Lead-free Assembly

Today's Webcast will start at 10:00AM PDT | 1:00PM EDT | 17:00 GMT

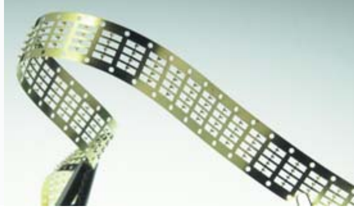
Thank you for your patience.

Gail Flower, Moderator

- **Professional author and magazine editor since 1982**
- **Founding editor of SMT magazine**
- **Industry-wide discussion leader**
- **Manager of editorial staff for *SMT* and *Advanced Packaging* Magazines, PennWell Corp.**

SMT

PennWell



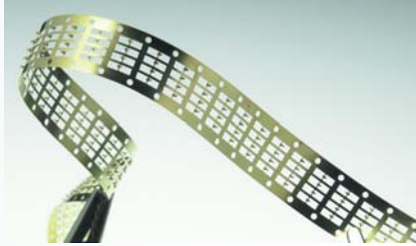
Meeting RoHS Guidelines

Tracing Responsibility Down the Supply Chain

Presented by Julia Goldstein,
Advanced Packaging Magazine

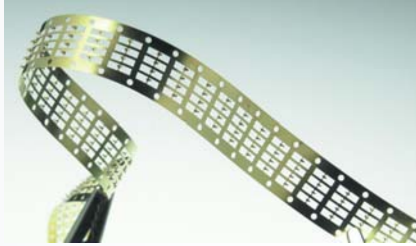
BRUSHWELLMAN
ENGINEERED MATERIALS

What is RoHS?



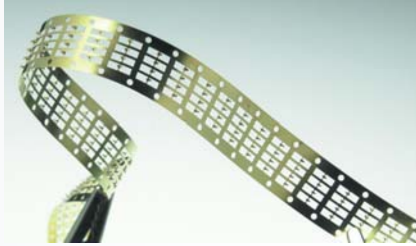
- European Union (EU) directive, “Restriction of Hazardous Substances in electrical and electronic equipment”
- Related Waste Electrical and Electronics Equipment (WEEE) directive requires re-use and/or recycling to reduce hazardous waste
- Recycling “necessary but not sufficient” – need to replace hazardous substances with safer alternatives

Scope of RoHS



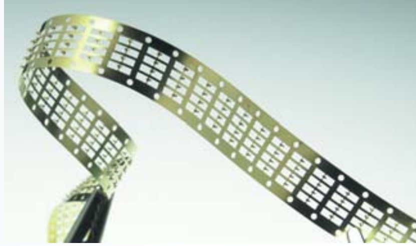
- Eight categories of electrical and electronic equipment:
  - Large household appliances
  - Small household appliances
  - IT and telecommunications equipment
  - Consumer equipment
  - Lighting equipment
  - Electrical and electronic tools (not including stationary industrial tools)
  - Toys, leisure and sports equipment
  - Automatic dispensers

Substances covered by RoHS



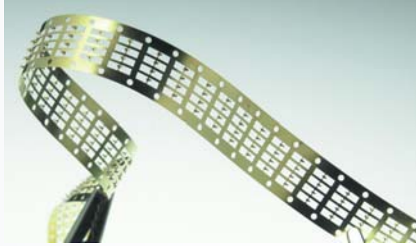
- Six substances are restricted:
    - Lead (Pb)
    - Mercury (Hg)
    - Cadmium (Cd)
    - Hexavalent chromium (Cr VI)
    - Polybrominated biphenyl (PBB)
    - Polybrominated diphenyl ether (PBDE)
- Maximum allowed values assumed to be 0.1 percent (Cd 0.01 percent)

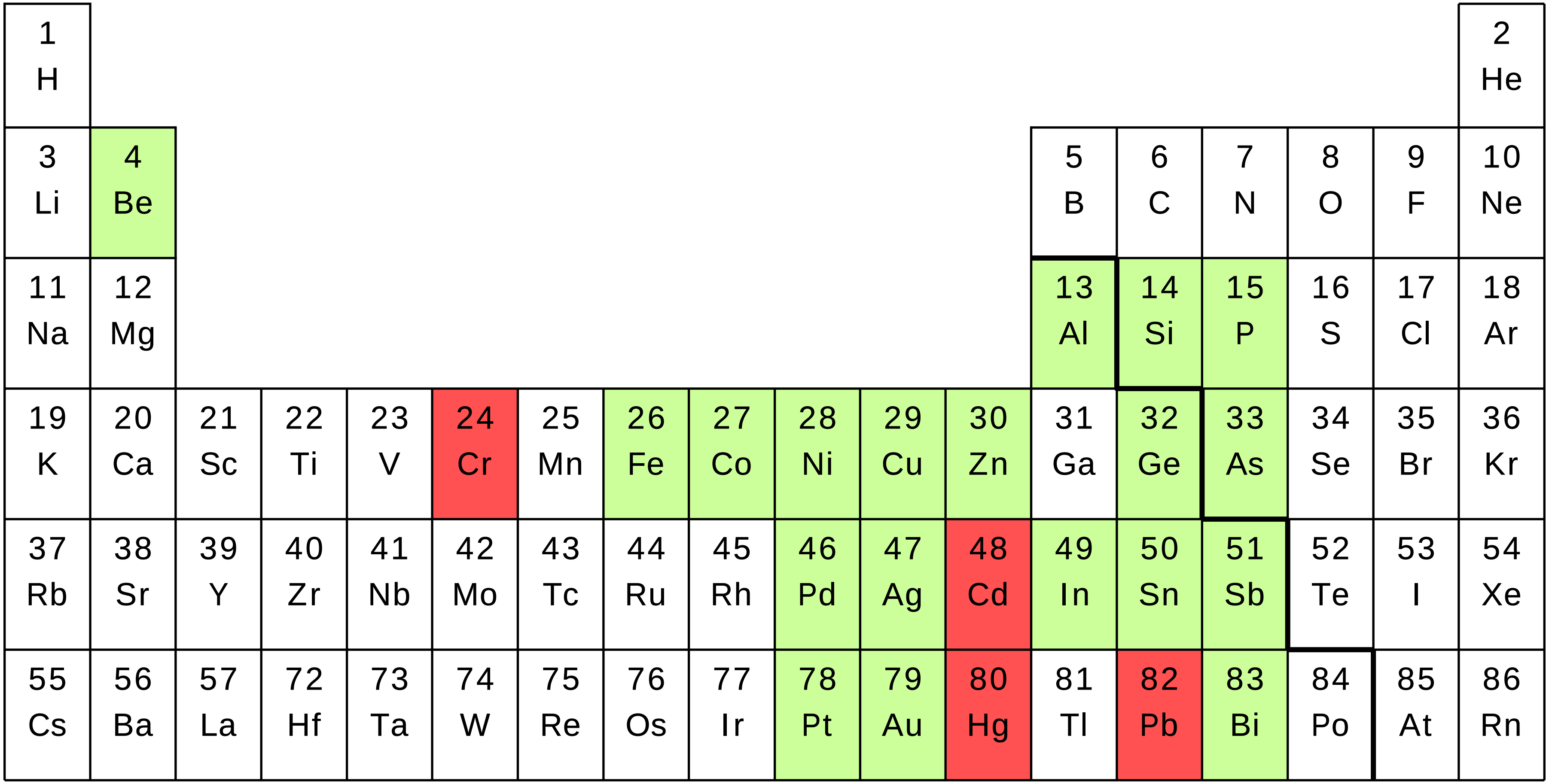
Substances not covered by RoHS



- Some elements used in electronic components that are not restricted:
  - Aluminum (Al)
  - Antimony (Sb)
  - Beryllium (Be)
  - Bismuth (Bi)
  - Cobalt (Co)
  - Copper (Cu)
  - Gold (Au)
  - Indium (In)
  - Iron (Fe)
  - Nickel (Ni)
  - Phosphorus (P)
  - Silver (Ag)
  - Tin (Sn)
  - Zinc (Zn)

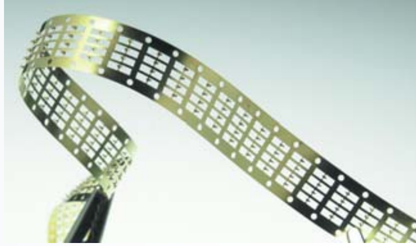
The Periodic Table





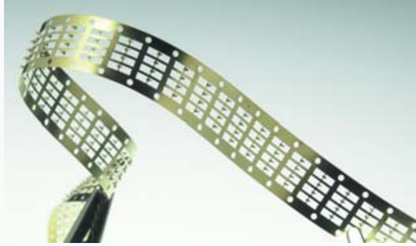
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn

Alloys Not Covered by RoHS



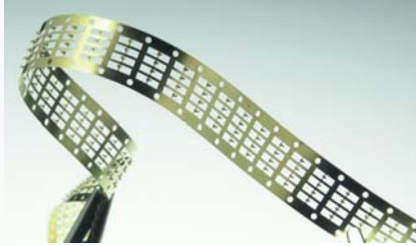
- Many commonly used alloys are made from elements that are not restricted:
  - Brass (Cu and Zn)
  - Bronze (Cu and Sn, + Zn and/or P)
  - Copper alloys (Cu, Ni, Si, Sn)
  - Copper beryllium alloys (Cu, Be, Co, Ni)
  - Ferrous alloys (Fe, Ni, Cr, Co)
- May need to verify Pb content

Exemptions to RoHS: Pb



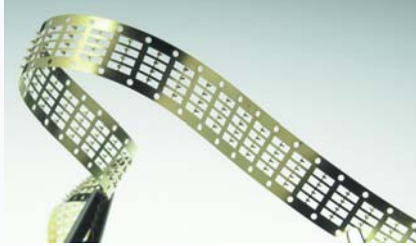
- Maximum concentrations of Pb: 0.35% in steel, 0.4% in Al alloys, 4.0% in Cu alloys
- High-melting solders with over 80% Pb
- Solders used in servers, storage systems, network equipment
- Electronic ceramic parts (piezoelectrics)
- Glass for CRTs, electronic components

Exemption Requests Under Review



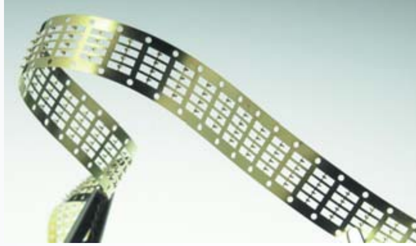
- Pb in tin whisker-resistant coatings for fine pitch applications
- Pb in connectors, flexible printed circuits, flexible flat cables
- Solders containing Pb and/or Cd for “specific applications”
- Pb in compliant pin connector systems
- 40 more…

RoHS Deadline and Compliance



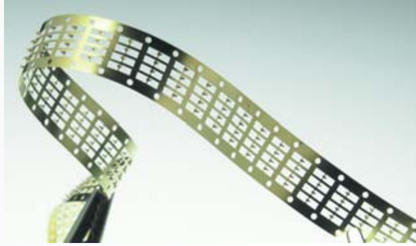
- You may not place on the EU market a non-compliant product after July 1, 2006
- Liability rests with OEMs but ultimately affects the entire supply chain
- All parts and materials that go into products covered under the scope of RoHS must be compliant

How RoHS Affects Suppliers



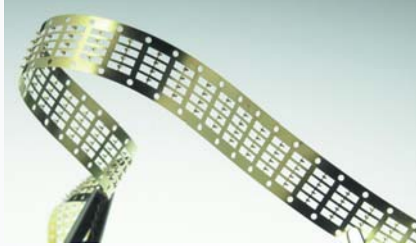
- Your OEM or EMS customers need assurance from you that your components are compliant
- Ensure that all materials that go into your products are compliant by working with your suppliers

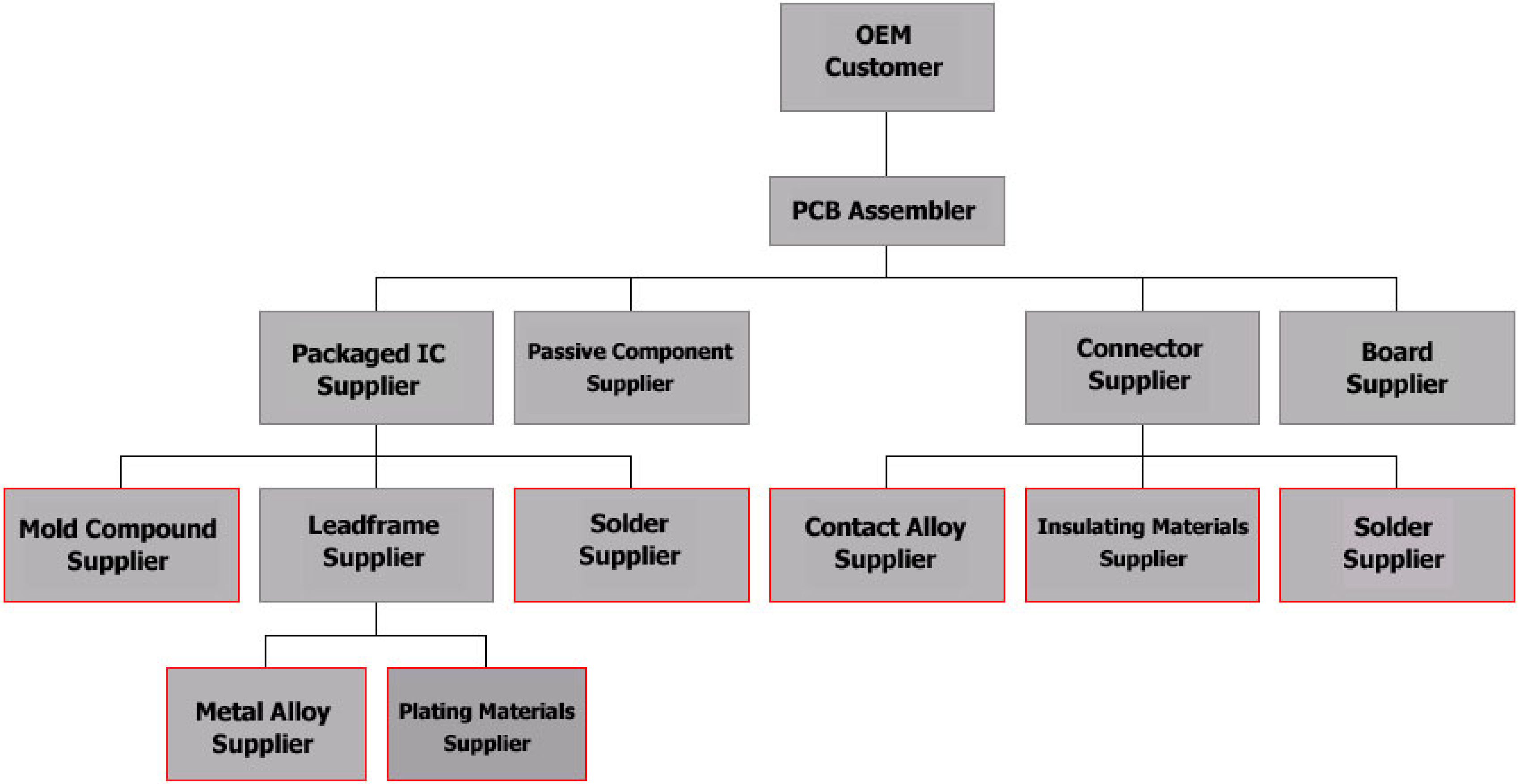
Steps Toward Compliance



- Contact your suppliers and obtain declarations that their products do not contain the restricted substances
- In some cases, analytical testing may be needed when working with new suppliers
- Trace the supply chain down to the “homogeneous material” level

RoHS Compliance Supply Chain





OEM Customer

PCB Assembler

Packaged IC Supplier

Passive Component Supplier

Connector Supplier

Board Supplier

Mold Compound Supplier

Leadframe Supplier

Solder Supplier

Contact Alloy Supplier

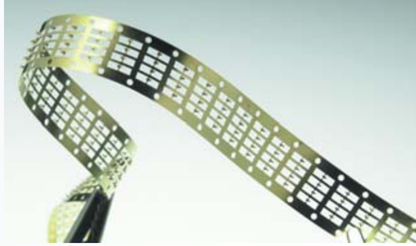
Insulating Materials Supplier

Solder Supplier

Metal Alloy Supplier

Plating Materials Supplier

Sample Certification Letter



Date

Bill Purchasing Manager
Mega Electronic Connectors Co.
1000 Main St.
Anywhere, NY 00000

Dear Mr. Manager:

In response to your inquiry regarding the presence of specific materials and substances which have been banned or restricted in electronic equipment by the European Union directive on the Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS) - 2002/95/EC, I provide the following information.

The materials and substances listed in the RoHS directive, specifically mercury, cadmium, hexavalent chromium, PBB and PBDE's, are not intentionally added to or believed to be contained in any of the following materials supplied by Quality Connector Supplier Co., except possibly in trace amounts and as specified.

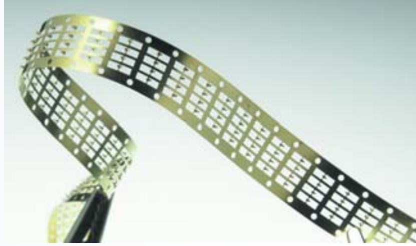
Material	Part Number(s)
Insert material/component information here	Insert part number here

Up to X.X percent lead is intentionally added to these materials. The RoHS directive specifically allows the use of up to 4% lead in copper alloys. Therefore, these alloys are acceptable for use in electrical and electronic equipment and are in conformance with the RoHS directive.

If there are any questions or I can be of further assistance in this matter, please do not hesitate to contact me at (XXX) XXX-XXXX.

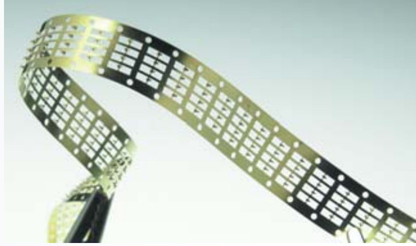
Sincerely,
Joe Compliance Manager
Quality Connector Supplier Co.

Concluding Remarks



- July 1, 2006 is less than a year away!
- If you have not already done so, the time to act is now
- Ensure that Pb, Hg, Cd, Cr (VI), PBB and PBDE are not present in your products above the maximum concentrations
- You need to demonstrate compliance to your customers

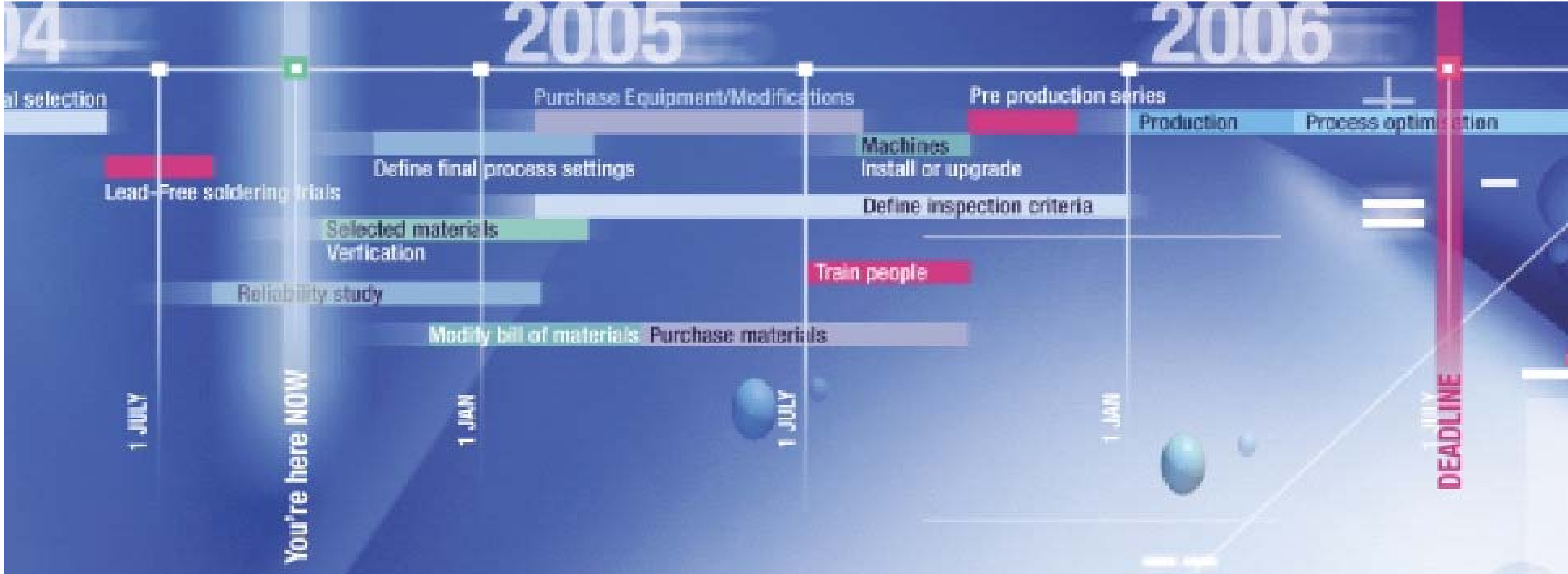
For More Information



- For information regarding compliance for copper and copper beryllium alloys, call Brush-Wellman's Product Safety Hotline: 1-800-862-4118

- For technical information on copper and copper-beryllium alloys, call Brush-Wellman's technical services hotline at 1-800-375-4205.

BRUSHWELLMAN
ENGINEERED MATERIALS



Lead-Free Soldering

How ready are you … Really ?

Denis Barbini, Ph.D.

Vitronics Soltec

A DOVER COMPANY

Global Lead Free Implementation

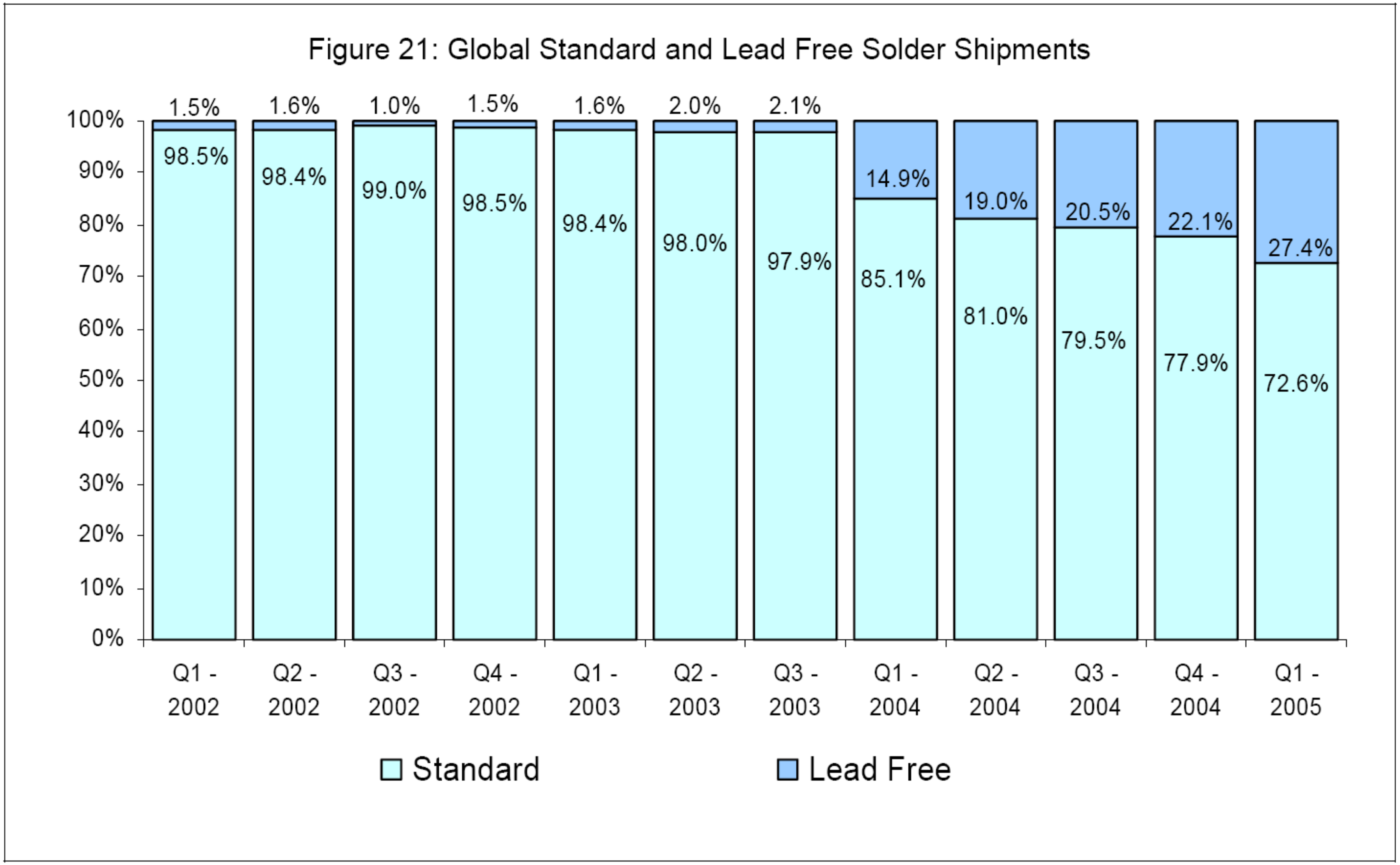
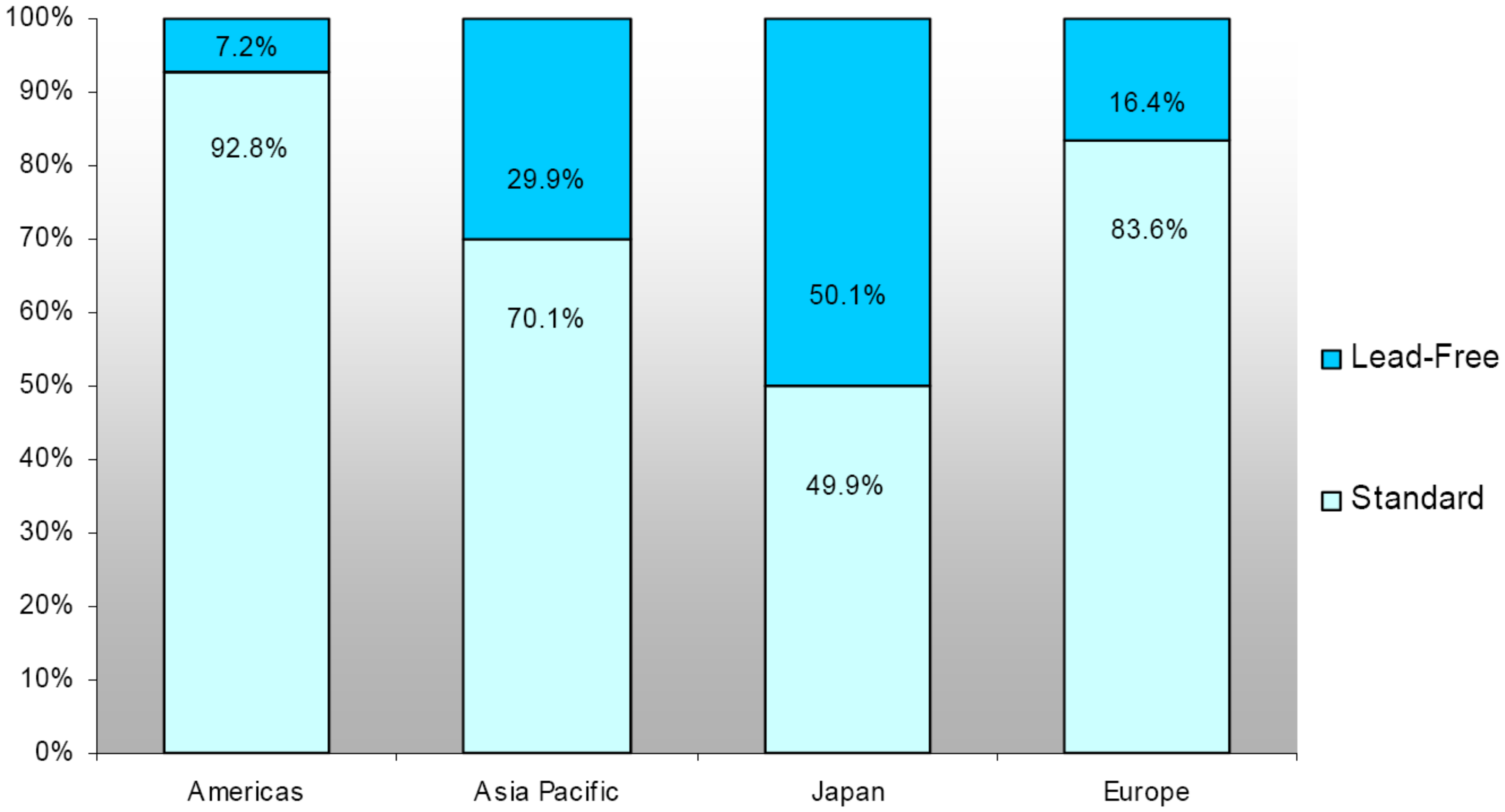


Figure 21: Global Standard and Lead Free Solder Shipments

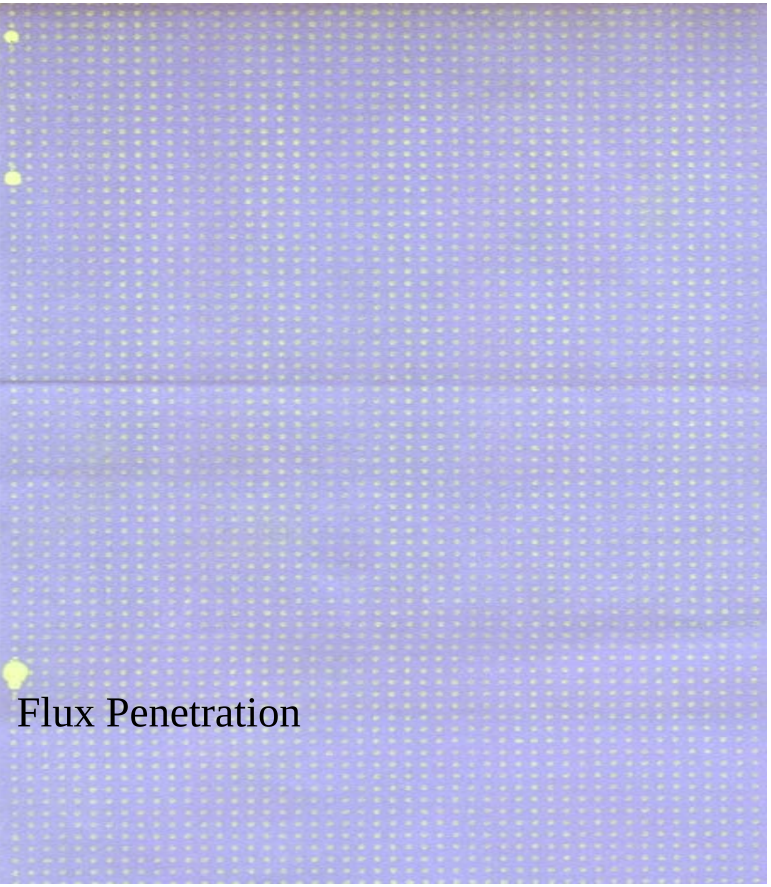
Lead Free Solder Use by Region

Figure 22: Consumption of Standard Versus Lead Free Solder for First Quarter 2005 by Region
(Solder Shipments in Kg)

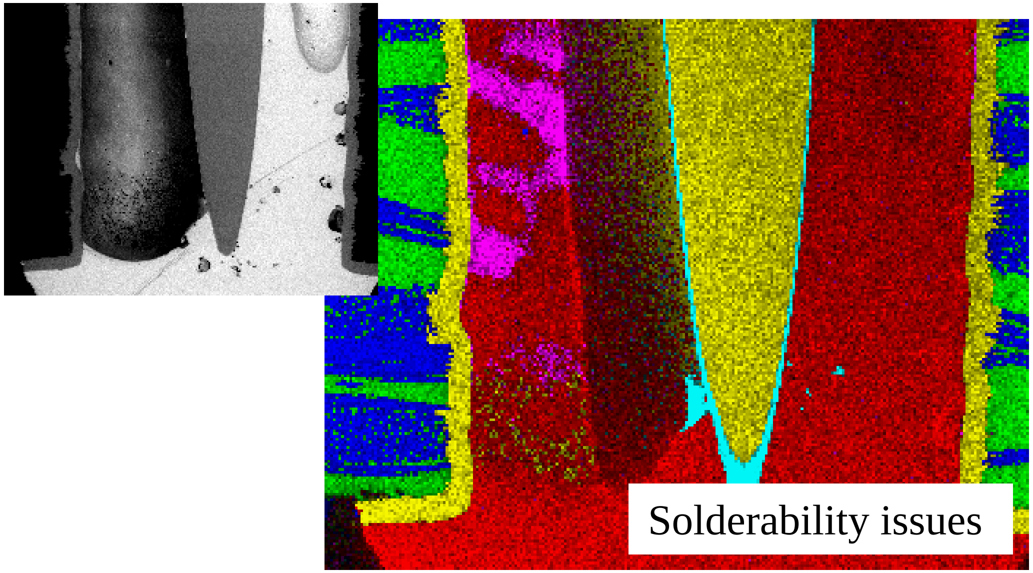


Source: IPC Solder Quarterly Survey

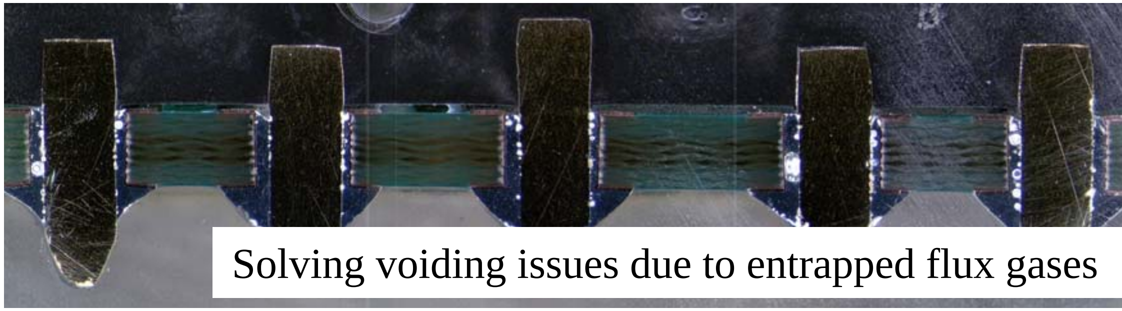
Challenges in Assembly



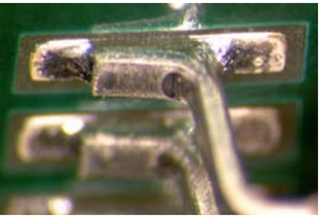
Flux Penetration



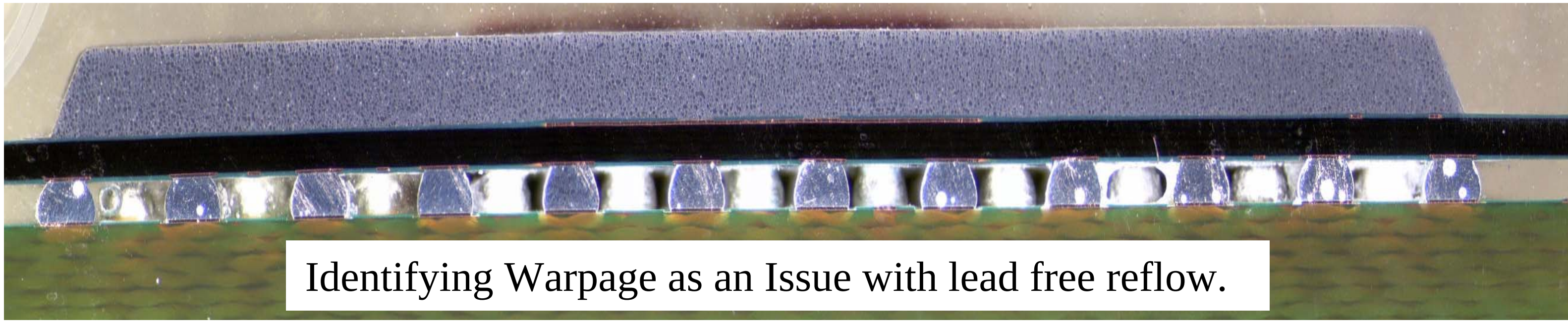
Solderability issues



Solving voiding issues due to entrapped flux gases



Achieving the perfect joint!

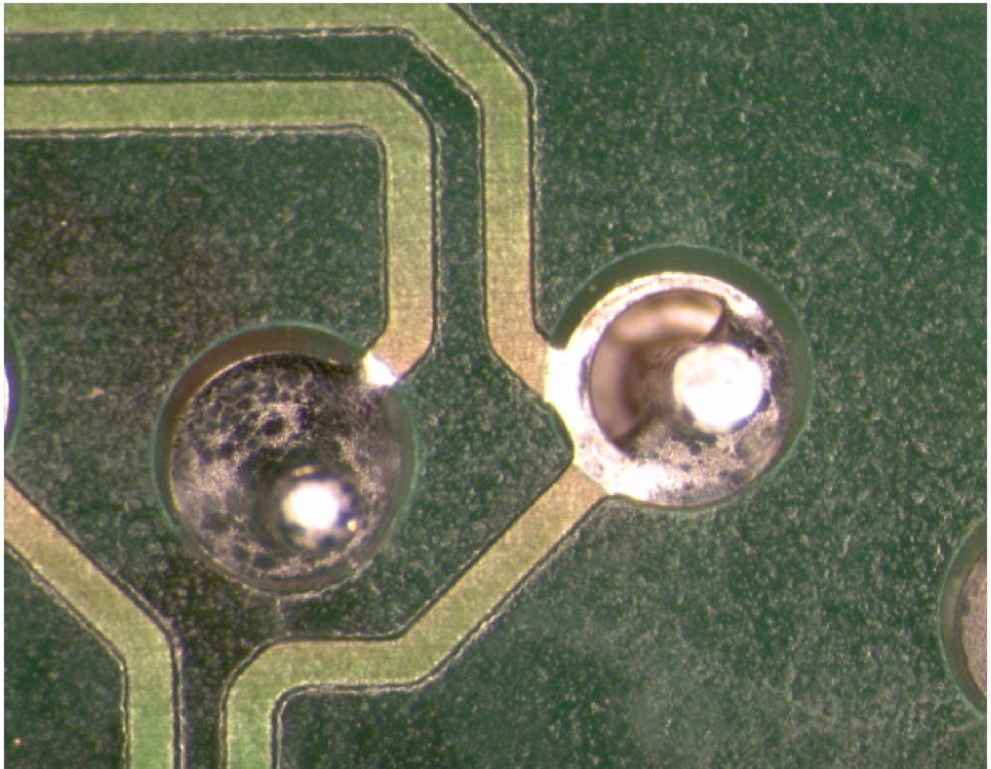


Identifying Warpage as an Issue with lead free reflow.

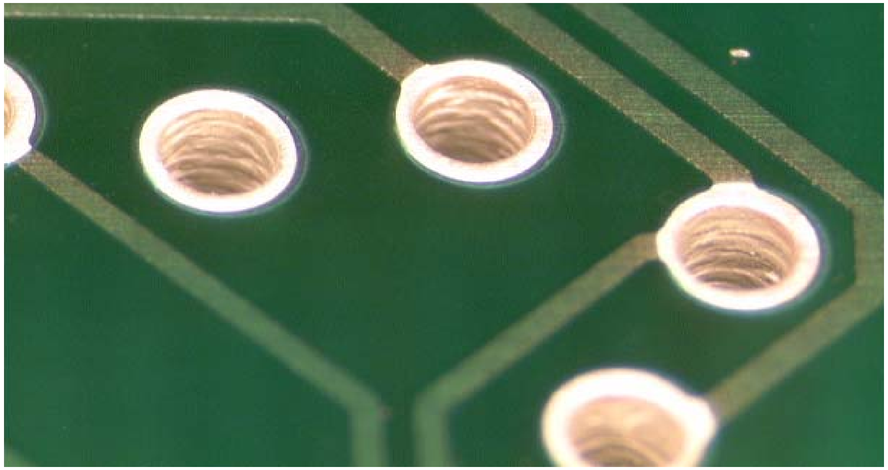
Case Study

THE PROBLEM

Improper joint formation during a lead free wave process.



Board Characterization



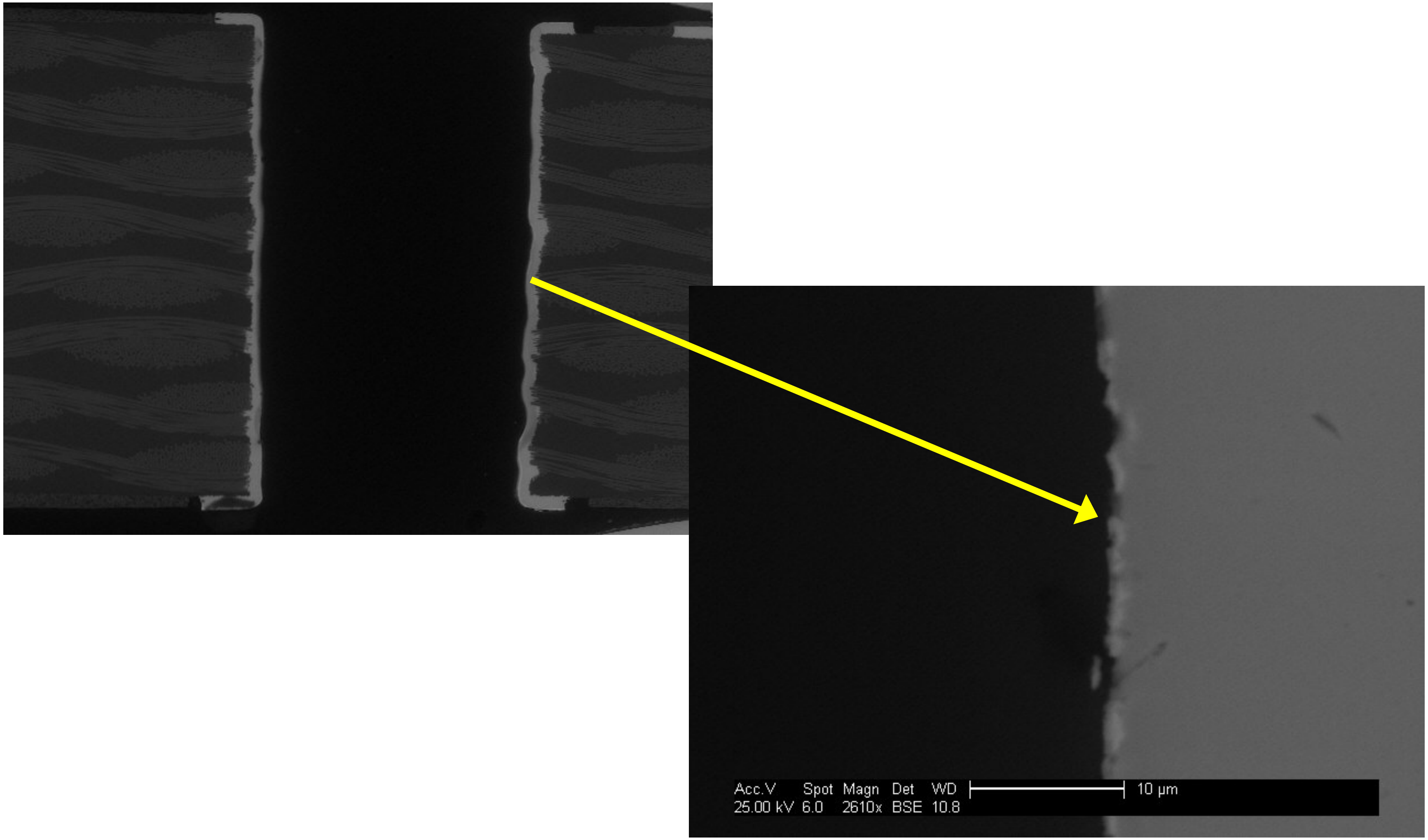
- Drilling characteristics
- Plating thickness by
  - XRF and dissolution techniques

Table 1. Thickness of Surface Finish (Micro Inches)

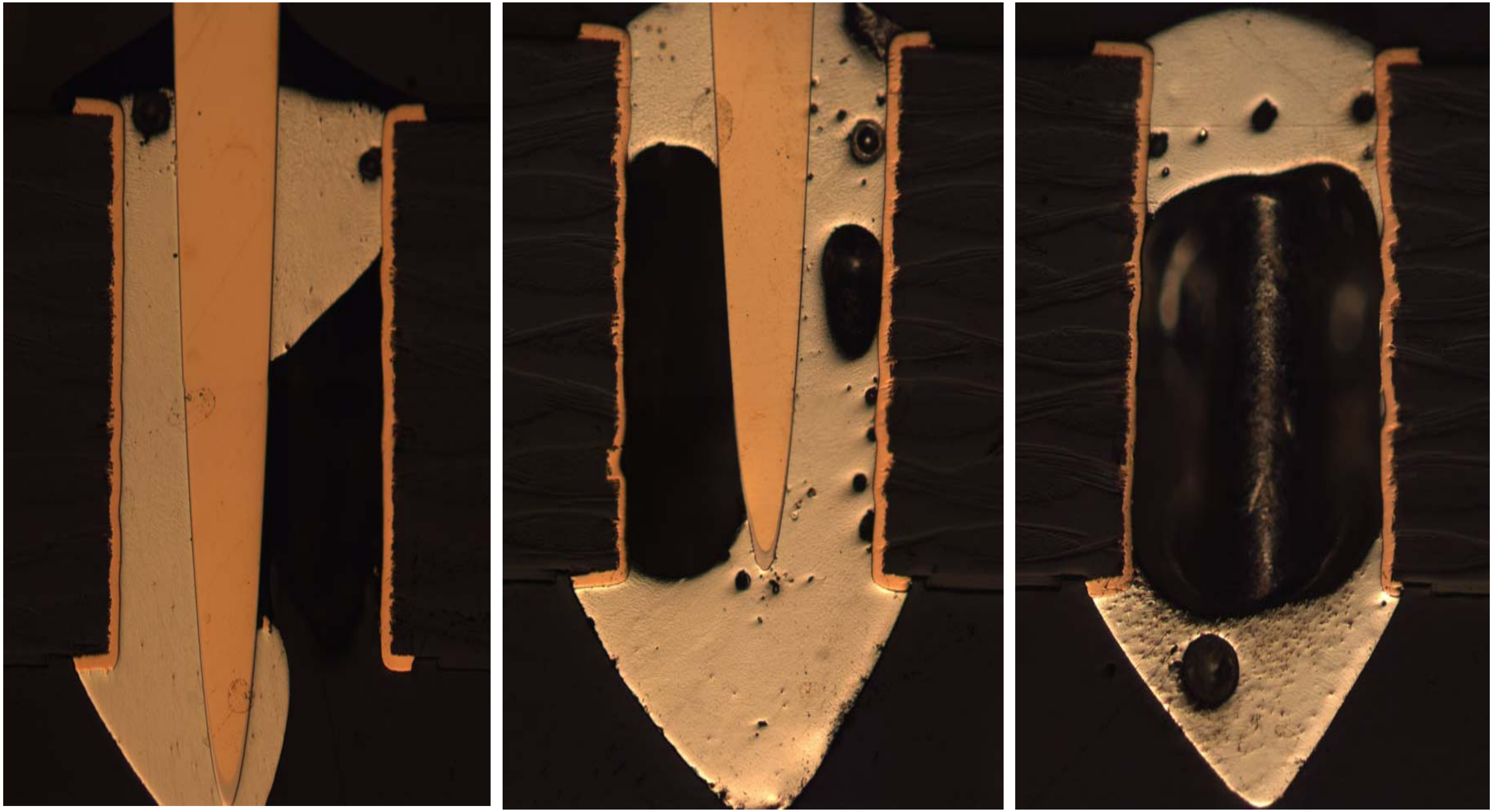
	Topside Pad	**Bottom Side Pad**	**Barrel -1**	**Barrel –2**
Average	88.94 ± 16.44	63.97 ± 12.72	48.73 ± 9.12	38.02 ± 11.12

  - recommended levels: 4 - 20 mils (MacDermid)
    8 - 12 mils (EMS)

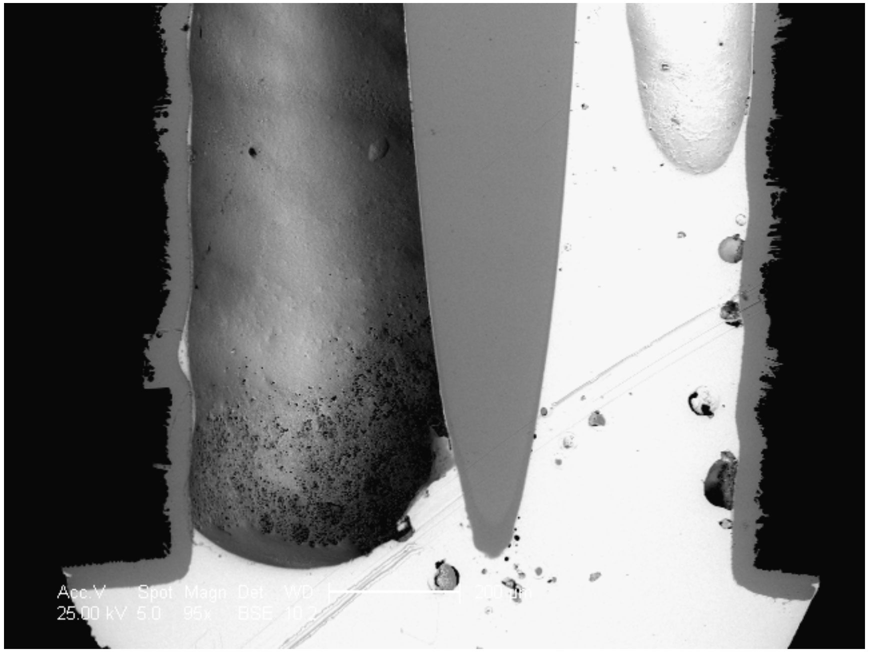
Immersion Silver Finish

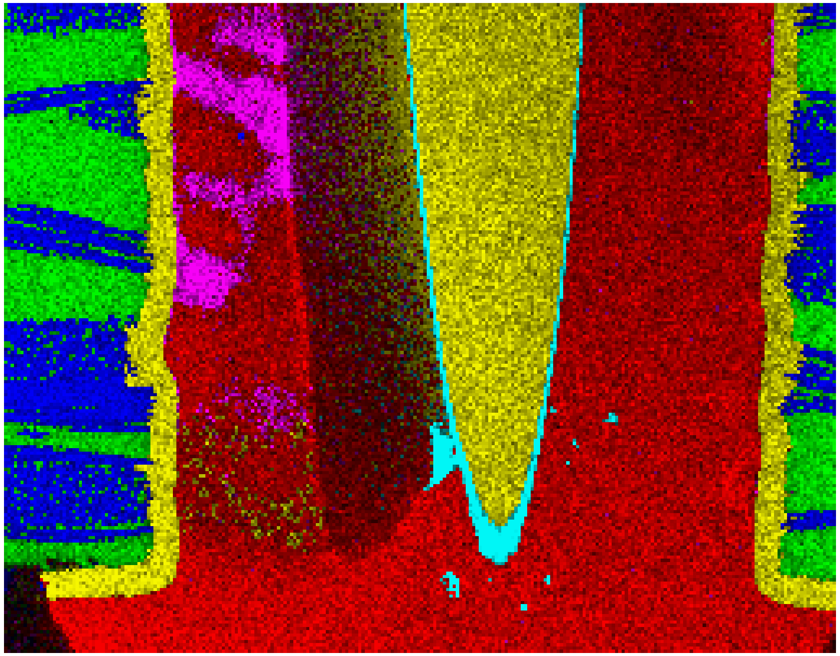


Failure Analysis Using X-Section



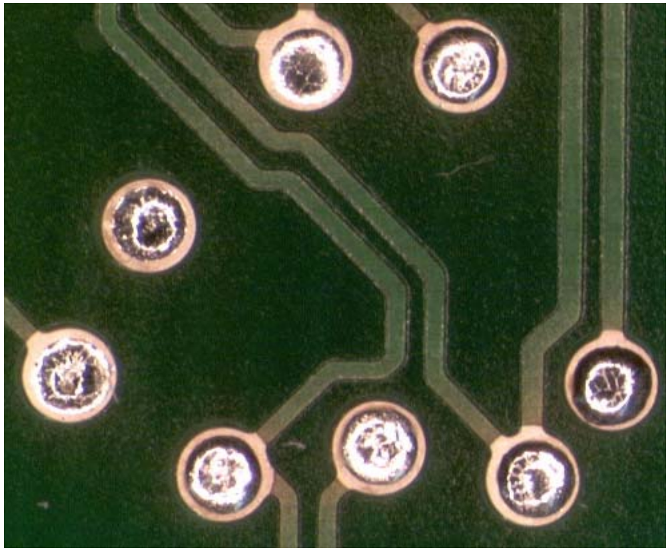
Failure Analysis Using SEM-EDX



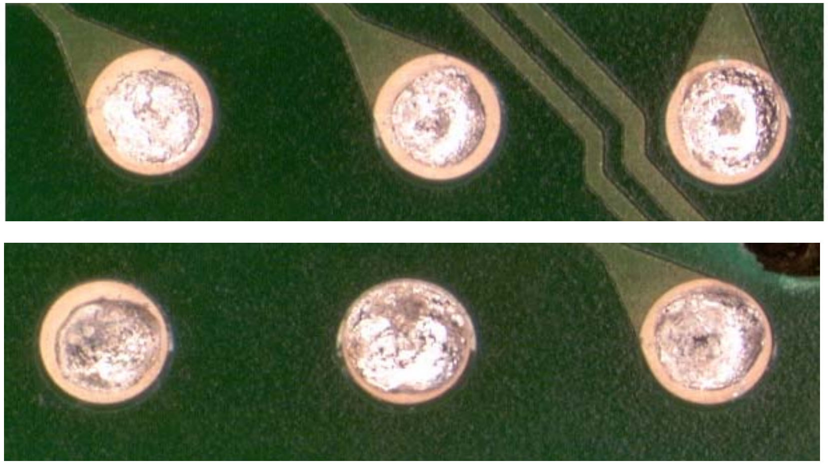


- **Evidence of Imm. Silver Finish**
- **Evidence of exposed Copper**

Solderability Testing



SAC 305



SnPb

- Using IPC specifications, we evaluated the solderability of the plating with both tin lead and lead free

Findings and Outcome

- Plating was poorly and unevenly applied.
- Resulting in unacceptable solderability.

- This illustrates the challenges lead free will have on the US market. Inexperience and lack of knowledge will impact assembly in many different ways.

Reflow Process for Lead Free

- Concerns with Lead Free are real.
  - Components, paste, board laminates can only handle certain exposure times at elevated temperatures.
  - Joints must still form properly which requires time at elevated temperatures.

- Result is better control, flexibility, and repeatability required for reflow ovens.

How ready are you … Really ?

- Materials and equipment will directly influence you ability and capacity to assemble lead free products.
- Careful selection of materials will give an understanding of the challenges lead free will present to your company.
- Equipment design will either challenge or enable your company to implement lead free processes.

SOLECTRON®

Best Practices in Environmental Compliance

Kim Hyland

Director

Process Technology

Solectron Corporation

SOLECTRON®

Environmental Compliance Team

W/W RoHS *Project Executive Manages the following team:*

Function	Goals
Engineering/Design	• Develop & define RoHS technical process, equipment, tooling & chemistry • Sites qualification process • FA testing & reporting
Materials/Warehousing	• Materials DFE services (Assess, status and convert BOMs) • RoHS materials, warehouse and logistic management strategy & definition
Operations	• RoHS compliant manufacturing, training, equipment needs & site readiness worldwide (PB-free)
Services	• RoHS compliant Repair services (PB-free) • Establish & support take-back logistics programs (WEEE)
IT	• Develop & Implement global database for materials compliance management • DFE (Design fro Environment) materials BOM scrub tools
Marketing	• Create RoHS DFE (design for environment) services, solutions and pricing • Train & enable sales & account mgmt teams
Sales/Business Process	• RoHS complaint manufacturing services and quotation models • Drive add-on manufacturing business
Government Affairs	• Guide Solectron RoHS Strategies (Environmental Regulatory Expert) • Assess & Anticipate future environmental laws
Legal/Contracts advisor	• *Assess & guide Solectron's customer contracts in support for RoHS DFE & compliant manufacturing services.*

Materials, Warehouse & Supply Base

Possible MFG/Customer Part Numbering Scenarios

Manufacturer			Customer	
Logistics	**Part Marking**	**Package Marking**	**Strategy**	**Timing**
Part Number Change (Could MFG both Pb and Pb Free)	Marked with standardized symbology	Outer Package may be marked with a standard or non-standard symbol	Change all Part Numbers	In Accordance With European Requirements
Part Number Remains the Same/ Date Code Cut-Over	Marked with their own symbology	Inner Package may be marked with a standard or non-standard symbol	Change Only Part Numbers in Parallel to Vendor Part Number Changes	Before European Requirements
Transition Date Only	No Markings	No Package Marking	Don't Change Any Part Numbers	After European Requirements or Never Change

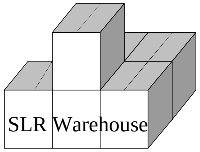
EMS must be able to develop a solution for any or all combinations of the above scenarios.

Ex: One of our current OEM RoHS Strategy is to manage their product transition using date codes rather than changing their CPNs.

A plan must be established to clearly segregate RoHS and non-RoHS inventory regardless of Manufacturer or customer choice to change PN, label, or not. Risks and implications are high.

Risks of Non-Compliance with RoHS in Warehouse and Material Handling

- **NCM/MRB** – The MRB could move non-compliant material to a compliant part number.
- **At Receipt** – A vendor ships non-compliant components as RoHS compliant



- **Part Number Change Requests** – Planners review ERP for alternative part numbers to fulfill shortages and could request a non-compliant part be moved to a compliant part number.
- **Warehouse Operations** – Warehouses operates with an inventory accuracy of ~ 95% - approximately a 5% chance that product could get mixed from daily activity.
- **Returns to Stock from Manufacturing** – Manufacturing returns non-compliant part as a compliant part because of excess from overissues and changes to schedules.

Potential Impact of Non-Compliance

- Product held at EU customs, time-to-market and sales affected
- Rework of product
- Epidemic liability for non-compliant product being placed on a large number of boards
- Potential for Millions of dollars lost
    - Example: Cadmium in Sony Playstations imported into the Netherlands for Christmas 2001 season
        - 1.3 million units blocked (worth $162M), $86M in rework, $141M in sales
- Possible government fines or penalties for non-compliance??
- EMS reputation tarnished
- Customer reputation and/or brand-name tarnished
- Other potential impacts may be unknown at this time due to lack of precedent

Warehouse and Logistics Compliance Plan

Establish and implement an end-to-end, warehouse and logistics management process that will:

- Segregate RoHS compliant and non-compliant material and mitigate risk of mixing materials
- Supply our customers with the ability to identify, contain and manage the transition of new RoHS compliant materials into the business

New site part numbers will be created for all RoHS compliant assemblies and all of their BOM components, regardless of the actions of MFGs or customers.

- Clear physical and financial separation of the supply chain (i.e. Inventory, Demand, Supply)
- Fully utilize MRP
  - Will be able to use effectivity dates to phase in/ phase out part numbers
  - Clean BOMs, AMLs and Orders
- Lowest risk of mixing inventory in warehouses
- Easier to capture and recover E & O created by the switchover

Environmental Compliance Readiness

- **Engineering & Operations**

Solectron Site Technology Deployment

Technical Center develops process and performs reliability tests and then each site must build the same qualification test vehicles:

a. **SMT, By following the leadfree SMT and rework qualification procedure**
   - Validate the process using corporate approved materials
   - Insure equipment readiness

b. **Wave, By following the leadfree wave solder process verification procedure**
   - Validate the process using corporate approved materials
   - Implement dedicated equipment

c. **Handsolder training, IPC Certified rework training**
   - Global train-the-trainers program using common curriculum worldwide
   - Use of standard rework equipment

Solectron Chemical Recommendation

- Solder paste – Sn3Ag0.5Cu
  - 96.5wt%Sn3.0Ag0.5Cu (melting point: 217°C), preferred
- Wave solder – Sn3Ag0.5Cu
  - VOC, no-clean, preferred
- Hand solder – 96.5Sn3.5Ag rework wire
  - Cored wire
  - Liquid rework flux, both on separate, distinct stations
- BGA rework – 95.5Sn3Ag0.5Cu solder paste or paste flux.
  - Tacky flux or Sn3.0Ag0.5Cu paste
- PCB: FR-4 Board surface finish: Im Ag, OSP-HT, Im Sn and ENIG
  - Low layer count can still use standard Tg (140°C) and decomp at 320°C
  - Complex cards will need non-dicey material, Tg (175°C) and decomp at 340°C

Designated production areas for lead-free wave and rework

- Dedicated lead-free wave solder machine
  - Logistics to separate lead-free SnAgCu and SnPb solder bar
  - Optional is to have “swappable” pots that can be interchanged
- Rework solders must be compatible with the manufactured solder – need separate designated lead-free rework area in production and methods to deal with field returns.
- Planning of production line is essential for lead-free assembly.
- Lead-free component and board labeling will be needed to differentiate between SnPb and lead-free assemblies for assembly, repair and rework (Refer to JEDEC standard, JESD97: Marking, Symbols and Labeling for lead-free assemblies, components and devices and IPC 1066 standard for lead-free labeling)

Solectron SMT and Reliability Lead-free Test Vehicle

Lead-free Component BOM List:

0201, 0402 to 1206 chips,

CSP84 0.5mm,CSP64 0.8mm,

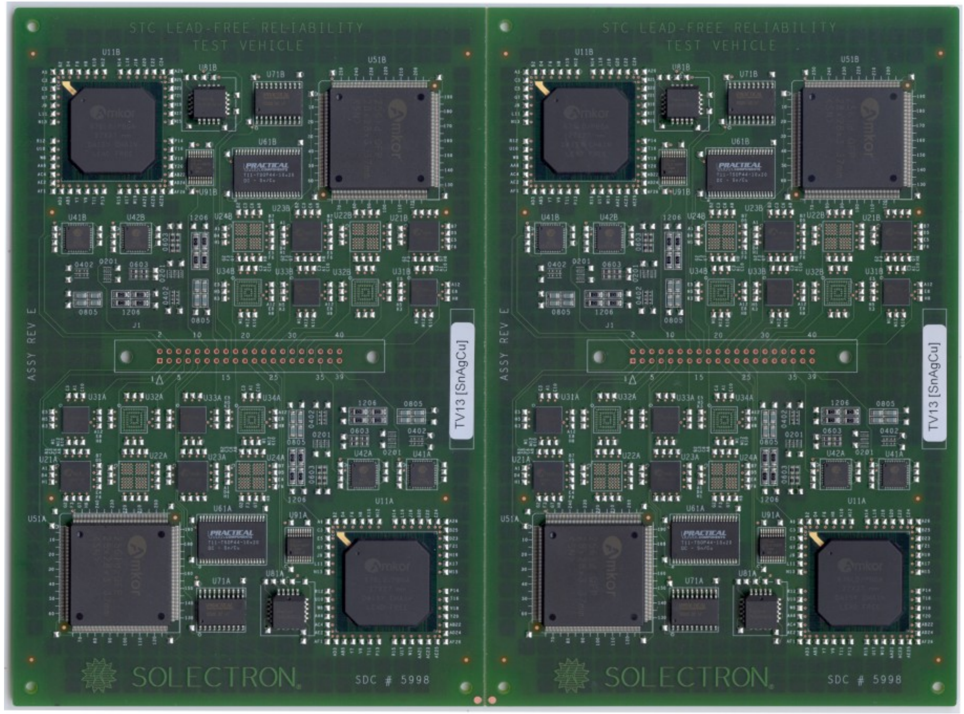
PLCC20, QFP256 0.4mm,
SOIC20,SSOP20,TSOP44,

MLF44 0.5mm

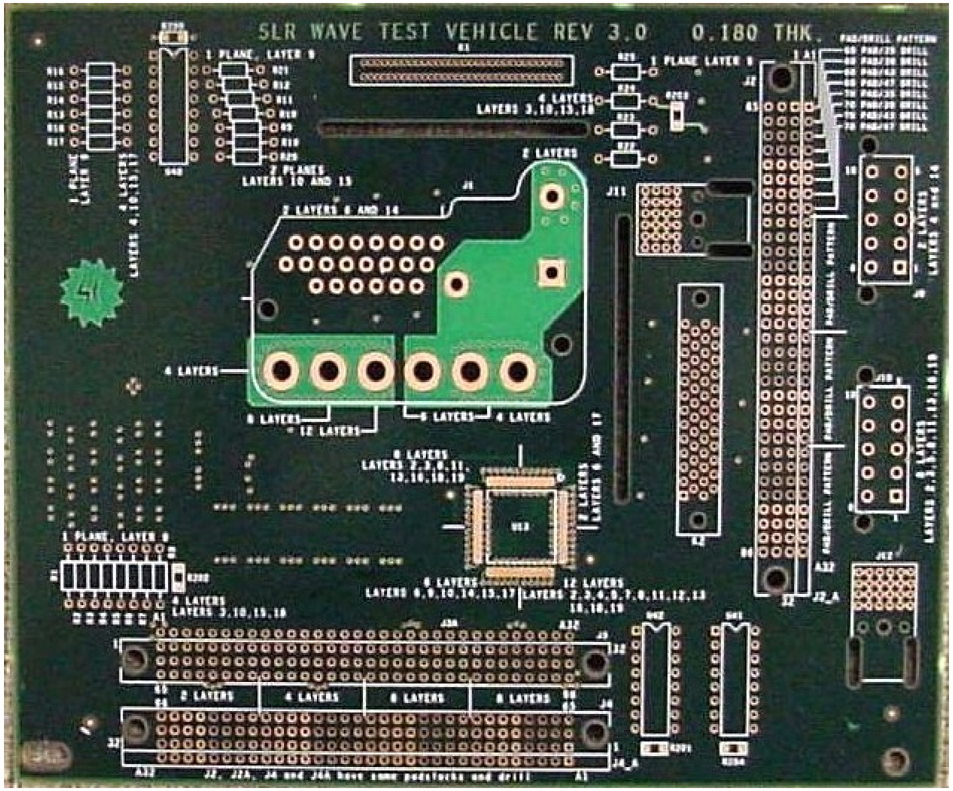
PBGA676 1mm

93mil thick board

High Tg FR4 (170°C)



Solectron Wave Test Vehicle



Top side

- **Size:** Single **(5.5" x7.0") or Panel (4UP, 12" x 15")**
- **Board Thickness: 62,** 93**, 125, & 180 mils**
- **Surface Finish:** OSP & Imm. Ag
- Various pad and hole diameters
- **Various copper layers:** 1, 2, 4, 6, 8 **(up to 12 layers for 0.180" thick board)**
- Various SMT and PTH pad spacing
- **Includes thermal relief design (for power brick design)**

Site Certification Process

- SMT & PTH test vehicle builds and associated laboratory analysis validate proficiency in PCBA soldering & rework.
- A 200-question RoHS self-assessment checklist needs to be filled out to thoroughly cover the areas of:
    - Training
    - Materials Management
    - Engineering & Test Capabilities,
    - Manufacturing Process & Control
    - Quality Assurance.
- A detailed Corporate on-site audit of the site’s RoHS preparations, controls, technical understanding, and compliance readiness.

RoHS Compliant Certification Schedule

Update: Oct 15, 2005

Provide RoHS compliant capability in all geographies approx. 6 months ahead of customers' production requirements

Region	**[1] RoHS Compliant**	**Audit Schedule**	
		by Aug 2005	**by Nov 2005**
Americas	FinePitch, **Charlotte,** Guadalajara, Milpitas, Austin	Complete	Kanata, Puerto Rico, Columbia, Sherbrooke, Creedmoor, Jaguariuna
Europe	**Timisoara,** Dunfermline, Herrenberg, Ostersund, Budapest, Bordeaux	Complete	Istanbul
So. Asia	**Penang,** Batam, **Singapore**	Complete	Bangalore
No. Asia	**Suzhou**, Shenzhen, Ibaraki	Complete	Shanghai
Services	**Singapore, Austin, Milpitas** Bordeaux	Complete	**Budapest,** Toronto, Koriyama, Chihuahua, Louisville, Memphis, Matraville, all other China repair centers

[1] SLR RoHS compliant checklist will be updated to conform with *de minimis* allowable levels when determined in the EU legislation

[2] Sites in bold (**Charlotte, Milpitas, Timisoara, Penang, Suzhou+ 3 service sites**) are production lead sites, responsible to showcase Solectron's capability to our customers and assist regional deployment.

Universal Instruments

Lead Free Assembly
(Panic now, beat the rush!)

Peter Borgesen, Ph. D.
Manager, Process Research

October, 2005

defining the future

Lead Free Assembly
(Panic now, beat the rush!)

It ***is*** happening. Many will be exempt (medical, military, flip chip, ...), at least for a while. However, eventually SnPb infrastructure will become an issue to all remaining. In the short term the worst problems for many are ‘non-technical’ (supply chain, inventory control, ...) – and RoHS is not only about the Pb.

Technically: We can assemble the stuff. Some have done it “without problems” for years. However, an increasing number of people are getting justifiably concerned about reliability/robustness. Major issues include

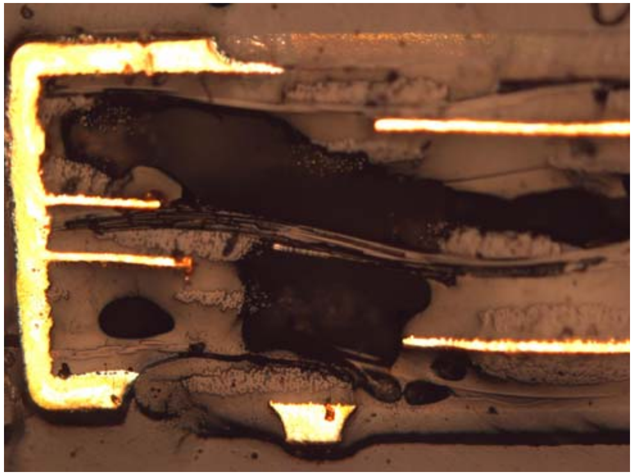
Whiskers: There are ways to mitigate, but only ***safe*** remedy is to avoid leaving any Sn surfaces unsoldered. Otherwise minimize and assess risk, design for it.

Component & PCB Damage: Higher temperatures, greater strains in reflow, harder solder joints may damage vias and laminates, crack passives, fracture low-k and other multilayer dielectrics on flip chips, ... in reflow and handling.

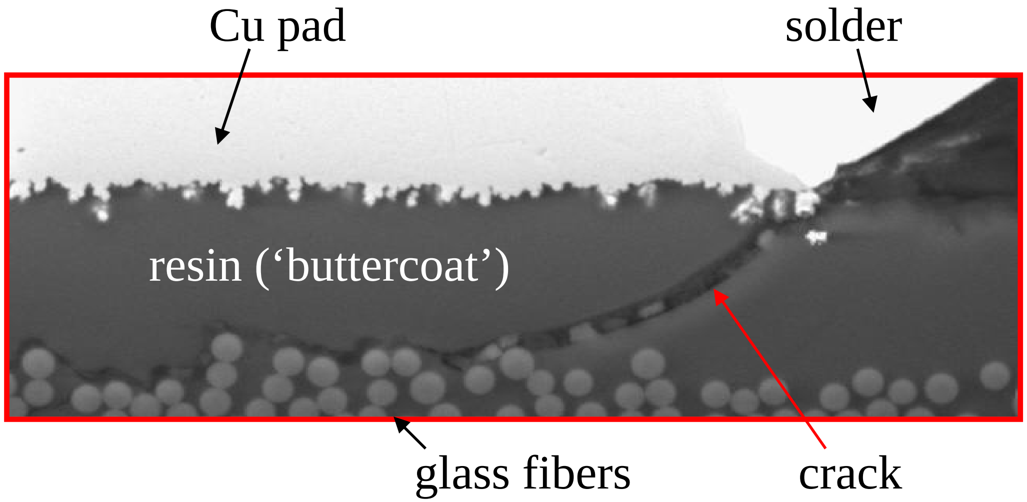
Solder Properties: Dangerous misconceptions and surprises arise from implicitly treating the alloys as ‘similar’ to SnPb. We are slowly starting to understand the very different nature of them and, in particular, of mixtures of these with SnPb.

Solder Pad Fragility: Very recently an ***occasional*** (!) degradation within the intermetallic structures on the pads has caused serious concern, but problem is still widely underestimated.

Component & PCB Damage



Obvious damage at via



Undetected initial component/PCB/solder specific damage caused intermittents in later thermal excursions

The potential for (often subtle) damage to laminate structures in lead free reflow (mass reflow, repair, wave soldering) may be greater than commonly expected.

Currently, at best a very limited range of tests is employed to check that boards (in particular) are no-Pb ready. Rarely addressed at all:

- latent, non-obvious damage
- effects of assembly (presence of components)

Component & PCB Damage

Damage is not simply a question of materials degrading at high temperatures. Rather, combined effects of temperatures and stresses/strains create variety of damage depending on ramp rates, design features, resin thicknesses, component expansion and rigidity, ...

In general we need to test for ***combinations*** of reflow, cleaning, handling, ambient exposure, repair (localized heating), ...

We need to test for effects on solvent resistance, moisture uptake, encapsulant/mold/die attach adhesion, long term degradation, robustness in handling, ...

Comprehensive testing for ‘surprises’ is a major undertaking and ongoing research efforts will clearly have to continue ‘after the fact’ (no-Pb transition).

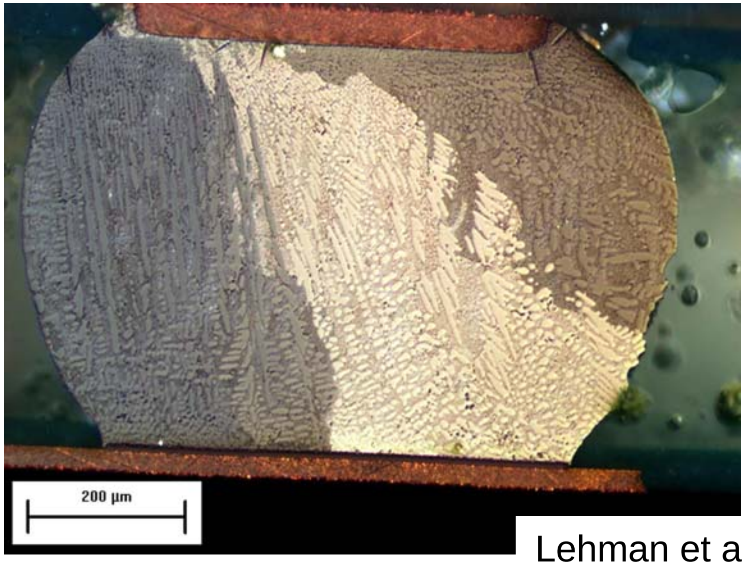
What’s So Different About The Solder?
(usually Sn joint with precipitates)

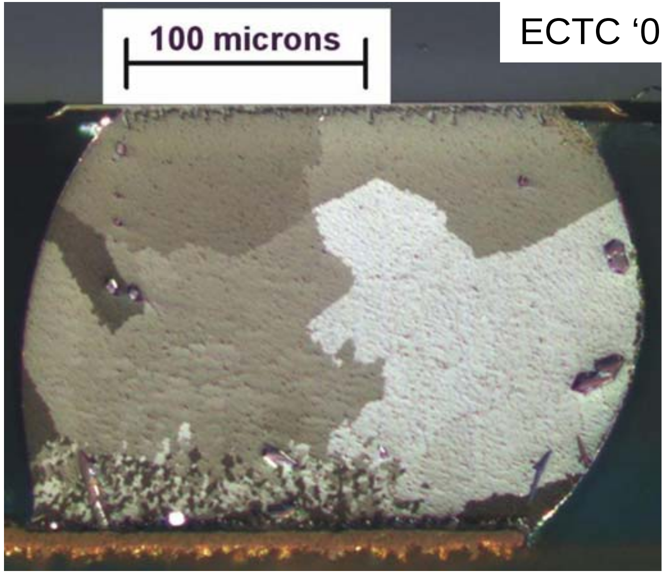
SnAgCu joints viewed with crossed polarizers:

Large joints usually consist of only a few Sn grains. Smaller joints often have many smaller grains (more grain boundaries) too.

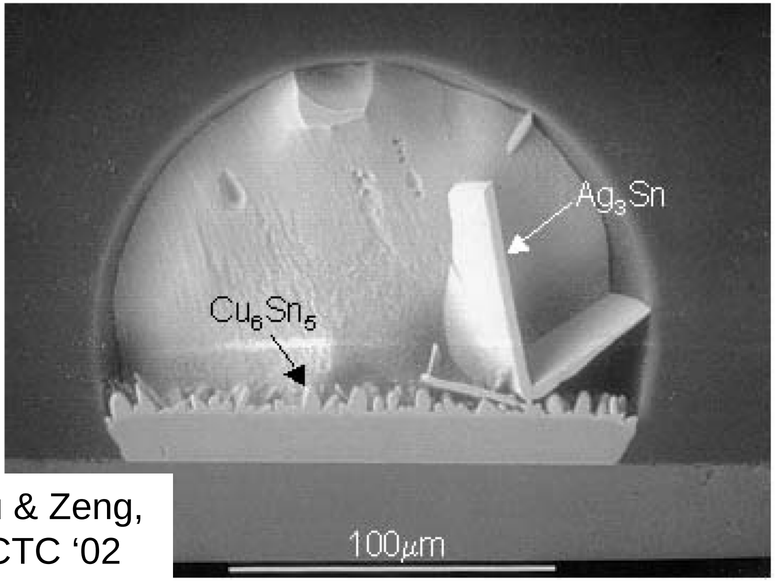
Totally different from SnPb

A few large Ag_3Sn platelets & Cu_6Sn_5 rods, and many smaller precipitates distributed within grains.





Lehman et al., ECTC ‘05



Tu & Zeng, ECTC ‘02

What's So Different About The Solder?

Typical no-Pb solders are largely Sn with minor concentrations of intermetallics. Properties determined by Sn grain structure and precipitate distribution. Understanding these and their dependencies on compositions, dimensions and time/temperature offers us a handle on it all, but it is not trivial. Lots of things that didn't matter much for SnPb now do.

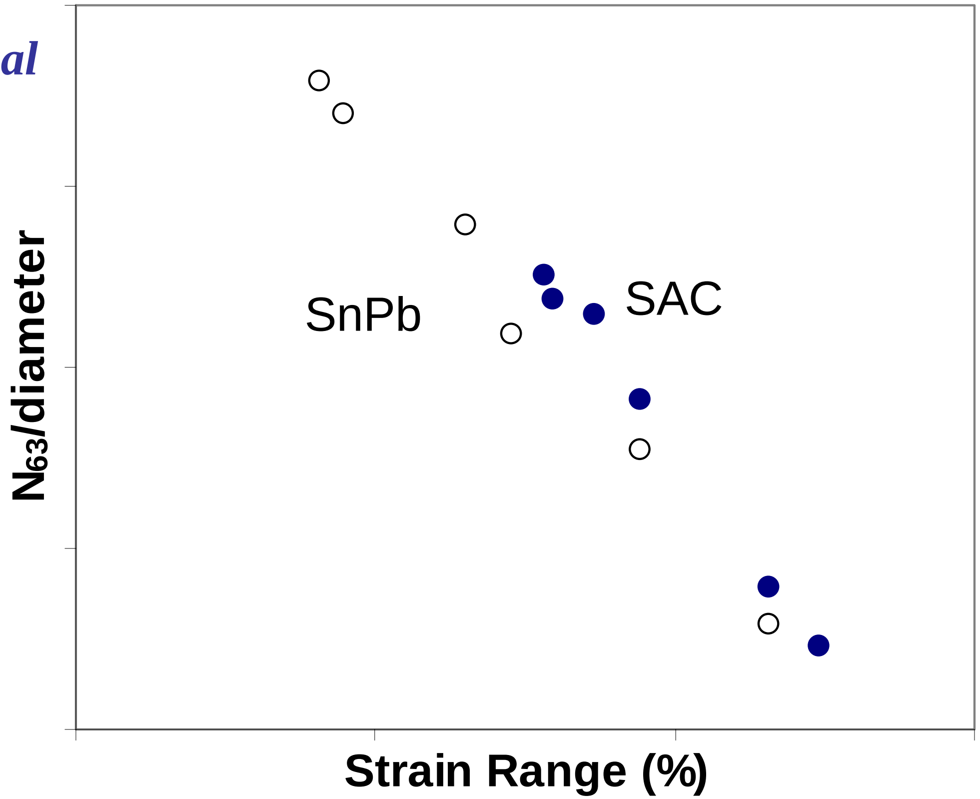
It has become much more difficult to generalize ('scale') results and experience. Even for a given SnAgCu composition, for example:

- Significant supplier dependence (contaminants, memory of process)
- Soldering properties (reflow process requirements and yields) vary with volume.
- Constitutive relations (deformation properties) and damage evolution vary much more strongly with size.
- Mechanical properties change significantly within hours/days at RT (faster at elevated temperatures).
- Even faster (stress enhanced) changes in cycling: Variations with location in array during thermal cycling (DNP).
- Different pad metallurgies are harder to compare
- ....

Most scary: The ***variability***

Example:
What's more reliable, SnPb or no-Pb?

Empirical scaling



SnAgCu tends to do better in standard thermal cycling tests up to about 125C. It is only expected to be worse at very high strains (rates)? Misleading!!

Proper test protocols taking different nature of the SnAgCu joints into account show a ***very*** different (and more complex) picture.

Which is more reliable (often SnPb by far) depends more on product and specific loading (history) of concern than commonly recognized. Qualification tests and comparisons can be designed to account for this, but significant background knowledge (data) required for practical applications.

What's So Different About The Solder?

Variability: Thermal cycling of a finite number of assemblies quite commonly lead to just as narrow failure distributions with no-Pb as with eutectic SnPb. However, both ATC and mechanical testing shows much more variability across a larger number (hundreds) of joints. Notably, indications of bi(multi)-modal distributions with order of magnitude outliers at the thousand joint level!

Solder Joint 'Summary'

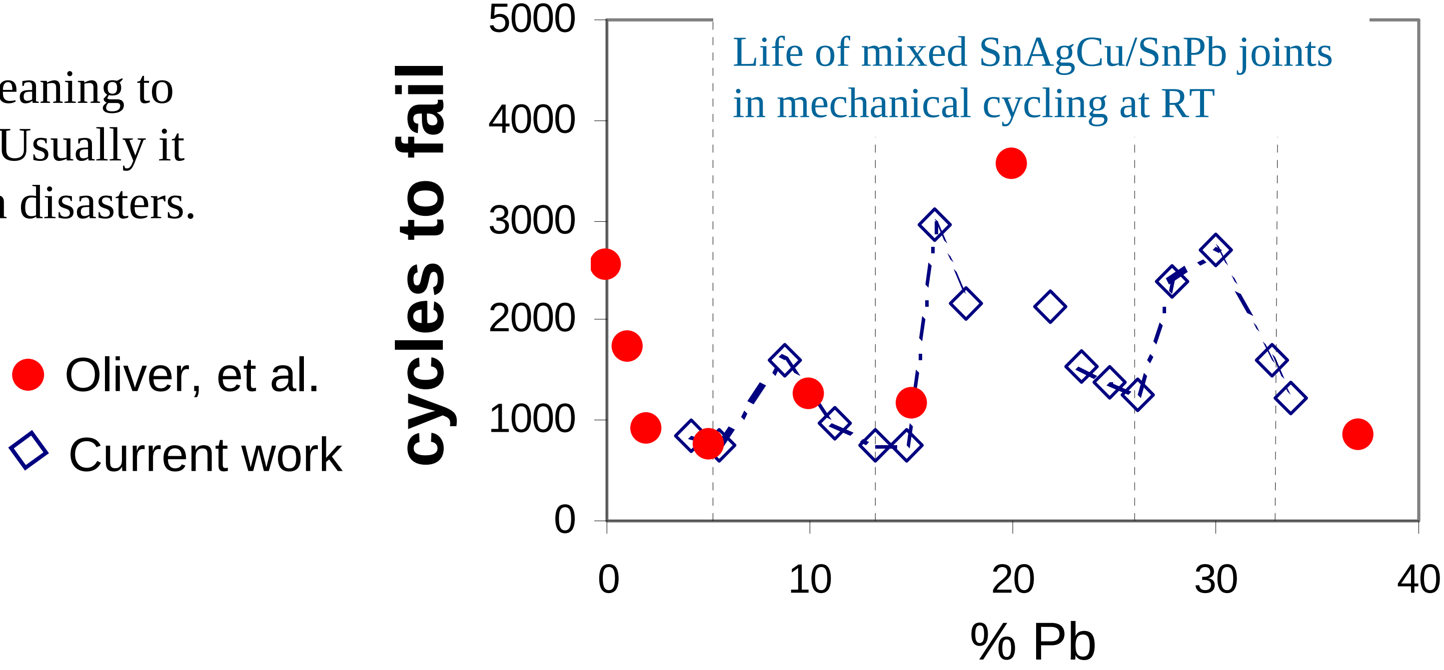
No-Pb joints are not 'variants' of SnPb, and lots of things that didn't matter much for SnPb now do. Notably, materials properties (stress and resulting damage evolution) depend on pre-assembly (supplier) processes as well as time and loading history (location in cycling). It has therefore become much more difficult to generalize ('scale') results and experience, and you'll have lots of 'occasional' surprises (apparent irreproducibilities). However, this is being dealt with through a combination of increasing mechanistic understanding and quantitative data. ***Variability*** (outliers) is the greatest challenge.

NOTE: Quantitative modeling/predictions may be useless or misleading unless they account for all the relevant 'new' dependencies, i.e. we can't just 'update' our SnPb models. For now we need to live without that (doable too).

‘Forward/backward Compatibility’
(don’t mix if you don’t *have* to!)

Calls for help with no-Pb assemblies that ‘used to work, but ...’ are rapidly increasing, but the number and severity of surprises are nothing compared to horror stories from practitioners who have ***mixed*** a no-Pb alloy with SnPb (on purpose or not!)

This gives new meaning to irreproducibility: Usually it works, but sudden disasters.

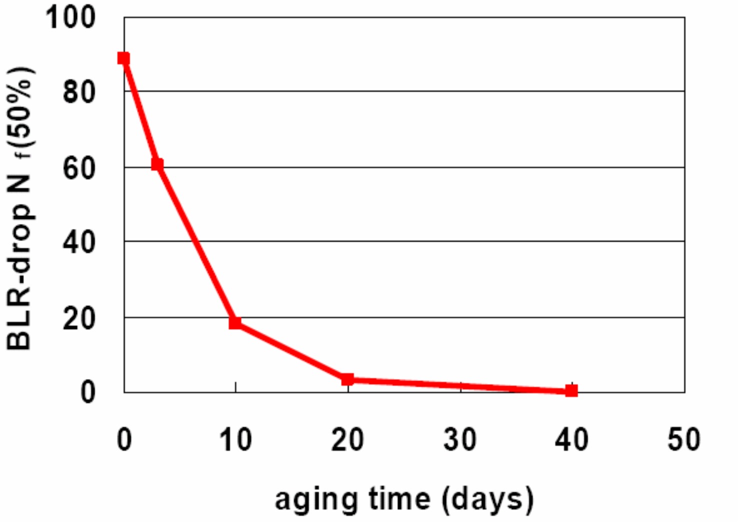

Life of mixed SnAgCu/SnPb joints in mechanical cycling at RT

The mixed systems make no-Pb look simple. Literature data on ATC scatter widely although trends still simpler than for isothermal loading. Limited control of mixing ratio across typical manufacturing volumes must be factored in. Important process guidelines have been established (and continue to be improved), but much greater mechanistic ***understanding*** needed.

Solder Pad Fragility

Solder pad finish issues are not news, but some recent ones are (or have been overlooked before). Common to all but one of the following problems is that they are not predictable – ***usually*** there is not a serious problem, but it can happen any time.

- The familiar ENIG issues, ‘black pad’ and degradation with temperature/time, are exacerbated with SnAgCu.
- The separate, well-understood, quantitatively predictable degradation mechanism for electrolytic Ni/Au is less of a problem for no-Pb.
- Immersion Ag-coated Cu-pads have caused some concerns (immature processes?)
- ‘New’ intermetallic structures on Ni-pads are usually robust but offer occasional problems (actually so does ‘similar’ structure for SnPb).
- Microscopic voids in intermetallics on ENIG ***and*** e-Ni concern (for high power apps.)



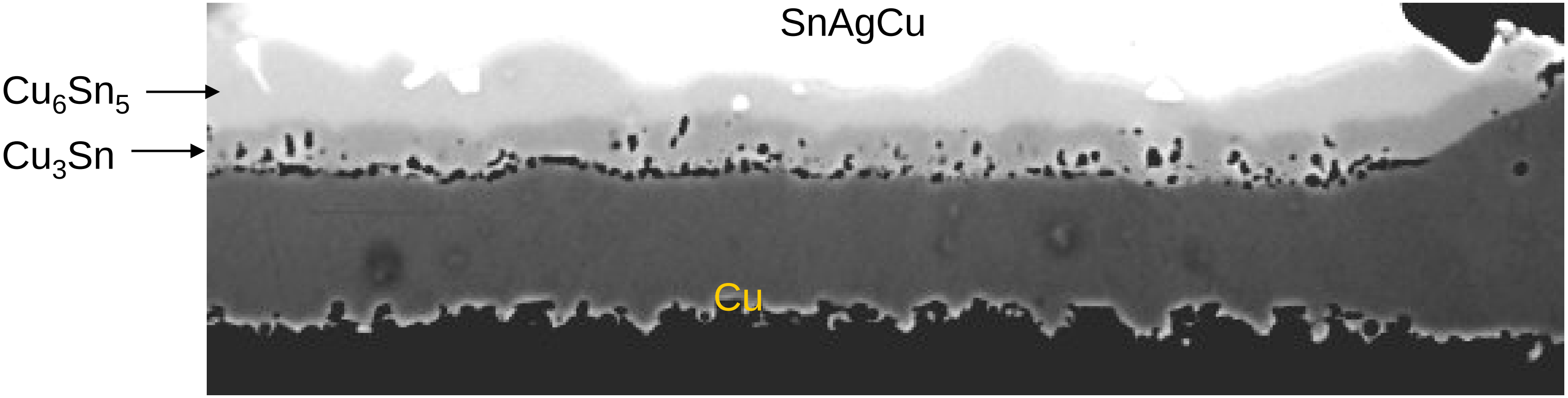
Chiu et al. ECTC 04:

Cu pads are also not as safe as we thought!

SnAgCu joints between Cu-pads: Drop test performance decreases with aging at 125°C

Solder Pad Fragility

It is quite common for drop testing to cause pad failure (depending on PCB design & materials), but this time the problem was found to be strong voiding in the Cu_3Sn layer:



Major ongoing consortium research program:

Continued voiding eventually problem in socket testing and even thermal cycling too.

Voiding just as prevalent with SnPb, but consequences delayed by greater compliance.

Not simple contamination effect.

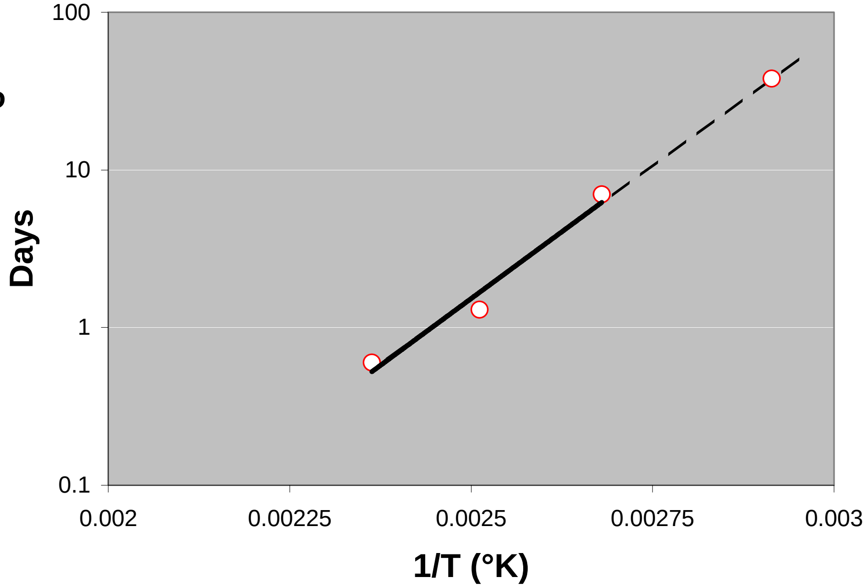
Primarily determined by the Cu, but not single plating chemistry or approach. Doesn't usually happen but serious voiding in something like 10% of all cases tested.

We cannot safely prevent it yet, so how do we test for it, and how do we extrapolate test results to service?

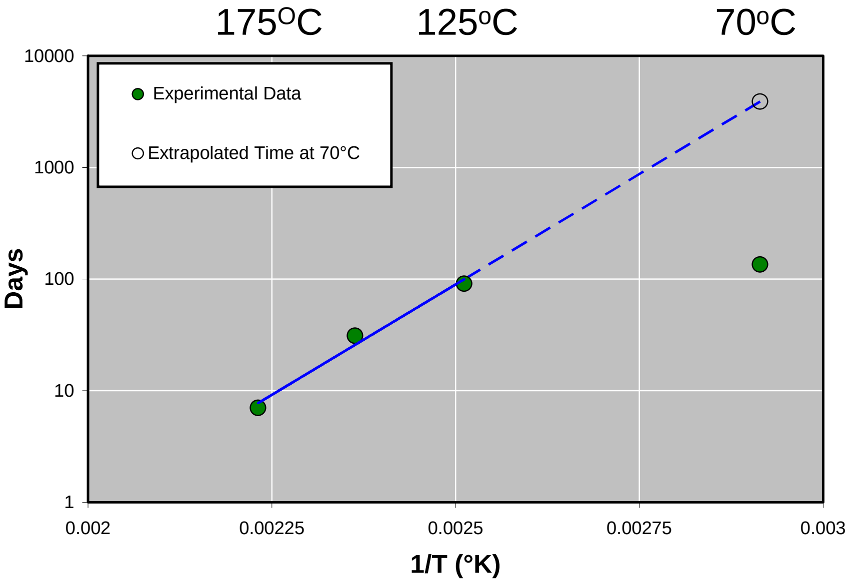
Solder Pad Fragility

When should who care?

When voiding reaches 25-75% of pad area, depending on application and loading of concern? And sometimes 'time-to-failure' seems to follow Arrhenius dependence at least down to 70°C:



but other times extrapolations overestimated life by orders of magnitude:



Our ability to predict temperature dependence (conservatively) improves daily, but there's much left to do.

Also, there is a strong need for mechanical ball level test procedure, but several groups report difficulties in correlating such procedures with voiding & drop.

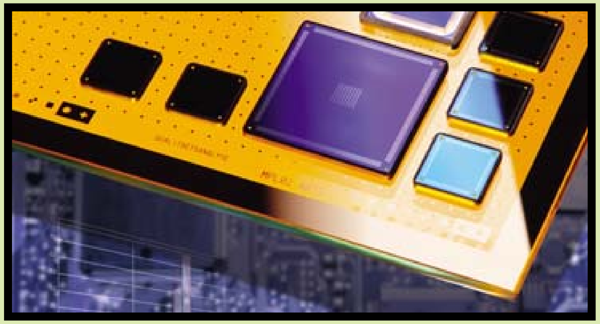
Finally

Pad Fragility Status

It seems that we ***can*** eliminate voiding but the only ‘solution’ so far (proprietary) would require enormous characterization & qualification efforts (ongoing). We are updating very preliminary screening test protocol on a daily basis (as we get smarter) but better mechanistic understanding is clearly required for quantitative extrapolations and eventual remedies. Recent results give us hope that we can resolve ball level test issues.

Lead Free Assembly

Like with eutectic SnPb it usually works, but sometimes things go wrong. It will do so more often with no-Pb. Like with SnPb this could usually have been avoided, but there will be more surprises, and there will be fewer people who can actually help then.



Machine Capability Testing Adds Quality Significance to Lead Free Assembly

October 11, 2005

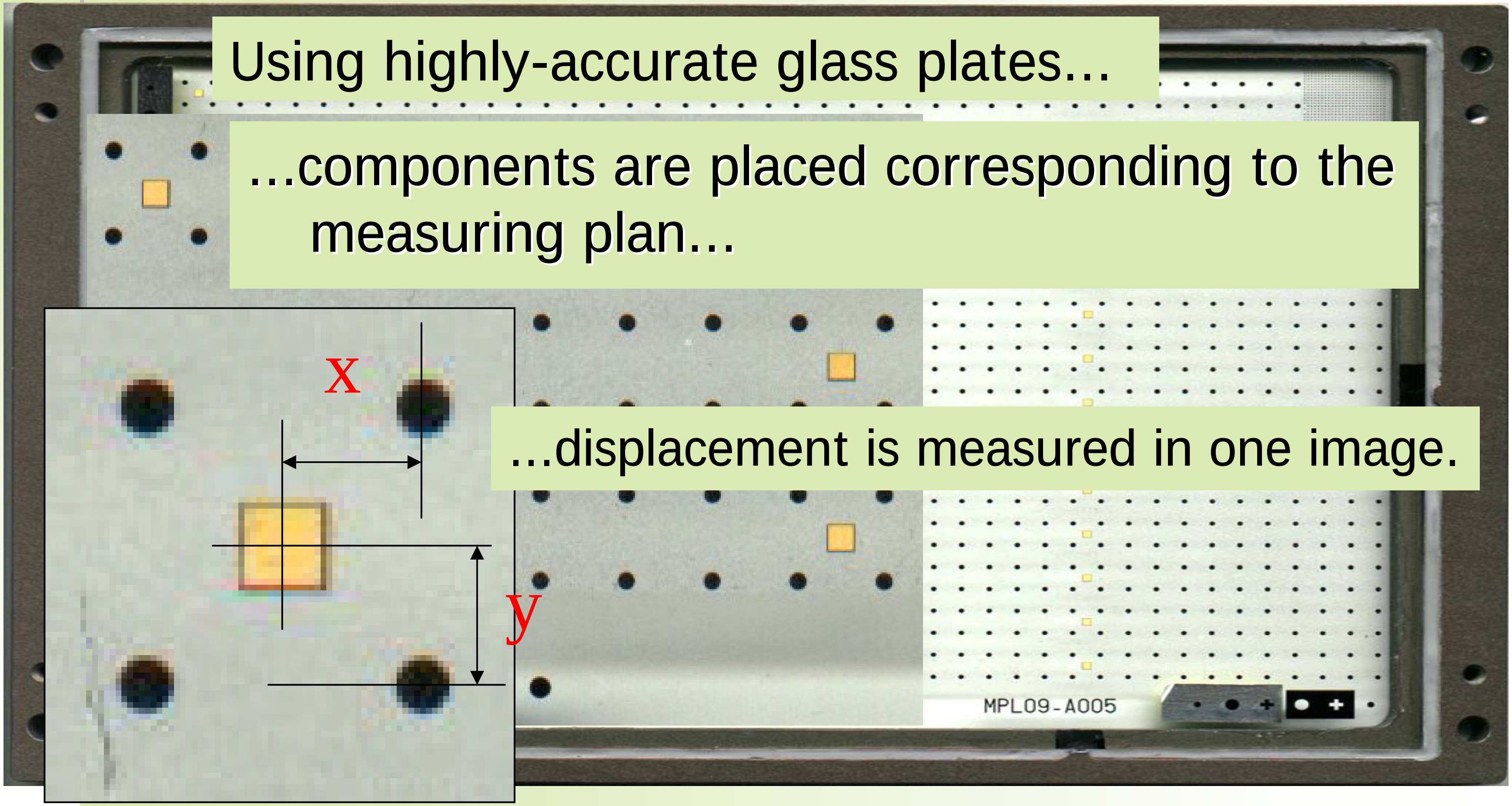
Presenting: Michael Sivigny

General Manager, CeTaQ Americas

Lead Free Assembly

- **Issue:** Smaller processing windows for printing, placement and reflow!
- **Issue:** Traditional reflow self-centering phenomenon is less effective!
- **Issue:** Large process deviations cause defects directly at machine, recognized or not!
- **One Solution:** Machine and Process Specification Validation!

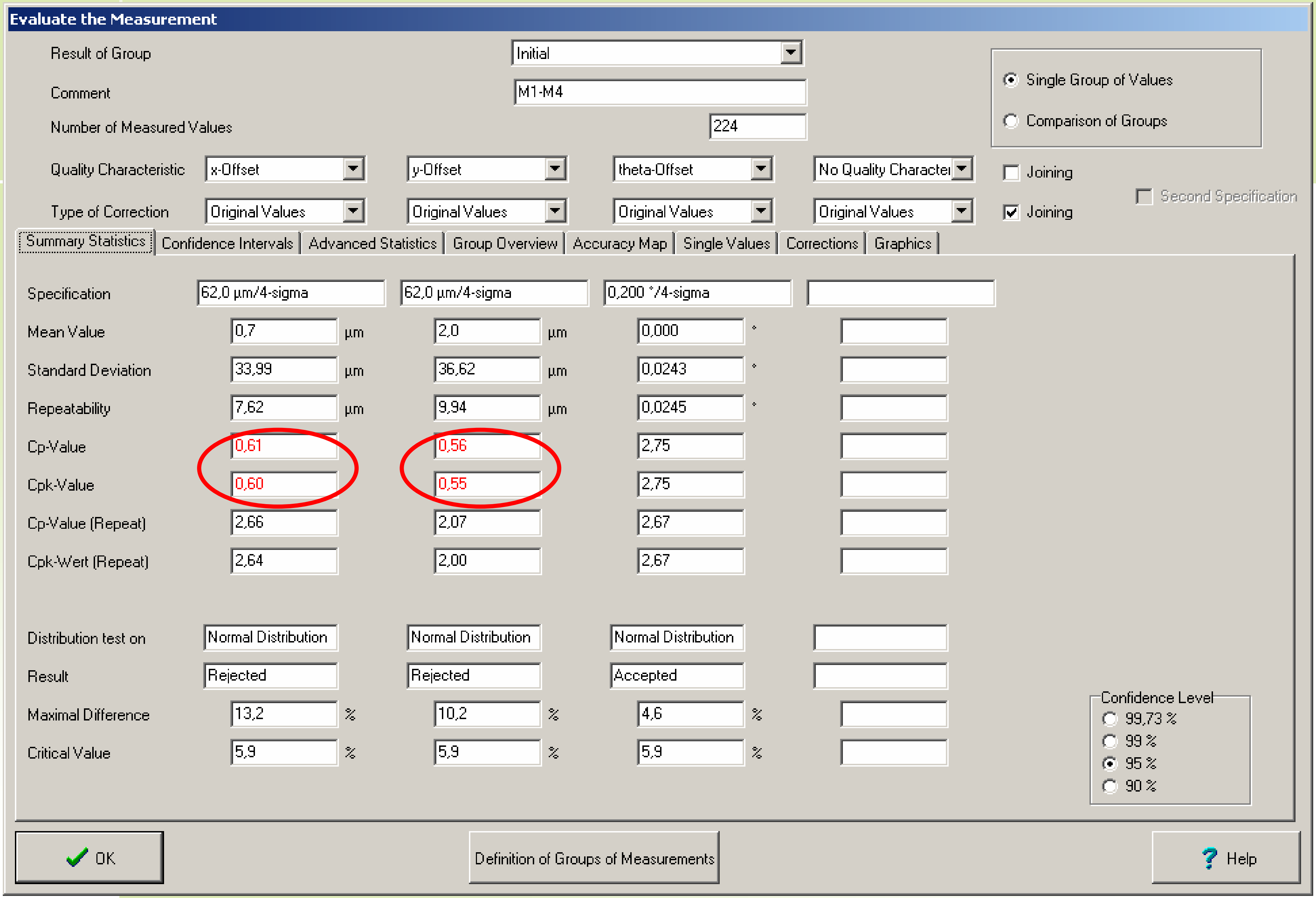
Relative Principle



Using highly-accurate glass plates…

…components are placed corresponding to the measuring plan…

…displacement is measured in one image.



Evaluate the Measurement

Result of Group: Initial
Comment: M1-M4
Number of Measured Values: 224

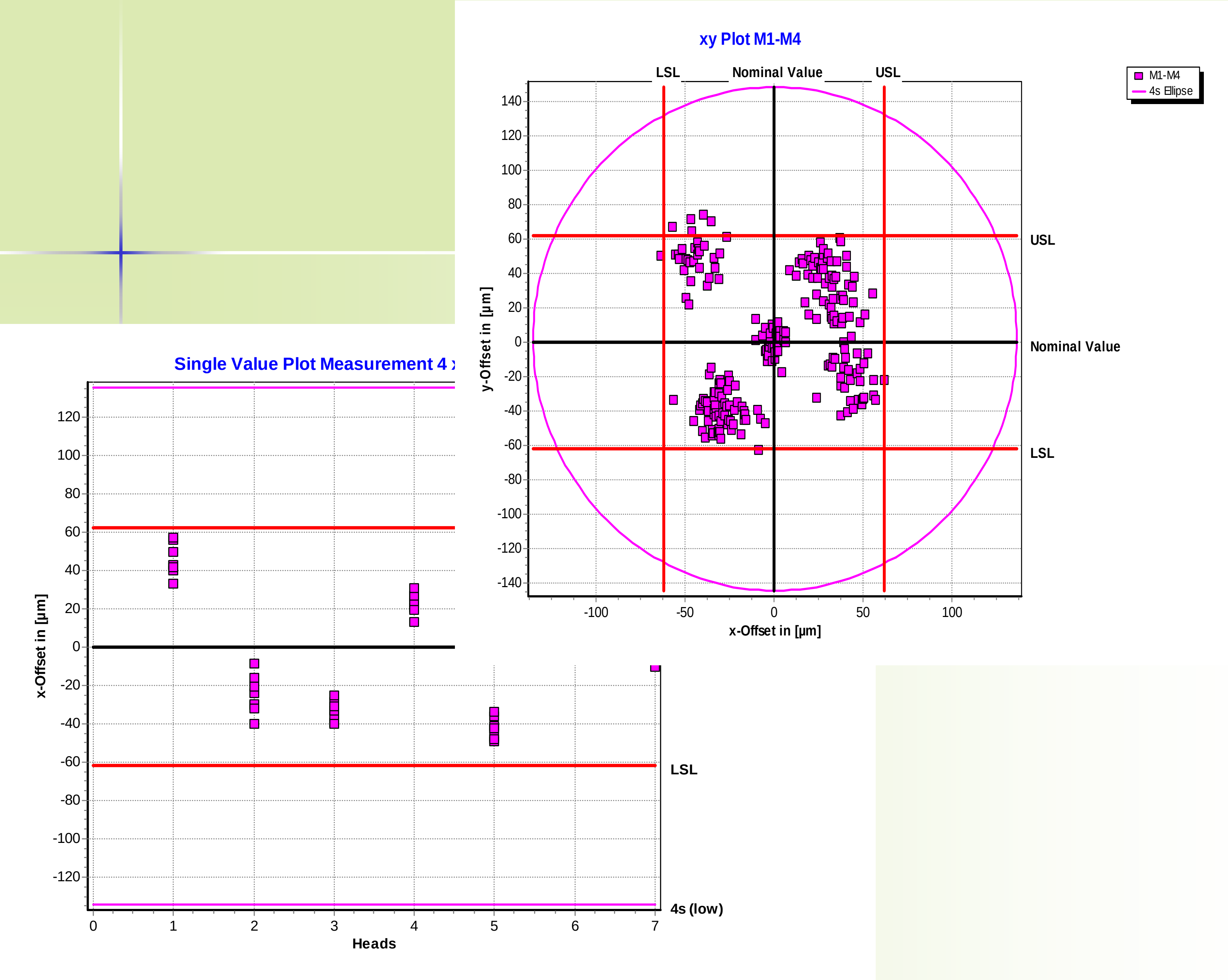
● Single Group of Values
○ Comparison of Groups

Quality Characteristic	x-Offset	y-Offset	theta-Offset	No Quality Characte
Type of Correction	Original Values	Original Values	Original Values	Original Values

☐ Joining
☑ Joining
☐ Second Specification

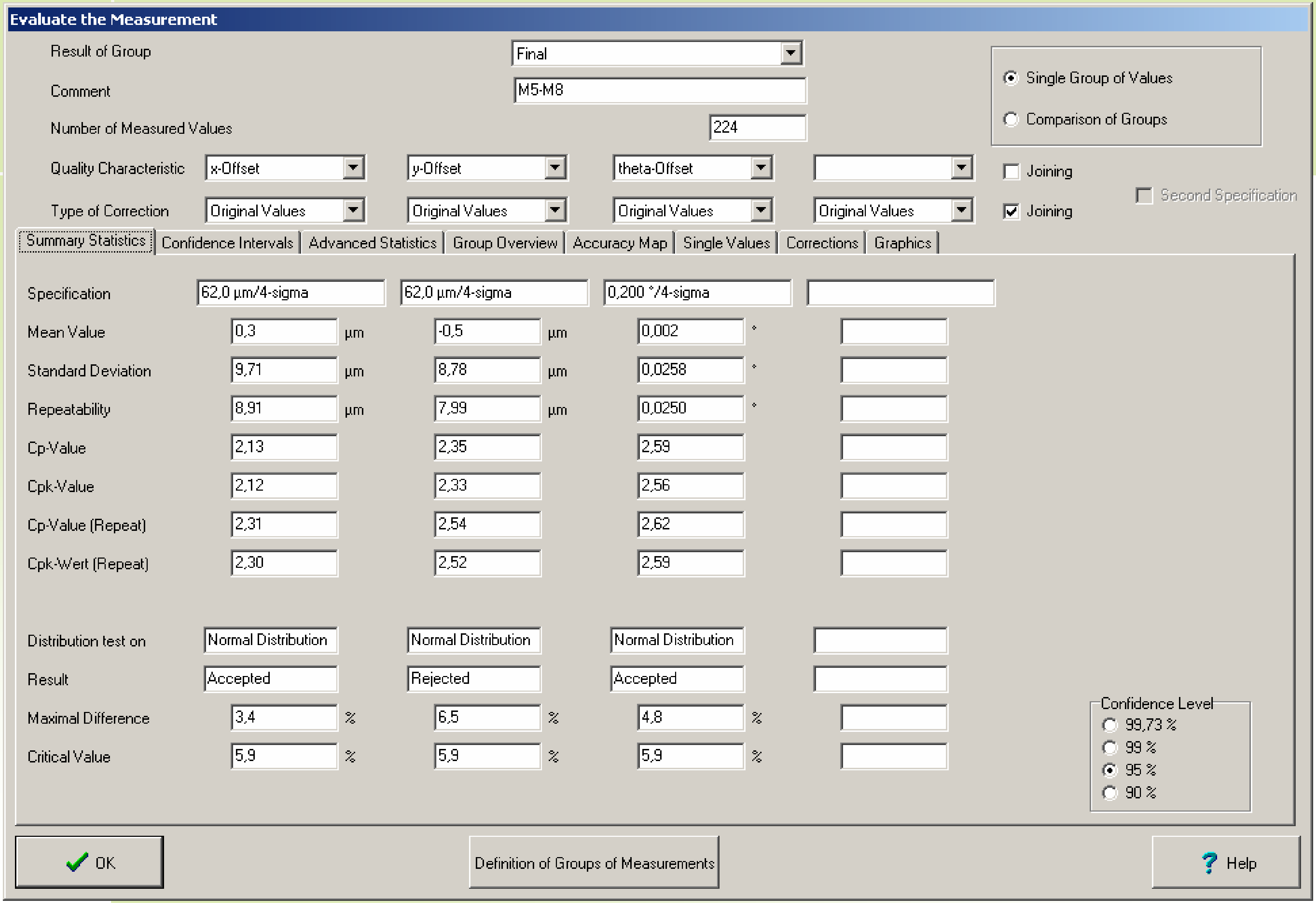
Specification	62,0 µm/4-sigma	62,0 µm/4-sigma	0,200 °/4-sigma	
Mean Value	0,7 µm	2,0 µm	0,000 °	
Standard Deviation	33,99 µm	36,62 µm	0,0243 °	
Repeatability	7,62 µm	9,94 µm	0,0245 °	
Cp-Value	0,61	0,56	2,75	
Cpk-Value	0,60	0,55	2,75	
Cp-Value (Repeat)	2,66	2,07	2,67	
Cpk-Wert (Repeat)	2,64	2,00	2,67	
Distribution test on	Normal Distribution	Normal Distribution	Normal Distribution	
Result	Rejected	Rejected	Accepted	
Maximal Difference	13,2 %	10,2 %	4,6 %	
Critical Value	5,9 %	5,9 %	5,9 %	

Confidence Level
○ 99,73 %
○ 99 %
● 95 %
○ 90 %



xy Plot M1-M4

Single Value Plot Measurement 4 x



Result of Group: Final

Comment: M5-M8

Number of Measured Values: 224

● Single Group of Values
○ Comparison of Groups

Quality Characteristic	x-Offset	y-Offset	theta-Offset		☐ Joining
Type of Correction	Original Values	Original Values	Original Values	Original Values	☑ Joining

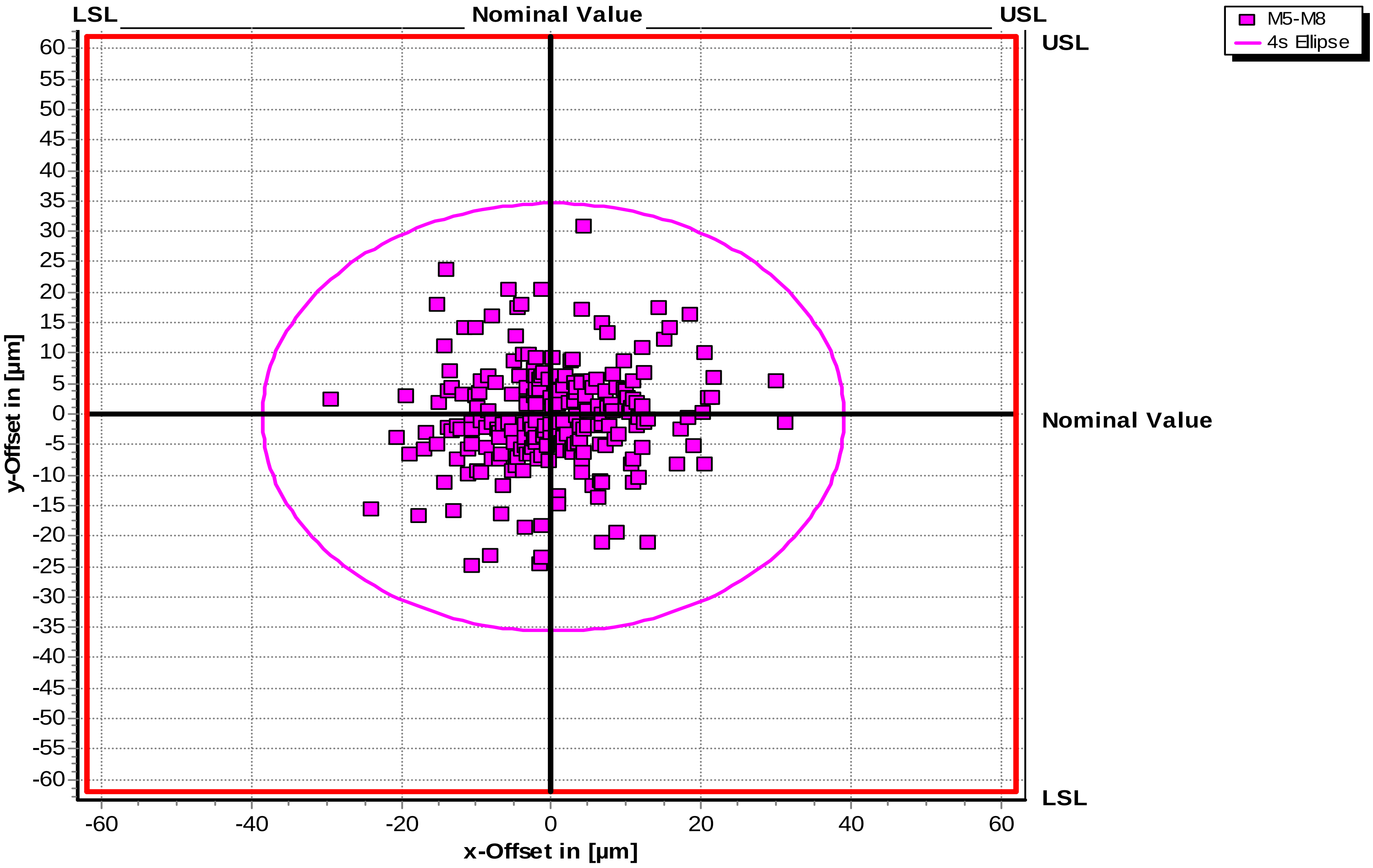
☐ Second Specification

Specification	62,0 µm/4-sigma	62,0 µm/4-sigma	0,200 °/4-sigma	
Mean Value	0,3 µm	-0,5 µm	0,002 °	
Standard Deviation	9,71 µm	8,78 µm	0,0258 °	
Repeatability	8,91 µm	7,99 µm	0,0250 °	
Cp-Value	2,13	2,35	2,59	
Cpk-Value	2,12	2,33	2,56	
Cp-Value (Repeat)	2,31	2,54	2,62	
Cpk-Wert (Repeat)	2,30	2,52	2,59	

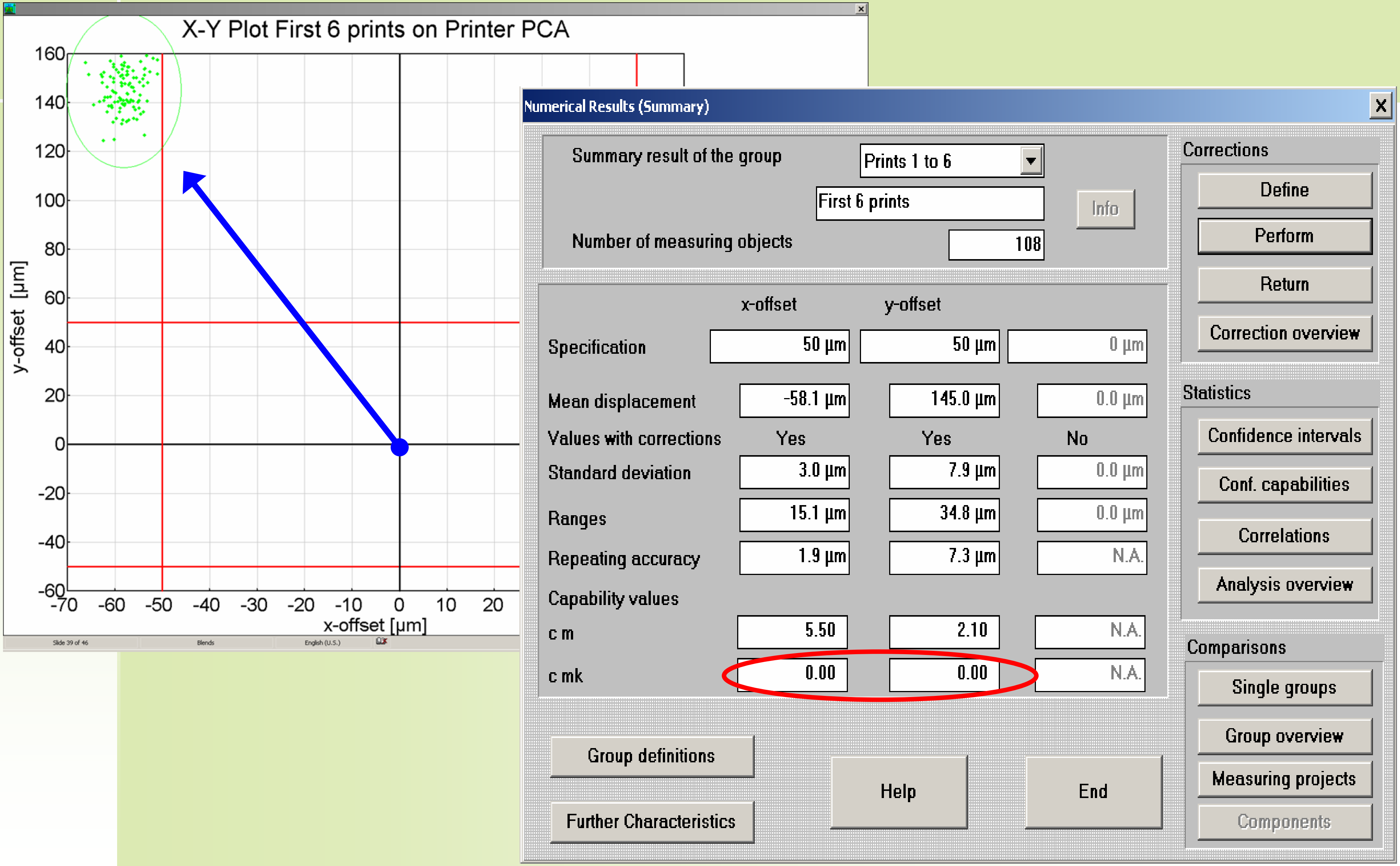
Distribution test on	Normal Distribution	Normal Distribution	Normal Distribution	
Result	Accepted	Rejected	Accepted	
Maximal Difference	3,4 %	6,5 %	4,8 %	
Critical Value	5,9 %	5,9 %	5,9 %	

Confidence Level
○ 99,73 %
○ 99 %
● 95 %
○ 90 %

xy Plot M5-M8


LSL
Nominal Value
USL
USL
Nominal Value
LSL
M5-M8
4s Ellipse
y-Offset in [µm]
x-Offset in [µm]
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-60
-40
-20
0
20
40
60

Printer Initial Results



Numerical Results (Summary)

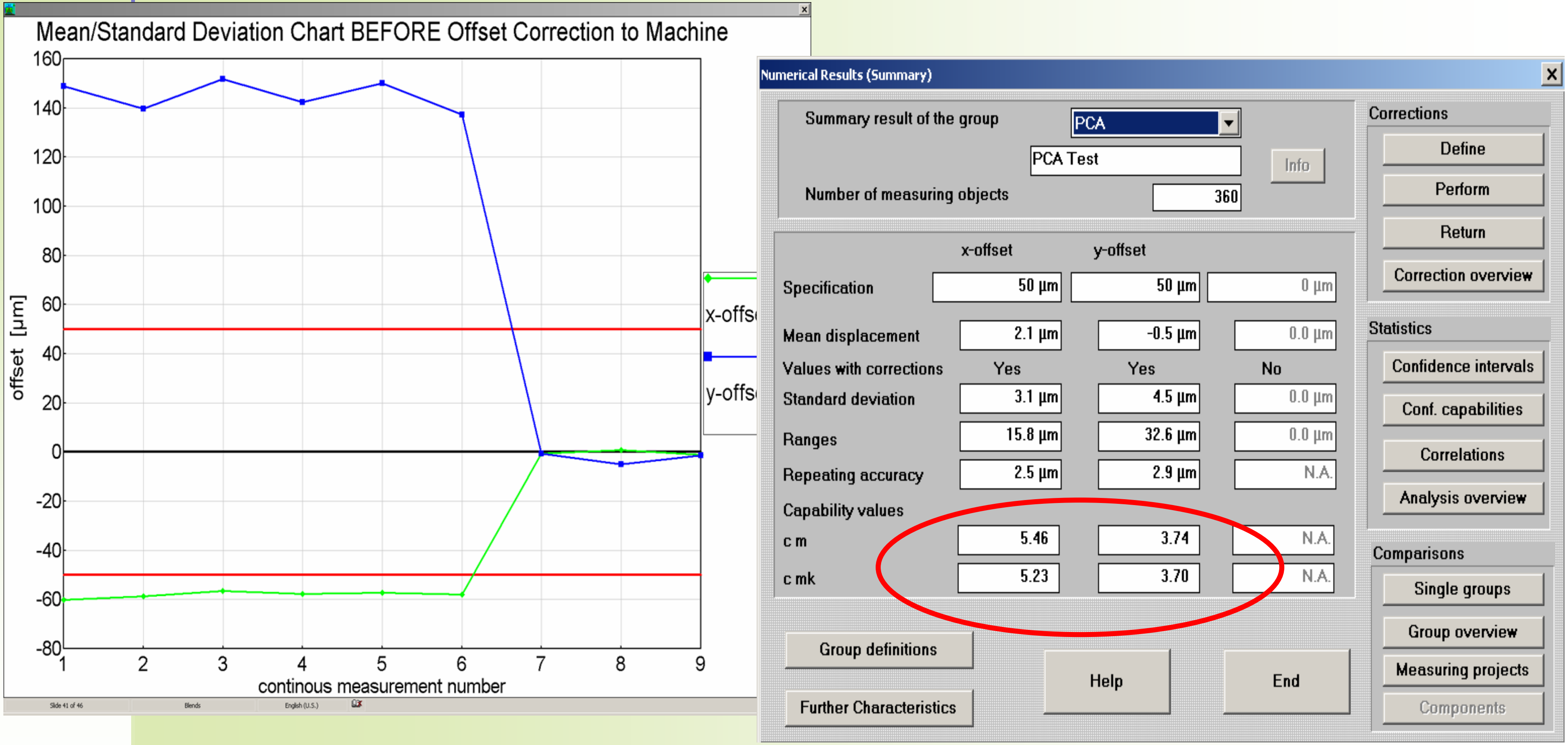
Summary result of the group: Prints 1 to 6

First 6 prints

Number of measuring objects: 108

	x-offset	y-offset	
Specification	50 µm	50 µm	0 µm
Mean displacement	-58.1 µm	145.0 µm	0.0 µm
Values with corrections	Yes	Yes	No
Standard deviation	3.0 µm	7.9 µm	0.0 µm
Ranges	15.1 µm	34.8 µm	0.0 µm
Repeating accuracy	1.9 µm	7.3 µm	N.A.
Capability values			
c m	5.50	2.10	N.A.
c mk	0.00	0.00	N.A.

Printer Optimized Results



Mean/Standard Deviation Chart BEFORE Offset Correction to Machine

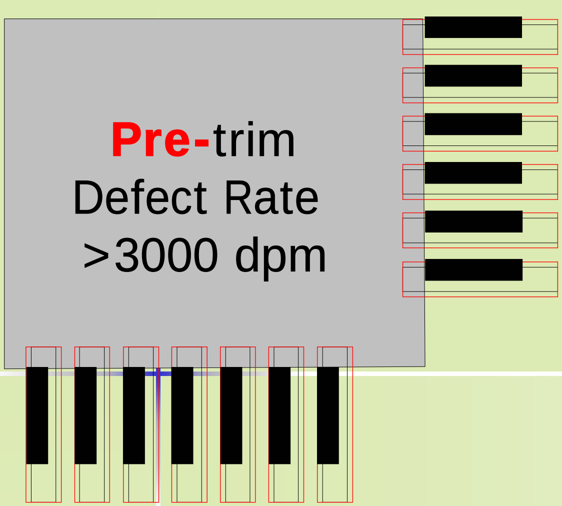
Numerical Results (Summary)

Summary result of the group: PCA

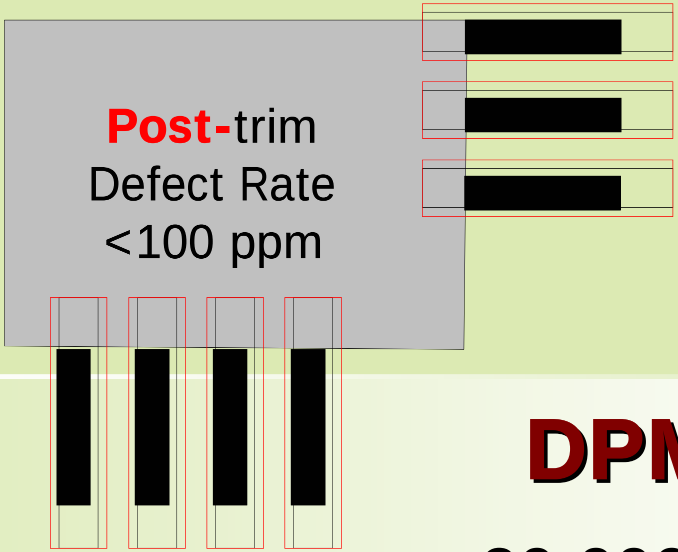
PCA Test

Number of measuring objects: 360

	x-offset	y-offset	
Specification	50 µm	50 µm	0 µm
Mean displacement	2.1 µm	-0.5 µm	0.0 µm
Values with corrections	Yes	Yes	No
Standard deviation	3.1 µm	4.5 µm	0.0 µm
Ranges	15.8 µm	32.6 µm	0.0 µm
Repeating accuracy	2.5 µm	2.9 µm	N.A.
Capability values			
c m	5.46	3.74	N.A.
c mk	5.23	3.70	N.A.



Pre-trim
Defect Rate
>3000 dpm



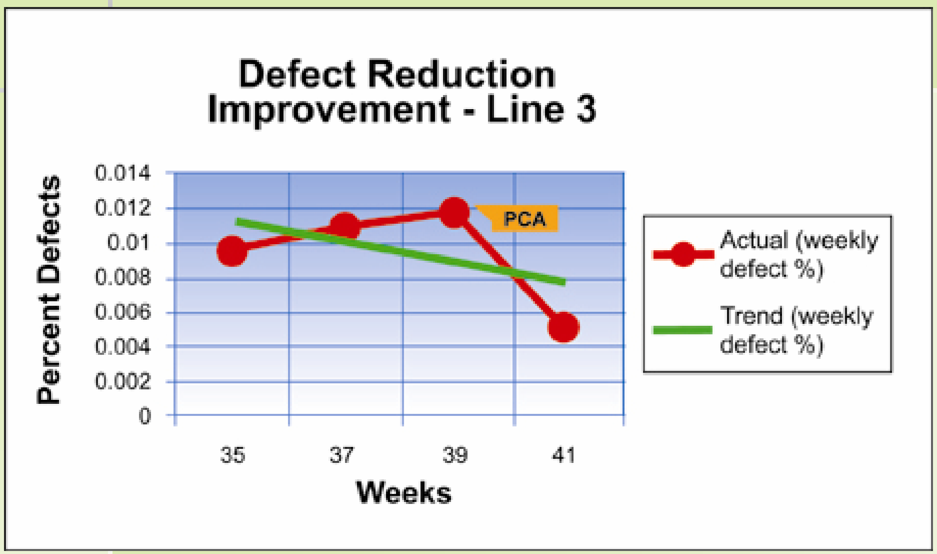
Post-trim
Defect Rate
<100 ppm

DPM and Cost

- 20,000 units per shift per line
- 3 shifts, 5 days
- $15 repair cost per defect unit
- Reducing defect rate from 3000 to 100 DPM
- Saving of $700,000 per year per line

QFP 144 0.5 mm Pitch
25 % Side Overhang

Defects Summary



- Consider the impact on multiple lines over the period of 1 year...

- More efficiency creates additional capacity!
- Reduced defects costs less!
- Resulting productivity has a penetrating effect on profitability!
- Effects are consistent in any economic or processing environment!

Lead-free Assembly

Join us for our next events!

November 10th, 2005: RFiD Electronics Assembly

December 13th, 2005: Lead-free Success Stories