THIRTEENTH ANNUAL BiTS 2012 Burn-in & Test Strategies Workshop

Session 7

ARCHIVE 2012

LIVING IN A MATERIAL WORLD

When you think about it, advanced materials are the steroids of the device testing world. The right material can often make the impossible possible. In this session, we hear about the improvements three innovative materials make to previous technologies. The first presenter introduces a new socket material that improves high frequency performance, then the second speaker examines socket contact plating and the impact on contact resistance in a burn-in environment. The final presenter talks about developing clad alloys for manufacturing test and burn-in sockets that better withstand the stress relaxation induced by high temperatures without sacrificing strength and performance.

Fully Impedance Controlled Socket With IM Material

Jiachun (Frank) Zhou, Dexian Liu, Khaled Elmadbouly, Brad Henry, Kevin DeFord
—IDI, Smiths Group

Socket Contact Plating and the Impact on Contact Resistance in a Burn-in Environment

Mike Noel—Freescale Semiconductor
Shawn Toth—Enplas

Using Clad Alloys to Make High Temperature Burn-in and Test Sockets

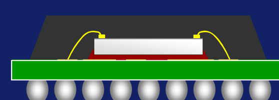
Jimmy Johnson—Materion Brush Performance Alloys
Terry Morinari—Enplas Semiconductor Peripheral Corp.

Fully Impedance Controlled Socket With IM Material

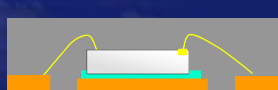
Jiachun (Frank) Zhou, Dexian Liu
Khaled Elmadbouly, Brad Henry, Kevin DeFord
IDI, Smiths Group

2012 BiTS Workshop
March 4 - 7, 2012

Content



- Background & Objective
- IM Material Basic Information
- IM Application - DaVinci Socket
- DaVinci Socket Performance
  Pin Cres over cycles
  RF measurement & simulation
- Summary



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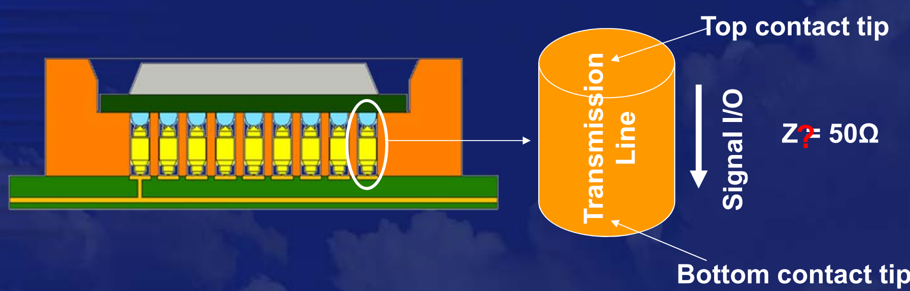
Background

Contactors within a socket connect electrically between the device and load board, which is similar to a transmission line.

To eliminate any signal loss the transmission line's impedance should ideally be controlled at 50Ω.

Very few contactors and sockets can meet 50Ωimpedance.



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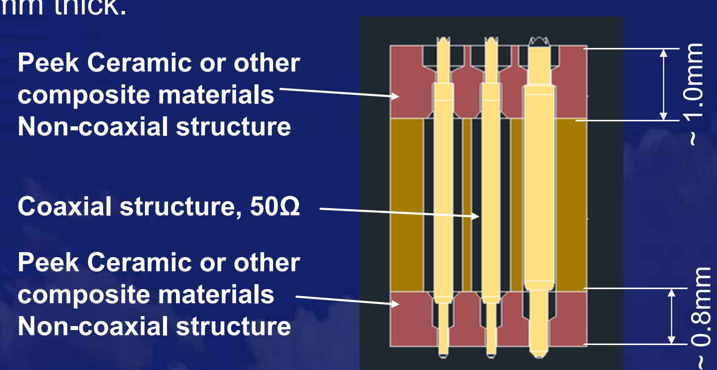
Background

Partially impedance controlled (50Ω) coaxial socket have been used commonly. The primary structure includes 3 layers; a metal coaxial structure sandwiched between two insulating composite retainers coaxial. Non-coaxial sections total ~ 2mm thick.



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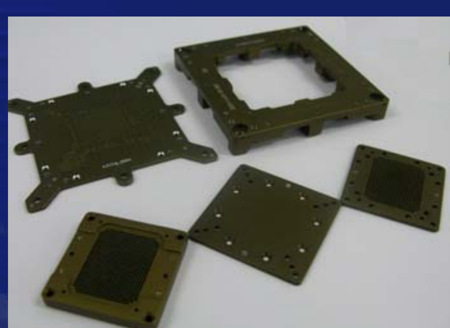
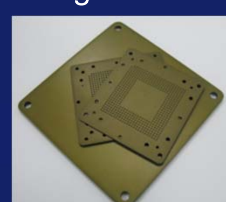
Objective

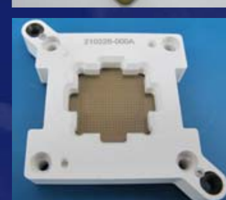
Develop a new structure & material to provide > 40GHz or fully impedance controlled socket .

IM Material Basic

- A special process has been developed to combine electrical insulator and high strength conductive material to form socket super structure.
- The basic characteristics of IM materials have been presented in poster paper “IM Material for High Pin Count Socket”.



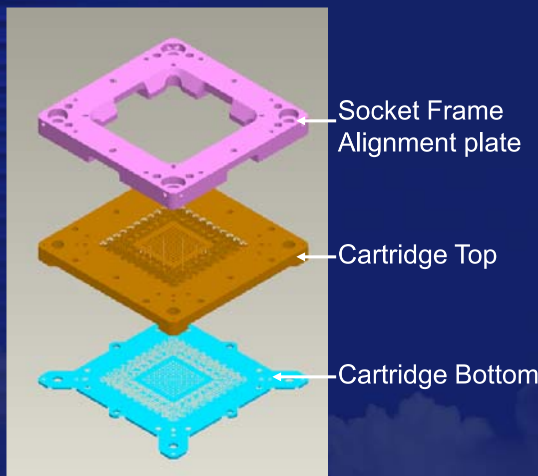


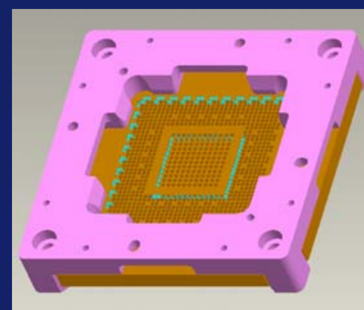


Patent pending

IM Application – DaVinci Socket

DaVinci socket applies IM material to specific components to achieve superior impedance controlled socket.





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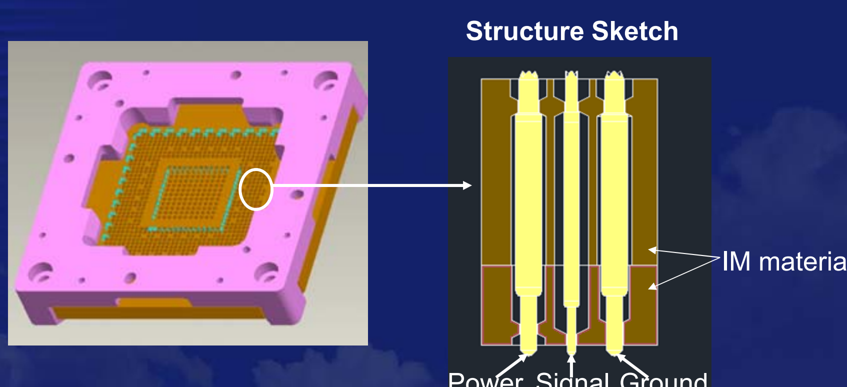
DaVinci – 40GHz Socket Structure

DaVinci socket is a fully impedance controlled socket offering 50Ω+/-10% from package contact tip to load board contact pad.



Patent pending

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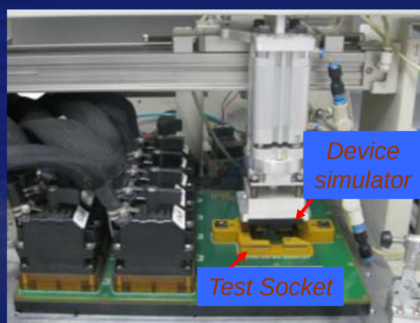
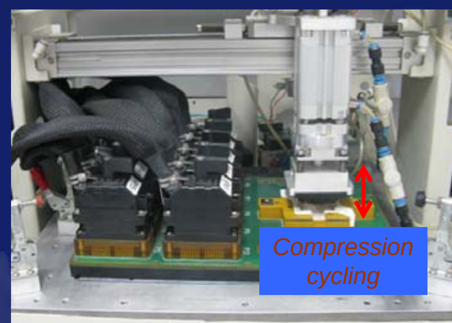
Paper #1
4

Spring Pin Performance

- Spring pins used in DaVinci socket were tested on contactor life tester, including mechanical cycles and measure contact resistance of contactor.
- Equipment Used:
  - Device simulator
  - Test socket & PCB
  - Cres measurement instrument





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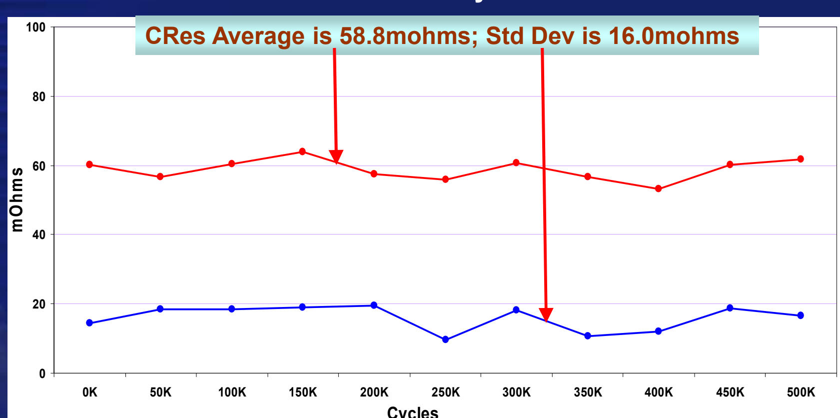
Spring Pin Performance

- Over 500K cycles, Cres of spring pin has average Cres < 60mOHm, with std dev ~ 16mOhm.

Cres vs. 500K Cycles



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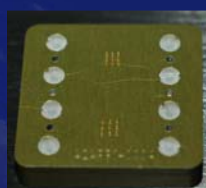
40GHz RF Measurement Set up

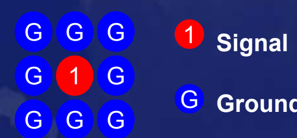
- RF measurement system is used to test DaVinci socket performance.
- The system can characterize ≥40GHz single-ended and differential performance of interconnector.
- Equipment Used:
  - Agilent E8368B, PNA Series Network Analyzer
  - IDI Standard RF Fixtures
  - IDI Standard Test Coupons

Test Coupon



RF Fixture

Pattern



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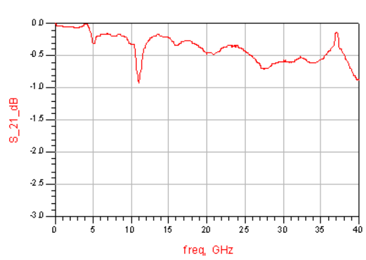
DaVinci – 40GHz Performance

Signal integrity:

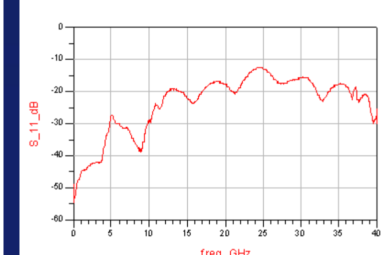
- **Measured on 40GHz RF measurement system.**
- **Insertion Loss: -1 dB IL > 40GHz**
- **Return Loss: -10dB RL > 40GHz.**

Insertion Loss



DaVinci: 0.8mm pitch

Return Loss



DaVinci: 0.8mm pitch

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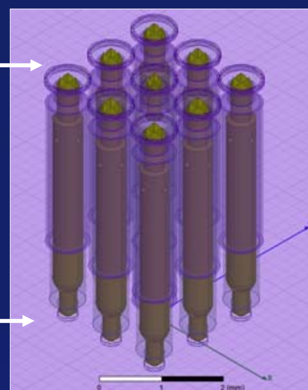
DaVinci – RF Simulation Model

- DaVinci socket RF performance is also simulated to compare actual measurement data.
- RF simulation uses same pattern as measurement coupon.

Device side



PCB side

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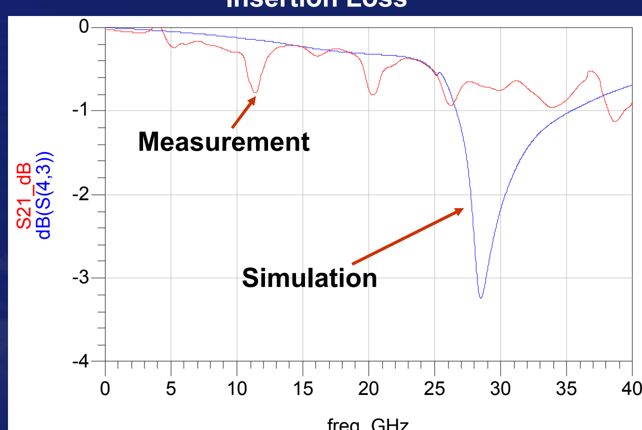
DaVinci – RF Simulation Results

- Simulation matches measurements very well. Simulation data are only reliable before 25GHz for insertion loss due to simulation method limitation.

Insertion Loss



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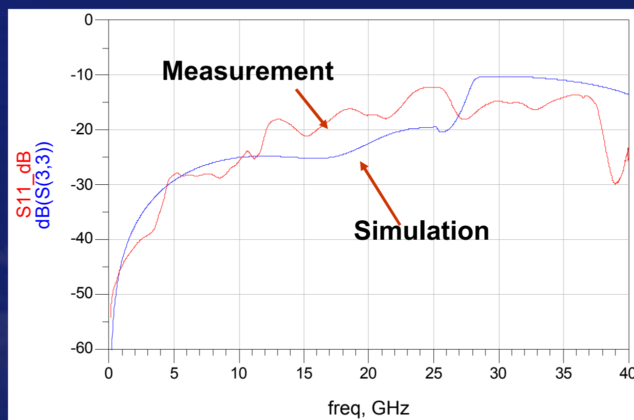
DaVinci – RF Simulation Results

- Return loss of simulations matches measurements very well over 40GHz.

Return Loss



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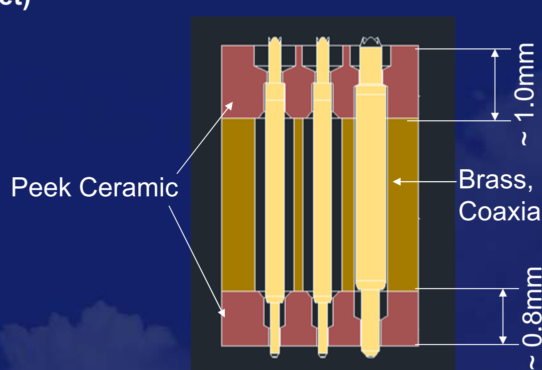
DaVinci vs. Short Pin & Old Coaxial

- Short pin (2.15mm compressed length) and conventional coaxial structure have been the best RF performance sockets.

Short Pin (Peek Ceramic socket)

Conventional Coaxial



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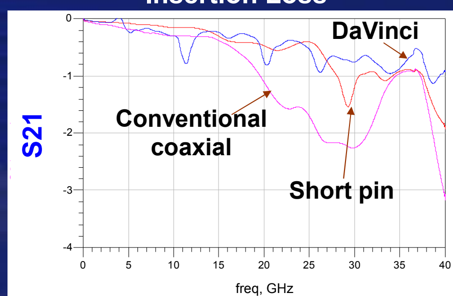
RF Performance Comparison

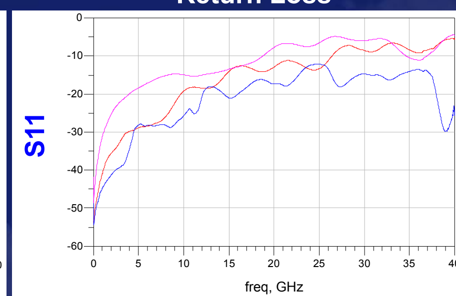
- RF performance of DaVinci, 2.15mm length pin, and conventional coaxial are compared as below. DaVinci socket has much higher bandwidth.

	IL, -1.0dB	RL, -10dB
DaVinci	>40GHz	>40GHz
2.15mm length pin	27GHz	27GHz
Conventional coaxial	19GHz	18GHz

Insertion Loss

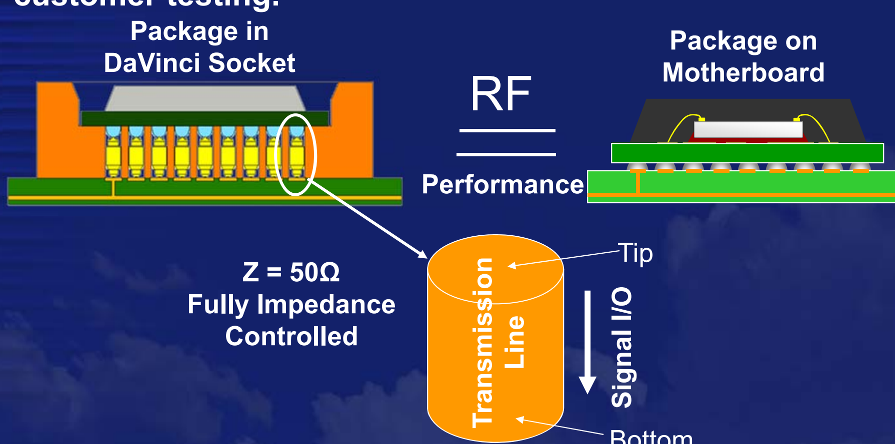


Return Loss



DaVinci – Customer Usage

RF performance of DaVinci socket is equal to a direct mounted package on the motherboard, confirmed by customer testing.



Summary

A new socket material has been developed to replace traditional insulation composite plastic materials.

This IM material plus proper pin and socket structures can build a fully impedance controlled socket for >40GHz RF performance. This excellent RF performance has been demonstrated through RF simulation, measurement and customer usage.

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Socket Contact Plating and the Impact on Contact Resistance in a Burn-in Environment

Mike Noel – Freescale Semiconductor
Shawn Toth - Enplas

2012 BiTS Workshop
March 4 - 7, 2012

Background

- RoHS – Restriction of Hazardous Substances
  - Drives change from Pb based plating to non Pb based plating
    - Matte Sn – Commonly used now
    - NiPdAu – Alternative but more expensive
  - Harder plating and different interactions impact contact quality and life of contacts

Background

- Previous BiTS work
  - 2003 and 2004 Full Sessions – "Socketing Lead-Free Packages"
  - Over a dozen other presentations under "Socketing Lead-Free Packages" on BiTS Archive
  - More recent paper 2009
    - "Contacting Pb-free finishes"

Dr James Forster, Kazumasa Sato, Don Hewer, St-Micro Malta & Antares-ATT USA

3/2012 Socket Contact Plating and the Impact on Contact Resistance in a Burn-in Environment 3

Production History

- Reviewing actual production data
  - Clear difference in yields between Matte Sn and Pb device types
  - Yields get worse over time
  - Clear difference between single and dual contact sockets

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Potential Factors

- Potential factors impacting socket performance and yields
  - Contact plating
  - Age of boards / sockets
  - Number of insertions
  - Oven / BI temperature
  - Burn-in duration
  - Socket design
  - Contact force / relaxation

We wanted to look closely at contact plating

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Experimental Objective

- Objectives
  - Determine the impact of the plating by running an evaluation where the *only* variable is the plating
  - Simulate real production as closely as possible
  - Evaluate using production devices plated with Matte Sn
  - New boards
  - New sockets
  - Production design
  - Production stress software
  - Production devices

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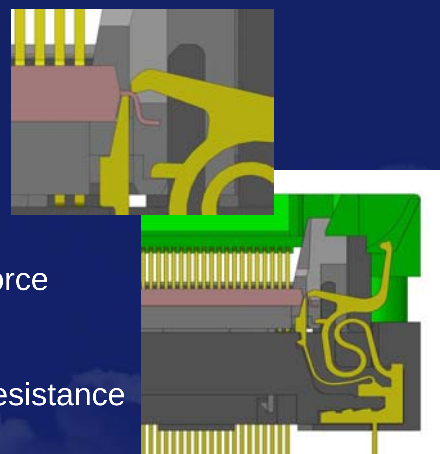
Experimental Outline

- **Process**
  - **Build boards with four different splits**
    - **Socket - Enplas OTQ**
      - **Au Plating**
      - **ES**
      - **Corsion Alloy**
      - **PdCo**



- ➢ Max 2.1kgf cover operating force
- ➢ Contact pressure 41gf
- ➢ 10,000 cycle life
- ➢ 50m ohm at 10mA Contact Resistance (Initial)

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Experimental Outline

Reasonably simple experimental outline

4 point milliohmmeter (HP34401A), with 4 wire probes

Measure Cres
↓
Run BI stress (approx 150 Hrs)
↓
Measure Cres

Repeat

49 measurements per device
5 devices per split, 4 splits, 18 readpoints ~ 20,000 measurements
Run production BI code during stress period
CR measured with shorted devices

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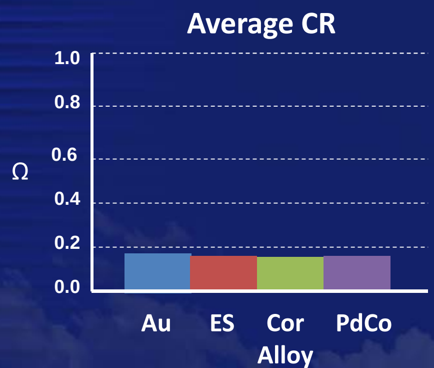
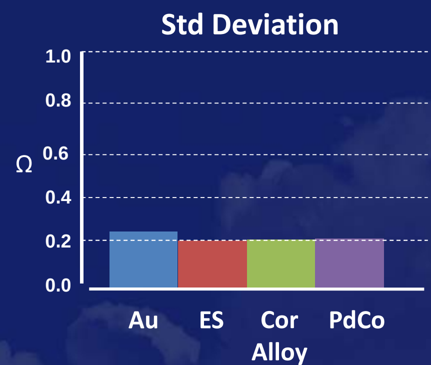
High Level Summary

Overall Initial Average and Std Deviation





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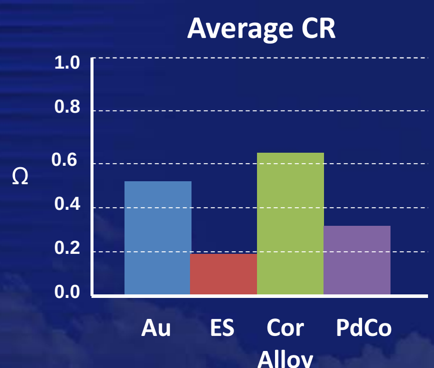
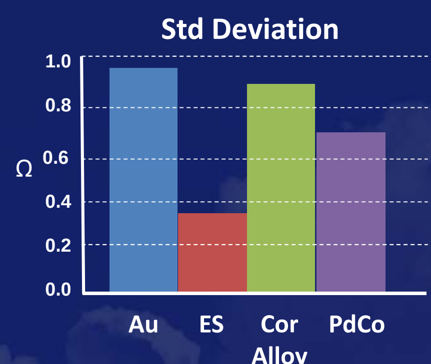
High Level Summary

Overall Final Average and Std Deviation





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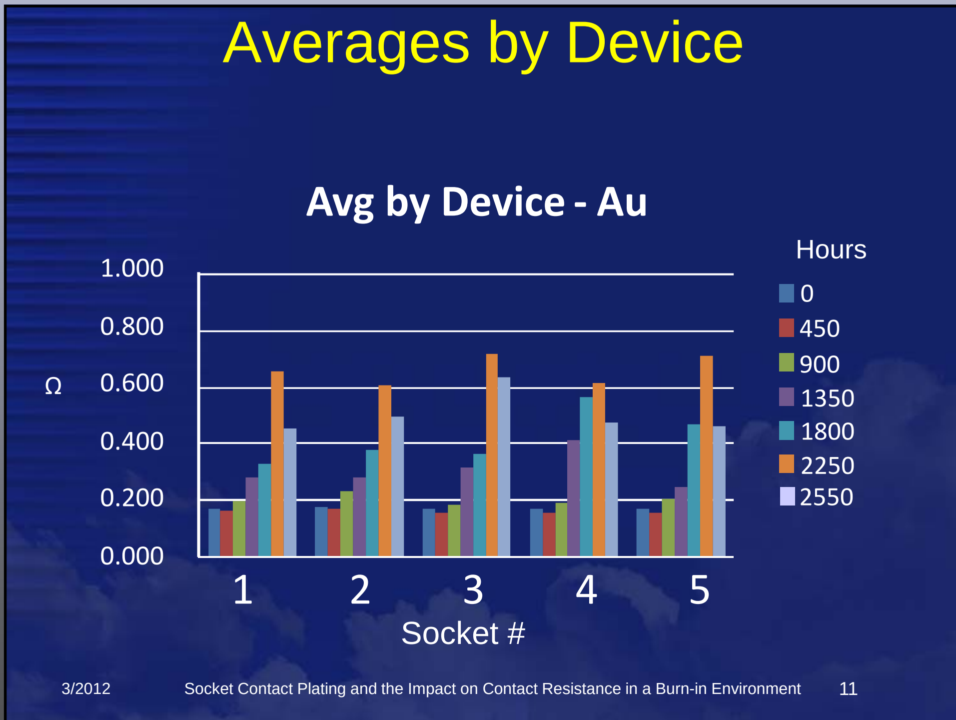
Averages by Device
Avg by Device - Au
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Socket #
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Socket Contact Plating and the Impact on Contact Resistance in a Burn-in Environment
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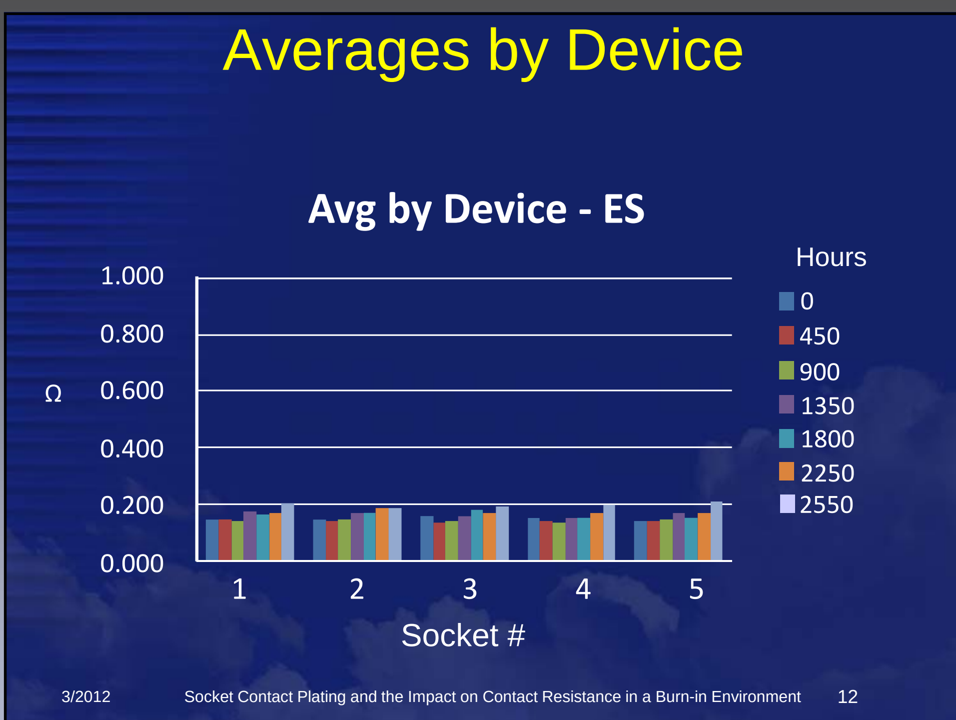
Averages by Device
Avg by Device - ES
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Socket Contact Plating and the Impact on Contact Resistance in a Burn-in Environment
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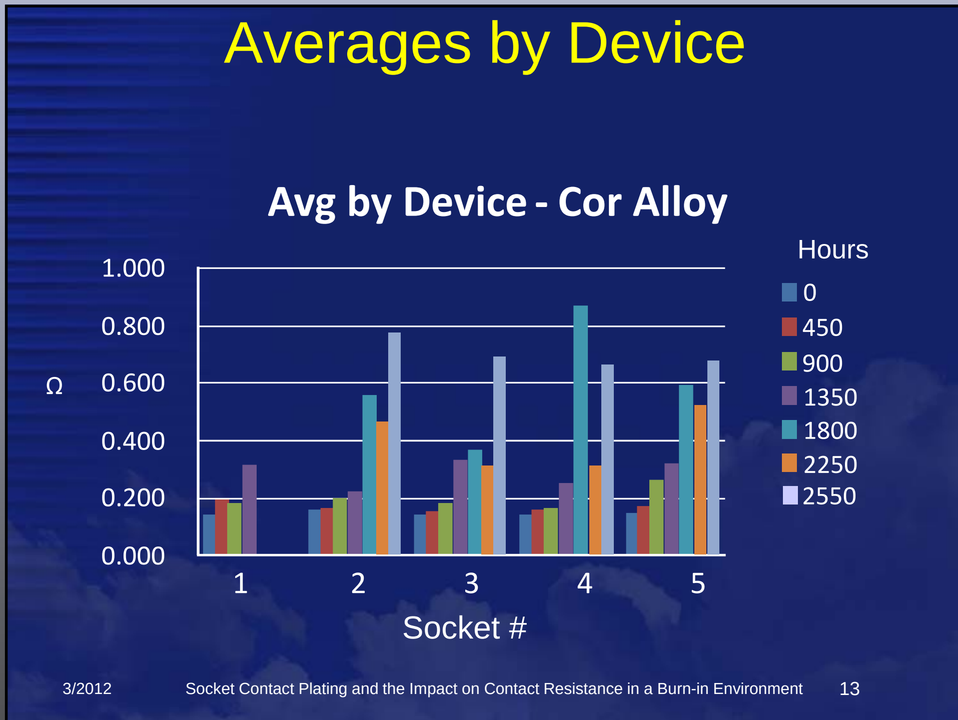
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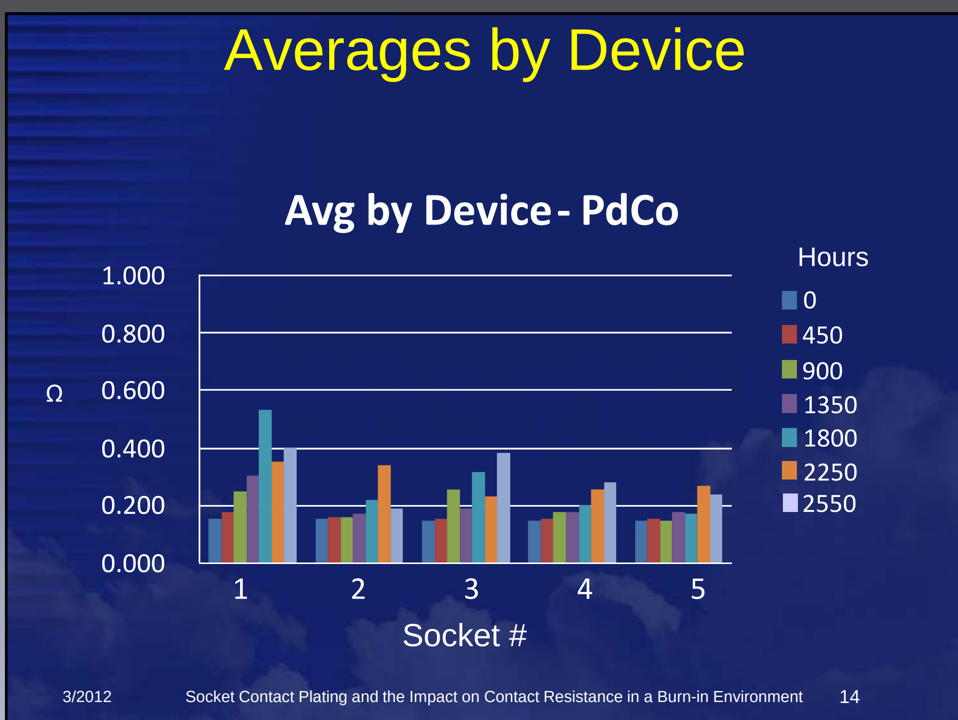
Averages by Device
Avg by Device - PdCo
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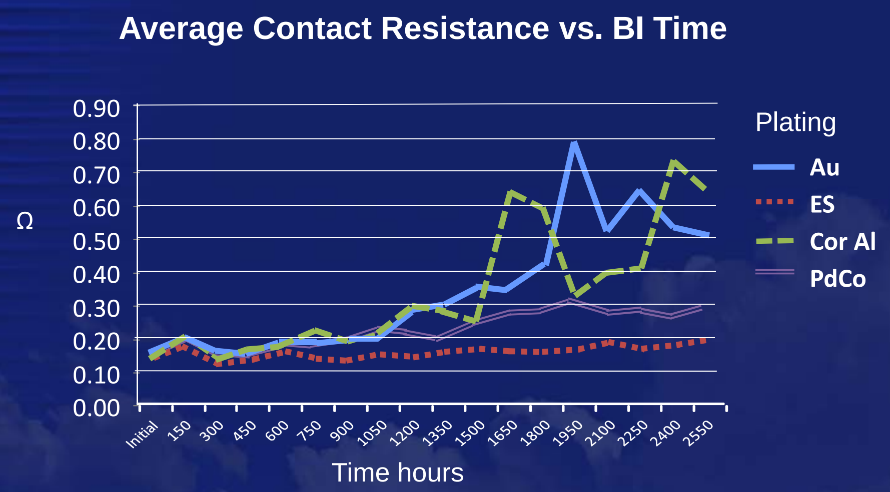
Overall Averages



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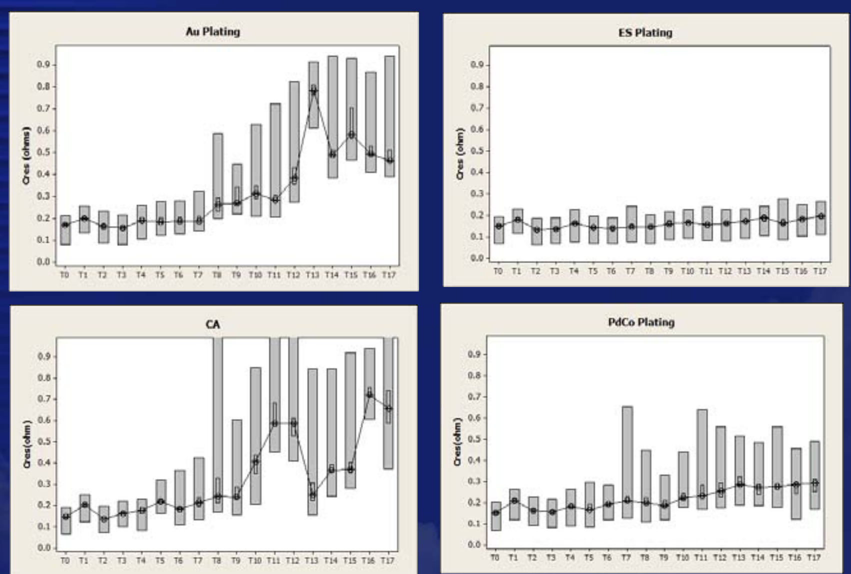
Mean & Distribution 0 to 2550 hrs.



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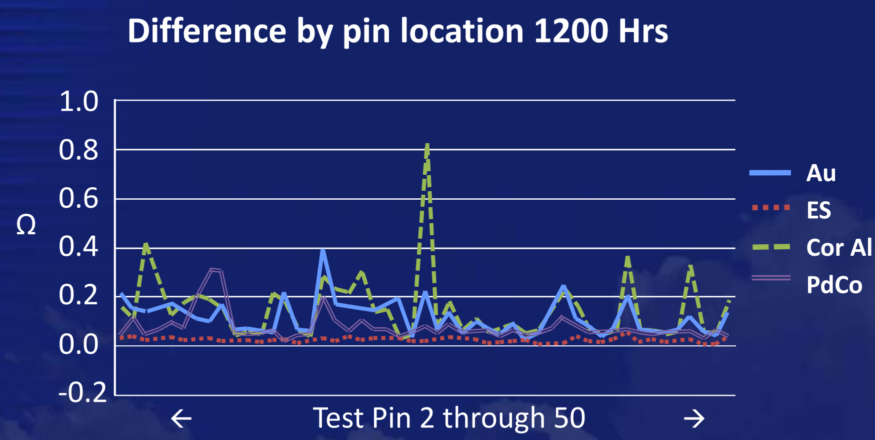
Change From Baseline (Time 0)



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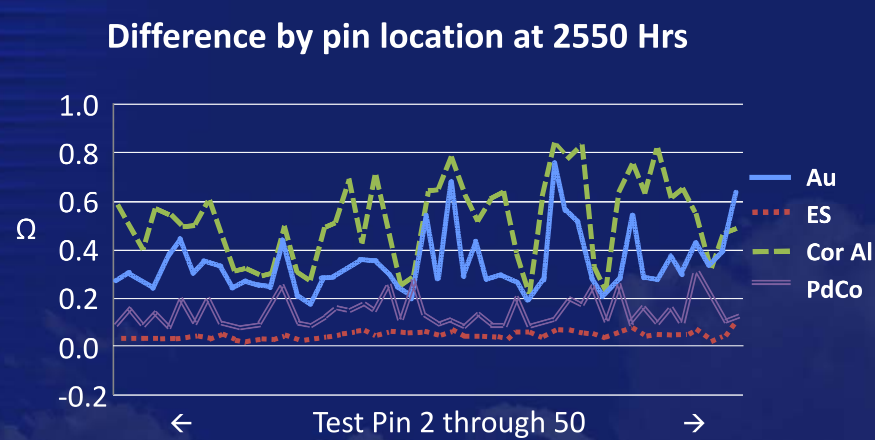
Change From Baseline (Time 0)



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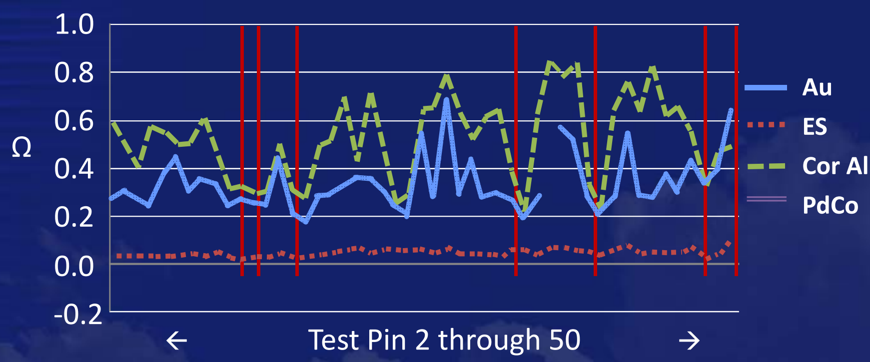
Change From Baseline (Time 0)

Change by Pin location, power pins at 2550 Hrs.



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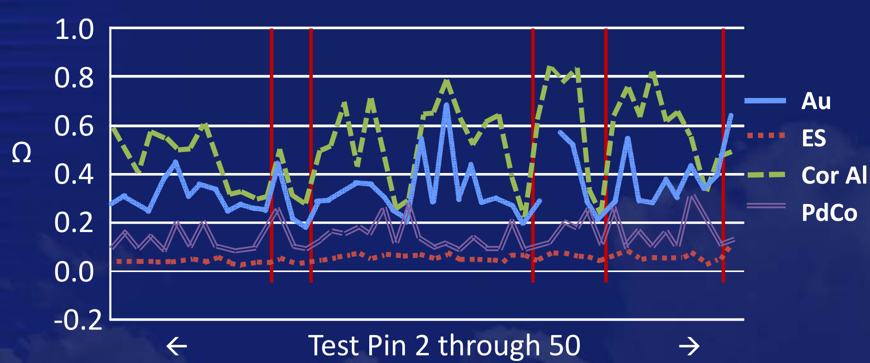
Change From Baseline (Time 0)

Change by Pin location, Ground pins at 2550 Hrs.



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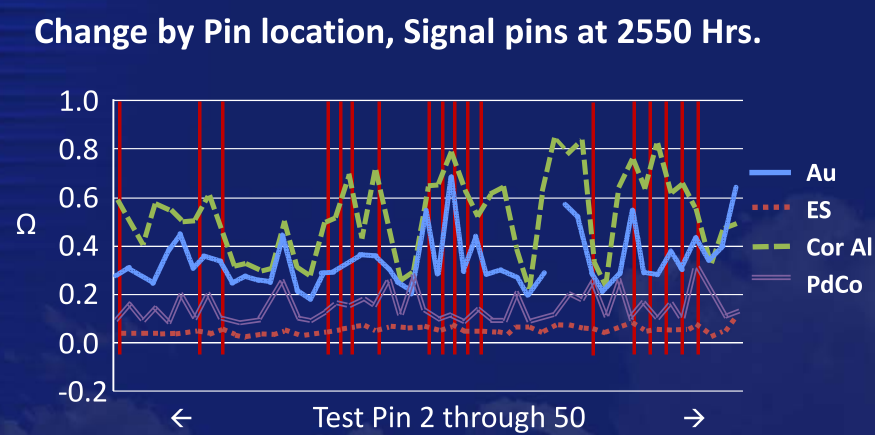
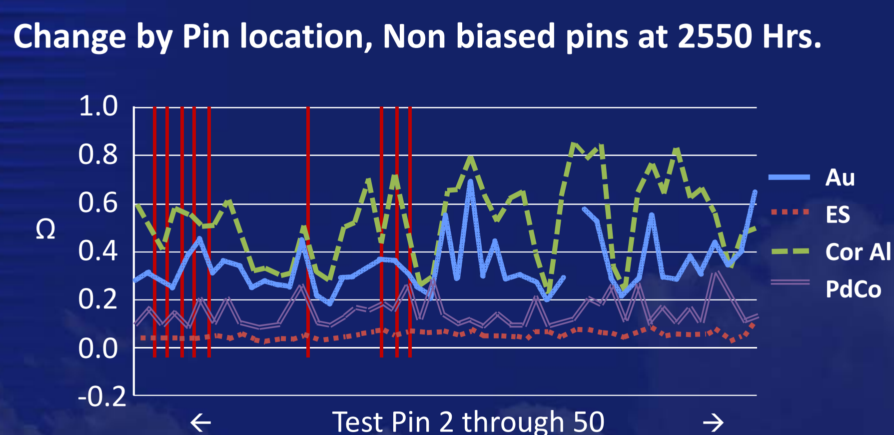
Change From Baseline (Time 0)



Change From Baseline (Time 0)



ES Plating

- **ES Plating**

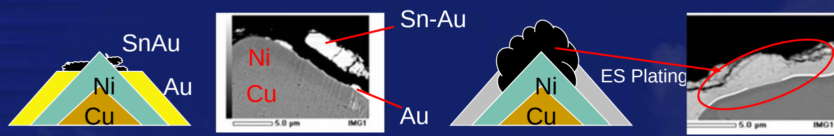
=> Total Cost Reduction by Long Cycle Life for Lead Free PKG

-Life Cycle: Longer Life than Au Plating
-Application: Test and Burn-in

ES Plating

Solder Migration Detail

Au Plating | **Alloy (Sn-ES Plating)**



Ni comes out after Cycle, and Contact Resistance becomes higher

ES Plating and Sn become alloy and Contact is stable even after cycling

US PAT NO. 8016624B2

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Contact Analysis

- Selected pin based on change in CR over time (signal pin)
- Focus on Au and ES
  - Au – Standard in use
  - ES – Showed most favorable and tightly distributed Cres results during evaluation
  - Perform visual, SEM (EDS) analysis on top and bottom of contact pin

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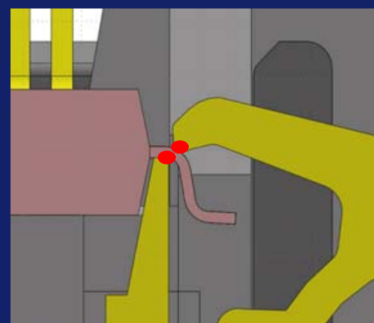
Contact Analysis

- Part Number
  - Socket : OTQ-100AS-0.5-001-00
  - Contact Pin: OTQ-100ASG-0.5-001-00
- Analyzed Contact Pin
  - Socket location: socket # 12
  - Contact pin location: pin #38 (signal pin)
  - Both upper and lower contacts



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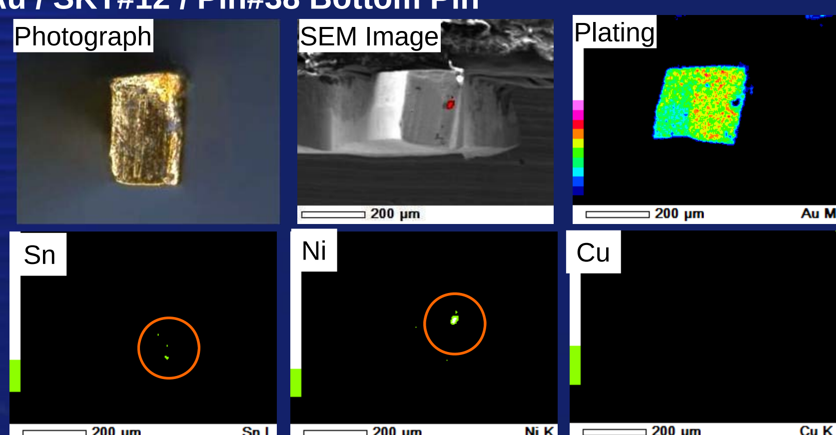
Contact Analysis

Au / SKT#12 / Pin#38 Bottom Pin



- Ni exposed
- No base material exposed

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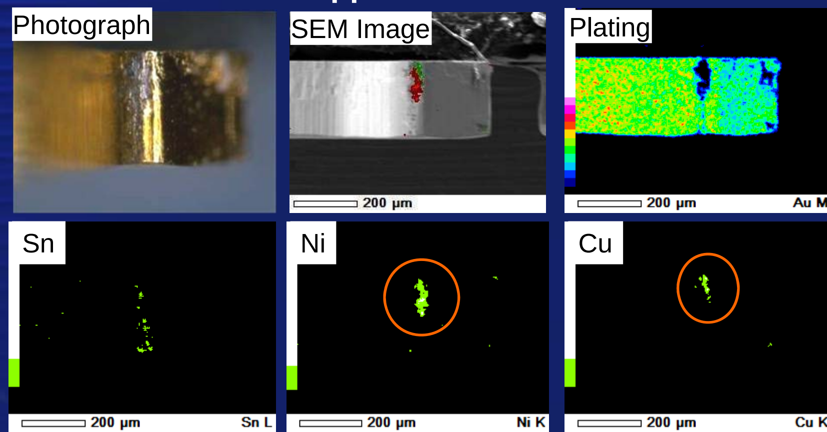
Contact Analysis

Au / SKT#12 / Pin#38 Upper Pin



- Ni exposed
- Base material exposed (Cu)

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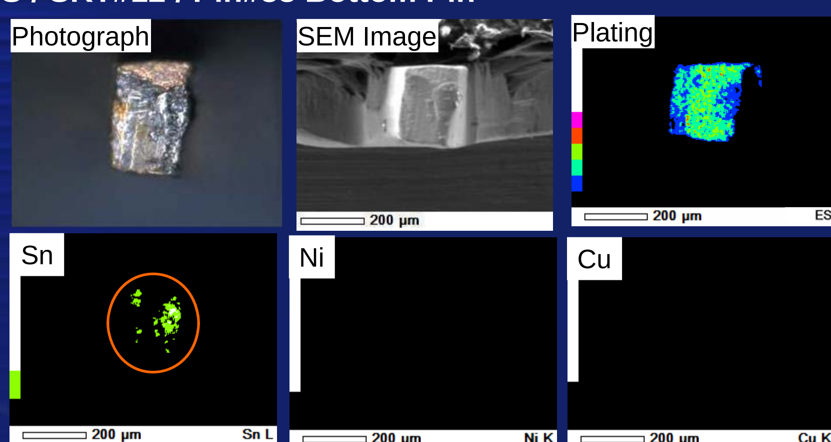
Contact Analysis

ES / SKT#12 / Pin#38 Bottom Pin



- No base material or Ni exposed
- Conductive alloy is visible

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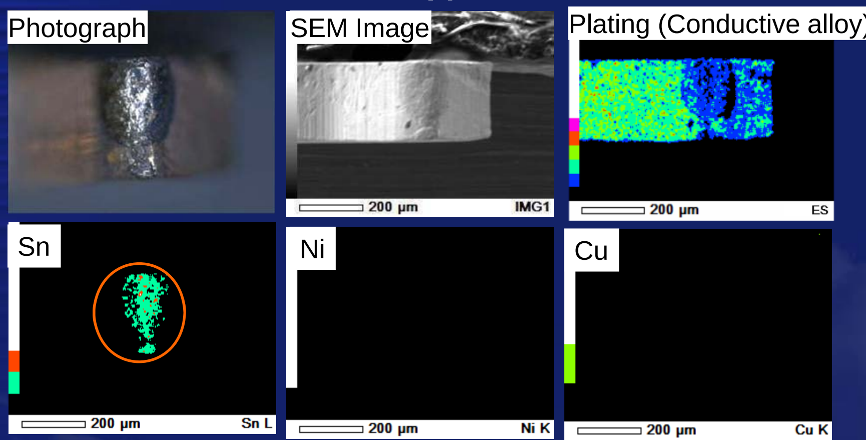
Contact Analysis

ES Board / SKT#12 / Pin#38 Upper Pin



- No base material or Ni exposed
- Conductive alloy is visible

Conclusions

- Contact pin plating does have a significant impact on contact resistance in a Burn-in environment
- Confirmed Au plating is compromised when used with Matte Sn device plating over long durations
- Confirmed device plating transfer on ES socket has a minimal impact on contact resistance over time
- SEM analysis confirms conductive Sn ES alloy is formed on ES plated contact pin
- Alternative platings can offer long term performance advantage compared to standard Au plating

Ongoing - Future Work

- Two sets (100ld, 128ld) of production BIBs in HVM sites
- Continue experiment to 15,000hrs with extended read points
- Running evaluations on other non-QFP socket types (OTB, ATE sockets)
- Experiments to compare Matte Tin plating types

Using Clad Alloys to Make High Temperature Burn-in and Test Sockets

Terry Morinari
Enplas Semiconductor Peripheral Corp.
Jimmy Johnson
Materion Brush Performance Alloys

2012 BiTS Workshop
March 4 - 7, 2012

Presentation Outline

- Recap of CM363 2010 BiTS Workshop presentation.
- Description of socket(s) made using the CM363
- Review test data at elevated temperatures collected on the sockets made CM363
- Conclusions
- Next steps

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Research Driving Forces

- 2009 BiTS Workshop
- Processor higher pin count
- Finer pitch
- Lower package profiles
- Higher current density
- Higher ambient temperatures during burn-in

Research Driving Forces

Type	Feature	Metric	2003	2005	2007	2009	2014	2019	Barrier
Test Sockets	Packages	Types	SO, LGA, BGA, mBGA, QFN, DFN, CSP, etc.						
	Contact Matl.	Alloy	Cu Alloy [brass, BeCu]					Same/New	None
	Max. # Contacts	#	1,000	1,000	2,000	3,000	5,000	10,000	10,000
	Max. # Cavities	#	1	1	2	4	8	16	64
	Min. Pitch	mm	0.65	0.4	0.3	0.3	0.25	0.2	100µm
	Max. Edge Rate	GHz	3	6	12	24	40	≥ 10Gbps	20Gbps
	Inductance	nH	1	1	0.4	0.3	0.2	0.1	0.1
Burn-In Sockets	Contact Matl.	Alloy	Cu Alloy [BeCu]					Same/New	None
	Max # Contacts	#	1,000	5,000	10,000	10,000	10,000	10,000	Pkg Size
	Max. # Cavities	#	16	32	32	64	64	64	64
	Min. Pitch	mm	1	0.8	0.65	0.5	0.3	≤0.3mm	0.2
	Max. Temp.	°C	150	150	150	175	250	250	250
	Housing	Material	Thermoplastic					250°C	250

Source: Bishop & Associates Inc., Post Recession Outlook Electronics Industry and Connector Road Map 2009-2019

HPAs* Used in BiTS Applications and Their Properties

- Alloy 25 (C17200)
  - Be 1.8 to 2.00%
  - Co + Ni 0.20% min
- Alloy 390 (C17460)
  - Be 0.15 to 0.50%
  - Ni 1.0 to 1.4%
- Alloy 390E (C17500)
  - Be 0.40 to 0.70%
  - Co 2.4 to 2.7%
- Alloy 3 (C17510)
  - Be 1.8 to 2.00%
  - Co + Ni 0.20% min
- Alloy 360 (NO3360)
  - Be 1.85 to 2.05%
  - Ti 0.4 to 0.6%

* Materion

HPAs* Commonly Used in BiTS Applications and Their Properties

Alloy	2% Offset Yield Strength ksi (MPa)	Modulus of Elasticity Mpsi(GPa)	Electrical Conductivity %IACS	1000 Hr Stress Relaxation Resistance (% stress remaining)			*Formability 90° Bend R/t	
				100C	150C	200C	Long	Trans
25 HT	165-205 (1130-1420)	19 (131)	22-28	95	87	55	2.0	0.7
390 HT	135-153 (930-1055)	20 (138)	44 min	96	84	68	2.0	2.0
390E EHT	138 min (951 min)	20 (138)	42 min	96	84	68	2.0	2.5
3 HT	95-120 650-870	20 (138)	48-60	96	85	66	1.0	1.0
360 HT	230 min	28-30 (195-210)	6 min	100	100	100	0.8	1.5

* Note: Formability at thickness = 0.1 mm, Alloys 25 and 360 formability rating prior to heat treating

* Materion

HPAs* Commonly Used in BiTS Applications and Their Properties

- Alloy 360 has excellent stress relaxation resistance, has good formability, and very high strength, but the electrical conductivity is poor

Alloy	2% Offset Yield Strength ksi (MPa)	Modulus of Elasticity Mpsi(GPa)	Electrical Conductivity %IACS	1000Hr Stress Relaxation Resistance (% stress remaining)			*Formability 90° Bend R/t	
				100C	150C	200C	Long	Trans
360 HT	230 min	28-30 (195-210)	6 min	100	100	100	0.8	1.5

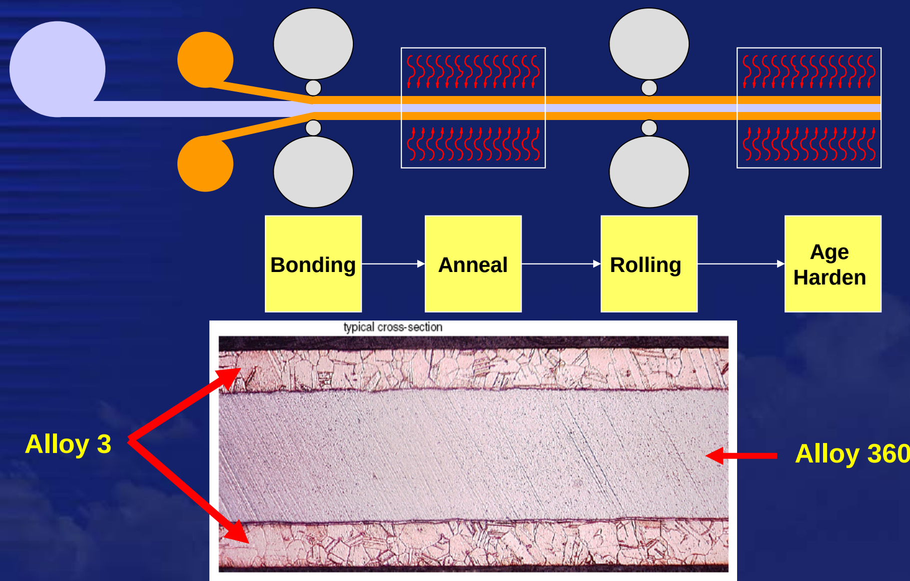
* Note: Formability at thickness = 0.1 mm, Alloys 25 and 360 formability rating prior to heat treating

* Materion

Mathematical Determination of Clad Metal Composite Properties

	Material	Modulus (Mpsi)	Fraction of X-Section (%)	Yield Strength (ksi)	Conductivity (%IACS)	Resistivity Ohm-in
Top Layer	3	20.0	20%	110	45	1.509E-06
Middle Layer	360	30.0	60%	188	6	1.132E-05
Bottom Layer	3	20.0	20%	110	45	1.509E-06
Composite		26.0	100%	157	21.6	3.14E-06

Cladding Process



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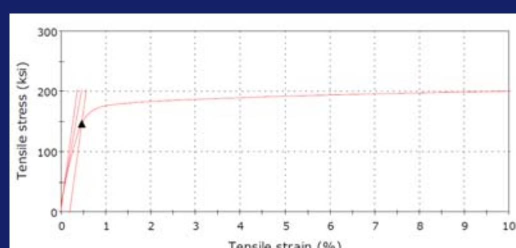
3-360-3 Clad Tensile Properties after Heat Treatment

950F (510ºC)/1.5 hrs or 1000F (538ºC) /15 min

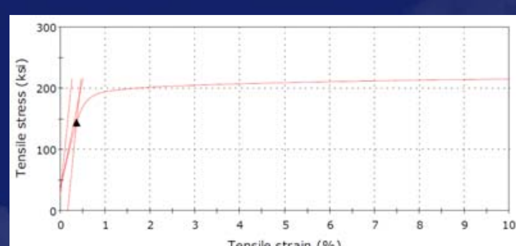
½ Hard → heat treated

UTS = 200 ksi (1379 MPa)
YS = 150 ksi (1034 MPa)



Full Hard → heat treated

UTS = 215 ksi (1482 MPa)
YS = 160 ksi (1103 MPa)



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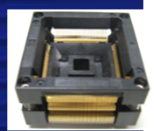
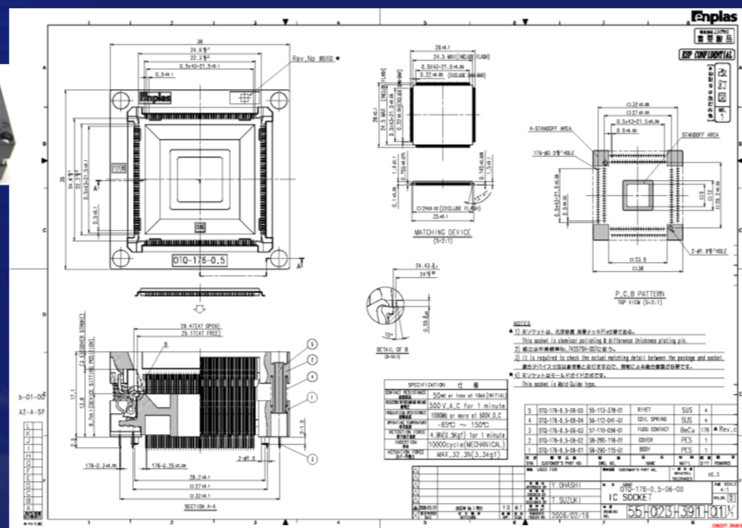
Socket Description





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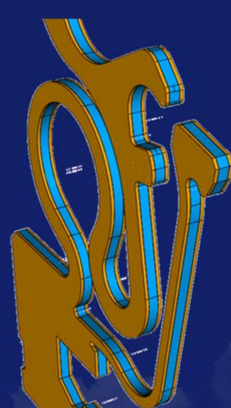
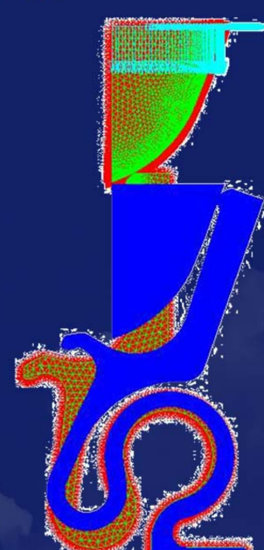
Socket Description

High yield strength is required for flexible contact pin material.





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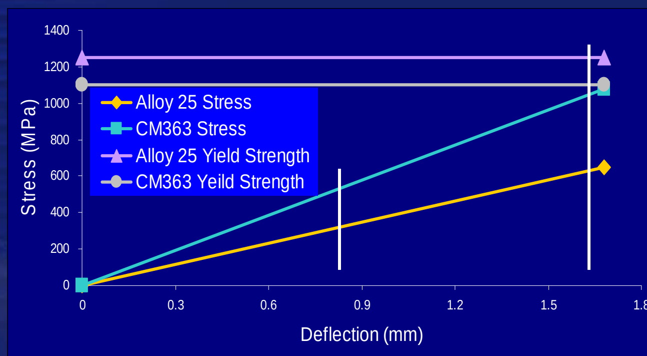
FEA Analysis

Stress condition

Alloy 25; 360MPa at device loaded
647MPa at Contact pin fully actuated
CM363; 600MPa at device loaded
1079MPa at Contact pin fully actuated



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Evaluation items

- Mechanical stress test
  - Actuate the contact pins under the socket assembly until one of them is broken
- Heat stress test
  - Put the socket under the high temp condition
- Heat & mechanical combination stress test
  - Apply heat and mechanical stress for certain cycles

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Evaluation results
Mechanical stress test

Test description

Actuate the contact pins until one of them is broken.

Socket sample;
1 each (Alloy 25, CM363)
Test condition;
Assembled in socket
Room temperature

Test result

CM363; 40,000 times (Broke in 50,000)
Alloy 25; 50,000 times (Broke in 60,000)

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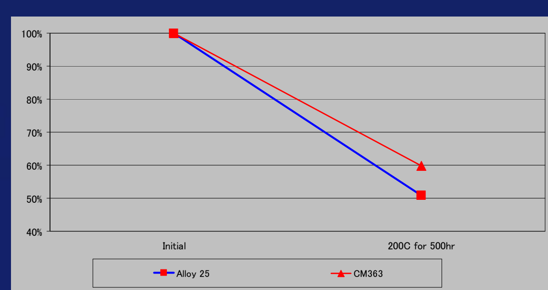
Evaluation results
Heat stress test

Test description

Leave the sockets under the high temperature and check the contact force reduction.

Socket sample;
1 each (Alloy 25, CM363)
Test condition;
Assembled in socket
Device loaded
200C



Test result

CM363 ; 40% contact force reduction
Alloy 25; 50% contact force reduction

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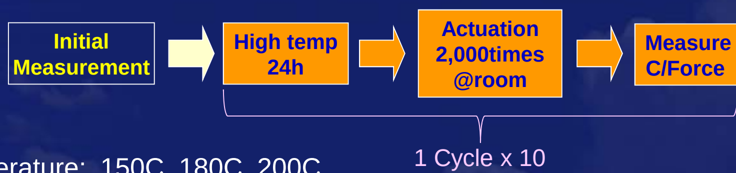
Evaluation results

Heat and Mechanical combination stress test

Test description

Check the contact force reduction under the test condition below:
Set "heat soak for 24hrs and 2k times actuation" as 1 cycle.
Repeat the cycles up to 10 times.
Measure Contact force on certain cycles at
"Initial", "1cycle", "2cycle", "5cycle", "10cycle"



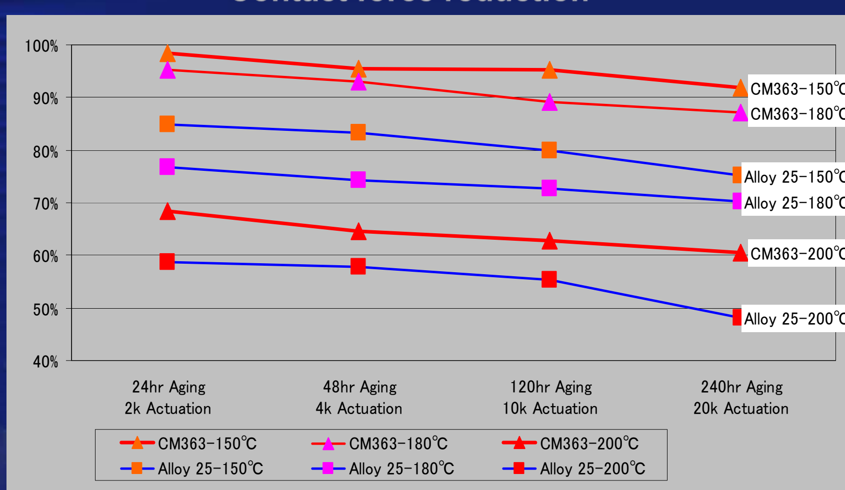
Temperature; 150C, 180C, 200C
Test samples; Alloy 25 for 1 each (total 3)
CM363 for 1 each (total 3)

Evaluation results

Heat and Mechanical combination stress test

Test result

Contact force reduction



Conclusions

- CM363 can withstand extremely high temperatures, showed improvement over Alloy 25 up to 200ºC with socket.

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Next steps

- More field trials with customers in high temperature burn-in applications
- Try other combinations of materials and layer thickness to meet application requirements

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