BiTS Burn-in & Test Socket Workshop 2008 Session 2

ARCHIVE 2008

CLEAN UP YOUR (SOCKET) ACT

"An Examination of the Causes of C_{res} Degradation Which Affect the Life of a Test Socket"

Nick Langston Jr.
Antares Advanced Test Technologies

"Improved Method for Socket Evaluation, Development and Cleaning"

Terence Q. Collier
CVInc

"CO_2 Composite Spray Technology For Test Socket Cleaning"

David Jackson
Cool Clean Technologies, Inc.

"Batting Cleanup: Approaches to Maintenance of WLCSP Probe Card Interposers"

Jon Diller, Jamie Andes
Interconnect Devices, Inc.

An Examination of the Causes of C_{res} Degradation Which Affect the Life of a Test Socket

2008 Burn-in and Test Socket Workshop
March 9 - 12, 2008

Nick Langston Jr.
Antares Advanced Test Technologies

Agenda

- Solder Alloy overview
- SAC105 Performance Issues
- Probe Design for Pb Free Solder Balls
- Cleaning Methodology
- Case Study
- Conclusions

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Popular Solder Alloys for Ball Grid Array

SAC105	Sn / 1% Ag / 0.5% Cu
SAC305	Sn / 3.0% Ag / 0.5% Cu
SAC405	Sn / 4.0% Ag / 0.5% Cu

Sn **A**g **C**u 40 5

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Why Sn Ag Cu?

- Ease of process transition from SnPb
- Low relative cost of change from SnPb
- Equivalent or superior reliability to SnPb
- Lower melting temperature when compared to SnAg
- Superior wettability, creep and fatigue characteristics when compared with SnAg or SnCu

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Comparative SAC Properties

Alloy Composition	SnPb	SAC105	SAC305	SAC405
Melting Point	183ºC	221ºC	217ºC	217ºC
% Elongation	48	21	46	35
Elastic Modulus [GPa]	40.2	47	51	53
Young's Modulus [GPa]	33.6	36	41.6	41.6
Tensile [MPa]	30	30	53.3	53.3

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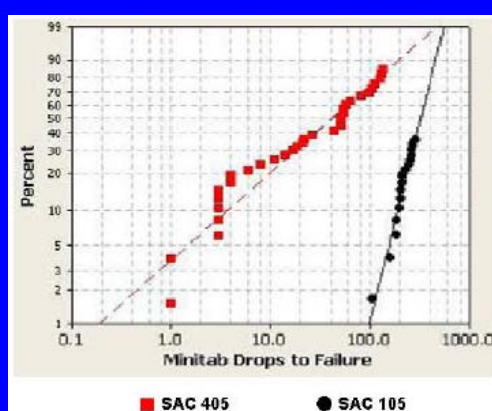
Why SAC105?

- Superior Drop Reliability



Source: "Improved Drop Reliability Performance with Lead Free Solders of Low Ag Content", Kim, et al, 2007 ©2007 IEEE

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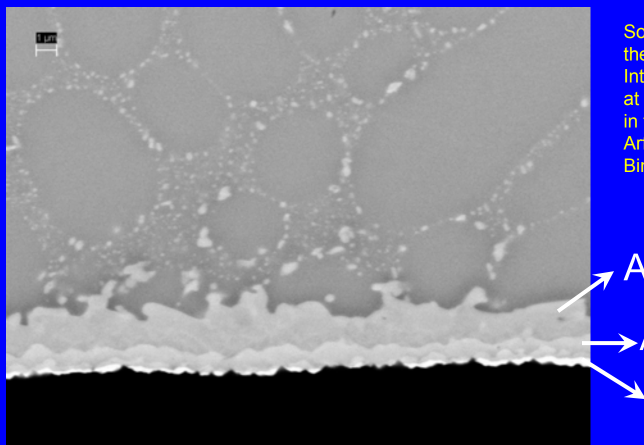
SAC105 Test Challenges

- Formation of intermetallic compounds



Source: "Examination of the Formation of Au-Sn Intermetallic Compounds at Au/SnAgCu Interfaces in the Solid State", Gao, Arfei and Cotts, SUNY Binghamton, 2007.

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SAC105 Test Challenges

- Pb free, but behaves like SnPb
  - More compliant than SAC405 or 305
  - Rapid contamination
  - Frequent cleaning cycles if used with standard "Pb Free" probe design methodologies

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Pb Free Probe Design

- 3 Primary design variables:

1. Force
2. Geometry
3. Plating

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Pb Free Probe Design

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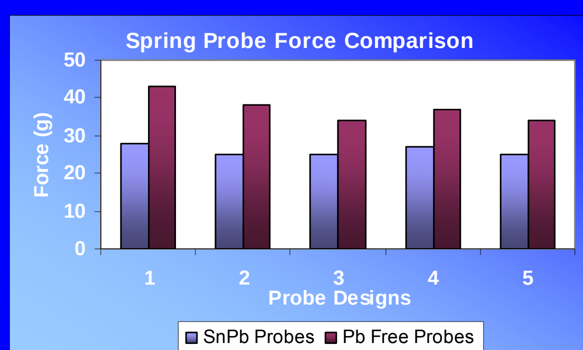

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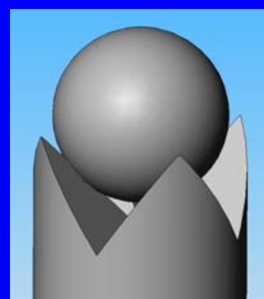
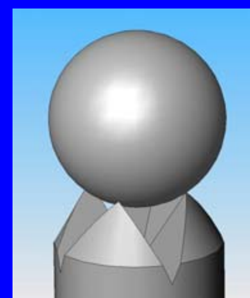
Pb Free Probe Design

- 3 Primary design variables:
  1. Force
  2. Geometry
  3. Plating



“Cradle”
For SnPb



“Stab”
For SAC

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Pb Free Probe Design

- 3 Primary design variables:
  1. Force
  2. Geometry
  3. Plating

Au
For SnPb

PdCo
For SAC

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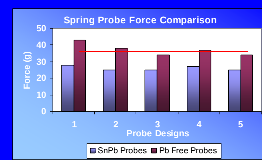
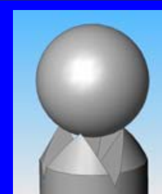
Pb Free Probe Design

- Conventional Wisdom Says:



1. Force: >30g
2. Geometry: Stab
3. Plating: PdCo



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Spring Probe Cleaning Methods

- Ultrasonic baths using:
  - Isopropyl Alcohol
  - Acetone
  - Methanol

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Spring Probe Cleaning Methods

Potential issues with current cleaning procedures:

- Assumes all contaminants are of organic nature.
- Left over flux and oxide build up are not addressed.

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Alternative Cleaning Method

De-Ox 1699

- Removes Oxides, Sn and Pb
  - RD Chemical Company

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Alternative Cleaning Method

Comparison with existing methods:

	C_{res} Pre-Clean (mΩ)	C_{res} Post-Clean (mΩ)	% Change
Acetone	1017	382	-62%
IPA	1345	651	-51%
Methanol	810	560	-31%
De-Ox 1699	1200	238	-80%
De-Ox 1556	1238	273	-78%

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SAC 105 Case Study

- Device:
  - BGA
  - 0.5mm Pitch
  - Low Current: <20mA / Pin
  - Temperature: Ambient to 110º C
- Spring Probe:
  - Force: Low (<25g)
  - Geometry: Stab
  - Plating: Pd hardened Au

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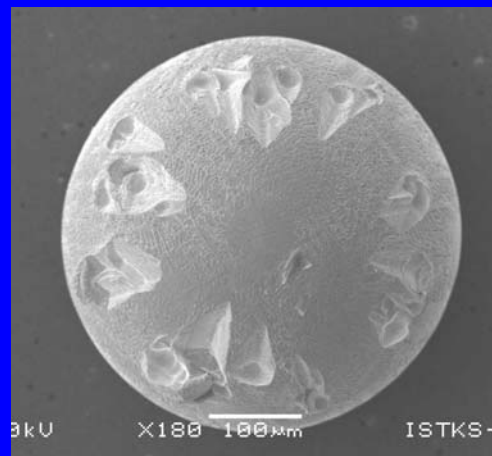
SAC 105 Case Study

- 3 Touchdowns
- Significant Witness Marks



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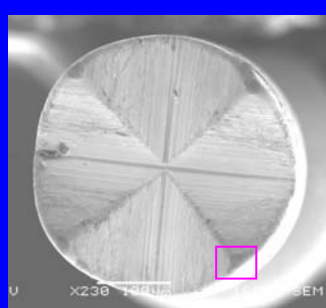
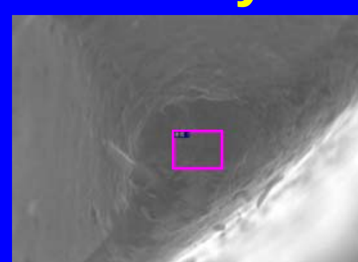
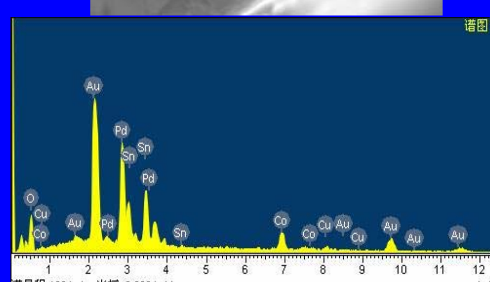
SAC 105 Case Study





- 100K insertions
- O & Sn present



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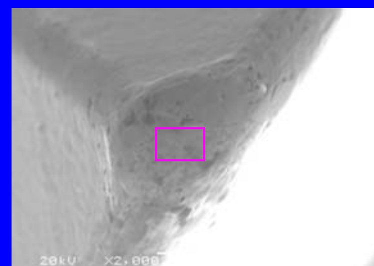
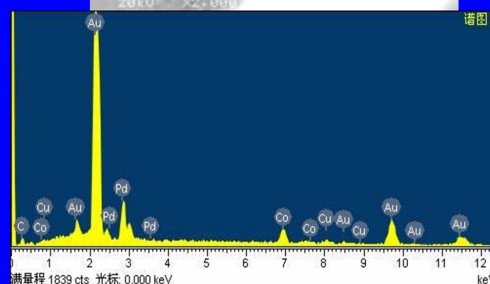
SAC 105 Case Study





- After De-Ox 1699 cleaning
- O and Sn are removed

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SAC 105 Case Study

Cleaned Pin Resistance Measurements

	C_{res} Pre-Clean	C_{res} Post-Clean
Avg	120 mΩ	51.5 mΩ
Std Dev	23.5 mΩ	11 mΩ
Avg+2 Std Dev	167 mΩ	73 mΩ

New Pin Resistance Spec

Avg	60mΩ
Avg+2 Std Dev	110mΩ

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Conclusions

- Proliferation of low Ag SAC alloys presents new challenges:
  - Shorter spring probe life
  - More frequent cleaning
  - Higher cost of test
- Alternative cleaning techniques can extend probe life.
- New probe design rules are required for low Ag alloys.

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Improved Method for Socket Evaluation, Development and Cleaning

Terence Q. Collier
CVInc

BiTS 2008

How to Build a Better Socket

To build a better socket, the designer and test engineer needs to be able to generate the following requirements quickly and economically:

- Optimum spring loading for a given probe tip geometry to determine the sweet spot for stable electrical contact.
- An ability to evaluate contact resistance (CRES), the impact of intermetallic formation at the probe tip, and the impact of contamination on the DUT pads.
- Life testing (including PM schedules) of individual components
- Incoming inspection capability on assembled sockets
- Impact of temperature on performance and components.

What is the best solution?

- Modified MHT is faster and cheaper than building sockets and probes.
- Cost and MMHT design allow the socket designer to do economical sided by side comparisons of contactor technology
- The MHT is programmable allowing tests to be run offline while the engineer or technician completes other tasks.
- Receiving inspection capability on the socket.
- Real time on-line capability to quickly isolate quality issues to device or socket.

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- Improvement
- Development
- Cleaning

Improvements

Old Method:

1. Historical socket results
2. Latest and greatest probe tip technology
3. Build a card
4. Verify
5. Redesign
6. Infinitely loop steps 3 through 5 until something works

New Method:

1. Verify the amount of force needed to make electrical contact
2. Match the spring to that force
3. Match the tip to the contact area
4. Verify the spring at time zero and 100k TD's
5. Build card correctly the first time

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Why the MMHT

Excellent accuracy and repeatability Fast and economical results!

No need for complete wafers

- MHT has the capability to probe individual bumps and pads

No need for complete probe card

- A single pin can be inserted into the tip

Eliminates the need to design and build mock test setups …… reducing the tolerance stack error in the Prober/Tester/Probe Card system:

Chuck Planarity	Wafer Planarity
Bond Pad Corrosion	Probe card
Die Performance	Electrical Contact Force

which can lead to invalid conclusion -and- result in REPEAT experiments.

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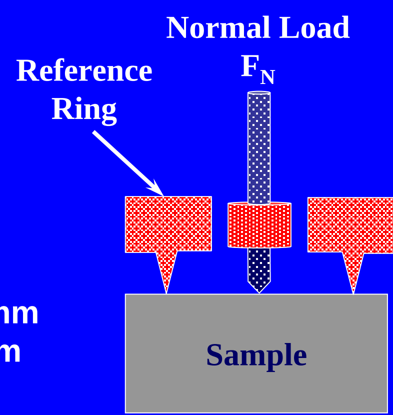
Modified Micro Hardness Tester



Maximum Force 30 N
Force Resolution:
10 N Scale = 0.3 mN
30 N Scale = 1 mN
Displacement Range 500 mm
Displacement Res 0.3 nm

10mN~1gram Static and dynamic loading including a camera, video and electrical sensing.

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Sample Probe Tips for Pad, Bump and Socket Analysis

Tips are cheaper and more versatile than fully populated!

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Development

No two springs are the same and neither are sockets

- Springs are not exercised as they would be in the real world
- Effects of current load
- Extended cycling
- Regional results
- Temperature constraints
- Test pin to pin and socket to socket to determine variation.

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Verify Time Zero Spring Constant

- What is needed
  - Verify time zero spring constant
  - Change in spring constant over time
  - Spring constant versus deflection
  - A method for rapid yet accurate analysis and validation (especially for high pin counts)
- Why its needed:
  - Helps with both design and incoming inspection
  - Ability to compare individual spring values to datasheet on a new and repaired sockets
  - Impact of nonconforming pins on adjacent pins
  - Not only is mechanical load data important but a sound analytical technique looking at CRES versus load on a single pin is critical.

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Sample of 5 Pins at 30 & 40 Grams

Loading	pin #	deflection(um)	peak load	stable load		deflectior	peak load	stable load
300mN max	1	78	240	180	max	78	290	220
	2	60	290	200	min	29	240	180
600mN/min	3	2.7	>300	N/A	delta	49	50	40
	4	29	240	220				
	5	2.6	>300	N/A				
400mN max	1	76	255	175	max	76	375	275
	2	58	240	200	min	13	240	175
800mN/min	3	47.5	375	250-225	delta	63	135	100
	4	28.5	250	225				
	5	13	350	275-250				
Deltas between		2	-15	5				
loadings		2	50	0				
		-44.8	#VALUE!	#VALUE!				
		0.5	-10	-5				
		-10.4	#VALUE!	#VALUE!				

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2nd Loading - 50 cycles on pins 1-4

	pin 1	pin 2	pin 3	pin 4	pin 5	pin 6		DELTA	
max load (g)	**40**								
load rate	**480**								
load	22.5	12.5	27.5	32.5	15	24		20	g
depth	155	160	165	155	150	114		51	um
load	23.5								
depth	155								
max depth (um)	**50**								
rate	**480**								
force	25	15.2	22.5	20				9.8	g
penetration	120	80	130	92				50	um
force	22.5	15	22.5	20				7.5	g
penetration	106	85	120	80				40	um
force	22.5	15	22.5	20.5				7.5	g
penetration	102	87.5	116	74				42	um
force	22.5	15	22.5	21				7.5	g
penetration	107	85	108	75				33	um
force	22.5	15	22.5	21.5				7.5	g
penetration	109	87.5	110	67				43	um
delta force	**2.5**	**0.2**	**0**	**1.5**					
delta penetration	**18**	**7.5**	**22**	**18**					

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Probe Needle Cycling

What can be said, there are tools out there to run this test. Its also easy to build a bench set-up system to fixture the probe card into place and cycle:

- The difference the MMHT makes is that the coordinates of the card can be loaded and each individual pin can be cycled at whatever rate, deflection and life desired.
- The variability of a pin over the life of the card can be analyzed to show deltas in position or tier.
- The tool will calculate the spring constant, simulated modulus and mechanical durability at temperature
- Maintaining a constant load and changing current demonstrates how the force on the pad changes during probing.

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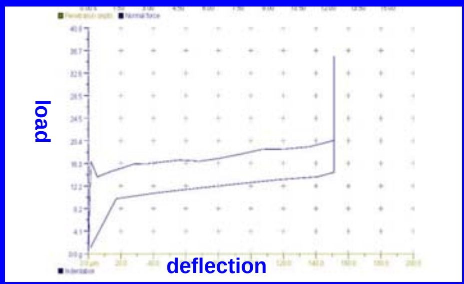
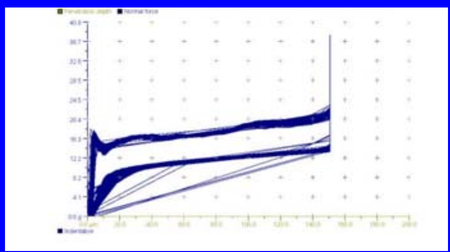
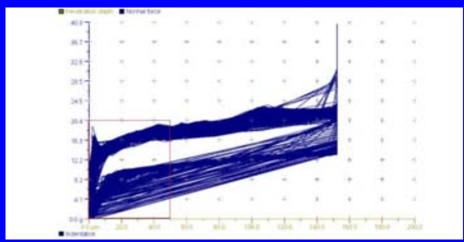
Load/UnLoad Cycles Impact on a Spring



CCW starting at the left: Load and unload highlights the spring constant variation. 500 and 5000 cycles show consistency but a change in the k-value. A change of 5 grams would result in 5kg change for 1000 pins.





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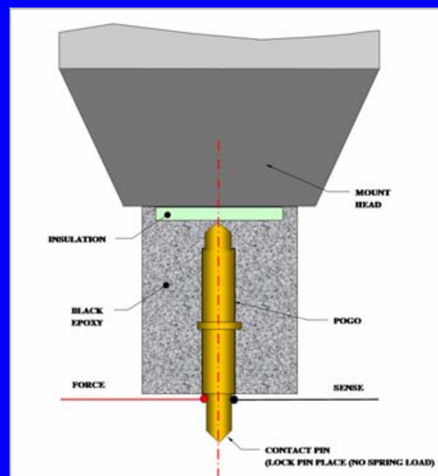
1 million TD's

- Under the correct conditions most materials react.
- Low reaction rates only means it just takes longer.
- Analysis of a gold pad (LGA) using a vertical probe demonstrates this task is difficult even on the macroscopic level.
- After 5k TD's a change in loading and resistance was noted.



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Flip Chip Determination

- **Typical probe cards requires large number of die for statistically significant results**
- **New probe card for each "new" pattern**
- **Multiple pin alloy selection without multiple probe cards**
- **Ability to evaluate individual pin geometries to quickly compare new technologies.**
- **Can introduce shear to evaluate the impact on reliability**

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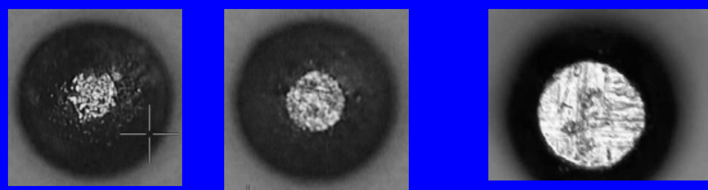
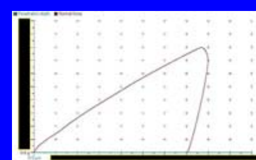
Pb-free Flip Chip Analysis



- Left to right SnPb under constant load
- SAC at 74% higher load to achieve similar spot size
- SnPb at same loading as SCA
- Total time to determine new load setting and BCF for SAC was 10 minutes

Pb-free



SnPb

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Cleaning

Don’t you just hate it when the cleaning makes the situation worse.

- When is it actually necessary to clean
- Is there a test tool for cleaning evaluation
- Perhaps some pins are just “stuck”
- How effective is my cleaning solution
- Are my cleaners taking me to the cleaners
- Should I clean my DUT’s

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Socket Repair and Cleaning

- Socket repair, life and cleaning are all intertwined
  - Without proper cleaning the socket can be overexercised during test either damaging the socket or the DUT.
  - In addition to shortening the life of the socket, aggressive cleaning may damage pins
  - Evaluation on socket fails found variables key to improvement:
    - Time zero variability between sockets
    - Time zero variability between pins within a socket
    - Poor contactor design (contact shape)
    - General design inadequacies
    - Spring life and design
  - "Sticking" pins and how does one develop reliable PMS

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No-clean/Non-Reactive Probes

- A good concept but no such animal.
- Because of the fab there are molecules on the surface of the pad that would not exist naturally.
- Even an Au pad has halogens that would cause a reaction with various probe materials.
- A quick validation only requires running a single site probe on the pad or bump of opportunity. Its quick and easy to remove the probe and insert in a SEM, EDX, Auger, SIMMS, etc, without destroying the card.

Probe tip after only 5 TD's on a "clean" pad.

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Cleaning and CRES

- A solution that will remove the oxide off metal contacts but not damage base metal extends the life of pins and minimize CRES.
- Non aggressive approaches:
  - Yield “non-rough” yet planar surfaces
  - Improve life and reduce sticking
  - Rough surfaces have high surface area and are likely to “bond”.
- The best cleaning solution:
  - Rapidly cleans contacts
  - Minimal consumption of pin or contact metallization
  - Slow regrowth of oxides
  - Reworkable and environmentally friendly
  - Helps extend the life of the pin a provides a real analysis on how pin to DUT interactions can lead to premature failure on both socket and longer term reliability issues on the bump

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BPS172 -vs- OSP

- Low etch rate on Cu and other metals
- Strips oxide not metal
- Reworkable real time
- Low cost alternative
- Short process time
- Simple to use
- Minimize oxide regrowth; less than 1A after 20 minutes and 10A after 24 hours
- Does not scratch the surface

- OSP can require special pin designs for effective probing
- Faulty failures
- Debris on pins requiring additional cleans
- Parts not reworkable

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Contact Resistance (CRES)

- CRES was measured at time zero and after 500 and 5k TD's.
- Even a gold pad probed with a PdCo needle shows changes in resistance.
- Root cause – don't know (pin was not analyzed); likely debris burned onto the tip (OSP)

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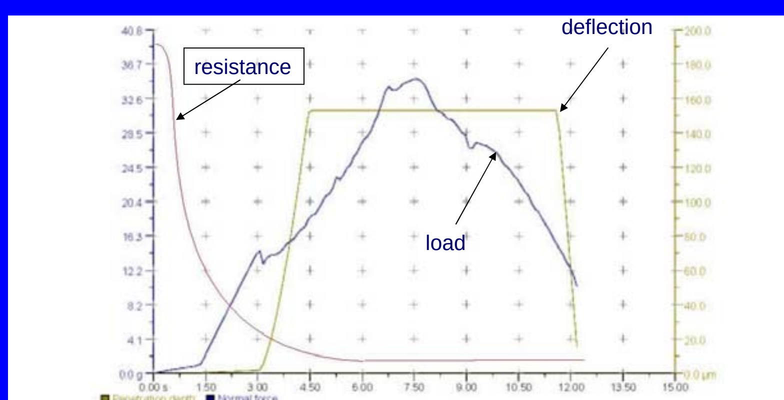
Resistance –vs- Load/Deflection



Red-resistance, blue-load and tan is deflection

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Intermetallics

- SnPb and SAC don’t mix well with Au or Pd or Pt
- SnPb and SAC don’t mix well with Cu
- AuSn does not like high current (reflows at 275C).
- AuSn, PdSn intermetallics (IMC) form a .25um to .4um layer on initial contact with very little load and current. The rate of IMC formation can be changed by changing either of the two parameters

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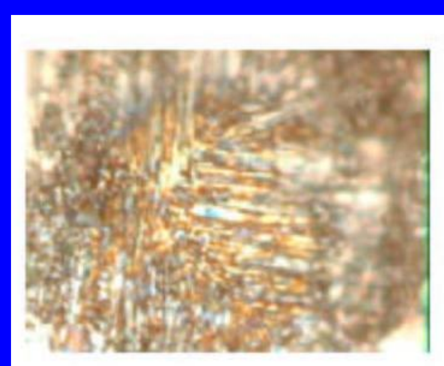
IMC formation on the bump. Image shows a probed bump with needle debris, and intermetallic formation.



IMC formation on the probe tip. AuSn, carbon residue as well as oxides are all present due to excess current and temp.

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Spring to DUT Interactions

- What happens during pin to DUT interactions
  - Ball deformation - Spring Deflection
  - Package Stress - CRES
  - and know good life.
- What is special about pin to DUT interactions
  - Dirty Pins – Excessive force
  - Excessive Force + High Current
    - Intermetallics, metal working (k-change) and
  - Excessive deformation/deflection will lead to premature failure on both socket and longer term reliability issues on the bump.
- A good modeling tool should provide:
  - Pin/spring life and a path to a PM schedule to pull sockets before KGD are failed by faulty sockets.

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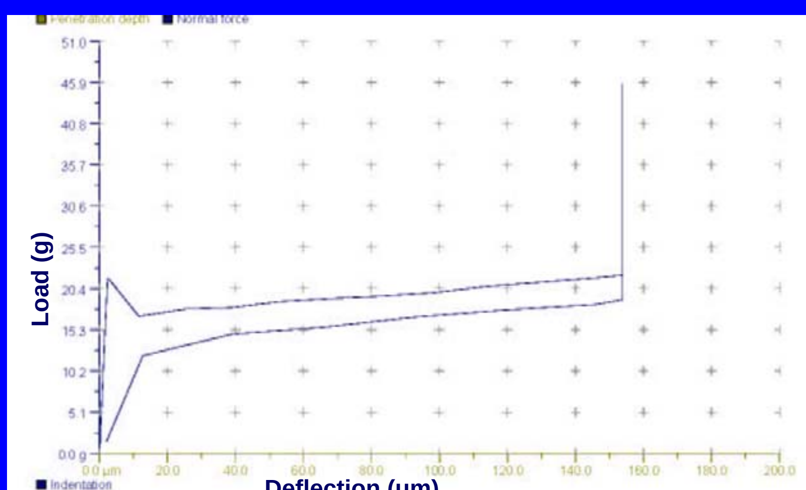

Pin 1 first cycle run with initial spring activation load around 22 grams and 50um deflection at 18.5 grams.

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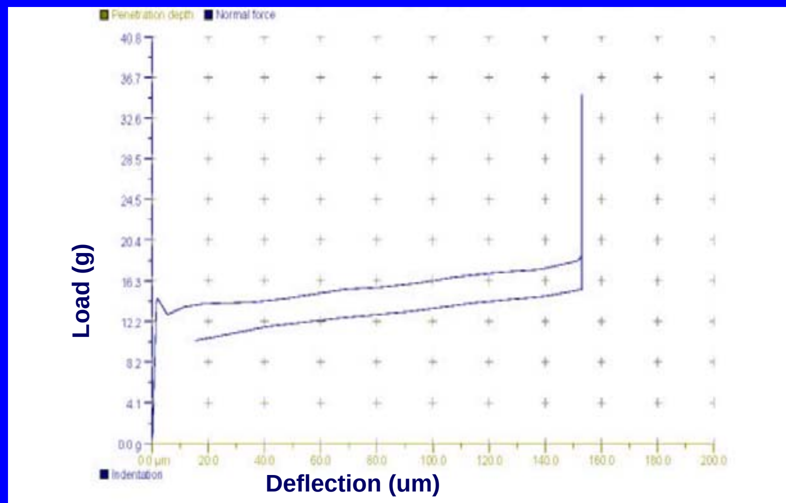
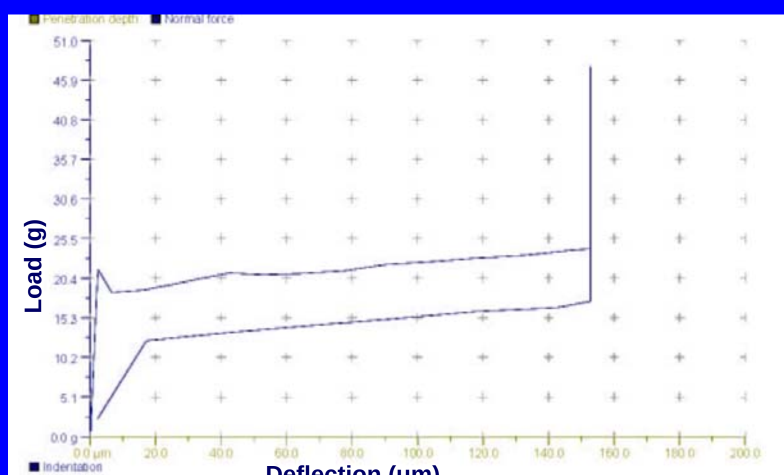


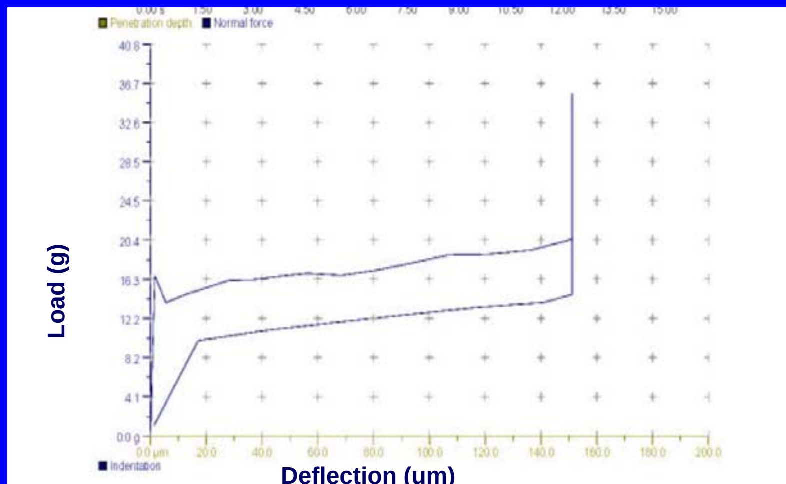
Pin 2 has a lower initial force and deflection force at 50um of deflection compared to pin 1.

3/2008 Improved Method for Socket Evaluation, Development and Cleaning 29



Pin 1 after 500 TD's. Initial force is slightly less but the force to push the pin to 50um is higher by 5 grams.

3/2008 Improved Method for Socket Evaluation, Development and Cleaning 30

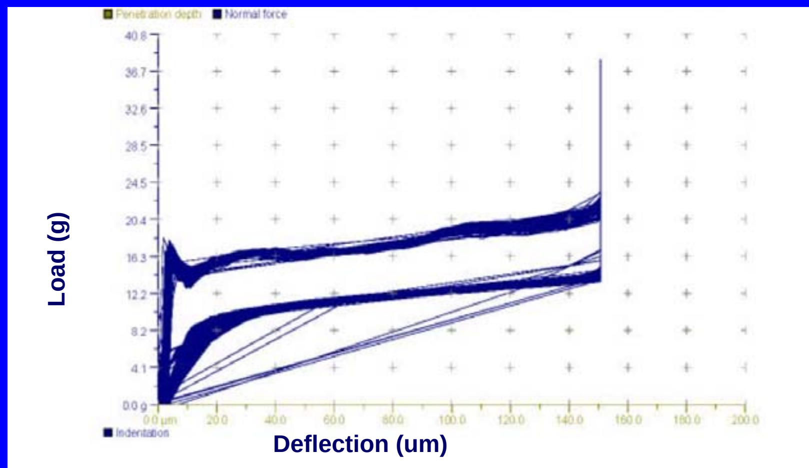


Pin 2 after 50 cycles.

3/2008 Improved Method for Socket Evaluation, Development and Cleaning 31

Pin 2 at 1+50+500th cycle; all load values are slightly higher.

3/2008 Improved Method for Socket Evaluation, Development and Cleaning 32



Pin 2 at 1+50+500+1000th cycle.

Results

Results of five randomly selected pins:

- 30 grams of force show that 2 of 5 pins have spring constants high enough that the probes would not move enough to make electrical contact with the DUT. With deflection values ranging from 2.6 to 78 microns, the variation would likely result in false failures during product testing.
- Load values ranging from 24 to over 34 grams demonstrates that deflection is not the only parameter that has large variation.
- The load had to be reset to 40 grams to make sure each pin moves

Results

cont:

- With a 60 microns deflection delta and an excess of 13 grams-force load delta, it's apparent that 40 grams is not the correct loading or there is a problem with 2 of the pins.
- When a second group of 5 are selected, pin to pin variation is still obvious -but- the consistency of a single pin is demonstrated at 50 cycles.
- When the cycle count is increased to 500 and 1500 cycles, a change is noted in the results that might suggests age (cycling) can increase the spring constant for this design.

Summary

SUMMARY

- The MMHT can be quickly used to effectively evaluate socket variation and performance.
- At least 2 pins failed to move at least 20 microns under 40 grams of loading with two moving less than 3 microns at 30 grams.
- Spring loads up to a primary k value with little to no deflection followed by a movement into a secondary position/k-value.
- The primary load is not the load required for stable electrical results but can be critical for a high pin count sockets.
- In one instance, the primary load is 37 grams with secondary load at 22 grams. A 1000 I/O device would result in a 15kg load delta (37kg primary versus 22 kg secondary).
- Electrical stability can be demonstrated based on loading and deflection.

Questions

Thank You

- We would like to thank Air Products (Chuck Lhota) for providing data on the BPS172.

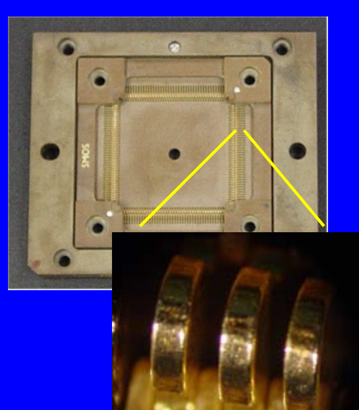
CO_2 Composite Spray Technology for Test Socket Cleaning

David Jackson, CTO, Cool Clean Technologies

Contributors
Roger Caldwell, Associate Engineer - Process, Vitesse Semiconductor
Andy Hoyle, Test Equipment Engineer, Vitesse Semiconductor

2008 Burn-in and Test Socket Workshop
March 9 - 12, 2008

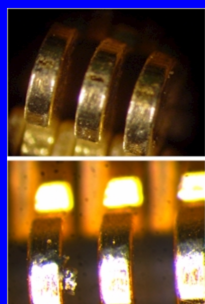
Resistive Surface Contamination


75x

- Metal Oxides (Sn, Pb, Al)
- Passivation
- Silicon Nitride
- Polymers (plasticizers/fibers)
- Lapping Compounds
- Adhesive Residues
- Outgas Compounds
- Metals (solder, Al)
- Human Contaminants
- Cleaning Residues
- Solder Flux

Cleaning and Cleanliness Issues

Contamination tends to bond/adhere in cohesive layers…



Contamination generates more contamination.

Contaminations:
- A mix of transferred metals, organics, inorganics, ionics and adsorbed films
- Thin and thick layers/films

Contact Surfaces:
- Surface area (contact zone) changes over time
- Small/complex topography (curved, pointed, crowned)

Cleaning Processes:
- Incompatibilities (damage/efficacy)
- Variability/Quality
- Long cleaning times (manual methods)

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 3

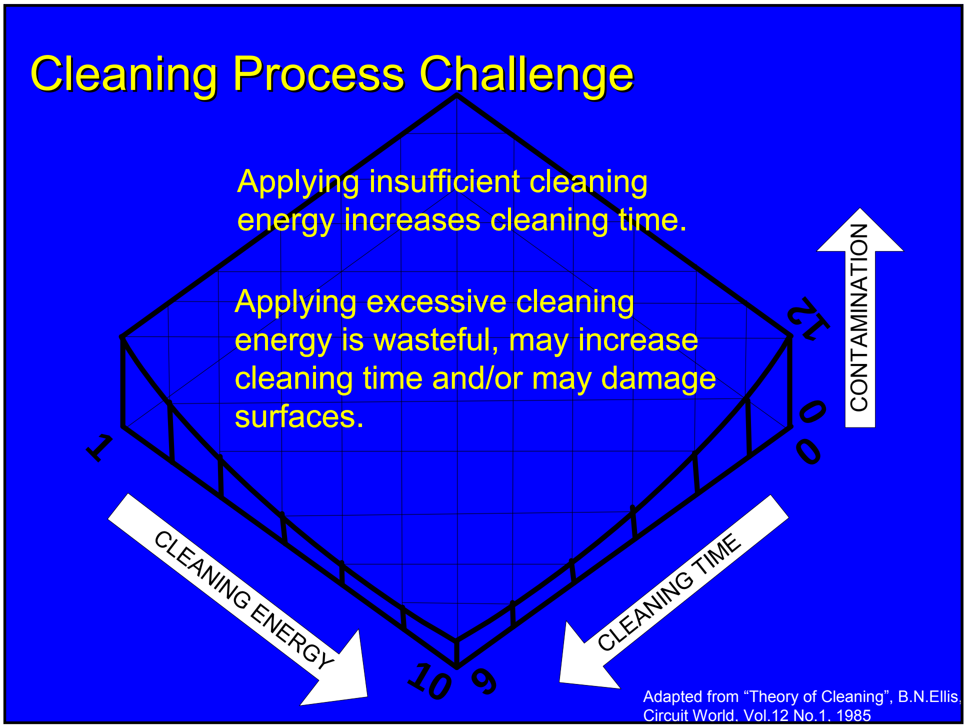
Cleaning Methods (probe/socket)

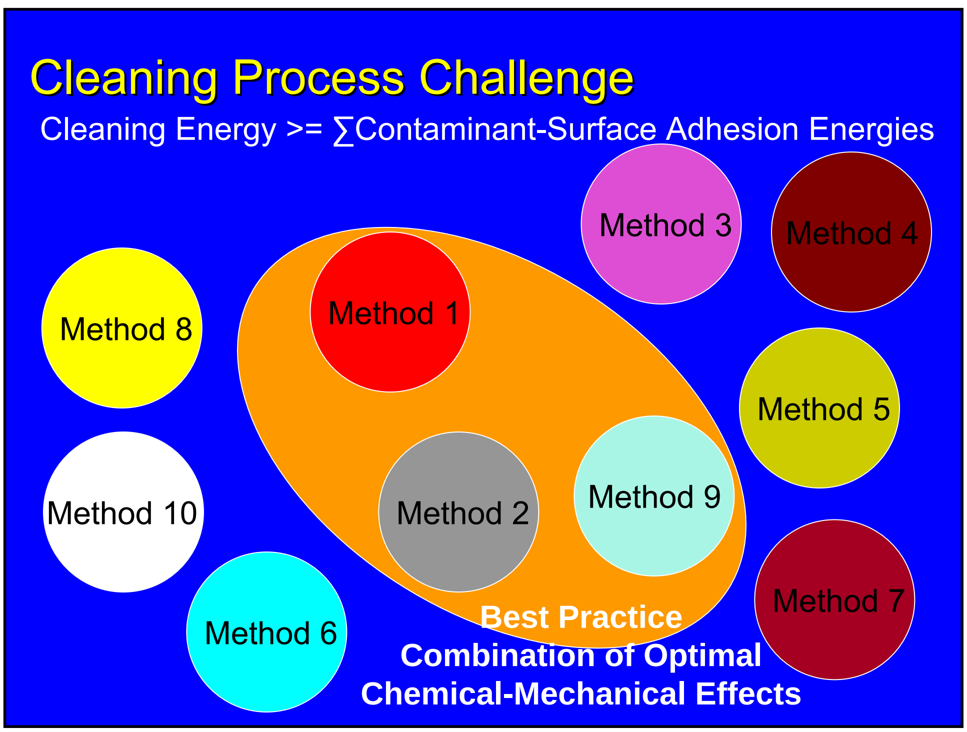
Method	M	T	C
1. WC Plate	x		
2. Lapping Films	x		
3. Metal/Polymer Brush	x		
4. Ceramic Block	x		
5. Polymer Sheets	x		
6. Microabrasive Spray	x		
7. Camel Hair Brushing	x		
8. IPA Wet Brushing	x		x
9. Weak Acid Cleaning	x	x	x
10. Ultrasonic Cleaning	x	x	x
11. Plasma Cleaning	x	x	x

Manual
- ✓ Direct Contact
- ✓ Low Capital
- ✓ High Labor

Automated
- ✓ Non-Contact
- ✓ High Capital
- ✓ Low Labor

M – Mechanical Energy T – Thermal Energy C - Chemical Energy


Cleaning Process Challenge
Applying insufficient cleaning energy increases cleaning time.
Applying excessive cleaning energy is wasteful, may increase cleaning time and/or may damage surfaces.
CONTAMINATION
CLEANING ENERGY
CLEANING TIME
1
12
0
0
10
9
Adapted from "Theory of Cleaning", B.N.Ellis, Circuit World. Vol.12 No.1. 1985


Cleaning Process Challenge
Cleaning Energy >= ∑Contaminant-Surface Adhesion Energies
Method 3
Method 4
Method 8
Method 1
Method 5
Method 10
Method 2
Method 9
Method 6
Method 7
Best Practice
Combination of Optimal Chemical-Mechanical Effects

Cleaning Process Challenge

The most desirable cleaning process:

- ✓ Non-destructive (contact surface/socket)
- ✓ Minimal or no human contact
- ✓ Robust (in terms of energy control)
- ✓ Both mechanical and chemical cleaning actions
- ✓ Ability to clean dense and complex surfaces
- ✓ Fast (less cleaning labor/time)
- ✓ Low cost-per-clean
- ✓ Minimal or no cleaning agent by-products
- ✓ Acceptable ROI

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 7

CO_2 Cleaning Technology

CO_2 technology has been used to produce consistently clean surfaces for high-tech products such as spacecraft devices, optical devices, sensors, lasers, disk drives, air bags, medical devices and many others…

Treatment Schemes

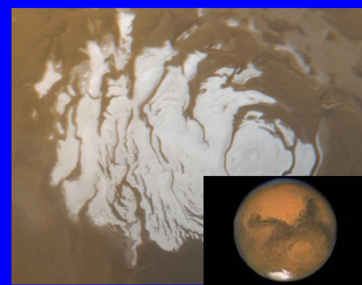
- Composite CO_2 Spray *
- Immersion Solvent (Liquid)
- Extraction Solvent (Supercritical)
- Atmospheric Plasma *
- Low Pressure Plasma
- UV-CO_2 Treatment
- Plasma-CO_2 *
- Laser-CO_2 *
- Microabrasive-CO_2 *

(UV-CO_2 Treatment through Microabrasive-CO_2: **Hybrid Processes**)

* - Socket cleaning candidates

CO_2 is Abundant

South Pole - Mars



A recycled by-product from industrial and natural sources such as refineries, $CaCO_3$ wells, and bakeries.

A recyclable and renewable resource.

Major commercial uses include beverage carbonation, fire extinguishing and welding.

CO_2 is Safe

Solvent	Ozone Depleting Potential (ODP)	OSHA PEL (ppm)	VOC
Carbon Dioxide	**None**	**5,000**	**No**
Isopropyl Alcohol	~0	400	Yes
Acetone	~0	1000	No
Trichloroethylene	~0	50	Yes
1,1,1-Trichloroethane	0.15	350	Yes
n-Propyl Bromide	~0	100	Yes

CO_2 is non-toxic, non-flammable and non-corrosive.

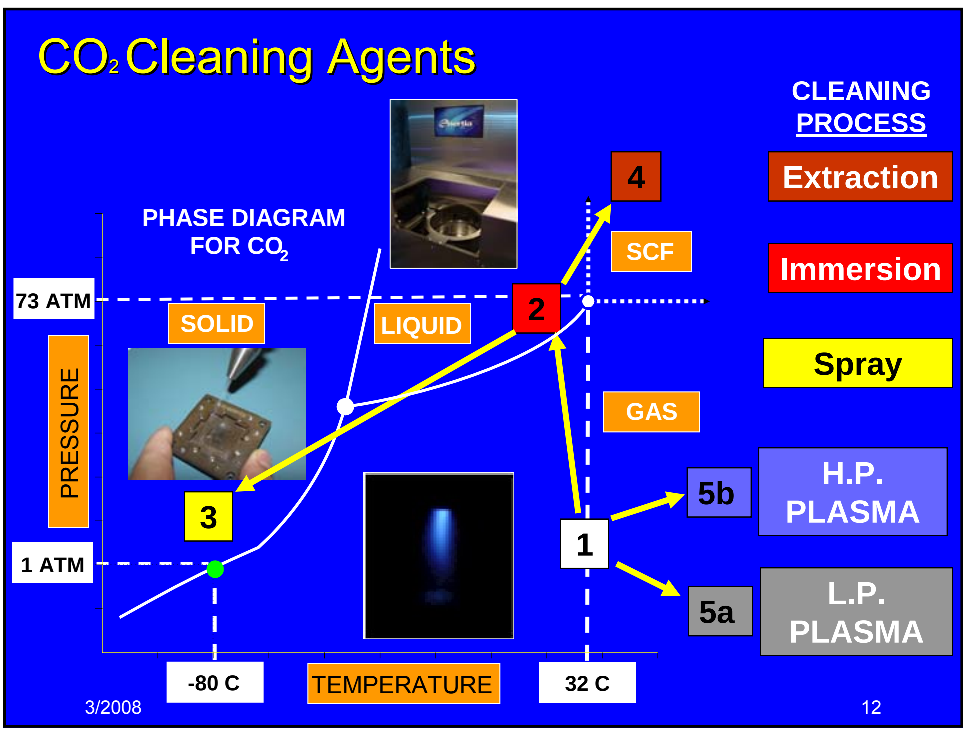
Recycled CO_2 is exempt from the EPA Global Warming legislation.

CO_2 is Inexpensive

Solvent	Bulk Price Range $/kg
Carbon Dioxide	**0.10 - 0.25**
Acetone	0.44 - 0.49
Isopropyl Alcohol	0.75 - 0.88
Methylene Chloride	0.80 - 1.25
1,1,1-Trichloroethane	1.25 - 2.00
n-Propyl Bromide	3.00 - 5.00

Just pennies of CO_2 are used in composite spray formulations for a cleaning operation…

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 11



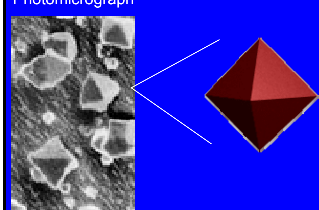
CO_2 Solvent Properties

	Carbon Dioxide: Solid	Carbon Dioxide: Liquid	Carbon Dioxide: Supercritical	Acetone
DENSITY g/ml	1.6	0.8	0.5	0.8
VISCOSITY mN-s/m^2	-	0.07	0.03	0.32
SURFACE TENSION dynes/cm	5-10	5	0	24
SOLUBILITY $MPa^{1/2}$	22	22	14	20

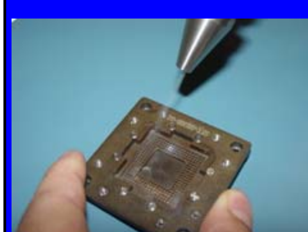
3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 13

Solid Carbon Dioxide

SEM Photomicrograph



1 µm



- **Structure** - molecular crystal, angular, octahedron
- **Solvency** – hydrocarbon-like, 22 $MPa^{1/2}$
- Impact phenomenon – ablation and phase change (solid->gas, solid->liquid->gas)
- **Chemistry** – can be modified with plasmas, liquids, solids, vapor-phase additives
- **Compressibility** - incompressible
- **Density** - 1.6 g/cm^3
- **Hardness** – 0.3 Hm (8 Hv)
- **Particle Size** – < 0.5 microns to > 500 microns, range adjustable (coarse/fine)
- **Impact Stress** - up to 60 MPa (8,700 psi)

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 14

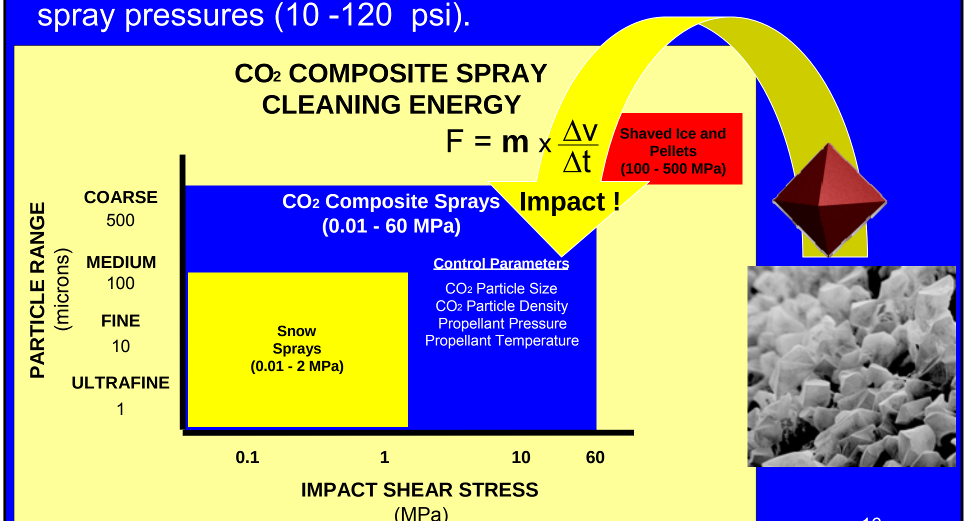
Conventional Snow Cleaning

- ✓ CO_2 "snow" particles are ***too small*** and can't deliver the shear stress required to dislodge resistive contaminants.
- ✓ CO_2 snow sprays are ***too dense and cold (- 80 F)***, which tends to shield/freeze surface contamination ("Igloo Effect").
- ✓ CO_2 snow sprays discharge at a ***high pressure*** (800+ psi) that can damage structures at close proximity (needed for cleaning effectiveness).

*CO_2 composite spray technology is better suited to the contact cleaning task…**Why ?***

First…Variable Particle Size and Density

Adjustable compositions of lean (high freq. impacts) energetic CO_2 particles (size control) and heated propellant gas…at low spray pressures (10 -120 psi).

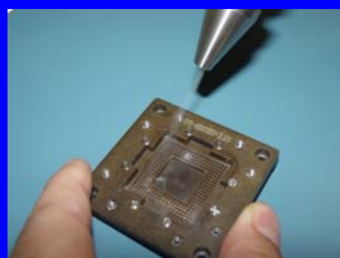


Second…Spray Composition Control

Additive(s) (Chemical/ Physical)

Gas (Propulsion/ Heating)

CO_2



Chemical
Thermal
Mechanical

Particle Size
Chemistry
Spray Density
Temperature
Pressure
Distance/Angle
Time

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 17

Third…Process Enhancement Tool

Existing Cleaning and Inspection Process

CO_2 composite sprays easily adapt to and augment an existing test socket preventive maintenance program to increase overall cleaning process efficiency and effectiveness ….

Composite sprays are additive without being mechanically destructive (energy control)…

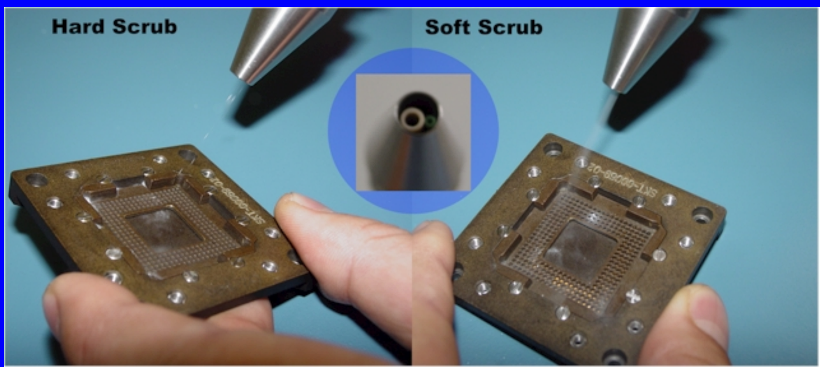
3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 18

CO_2 Composite Spray Technology

- Capillary condensation for particle size control
- Micro-metered mass flow for precise spray density control
- Clean hot propellant gas for pressure and temperature control
- Coaxial and Coanda composite spray nozzles
- Chemical co-solvents easily employed
- Hybrid CO_2 composite spray treatments - Microabrasives, Laser, Atmospheric Plasma, Chemical Adjuncts, Brush

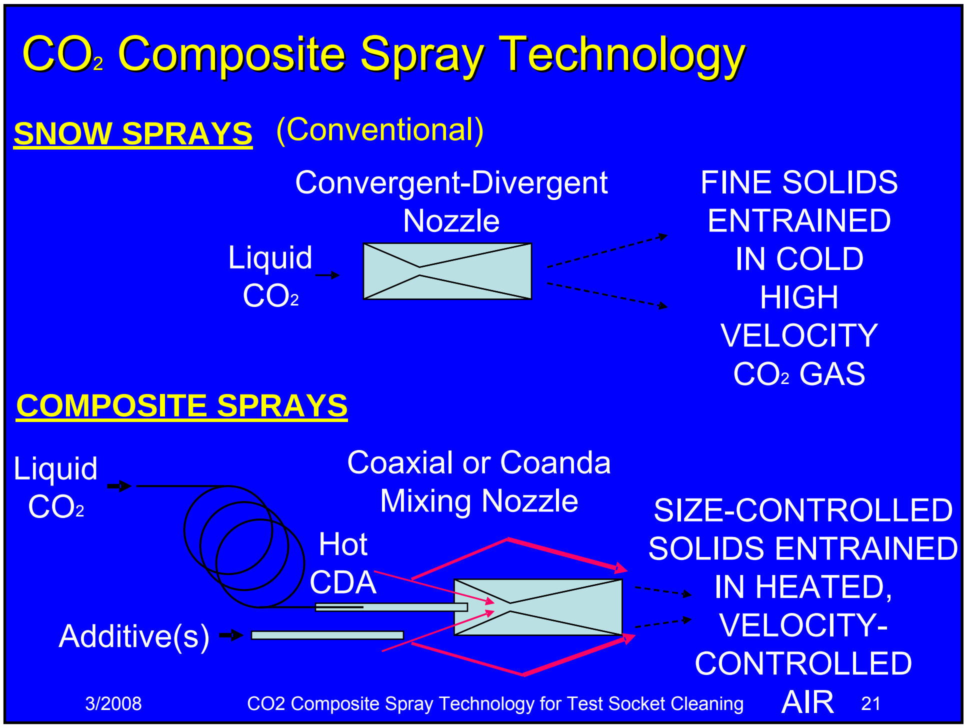
3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 19

CO_2 Composite Spray Technology



Lean Composite CO_2 Sprays, used in cooperation.

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 20



CO_2 Composite Spray Technology

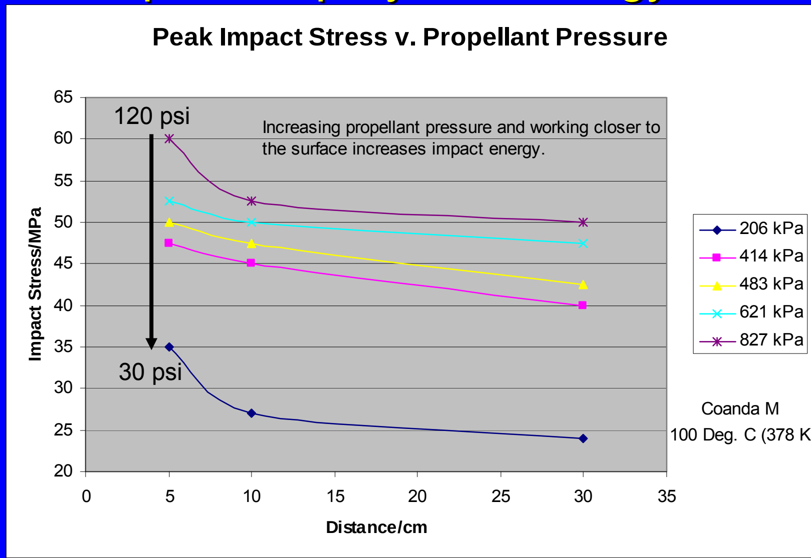
Mechanical and Tribo-Chemical Cleaning Actions

CO_2 composite spray cleaning process effectiveness and efficiency is controlled by:

- ✓ Particle velocity
- ✓ Particle mass/size
- ✓ Spray chemistry
- ✓ Particle hardness (fine → coarse)
- ✓ Particle shape (angular is better (stress conc.))
- ✓ Impact frequency
- ✓ Time

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 22

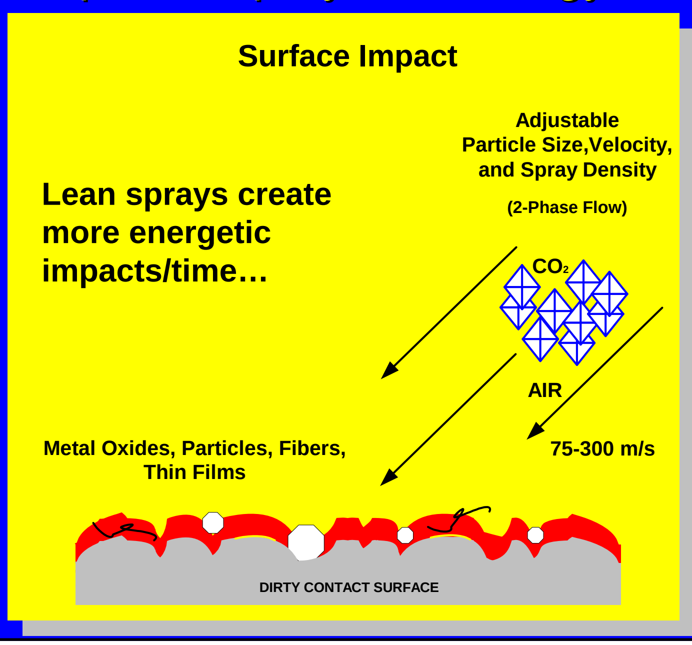
CO_2 Composite Spray Technology



CO_2 composite spray cleaning energy varies with pressure, temperature, particle size and additive energy…

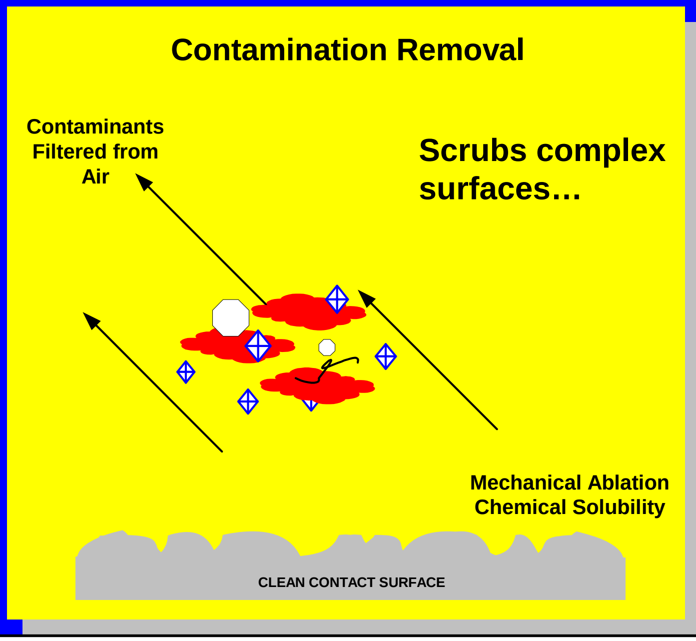
23

CO_2 Composite Spray Technology



24

CO_2 Composite Spray Technology

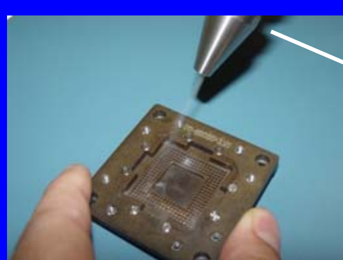


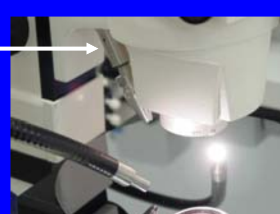
25

CO_2 Composite Spray Cleaning System

Several CO_2 composite spray cleaning methods and processes under development for test sockets (and probe cards)…

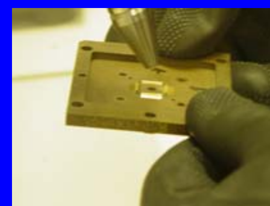
Manual – Automated - Hybrids

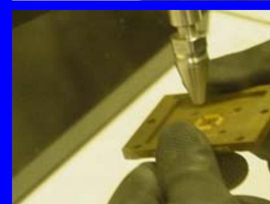




3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 26

Cleaning Process Development





R&D System in use at customer

Cleaning Process Development

Goal: Minimize or eliminate direct contact cleaning.

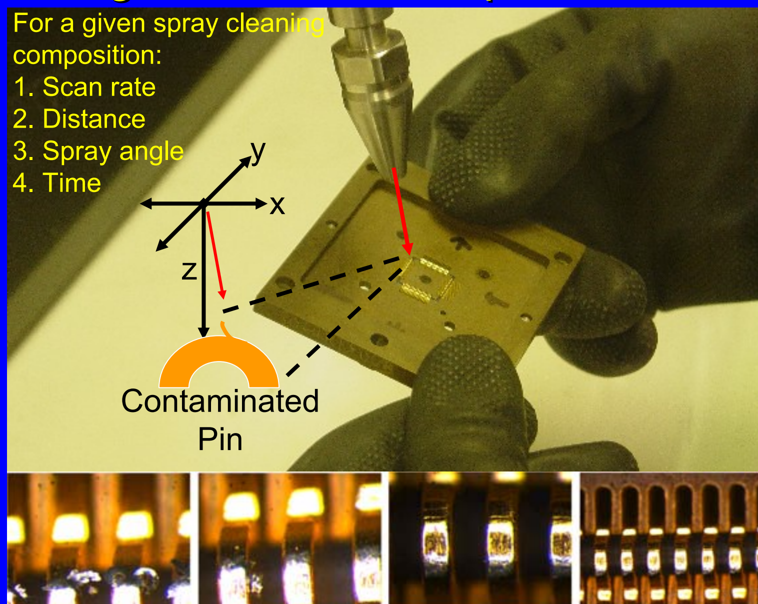
Clean-during-Inspection

CO_2 Pretreatment (no additives) → Manual Mechanical

As much as possible ↑

↓ As little as possible

Cleaning Process Development



29

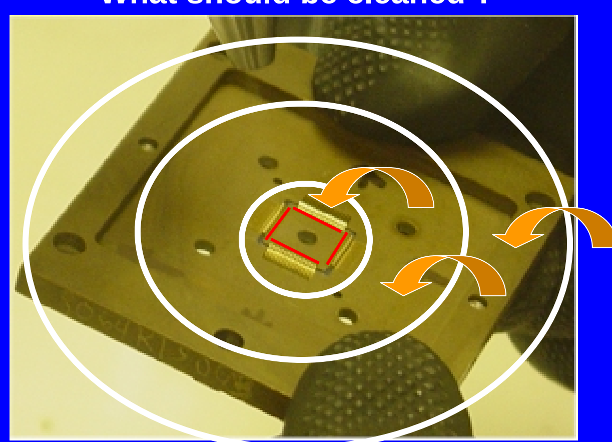
Cleaning Process Development

What should be cleaned ?

Best Practice:

Contacts and Peripheral Surfaces

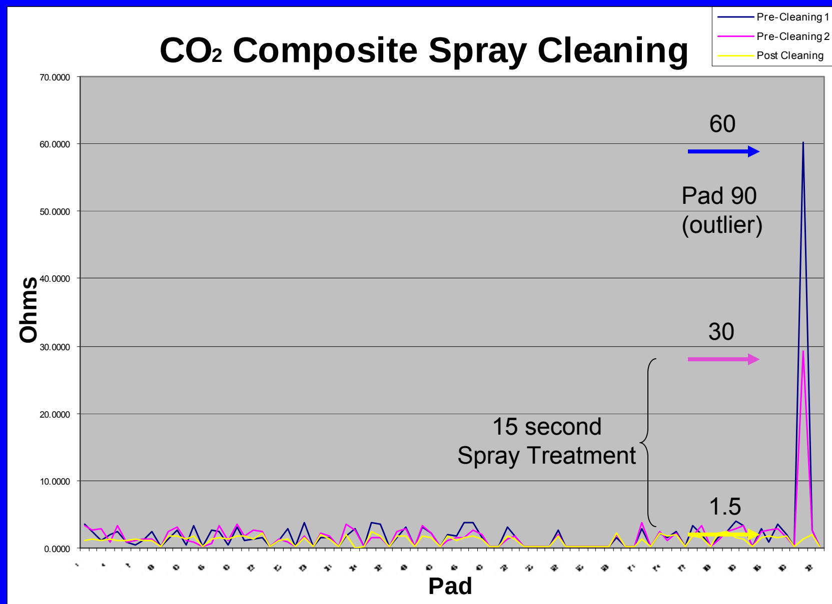
Contamination migrates through ES-Fields, thermal gradients, physical transfer modes…



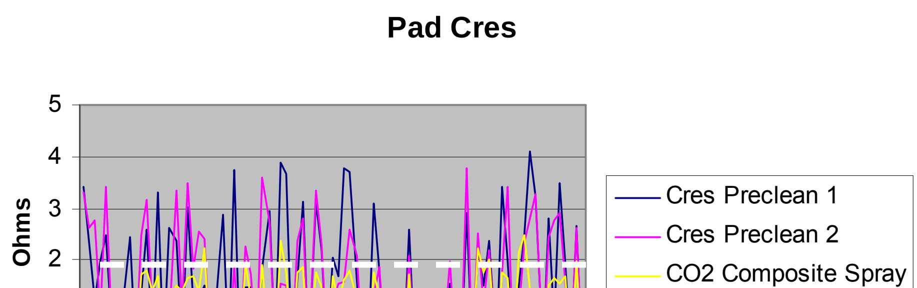
Not cleaning the entire surface creates the potential for cross-contamination…

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 30

Cleaning Process Development



Cleaning Process Development



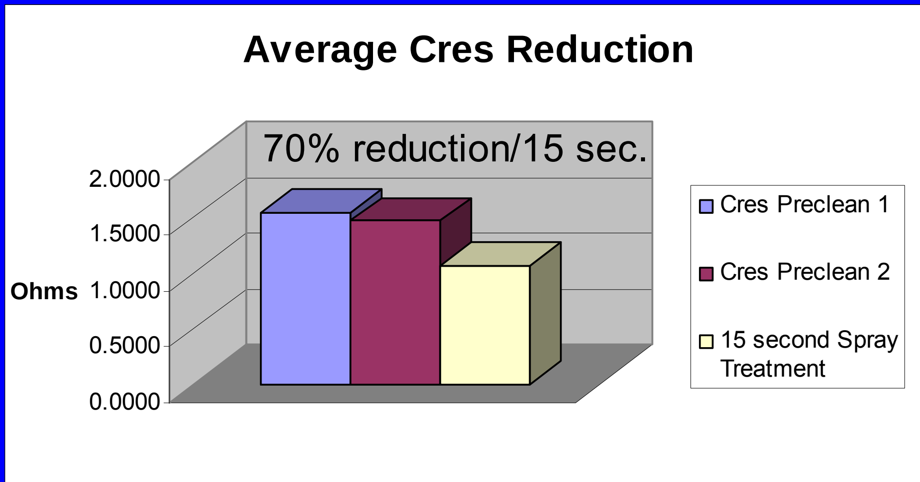
82% reduction in pad Cres failures/ **15 sec** spray treatment.

33→6

Outlier data (Pad 90) removed from data set

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 32

Cleaning Process Development

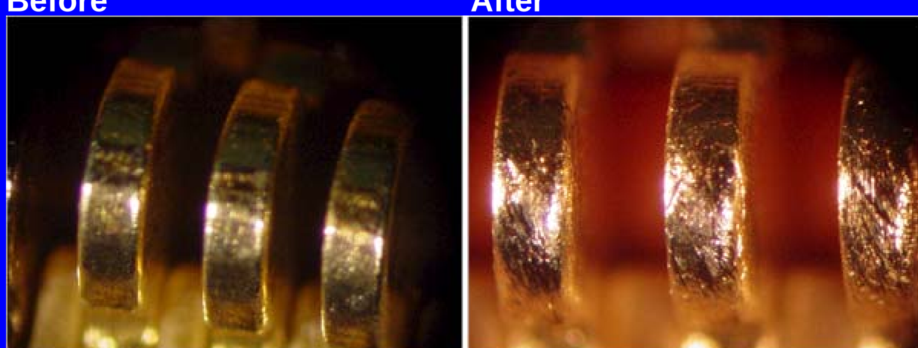


Outlier data (Pad 90) removed from data set.

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 33

Cleaning Action

Before **After**



Metal Oxides/Solder

Cleaning Spray Parameters:

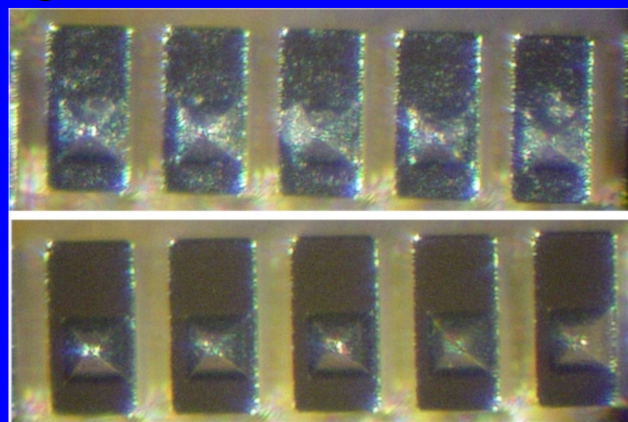
Spray Pressure/Temp: 80 psi, 120 C
Cleaning Time: 1 min.
Chemistry: CDA, Coarse CO_2 Particles

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 34

Cleaning Action

Before

After



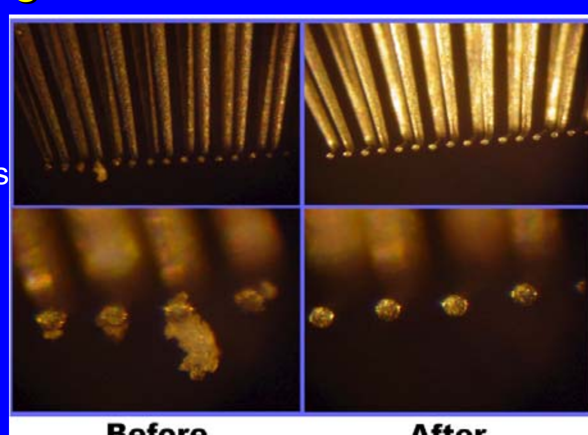
Aluminum/Al_2O_3

Cleaning Spray Parameters:

Spray Pressure/Temp:	70 psi, 120 C
Cleaning Time:	3 min. (robotic process)
Chemistry:	CDA, Fine CO_2 Particles

Cleaning Action

Metal Oxides and Solder Flux



Cleaning Spray Parameters:

Spray Pressure/Temp:	40 psi, 120 C
Cleaning Time:	30 seconds
Chemistry:	CDA, Fine CO_2 Particles

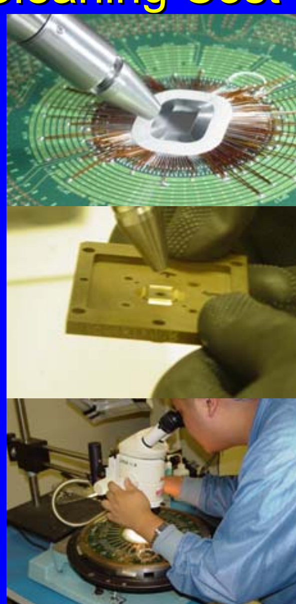
Cleaning Cost Reduction

Old Process:

- Easy to get lost under scope
- Surface contamination remains in complex topography (crevices)
- Potential physical damage to surfaces with manual brush
- Time intensive

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 37

Cleaning Cost Reduction



In combination with CO_2 pretreatment:

- ✓ Up to 80% reduction in maintenance labor
- ✓ Cleaner surfaces…faster
- ✓ Much less direct contact

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 38

Wrap-up

- Composite CO_2 sprays are fully adjustable and provide quick, clean, and non-destructive socket cleaning.
- Worker- and equipment-safe cleaning process.
- Adaptable to existing cleaning processes. Minimizes manual cleaning, potential to replace mechanical contact treatments.
- Low cost-per-clean with a significant socket maintenance labor (time) reduction potential.

3/2008 CO2 Composite Spray Technology for Test Socket Cleaning 39

Batting Cleanup

Approaches to Maintenance of WLCSP Probe Card Interposers

2008 Burn-in and Test Socket Workshop
March 9-12, 2008

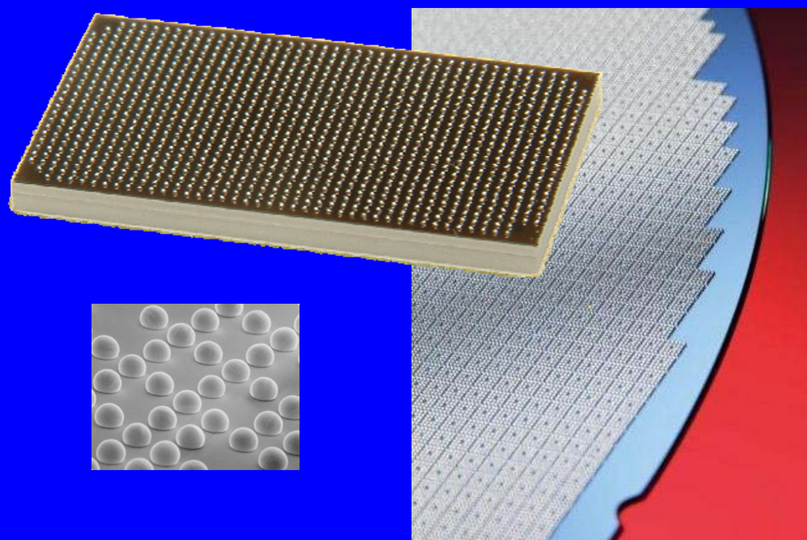
Jon Diller, Jamie Andes
Interconnect Devices, Inc.

Summary

- Introduction to WLCSP Interposers
  - How they're different
  - Why bother
- Cleaning Techniques
  - Approaches
  - Quantified results
  - Aberrances
- Conclusions

March 2008 Batting Cleanup - Approaches to Maintenance of WLCSP Probe Card Interposers 2

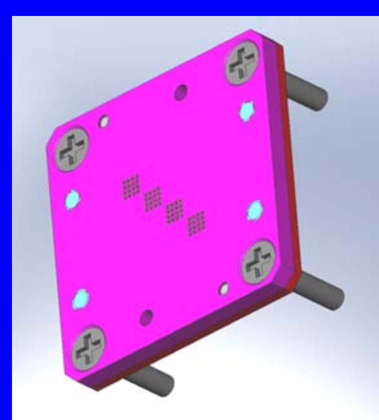
WLCSPs



March 2008 Batting Cleanup - Approaches to Maintenance of WLCSP Probe Card Interposers 3

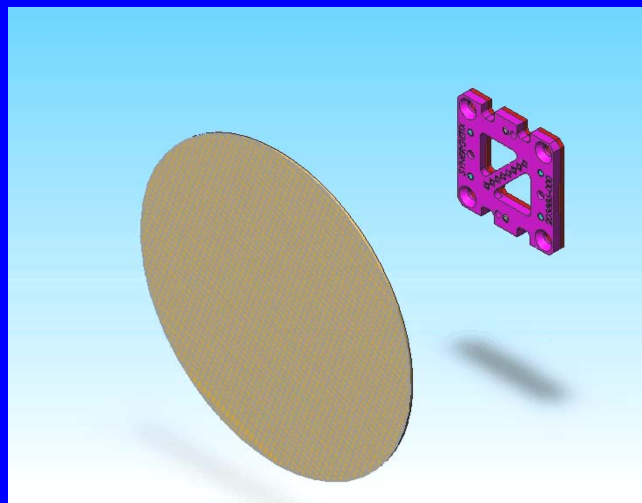
Contacting Technologies

- Singulated vs. on wafer
- Vertical probes vs. package test technologies
- Capital, maintenance, familiarity



March 2008 Batting Cleanup - Approaches to Maintenance of WLCSP Probe Card Interposers 4

Contacting Method



March 2008 | Batting Cleanup - Approaches to Maintenance of WLCSP Probe Card Interposers | 5

Contact Technology

- Conventional spring contact of common design
- Beryllium copper base material

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Cleaning Techniques: Off-Line

- Brushing
  - Conventional technique for package test
  - Well understood
  - Minimal benefit
  - Minimal risk
- Laser
  - Seems effective
- By yield (80-90%)
- By cycle (20-50K)
- Contact life ~50K-100K cycles

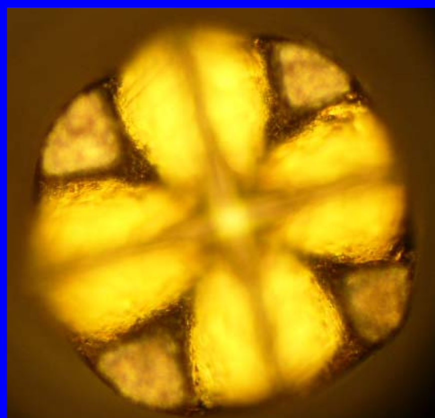
March 2008 Batting Cleanup - Approaches to Maintenance of WLCSP Probe Card Interposers 7

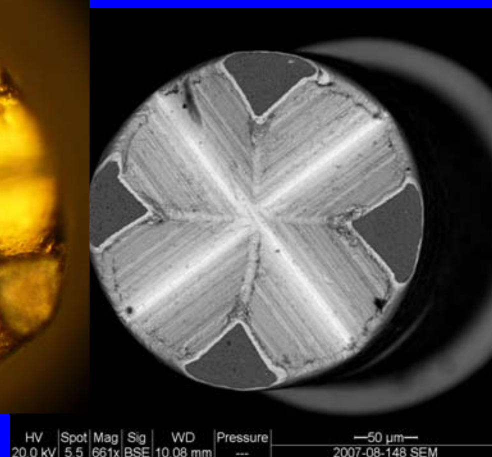
Cleaning Techniques: On-Line

- Abrasive discs used with normal wafer prober function
- Typ. 15-30x td @ 150 cycles
- Contact life >800K cycles

March 2008 Batting Cleanup - Approaches to Maintenance of WLCSP Probe Card Interposers 8

Contacts After Cleaning





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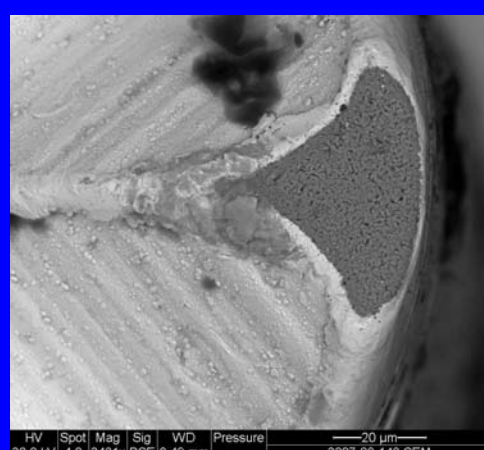
Contacts After Cleaning

- Copper base material exposed
- Similar appearance at most stages of contact life
- Contact length reduced 100µm



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Customer Snapshot

- Contacts per day 20,000
- Cleaning time 30 seconds
- Interval ~ 8 minutes
- No pre-check for alignment
- Typ yield 92% first, 95% final
- Brush or laser clean ~weekly, yields @85%

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Issues Raised

- Significance of plating
- Potential gains from automated cleaning
- Implications for conventional package test
- Impact to test strategies for WLCSP

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