BiTS™

Burn-in & Test Socket Workshop

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

ARCHIVE

Burn-in & Test Socket Workshop TM

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Session 7
Wednesday 3/10/04 8:00AM

DEFORMATION AND CONTAMINATION

“Effects Of Contaminants On Test Pad Surfaces”

Therese Souza – Rika Denshi America, Inc.

“Effects Of Solder Ball Deformation On Interconnect Quality And Reliability”

John Caldwell – Micron Technology, Inc.

“Testing Of VQFN With Palladium Cobalt Pogo Pin”

Thuan-Lian Chua – Infineon Technologies
Jayachandrian – Infineon Technologies **Dieter Schuetz** – Infineon Technologies

Effects of Contaminants on Test Pad Surfaces

Identifying A Potential for Yield Loss

Author:

Therese Souza, Rika Denshi America

Historical

- Contamination recognized as a problem by Bell Labs
  - Problem identified in assembled products
- Separable connectors and wiping effectiveness
  - Displacing contamination
  - Complicates contact design
- A real & serious problem for microelectronics

Possible Contaminants

- Handling – skin oils, flakes of skin, smoke, dust
- Packaging – residues from plastic bags
- Process chemicals – plating residues, solder flux, tap water, cleaners, oils, outgassing from plastic fixtures
- Storage & environmental gases - hydrocarbons, sulfides

Challenge for Contactors

Smaller test probes have decreased surface area, normal force, and operating/testing voltages.

These factors lead to:

Increase in sensitivity to surface contamination

Symptoms of Contamination

- Failure or erratic data at electrical testing
- May pass initial testing but fail at a later date

Note: In each case the product passes tests after cleaning

Example using resistance measurements:

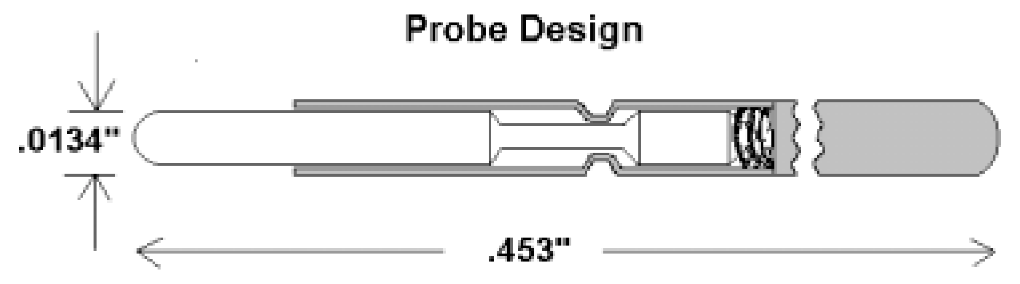
- Initial resistance is high or erratic – decreases with cycling or with increased normal force

Yield Loss, 0.1%

Opportunity lost per 1,000,000 devices tested

Cost of Device, $	Opportunity Lost, $
1000	1,000,000
750	750,000
500	500,000
100	100,000

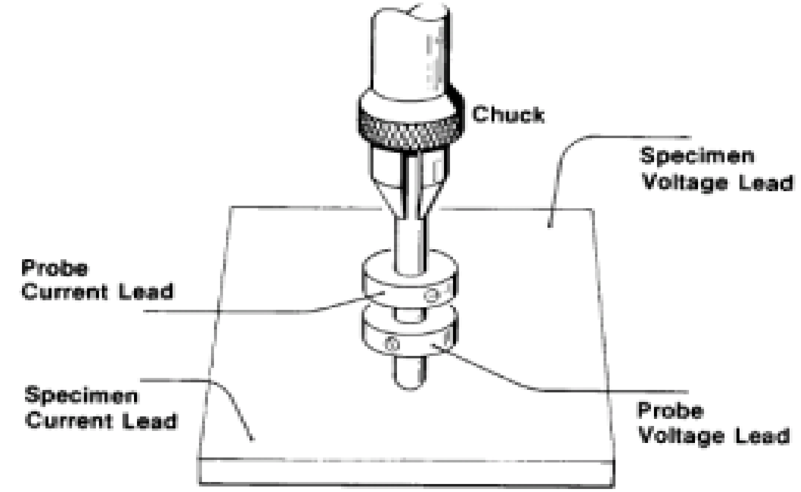
Experiment



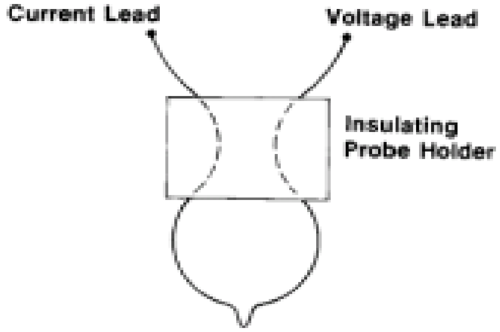
- 50 test probes
- 50 cycles per test
- 7 test samples (blocks)
- Resistance before and after contaminating test samples
- Contact force 62 grams
- Plunger tips cleaned
- Based on ASTM B667-97
- Cannot prevent vibrations

ASTM B667-97

- 4-wire contact resistance method
- Effects of films on conductive surfaces
- No wipe or vibrations
- Produce normal force vs. resistance curve



(a) *Rod Probe* with hemispherical end and having the voltage lead secured as close as possible to the point of contact



(b) *Wire Probe*

FIG. 1 Arrangement of Current and Voltage Leads to Probe and to Specimen (Typical)

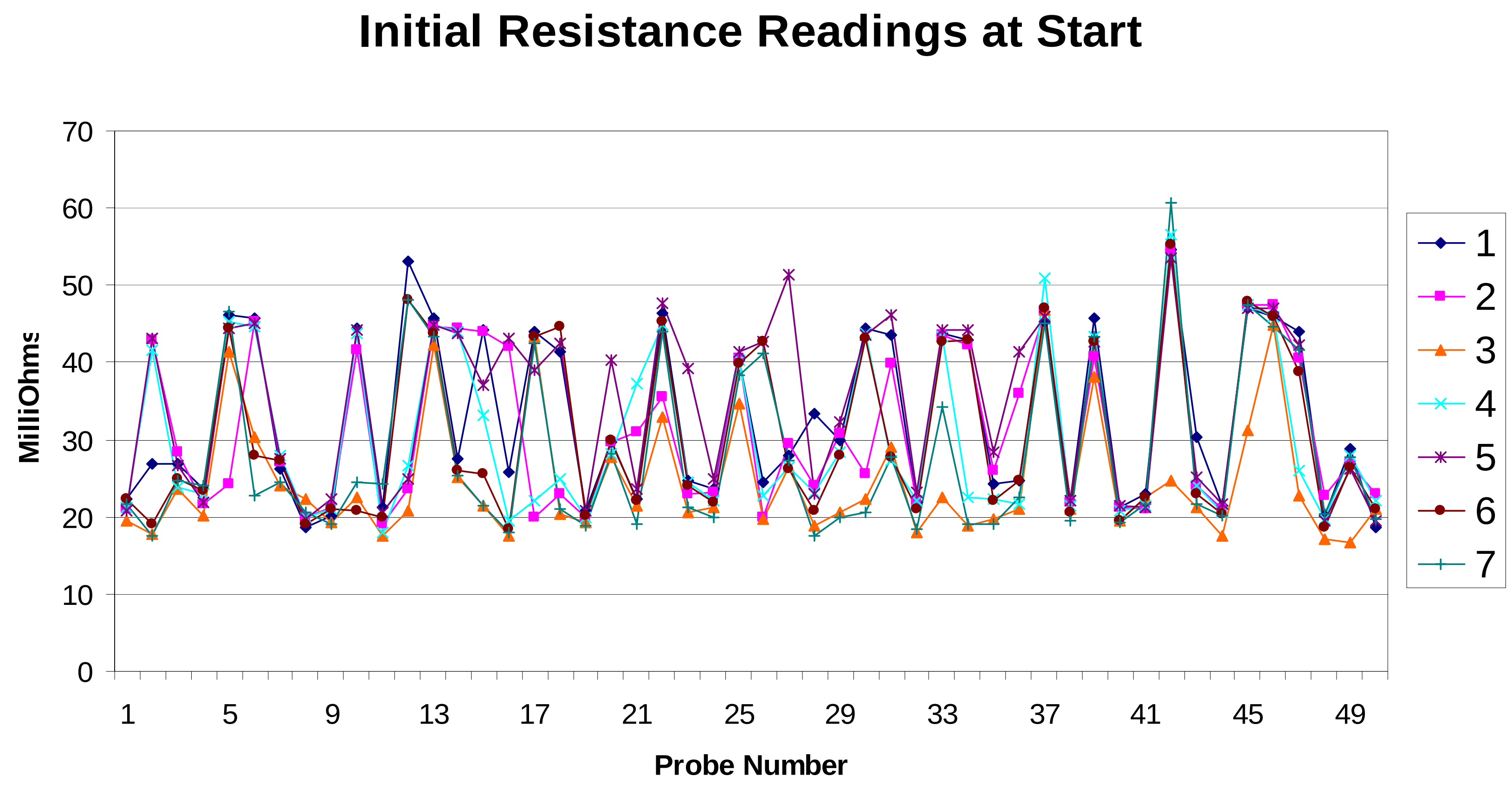
Cycle Tester

Selected Contaminants Applied to Test Surface (Block)

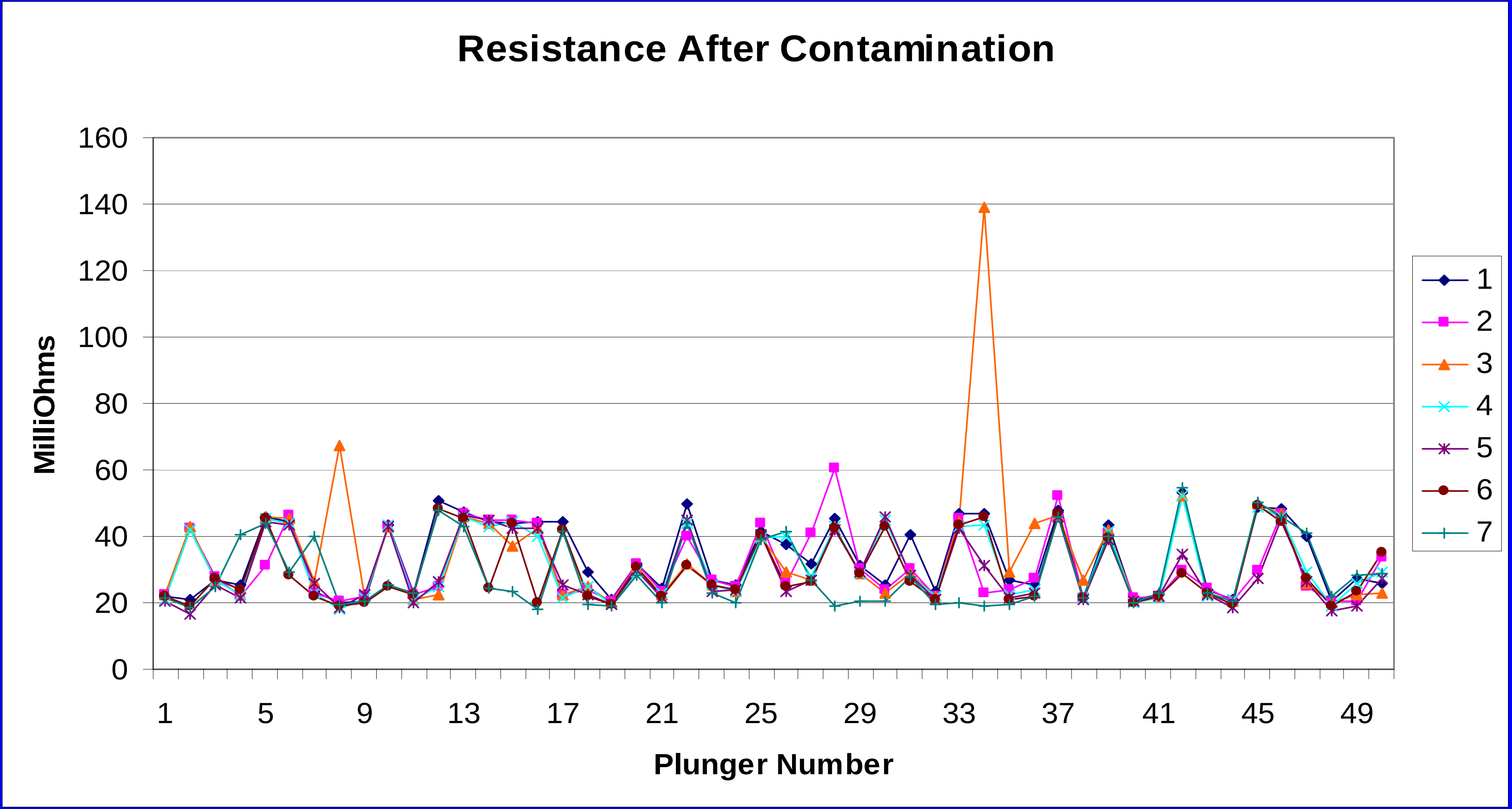
Test Surface has a copper base plated with 1 micron of nickel then .75 micron of hard gold.

1. Tap Water
2. Skin Oils
3. Dust
4. Storage in Plastic Bag, 24 hours, 100 ^{o}F
5. No Clean Flux (ORL-O), 250 ^{o}C, 5 minutes
6. Cigarette Smoke
7. Control – not contaminated

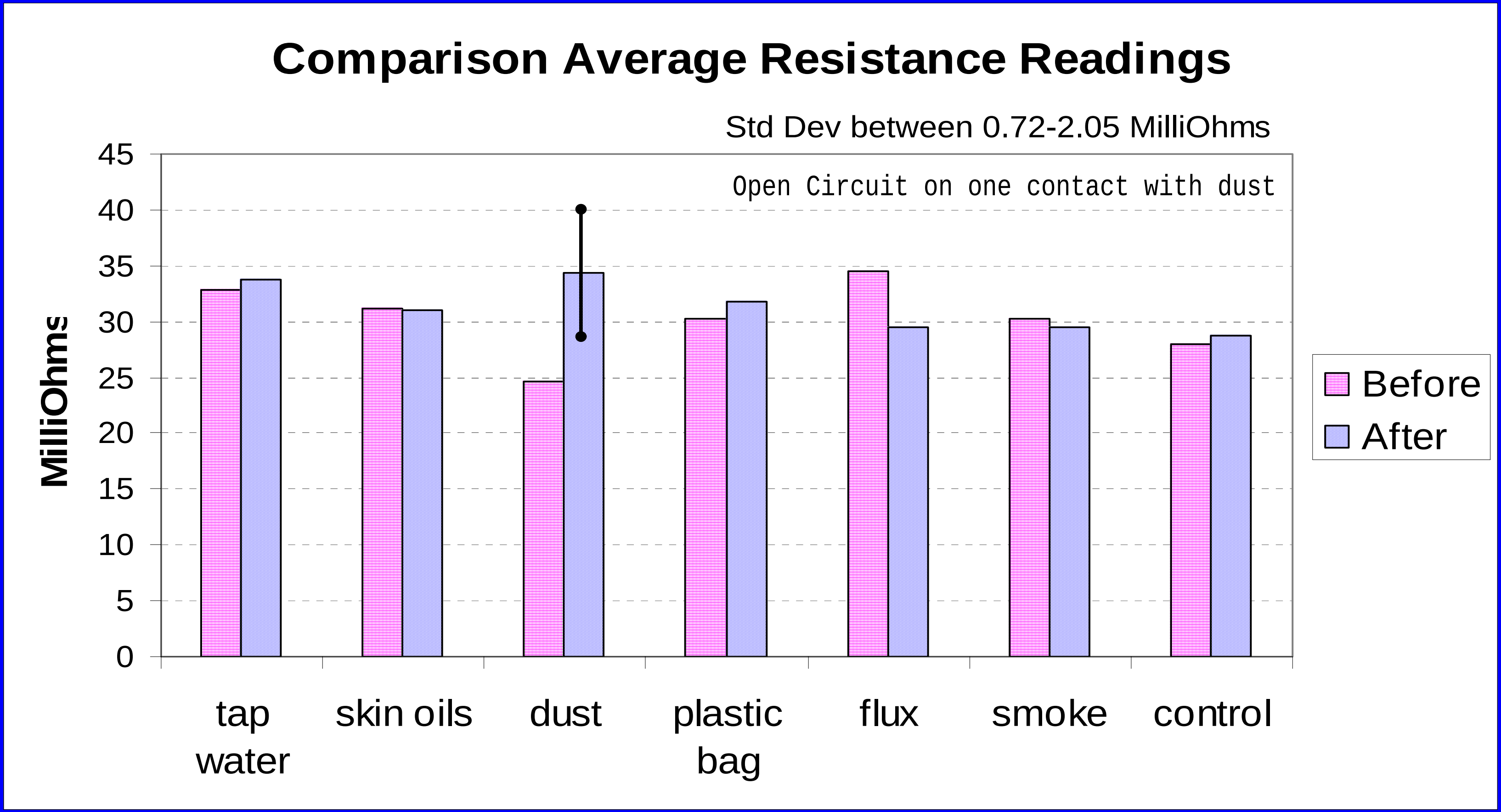
Before Contamination



After Contamination



After Contamination



Cleaning

- Identify the contaminant
  - ESCA, Auger… etc
- Test several cleaners or processes.
  - Do not assume that a cleaner is “safe” and will not leave contaminants
- Plasma cleaning
- Vacuum instead of high pressure air

Contamination Prevention

- Prevention is better than repair
- Program that:
  - Identifies potential sources of contamination
  - Includes process steps that prevent or repair contamination
  - Routine testing for clean surface
    - UV lights
    - Ionic contamination testing

Conclusions

- Surface contamination can affect electrical testing
- Potential contaminants can be identified
- Contamination can be prevented with a proactive plan
- Repair is possible with right process

References

- Robert S. Mroczkowski, ***Electronic Connector Handbook***, McGraw-Hill 1998

- ***Outgassing of Engineering Plastics In High-Vacuum Applications*****,** **http://www.boedeker.com/outgas.htm**

- H. W. Hermance and T. F. Egan, **“Organic Deposits on Precious Metal Contacts”,** *The Bell System Technical Journal,* May 1958, pp 739-776.

References

- **T. F. Egan, *Ionic Contamination*,** Plating, April 1973
- ***Rinsewater Quality….Hard Data*,** http://www.pcbfab.com/rinsew.html
- Piet van Dijk, ***Critical Aspects of Electrical Connector Contacts****;* http://www.pvdijk.com/images/21thiceccriticalaspects.pdf

Effects of Grid Array Ball Deformation on Solder Joint Quality and Reliability

2004 Burn-In and Test Socket Workshop

March 7–10, 2004

John Caldwell
Test R&D Engineer
Micron Technology, Inc.

Agenda

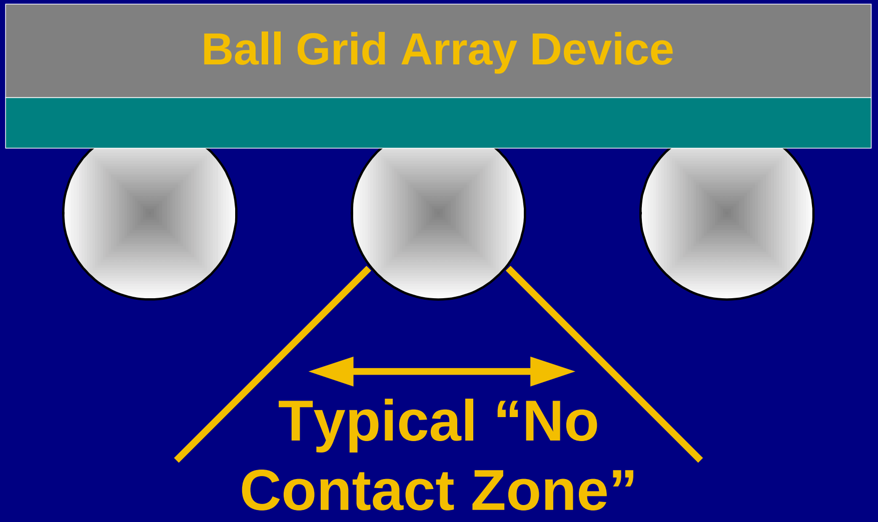
- Industry concerns & opposing arguments
- The “No Contact Zone”
- Design of experiment
- Device coplanarity
- Solder joint quality and reliability
- Follow-on research
- Q&A

Background

- **Industry concerns**
  - Entrapped flux and contaminates may cause voids in the BGA solder joint during SMT reflow
  - Deformation on the upper hemisphere of the solder ball may cause coplanarity error
  - Cosmetics (??)
- **Opposing arguments**
  - Solder ball contamination/residual flux, PCB land contamination, reflow oven profile, and solder paste/flux chemistry have a profound impact on voiding [1]
  - Voided solder joints have been shown to perform *better* during reliability testing [2]
- **<u>Bottom line</u>: The surface mount process MUST be done right**

The “No Contact Zone”

- **Some semiconductor producers adhere to a “no contact zone” policy**
  - Require test socket suppliers to provide alternate solution
  - Semiconductor producers may address within their own process (i.e. post electrical test reflow)
- **Is this really necessary?**



Design of Experiment

- **SDRAM devices contacted repeatedly, then segregated into “damage level” groups**
  - Sample set = 300 SDRAM fBGA’s per damage group
  - One “contact” = One insertion into *each* of the *three* contact styles (crown, cup, pincher)
- **Device packages laser scanned for packaged component dimensions (coplanarity, etc.)**
- **Damage level groups randomized and assembled onto dual in-line memory modules (DIMM)**
- **Initial module failures investigated for *possible* correlation to preexisting solder damage**
- **Passing modules reliability tested up to 3,250 temperature cycles**
- **Failure verification post temperature cycle**

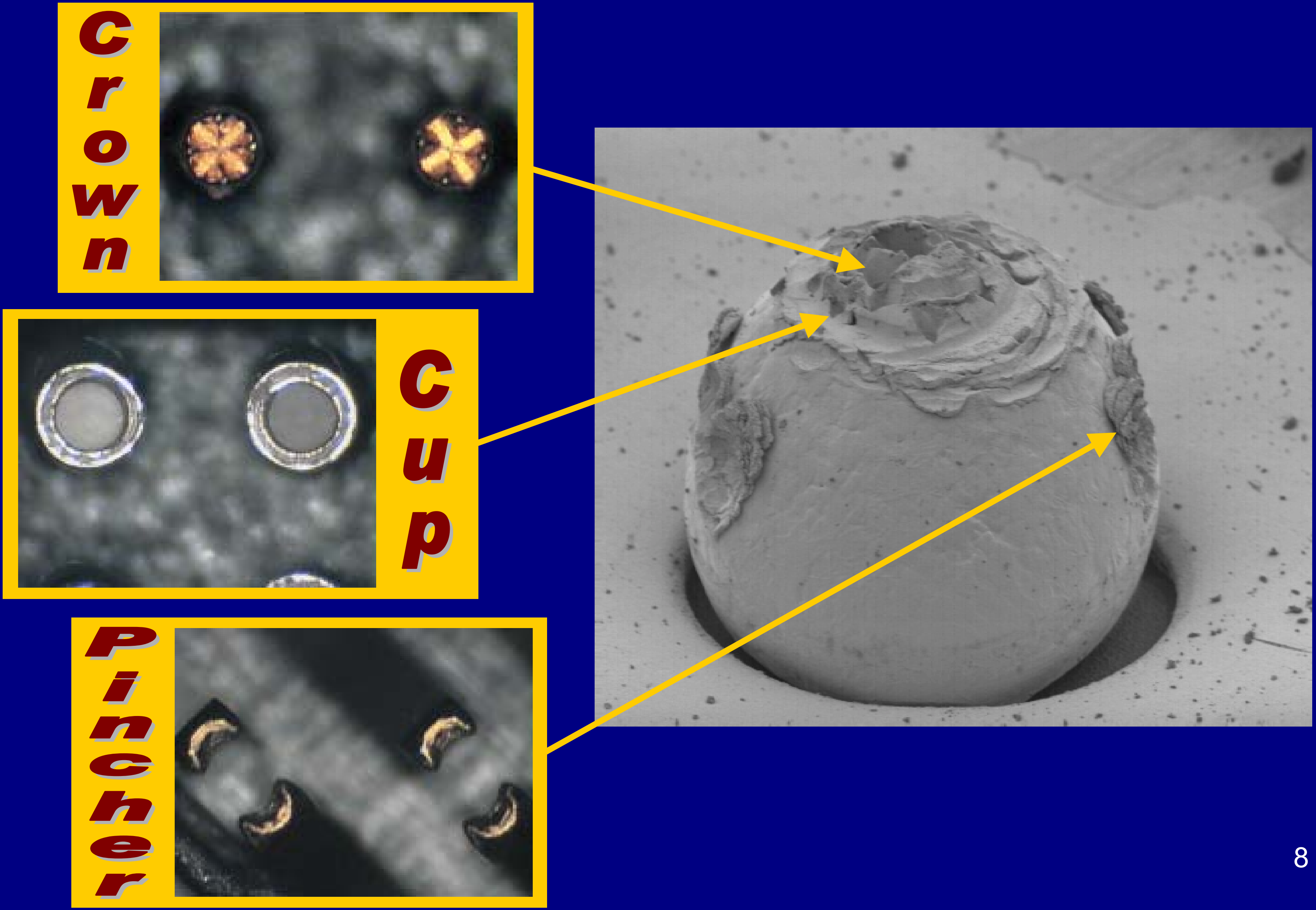
Materials & Process

Device Size (mm):	8 x 16
Solder Balls:	60
Pitch:	0.8mm
Device Package:	Board-on-Chip (BOC)
Solder Ball Diameter:	0.40mm
Land Pad Diameter:	0.33mm
Solder Composition:	63% Tin/37% Lead
PCB Attach Medium:	Eutectic Solder Paste
Reflow Profile:	Standard (215°C peak)

Build & Test Parameters

- **Memory module**
  - 8-component DIMM
  - 6-layer FR4
  - PCB thickness = 1.27mm
  - PCB length = 133.35mm
  - PCB height = 31.75mm
- **System level motherboard test to gauge time-zero module quality**
- **Reliability test**
  - -40°C to +85°C, air-to-air, two cycles per hour

Excessive Solder Deformation?

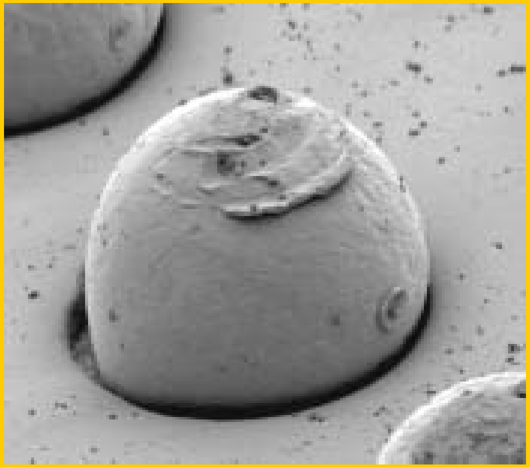


Crown

Cup

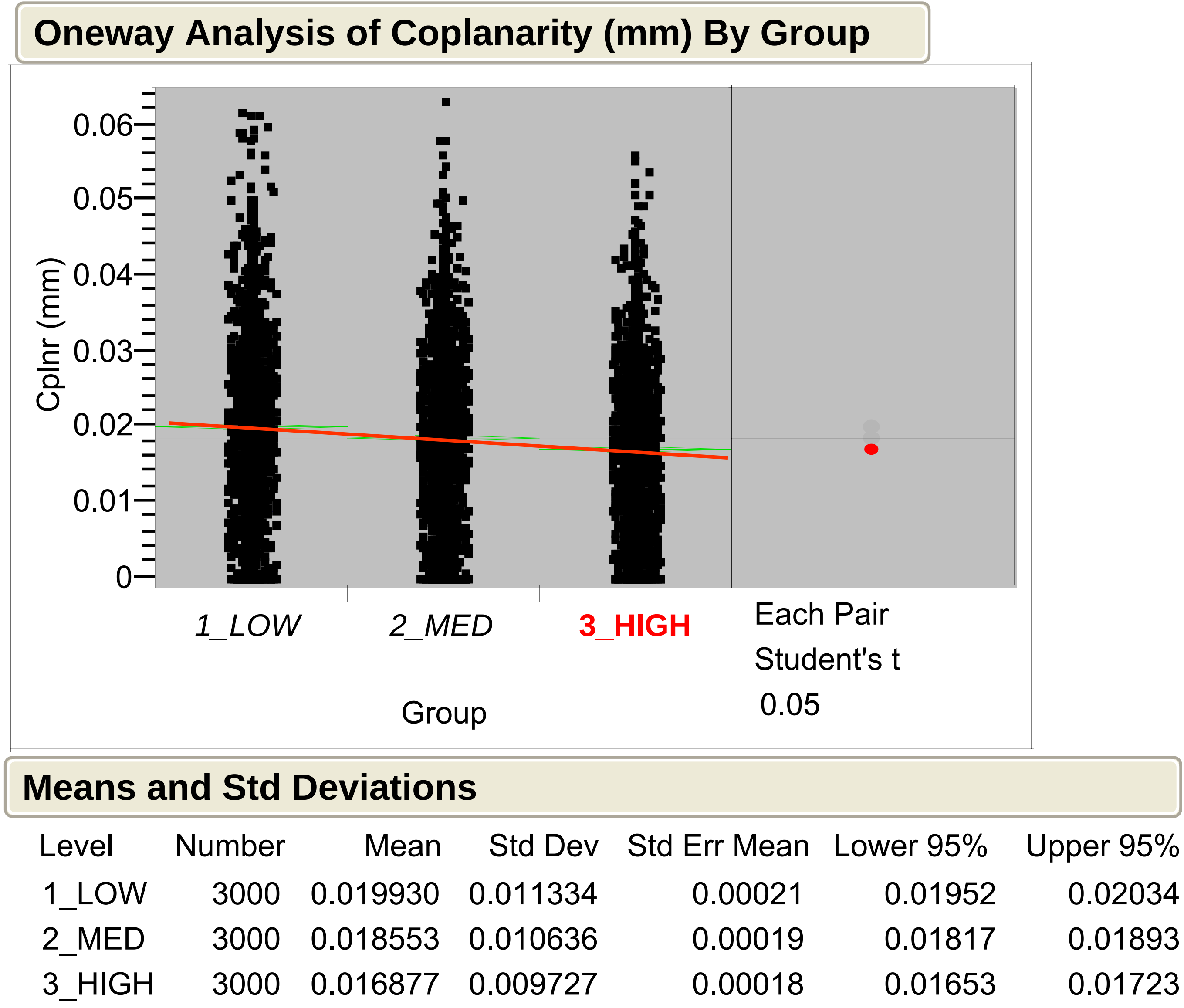
Pincher

Levels of Deformation



- Low: control
- Medium: up to 24 insertions
- High: up to 50 insertions

Device Coplanarity



Oneway Analysis of Coplanarity (mm) By Group

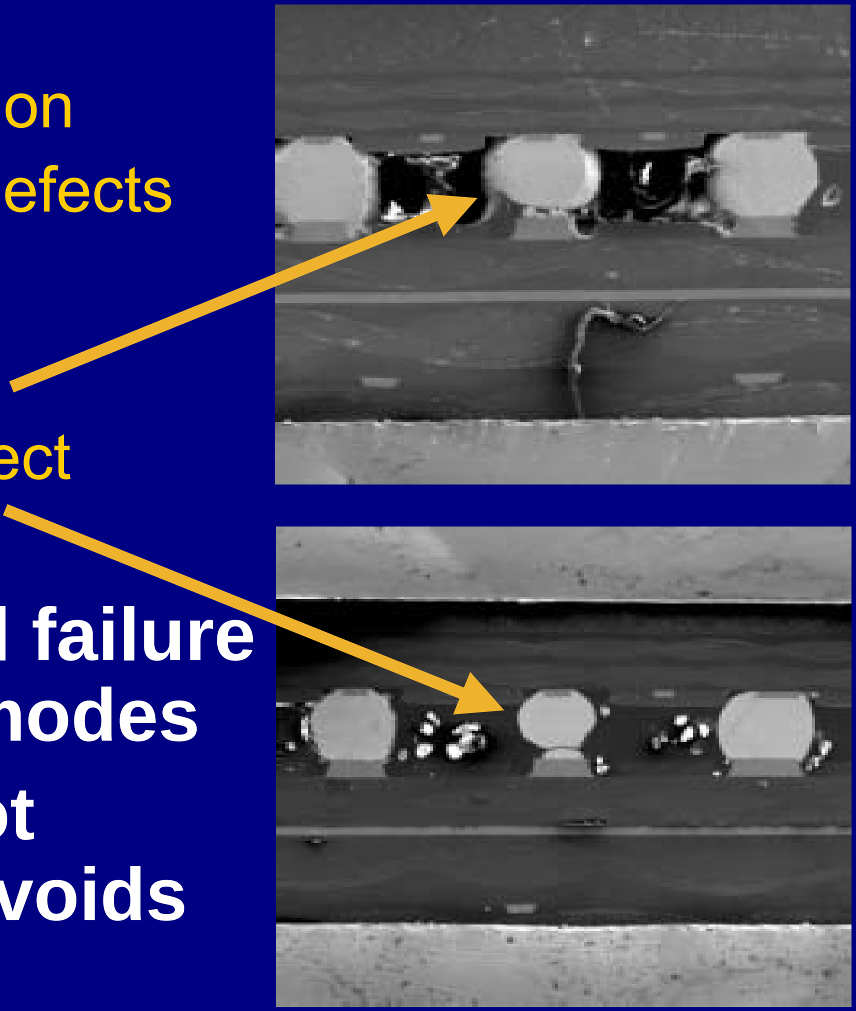
Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
1_LOW	3000	0.019930	0.011334	0.00021	0.01952	0.02034
2_MED	3000	0.018553	0.010636	0.00019	0.01817	0.01893
3_HIGH	3000	0.016877	0.009727	0.00018	0.01653	0.01723

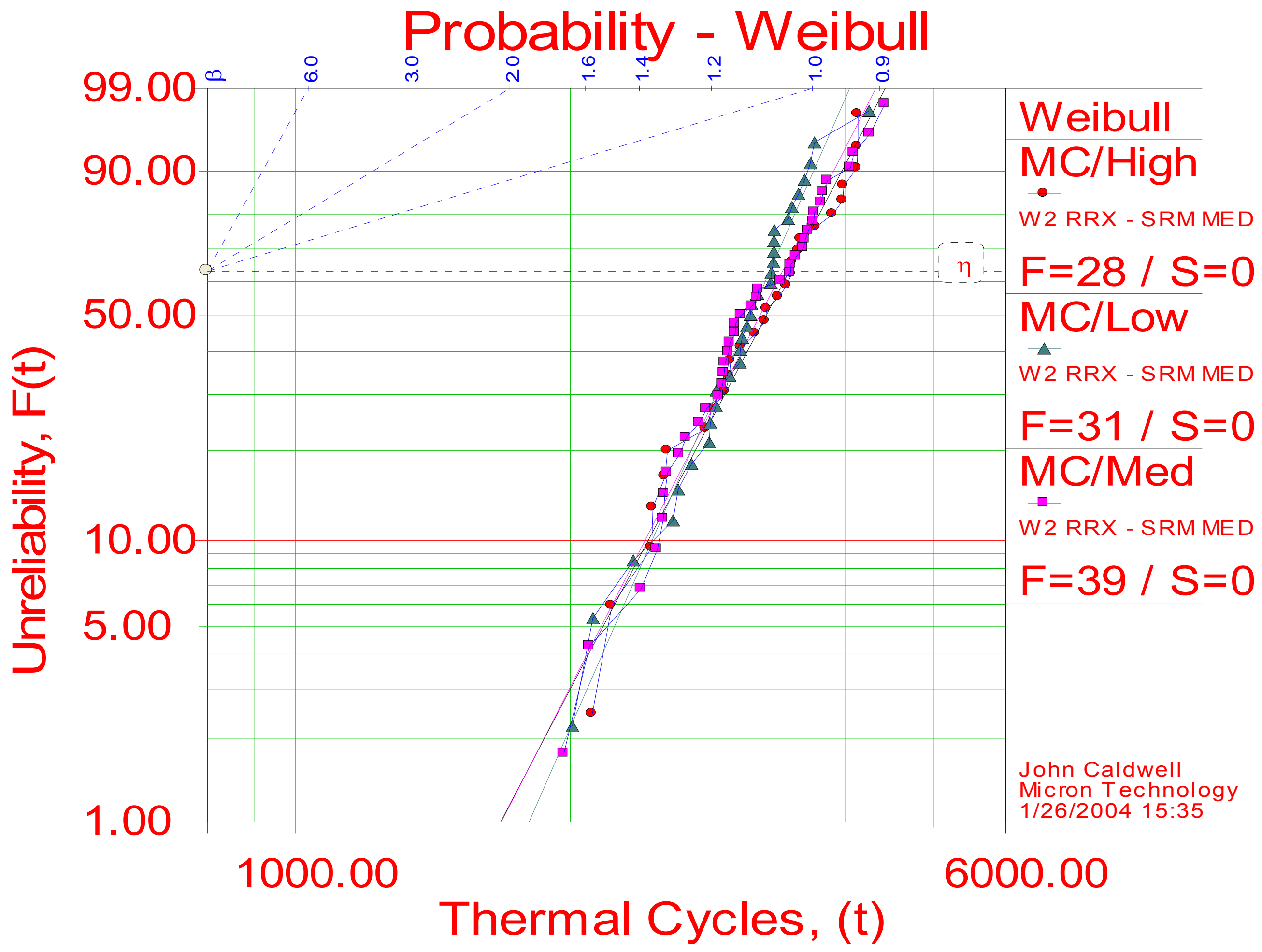
- ▶ **Laser scan data analyzed statistically**
- ▶ **No adverse impact**

Time-Zero Module Quality

- **6 component failures**
  - Internal component degradation
  - Consistent with silicon level defects
- **2 component failures**
  - Poor solder joint geometry
  - Low volume solder interconnect
  - No voids
- **X-ray, x-section, electrical failure analysis to verify failure modes**
- **Time-zero module fails not related to solder damage/voids**



Solder Joint Reliability (-40°C to +85°C)



$\beta1=6.3121, \eta1=3477.0726, \rho=0.9878$

$\beta2=7.5691, \eta2=3309.2888, \rho=0.9882$

$\beta3=6.4851, \eta3=3417.0370, \rho=0.9874$

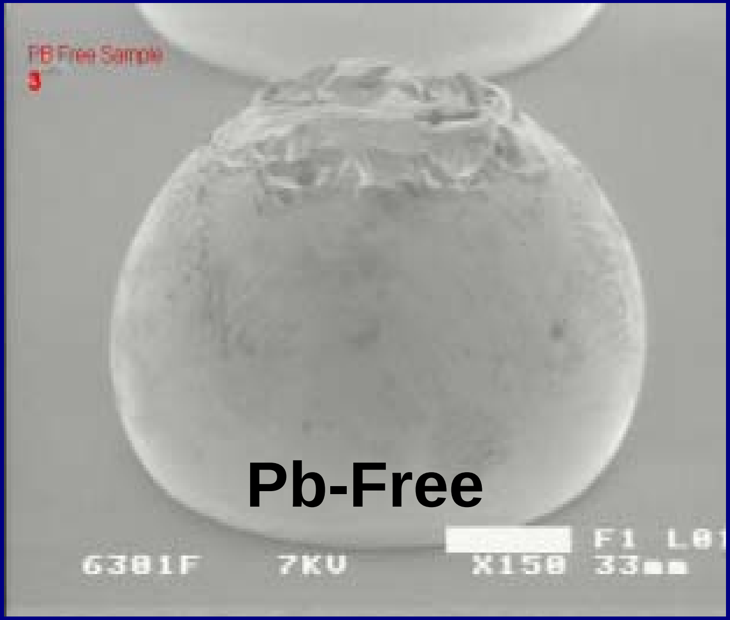
Source: Micron Technology, Inc.

Conclusion

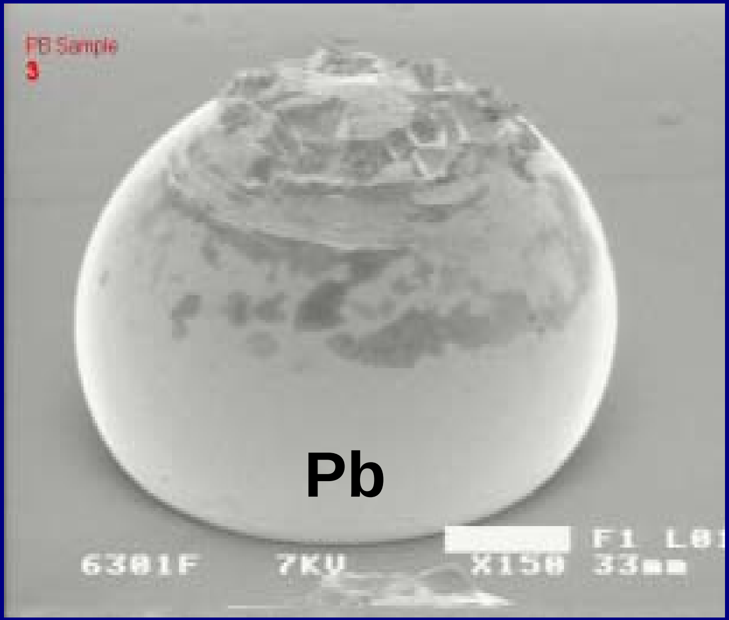
- **Surface mount process maturity and monitoring is VERY important**
  - X-ray (void volume & frequency)
  - X-section (standoff height measurements)
  - Reflow oven profile
  - Solder paste/flux chemistry
  - Clean BGA solder alloys & PCB land pads
- **No correlation between degree of solder ball damage and -**
  - Component coplanarity degradation
  - Time-zero solder interconnect quality
  - Solder joint reliability (SJR)

Follow-on Research

- **96.5Sn/3.0Ag/0.5Cu (lead-free) versus 62Sn/36Pb/2.0Ag**
  - Daisy chain WLCSP's
  - In-situ solder joint monitoring
- **Results → April 2004**



Pb-Free



Pb

Acknowledgements & Sources

- **Special thanks to:**

  William Casey, Mike Morrison, John Odle, Faye Sinclair, Rich Mansfield, David Sammons, Glen Watson, Gregory Barnett, Ismat Sulaivany, Syed Ahmad, Ken Eytchison, Von Sorenson, Arlene Haugse

- **Effects of solder joint voiding on plastic ball grid array reliability**

  Donald R. Banks, et al.

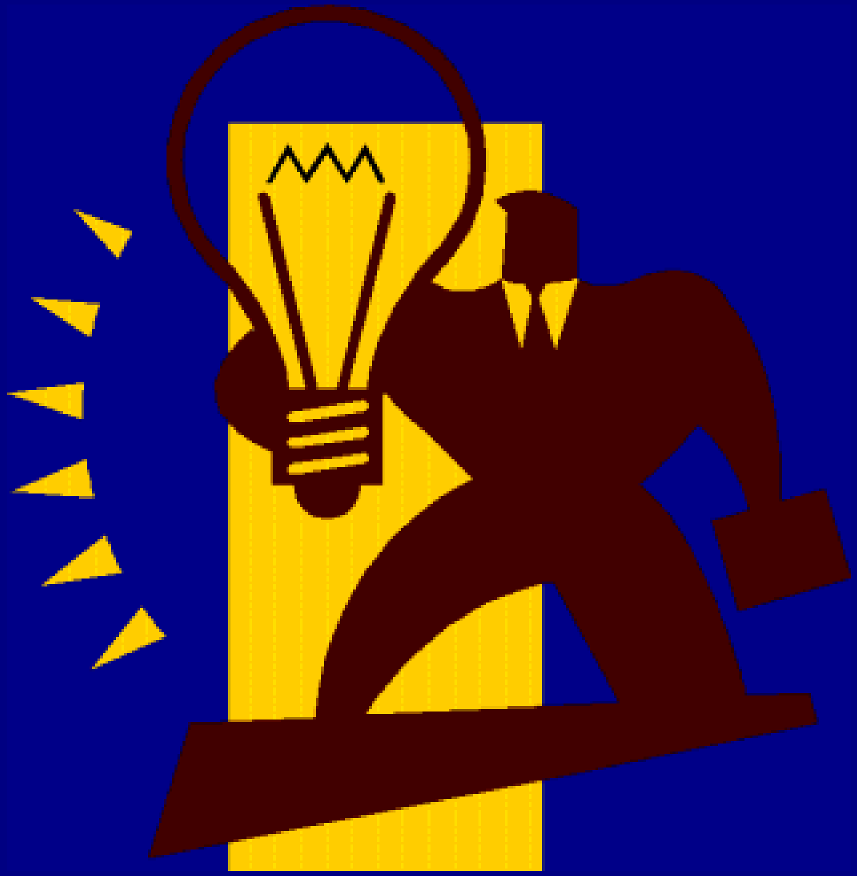
  Motorola Semiconductor Products Sector

- **Reduction of voiding in eutectic ball grid array solder joints**

  William Casey

  Micron Technology, Inc.

Q & A



Testing of VQFN with Palladium-Cobalt Pogo Pin

Chua Thuan Lian

Jayachandrian

Schuetz Dieter

BURN-IN & TEST SOCKET WORKSHOP

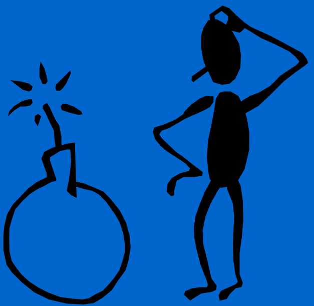
Contents

VQFN - PACKAGE OF THE FUTURE

BACKGROUND

Testing → **VQFN 48**

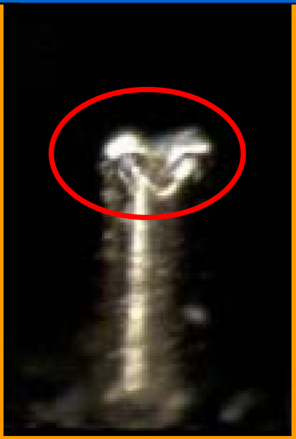
- Low Production Output Capacity
- High Invalid Test Failures
- High Tester/Handler Downtime due to frequent cleaning of contactors
- High Consumption of Pogo Pins



Problems Encountered

1. Short life-span of pogo pins due to deposition of solder on the pin (<12k insertions).

New crown tip pogo pins



Solder debris on tips after 12k insertion

2. High downtime due to regular cleaning of pogo-pins.

3. High % of invalid parametric failures (12% ~ 40%) .

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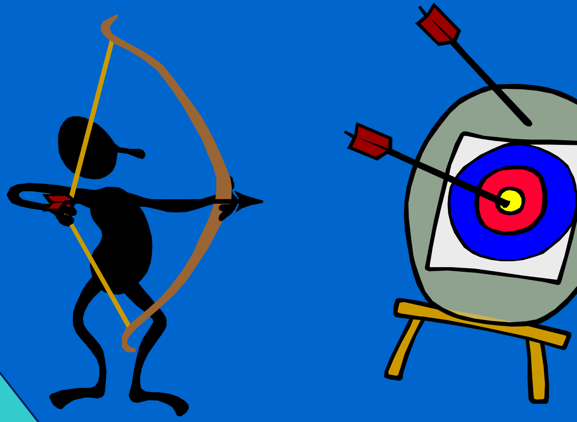
Testing of VQFN with Palladium-Cobalt Pogo Pin

Targets



Reduce Down-time of Equipment by 50%

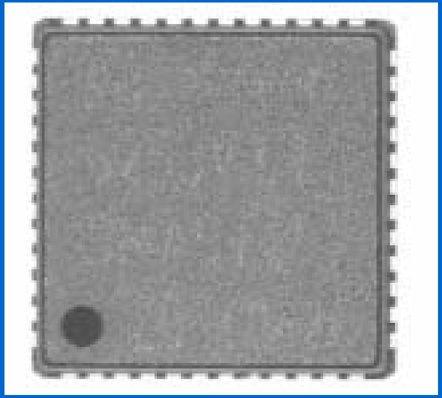
Improve Contactor Performance by 50%

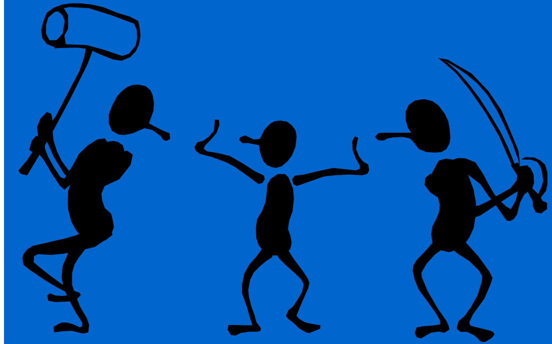
Reduction in Production Cost by 50%

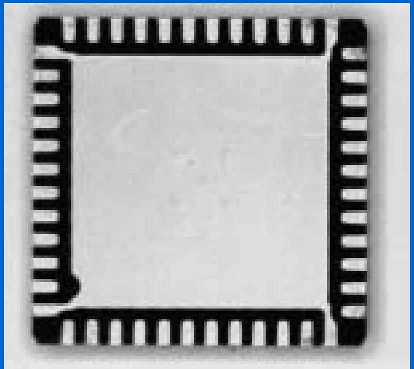
Improve production Output Capacity by 50%

Introduction to Testing of VQFN Package

Introduction to Very thin Quad Flat Non Leaded Package (VQFN







Mold side view of VQFN 48

Pad side view of VQFN 48

Package	*Body size (mm)*	*Package thickness (mm)*	*Terminal pitch (mm)*	*Status*
VQFN 48	7 x 7	0.9	0.5	In production
VQF N 40	5.5 x 6.5			In production
VQFN 32	4.5 x 5.5			Q4/ 2004
VQFN 24	3.5 x 4.5			Q2/ 2004
VQFN 20	3.5 x 3.5			In production

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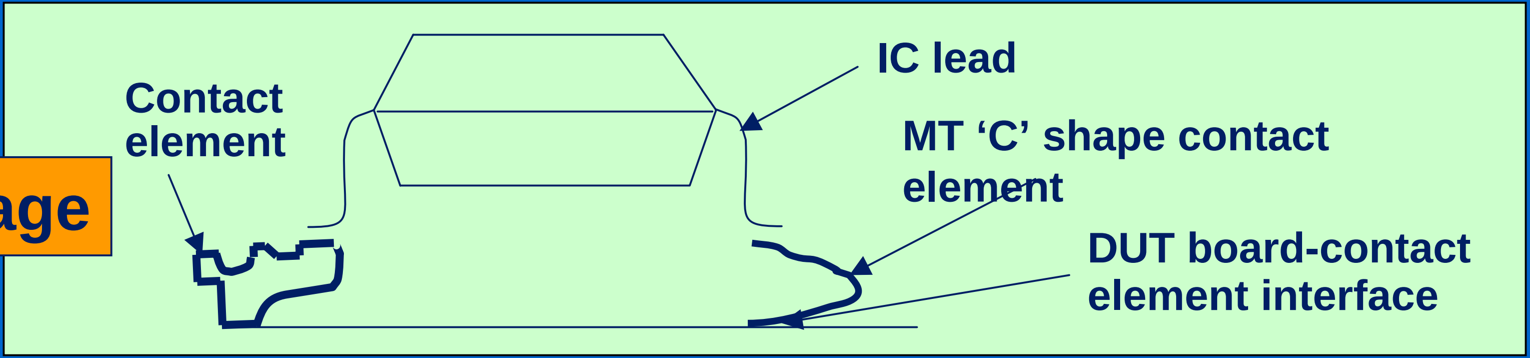
Test Contacting Methodology

eaded Package



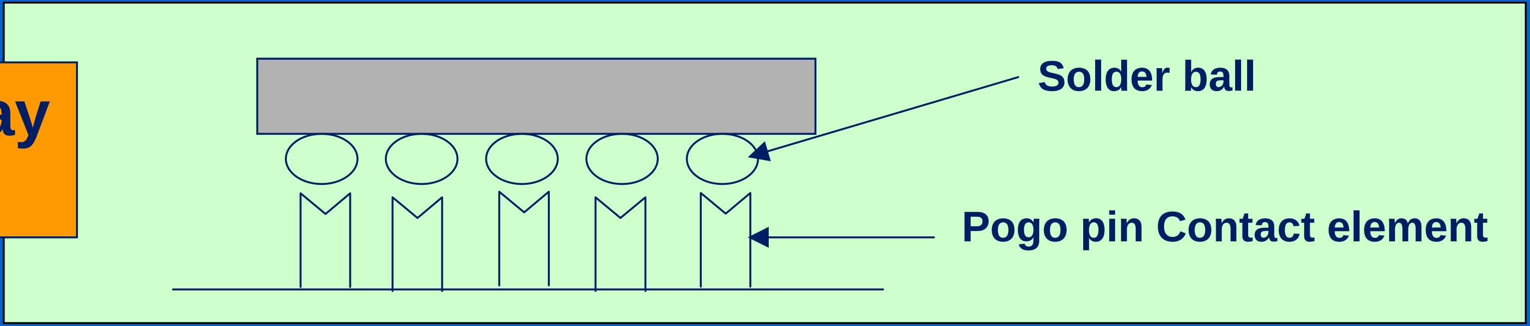
Contact element

IC lead

MT ‘C’ shape contact element

DUT board-contact element interface

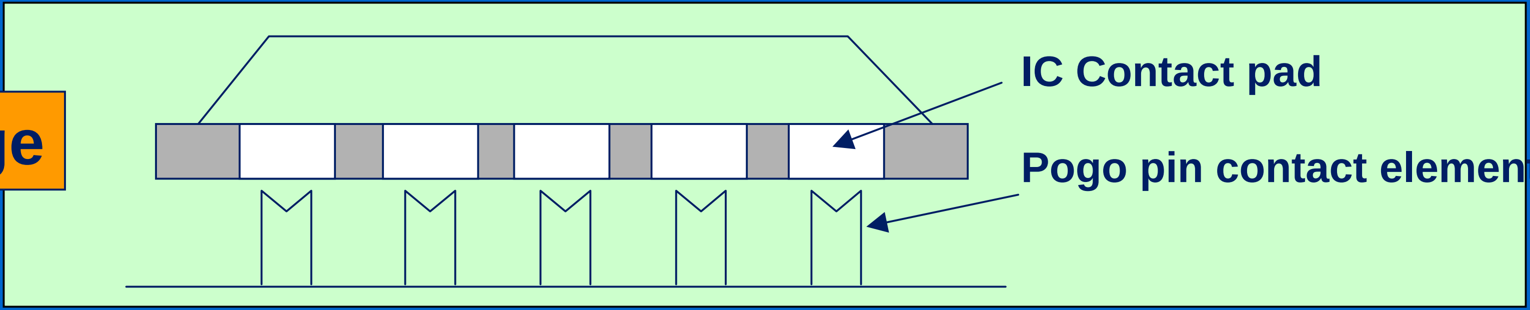
all Grid Array Package



Solder ball

Pogo pin Contact element

QFN Package



IC Contact pad

Pogo pin contact element

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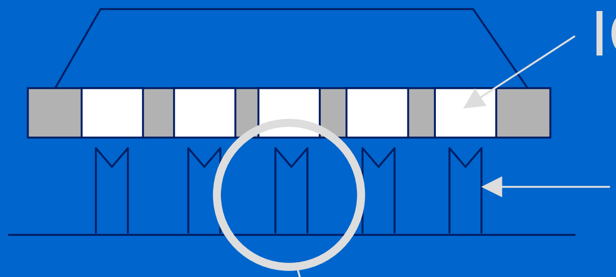
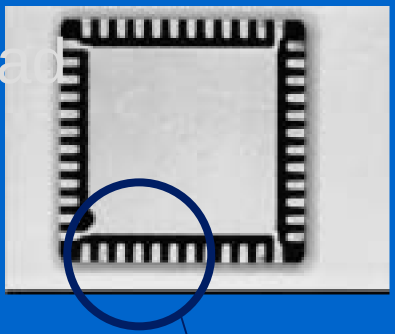
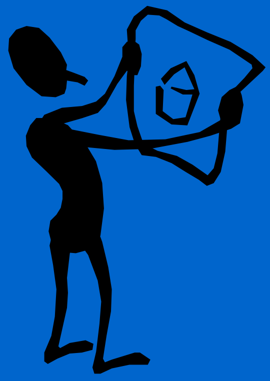
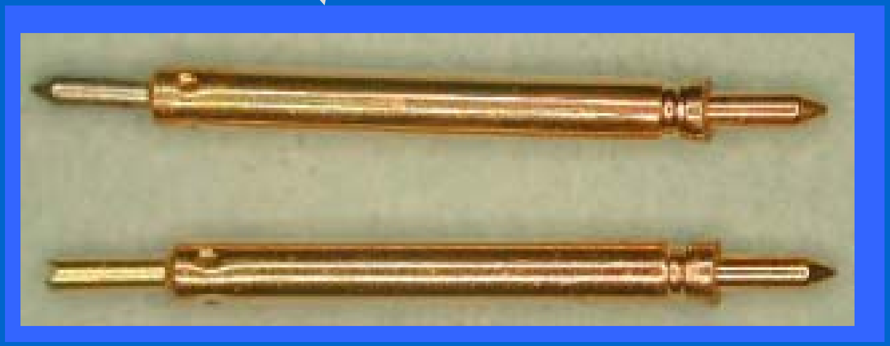
VQFN package contact element

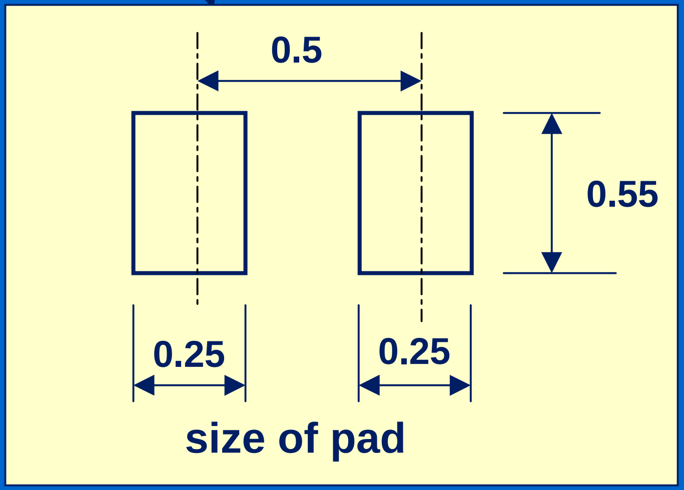
Pogo-pins are used as contacting elements between device and DUT board.











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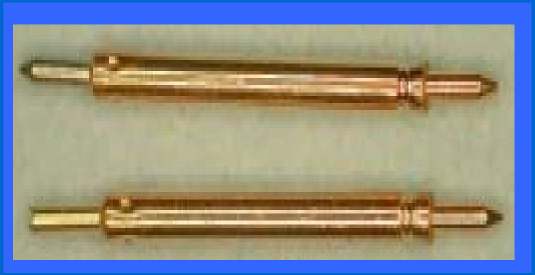
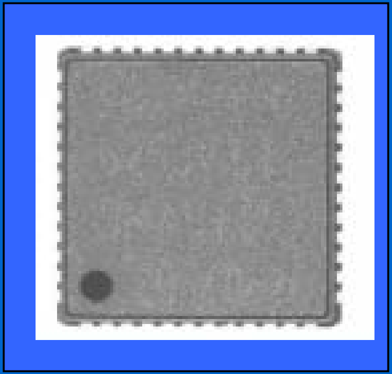
Test Handling Technology

Gravity handlers are used to test VQFN 48-1 packages by means of pogo pin contactors.



Test



The initial pogo pin design used was the crown tip pogo pins.

Crown tip pogo pins from RXX

Study the Poor Performace of the Gold Pogo Pins

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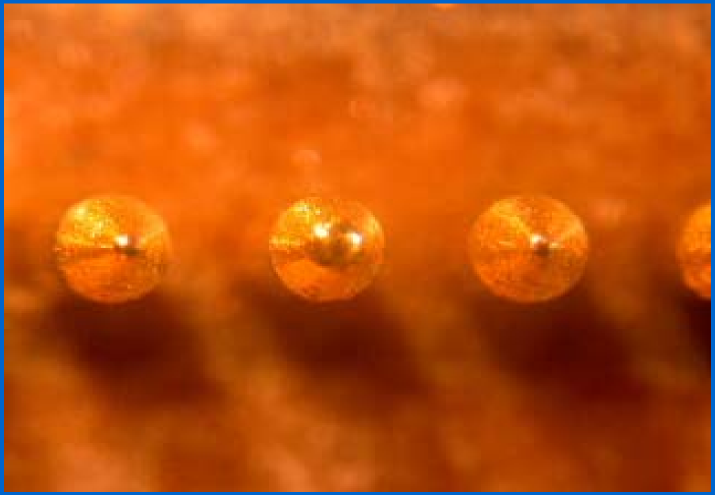
Gold Plated Pogo Pins

- Study of the gold plated pogo pin from different supplier.
- Solder deposit were confirmed on all evaluated gold plated plate.



Nxx pogo pin

Vxx pogo pin

Rxx pogo pin

Testing of VQFN with Palladium-Cobalt Pogo Pin

Gold Plated Pogo Pins

- Study of the electrical impact on the solder deposit on the tip surface.
- Increase of resistance is observed as early after 1K insertion. And worst at 10K

New Pogo pin

Pogo pin at 100K insert

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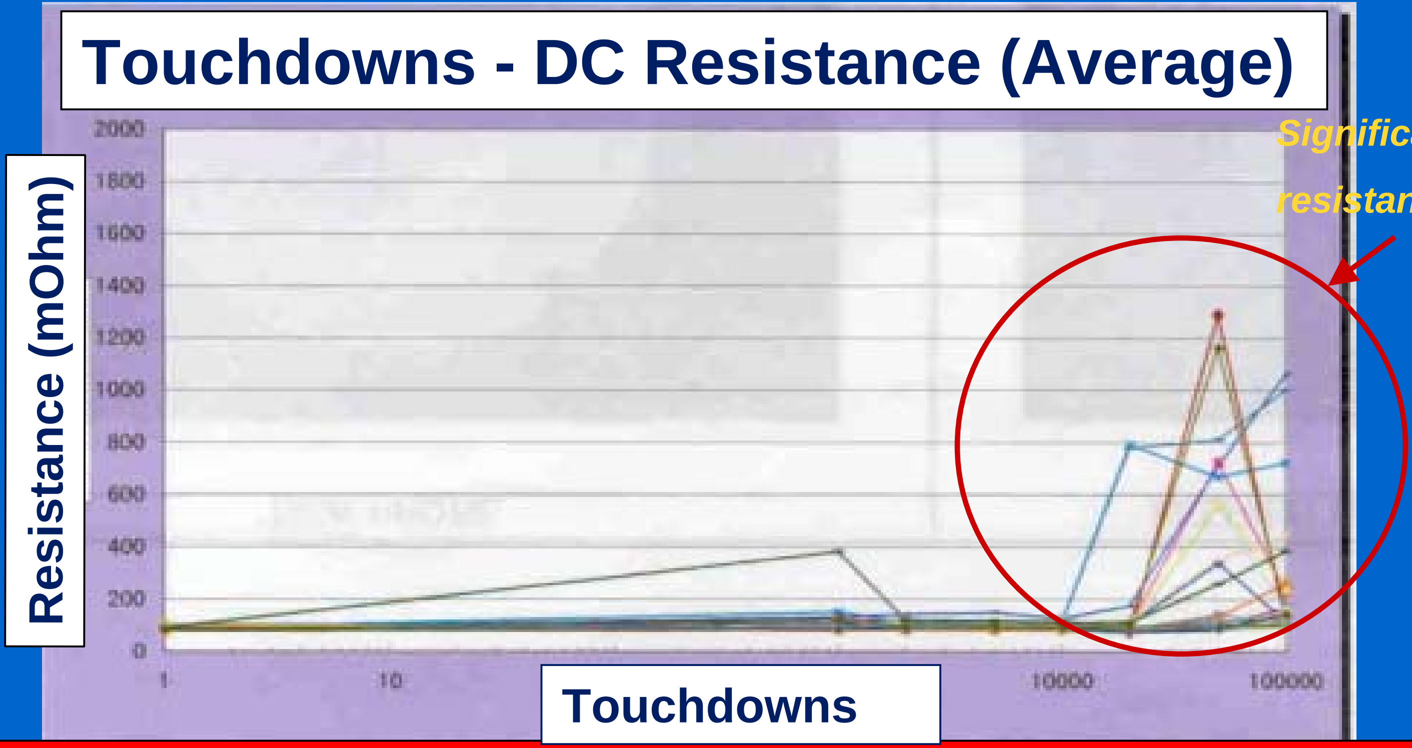
Gold Plated Pogo Pins

Experiments shows that as solder deposition increases, the conta resistance will also increase.



Touchdowns - DC Resistance (Average)

Significant increase in cont resistance after 10k inserti

Increase in contact resistance of pogo pins will lead to high % of invalid parametric failures.

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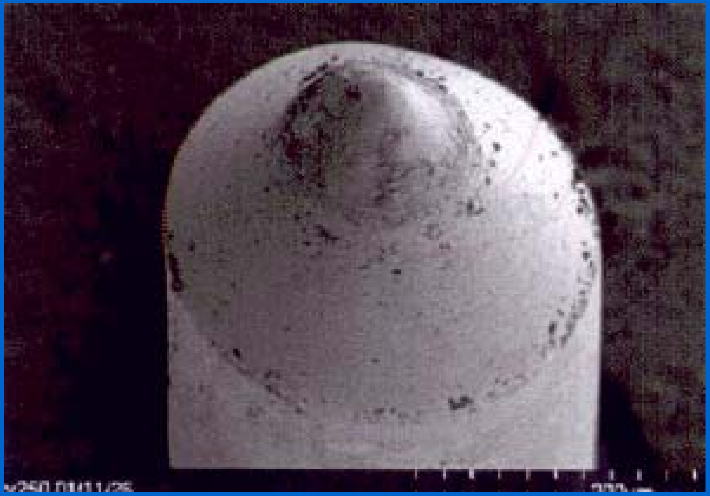
Testing of VQFN with Palladium-Cobalt Pogo Pin

Gold Plated Pogo Pins

- Study of the impact of cleaning on gold plated pogo pin.
- Solder deposit was able to be remove after cleaning.
- Pogo pin based was exposed after freq cleaning

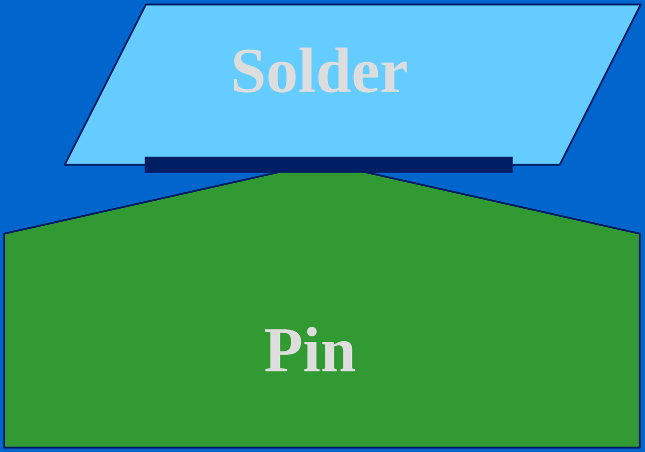
Pogo pin before cleaning



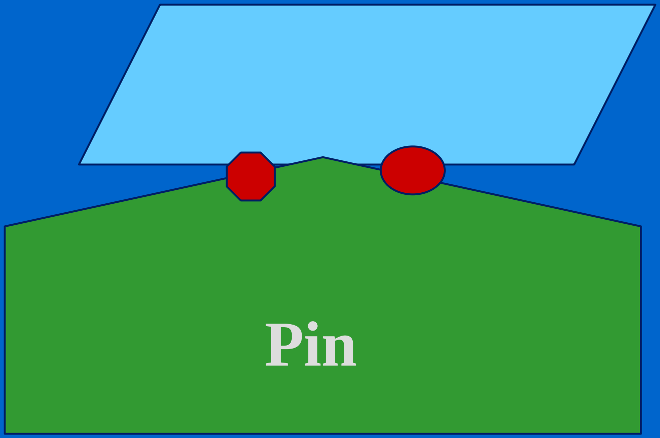
Pogo pin after cleaning

Gold Plated Pogo Pins

- Study of the mode of the gold plating removal.
- Adhesive effect of gold plating removal was observed after freq cleaning



Adhesive Mode



Abrasive Mode

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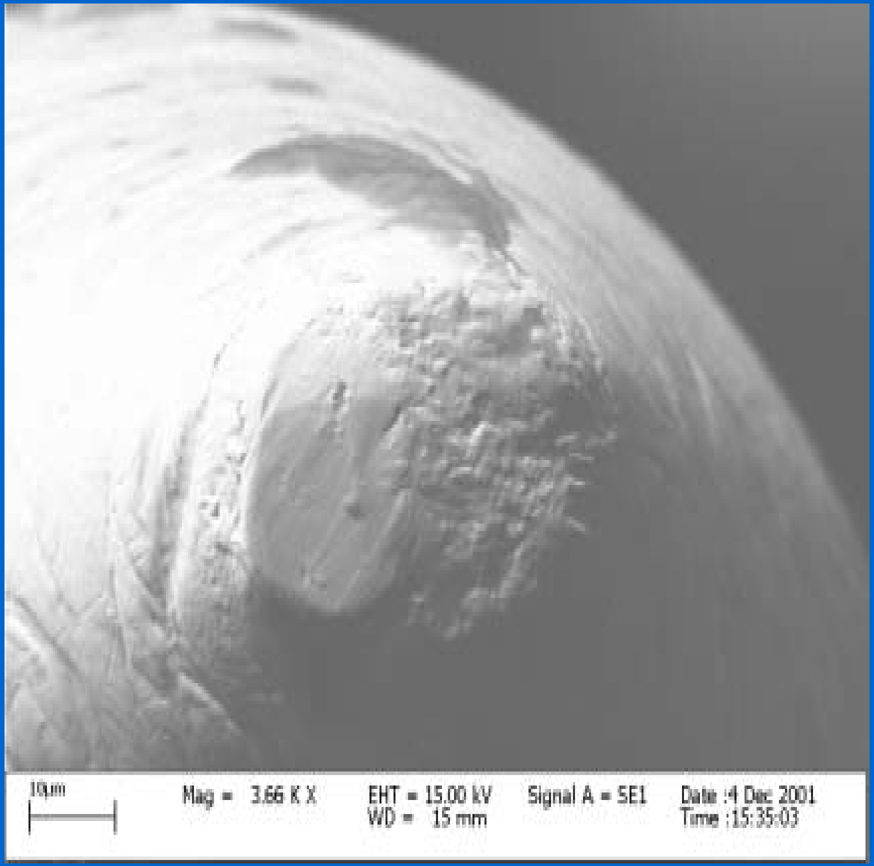
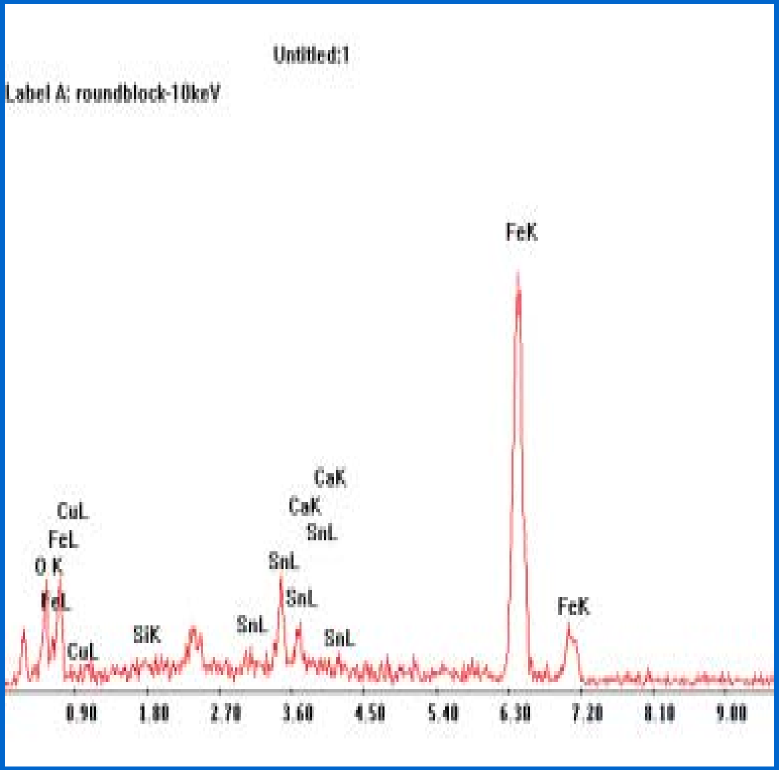
Gold Plated Pogo Pins





Attached are the SEM picture (showing adhesive failure) and EDX revealing the base material (steel).

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Testing of VQFN with Palladium-Cobalt Pogo Pin

Finding of the problem

- The solder deposit, which has an adhesive effect on the pogo pins, has caused an increase in the contact resistance of the pins.

- The same adhesive effect was observed in the various types of pogo pins used for the VQFN packages.

- Cleaning is needed to remove the solder deposit from the pogo pins, but this will cause a deterioration in the life-span of the pogo pins.

Pogo Pin Selection and Study

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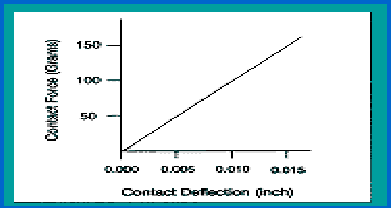
Testing of VQFN with Palladium-Cobalt Pogo Pin

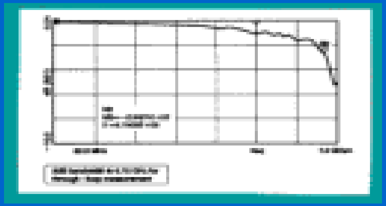
Selection criteria and Study Method

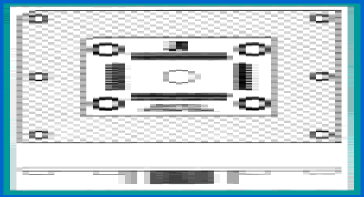
Main criteria for the selection of test contactor

- Reliable and Good Electromechanical Performance
- Long Life-span, >500k Insertions
- Robust Housing, > 1million insertions
- Modular Design for Ease of Maintenance
- Low Cost

Test contactor qualification test







- Mechanical life cycle test
  (Contact element life)
- Electrical performance
  (True test monitoring)
- Mechanical performance
  (Test pad protection, DUT board)
- Mechanical requirements
  (Cleaning, contact replacement)

Testing of VQFN with Palladium-Cobalt Pogo Pin

Selection criteria and Study Method

- Look into different material or plating with better solder resistance property
- Conduct cycle test to check on insertion life cycle vs resistance
- Conduct contact housing evaluation with actual production loading
- To compare the Operating mechanism of pogo pin

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Cycle Testing

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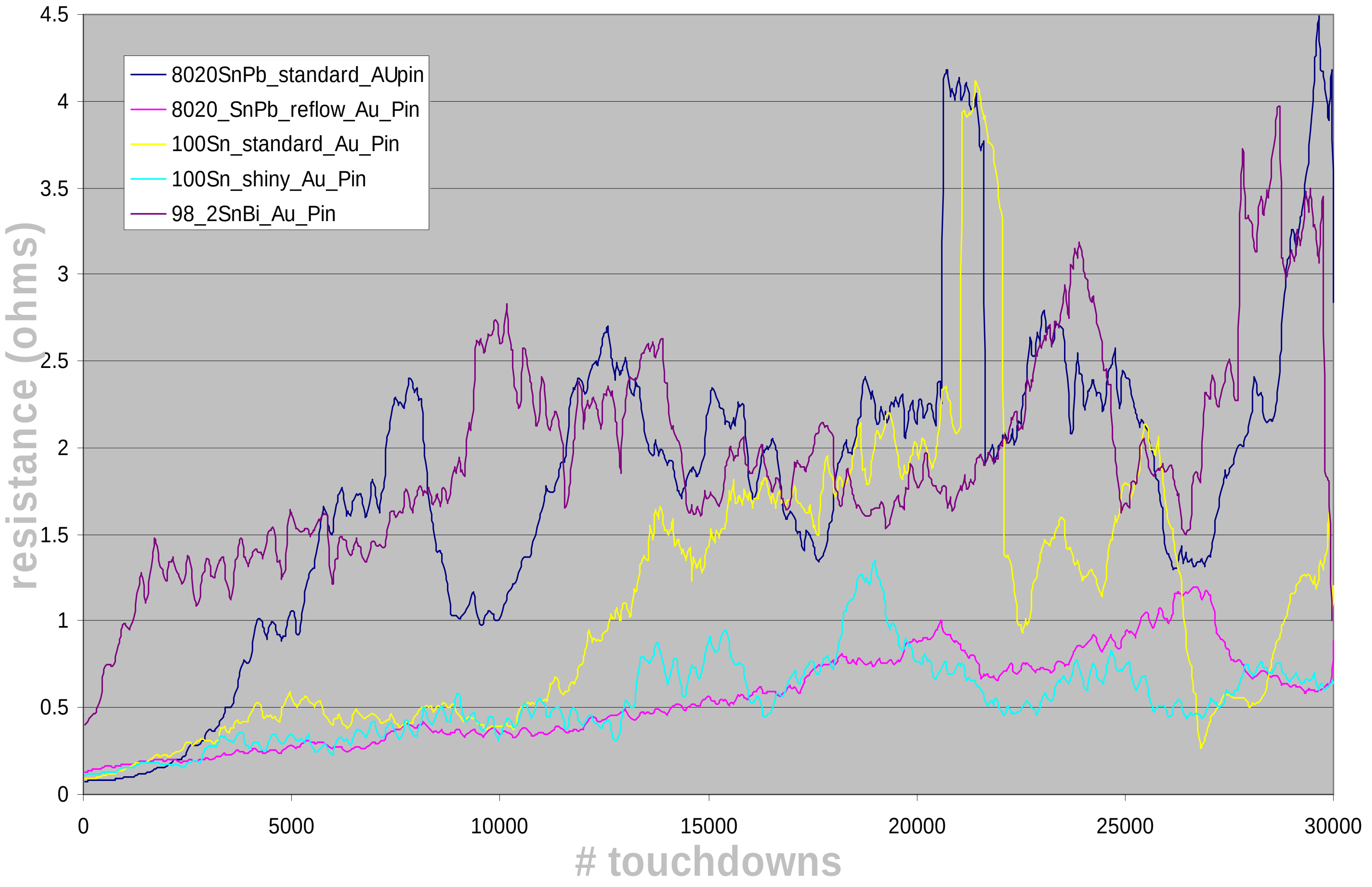
Life Cycle Resistance Study

Gold Pin



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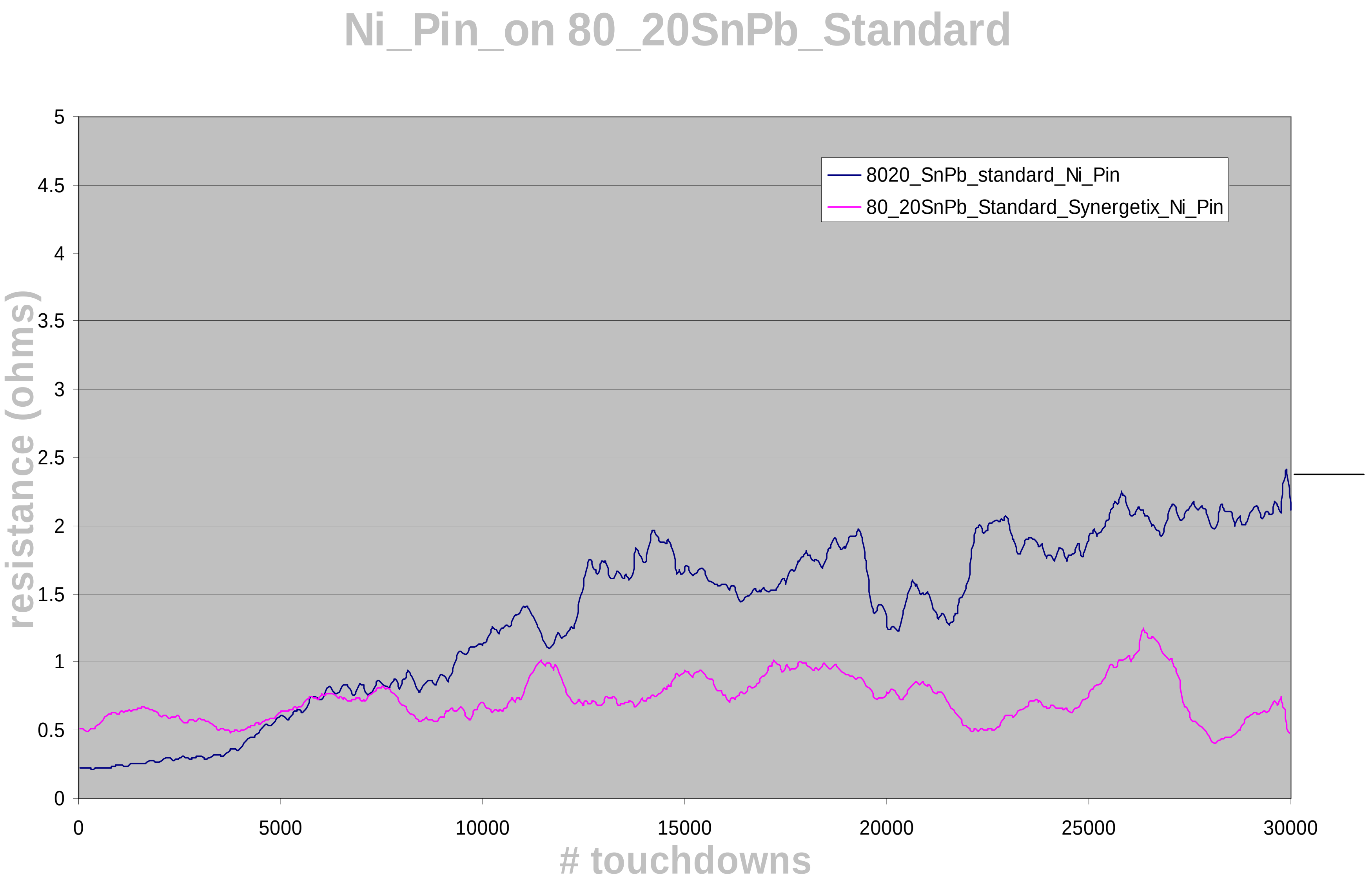
Life Cycle Resistance Study



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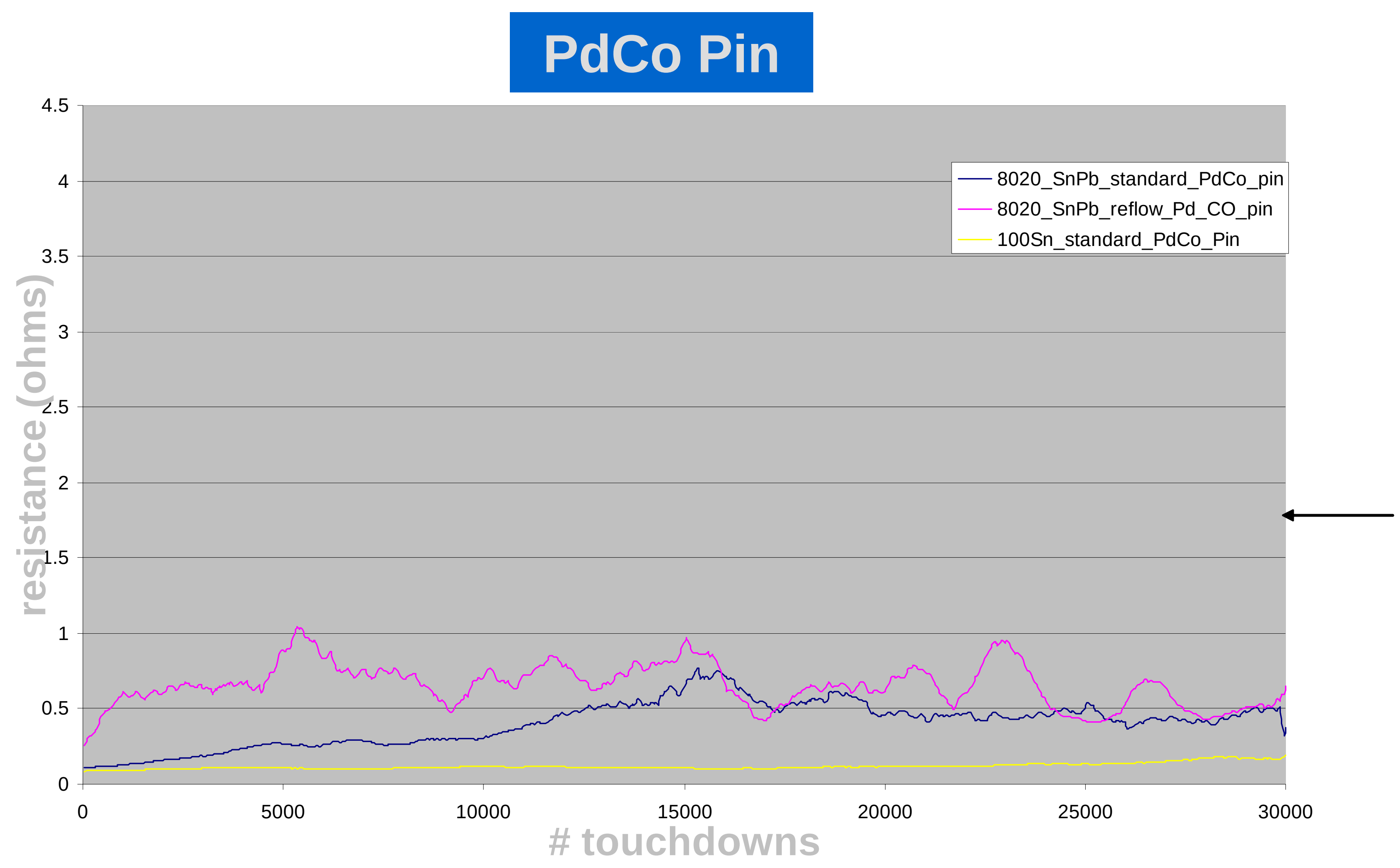
Life Cycle Resistance Study



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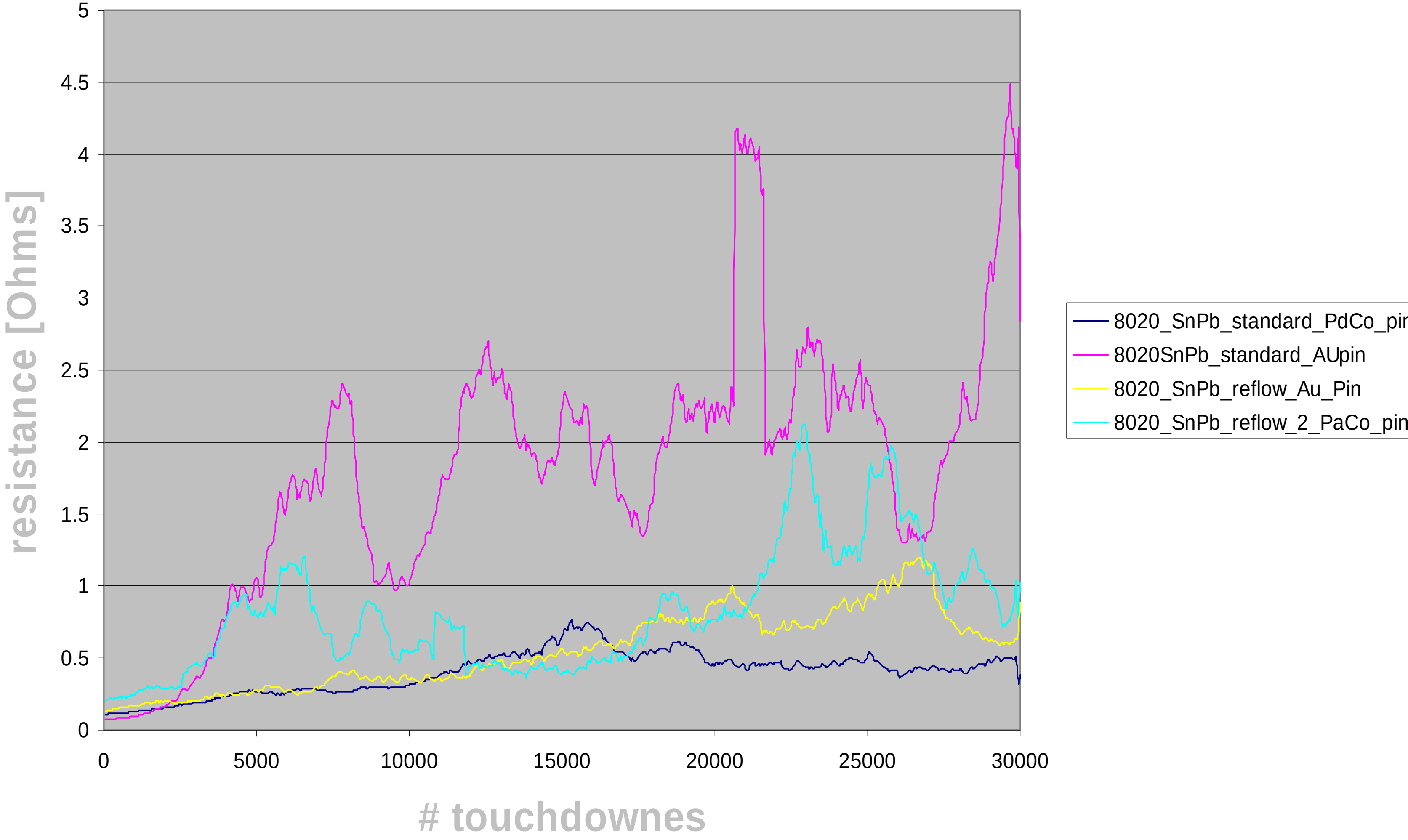
Life Cycle Resistance Study

Contact resistance vs Standard and reflow



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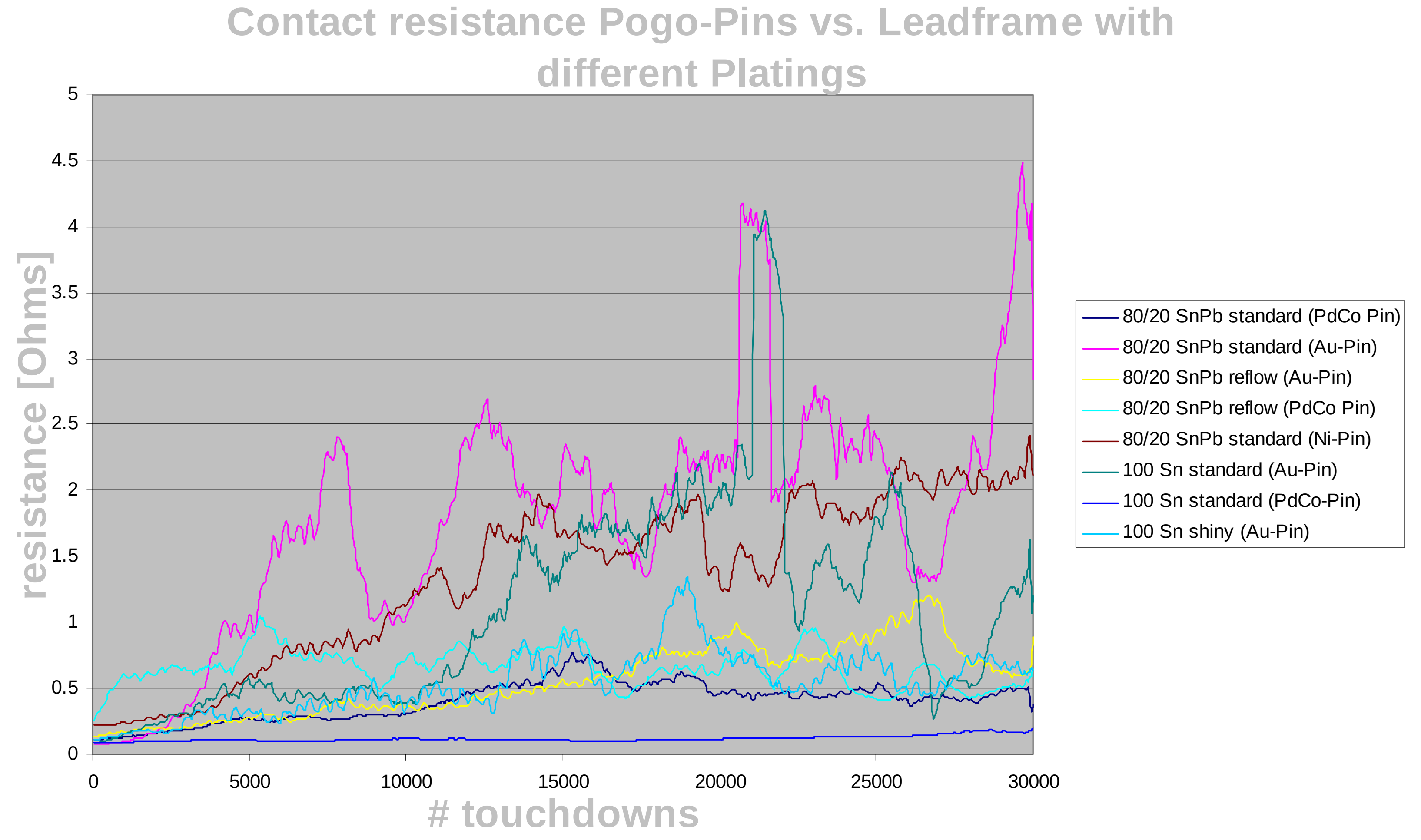
Life Cycle Resistance Study



Contactor Evaluation Matrix

Handler Type	Pin Type	Housing	Result	Cleaning Freq
Multitest	“X” Source (250K)	Multitest	High Parametric Failures when reaching end of life span	3
Multitest	“X” Source (250K)	*SNR	High Parametric Failures when reaching end of life span	3
Multitest	K&S (500K)	*K&S	**Good Elect. Yield. Life Span >500K**	1
Rasco	“X” Source (250K)	Rasco	Good Elect. Yield. Life Span ~200K.	2
Rasco	K&S (500K)	*K&S	**Good Elect. Yield. Life Span >500K**	1

Note:
1. * denotes design based on Infineon Outline.
2. Material used for pogo pins is Palladium Cobalt.

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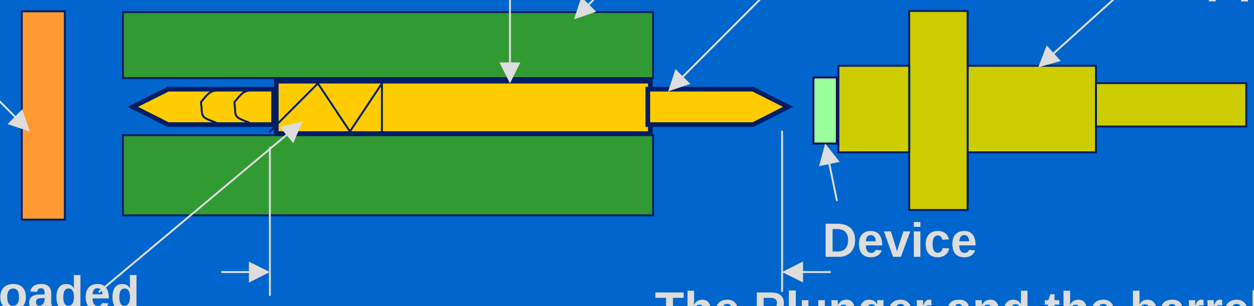
Testing of VQFN with Palladium-Cobalt Pogo Pin

omparison of “X” Source and K&S Pogo-pin Operating Mechanis

X” source Pogo pin (Single Acting)



Barrel

Pogo-pin housing

Handler Plunger

Plunger (fixed-End)

DUT Board

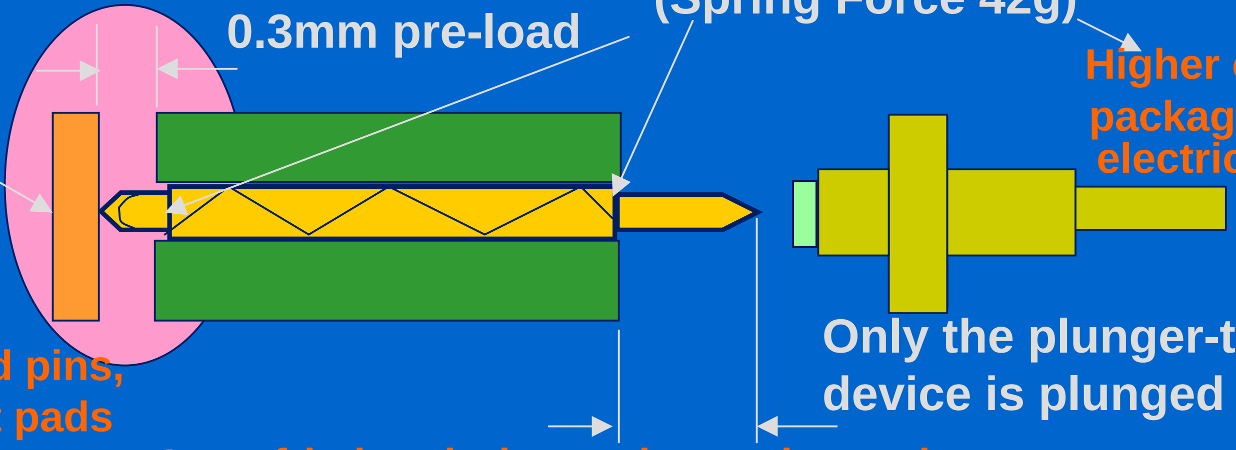
Device

nly DUT-end spring loaded
pring force19g)

The Plunger and the barrel moves together when device is plunged

&S Pogo pin (Double Acting)

Both ends spring loaded (reciprocatin
(Spring Force 42g)



0.3mm pre-load

DUT Board

Higher contact force
package pads improv
electrical performan

-load ensures good
ntinuity
ween DUT board and pins,
uces damage to test pads

Only the plunger-tip moves wh
device is plunged

Less friction during reciprocating action

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Testing of VQFN with Palladium-Cobalt Pogo Pin

Summary of the Study of PdCo

- The PdCo plated pogo pin has longer insertion life-span and minimum change in contact resistance, relative to large number of insertions
- PdCo plating exhibits low coefficient of friction and makes it easier for foreign matter to slide along the surface of the plunger and prevents solder deposition
- Contactor design also plays a key role in the insertion life cycle performance
- Contactor with Pre-load design also reduces damage to test pads through good continuity between DUT board and pins
- Minimum cleaning frequency during production is achieved.
- PdCo plated pogo pins are suitable for testing of VQFN package

Result of the Performance of the PdCo Pogo Pin

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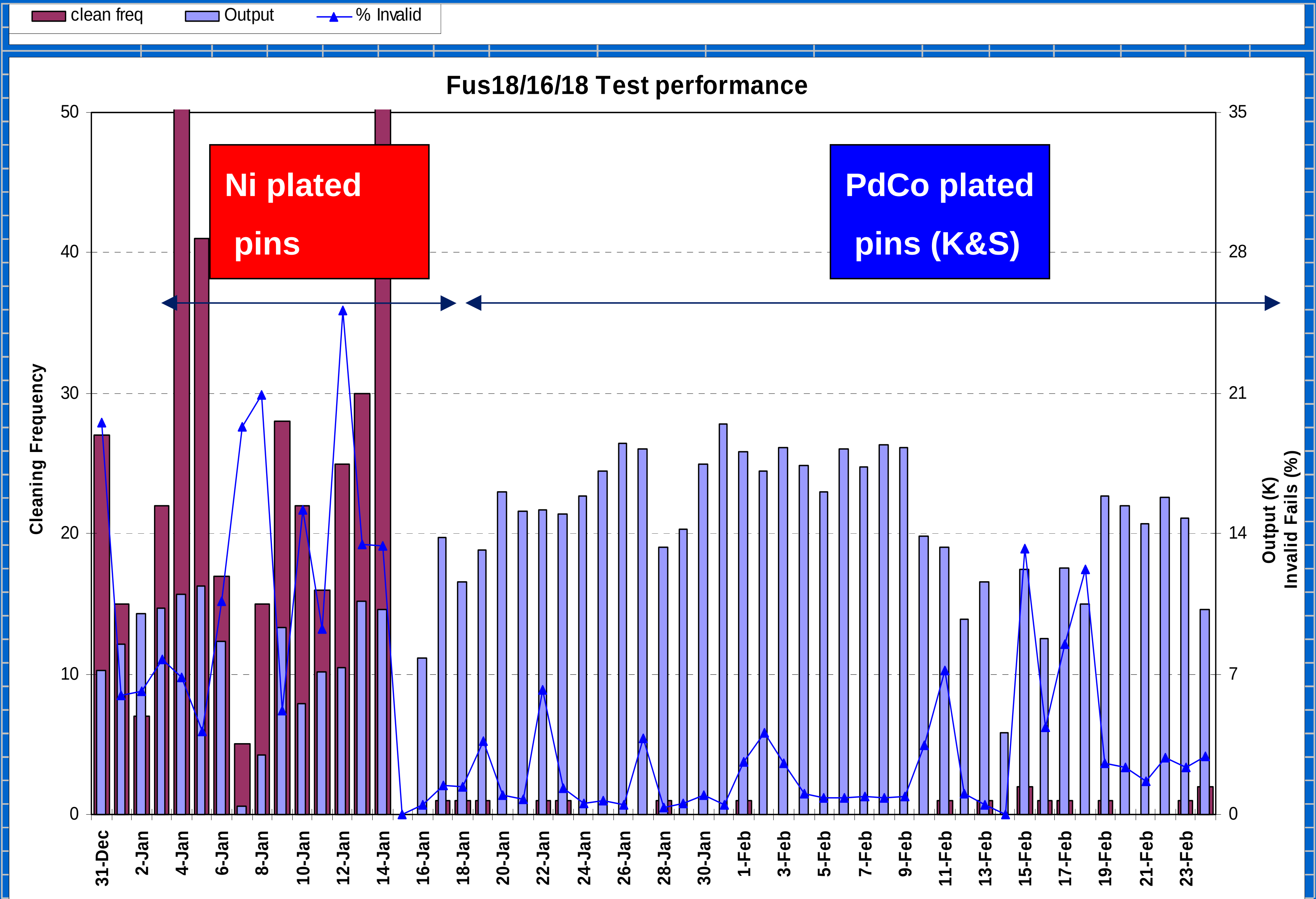
Testing of VQFN with Palladium-Cobalt Pogo Pin

Actual Production Monitoring



Ni plated pins

PdCo plated pins (K&S)

Monitoring Results

Characteristics	~~Gold plated pogo-pins~~	(PdCo) plated pogo-pins
Life-Span(No.of insertions)	~~50,000~~	500,000
Vendor’s Spec.	~~100,000~~	500,000
Cleaning Freq./Day	~~48~~	2
% Invalid Test Failures	~~12 - 40%~~	< 5%
Avg 1st Pass Yield	~~70 - 75%~~	90 - 94%
Avg Daily Production Output	~~7,000~~	14,000
		☑

Benefits of Introduction of PdCo Pogo Pin

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Testing of VQFN with Palladium-Cobalt Pogo Pin

Results (Quantifiable)

Reduction in Pogo-Pin Consumption

Cost of Pogo-pins

Nickel plated pins : S$ XX.XX

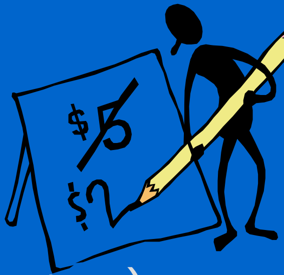
Palladium Plated pins : S$ YY.YY

Cost Savings/set-up

Assumption

Output / day : 14,000

Package : VQFN 48 (48 pins/set-up)



Characteristics	Gold plated pogo-pins	Palladium Cobalt plated pogo-pins
Life-Span(No.of insertions)	50,000	250,000
Cost of pins consumed /month	S$7,344	S$974
Cost of pins Consumed/Yr	S$88,128 [S$7,344 x 12mths]	S$11,688 [S$97 12mth
Savings per year	S$76,440 (S$88,128 - S	

86% Savings

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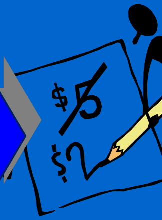
Testing of VQFN with Palladium-Cobalt Pogo Pin

Results (Quantifiable)

Reduction in Tester and handler downtime
(Due to frequent cleaning of pogo-pins)

Cost Savings/set-up



Characteristics	Gold plated pogo-pins	Palladium Cobalt plated pogo-pins
No.of cleaning/day	48	2
Down Time/day Due to cleaning	240 mins [48cleaning X 5mins]	10 mins [2 x 5mins]
Cost impact on tester Downtime/ per year	S$199,065	S$8,294
Cost impact on handler downtime/day(per year)	S$60,652	S$2,527
Savings per year	S$248,9	27)]

Total savings per year

SGD 325,340

PER SETUP!!

95% Savings

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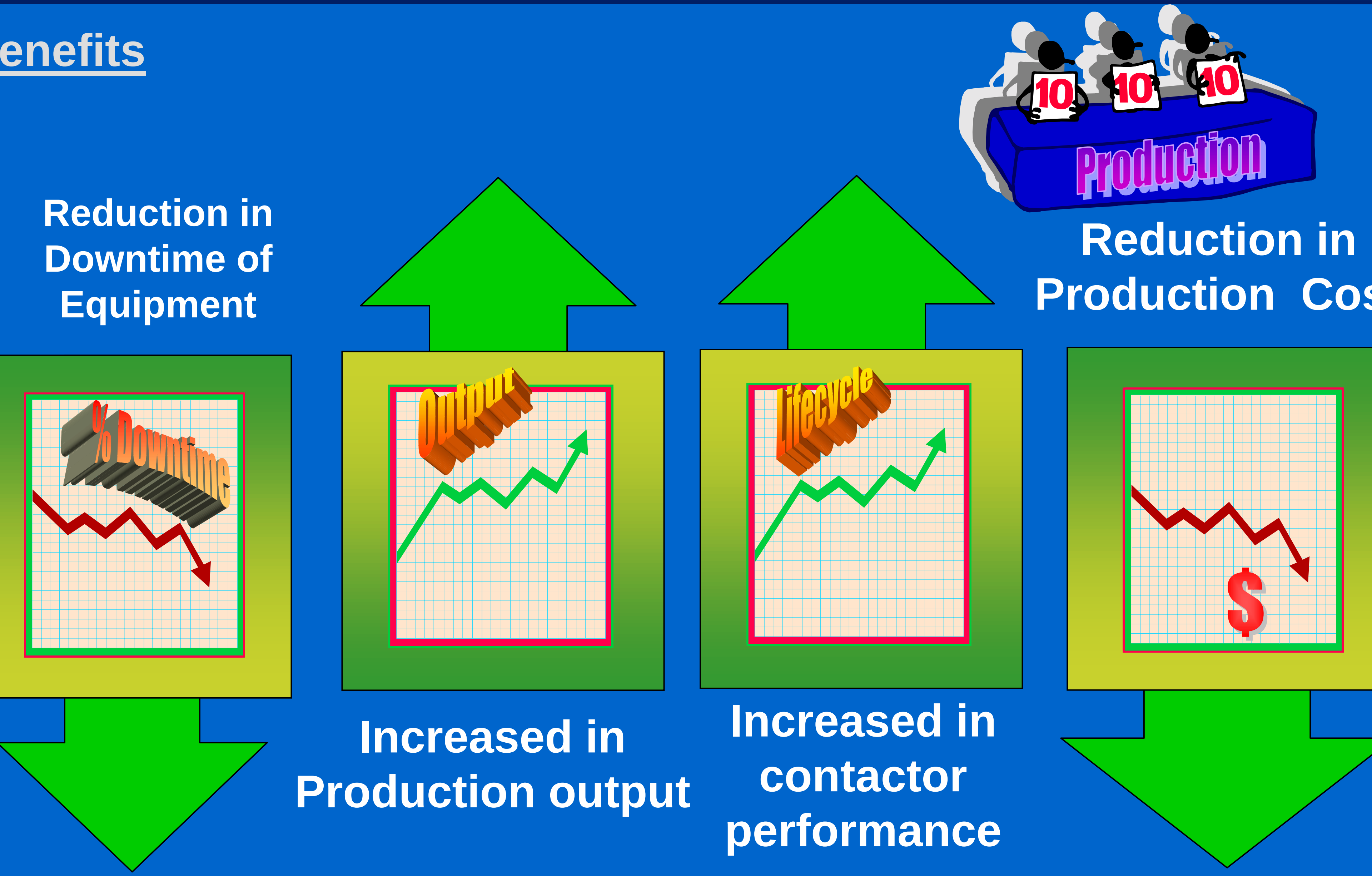
Testing of VQFN with Palladium-Cobalt Pogo Pin

enefits



Reduction in Downtime of Equipment

Increased in Production output

Increased in contactor performance

Reduction in Production Cos

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