - 0.5mm Pitch
  - Crown tipped
  - 5.7mm free length
  - Avg Cres 70mΩ
  - Plunger Material
    - BeCu
  - Plunger Plating
    - Ni / Au

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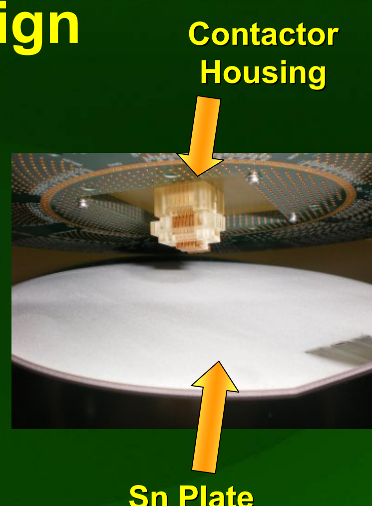
Test Design

- Tokyo Precision A-PM-90A Wafer Prober
- Surrogate Plate
  - Sn 100%
- Contactor Housing
  - 3 Au plated probes
  - 3 CSH coated probes



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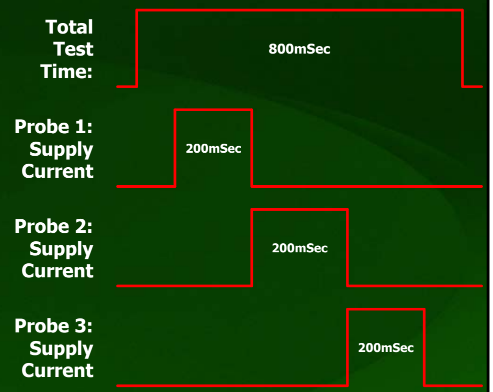
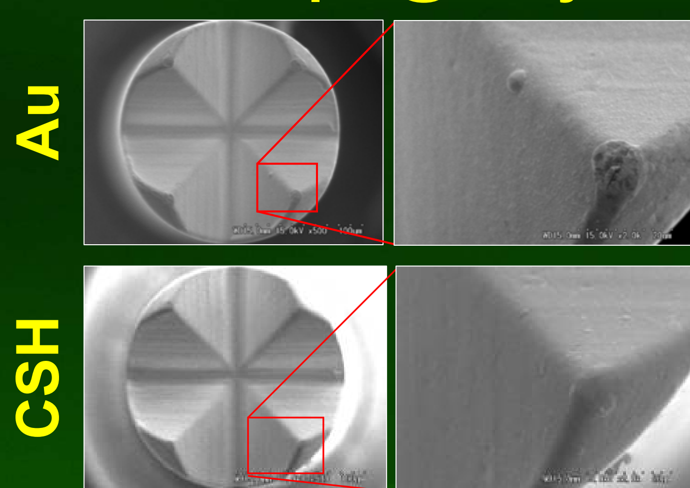
Test Design

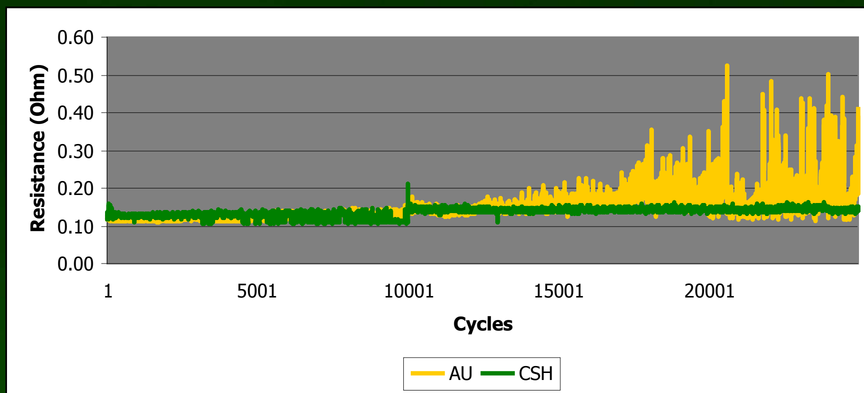
- Apply 100mA current during cycling.
- Measure Contact Resistance at every cycle.
- Kelvin 4 wire measurement
- If Cres > 500mΩ, clean with Mipox (2 touchdowns)
- If cleaning required 5x within 100 cycles, end test.



Probe Tips @ 0 Cycles



Results: 1-25K Cycles



Median Values Shown

Max Au: 10 Ω
Max CSH: 0.238 Ω

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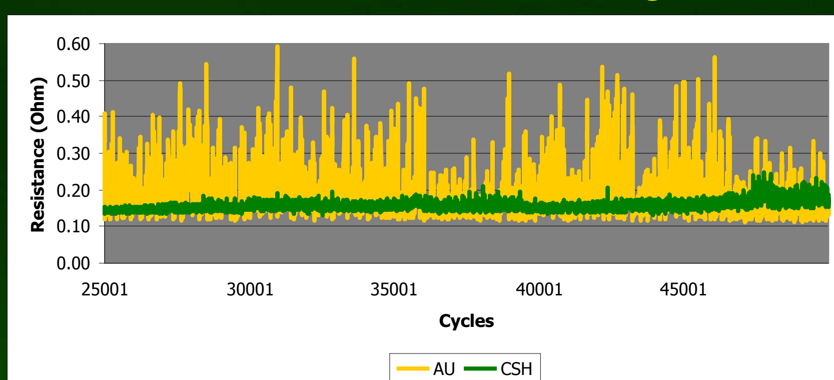
Results: 25K – 50K Cycles



Median Values Shown

Max Au: 7.59 Ω
Max CSH: 0.357 Ω

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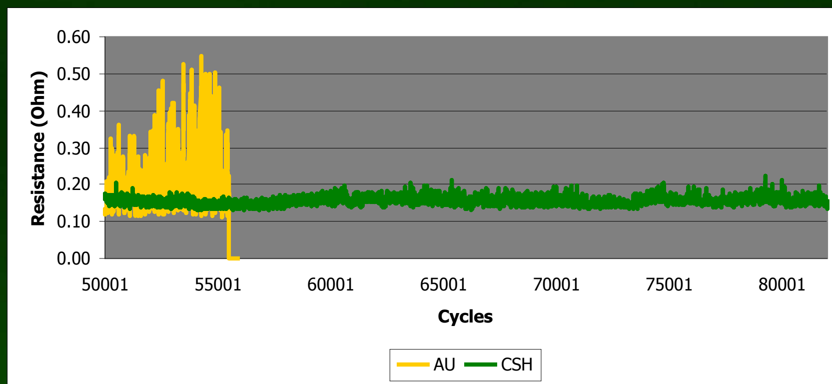
Results: 50K – 100K Cycles



Median Values Shown

*Au probe cycling cancelled @ 55K due to 5 cleaning events in less than 100 cycles.

Max Au: 0.961 Ω
Max CSH: 0.576 Ω

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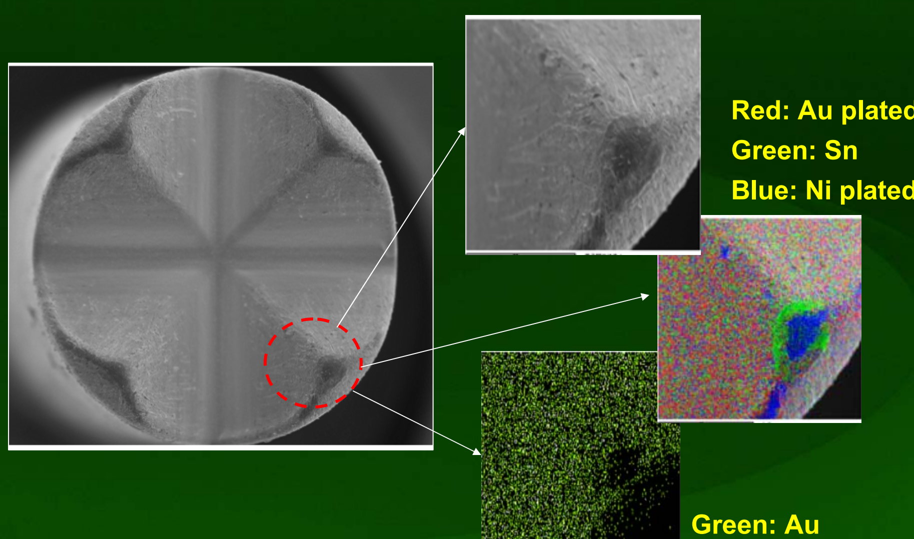
Au Plated Probes: 55K Cycles



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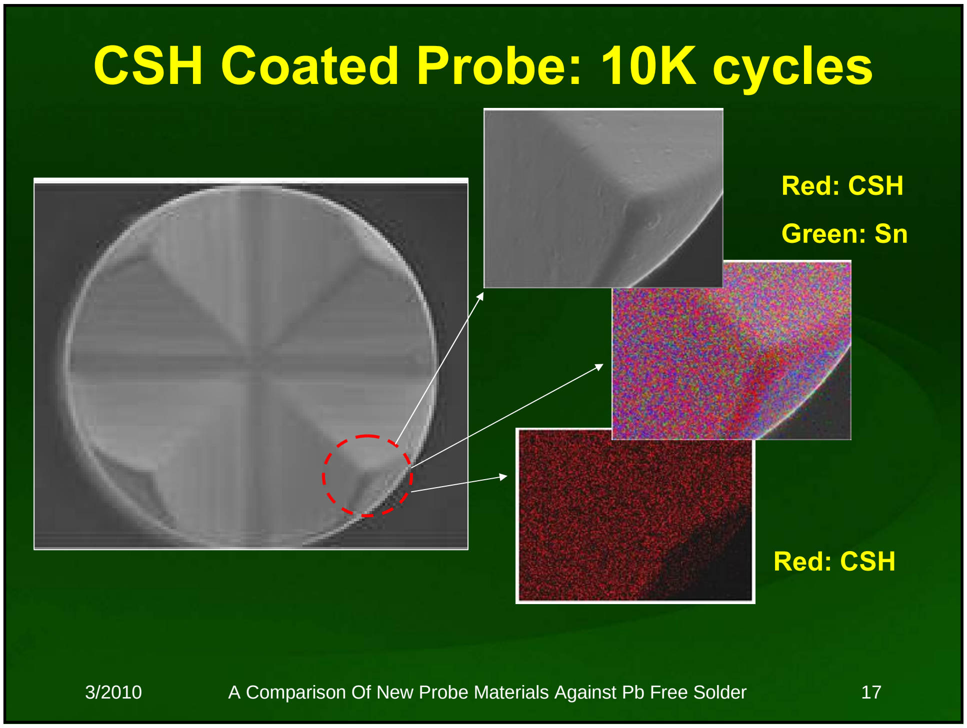
CSH Coated Probe: 10K cycles
Red: CSH
Green: Sn
Red: CSH
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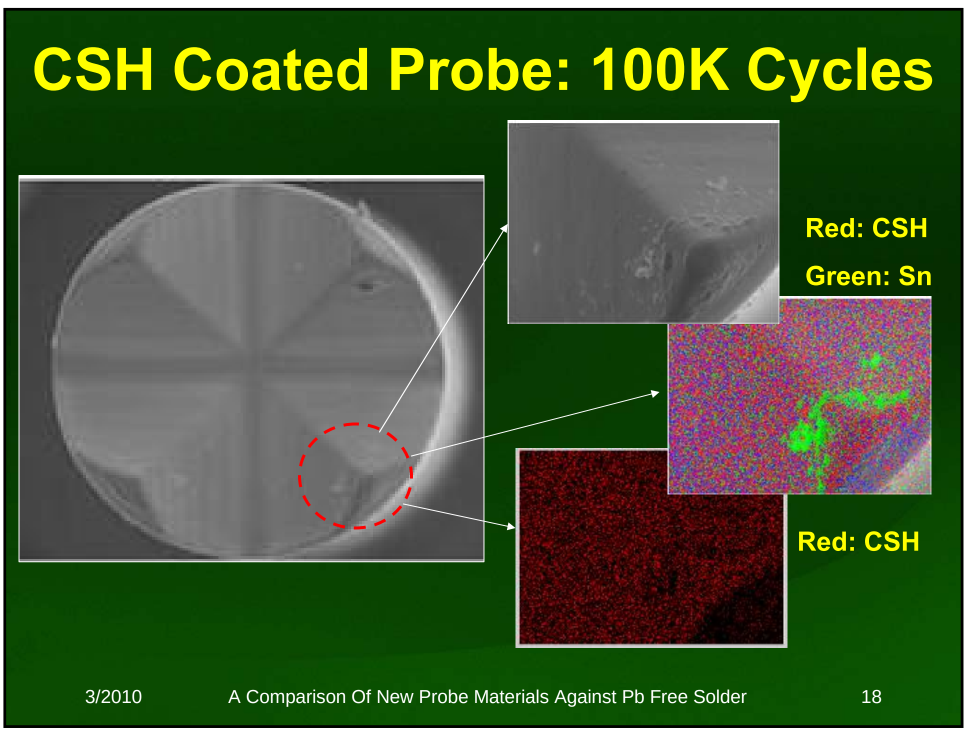
CSH Coated Probe: 100K Cycles
Red: CSH
Green: Sn
Red: CSH
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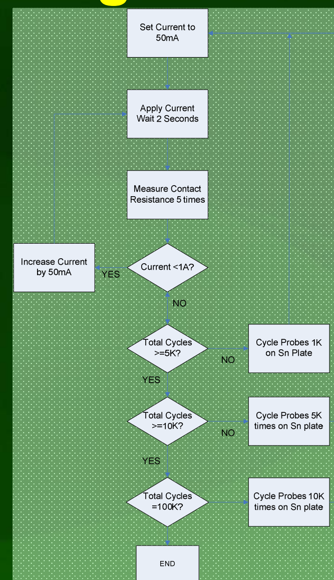
Further Testing

- Cycle while measuring resistance over a range of currents
  - New Probes
  - 50mA to 1.00A
- Expose non-linear performance
  - Refer to "Current / Voltage Nonlinearities" BiTS 2009, Dr. Hohenwarter



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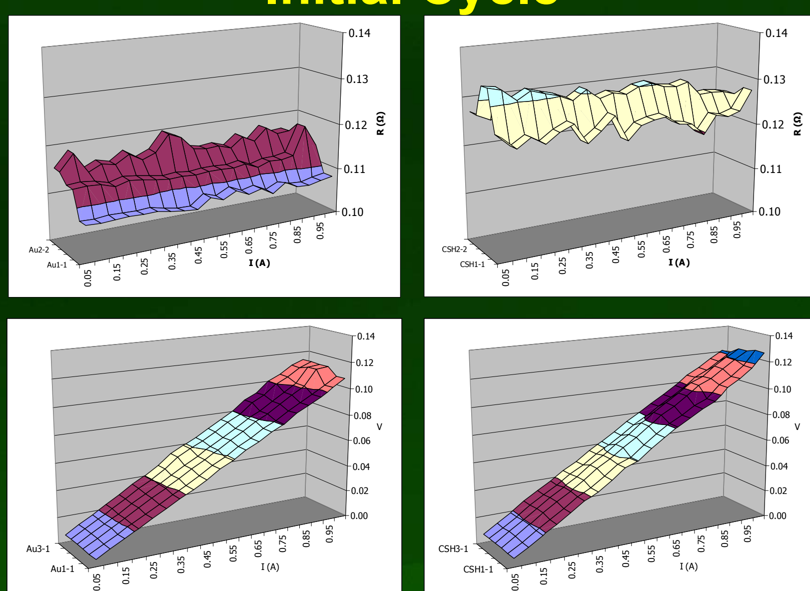
Initial Cycle

Au



CSH

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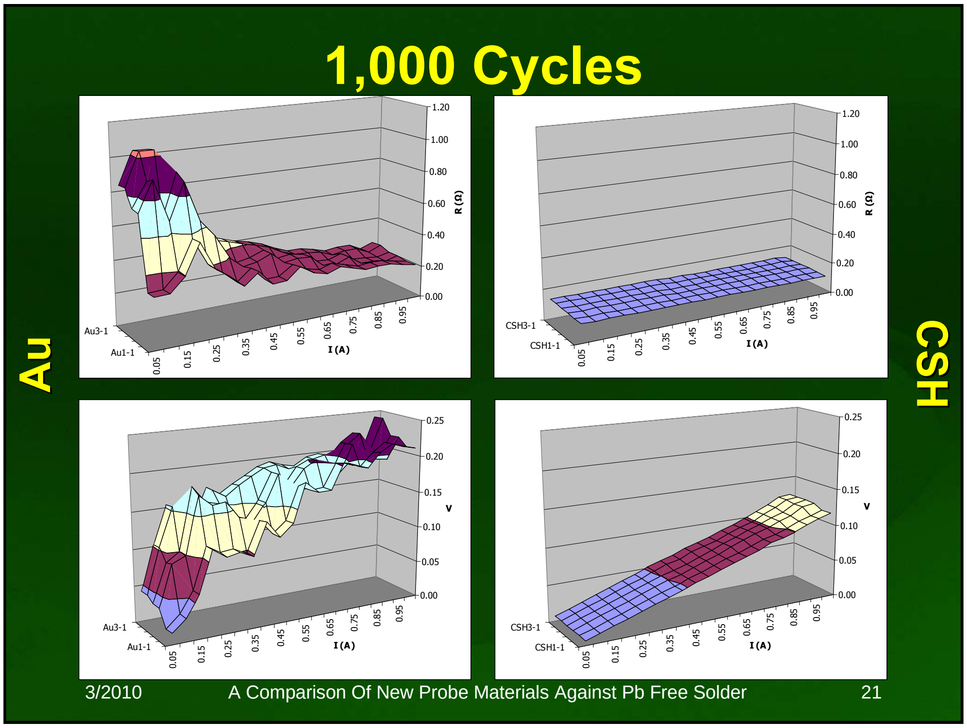
1,000 Cycles
Au
CSH
R (Ω)
V
I (A)
Au3-1
Au1-1
CSH3-1
CSH1-1
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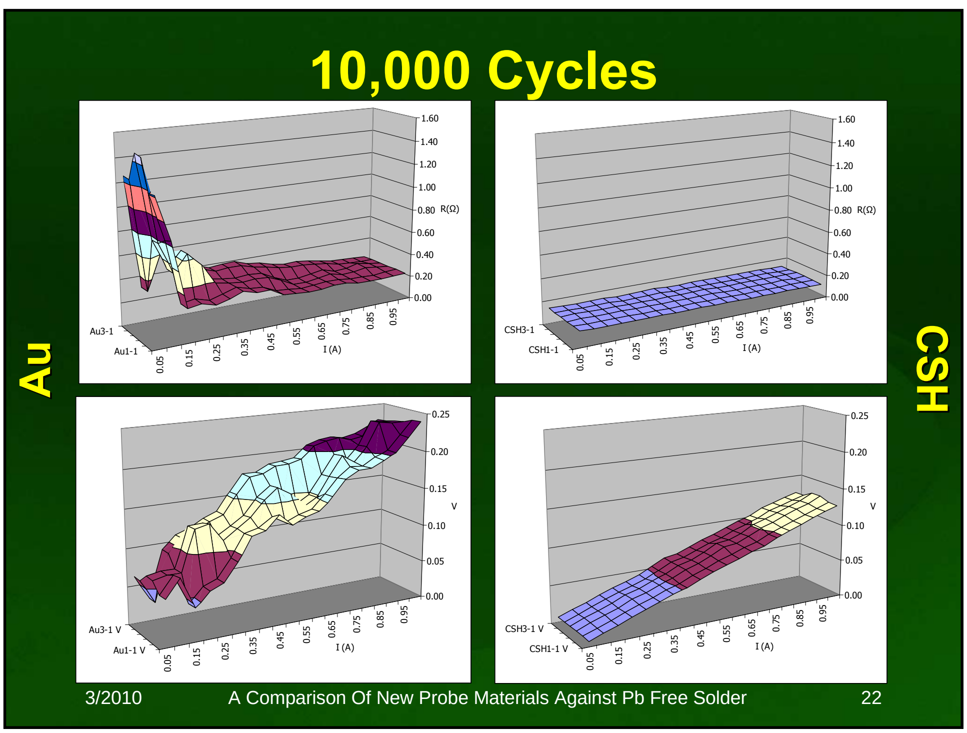
10,000 Cycles
Au
CSH
R(Ω)
V
I (A)
Au3-1
Au1-1
CSH3-1
CSH1-1
Au3-1 V
Au1-1 V
CSH3-1 V
CSH1-1 V
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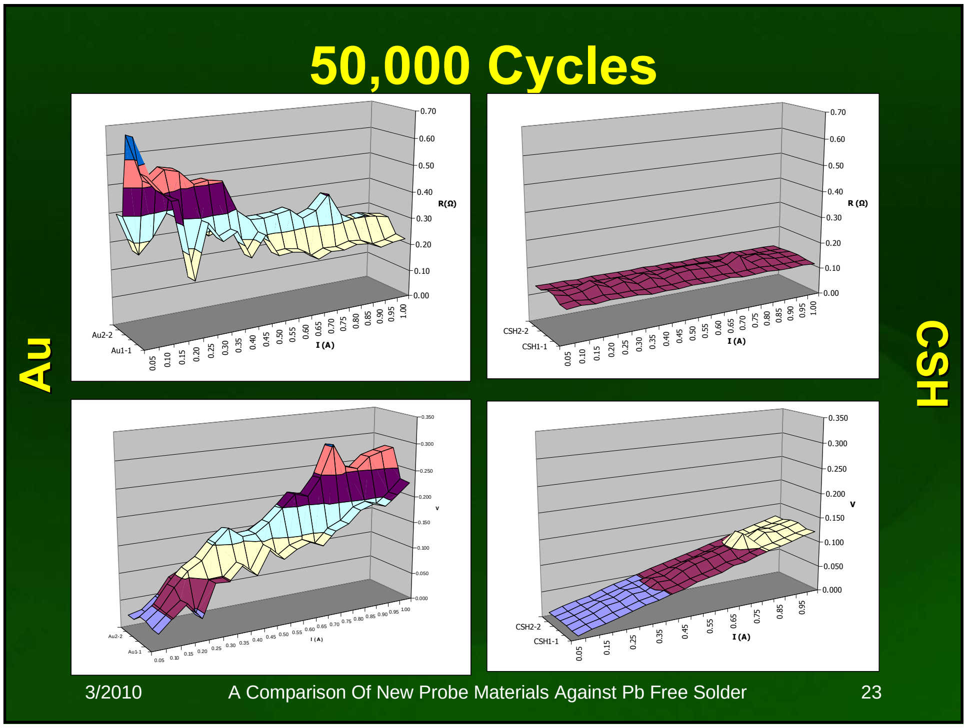
50,000 Cycles
Au
CSH
R (Ω)
I (A)
V
Au2-2
Au1-1
CSH2-2
CSH1-1
3/2010
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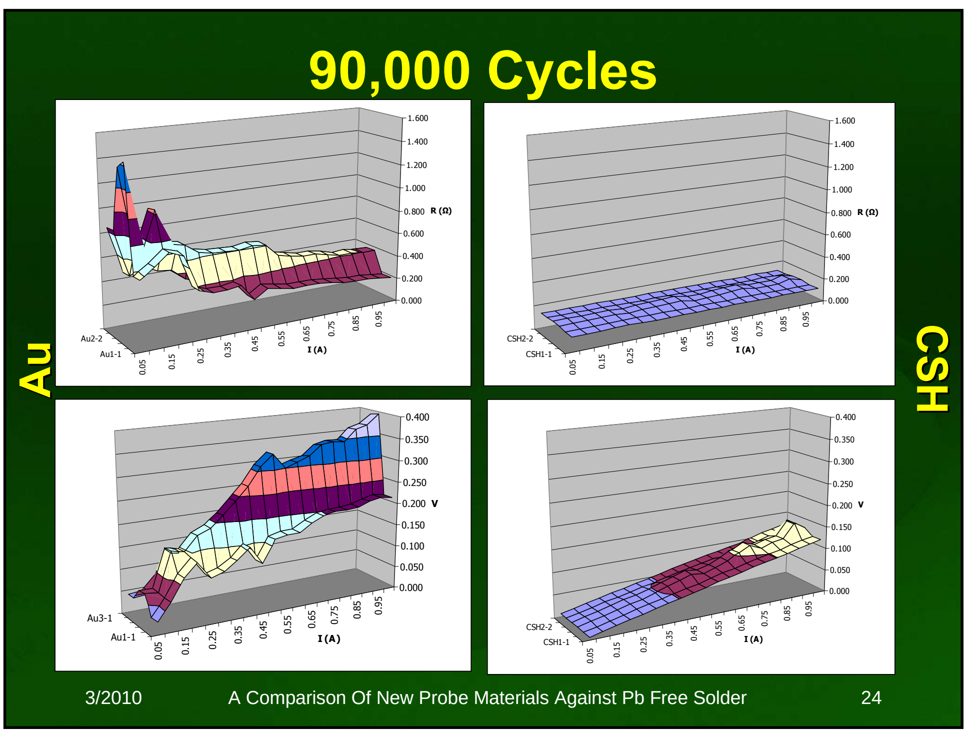
90,000 Cycles
Au
CSH
R (Ω)
I (A)
V
Au2-2
Au1-1
Au3-1
CSH2-2
CSH1-1
3/2010
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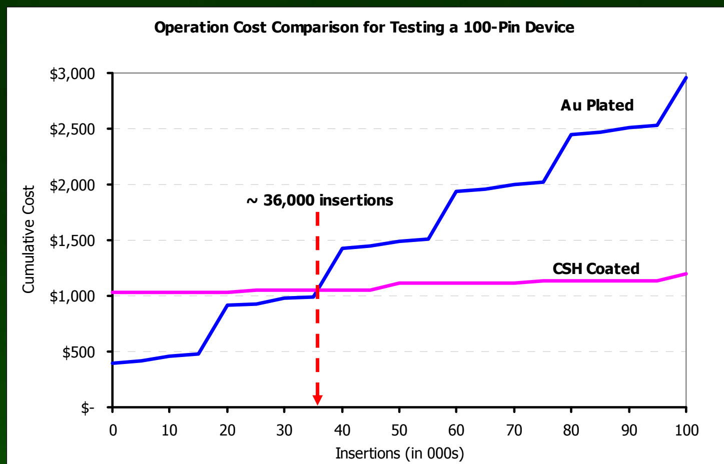
Cost of Ownership



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Next Steps / Further Research

- Determine the impact of tip geometry.
- Determine the impact of contact force.
- Characterize other probe materials & platings.

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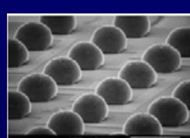
Conclusions

- CSH / DLC offers significant improvements over Au plating
  - Durability over time
  - Stability across currents
  - Low solder adhesion

Pb Free BGA Contactor - FA & Solutions

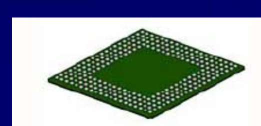
Jiachun Zhou (Frank)
Kevin DeFord
Interconnect Devices, Inc.

2010 BiTS Workshop
March 7 - 10, 2010



Content

- Challenge & Approach
- Phenomena on Contactor Crown
- Macro and Micro Analysis
- Approach: Crown Structure
- Approach: Plunger Material
- Approach: Cleaning
- Summary
- About Authors



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Challenge

Pb free BGA package uses SAC alloys. Due to specific properties, SAC BGA ball generates more challenges to contactor technology due to more contamination, less cycling life, more cleanings for crown, etc.

Approach

Extensive development works have been done in order to provide best solutions for customers.

- Failure mechanism study
- Contactor crown structure
- Apply new material for contactor
- A new cleaning methodology

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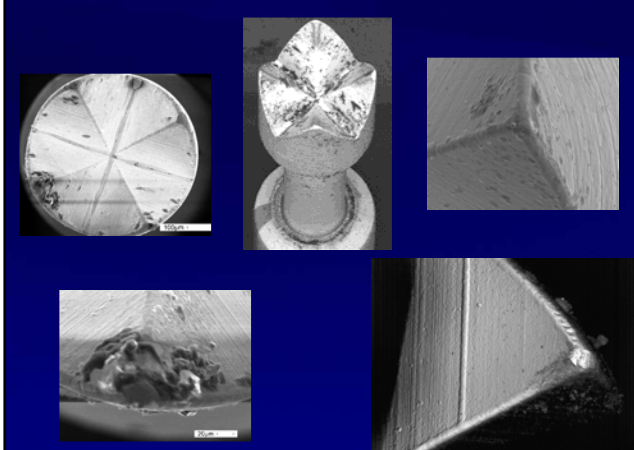
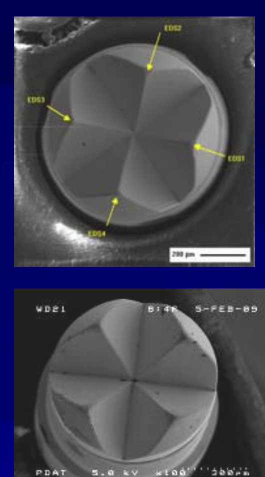
Phenomena on Contactor Crown

I. High Cres with large to small contaminates



II. High Cres with clean crown



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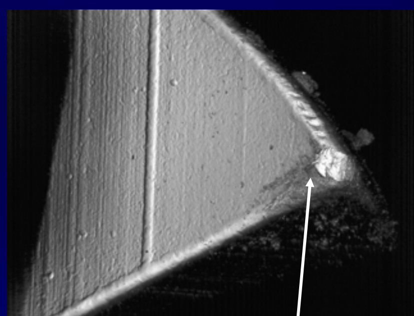
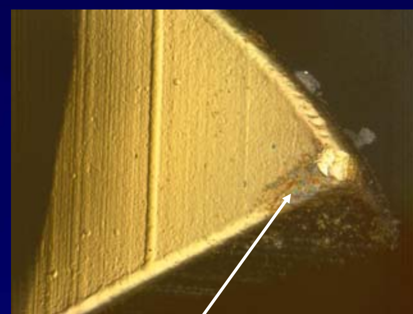
Phenomena on Contactor Crown

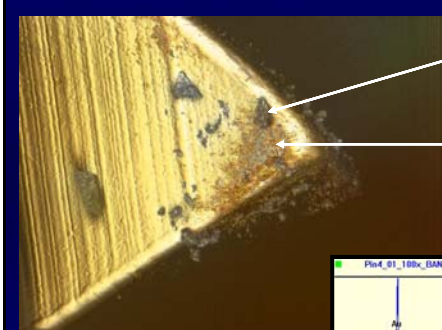


Contaminates on SEM



Contaminates on 3D Laser Confocal Microscope: Colors metallic oxides.

Macro & Micro Analysis

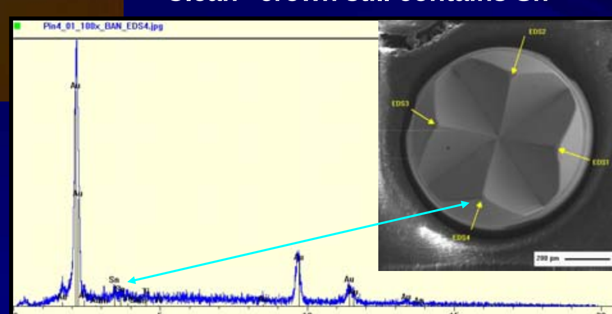


Macro: Sn particle surface

Micro: thin layer contamination

Au plating surface

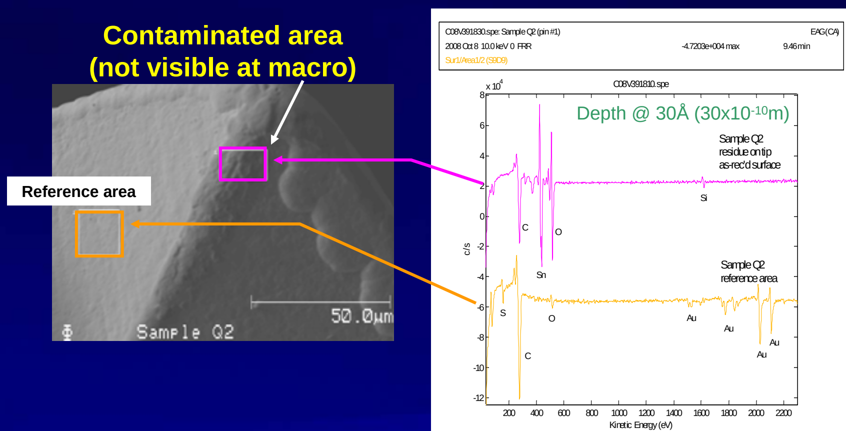
“Clean” crown still contains Sn



Macro & Micro Analysis

- Auger Electron Spectroscopy to analyze composition of pin tip surface.
- At the depth of 30Å (Ångstrom = 10^{-10}m), contaminated area has much more Sn and O elements than no-contaminate surface. No Au element is detected at contaminated area.

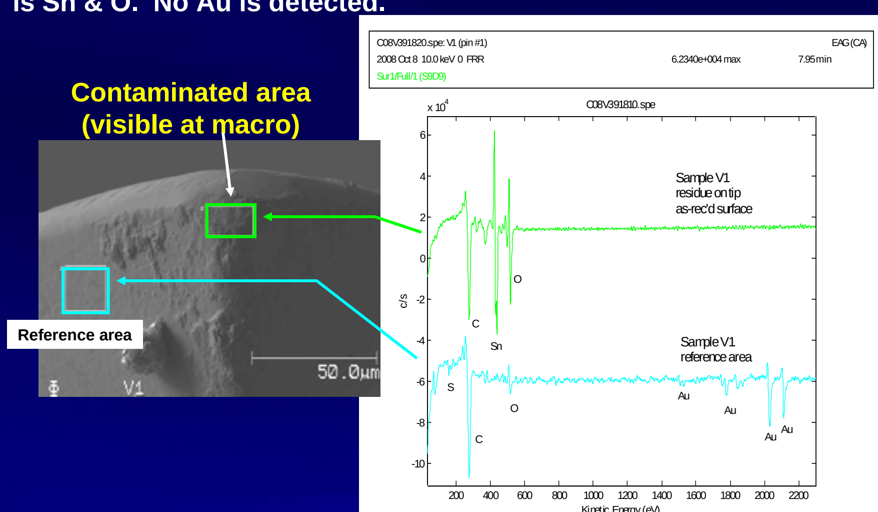
Contaminated area
(not visible at macro)



Macro & Micro Analysis

- Comparing to reference area, major elements at contaminated area is Sn & O. No Au is detected.

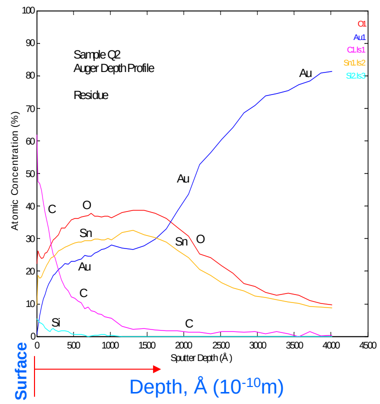
Contaminated area
(visible at macro)



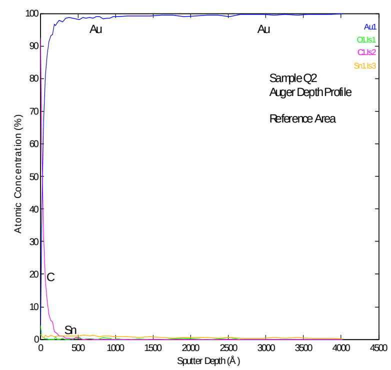
Macro & Micro Analysis

- Sn & O have same distribution along contamination layer. SnxOy must be the major contaminates stuck on crown surface to cause high Cres.
- Test temperature can affect formation and growth of SnxOy.

Contaminated area



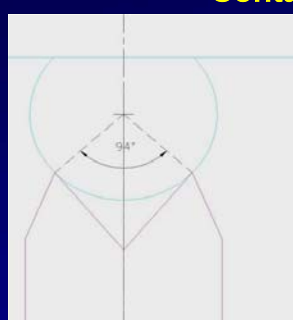
Reference area

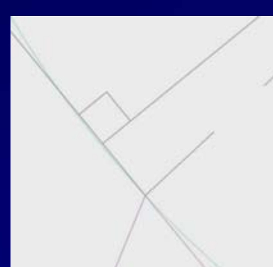


Solution: Crown Structure

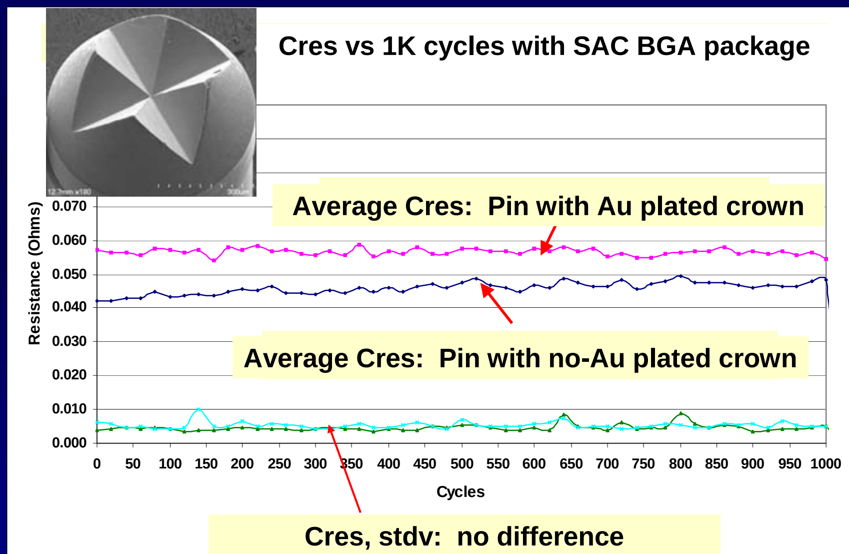
Two basic contact modes:
- Cradle contact: Ball sites inside crown and contacts with four cutting edges
- tab contact: Ball sites on tips of crown and contacts with four sharp tips

Contact Example





Solution: Material



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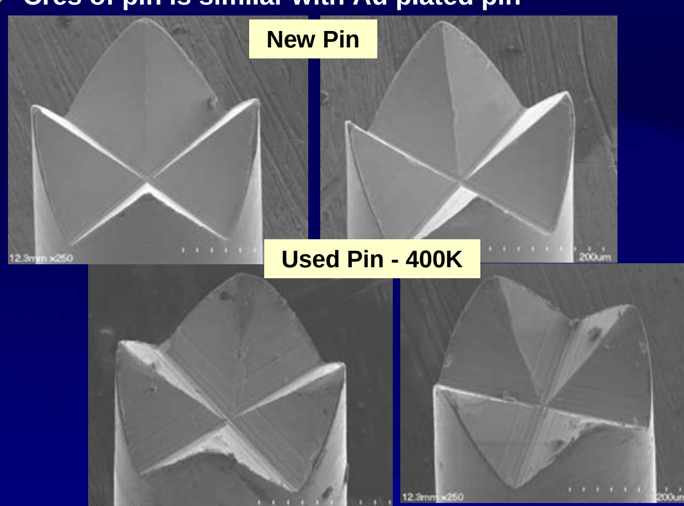
Solution: Material

A new material is used for pin crown to replace Au plating:

- Crown keeps sharp tip over 400K cycles & several cleanings
- Cres of pin is similar with Au plated pin



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Solution: Cleaning

Cleaning Kit

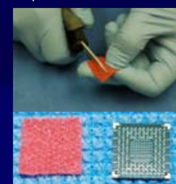
1. Rotary Tool
2. Rotary Tool Brushes
3. Hand Brush
4. Saturated Cleaning Cloth
5. Sacrificial Device
6. Scissors
7. Tweezers
8. Latex or Nitrile Gloves

Step 1

- Remove socket & board to cleaning work place;
- Keep socket on board

Step 2

- Trip pre-saturated cloth to package size;
- Use a sacrificed package as sample.



Step 3-1

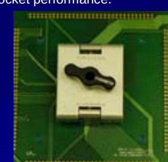
- Put trimmed cloth into packet and ensure to cover all tip;
- Use a sacrificed package as cover cloth.

Step 3-2

- Put lid on socket;
- If no lid, cycle package 10 times.

Step 4

- Saturated cloth to soak over 20 min.
- Longer soak time no detrimental to socket performance.



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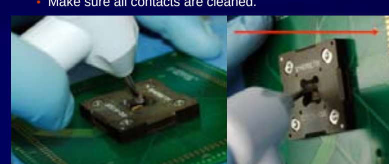
Solution: Cleaning

Step 5

- Remove cloth from socket;
- Discard used cloth.

Step 6

- Hold nylon bristles rotary brush at ~ 30° ;
- Light pressure to actuate brush by pushing back of tool;
- Sweep from upper corner slowly at one direction;
- DO NOT sweep back and forth;
- Make sure all contacts are cleaned.



Step 7

- Hand brush is used to remove loose particles.

Step 8

- Rinse brush with Isopropyl Alcohol (IPA).
- Make sure all IPA is completely evaporated on brush before next time usage.

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Summary

- Extensive studies have been done on Pb-free BGA contact contaminations. Formation of SnxOy is major root cause of high Cres. Mechanisms of Sn & O atoms migration and diffusion can be applied to control formation of contaminates.
- The approaches to improve spring probe contact performance for Pb-free BGA package testing:
  - Crown structure matching with BGA ball
  - Using different material on top side plunger
  - New cleaning process
- Following procedure is the key of efficient function of cleaning methodology.

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New Probe Architecture in High Volume Production

Tony DeRosa
Multitest

2010 BiTS Workshop
March 7 - 10, 2010

Introduction

- Package innovation and DUT complexity create challenges that are beginning to exceed traditional spring probe capabilities
- Requirements – long life – high yield and low cost
- New flat probe architecture addresses these challenges

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Agenda

- Challenges from Packaging & Device Advancements
- Contactor Performance Requirements
- Flat Probe Technology Advantages
- High Volume Production (HVP) Test Results
- Summary

Challenges from Packaging & Device Advancements

Packaging innovation & Device Complexity

– **Fine pitch – 0.4mm today, 0.3mm on it's way**

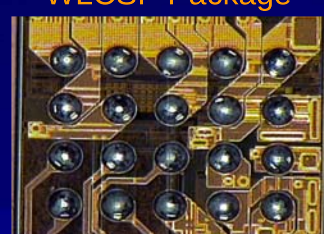
– **RF requirements – high bandwidth, low inductance**

– **SOC – System on Chip**

– **WLCSP – Wafer Level CSP**

– **POP – Package on Package**

WLCSP Package



High Volume Production HVP Contactor Performance Requirements

- High mechanical performance
  - Can compromise electrical performance and/or increase initial cost
- High electrical performance
  - Can compromise mechanical performance and drive initial cost up
- Low cost
  - Can compromised mechanical and electrical performance from lower quality components

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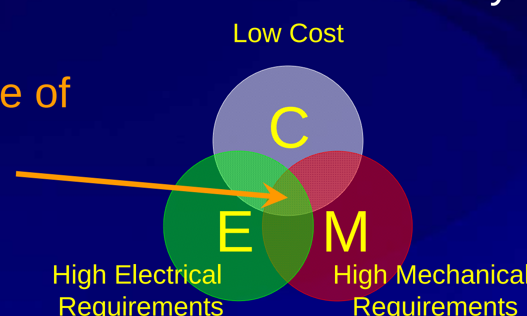
HVP Contactor Performance Requirements

- Difficult to meet all three requirements using conventional spring probe technology
- For a probe to be relevant and commercially viable…..

it must be capable of addressing all requirements simultaneously



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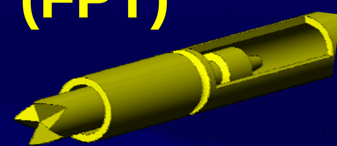
Advantages of Flat Probe Technology (FPT)

- **No internal surfaces**
  - **Improved plating quality**
  - **Consistent electrical performance**



Conventional Spring Probe

- **No barrel / plunger interaction**
  - **Multiple contact surfaces between top and bottom plungers**
  - **Improved biasing**
  - **Consistent electrical performance**

Mercury Flat Probe

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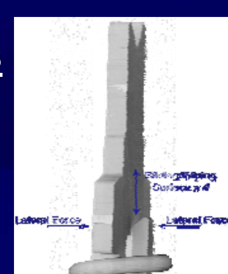
Advantages of FPT

Proprietary manufacturing process

- Precise control of key features
- Rubbing areas controlled to micron level
  - Consistent bias
  - Repeatable electrical performance



Plunger Interaction

- Sharp edges for optimal lead contact
  - Minimal solder build up
  - Longer cleaning intervals

Ball Mark

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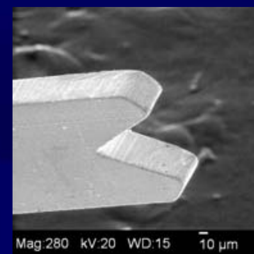
Advantages of FPT

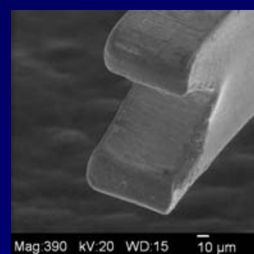
Hard Base Material

- Less wear of sliding surfaces
  - Longer life
  - Higher 1st pass yield

New Mercury Probe



- Improved tip wear
  - Consistent contact
  - Longer life
  - Higher 1st pass yield



550 k Insertions

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Advantages of FPT

Scalability & Flexibility

- Same basic architecture can be used
  - Pitch capabilities down to 0.3mm
- Allows for design variation to address different applications
  - Kelvin – off-set tip geometry
  - High speed - short electrical path

Gemini Kelvin Probe Pair

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Summary of Specifications

	MER040	MER050	MER080
Probe Test Height	3.3 mm	3.3 mm	3.8 mm
Probe Compliance	0.43 mm	0.48 mm	0.57 mm
Force - Test Height	30g	30g	30g
Bandwidth -1dB*	18 GHz	20 GHz	18 GHz
Inductance*	0.98 nH	1.16 nH	1.43 nH
Contact Resistance **		< 80 mOhm	
Life		> 500,000 (typical)	

* Bandwidth and inductance are measured at native pitch, GSG in Vespel ** New Probe

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High Volume Test Results

- Superior performance against competing spring probes
- Evaluations conducted on 3 devices
- Customers:
  - Large fabless semiconductor company based in Irvine, CA
  - Multiple Singapore-based test sub-cons

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High Volume Test Results Device 1

- 407 BGA, 0.5 mm pitch, 12x12 mm
- Application: EDGE/GPRS/GSM Cellular Processor
  – Integrated RF transceiver
  – Mixed signal analog
- Key Test parameter: Signal-to-Noise Ratio (SNR)

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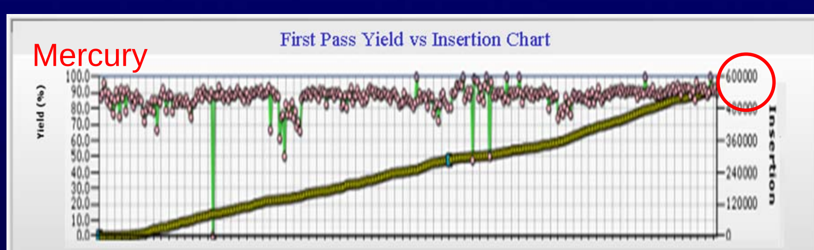
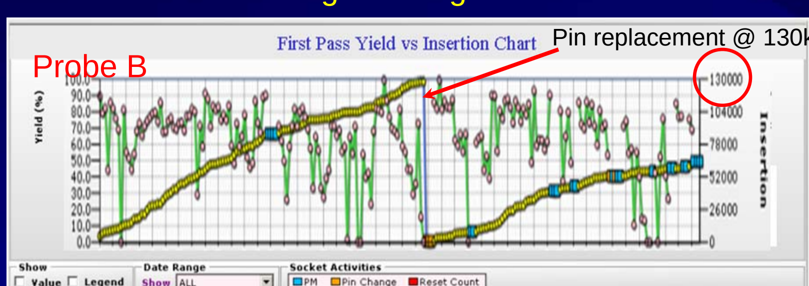
Device 1: HVP Results MER VS Probe B



550 k insertions Long cleaning intervals Solid FPY



130 k insertions Short cleaning intervals Poor FPY

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High Volume Test Results Device 1

	Mercury	Probe B
Insertion Life	600k +	300k
First Pass Yield	90+%	80+%
Cleaning Intervals	40K	20k

Similar results were achieved with 28 Mercury contactors at multiple test houses

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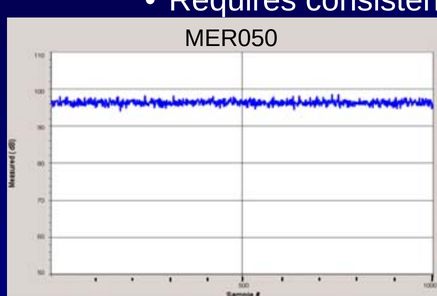
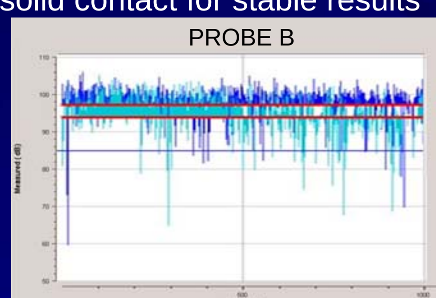
High Volume Test Results Device 1

- Signal-to-Noise Ratio (SNR) Measurement at 20kHz
  - Ratio of signal amplitude to noise floor
- Measurement is extremely sensitive
  - Requires consistent, solid contact for stable results





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High Volume Test Results Device 1

Why did Mercury outperform the competition?

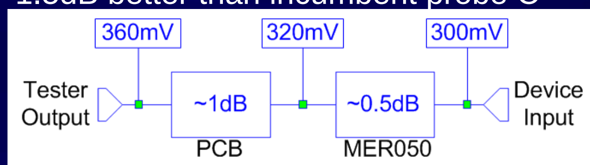
- Better contact
  - Sharp edge contact to solder ball
  - Better tip wear
  - Better plating

High-Speed Performance Device 2

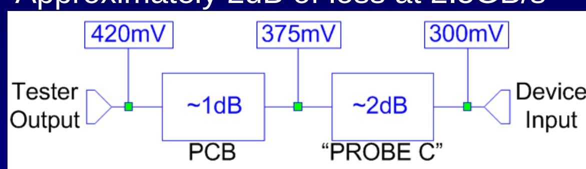
- 48 QFN, 0.5 mm pitch, 7x7 mm
- Application: Gigabit Ethernet Controller
  - 2.5 Gbit/s Differential PCI-express
- Shmoo Plot Results
  - Shows performance of device across a range of input voltages
  - Minimizing loss through test interface allows device to function with lower input voltage
  - Test requirement: Device must consistently pass with maximum input voltage of 400 mV

High-Speed Performance Device 2

- MER050
  - Approximately 0.5dB of loss at 2.5GB/s
  - 1.5dB better than incumbent probe C

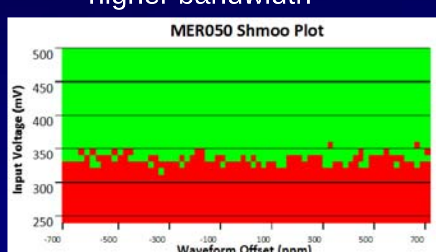


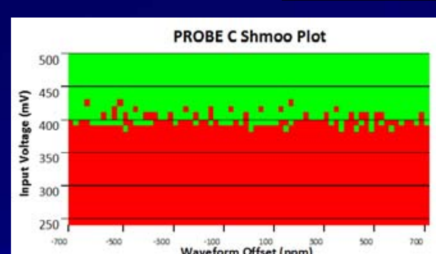
- PROBE C
  - Approximately 2dB of loss at 2.5GB/s



High Speed Performance Device 2

- Results: Test Parameter – Input Voltage (lower is better)
- Probe C requires 420 mV for consistent passes
  - MER050 requires only 360 mV for consistent passes
  - Improved performance due to higher bandwidth contactor
    - MER050 length, impedance match contribute to higher bandwidth





RF Characterization Device 3

- 121BGA, 1.0mm pitch, 12x12mm
- Dual-Channel 10 GBE SFI-TO-XFI (10-Gigabit serial electrical interface) with Electronic Dispersion Compensation (EDC) equalizer
- One DUT is used as signal source
- DUT TX (SFI+) sends PRBS7 pattern at 10.3125Gbs

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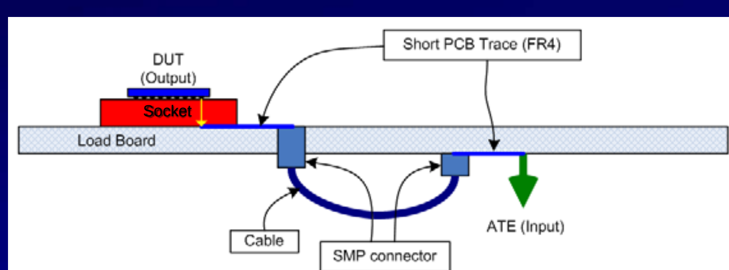
RF Characterization Device 3

- DUT used as signal source
- ATE captures the signal from DUT TX
- Results show insertion loss from DUT-to-ATE
- Setup measured with two different contactors
  - MER080
  - Probe A



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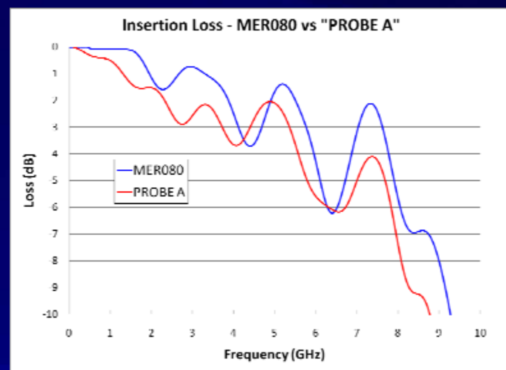
RF Characterization Device 3

- MER080 outperforms probe A through 10GHz
  - Typically ~10% better insertion loss
  - Up to 18% improvement

Freq (GHz)	MER080 (dB)	PROBE A (dB)	Δ%
1	-0.1	-0.5	4.4
2	-1.2	-1.5	3.0
3	-0.7	-2.6	18.1
4	-2.5	-3.7	9.7
5	-1.7	-2.1	3.7
6	-4.3	-5.6	8.5
7	-3.2	-5	12.9
8	-5.7	-7.4	9.2
9	-8	-12	14.7
10	-26.2	-26.7	0.3



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Summary

- Packaging and device complexity increasing
- Cost effective solutions must include mechanical reliability and electrical performance - all in one probe/contactor
- The innovative flat probe technology has demonstrated the ability to meet all three requirements in high volume production

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Acknowledgement
Thanks to Ryan Satrom
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