BiTS

Burn-in & Test Socket Workshop

March 2 - 5, 2003
Hilton Phoenix East / Mesa Hotel
Mesa, Arizona

IEEE COMPUTER SOCIETY

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Burn-in & Test Socket Workshop

Technical Program

Session 6
Tuesday 3/04/03 4:00PM

Socketing Lead Free Packages

"Lead Free Area Array Module Test And Burnin"
Ethan Gallagher – IBM Microelectronics
Zenon Podpora – IBM Microelectronics

"Lead Free Contacting"
Bert Brost – Johnstech International Corporation

"The Effects Of No Lead Solder Balls On Burn-in Socket Design Decisions"
Mike Noel – Motorola Semiconductor Products
Don VanOverloop – Motorola Semiconductor Products
Daniel Wilcox – Motorola Semiconductor Products
K.Y. Yap – Motorola Semiconductor Products
Tom Lyzinski – Wells-CTI **Keith Callahan** – Wells-CTI

Lead Free Area Array Module Test and Burnin

2003 Burn-in and Test Socket Workshop

Ethan Gallagher / Zen Podpora

Contacting Systems Engineering

IBM Microelectronics

Objectives

- **Determine impact of lead free BGA and CGA on common test and Burnin sockets (preliminary findings)**
  - **Assess product interconnect lead damage**
  - **Evaluate contact resistance**

Agenda

- **Brief history on lead free packaging**
- **Test**
  - – Plastic BGA contact resistance
  - – Ceramic BGA & CGA contact resistance and ball damage
- **Burnin**
  - – Plastic BGA contact resistance and ball damage
- **Summary of the early learning evaluations**

Pb free – Background

- **Why Pb free microelectronics packages?**

  – Environmental concerns with Pb disposition
    – consumer electronics

  – Drivers
    - Legislative - RoHS - Restriction of Hazardous Substances
      – Implementation July 2006
      – Server exemption till Jan 2010
      – Somewhat ambiguous – many items undefined
    - Customer/Market – most urgent ??

Pb Free – Background

- **What materials to replace PbSn?**
  - **SAC - Tin (Sn) , Silver (Ag) , Copper (Cu)**
- **What is the challenge?**
  - **Product - Match connection reliability-**
    - **thermal expansion differences-**
  - **Test – Maintain / Improve Yield**
    - **Assess Performance w/POR Hardware**

Typical Test Setup

- Pneumatic controlled sockets

- Thermostream heating
- Thermocouple sense

Typical Test Setup

DC resistance measurements on Socket Analog Resistance Analyzer

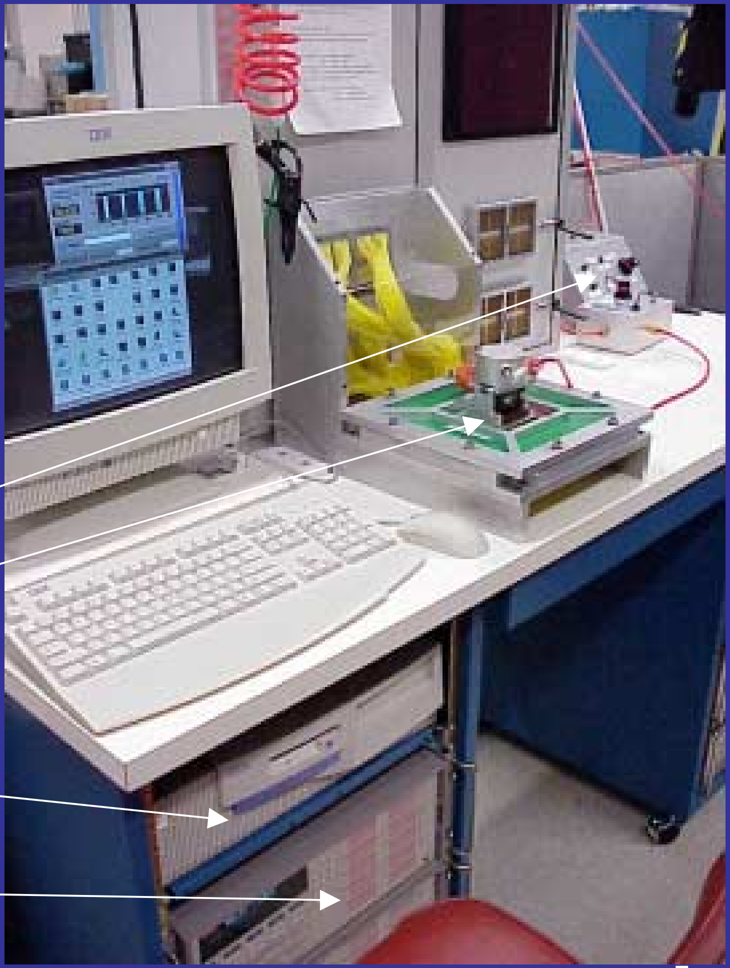
– "Pseudo" four point

Pneumatic controls

Socket & Board

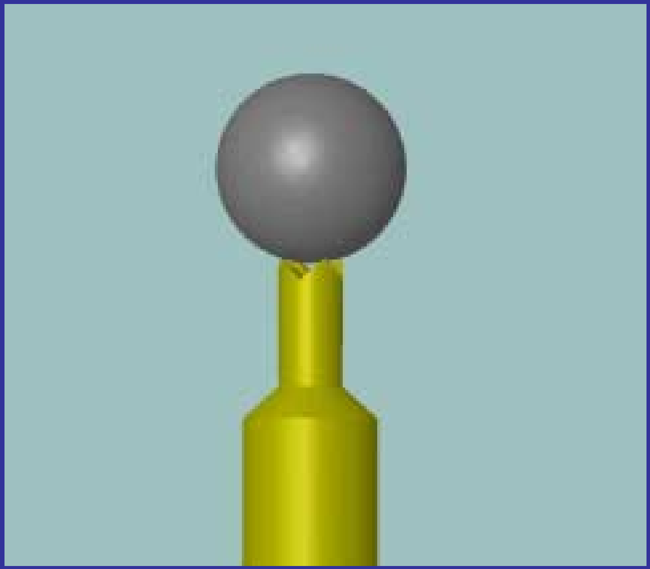
Data Collection Computer

Relays

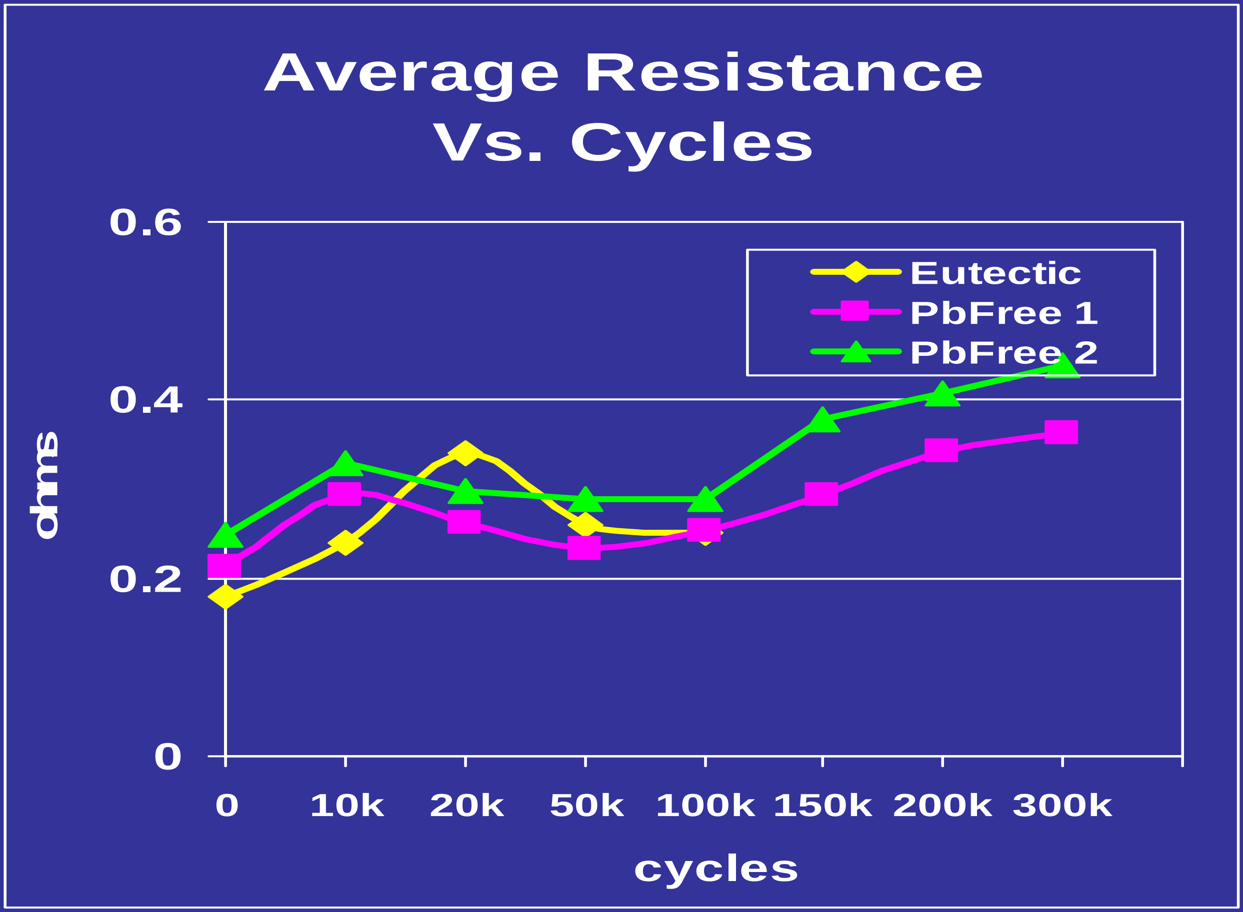


PBGA Test Socket Resistance at Cycling

- **Test Parameters**
  - Surface mount pogo socket
  - Device temp at test: 120C
  - Normalized with golden module at room temp
  - Eutectic BGA device → daisy chain, 35mm, 1mm pitch, 580 I/Os
  - Pb free BGA device → daisy chain, 42.5mm, 1.27mm pitch, 1089 I/Os

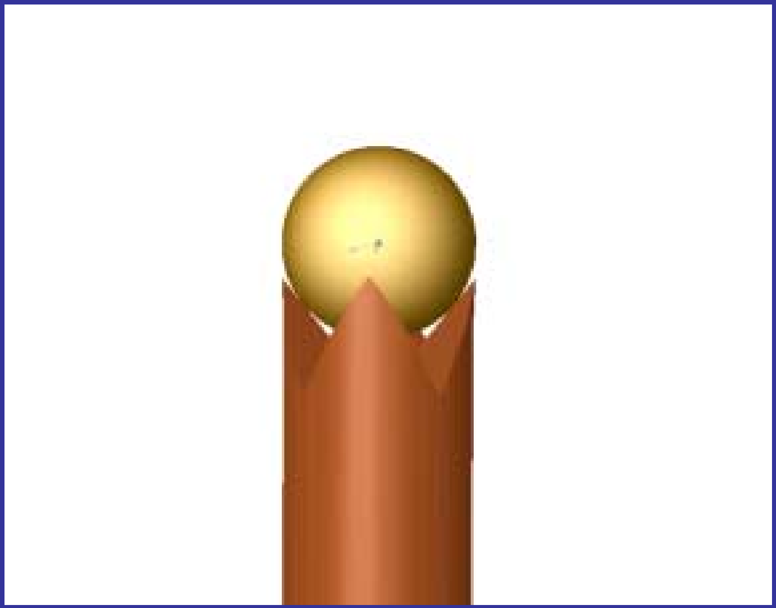


PBGA Test Socket Resistance

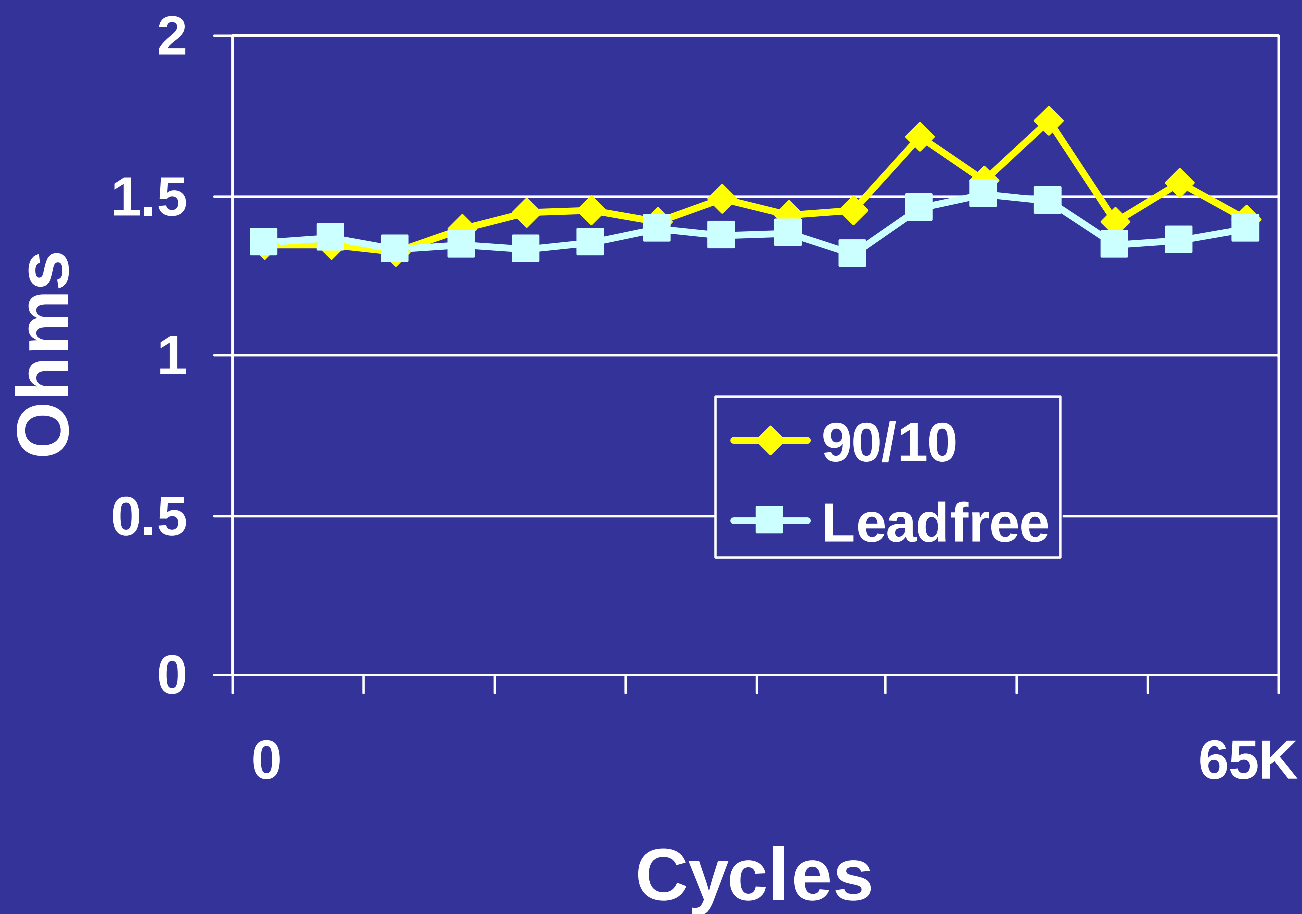


CBGA Test Socket Resistance

- Daisy-chain substrates
- Temp = ambient
- Surface mount crown contact on 90/10 balls
- Surface mount crown contact on lead-free SAC balls



CBGA Contact Resistance

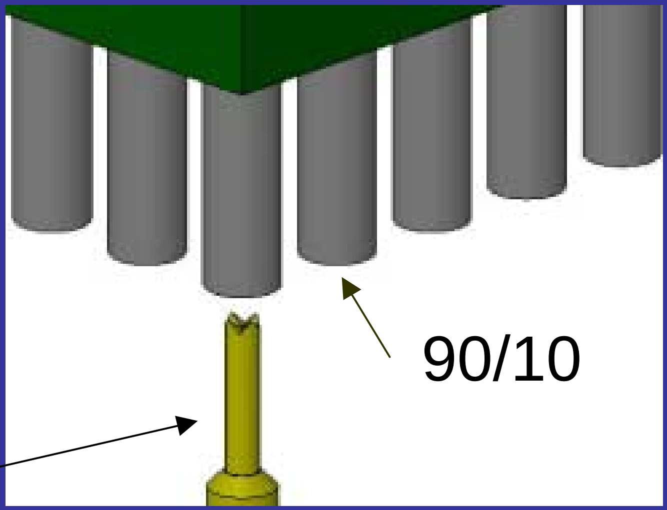


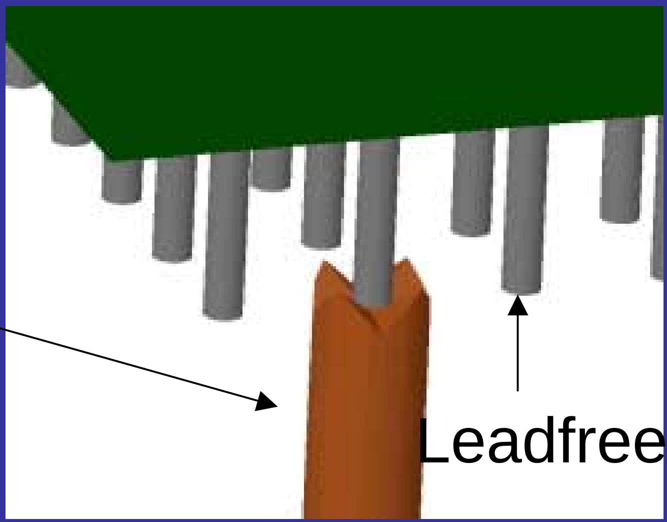
CBGA Test Damage

90/10 Leadfree

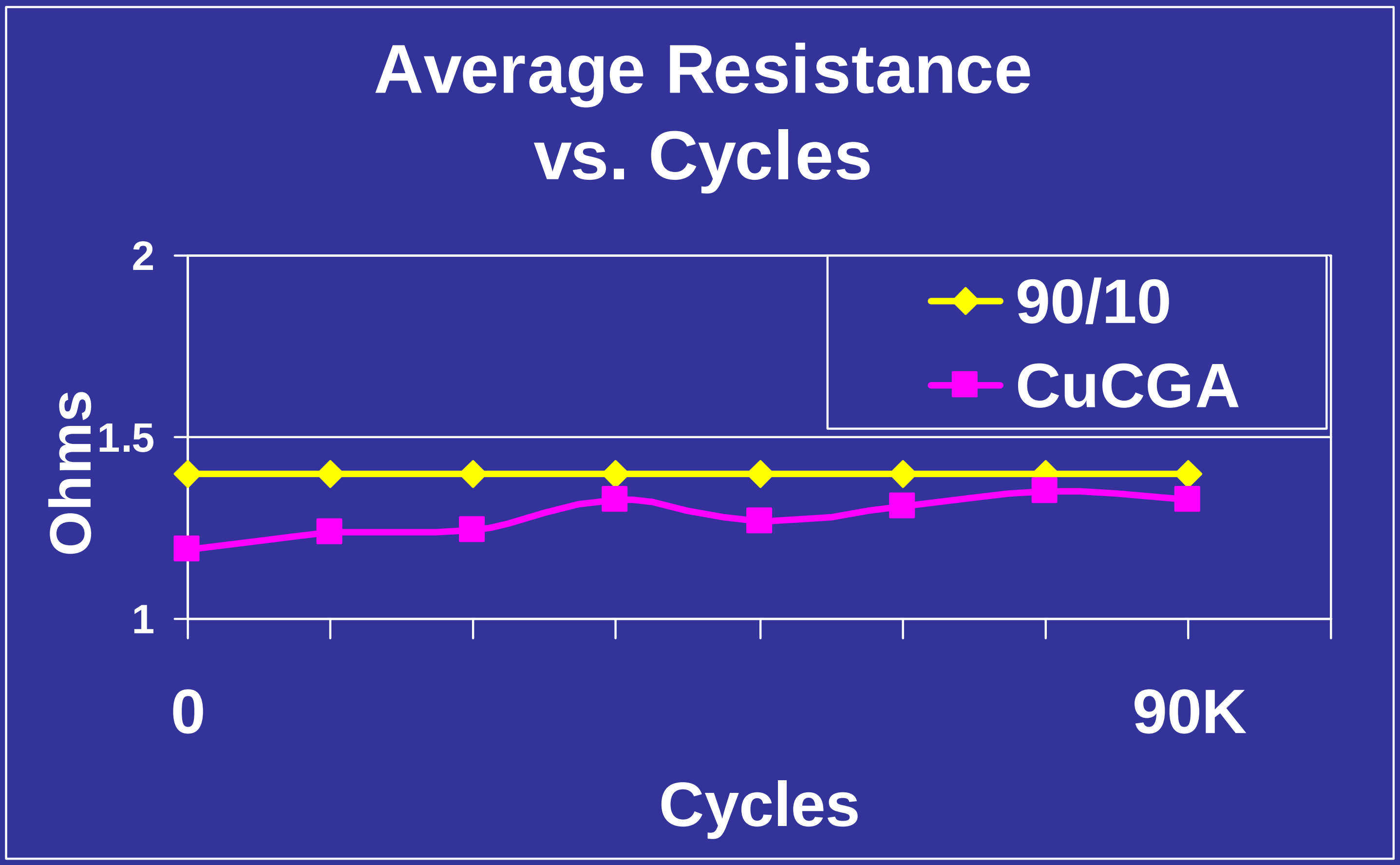
CCGA Test Cycling

- **Daisy-chain modules**
- **Temp = ambient**
- **POR contact on 90/10 columns**
- **Surface mount crown contact on lead-free CuCCGA**



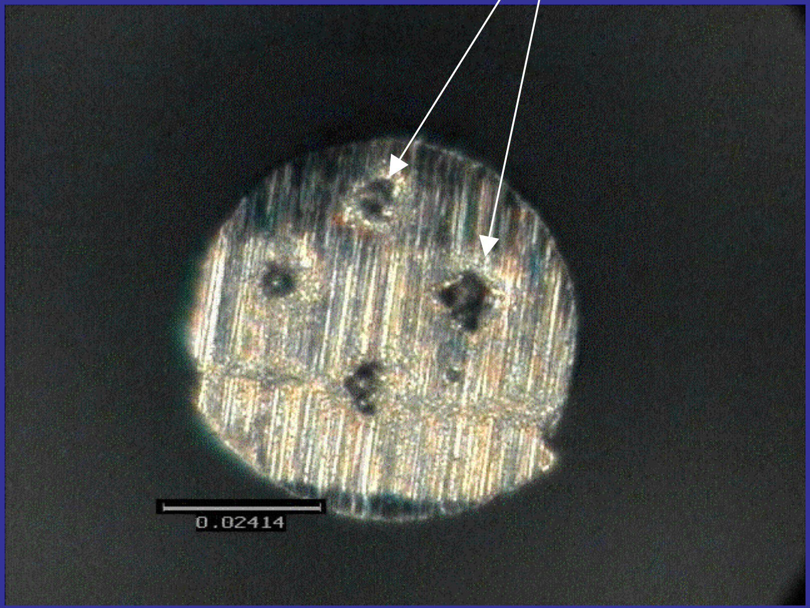


CCGA Contact Resistance

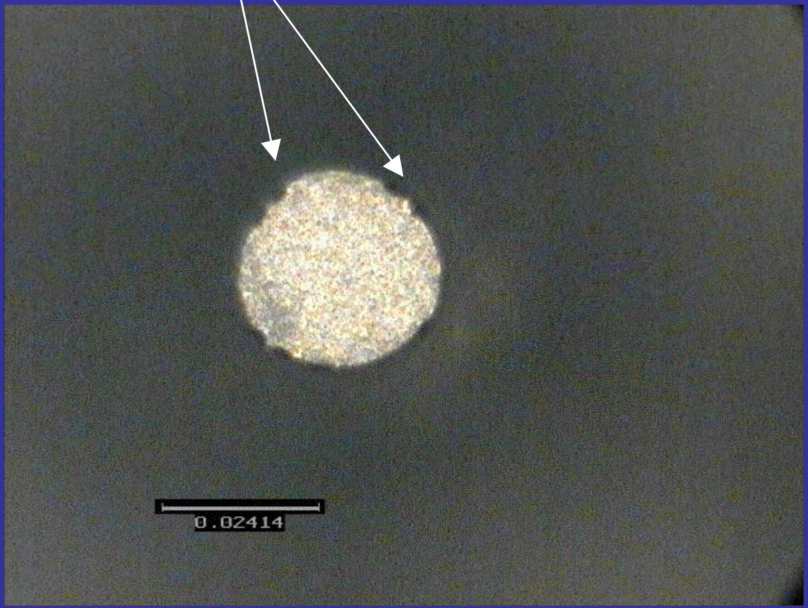


Column Damage

Witness Marks



90/10

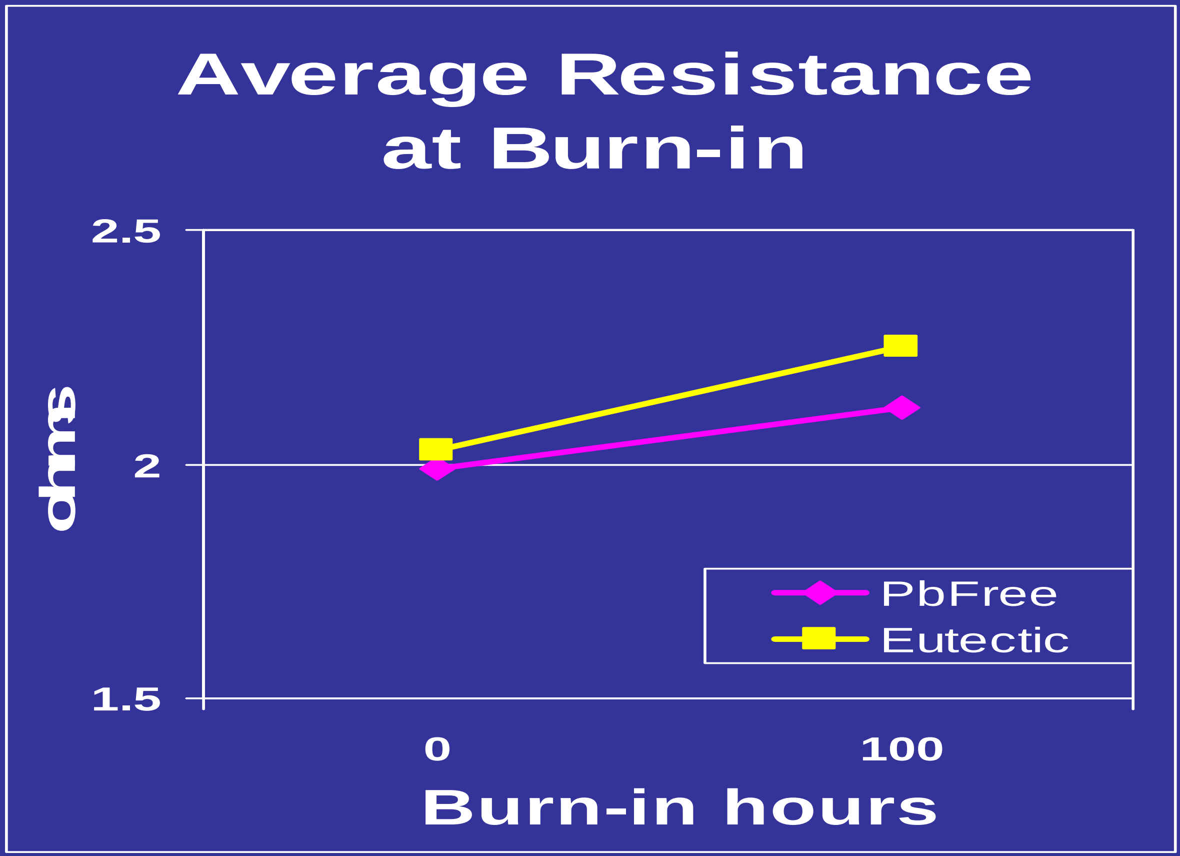


Pb Free

PBGA Contactor Resistance at Burnin [1mm]

- Burn-in parameters @140C
  - Compression mount BGA socket
  - Resistance test at room temp
  - BGA device: daisy chain 42.5mm, 1mm pitch
  - Setup NOT normalized
  - Eutectic data → average of 7 modules (~1500 IO/mod)
  - Pb free data → average of 4 modules (~1500 IO/mod)

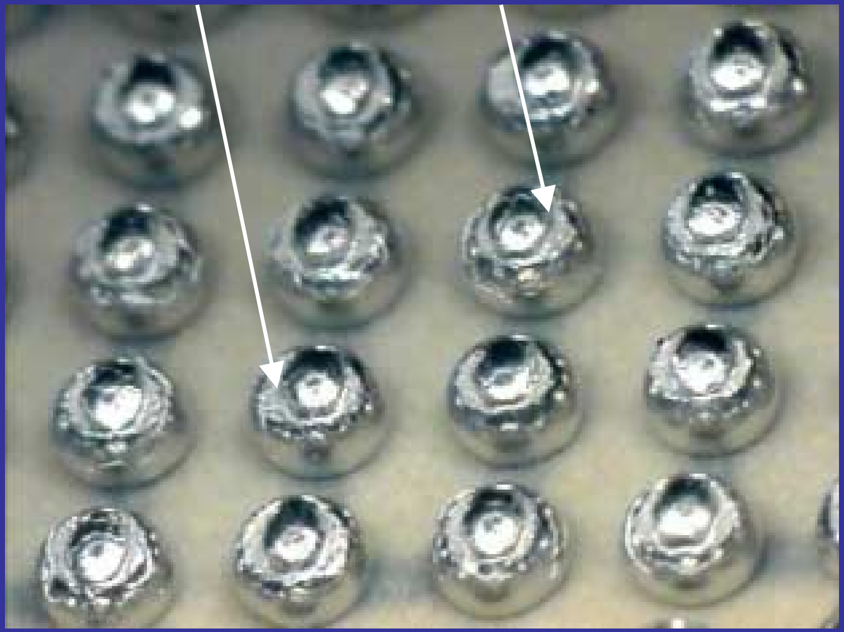
PBGA Contactor Resistance at Burnin [1mm]



Lead-free resistance change ~ 130 mohms

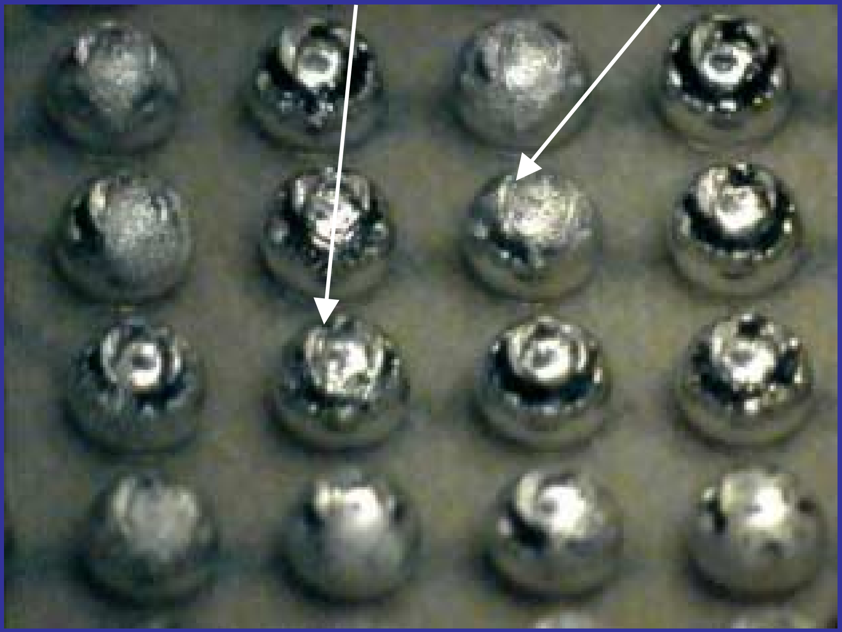
Ball Damage 1.00mm Pitch

Contactor witness mark



- 1.00mm eutectic Hyper BGA
- Compression style contactor
- 162 hrs @ 140C

Contactor witness mark

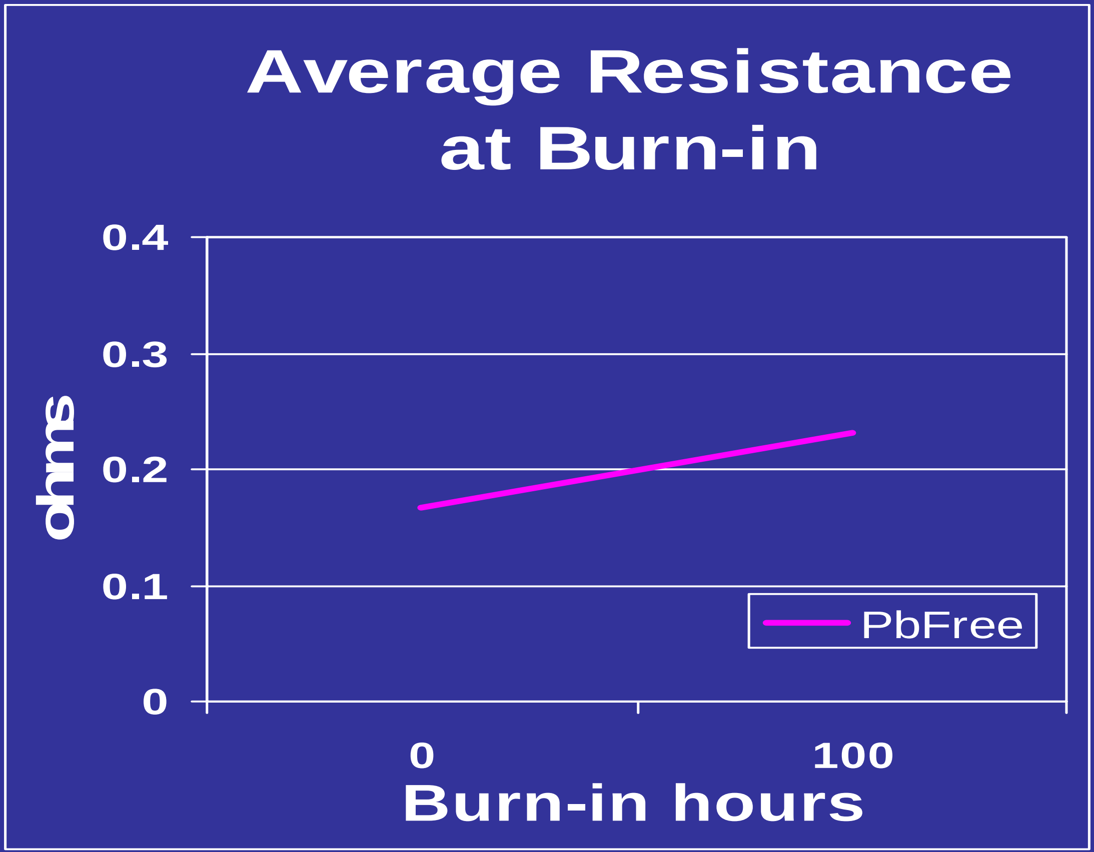


- 1.00mm Pb Free Hyper BGA
- Compression style contact
- 120 hrs @ 140C

PBGA Contactor Resistance at Burnin [1.27mm]

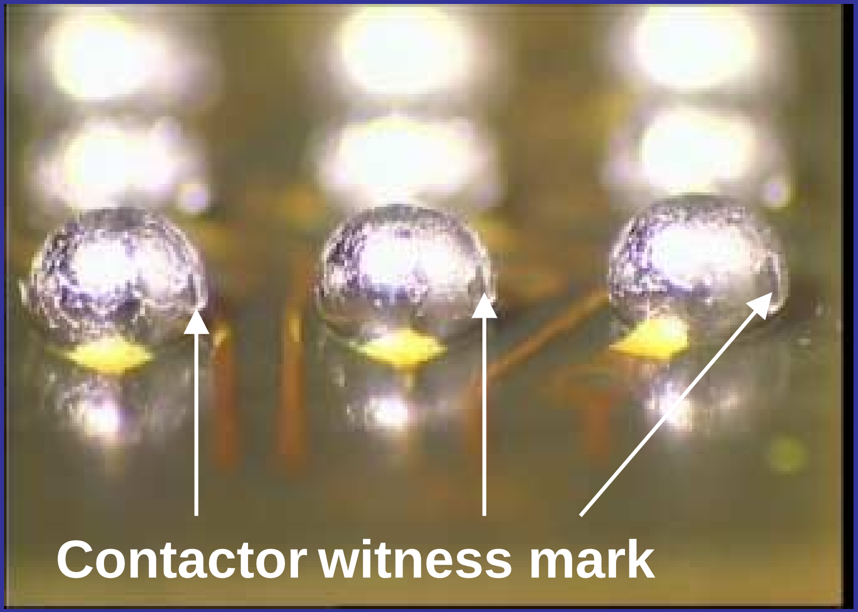
- **Burn-in Parameters**
  - Pinch style BGA socket
  - Burn-in temp: 140C
  - Resistance measured at room temperature
  - BGA device → daisy chain 42.5mm, 1089 I/O
  - Setup normalized with 3 daisy chain devices at room temp
  - No control (Eutectic BGA) module
  - Pb free data → average of 6 modules (971 IO/mod)

PBGA Contactor Resistance at Burnin [1.27mm]



Resistance change → 0.065 ohms / 100hrs

Ball Damage 1.27mm Pitch

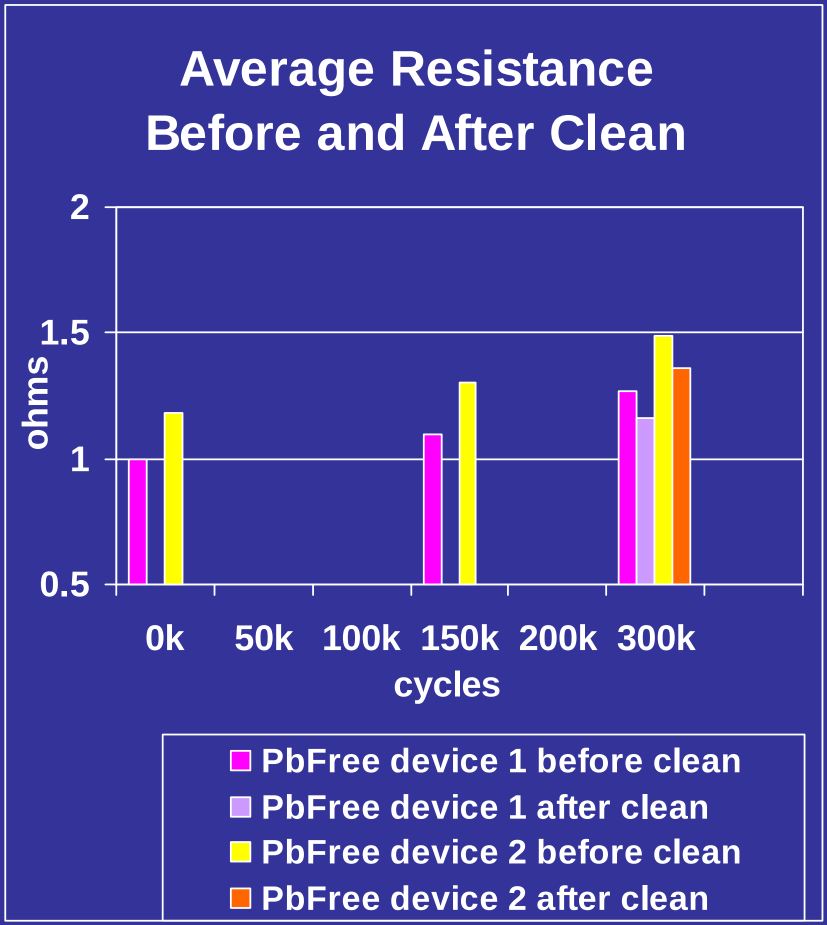


- 1.27mm eutectic PBGA
- Pinch style contact
- 140 hrs @ 140C

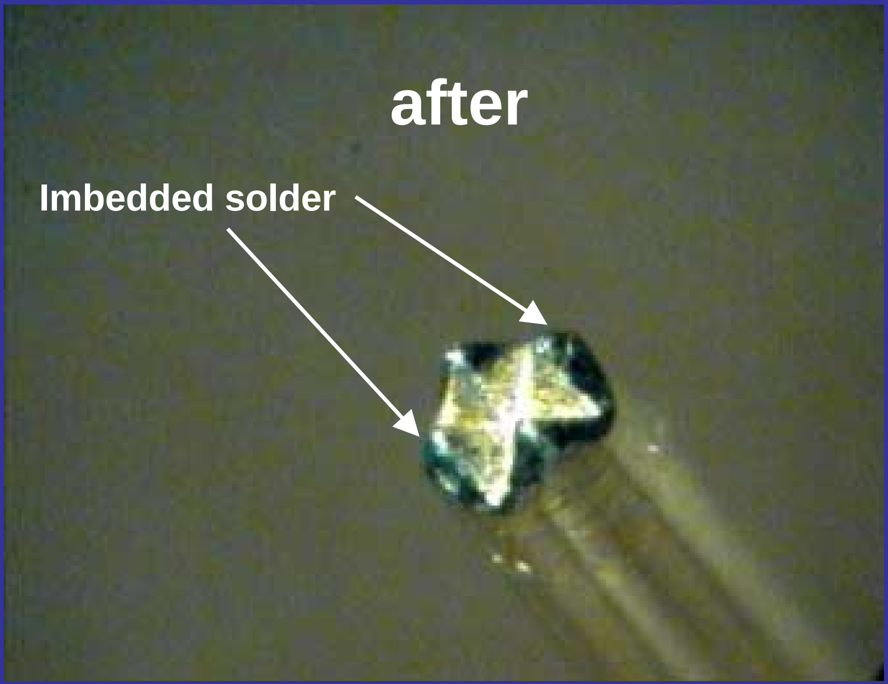
- 1.27mm Pb Free PBGA
- Pinch style contact
- 120 hrs @ 140C

PBGA Contactor Cleaning

- Surface mount pogo socket
  - Two 1089 I/O Pb free BGA devices to test on
  - Four 1089 I/O Pb free BGA devices to cycle on
  - Test temperature: 120C
  - Cleaning method: soft brass brush + air blow off
  - 10% improvement at 300k



Contactor Cleaning



- Cleaning technique – soft brass brush + air blow off
- Cleaning frequency – in depth experimentation required
- Pb free solder material transfer seems lesser than SnPb

Pb Free Early Learning Summary

- ✓ Contact resistance similar or lower than that of eutectic BGA and 90/10 BGA and CCGA
- ✓ Ball deformation from burn-in sockets less than with eutectic BGA
- ✓ Less solder material transfer onto socket contact than with eutectic solder
- ✓ Early learning results indicate no problems with using existing BGA interconnect hardware in lead free module test and burn-in

Lead Free Contacting

2003 Burn-in and Test Socket Workshop

March 2-5, 2003

Bert Brost, Johnstech International

BiTS
BURN-IN & TEST SOCKET WORKSHOP

Johnstech™

Up Front Concerns with Lead-Free Soldering

- Solder alloys need to be clearly understood to:
  - Meet customer and government health requirements
  - Meet customer quality and reliability requirements
  - Meet company and customer cost requirements
  - Be compatible

Base Line Information

- The phase out of Pb in solder is required to reduce Pb alloys from leaching from landfills into the air, soil, and drinking water
  - The move to Pb-free solders creates stimulating and interesting tasks with real opportunities for those that are first with Pb-free product offerings
  - Solder suppliers have solder alloy variations available that are Pb-free
- Each alloy has its unique properties and characteristics

Lead-free Alloy Wish List (Short List)

- Low cost
- Direct replacement for 63/37 or 60/40 Sn/Pb Alloys
- Non-hazardous
- Compatible with current equipment
- Compatible with a variety of lead-bearing and lead-free surface coatings
- Mechanically reliable, thermal fatigue resistance, easily repairable
- Available in sufficient supply

The Three Families of Pb-free Solder

- Most likely, there will be a family of Pb-free solder alloys that provide the results required for various applications
  - Sn96/Ag4
    - Available with a good record of use in electronics with a majority being hybrid applications
  - Sn/Ag/Cu
    - Tests have shown this family member has the potential to replace Pb-bearing solders
    - Good wetting characteristics & good fatigue resistance
    - Cost are higher than traditional Pb-bearing solders
  - Sn/Cu Alloys
    - Have gained some acceptance due to low costs
    - Offers poor wetting and poor mechanical strength of the preceding family member

Undesirable Effects of Other Elements

- Cadmium: Toxicity
- Indium: Potential for corrosion with rapid oxide formation during melting
- Gallium: Cost, brittleness
- Bismuth: Becomes brittle, Secondary eutectic (minimum melting point) of 96°C created if exposed to Pb
- Zinc: Not easy to use, oxidation, corrosion

Setting a Pb-Free Contacting Baseline

- Why
  - Lack of information on electrical and mechanical interfacing to Pb-free plated device leads
  - Lack of data on device-under-test interfacing in the public domain
- What
  - Gathering and interpreting data as a starting point for Pb-free solder application knowledge
- Where
  - Lab and field testing and evaluation
- How
  - Generate a report, spread the word

Test Objective

- Metallurgical Plating Test
  - To determine the elemental content of the tin-lead and tin plated leads
  - Sample(s) Tested
    - TSSOP – 90% Sn 10% Pb lead, 3 device samples
    - TSSOP – 100% Sn lead 3 device samples
- Contactor Variable Resistance Test
  - Focus on contact resistance variability when contacting 100% Sn plated contact leads with engineering changes to:
    - Contact wipe point of the device lead
    - Pin surface micro roughness
    - Elastomer durometer selection

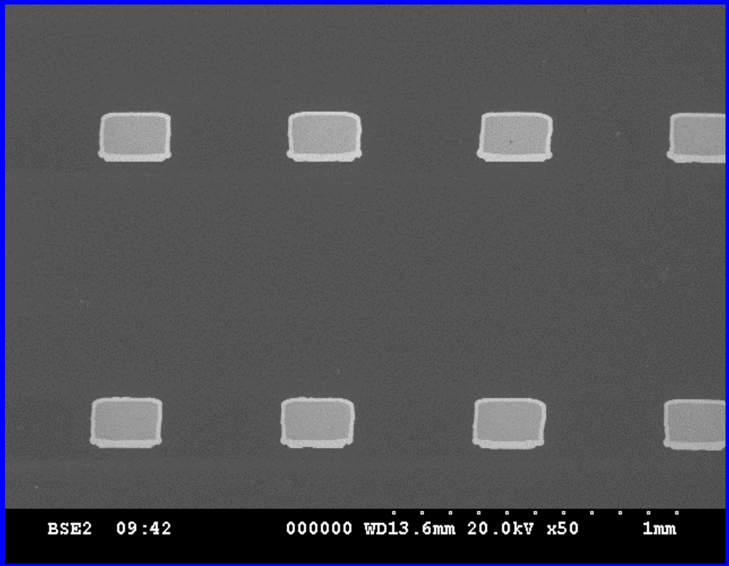
Test Process

- Build several contactors of the same design populated with three different pins
  - Measure metallurgical content of lead plating
  - Our standard pin
  - Standard pin with a smoother micro surface
  - Standard pin with a surface profile that will provide a nominal point scrub on the device
  - Plot pin resistance measurements (Mean, Variance, Median, Mode, and Range)
  - Measure the Kelvin contact resistance of the pins and and its variance at six different temperatures: -40° C, -20°C, 0°C, controlled ambient (22°C), +80°C, +125°C when contacting
    - 100% Sn device lead plating
    - 10% Pb/90% Sn device lead plating

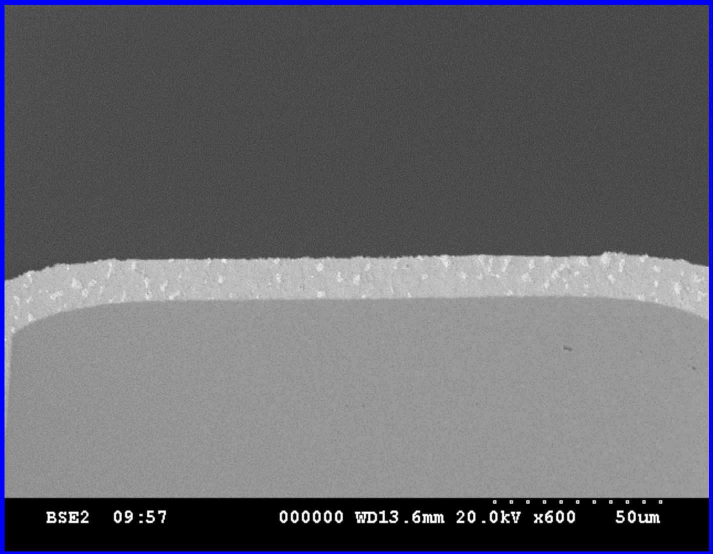
Metallurgical Plating Test

- Test Method(s) Description:
  - Scanning electron microscopy (SEM) with a light element energy dispersive spectrometer (EDS) was used to provide the data for the plating composition of the two types of leads provided
  - Three leads in a set of fourteen, the third, seventh, and twelfth leads had three area analyses performed on each of the samples
  - Area analyses rather than spot analyses were performed due to the non-homogenous nature of the tin lead plating composition
  - The analyses were performed at an accelerating voltage of 20 kV, a working distance of 13.5 mm, and at a magnification of 600X

90% Sn 10% Pb Plated Lead



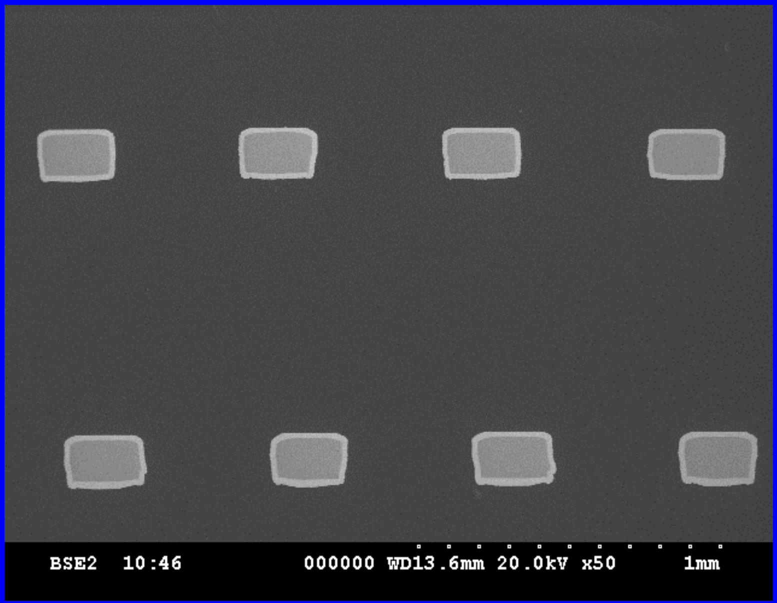
SEM micrograph taken at 50X showing an overview of the Sn/Pb leads



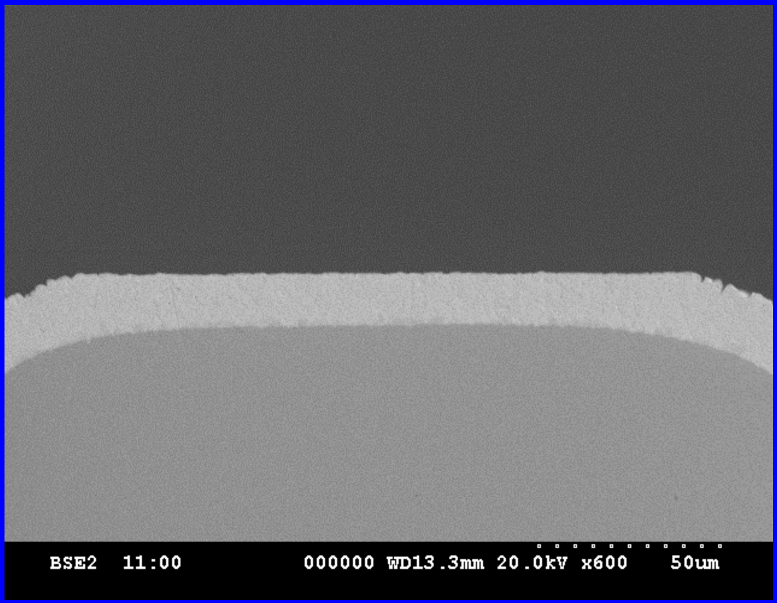
SEM micrograph taken at 600X showing the side analyzed on the Sn/Pb lead

This micrograph shows the non-homogeneous nature of the tin lead plating

100 % SN Plated Lead



SEM micrograph taken at 50X showing an overview of the Sn leads



SEM micrograph taken at 600X showing the side analyzed on the Sn plating on a lead

Plating Composition Measurement Matrixes

Elemental Composition TSSOP 90% Sn 10% Pb Plated Samples

Elements	**Samples (wt. %)**			**Statistics**		
	119151	**119152**	**119153**	**Average**	**STD**	**%RSD**
Carbon	9.1	9.4	9.0	9.2	0.52	5.7
Oxygen	0.4	0.5	0.4	0.4	0.24	55.3
Aluminum	0.2	0.2	0.3	0.3	0.05	20.8
Lead	7.6	7.9	8.3	8.0	3.63	45.6
Tin	76.7	76.6	75.7	76.3	3.50	4.6
Copper	5.9	5.4	5.7	5.7	0.53	9.4

Elemental Composition TSSOP Sn Plated Samples

Elements	**Samples (wt. %)**			**Statistics**		
	119157	**119158**	**119159**	**Average**	**STD**	**%RSD**
Carbon	8.6	8.4	8.8	8.6	0.40	4.7
Oxygen	0.7	0.2	0.3	0.4	0.41	102.4
Aluminum	0.2	0.2	0.2	0.2	0.05	24.33
Tin	85.4	86.2	86.0	85.9	0.94	1.1
Copper	5.2	5.0	4.7	5.0	0.69	13.9

Elemental Composition of the Surface of a TSSOP Tin Lead Plated Sample

Elements	119154 wt. %
Carbon	4.1
Oxygen	1.6
Aluminum	0.3
Silicon	3.2
Lead	14.2
Tin	76.7

Internal Device Resistance Baseline

- Contactor boards built by Johnstech to measure the Kelvin contact resistance of the pins and and its variance when contacting both the 10% Pb/90% Sn and 100% Sn device lead plating
- Internal bond wire average resistance measure from a sample of twenty (20) device packages

100% Sn Lead Plating:
This table illustrates the average internal resistance from a sample of 10 units

Resistance	0.01888Ω	0.01637Ω	0.01782Ω	0.01826Ω	0.01820Ω	0.01869Ω	0.01863Ω	0.01827Ω
Pin #	Pin 1	Pin 3	Pin 5	Pin 7	Pin 8	Pin 10	Pin 12	Pin 14

90%Sn & 10%Pb Lead Plating
This table illustrates the average internal resistance from a sample of 10 units

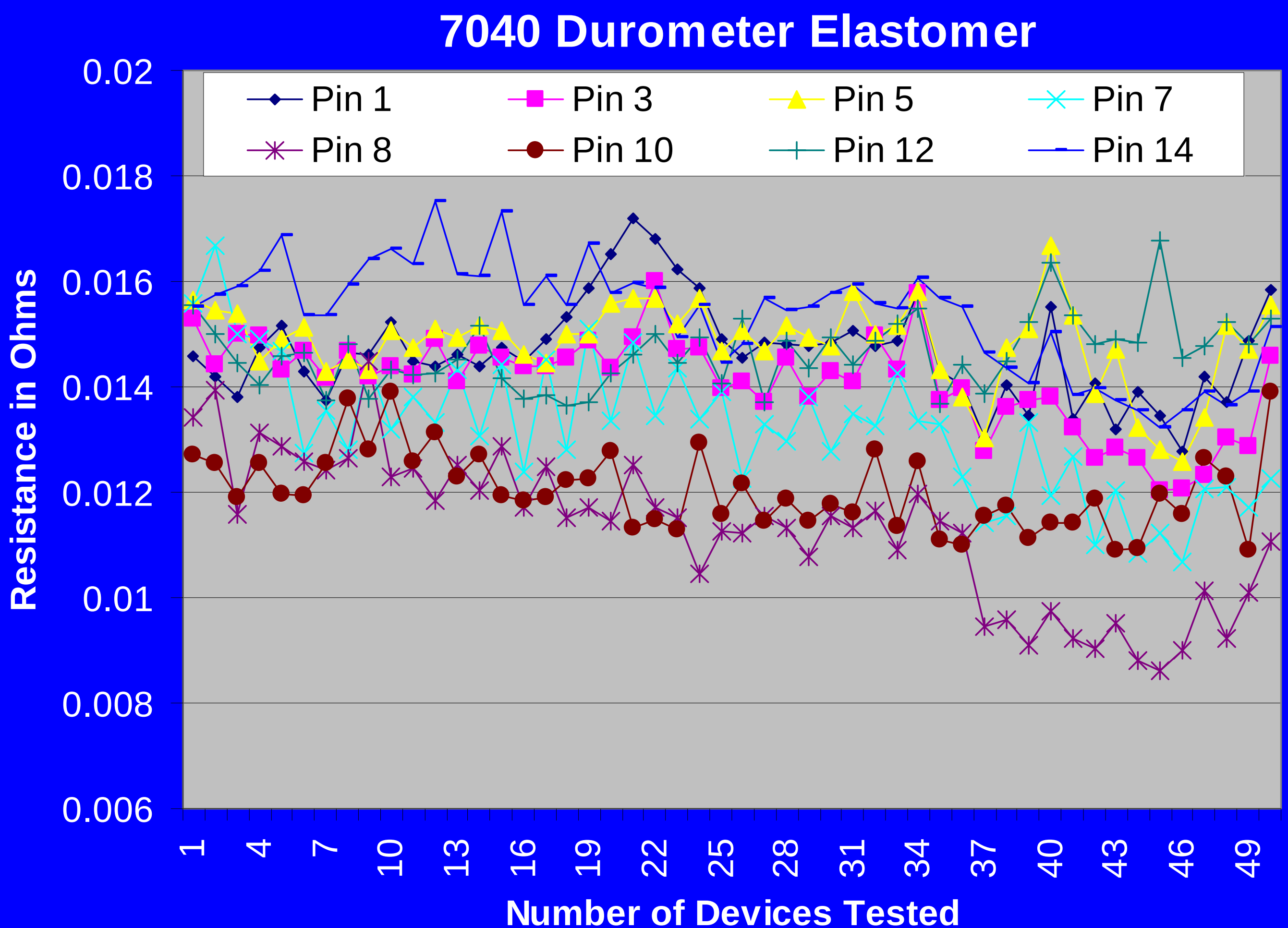
Resistance	0.02031Ω	0.01784Ω	0.01918Ω	0.01967Ω	0.01924Ω	0.01864Ω	0.01876Ω	0.01958Ω
Pin #	Pin 1	Pin 3	Pin 5	Pin 7	Pin 8	Pin 10	Pin 12	Pin 14

Test Plunge Fixture and Temperature Chamber

4 Wire Kelvin resistance measurement instrument used:

Keithley Multimeter Switch, Model 2750

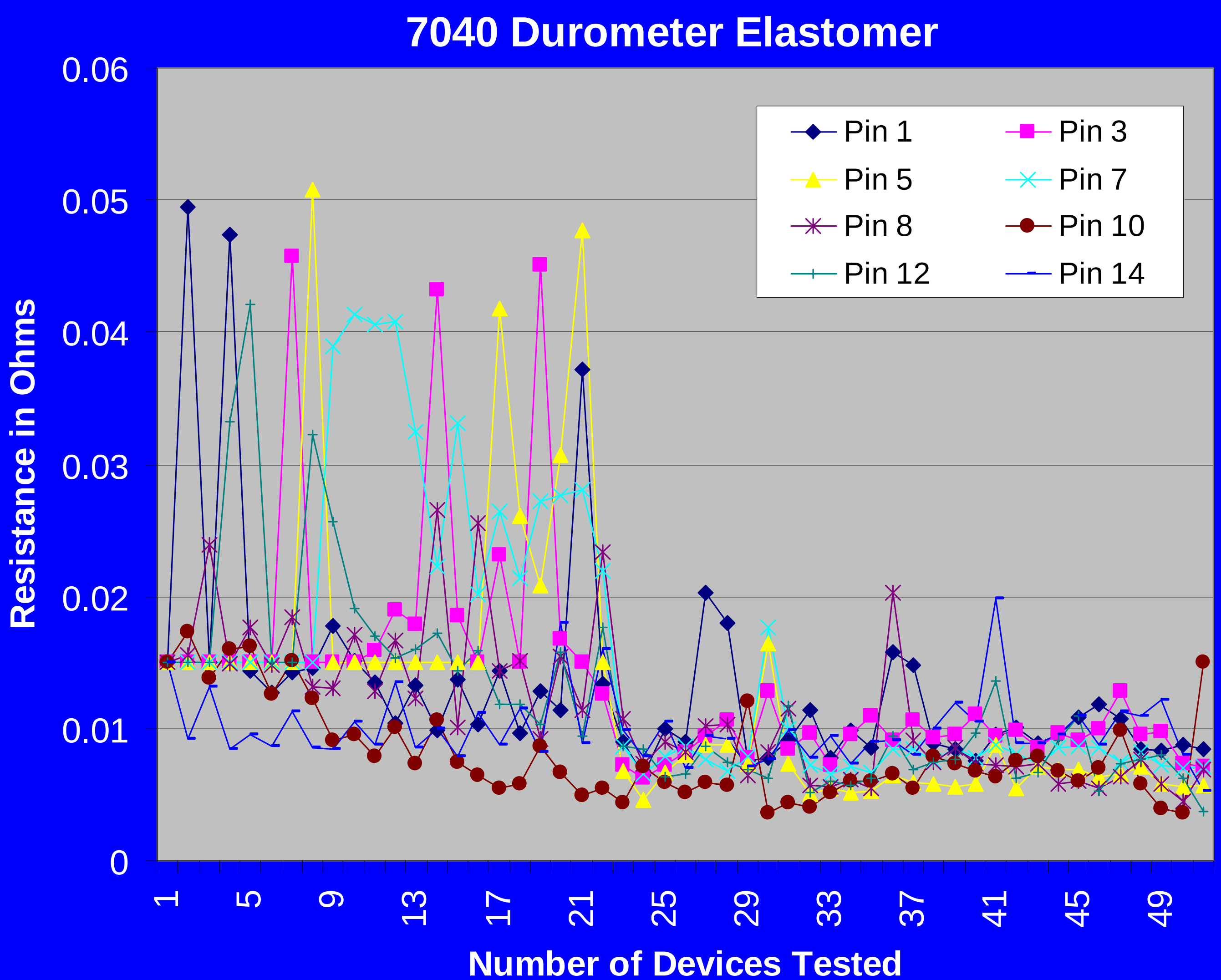
90% Sn 10%Pb
Tested at Plus 125º C.
Standard 2mm Contact Pins



- **Min 0.00862**
- **Max 0.01751**
- **Range 0.00889**
- **Median 0.01418**
- **Mean 0.01377**
- **Sample Standard Deviation 0.00168**
- **Average Deviation From Mean 0.00137**

- **Contact pin resistance spread from pin to pin 0.009 Ohms**
- **Spread approximately 50% of the mean**

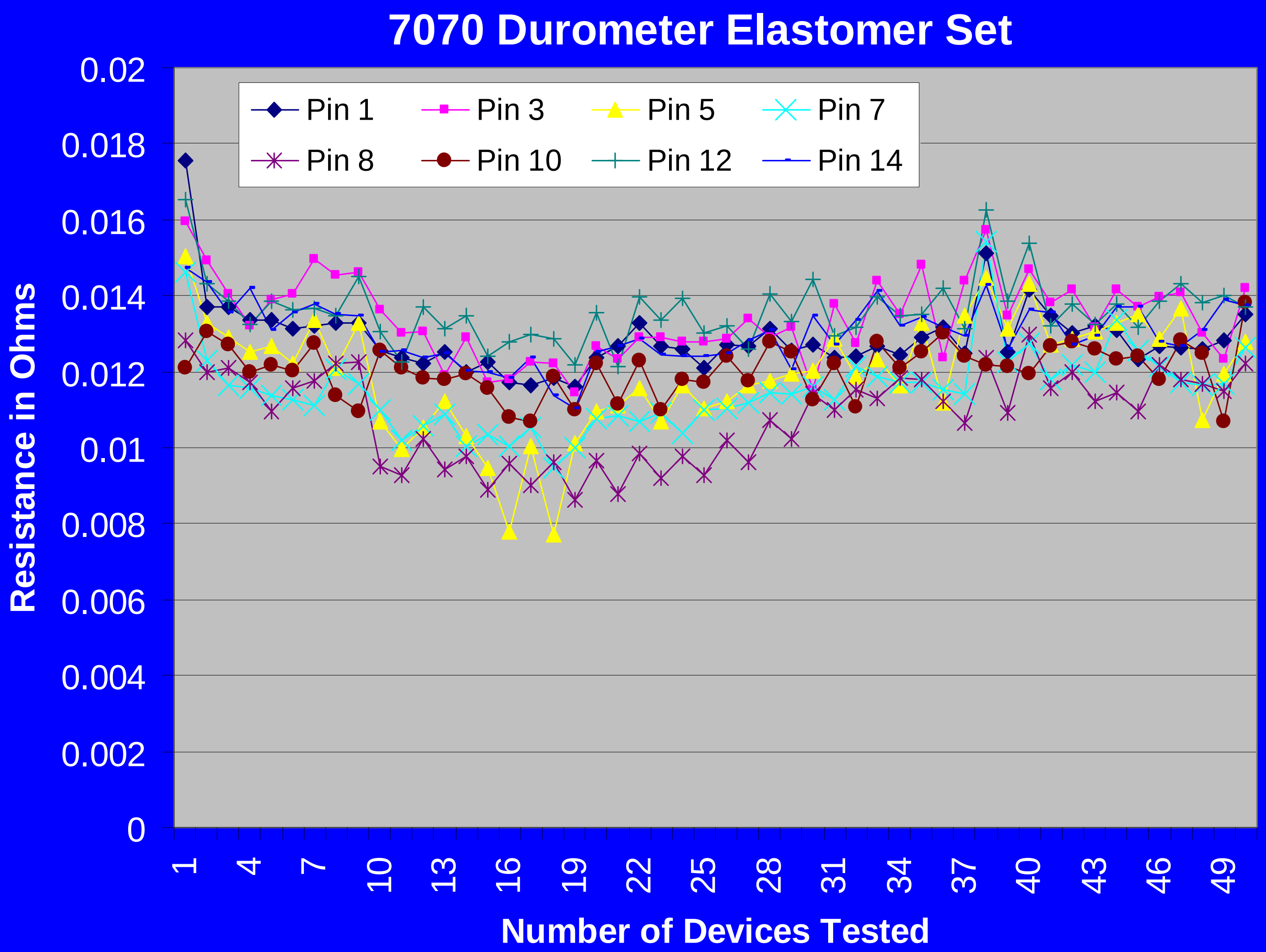
90% Sn 10%Pb
Tested at Minus 40º C.
Standard 2mm Contact Pins



- **Min 0.00097**
- **Max 0.00571**
- **Range 0.00774**
- **Median 0.00361**
- **Mean 0.00366**
- **Sample Standard Deviation 0.00118**
- **Average Deviation From Mean 0.00091**

- **Contact pin resistance spread from pin to pin less than at 125°**
- **Spread approximately twice the value of the mean**
- **Contact stabilized after 25 insertions**

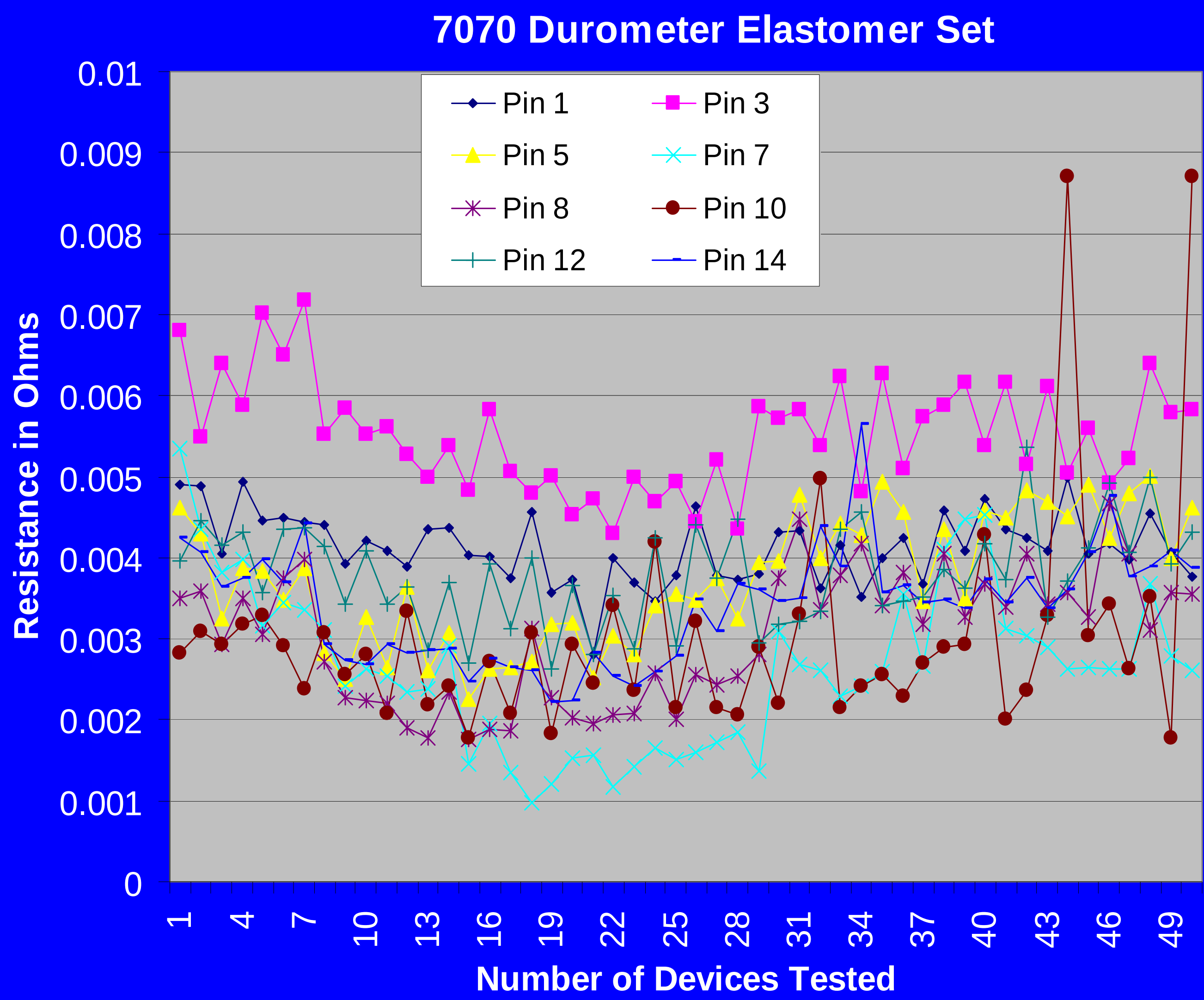
90% Sn 10% Pb Lead Plating Tested at Plus 125º C. Standard 2mm Contact Pins



- **Min 0.00770**
- **Max 0.01757**
- **Range 0.00987**
- **Median 0.01250**
- **Mean 0.01241**
- **Sample Standard Deviation 0.00137**
- **Average Deviation From Mean 0.00105**

- **The harder elastomer caused the overall distribution to be tighter**
- **The range increased by 0.001 Ohm**

90% Sn 10% Pb Lead Plating Tested at Minus 40º C. Standard 2mm Contact Pins

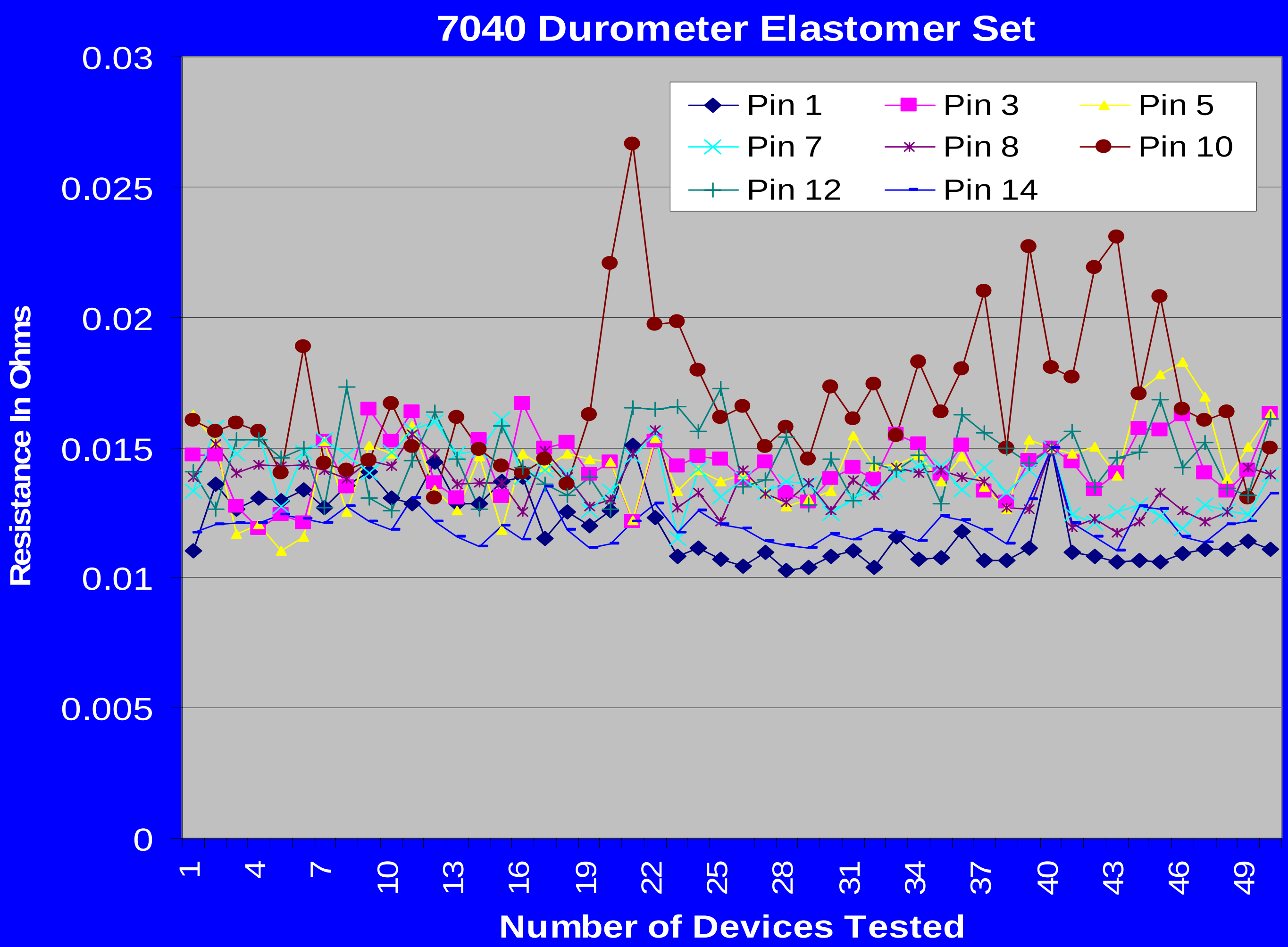


- **Min 0.00097**
- **Max 0.00871**
- **Range 0.00774**
- **Median 0.00361**
- **Mean 0.00366**
- **Sample Standard Deviation 0.00118**

- **Average Deviation From Mean 0.00091**

- **The harder elastomer caused a larger pin to pin distribution**
- **The range did not increase**

100% Sn Lead Plating Tested at Plus 125º C. Standard 2mm Contact Pins



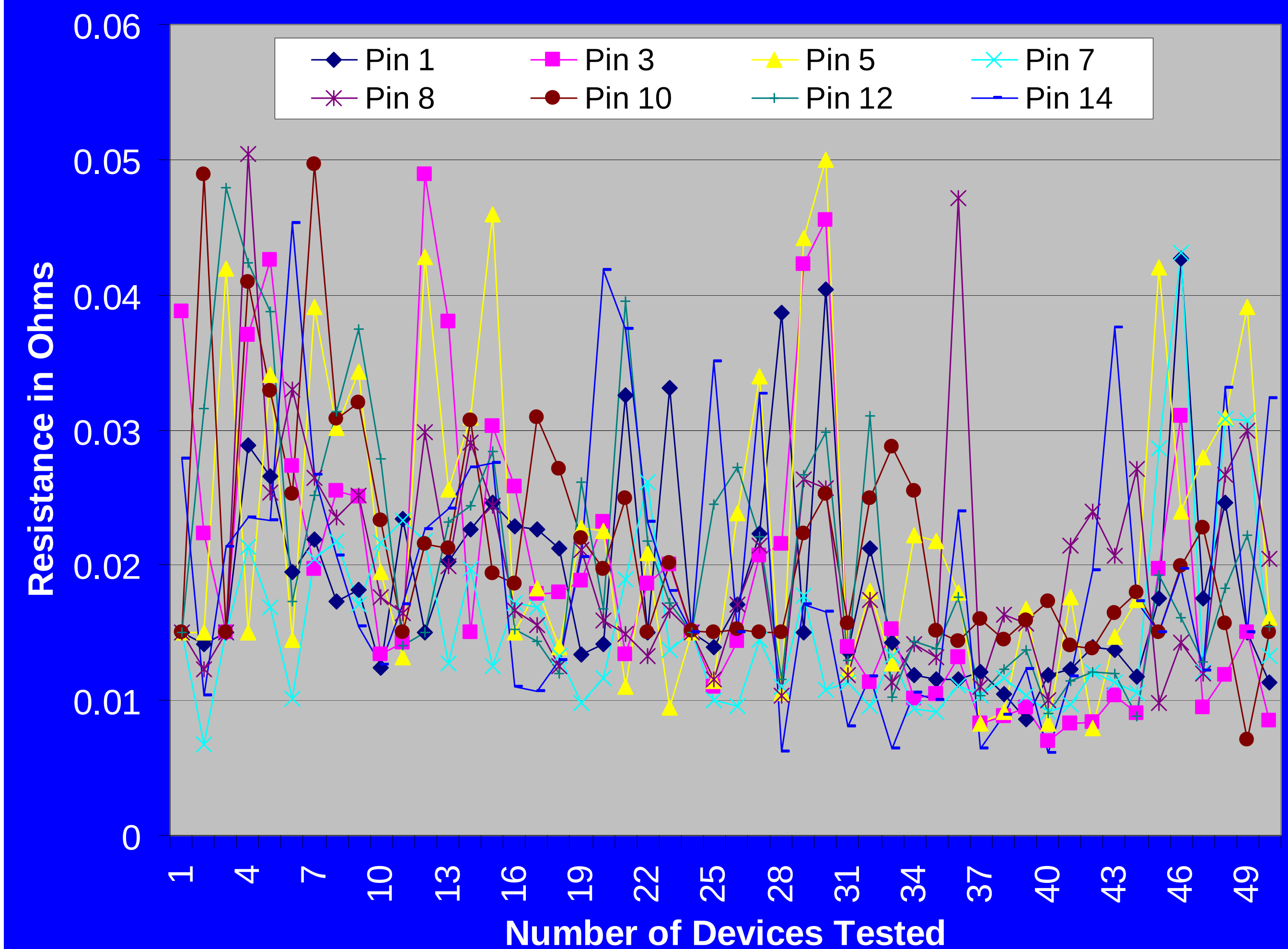
- **Min 0.01030**
- **Max 0.02577**
- **Range 0.01547**
- **Median 0.01368**
- **Mean 0.013802**

- **Sample Standard Deviation 0.001979**
- **Average Deviation From Mean 0.001467**

- **The range doubled over the 90/10 alloy**
- **The mean remained almost the same**
- **The standard deviation increased by 0.0005 Ohms**

100% Sn Lead Plating Tested a Minus 40º C. Standard 2mm Contact Pins

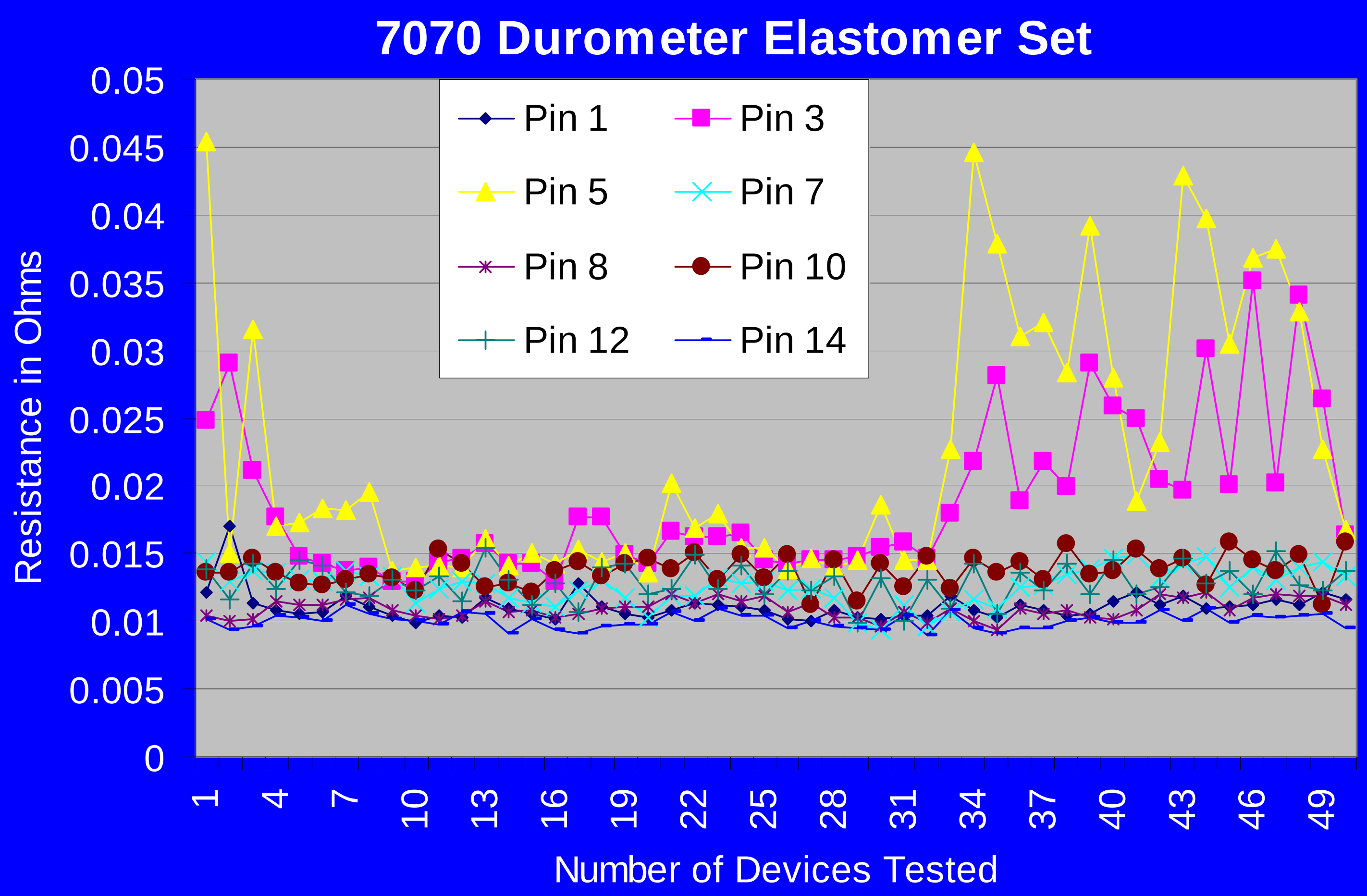
7040 Durometer Elastomer Set



- **Min 0.00609**
- **Max 0.05041**
- **Range 0.04432**
- **Mean 0.019738**
- **Sample Standard Deviation 0.009466**
- **Average Deviation From Mean 0.007435**

- **The change from 90/10 alloy testing is that the pins did not stabilize to a tighter range**
- **The mean and standard deviation increased at -40° C over that of the testing at 125°**

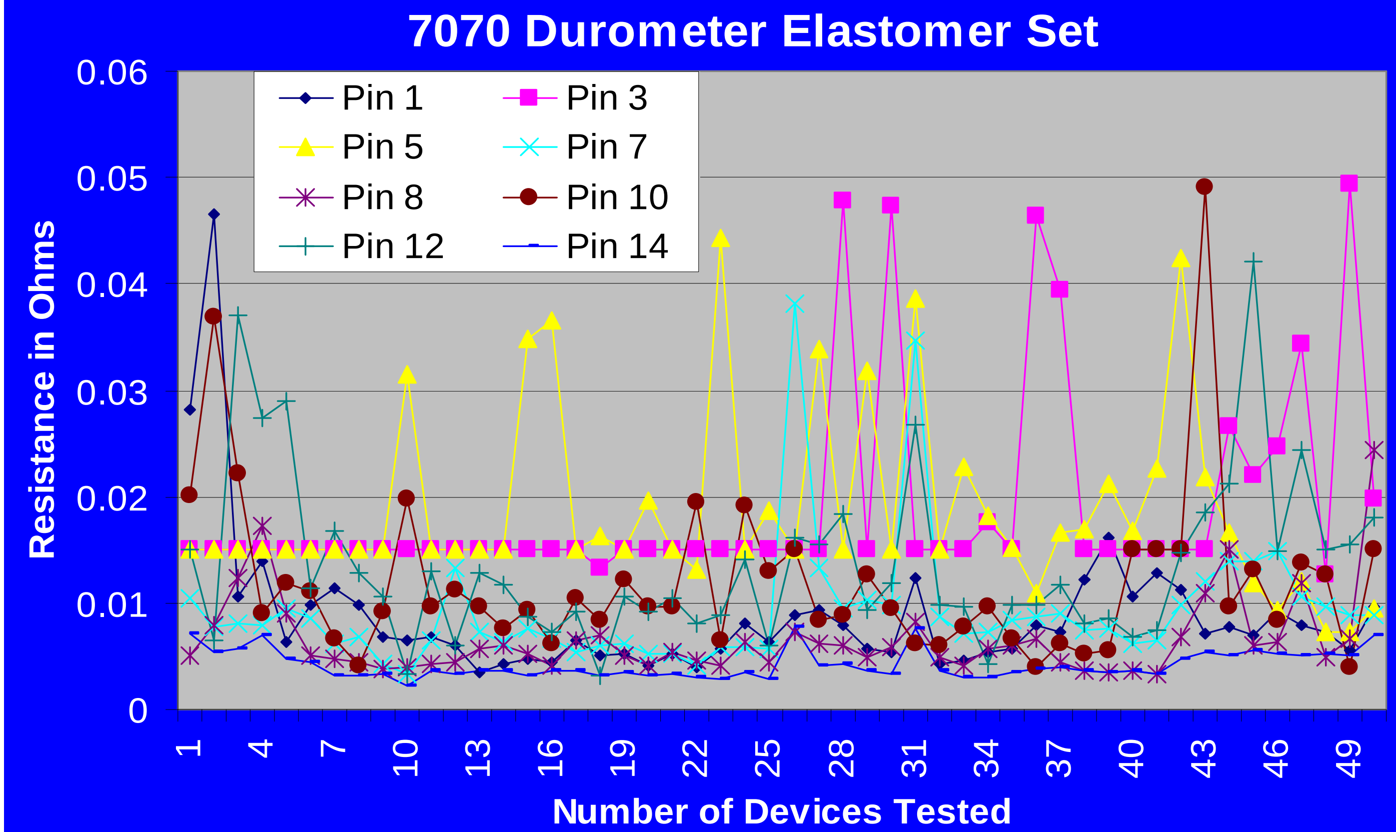
100% Sn Lead Plating
Tested at Plus 125º C.
Standard 2mm Contact Pins



- **Min 0.00901**
- **Max 0.04540**
- **Range 0.03638**
- **Median 0.01092**
- **Mean 0.01110**
- **Sample Standard Deviation 0.00572**
- **Average Deviation From Mean 0.00341**

- **The change to a harder elastomer caused an increase in the mean**
- **The overall range increased after 28 insertions**

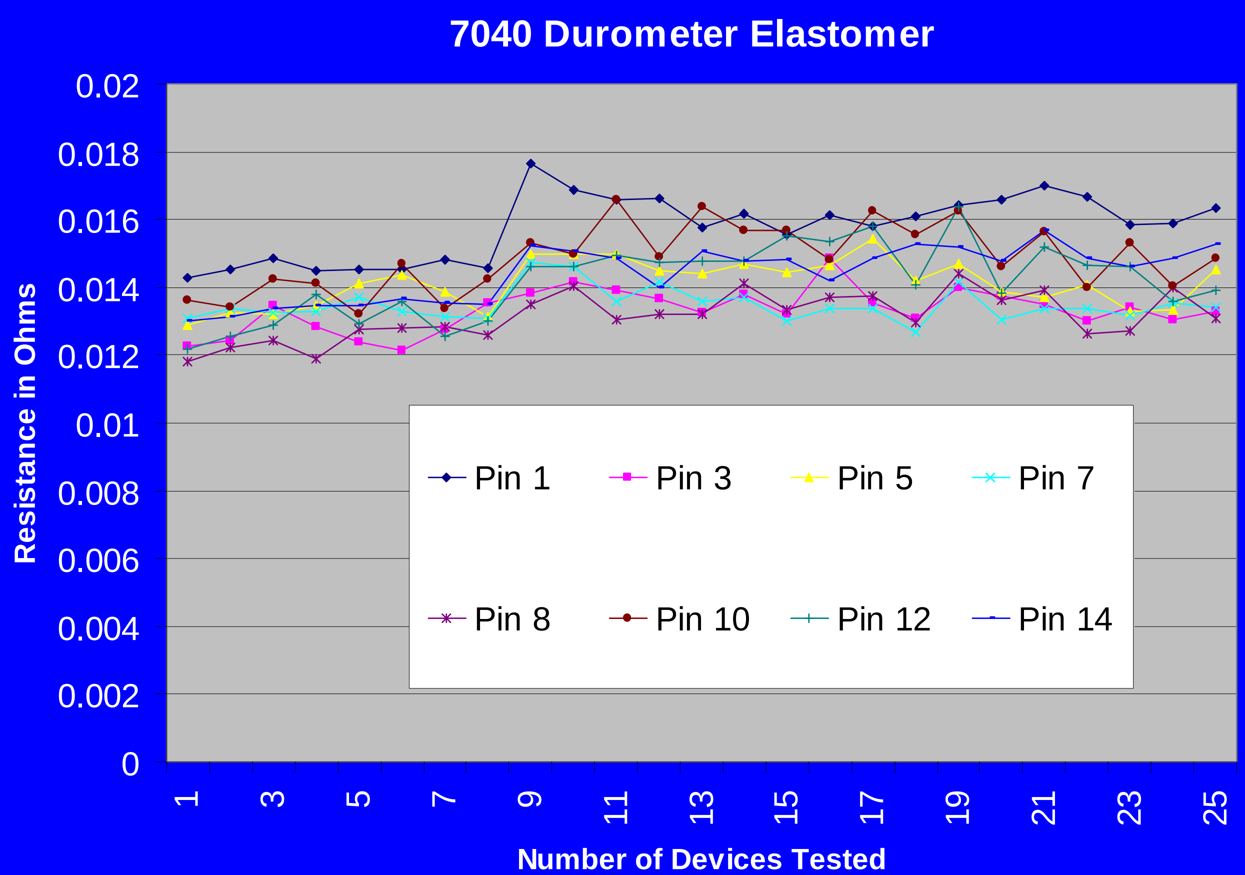
100% Sn Lead Plating Tested at Minus 40º C.
Standard 2mm Contact Pins



- **Min 0.00323**
- **Max 0.04945**
- **Range 0.04945**
- **Median 0.01218**
- **Mean 0.01380**
- **Sample Standard Deviation 0.00882**
- **Average Deviation From Mean 0.00660**

- **The standard deviation increased at -40° C over 125°, same as with the softer elastomer**

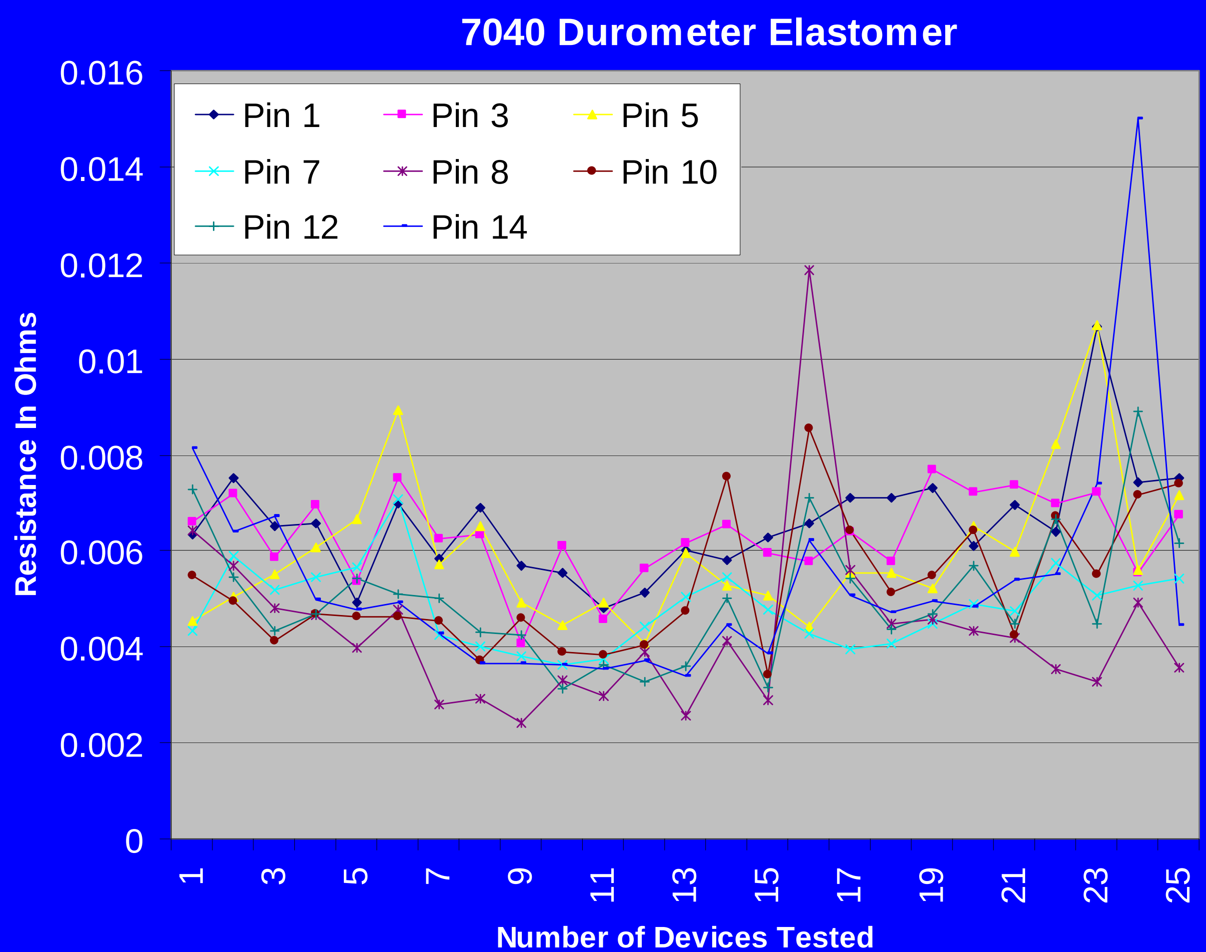
90% Sn 10% Pb Lead Plating Tested at Plus 125º C. Standard 2mm Contact Pins with a Polished Surface



- **Min 0.01181**
- **Max 0.01766**
- **Range 0.00585**
- **Mean 0.01416**
- **Median 0.01401**
- **Sample Standard Deviation 0.00115**
- **Average Deviation From Mean 0.00095**

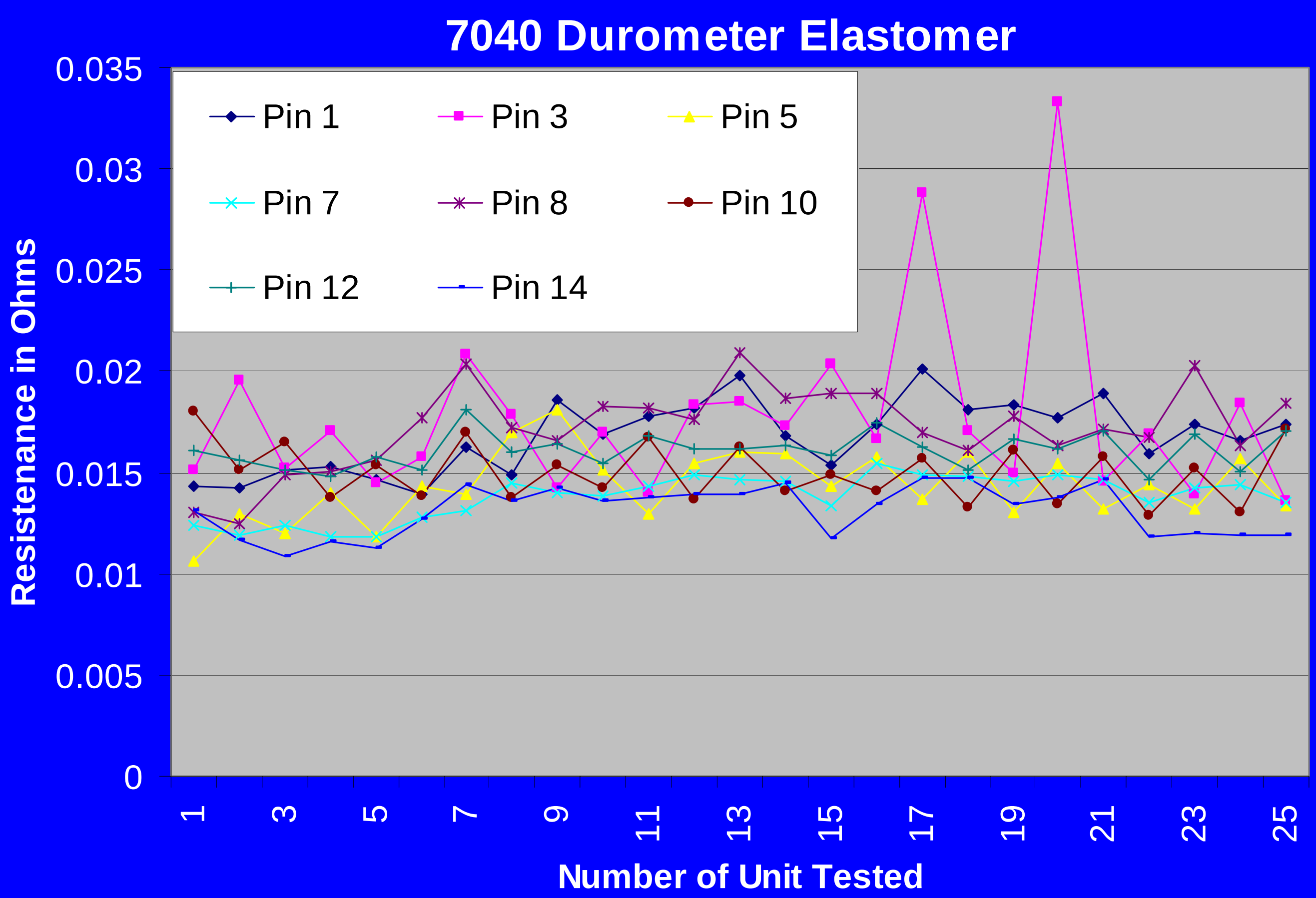
- **Notable improvement over the standard pins**
- **The range decreased by 0.003 Ohms**
- **The mean decreased by 0.001 Ohm**
- **The standard deviation decreased by 0.0005 Ohms**

90% Sn 10%Pb
Tested at Minus 40ºC.
Standard 2mm Contact Pins with a Polished Surface



- **Min 0.00240**
- **Max 0.01500**
- **Range 0.01259**
- **Mean 0.00545**
- **Sample Standard Deviation 0.00164**
- **Average Deviation From Mean 0.00121**
- **There is an increase in the range from the standard pin**
- **The randomness of the standard pin resistance was significantly reduced from the standard pin at -40 degrees C**

100% Sn Lead Plating Tested at Plus 125º C. Standard 2mm Contact Pins with a Polished Surface

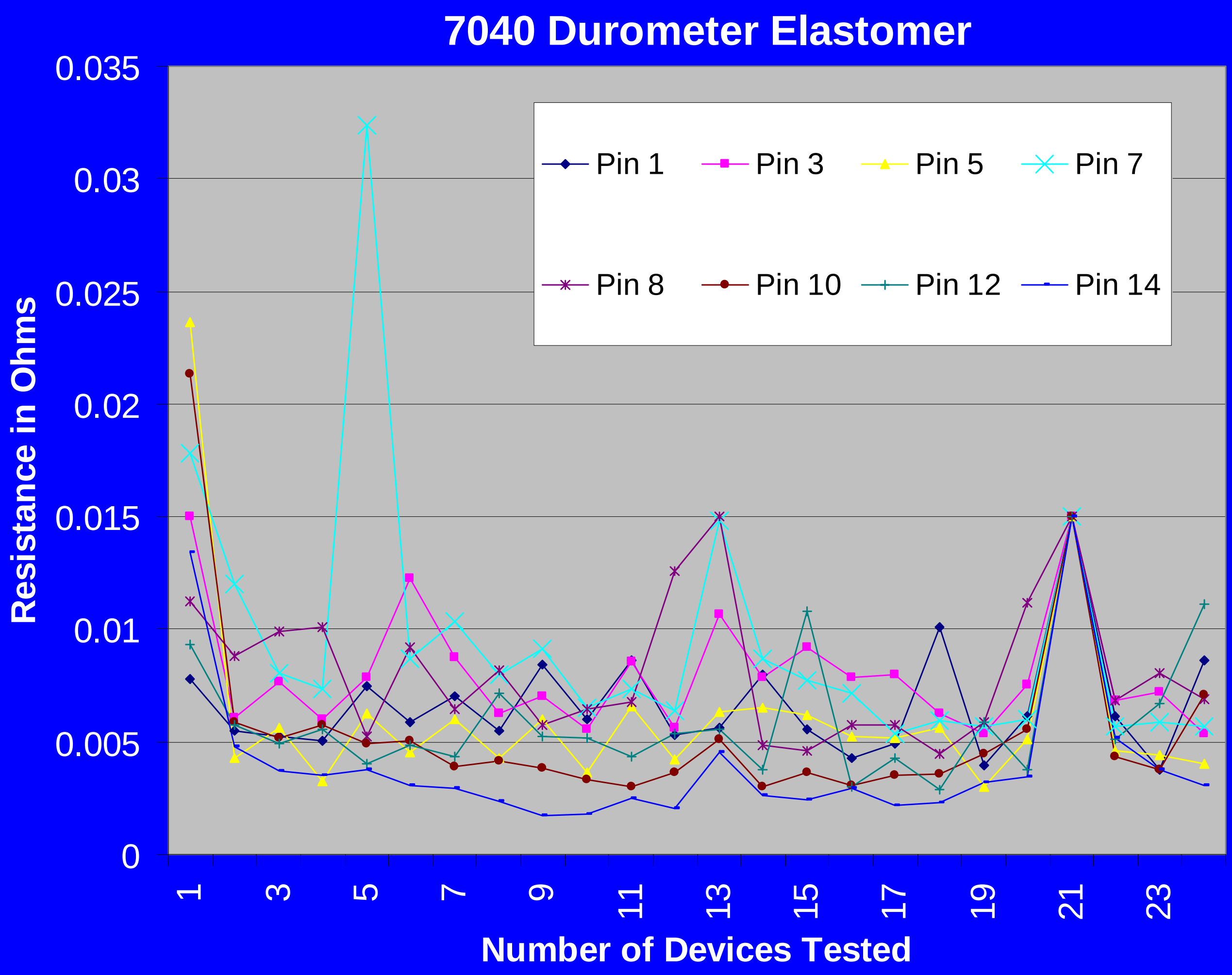


- **Min 0.01060**
- **Max 0.03332**
- **Range 0.02272**
- **Median 0.01514**
- **Mean 0.01551**
- **Sample Standard Deviation 0.00264**
- **Average Deviation From Mean 0.00187**

- **There is a reduction in the data range from the standard pin, with the exception of two spikes on pin 3**
- **The sinusoidal randomness seen with standard pin resistance was eliminated**

100% Sn Lead Plating Tested a Minus 40º C.

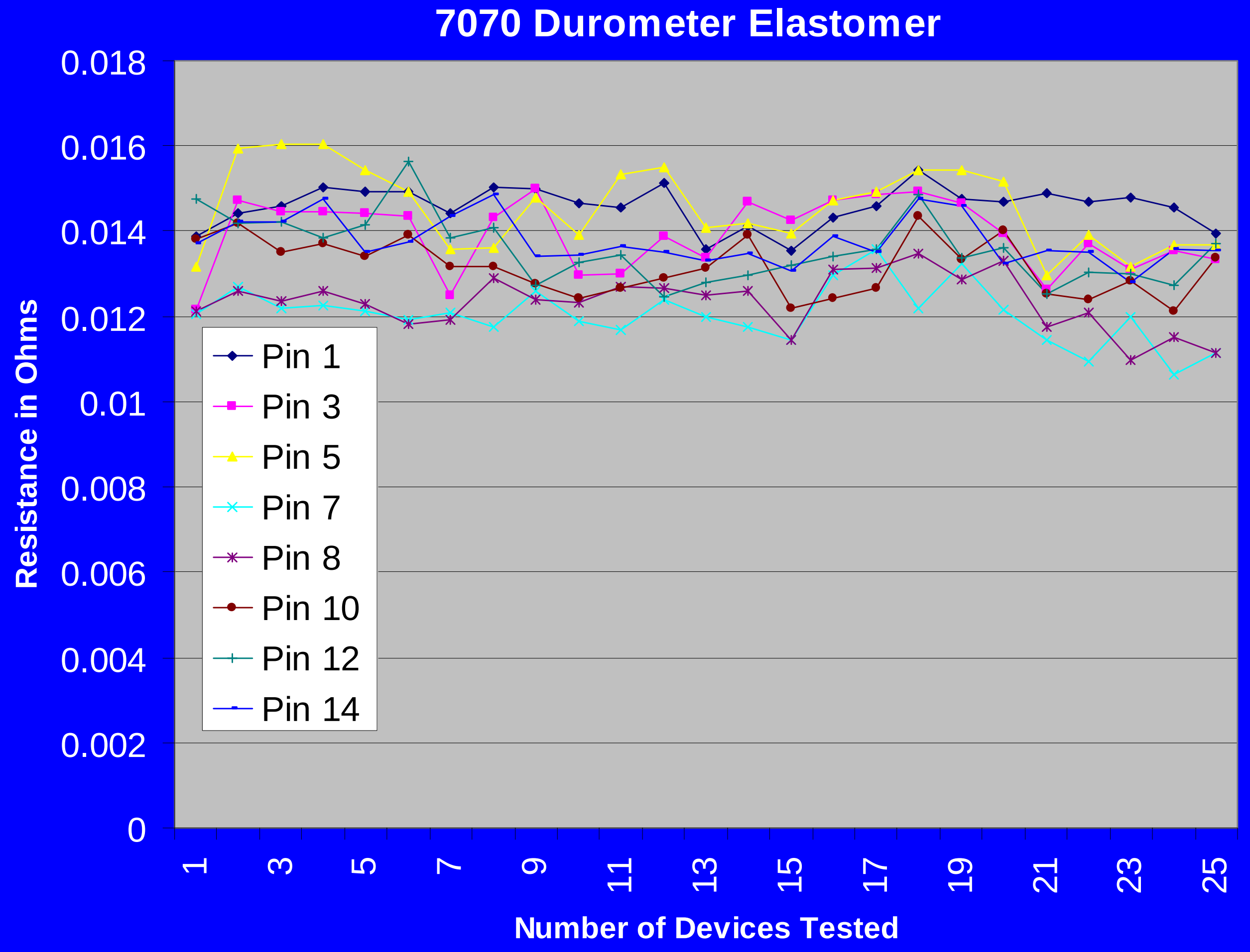
Standard 2mm Contact Pins with a Polished Surface



- **Min 0.00175**
- **Max 0.03238**
- **Range 0.03063**
- **Median 0.00574**
- **Mean 0.00676**
- **Sample Standard Deviation 0.00402**
- **Average Deviation From Mean 0.00271**

- **The improvements at -40 over the standard pin are as follows:**
- **Reduced STD by 0.003 Ohms**
- **The range did not decrease due to a pin 7 spike**
- **Overall contact pin resistance is more reliable**

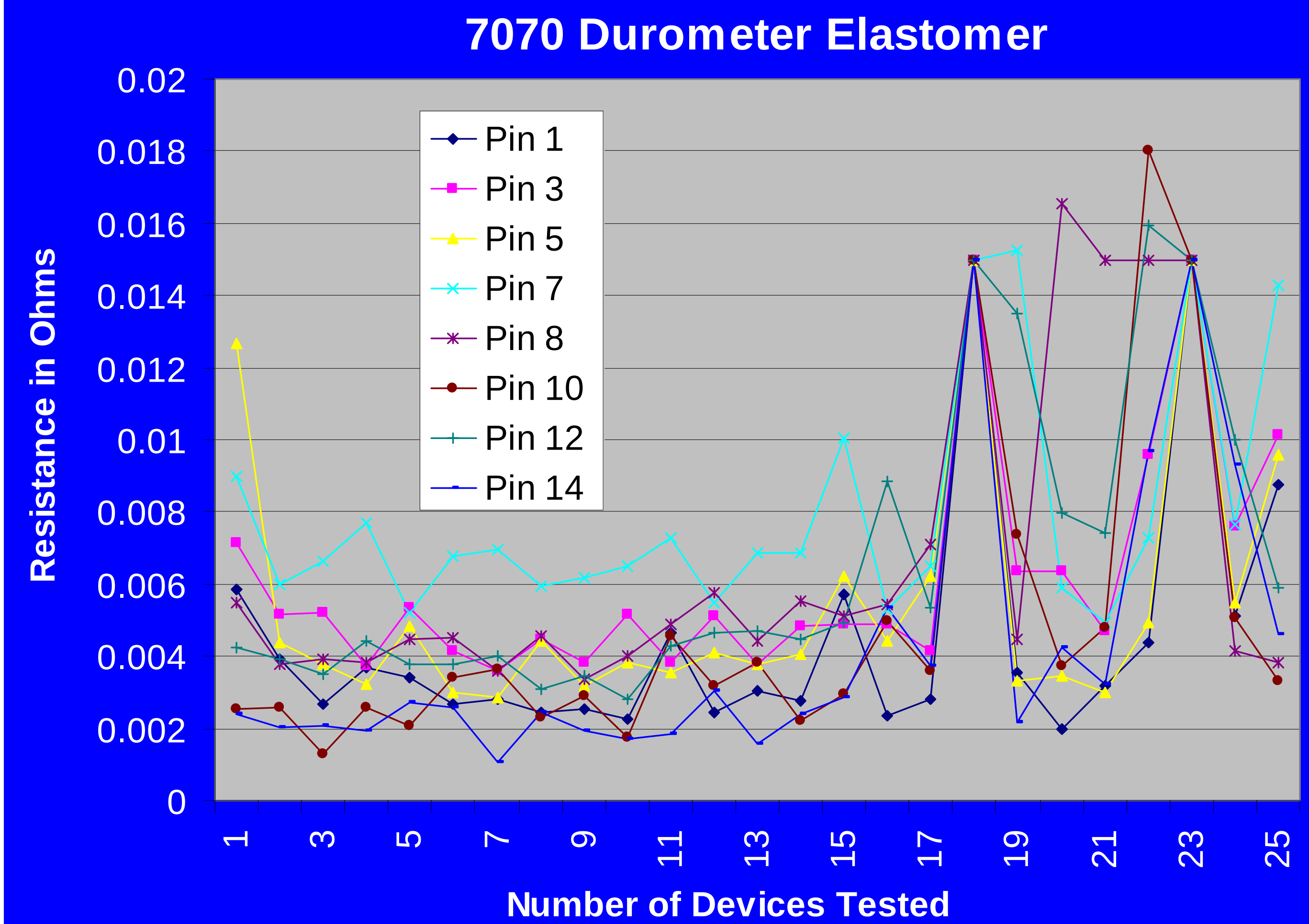
90% Sn 10%Pb
Tested at Plus 125º C.
Standard 2mm Contact Pins with a Polished Surface



- **Min 0.01062**
- **Max 0.01605**
- **Range 0.00543**
- **Median 0.03235**
- **Mean 0.01350**
- **Sample Standard Deviation 0.00112**
- **Average Deviation From Mean 0.00091**

- **The data spread is without spikes and is more predictable**
- **The mean is greater than that of a standard pin**

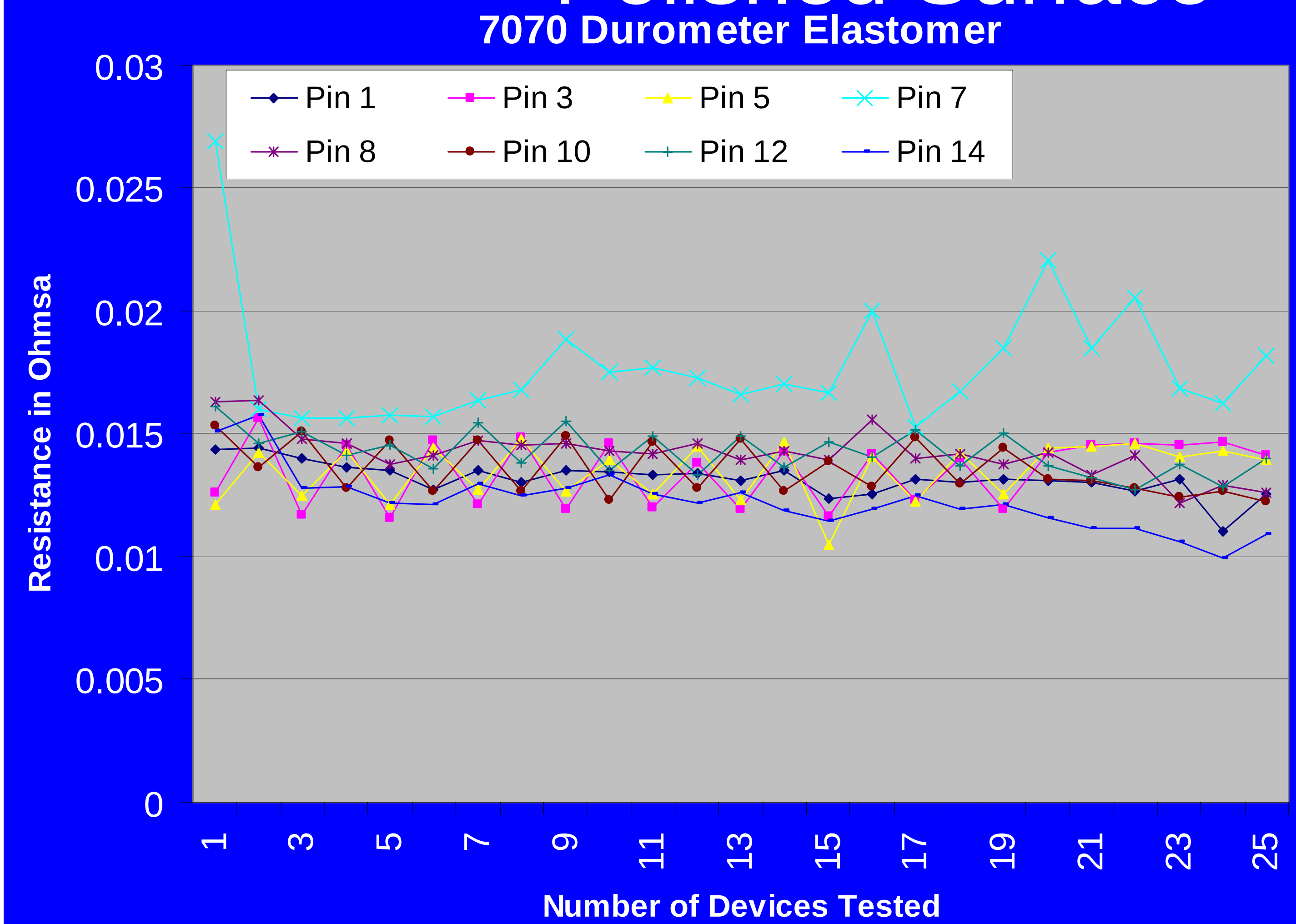
90% Sn 10% Pb Lead Plating Tested at Minus 40º C. Standard 2mm Contact Pins with a Polished Surface



- **Min 0.00107**
- **Max 0.01800**
- **Range 0.01693**
- **Mean .00584**
- **Sample Standard Deviation 0.00394**
- **Average Deviation From Mean 0.00292**

- **Contact pin resistance performance degraded**
- **The overall contact pin resistance is less with a distribution range increase**

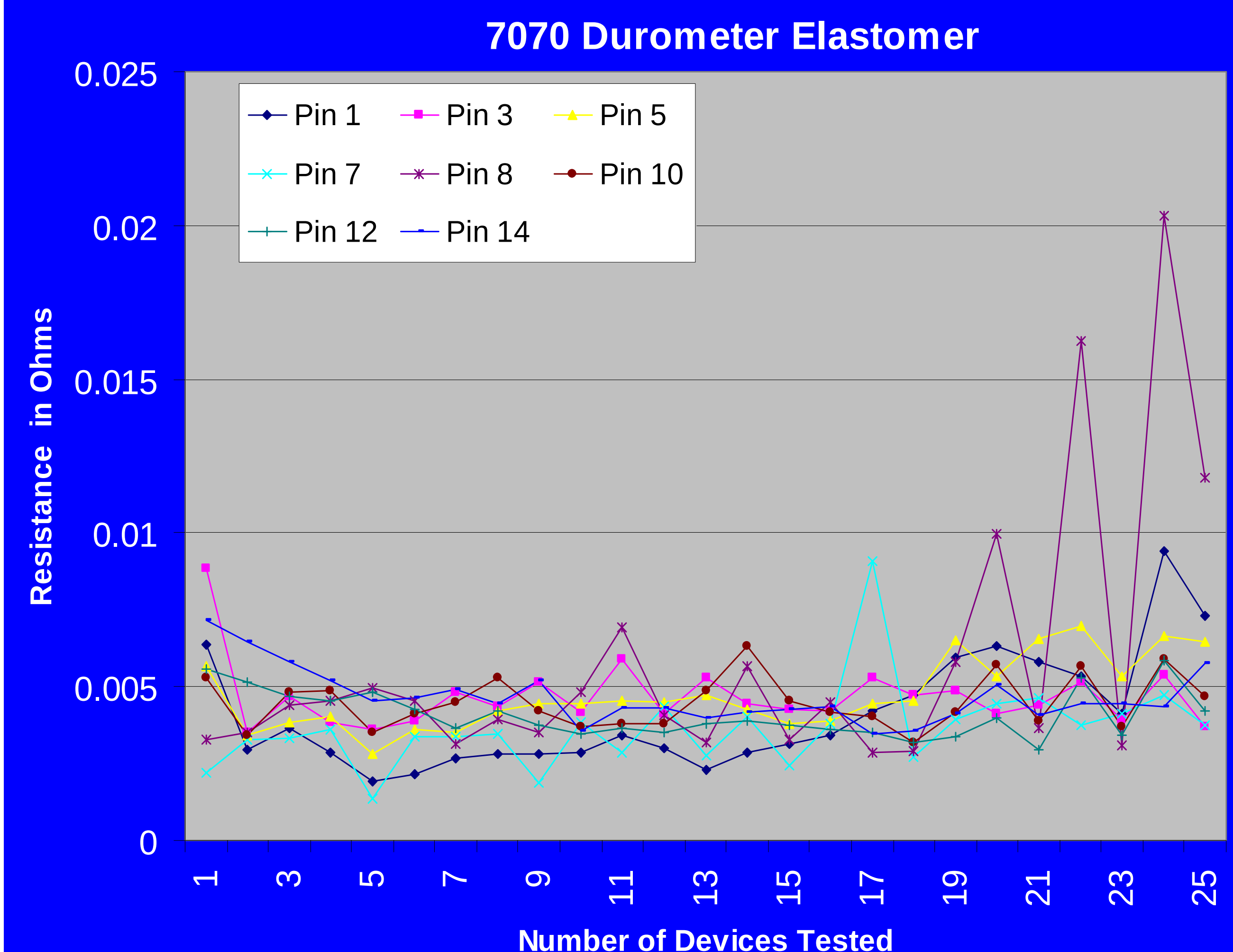
100% Sn Lead Plating
Tested at Plus 125º C.
Standard 2mm Contact Pins with a Polished Surface



- **Min 0.00996**
- **Max 0.02693**
- **Range 0.01698**
- **Mean 0.01402**
- **Sample Standard Deviation 0.00201**
- **Average Deviation From Mean 0.00139**

- **Pin 7 exhibited resistance higher than the rest**
- **We chose not to change it for the purpose of maintaining test group control**
- **The data is tighter and reliable within the range**

100% Sn Lead Plating Tested at Minus 40º C. Standard 2mm Contact Pins with a Polished Surface



- **Min 0.00134**
- **Max 0.02031**
- **Range 0.01897**
- **Median 0.00421**
- **Mean 0.00452**
- **Sample Standard Deviation 0.00196**
- **Average Deviation From Mean 0.00112**

- **Pin 10 exhibited increasing resistance over the life of the test**
- **We chose not to change it for the purpose of maintaining test group control**
- **The data is tighter and reliable within the range**

Conclusion

- Changes made to contact pin surface and elastomer durometer did show an improvement in contact pin resistance variance with high tin content solders
- A device lead with a 100% tin plating in combination with the harder durometer elastomer and polished pin surface appeared to perform better than standard pins
- Results show a predictable range of operation
- Results of this study are preliminary

Conclusion

- Contactor work with Pb-free is a top priority
  - More work is required including evaluation of:
    - Contact pin surface
    - Contact pin alloy
    - Pb-free solder alloy compatibility development work
    - Device insertion force/resistance curve analysis
    - Live field data is required with future work

The Effects of No Lead Solder Balls on Burn-in Socket Design Decisions

Motorola SPS

Mike Noel – Austin, TX

Don VanOverloop – Austin, TX

Daniel Wilcox – Austin, TX

K.Y. Yap – Kuala Lumpur, Malaysia

Wells-CTI

Tom Lyzinski – Phoenix, AZ

Keith Callahan – Phoenix, AZ

MOTOROLA

WELLS-CTI

A subsidiary of PCD Inc.

Introduction

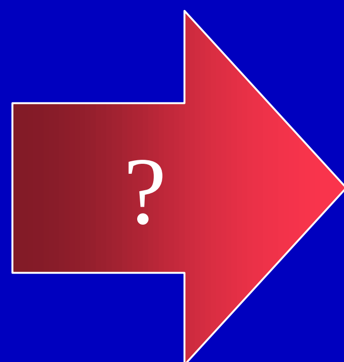
This paper summarizes the results of an evaluation to determine the relative impact of Pb and No Pb solder balls on socket performance with various contact platings and contact designs under simulated burn-in conditions.

Experimental Objectives

What we asked…

How Do These:

- **Ball Composition**
- **Contact Plating**
- **Contact Force**
- **Current**
- **Temperature**
- **Time**
- **Contact Types**



Influence These:

- **Contact Resistance**
- **Ball Sticking**
- **Witness Marks**
- **Ball Hardness**
- **Solder Transfer / Migration**
- **Ball Deformation**

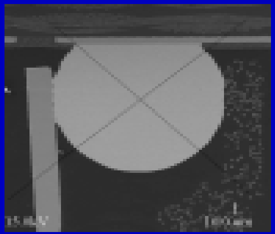
By examining the performance of different socket types and plating on Pb and No Pb solder balls, what can we learn?

Experimental Objectives

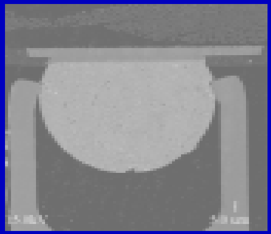
Experimental Outline

Solder Ball	Contact Type	Plating Type	Temp °C	Force	Current	Time (Hrs.)
Pb (A)	Spoon (1.0mm)	Au	35	100%	0 mA	0
No Pb (B)	Pinch (0.8mm)	PdNi	100	125%	50 mA	24
	Spring (0.5mm) Crown	NiBn	125			72
	Spring (0.5mm) V-Groove		150			168
						504

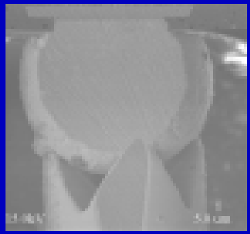
(A) Sn62/Pb36/Ag2
(B) Sn95.5/Ag4/Cu0.5



Spoon (1.0mm)



Pinch (0.8mm)



Spring (0.5mm) Crown

Overview of Experiment

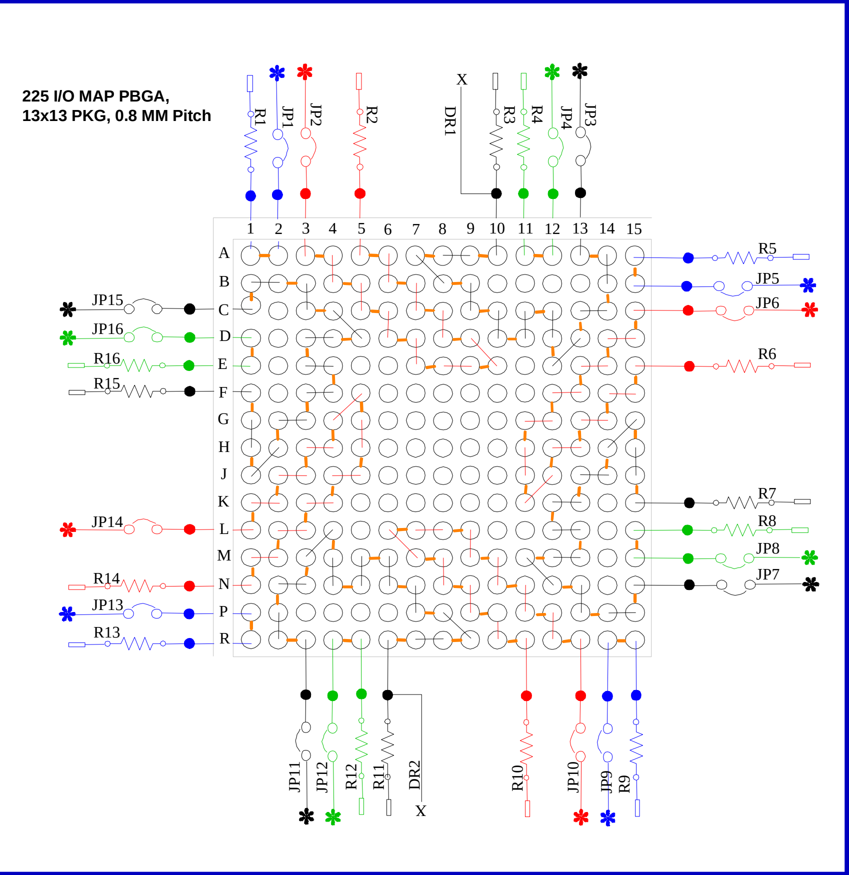
Evaluation Criteria

- Contact Resistance / Device Monitoring
  - Room temp tests, 2 and 20 ball chains (16 per socket)
  - Real time monitoring during bias burn-in (2 per socket)
- Ball Sticking
  - Instron force measurement of socket actuation
- Ball Deformation
  - RVSI scanning for diameter, coplanarity
- Witness Marks
  - Visual inspection, imprint measurement for various contacts
- Ball Hardness
  - Hardness testing of solder balls after experiment
- Solder Transfer / Migration
  - Visual inspection, cross sectioning and analysis of interfaces

Overview of Experiment

Test Methods

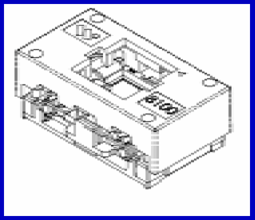
- ➢Packages
  - ➢ 208 BGA 17x17mm 1.0mm
  - ➢ 225 PBGA 13x13mm 0.8mm
  - ➢ 244 PBGA 12x12mm 0.5mm



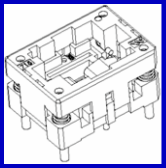
- ➢Daisy Chain Structures
  - ➢ 4 chains 2 ball W/ bias
  - ➢ 4 chains 2 ball non-biased
  - ➢ 4 chains 20 ball W/ Bias
  - ➢ 4 chains 20 ball non-biased

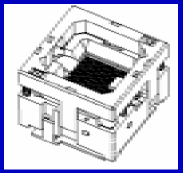
Overview of Experiment

Test Methods

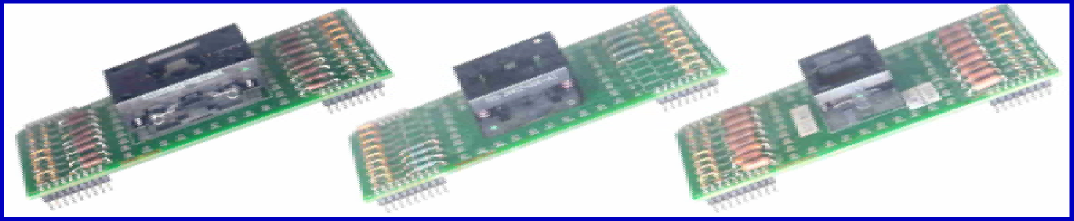


- Sockets
  - Wells-CTI - 8117-208AnE-00, Au, PdNi, NiBn
    - Spoon Contact
  - Wells-CTI - 777B1225-n02, Au, PdNi, NiBn
    - Pinch Contact
  - Wells-CTI - 715-24412-5nn, Au, PdNi, NiBn
    - Spring Contact (Crown, V-Groove)





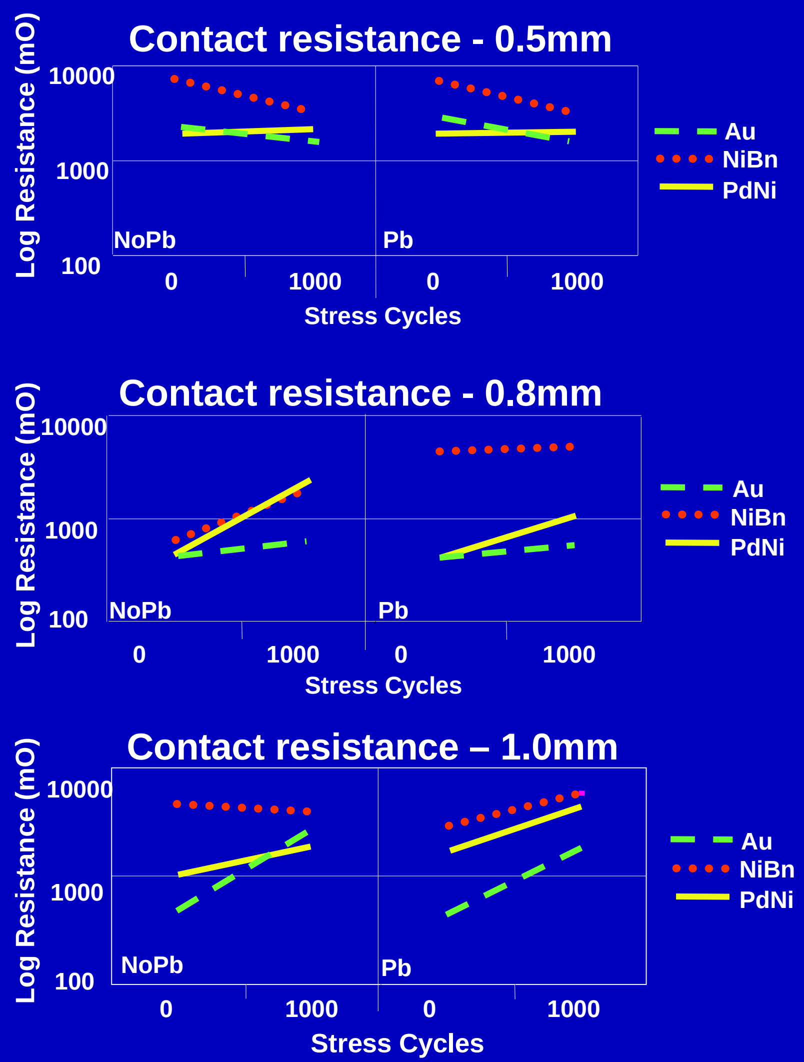
- Test Cards for each socket type



Experimental Detail / Analysis

Stage 1 Observations

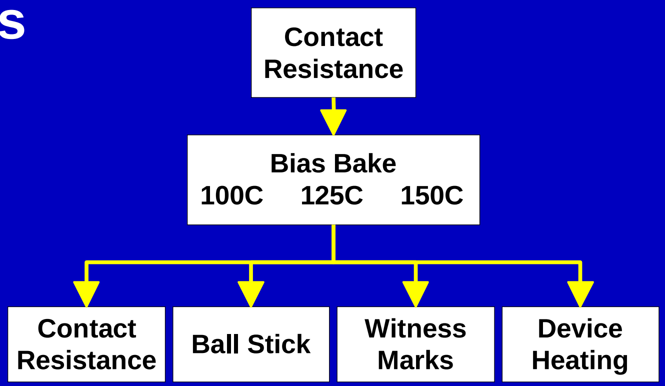
- Contact resistance after 0 cycles and 1000 cycles taken with same device
- Without bias or exposure to temp, contact resistance increased in most cases after durability testing
- Difference in behavior may be attributed to wipe and depth of penetration



Experimental Detail / Analysis

Stage 2 Objective

- Establish baselines for test conditions
- Confirm experimental parameters
  - Current
  - Temperature
  - Measurement techniques

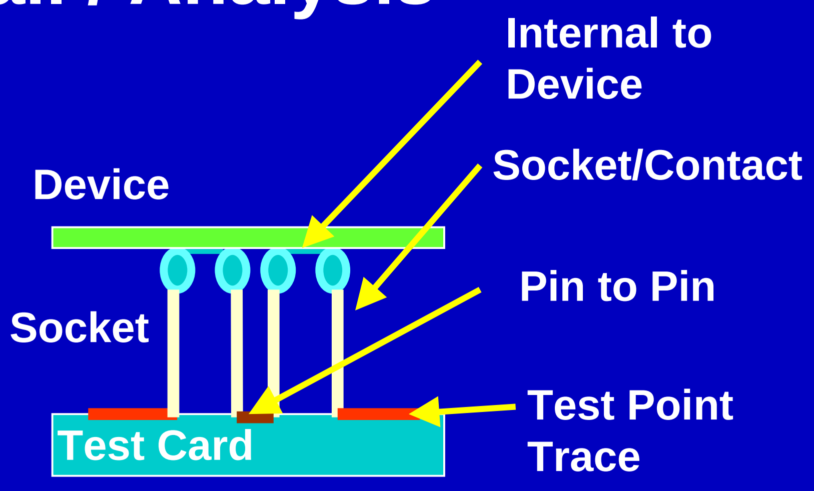


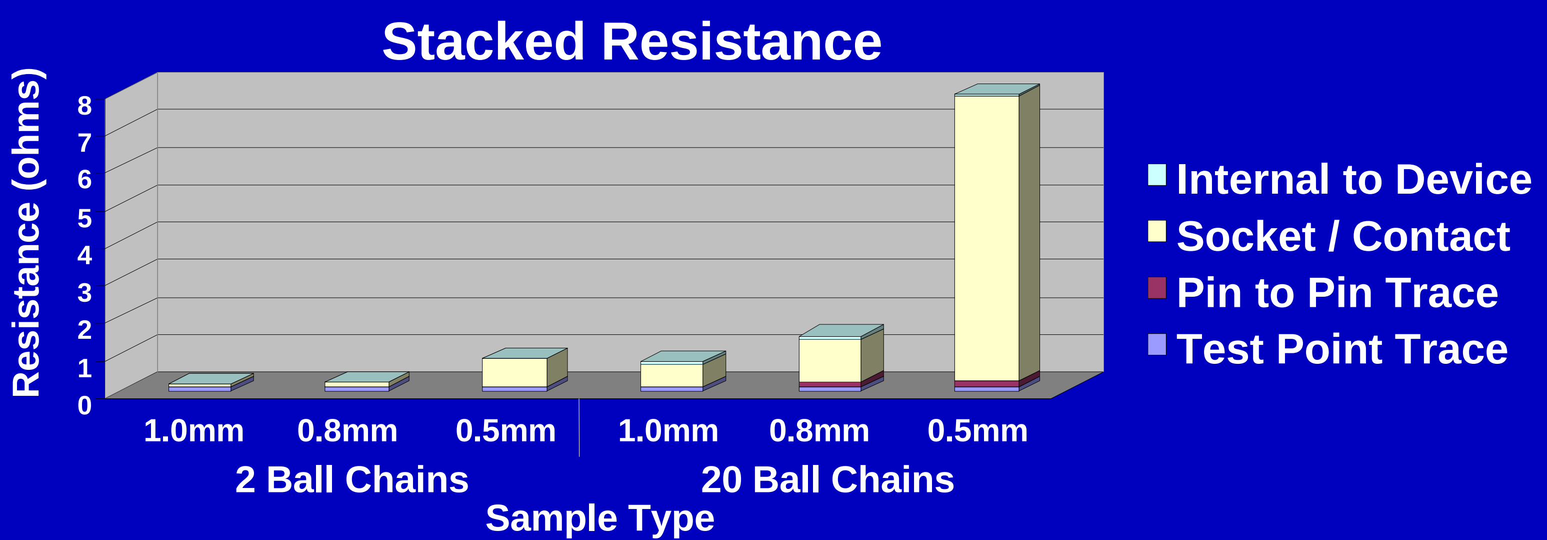
Solder Ball	Contact Type	Plating Type	Temp °C	Force	Current	Time (Hrs.)
Pb	Spoon (1.0mm)	Au	35	100%	0 mA	0
No Pb	Pinch (0.8mm)	PdNi	100	125%	50 mA	24
	Spring (0.5mm) Crown	NiBn	125			72
	Spring (0.5mm) V-Groove		150			168
						504

Experimental Detail / Analysis

Stage 2 Summary

- Contact Resistance
  - Initial readings consistent with expectations
  - Stacked up resistances identified
  - Resistance of 0.5mm spring contact significantly higher than 1.0mm and 0.8mm

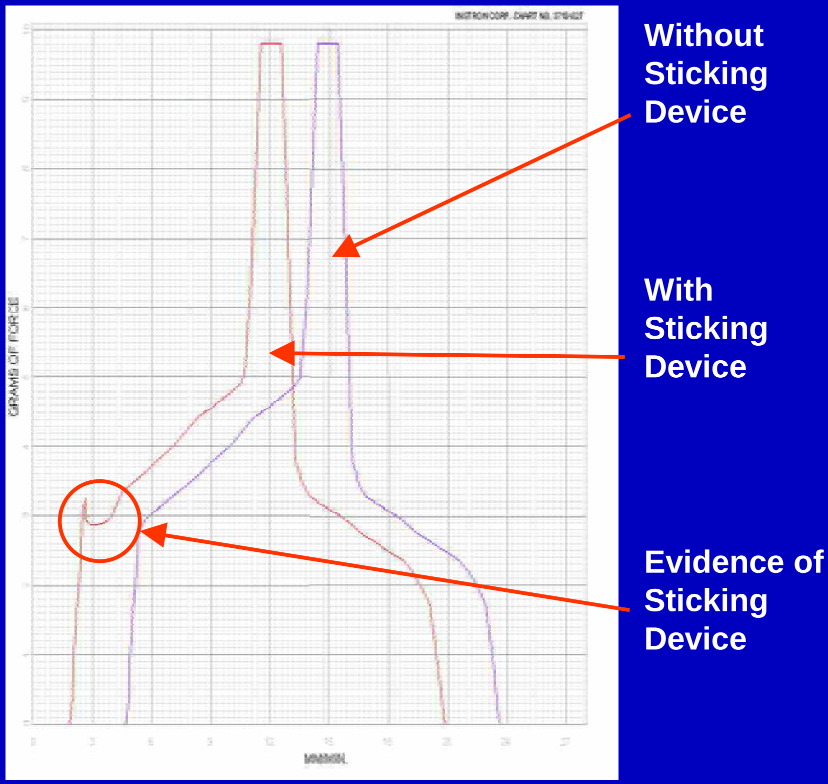




Experimental Detail / Analysis

Stage 2 Summary

- **Ball Sticking**
  - Pre and post stress measurements indicate sticking is clearly quantifiable
  - Socket actuation force curves were very consistent across socket family
- **Ball Deformation**
  - Metrics established for ball coplanarity and diameter
    - Average coplanarity of all balls on a device
    - Average diameters of all balls on a device

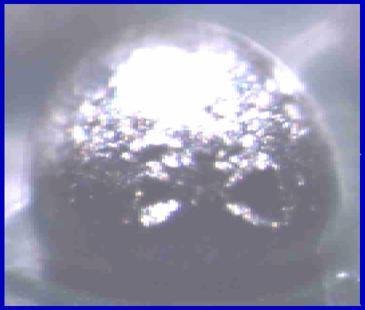


Example of force curve

Experimental Detail / Analysis

Stage 2 Summary

- Witness Marks
  - Witness marks clearly visible on all contact types
  - Surface area of witness mark used as criteria



0.8mm pinch witness marks

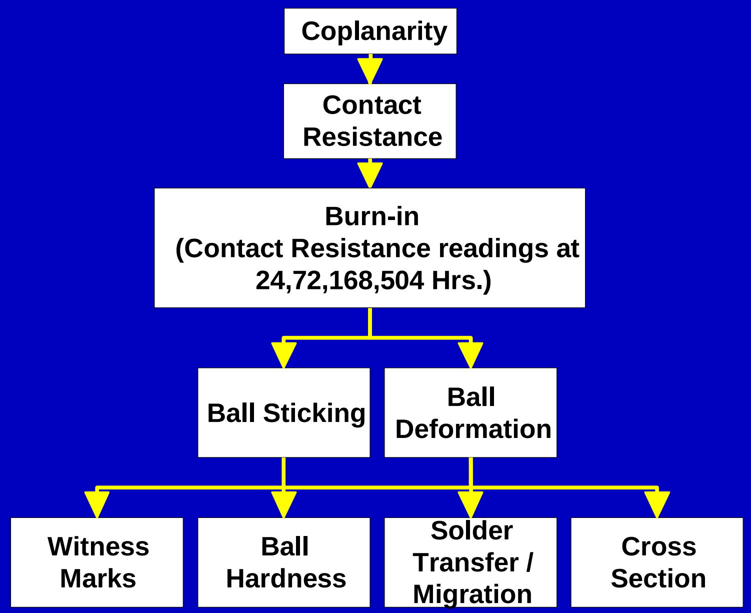
- Current Capability, Device Temperature
  - Temperature characterization established operating parameters for subsequent stages
  - 50 mA did not significantly increase device temperature

1.0mm spoon witness marks

Experimental Detail / Analysis

Stage 3 Objective

- **Evaluate time, temperature and bias in a typical qualification / production burn-in environment**
- **Parameters**
  - **Single device for entire test duration in each socket sample**
  - **Controls maintained (at room temp)**

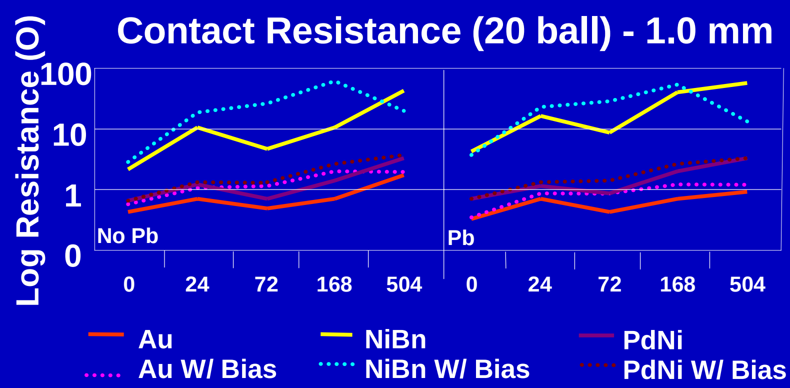


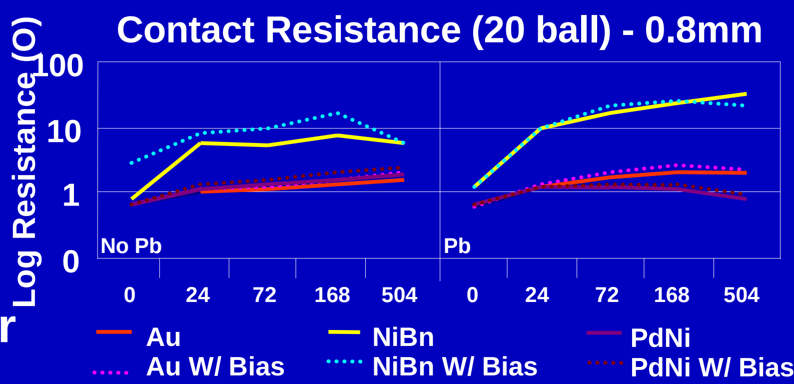
Solder Ball	Contact Type	Plating Type	Temp °C	Force	Current	Time (Hrs.)
Pb	Spoon (1.0mm)	Au	35	100%	0 mA	0
No Pb	Pinch (0.8mm)	PdNi	100	125%	50 mA	24
	Spring (0.5mm) Crown	NiBn	125			72
	Spring (0.5mm) V-Groove		150			168
						504

Experimental Detail / Analysis

Stage 3 - Summary

- Contact Resistance
  - Changes clearly identifiable
  - Trends consistent on long/short chains
  - Increases with and without bias over time in all cases
  - No significant difference between:
    - 0.8 mm and 1.0 mm sample trends
    - Pb and No Pb samples
    - Bias and No Bias chains
    - Au and PdNi
  - NiBn overall highly variable, high contact resistance
  - Resistance increased much quicker for controls (room temperature)
  - Scrubbing devices (actuation of socket or changing devices) most effective at reducing contact resistance for both Pb and No Pb samples

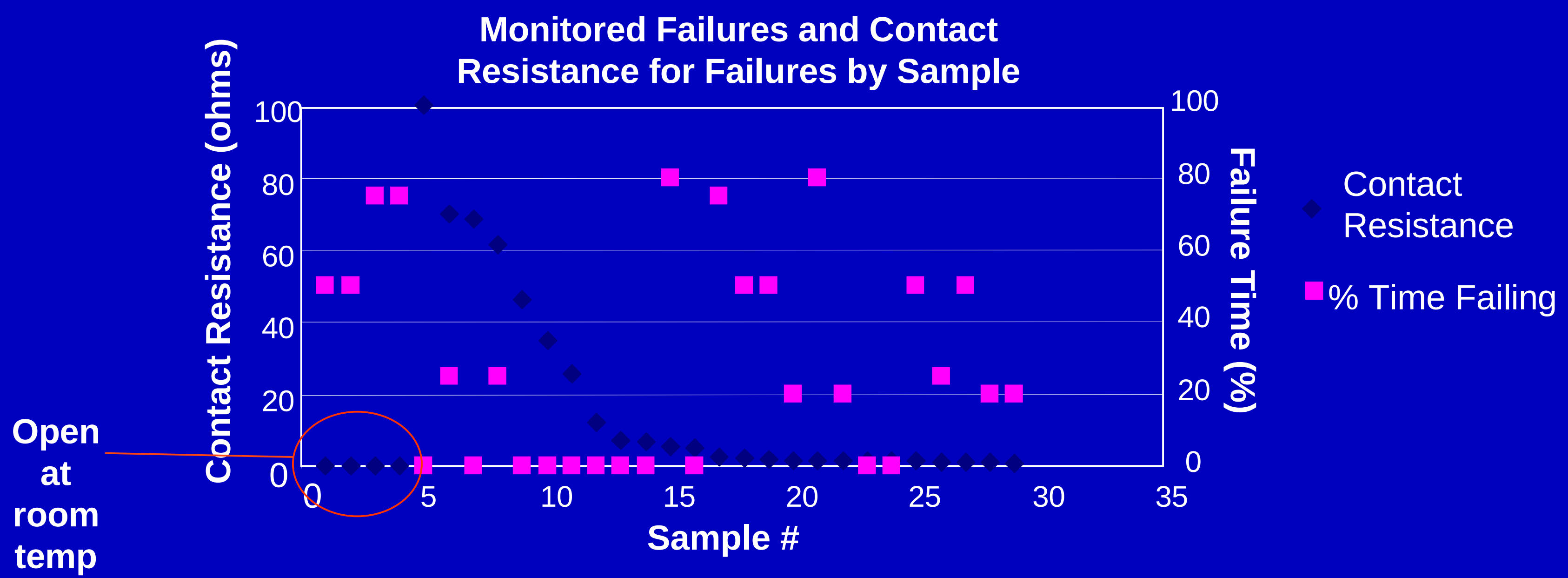




Experimental Detail / Analysis

Stage 3 Summary

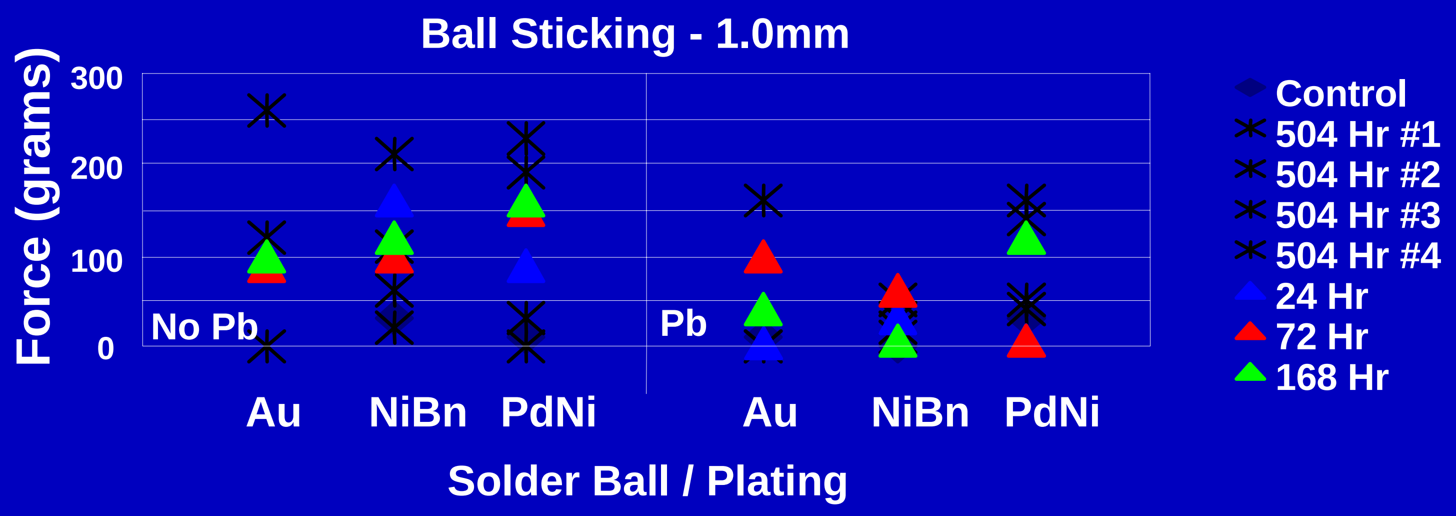
- **Burn-in Monitoring**
  - **Two 20 ball chains monitored real time for duration of test, no clear pattern with socket type or plating**
  - **High resistance readings at room temp did not correlate to opens under Burn-in conditions**
  - **Very small percentage of opens reported overall during Burn-in monitoring**



Experimental Detail / Analysis

Stage 3 Summary (Cont.)

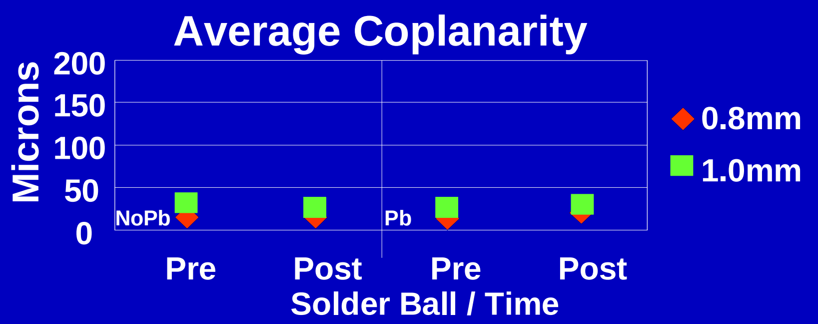
- **Ball Sticking**
  - **Large variation in ball sticking in all splits, but all appear to have increased over time**
  - **No Pb appears to have higher sticking**
  - **Samples exposed to high temperature clearly stuck more than controls**
  - **Au and PdNi contacts stuck more than NiBn**
  - **Ball sticking residue visible on both biased and unbiased contacts**

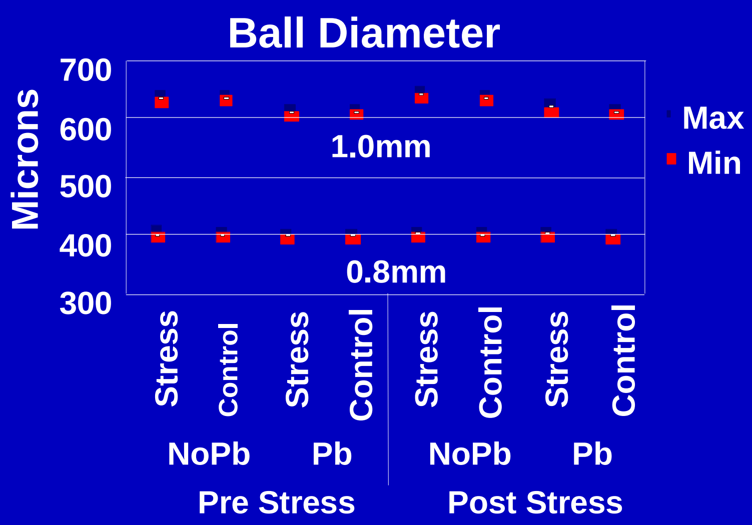


Experimental Detail / Analysis

Stage 3 Summary (cont.)

- **Ball Deformation**
  - **No significant difference between Pb and NoPb for coplanarity and diameter pre and post stress**
  - **All devices well within spec**
    - **200 micron change allowed for diameter and coplanarity on 1.0mm**
    - **100 micron change allowed for diameter and coplanarity on 0.8mm**
- **Overall: Minimal impact after stress to both ball diameter and coplanarity**

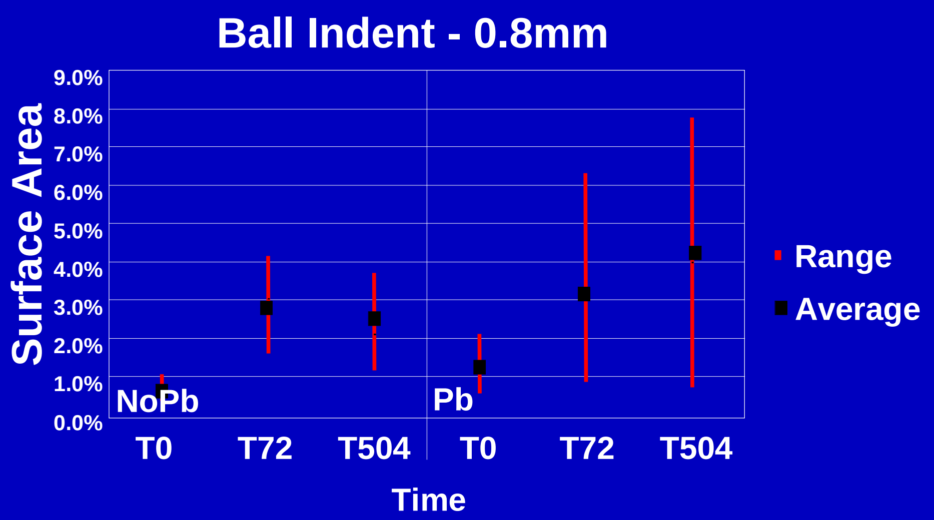


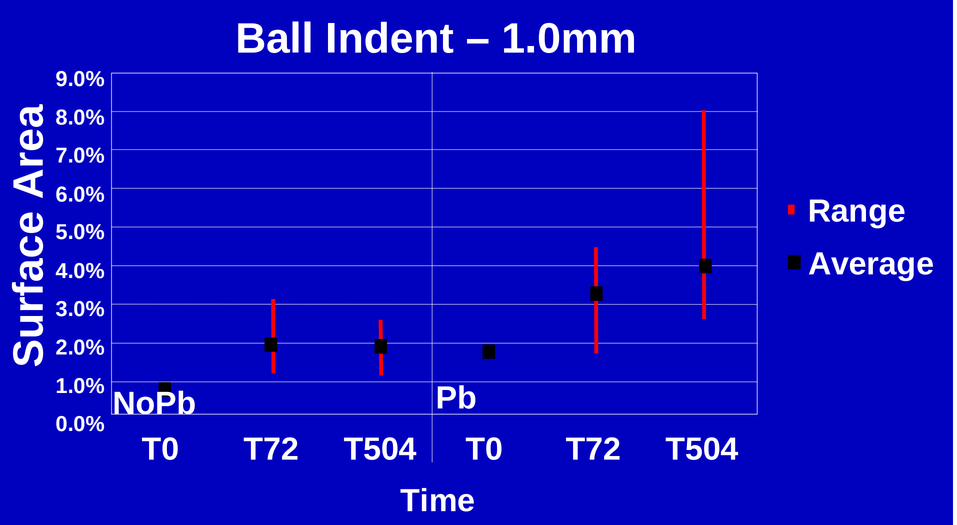


Experimental Detail / Analysis

Stage 3 Summary (cont.)

- Witness Marks
  - Witness marks much more evident on Pb than on No Pb (nearly 50% larger)
  - In general, witness marks covered very small percentage of surface area
  - Devices exposed to temperature had much larger witness marks for both Pb and No Pb samples, increased over time
  - Controls showed very little witness marks, similar in size between Pb and NoPb

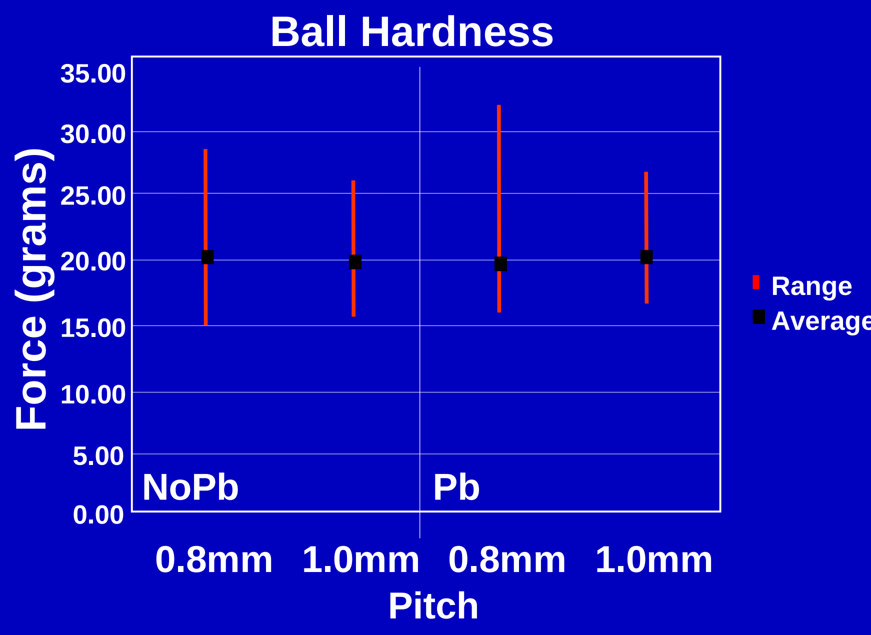


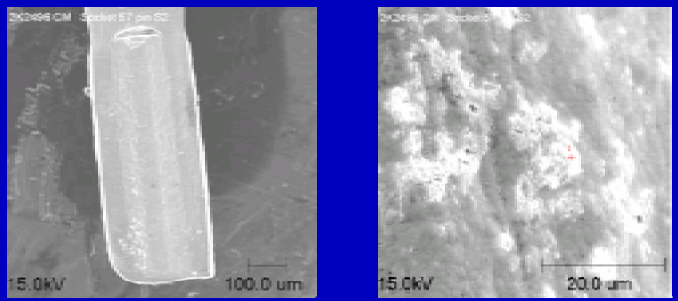


Experimental Detail / Analysis

Stage 3 Summary (cont.)

- Ball Hardness (Room Temp)
  - No significant difference due to:
    - Ball diameter (1.0mm and 0.8mm pitch)
    - Pb and No Pb samples
- Solder Transfer / Migration
  - Solder transfer observed on several samples.
  - Minimal initial evidence of migration in Au or PdNi contacts at T504 (Continuing analysis of migration at this time).



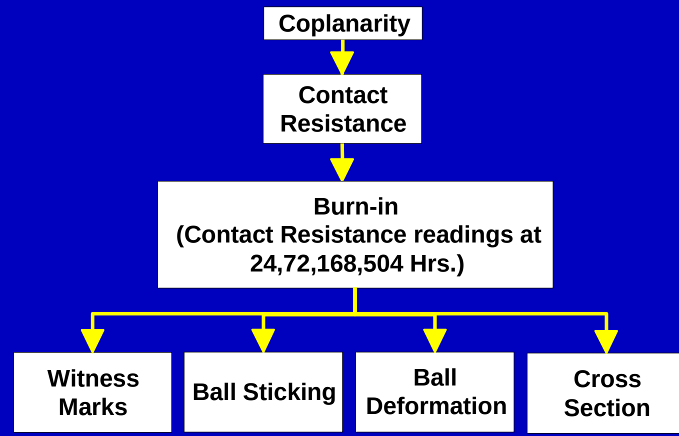


Examples of Solder transfer to spoon contact

Experimental Detail / Analysis

Stage 4 Objective

- **Evaluate 100% and 125% force**
- **Evaluate 0.5mm spring contacts (Crown and V-groove)**



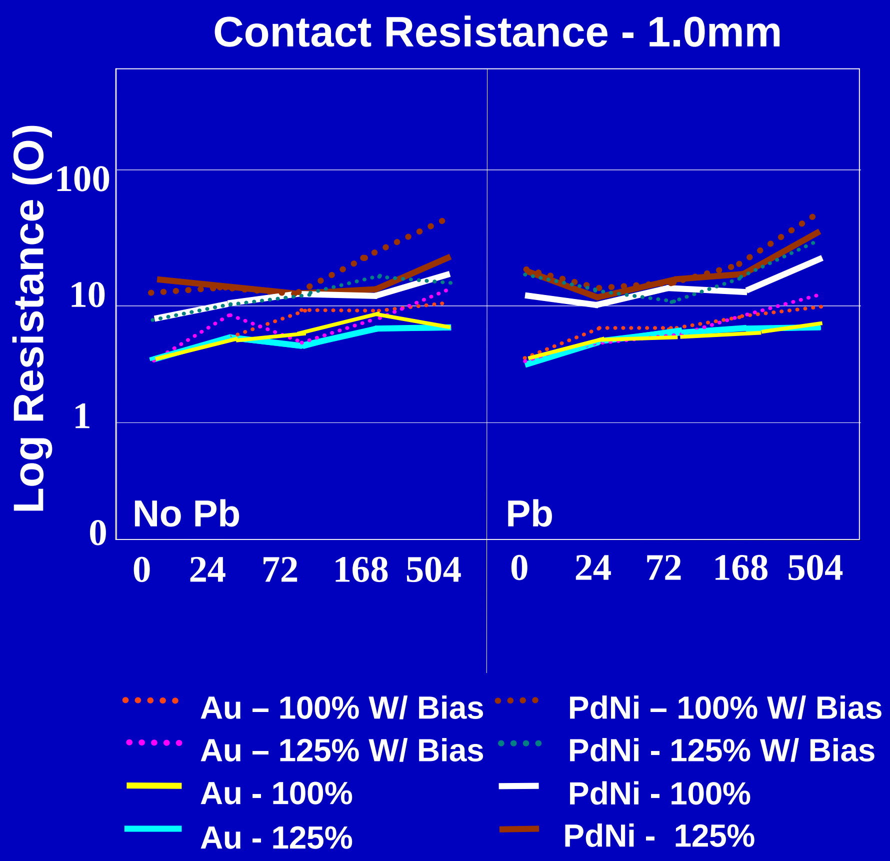
- **Parameters**
  - **Devices changed between readings**
  - **Contact resistance readings before and after each time interval (with fresh device)**
  - **BI Temperature 125°C**

Solder Ball	Contact Type	Plating Type	Temp °C	Force	Current	Time (Hrs.)
Pb	Spoon (1.0mm)	Au	35	100%	0 mA	0
No Pb	Pinch (0.8mm)	PdNi	100	125%	50 mA	24
	Spring (0.5mm) Crown	NiBn	125			72
	Spring (0.5mm) V-Groove		150			168
						504

Experimental Detail / Analysis

Stage 4 Summary

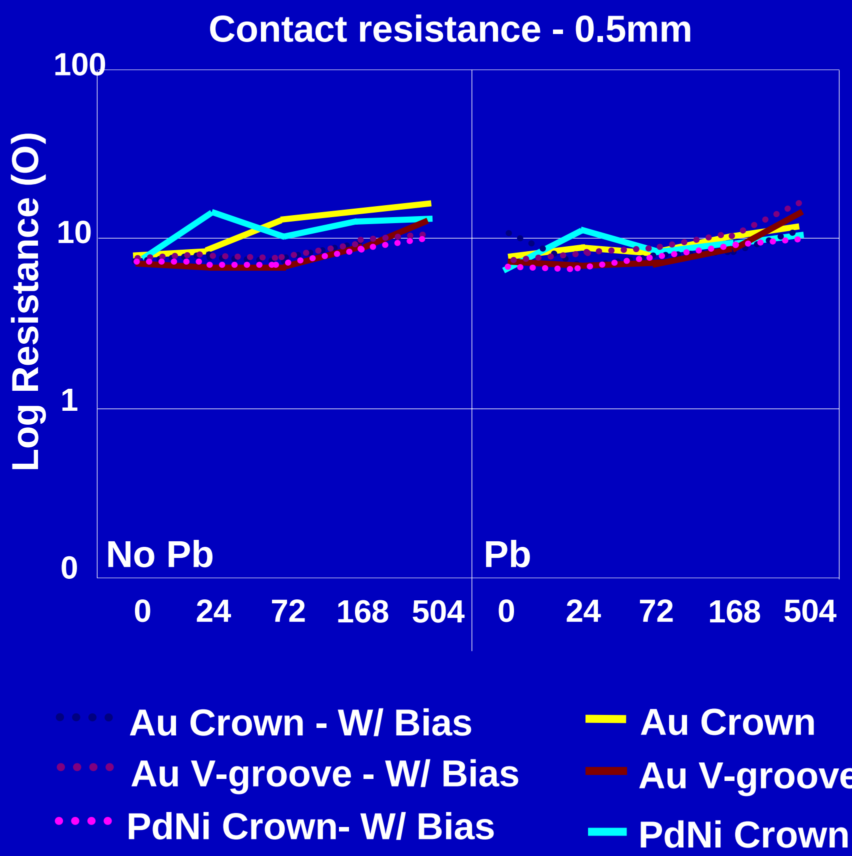
- Contact Resistance (1.0mm)
  - Increases in contact resistance with and without bias over time in all cases
  - No significant difference between:
    - Pb and No Pb samples
    - Bias and No Bias chains
  - PdNi worse in all cases than Au
    - Difference between Au and PdNi visible, possibly because of fresh devices at each reading?
  - 125% force appears to lower overall contact resistance rate of increase over time on both plating types



Experimental Detail / Analysis

Stage 4 Summary

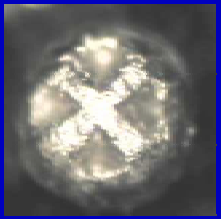
- Contact Resistance (0.5 mm)
  - Overall resistance much higher with spring contact (both Crown and V-groove)
  - PdNi and Au very similar in all cases
  - Overall resistance much less variable than other contact types
  - Crown contact slightly more variable on NoPb samples



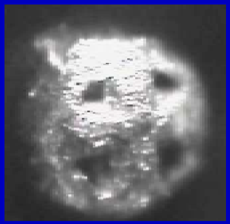
Experimental Detail / Analysis

Stage 4 Summary

- **Witness Marks**
  - Differences between Pb and No Pb were significant
  - Multiple insertions had largest impact on total deformations
  - Witness marks across all balls of each sample device were very consistent
  - Wide variation in witness marks between samples
- **Ball Sticking**
  - Crown contact with Pb worst sticking

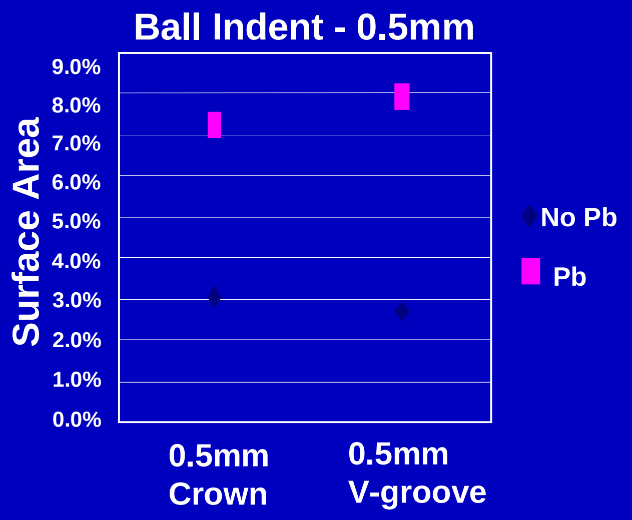


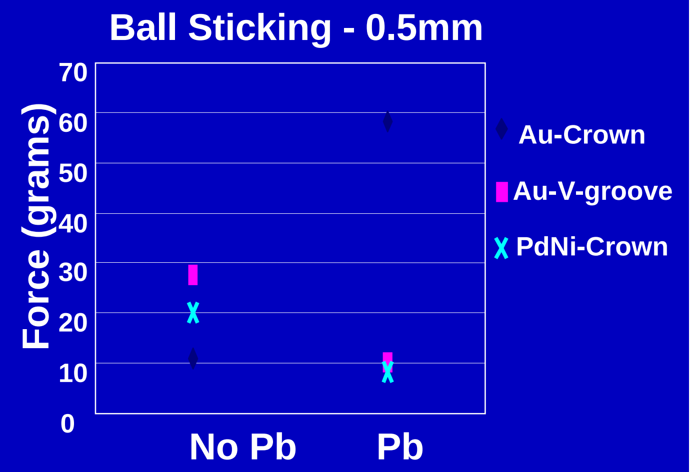
0.5mm Crown witness marks



0.5mm Crown witness marks

0.5mm V Groove witness marks





Summary of Observations

General Observations

- **Contact resistance for Pb and No Pb similar at room**
- **Contact resistance for Au and PdNi similar for Pb and No Pb**
- **Contact resistance for 125% force appears to decrease over time on Au and PdNi**
- **Ball sticking worse on No Pb than on Pb for 1.0mm and 0.8mm**
- **Ball sticking on 0.5mm with Au worst on Pb (also largest witness marks)**
- **Ball sticking increases over time at temperature**

Summary of Observations

- **General Observations**
  - **Ball deformation (coplanarity and diameter) were not impacted in this experiment**
  - **Ball hardness similar for Pb and No Pb at room temperature**
  - **Witness marks on Pb larger than on No Pb (Pb balls soften at temperature)**
  - **Witness marks largest on 0.5mm contacts, followed by 1.0mm, then 0.8mm**
  - **Solder transfer evident on Pb and No Pb samples on all Au and PdNi contact types**

Summary of Observations

- **Further Study**
  - **Extend cycles to simulate longer "life" use of typical socket in production**
  - **Extend evaluation of 125% force on NoPb**
  - **Additional ball sticking tests**
  - **Ball hardness at temperature**

Conclusions

- Overall performance of existing socket contact and plating for No Pb solder is similar enough to performance with Pb solder that we do not believe dramatic changes in burn-in socket technology are necessary. Increased sticking of No Pb solder balls and long term performance both need further investigation.

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