BiTS™

Burn-in & Test Socket Workshop

March 7 - 10, 2004
Hilton Phoenix East / Mesa Hotel
Mesa, Arizona

ARCHIVE

Burn-in & Test Socket Workshop
TM

COPYRIGHT NOTICE

Burn-in & Test Socket Workshop

Technical Program

Session 8
Wednesday 3/10/04 10:30AM

SOCKETING LEAD-FREE PACKAGES

"Effect Of Compression Style Contactors On Lead Free Solder"

Ila Pal – Ironwood Electronic, Inc.

"Pb-Free Leadframe Devices And Their Impact On Pogo Pin Socket Performance"

Valts Treibergs – Everett Charles Technologies

Ironwood Electronics, Inc.

Effect of Compression Style Contactors on Lead Free Solder

ILA PAL

Agenda

- Pb free background
- Experimental objectives
- Contact resistance analysis
- Ball damage analysis
- Electrical performance
- Force characterization
- High speed characterization
- Conclusions

Why lead free?

- To avoid legislation that would force a change
- To protect our environment
- To meet consumer demand

National Electronics Manufacturing Initiatives

- Group of 30 different organizations including OEMs, contract manufacturers, solder manufacturers, government agencies, and universities.
- Focus
  - Lead free assembly
  - Solder alloys
  - Components
  - Solder reliability

National Electronics Manufacturing Initiatives

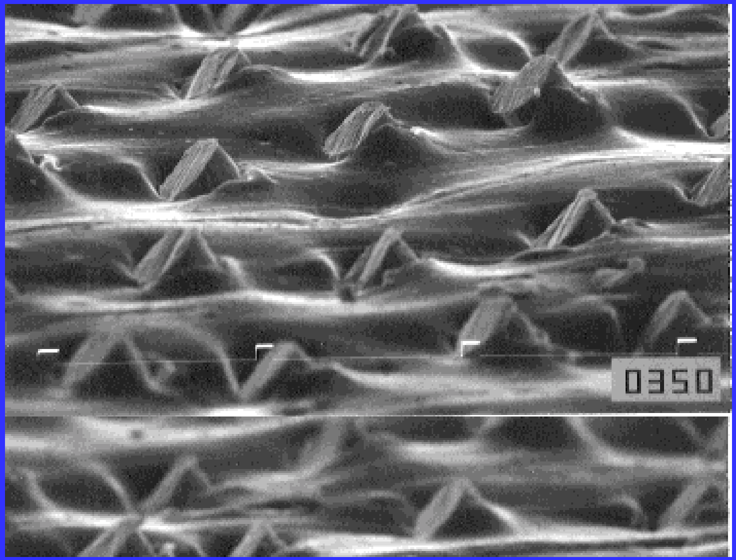
NEMI has developed a ranking system, based on strengths and weaknesses of the major alloy candidates. They have concluded that the SnAgCu alloy family is more viable than the SnAgBi family.

Experimental Objectives

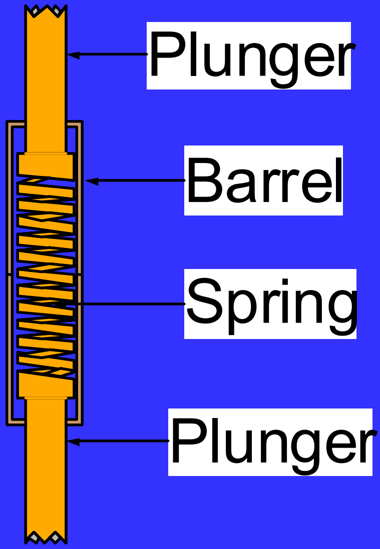
- Solder alloys
  - 63Sn 37Pb
  - 95.5Sn, 3.8Ag, 0.7Cu

- Compression style contactors
  - Elastomer
  - Spring pin

Compression style contactors

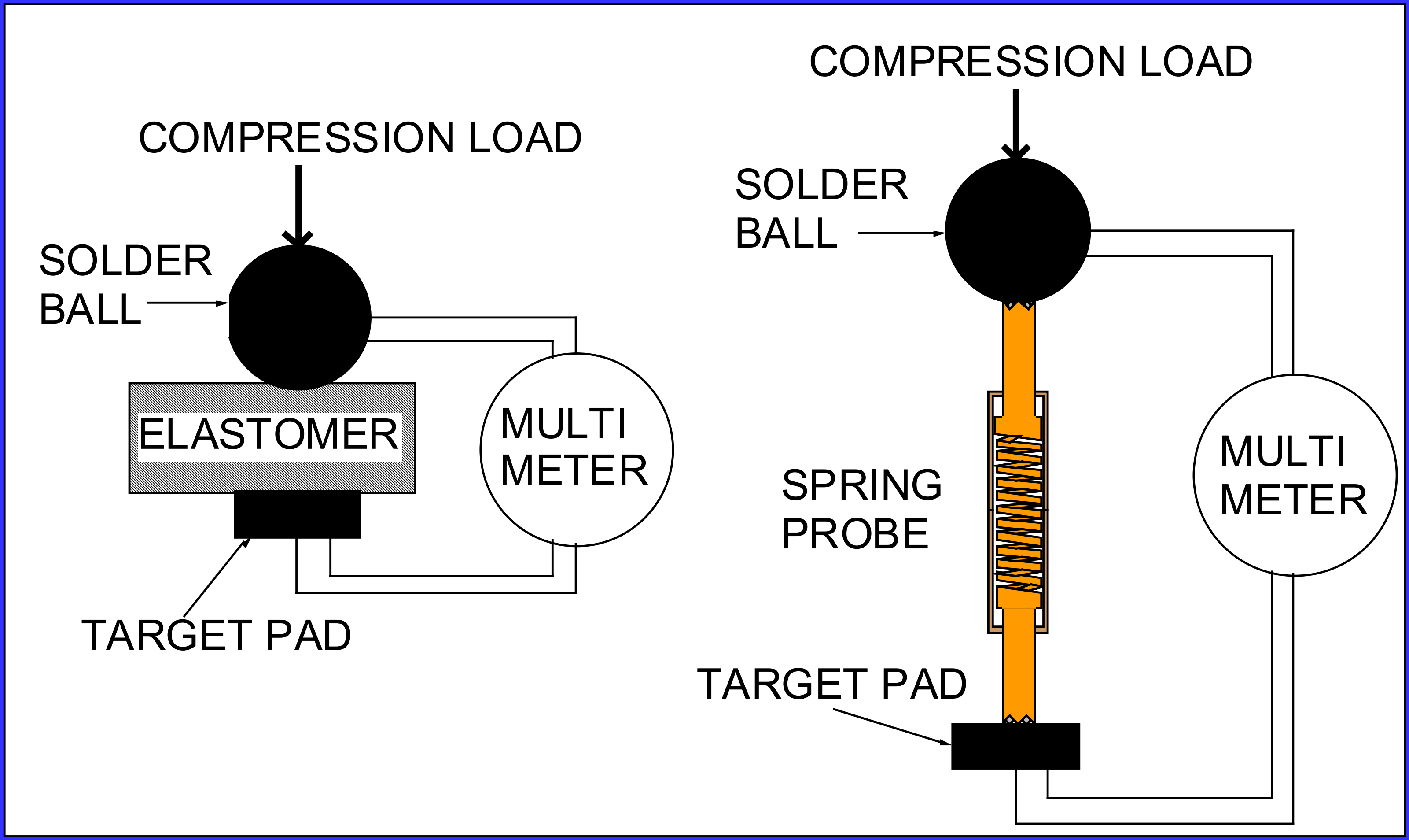


SEM picture of
Elastomer

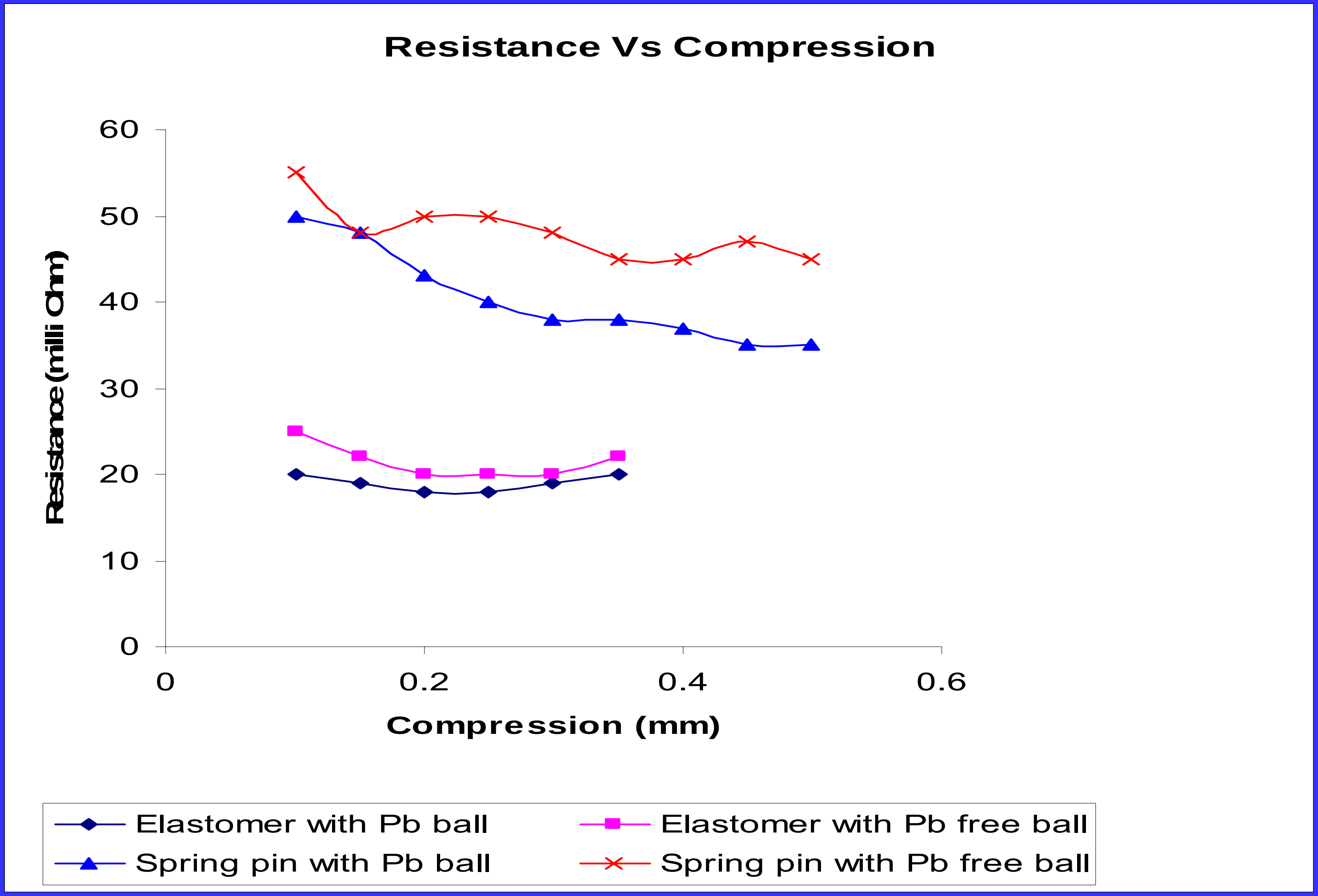


Spring Probe
Cross Section

Contact Resistance Experiment



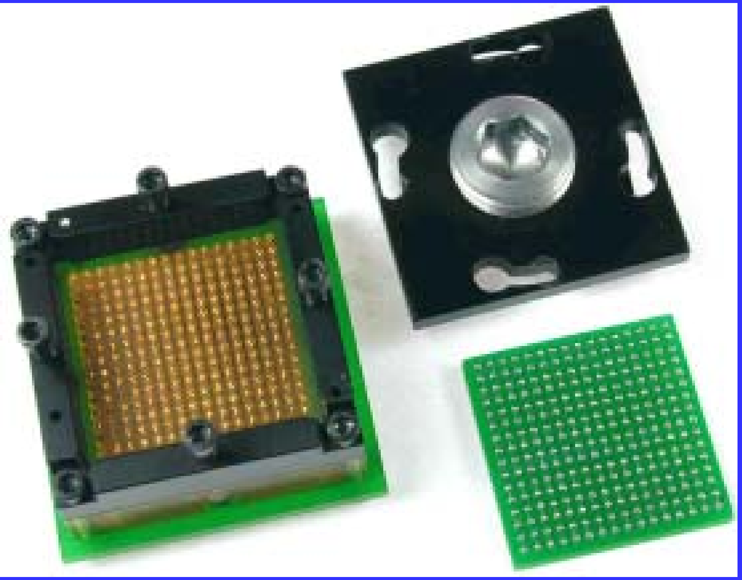
Contact Resistance Data



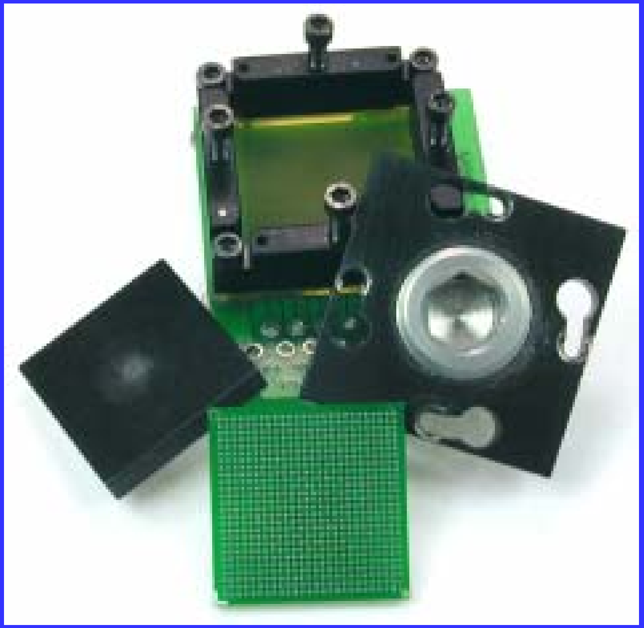
Contact Resistance Experiment at 85C

- Elastomer socket and spring probe socket were mounted on a daisy chained test board.
- Daisy chained test chips (with Pb and with Pb free) were placed inside the socket.
- Testing the two end pins, the complete array can be verified and contact resistance per pin can be calculated.
- The two end pins were routed to four pads for Kelvin measurements using 4-wire setting.
- The socket was placed inside an oven at 85C.
- Total contact resistance was measured at regular time intervals.

Test components

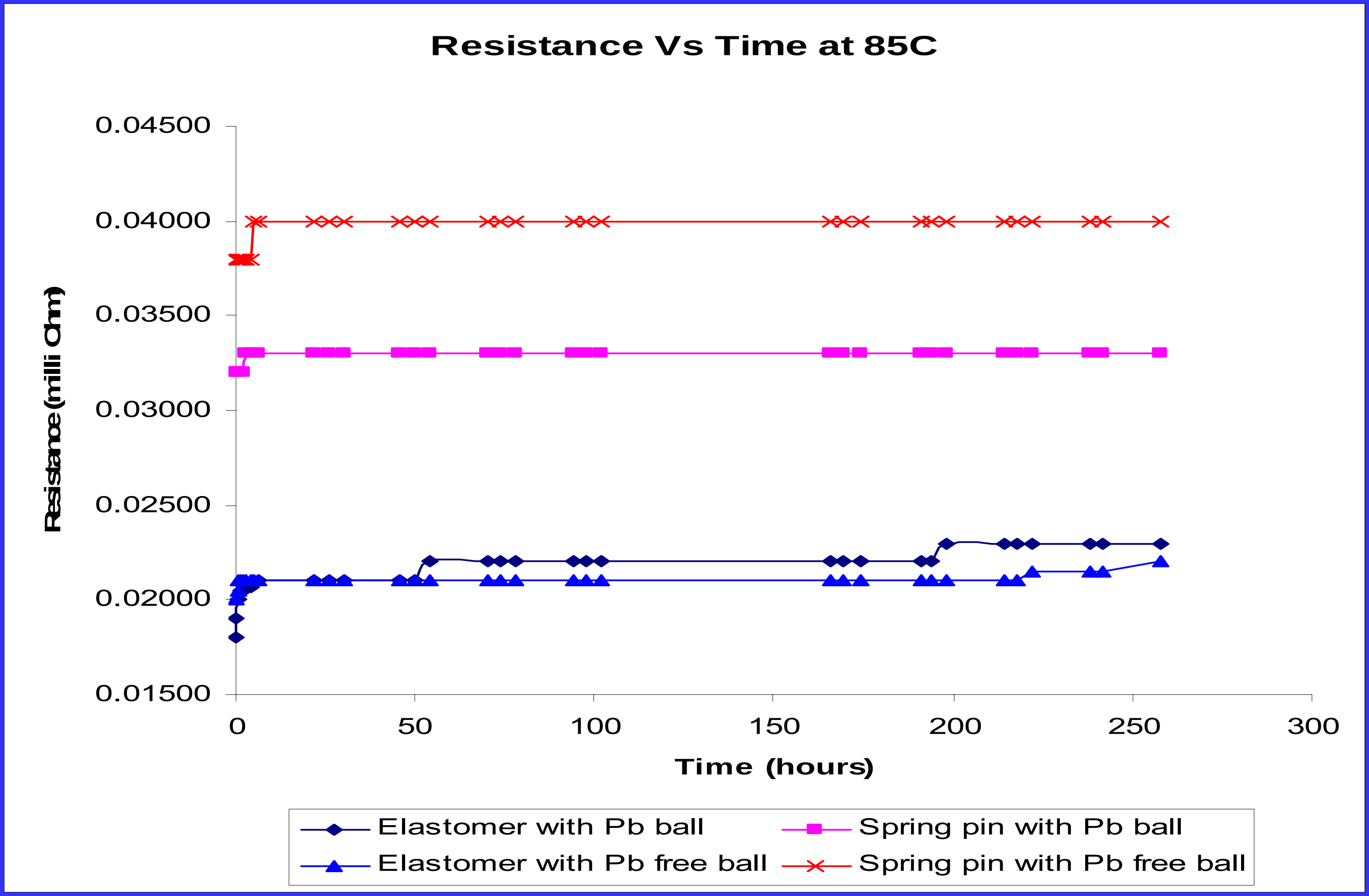


Daisy chain testing of spring pin socket



Daisy chain testing of elastomer socket

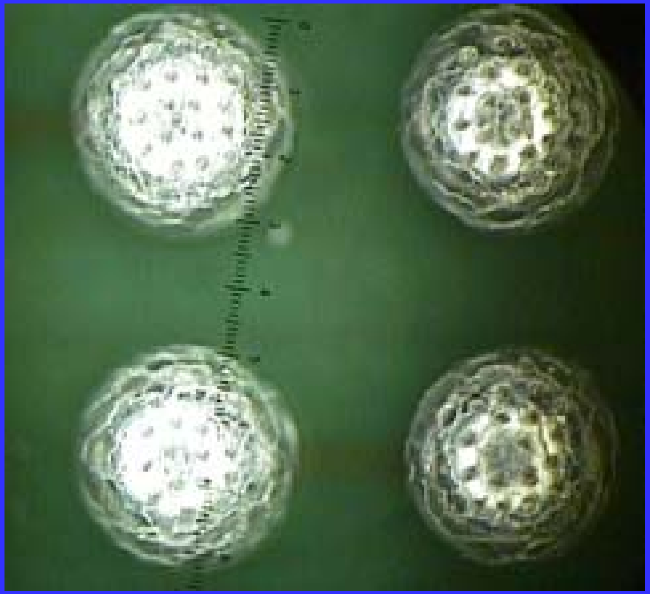
Contact Resistance at 85C



Ball damage analysis

- micro BGA (0.5mm pitch, 0.3mm diameter solder ball) test chip
  - with Pb
  - with Pb free
- micro BGA was compressed to 0.1mm in the elastomer socket and 0.3mm in the spring probe socket.
- same device was placed in and out for 20 cycles.
- device was examined under microscope to determine the ball damage after 20 cycles.

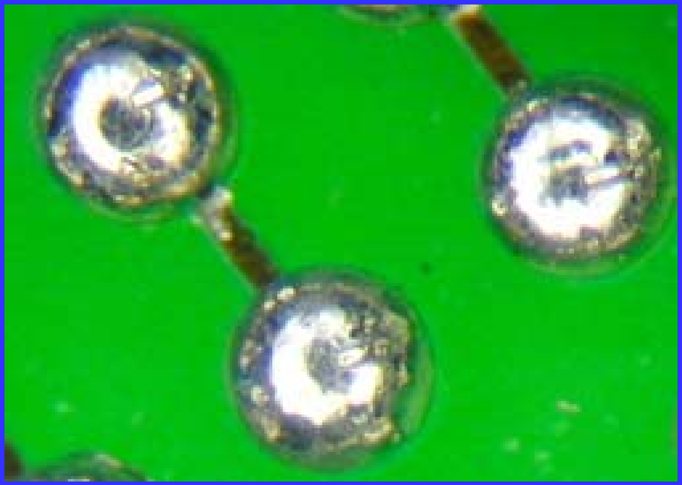
Ball damage analysis



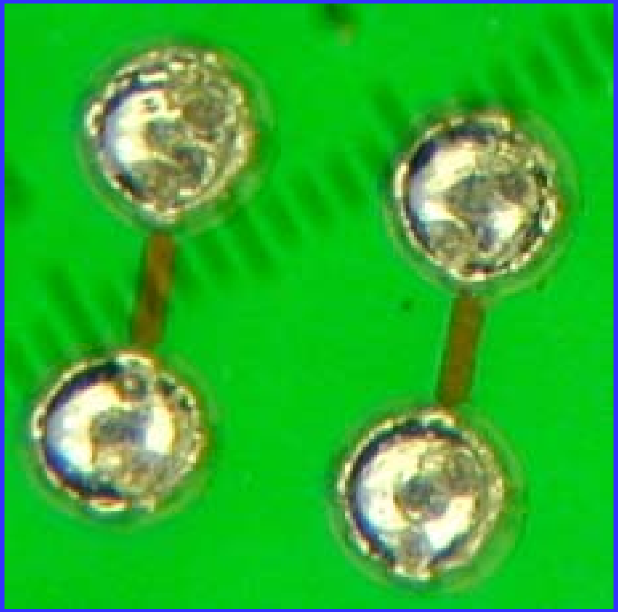
Elastomer marks – with Pb free

Elastomer marks – with Pb

Ball damage analysis



Spring pin marks
– with Pb free

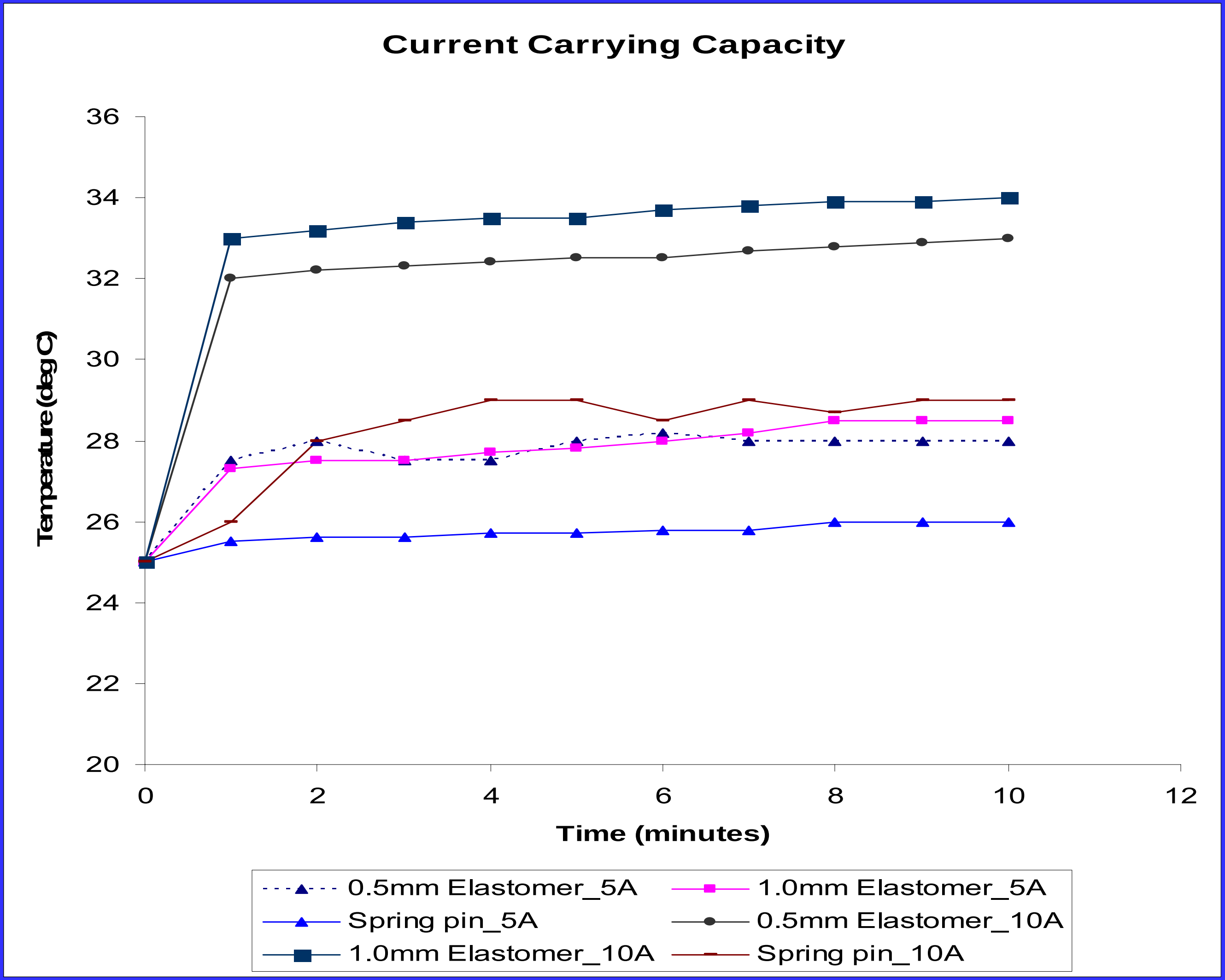


Spring pin marks
– with Pb

Current carrying capacity

- 1.0mm diameter gold plated pin is compressed 0.25mm down on the elastomer and 0.3mm down on the spring probe.
- The bottom side of the contactor is compressed on a gold plated copper pad.
- Thermo couple was connected to the contactor to measure the change in temperature.
- Power supply was connected in parallel to the gold plated pin and copper pad.
- 5A and 10A current was supplied continuously for 10 minutes and the changes in temperature were recorded.

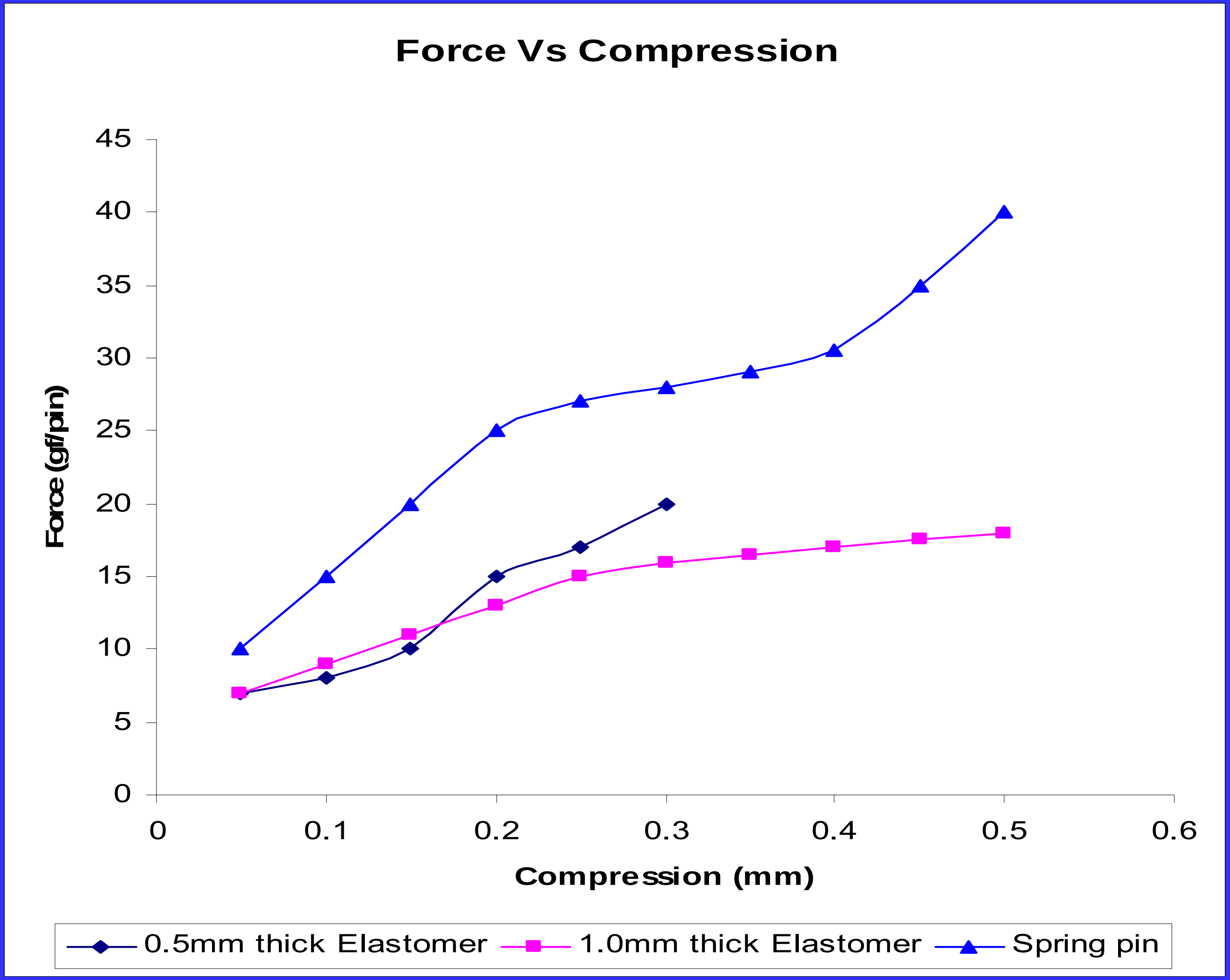
Current carrying capacity



Force characterization

- Test system was developed with a force sensor circuit.
- A load cell with flat surface was placed on top of the contactor.
- Force sensor transmits any force variations in terms of voltage drop to a volt meter.
- Measured voltage variations were converted to the corresponding force.

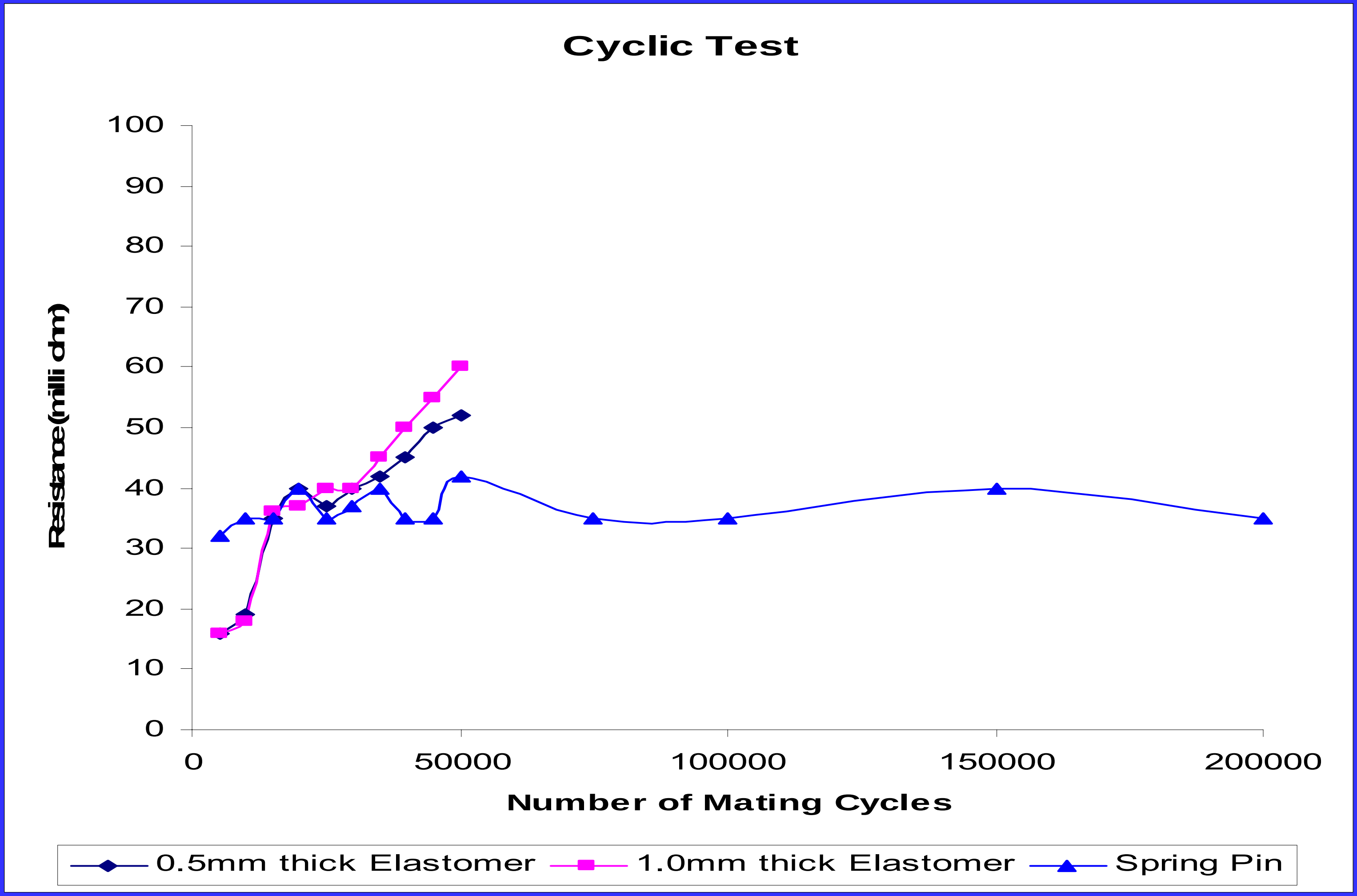
Force data chart



Endurance characterization

- Contactor was mounted on a circuit board with gold plated copper pad.
- Gold plated steel ball was used for compressing into the contactor.
- Compression pressure of 275g/mm^2 was applied with 1 second ON and 1second OFF compression cycle.
- Change in resistance was read using HP4338A multi-meter which was connected to the gold plated ball and the copper pad.

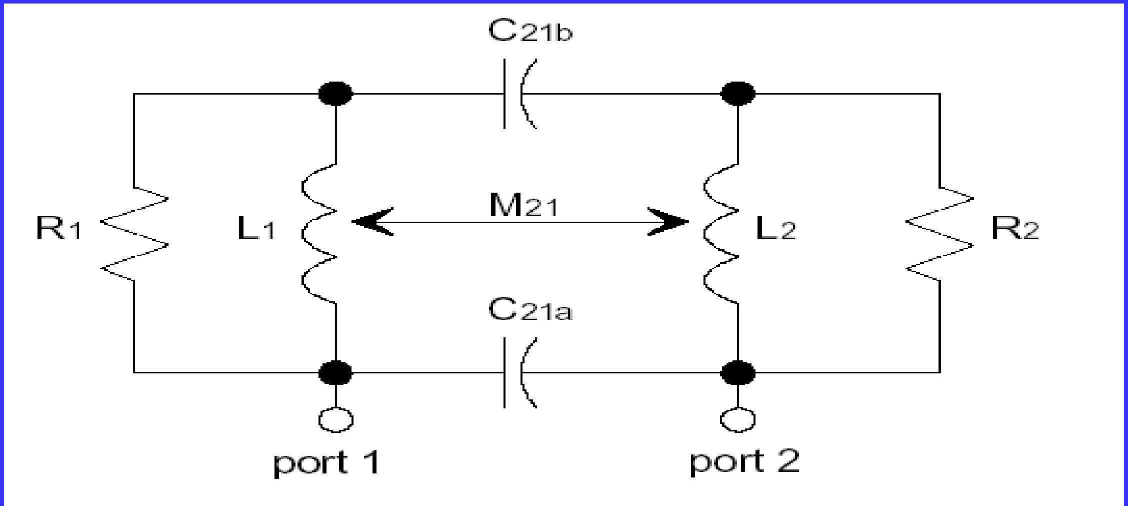
Endurance data chart



High speed characterization

- Contactor was mounted onto a custom board, designed to exhibit low parasitic and allows the use of coplanar probes (for probing adjacent pins).
- Test chip with measurement standard pattern was mounted on top of the contactor.
- Setup allows pins to be measured under three conditions (open, shorted and thru).
- Hewlett-Packard MDS (Microwave Design System) software was used to extract an equivalent-circuit model, which is SPICE compatible.
- Hewlett-Packard 8510C network analyzer & GGB Pico-probe™ 450 mm pitch were used.

Equivalent circuit model



L1, L2: Pin self inductance

M_{21}: Mutual inductance between adjacent pins

R_1, R_2: Shunt resistance of inductors L1 and L2, used to model high frequency loss due to skin effect and dielectric loss

C_{21a}: Mutual capacitance between adjacent pins on PCB side

C_{21b}: Mutual capacitance between adjacent pins on IC side

Results

Pins	Field Adjacent	Edge Adjacent	Diagonal Adjacent	Corner Adjacent
L1, L2 (nH)	0.15	0.23	0.15	0.26
M21 (nH)	0.025	0.04	0.002	0.05
R1, R2 (Ω)	700	700	700	700
C21a (pF)	0.01	0.02	0.003	0.03
C21b (pF)	0.015	0.03	0.004	0.03

0.5mm Elastomer

Results

Pins	Field Adjacent	Edge Adjacent	Diagonal Adjacent	Corner Adjacent
L1, L2 (nH)	0.37	0.39	0.37	0.46
M21 (nH)	0.035	0.09	0.002	0.05
R1, R2 (Ω)	700	700	700	700
C21a (pF)	0.014	0.04	0.005	0.05
C21b (pF)	0.015	0.04	0.007	0.05

1mm Elastomer

Results

Pins	Field Adjacent	Edge Adjacent	Diagonal Adjacent	Corner Adjacent
L1, L2 (nH)	2.2	2.3	2.2	2.4
M21 (nH)	0.3	0.4	0.09	0.3
R1, R2 (Ω)	700	700	700	700
C21a (pF)	0.03	0.04	0.005	0.05
C21b (pF)	0.06	0.09	0.01	0.05

Spring probe

Conclusions

- Pb and Pb free balls exhibit similar contact resistance.
- Elastomer provides better contact resistance than the spring probe.
- Spring probe exhibits better thermal performance than the elastomer.
- Pb balls have more witness marks than Pb free balls.

Conclusions

- Spring probe sustains better current rating than elastomer.
- Spring probe withstands 200K mating cycles as opposed to elastomer (10K).
- Elastomer demonstrates far superior results than spring pin for high speed testing.

Conclusions

- Universal socket footprint – Standardization
- Replacement modules
  - Conductive elastomer
  - Spring probe
  - Compliant metal contact
  - Other compression contact technologies

Pb-FREE LEADFRAME DEVICES AND THEIR IMPACT ON POGO PIN SOCKET PERFORMANCE

Valts Treibergs, ECT-Semiconductor Test Group - MN

Presentation Topics

- Why Pb-Free Packaging?
- Challenges for Test
  - » Package Lead Hardness
- Proposed Pogo Pin Solution
- Validation Testing
  - » Test Sequence
  - » Test Apparatus
- Results
  - » Resistance vs. Pogo Cycle
  - » Solderability
- Next Steps

Why the Shift to Pb-Free Packaging?

- Many IC customers are requiring ‘green’ microelectronic packaging
  - The push is being seen particularly by Japanese and European customers
- Worldwide directives / legislation to protect the environment:
  - NEMI - North America
  - WEEE, RoHS - Europe
  - MITI - Japan
  - Others pending

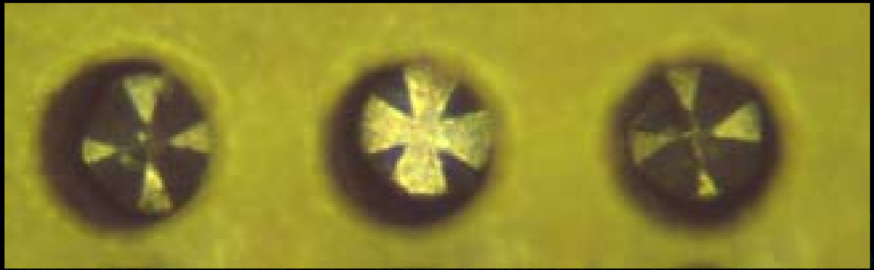
Most Common Pb-Free Options for Leadframe IC's

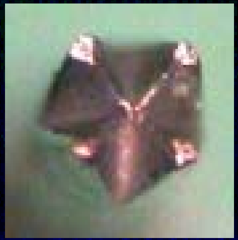
Post-plate Matte Tin or Pre-plate NiPdAu or NiPd

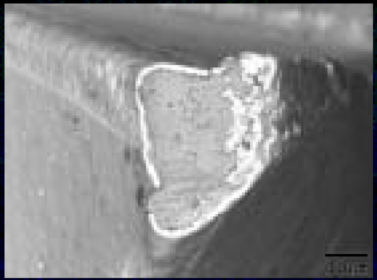
- Finish options are dependent on IC type and/or application
- Also dependent on assembly facility process
- Many IC manufacturers are shipping these now - many others in conversion
- Extensive reliability studies have been done - solderability, whisker growth, reflow, etc.

NiPd - Challenges for Test

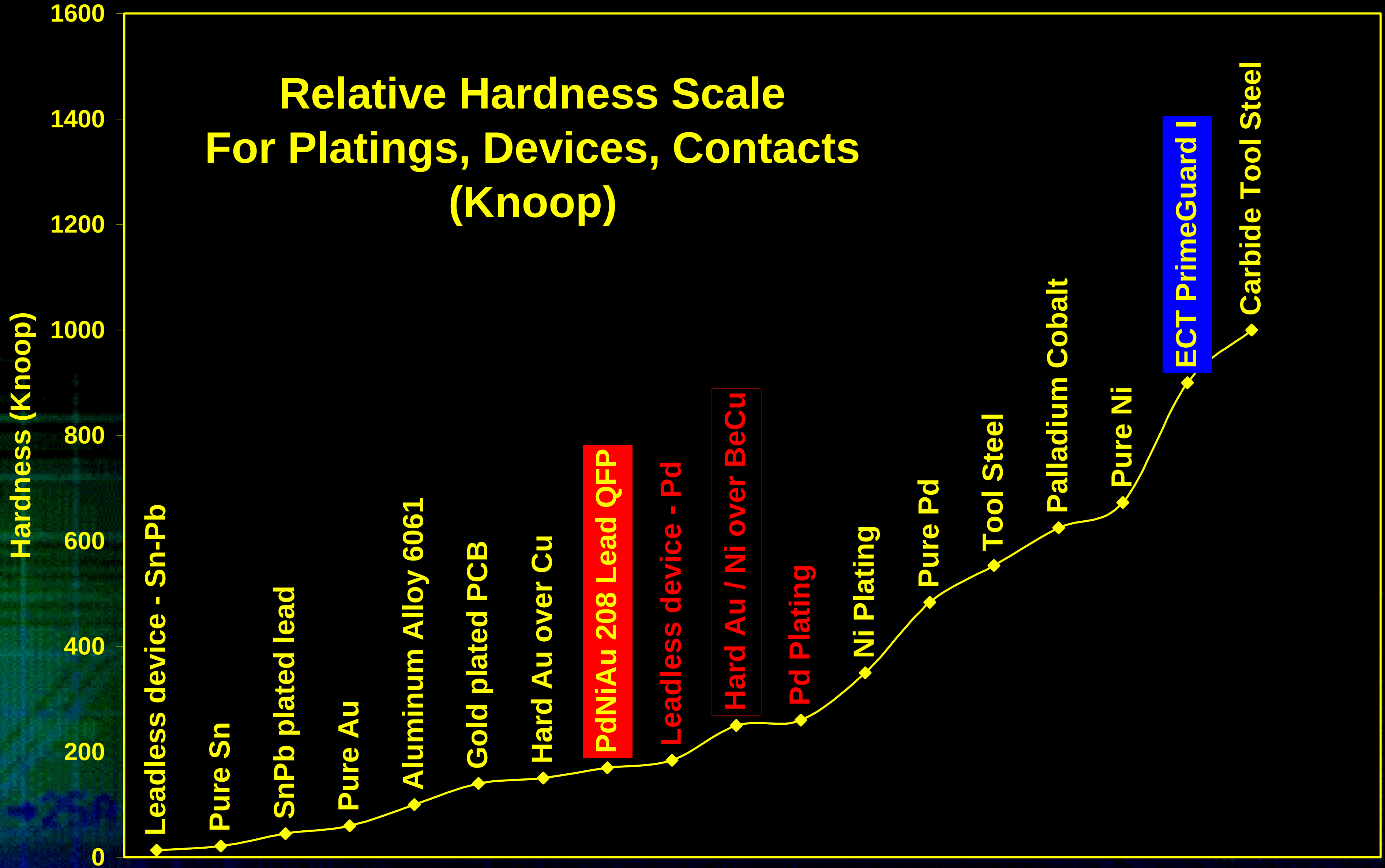
- Preplated NiPd and NiPdAu have been proven to be very abrasive to contact technologies
- Very early wear-out has been observed using hard gold over nickel - pogo and cantilever technologies
- Plating wear exposes base material (BeCu or steel) and accelerates corrosion and increases contact resistance. YIELD drops after <10K insertions







Package Lead Hardness Comparison



Proposed Pogo Pin Solution

- A contact metallurgy is needed that is significantly harder than the NiPdAu leadframe
  - » Hard gold / Nickel over BeCu
    - Not hard enough - too close to NiPdAu
  - » Palladium Cobalt a possible option
    - Not tested in production for leadframe contacting
  - » ***ECT PrimeGuard-I***
    - A proven HVM solution for pre-plated NiPd leadframe contacting for 3+ years

Validation Testing

- Pb-Free device samples were limited - available parts were not bussed or daisy chained. Gold nest designed and built to allow LLCR contact measurements
- Most important factors to investigate contactor solutions:
  - » LLCR stability at room temperature to 100K cycles min
  - » Pogo pin wear - no wear to 100K cycles min
  - » No post-contacting solderability issues on DUT leads
- Concentrate on Pogo pin tip to DUT lead contact interface
  - » Test does not include variation of internal Pogo resistance (well proven and documented in other studies)

Test Sequence

- All testing at room temp.(20°C)
- Used single Pogo Pin plunger used for each sequence
- 40 unprocessed Pb-Free 208 lead QFP devices used per sequence
- Robot probed each lead 5 or 15 times (simulating standard process flow) per lead - recording force and LLCR when mounted in a gold plated nest
- 30g and 50g probe normal forces investigated
- Samples marked and returned to customer for solderability 'Dip & Look' test

Test Sequence

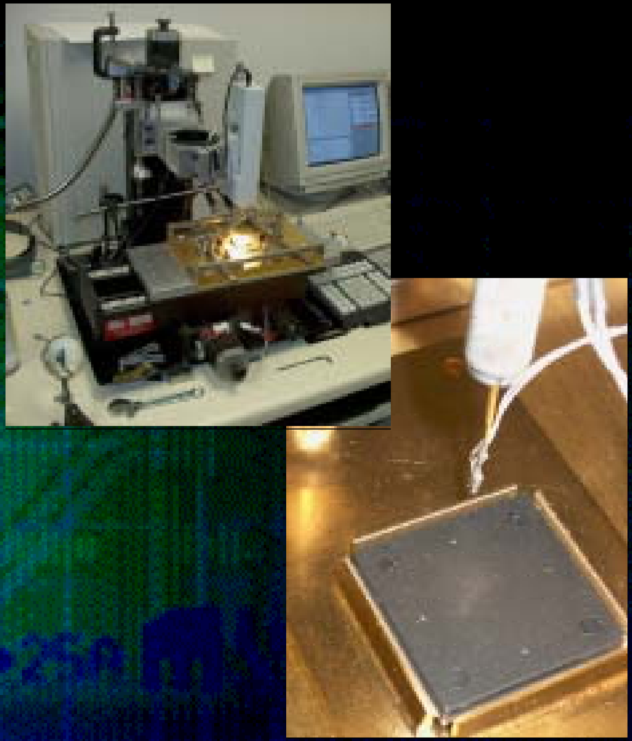
SEQUENCE	1	2	3	4
APPLIED FORCE	30g	50g	30g	50g
TOUCHDOWNS PER LEAD	5 hits	5 hits	15 hits	15 hits
TOTAL # TOUCHDOWNS	41600	41600	124800	124800
Dip & Look	10 pcs	10 pcs	10 pcs	10 pcs

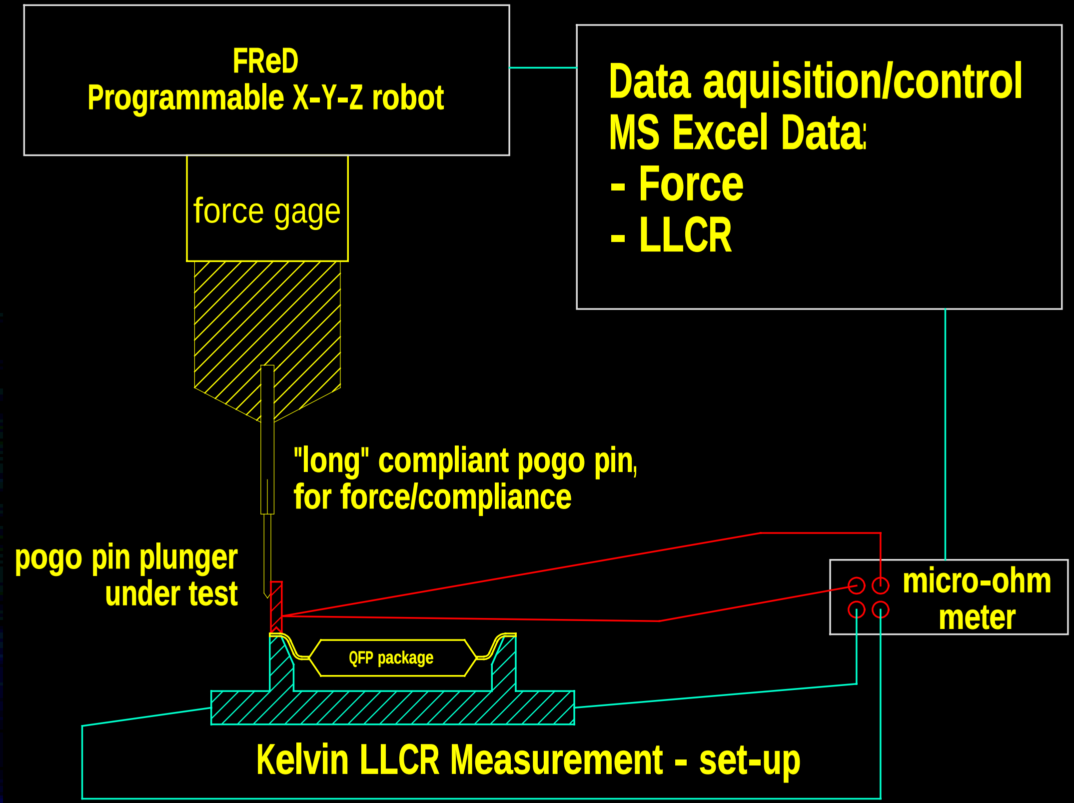
Dip & Look Parameters

SOLDER BATH	PRECONDITIONING STEP
SnPb	8 hours bake at 150° C
SnPb	8 hours steam age 85/85
SnAgCu	8 hours bake at 150° C
SnAgCu	8 hours steam age 85/85

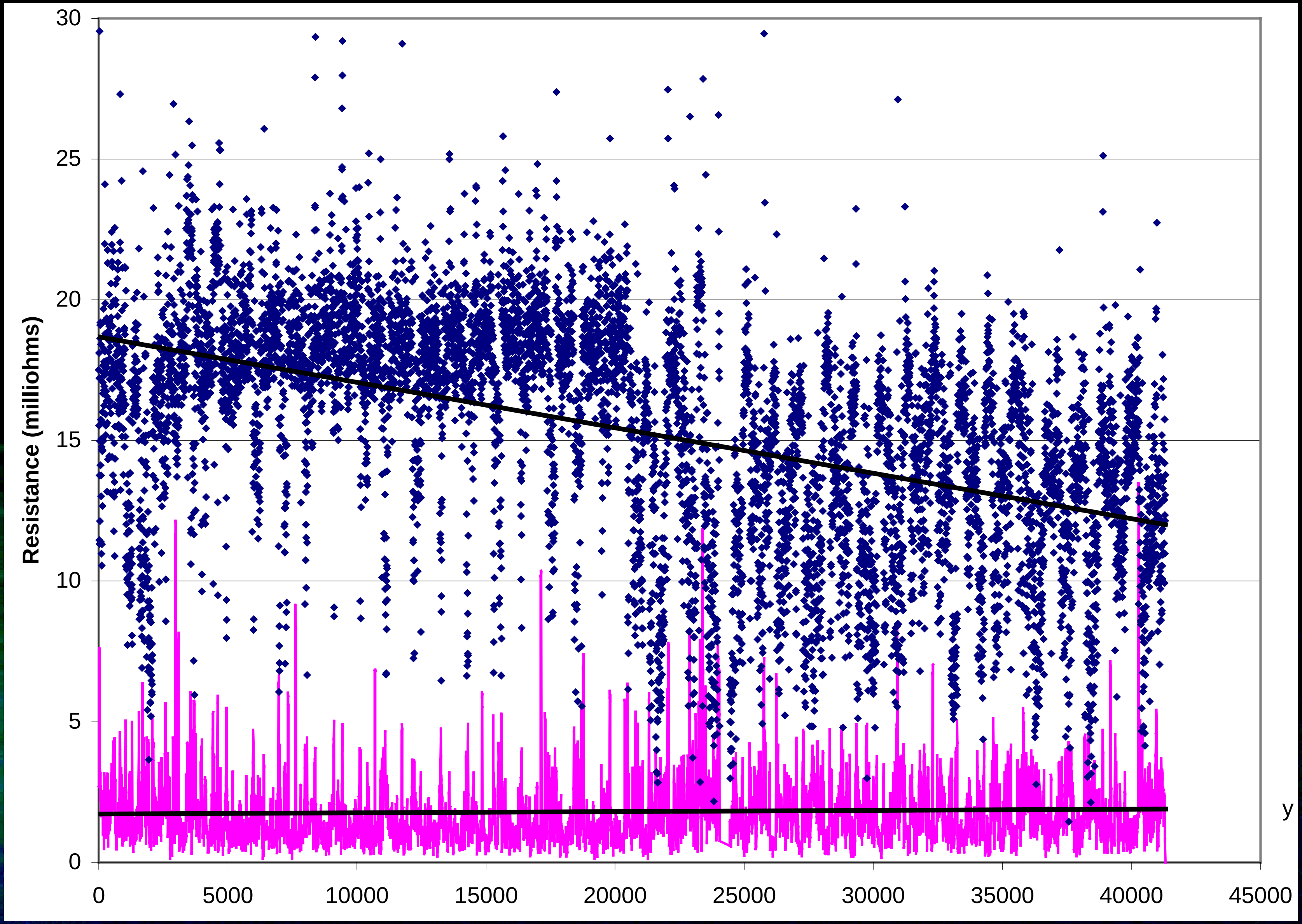
Test Apparatus

- ECT FReD robot used to probe single POGO interfaces on 208 QFP package
- Gold plated package nest used to hold DUT during test
- Set-up isolates pin-DUT interface



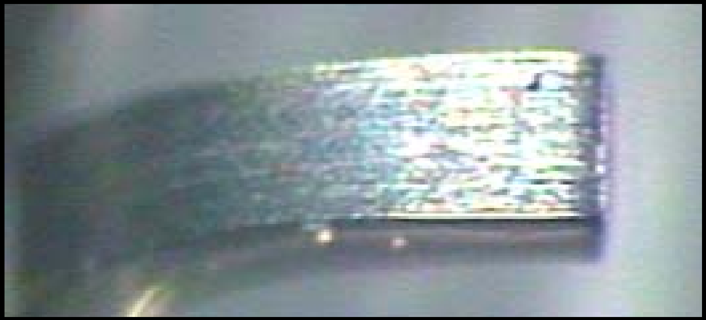


Results - Sequence 1 (5 Hits @ 30g)



Witness Marks / Solderability - Seq. 1

Unprobed DUT lead



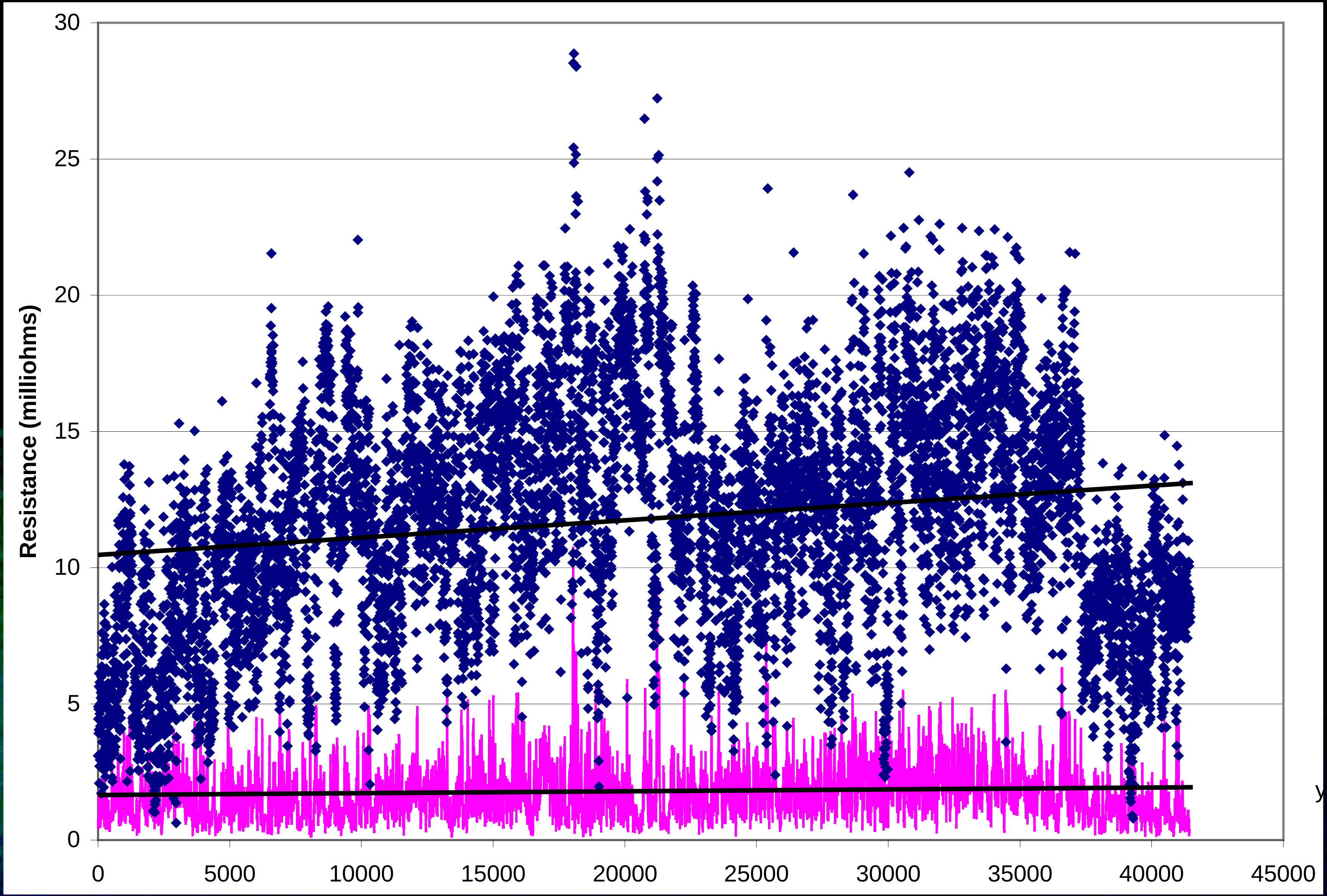
Dip & Look:

Dip & Look: NW with SnAgCu heat aged failure

Typical lead mark with 5x hits@30g

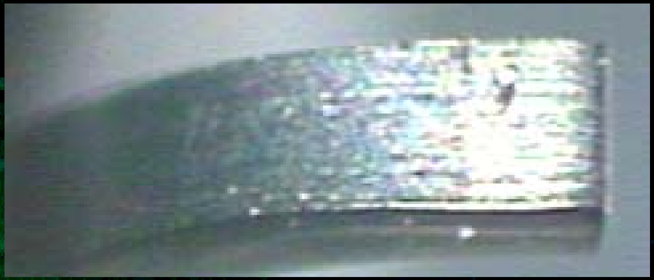
Pogo tip condition after seq. 1 - MINIMAL WEAR

Results - Sequence 2 (5 Hits @ 50g)



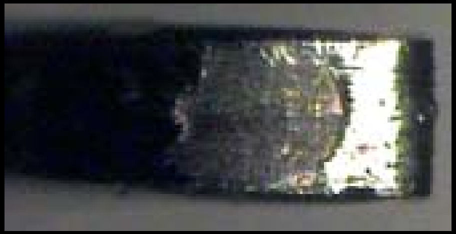
Witness Marks / Solderability - Seq. 2

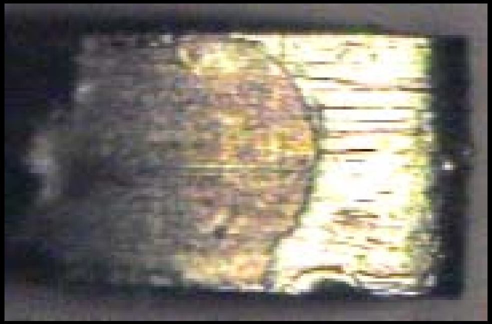
Unprobed DUT lead



Typical lead mark
with 5x hits@50g

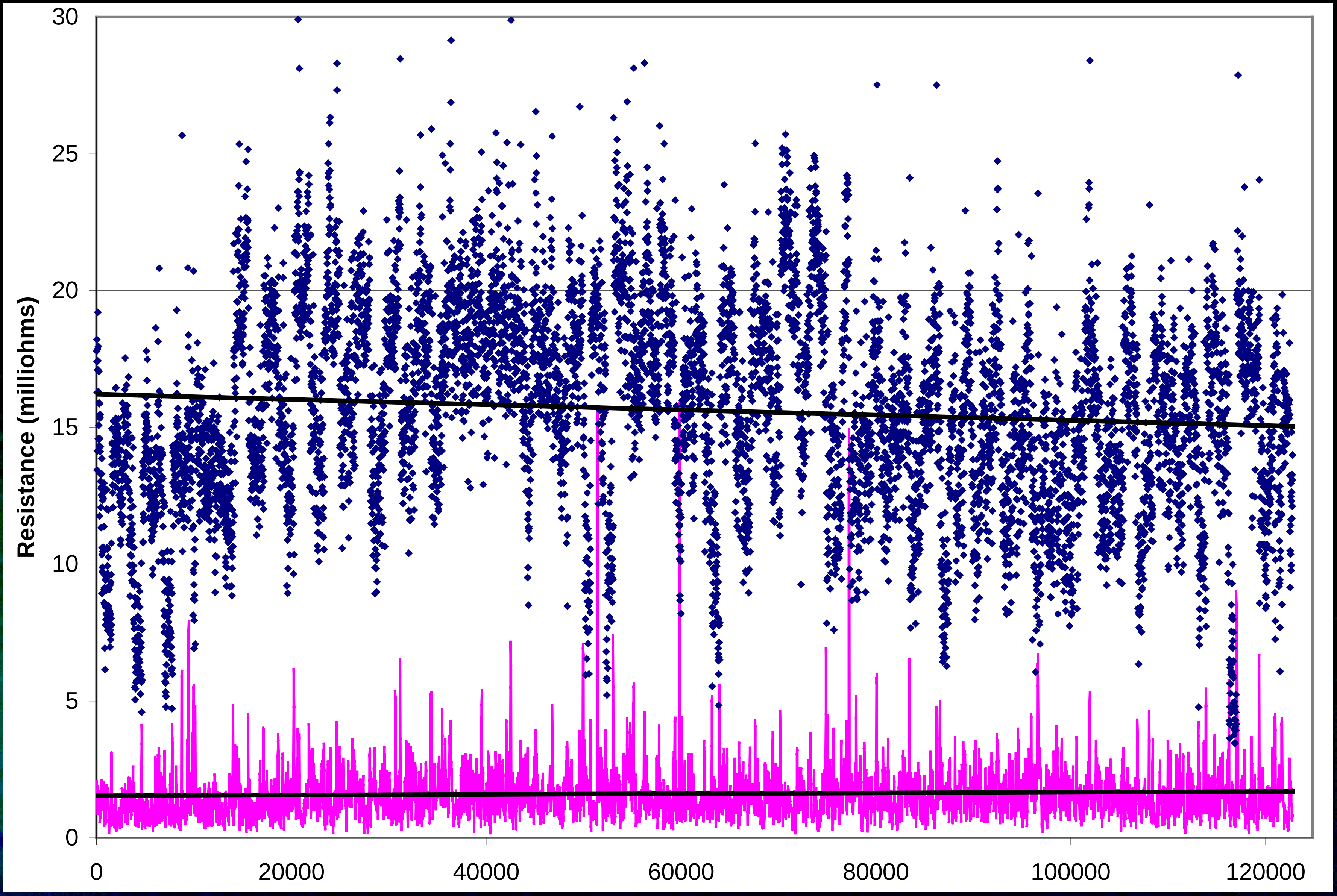
Dip & Look results - NW patterns not related to probe marks





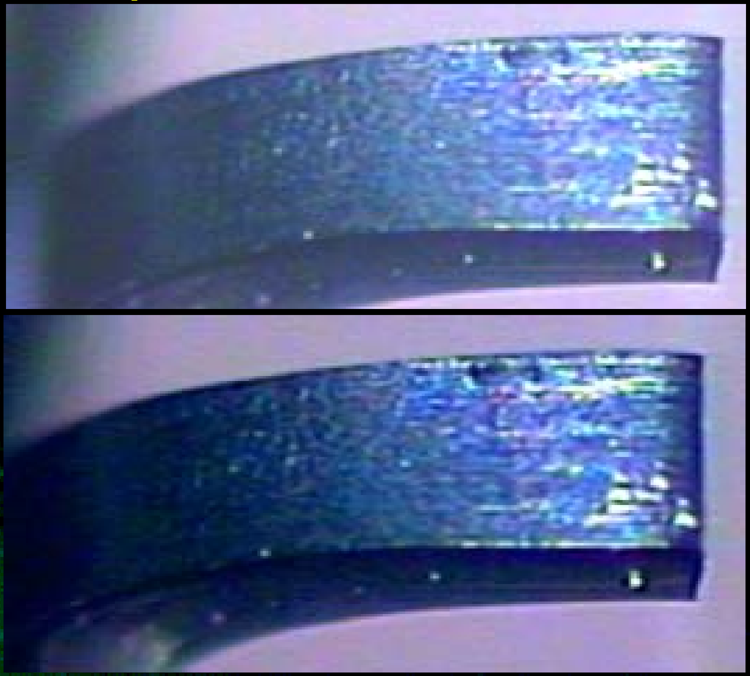
Pogo tip condition after seq. 2
- some tip flattening observed

Results - Sequence 3 (15 Hits @ 30g)



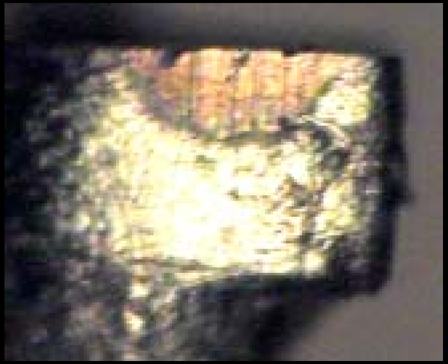
Witness Marks / Solderability - Seq. 3

Unprobed DUT lead



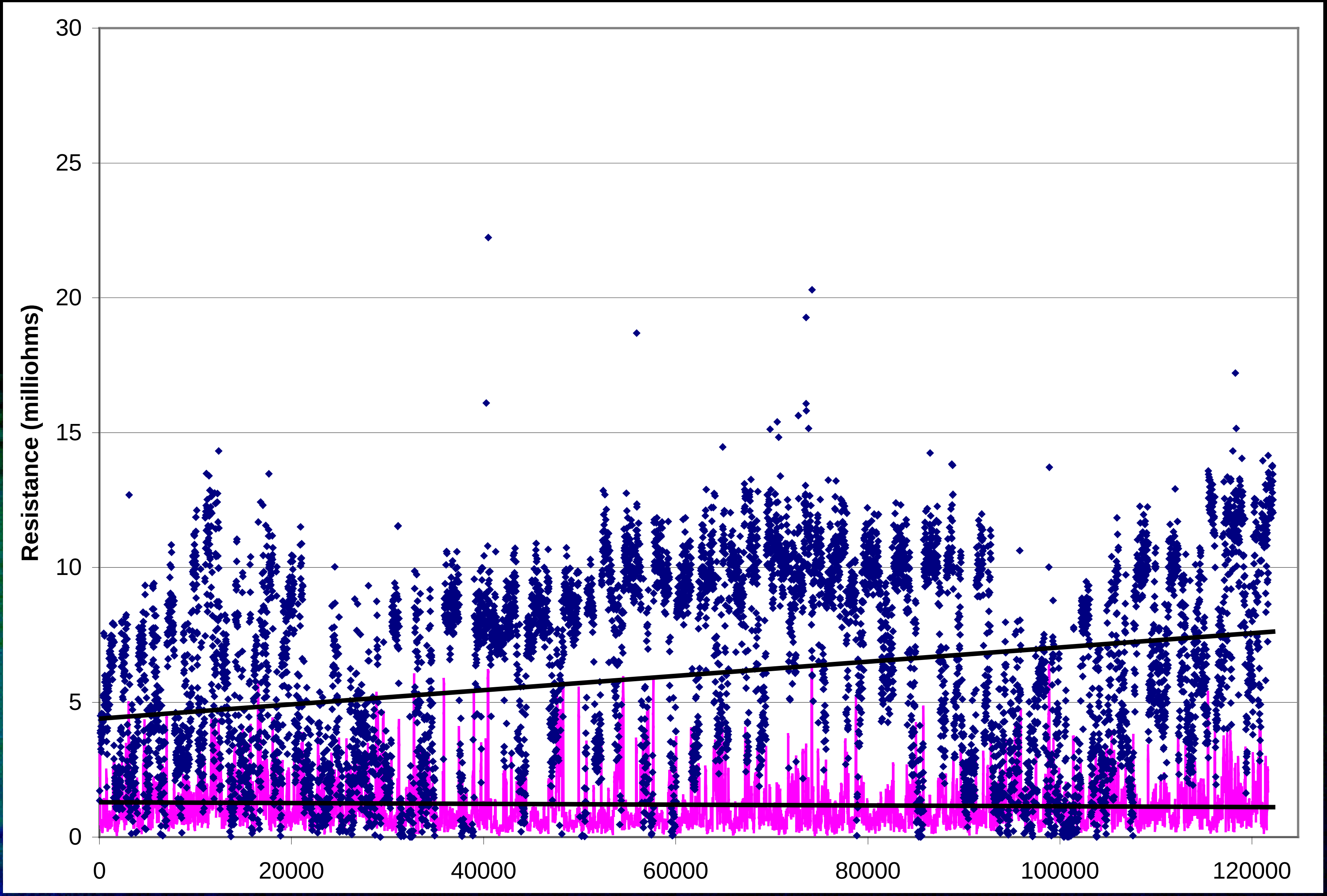
Typical lead mark with 15x hits@30g

Dip & Look: NW with SnPb heat aged failure - probe related ???



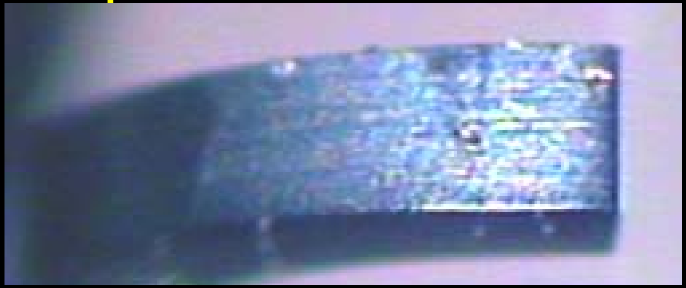
Pogo tip condition after seq. 3 - MINIMAL WEAR

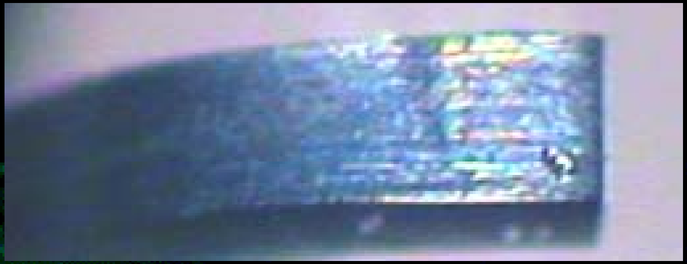
Results - Sequence 4 (15 Hits @ 50g)



Witness Marks / Solderability - Seq. 4

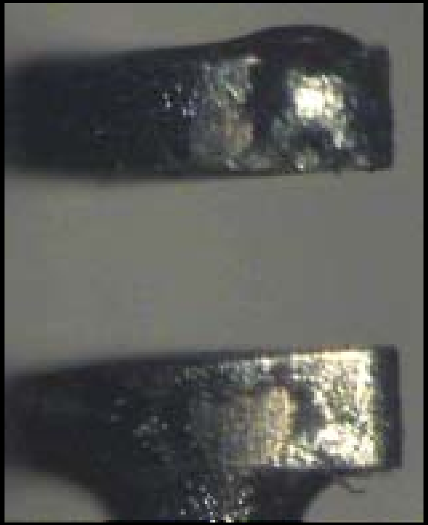
Unprobed DUT lead





Typical lead mark with 15x hits@50g

Dip & Look:

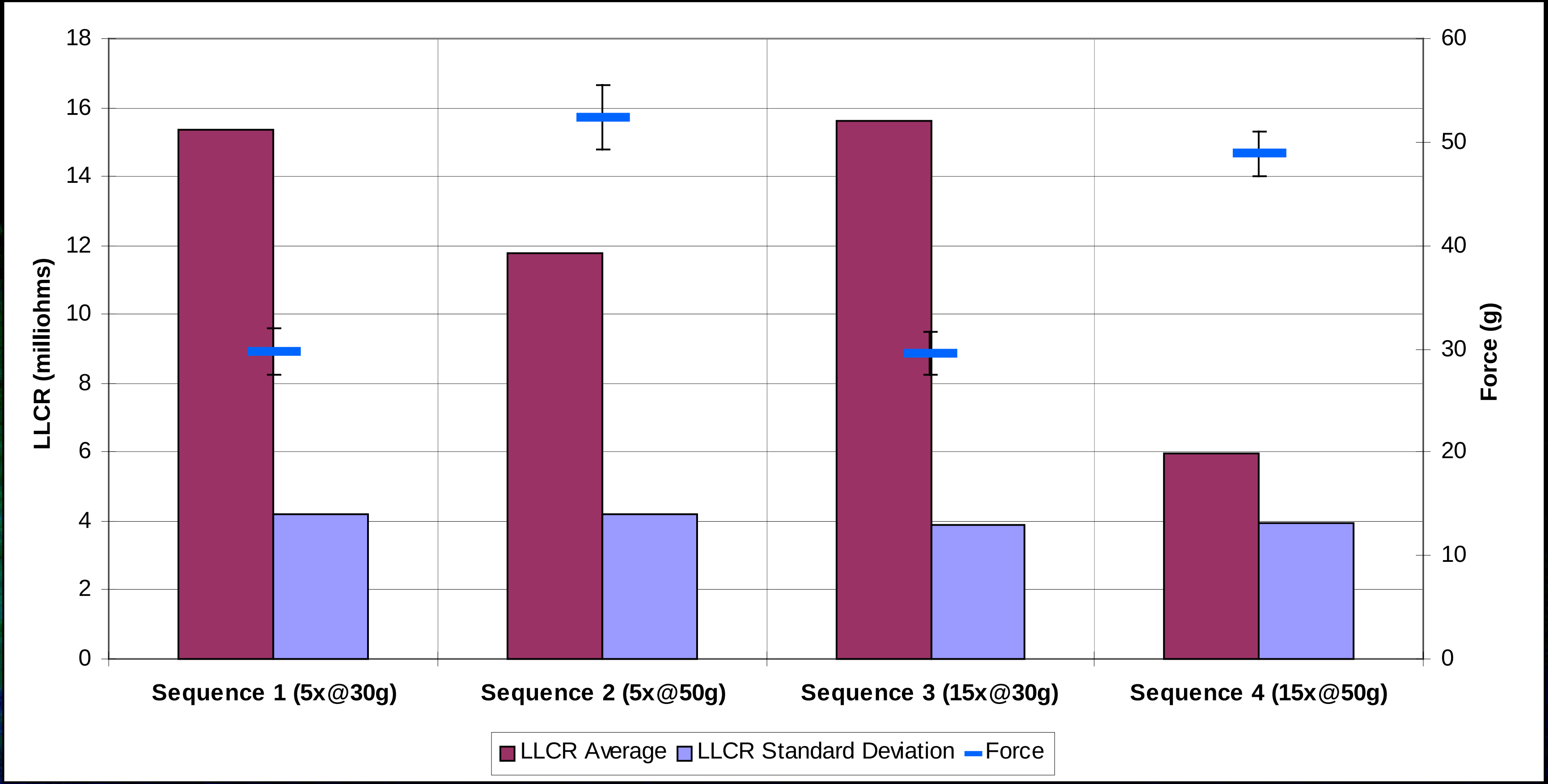


Dip & Look: NW with SnAgCu and SnPb heat aged failure

Pogo tip condition after seq. 4 - some tip flattening and debris build-up observed

Results Summary - Interface Resistance

- As expected - higher normal force resulted in a lower LLCR
- 15 touchdowns at 50g seemed to scrub the leads clean
- In any case - LLCR was within acceptable values - deviation all about the same



Results Summary - Solderability

SEQUENCE	1 (5x@ 30g)	2 (5x@ 50g)	3 (15x@ 30g)	4 (15x@ 50g)
SnPb	9 pcs NW < 5% 1 pcs – no defects ACCEPTED	9 pcs – NW < 5% 1 pcs NW > 5% INVESTIGATE	8 pcs – NW < 5% 2 pcs NW > 5% INVSTIGATE	9 pcs – NW < 5% 1 pcs NW > 5% INVESTIGATE
SbPb 85/85	10 pcs NW < 5% ACCEPTED	10 pcs NW < 5% ACCEPTED	10 pcs NW < 5% ACCEPTED	10 pcs NW < 5% ACCEPTED
SnAgCu	8 pcs – NW < 5% 2 pcs NW > 5% INVESTIGATE	10 pcs NW < 5% ACCEPTED	10 pcs NW < 5% ACCEPTED	8 pcs – NW < 5% 2 pcs NW > 5% INVESTIGATE
SnAgCu 85/85	2 pcs - no defects 8 pcs – NW <5% ACCEPTED	1 pcs - no defects 8 pcs – NW <5% 1 pc – NW > 5% INVESTIGATE	10 pcs NW < 5% ACCEPTED	10 pcs NW < 5% ACCEPTED

- Some non-wetting noted
- Percentage of non-wetting similar to baseline data for Pb-Free leads after heat and 85/85 conditioning
- Pb-Free generally more difficult to solder

Where Do We Go from Here?

- Other observations from the test:
  - » LLCR was dependent on QFP position on the nest - bulk resistance varied slightly in set-up depending on what lead was probed
  - » Slight LLCR variations were seen, depending on accuracy of probe on DUT foot - 1-2 crown points touching had lower LLCR than 3-4 crowns touching
- We need to understand behavior at temperature extremes: (125°C & -40°C) - fixture developed - test in process
- What about Sn plated leads? - test in process.
- BGA? Similar test have been done, however, not all Pb-Free BGA is the same…….

Acknowledgments

- Everett Charles Technologies
  - » Ken Snyder

    Contact Products Division

    Pomona CA
  - » Randy Thill

    Semiconductor Test Group - Contactors

    St. Paul MN

THANK YOU!

QUESTIONS?