Economic and Technical Advantages of Chemical Dross Elimination and Prevention

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Abstract
Dross generation has always been a costly issue for the electronics assembly industry. At least half, and in many cases, more than half of the metal (solder) purchased for electronic manufacture is wasted as it becomes tied up in dross. With the advent of lead free solders as well as the spike in tin prices during 2008 the moderate economic pain of dross generation has become acute. In addition to metal cost, lead free solders have become known to exacerbate quality issues such as copper dissolution. A process introduced two years ago cures virtually all problems caused by dross and has now been shown in production to mitigate some of the other issues associated with lead free solders.

This paper will show the true cost of dross in 2008/2009 terms, including metal replacement, loss of efficiency, and safety as well as environmental and quality issues which clearly demonstrate a need for a solution to this problem. In addition to dross elimination the process has been shown in the lab to reduce temperatures for wave and selective soldering and to improve wetting. Updated full production data at major EMS assemblers as well as lab test data will be presented.

In addition to answering the technical questions, why and how the "economics of dross" will be examined and a specific and significant cost savings scenario will be presented based on the first two years of full production.

Additional Information
This is a new paper which builds on one I gave two years ago at IPC Expo/Apex. This paper has new information with the economic and quality examples based on full production data at major companies.

Economic and Technical advantages of Chemical Dross Elimination and Prevention

Solder dross has been a problem for the electronic assembly industry since wave soldering overtook manual placement and soldering decades ago. Dross is a costly byproduct of molten solder, oxygen and turbulence. Once solder is converted into dross it becomes hazardous waste with an emphasis on waste. When solder cost was under $2.50/Lb sending out 50% to 70% of your solder and getting a fraction of its value was not a real big deal. With all metal prices hitting new all time highs earlier this year and with the mandated use of very expensive lead free solders the cost of dross has now gotten the attention of upper management at most leading companies. Consider this; an average wave solder machine generates 2.7 Lbs of dross per hour. Dross causes solder related defects, higher lead free alloy melting points cause even more dross, Dross creates defects such as bridging, shorts and skips and you also have to consider the cost to remove the dross, clean the unit and then add solder and perhaps even recalibrate the wave. Overall dross is a VERY expensive and disruptive process.

There have been a number of dross reduction processes for quite some time, they include oxygen barriers such as powders and oils. These are partially effective for a short period of time but they only modestly reduce the amount of dross and they do not stop dross from forming. There are even mechanical devices to squeeze some good metal from the hot dross. These devices do not convert dross back into useable metal instead they try to separate good metal from unusable dross. The metal that is recovered is of low quality and the process is not really effective. What has been needed is a process that virtually eliminates dross while at the same time keeping new dross from forming. The Molten Solder Surfactant from P. KAY Metal (MS2) does precisely that. For the remainder of this paper this material will be referred to as "the material" or MS2 if needed for clarity.

The material eliminates dross and therefore reduces solder purchases by up to 75% and it does it without mixing with the metal.

A triple blind test was performed by three independent testing facilities comparing solder alloy before the material was added to the process and solder alloy after use in a MS2 treated wave. The three facilities could not determine any difference in the metal samples. This material simply eliminated the issue of dross from the manufacturing process.

Figure 1. Shows a typical wave solder unit in production. You can see that dross is forming. Soon the process will have to be stoped and the dross removed and then fresh solder will have to be added to replace the dross that has formed and was removed.

(Figure 1)

Figure 2 shows the same wave after the material has been added. Note that there is no dross and therefore no wasted solder. The solder alloy is clean and pristine with virtually no reduced chance of providing dross related defects to the soldered assemblies.

(Figure 2)

When using this material there are no other process changes necessary. This material does not mix with the metal and therefore it is compatible with any alloy of type of solder. It is not necessary to change flux type or brand or to make other adjustments. In fact, because the solder unit remains dross free it is running in a steady state mode and therefore frequent adjustments are not necessary.

The Economics of Dross

One of the first things to be considered is savings to be realized. In order to generate a typical representation of what savings could be expected a company was chosen as a partner. Their process was benchmarked and costs/usage measurements were taken before and then while using this material in their process. The facility which did the testing has four wave solder units. First here are some averages. A typical wave solder machine generates 2.7 Lbs of dross per hour. If expensive nitrogen is used then the dross generation can be somewhat less and if the unit has multiple waves or is turbulent then dross generation can be higher but the average is 2.7 Lbs/Hr. In some facilities up to 70% of the solder added to the unit can be to replace dross that had to be removed. In this facility, as they are a controlled higher production facility a little over 50% of the solder that is added was due to dross.

This facility uses SAC 305 and at the time of the test they were paying $20/Lb for their solder. This facility purchases on average 2000 Lbs of solder per month which at $20/Lb equals $40,000 for their four units.

Using the 50% dross/waste number, which is a little conservative, they had to add 1000 Lbs of solder/Mo to replace metal that was tied up in dross. They do sell the dross to a scrap broker and usually do not get credit for the full (on average) 1000 lbs but they do get $7/Lb for the dross. Their net cost for solder per month therefore averaged $40,000 minus the $7,000 they received from the scrap broker for a net cost of $33,000.

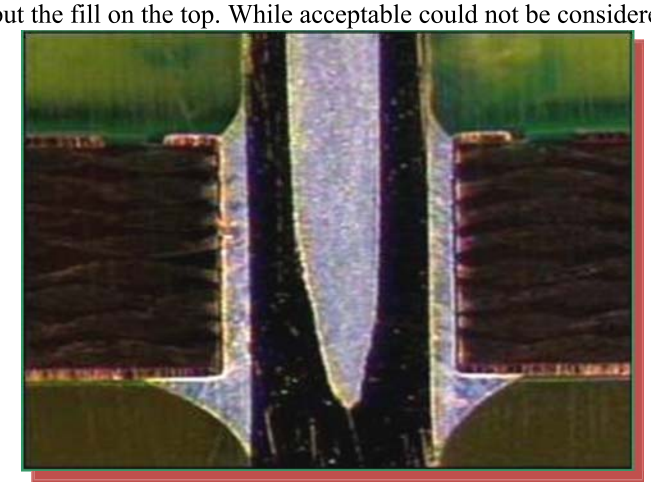
Whey using the dross eliminating material, since there is no dross they only have to purchase 1000 Lbs of solder (the original 2,000 Lbs minus the 1,000 Lbs that was wasted as dross) Their cost for solder is therefore reduced by half or $20,00/Mo. You still have to add in the cost of this material which is $2,600/Mo which, when deducted from the savings provides a total savings of $17,400 per month or a yearly savings of $208,000 or a 47% savings.

Obviously the savings will vary from facility depending on the amount of dross generated, the alloy used and therefore the price they are paying for solder.

There are others savings that must be considered. Issues such as. Down time to clean dross from the unit, Time to recalibrate the wave as dross builds up, safety issues having to do with removing hot dross from the unit, cost of storage and shipment of dross to a scrap broker as well as “shrinkage of dross” in the supply/recycling chain will all vary from facility to facility but are meaningful. There is also the big one, the savings associated with a reduced DPMO having to do with a dross free process can be significant. Some companies using this material have also reported being able to increase the conveyer speed and to also reduce the solder temperature. These calculations have not been quantified in a controlled experiment as yet however.

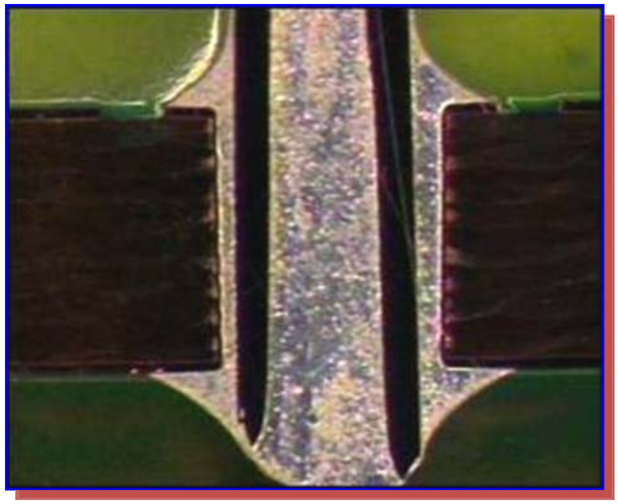
Improved Quality

There is case after case where the using company reports improved solder joint quality when using this material. Following are but a few graphics depicting the type of improvement seen. These graphics were supplied by a company while using this material. In figure 3 below they show their typical solder joint without using this material. As you can see the fill on the bottom of the hole is excellent but the fill on the top. While acceptable could not be considered ideal.



(Figure 3)

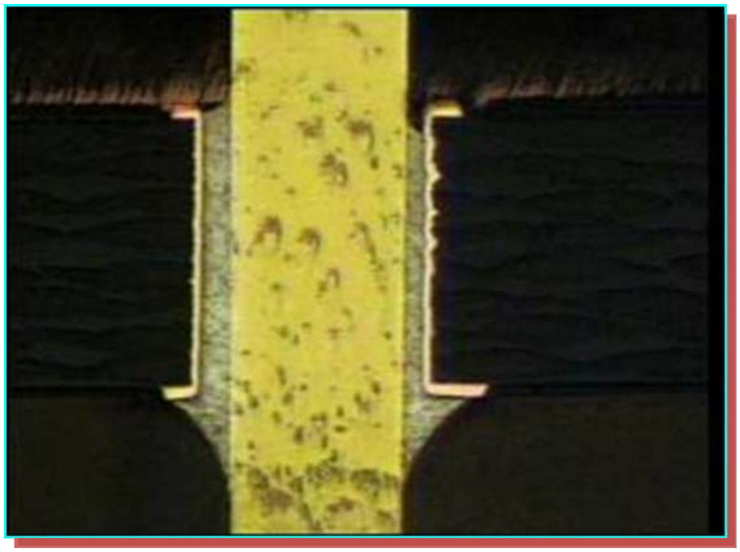
In Figures 4 and 5 below you can see that while using the dross elimination material, the solder pot is clean and dross free and therefore wets and flows better.



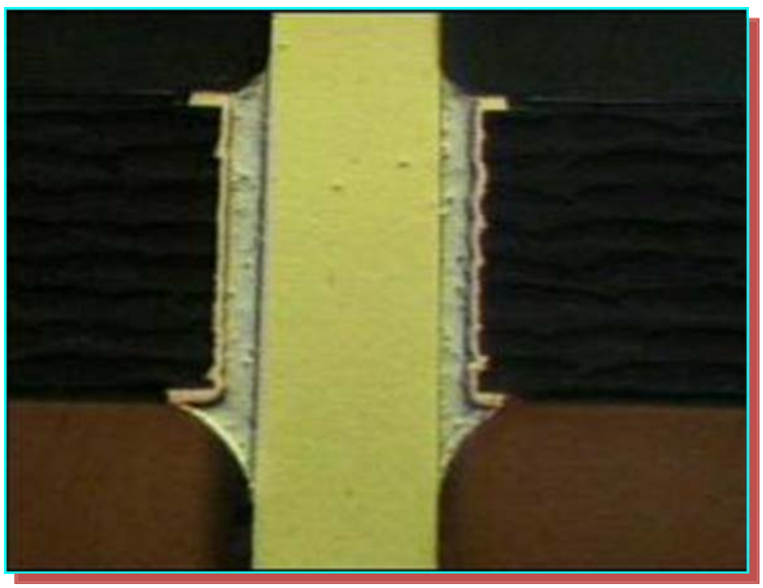
(Figure 4)

(Figure 5, magnified top left of figure 4)

Following are additional examples (Figures 6 and 7) of “Before” and “After” provided from yet a different using facility.



(Figure 6, note the poor fill on the top plane, no material used)



(Figure 7, Note the improved top fill)

In addition to fill both testing as well as observations regarding wetting show a measurable improvement when using this material. Following are two pictures, Figure 8 shows a solder dip test without the material in the process and figure 9 shows the improved wetting with the material employed.

(Figure 8, no material in use) **(Figure 9, using the dross elimination material, note imporved wetting)**

Significant testing has been undertaken at various well known and respected test and reliability sites, far more testing than there is room to discuss here. There have been no issues with reliability or contamination. All test conducted by these facilities as well as by numerous using companies for SIR electrical performance and ion chromatography testing have passed with levels well above the SIR criteria of J-STD-001C ($1E^8$ Ω).

This material does not attack the board, the solder mask, the wave solder equipment of anything else. All it does is reduce dross back into useable metal and prevent new dross from forming. This material has been submitted to leading wave solder machine manufactures for testing and it has been confirmed there have been no observed detrimental effects to the board, the solder mask, the wave machine or anything else.

In Conclusion

The use of this new material provides a path to reduce at least part of the increased costs associated with lead free soldering while standard leaded soldering also benefits from the use of this material.

There is data generated by testing labs and production users that show cleaner, brighter solder joints and improved wetting as well as a measurable and significant reduction in solder process related defects and improved throughput.

This process allows for a significant reduction in a using facilities hazardous waste

This makes sense as the solder bath itself is clean and running in a steady state mode when using it AND, The Cost Savings Are Substantial.

APEX EXPO IPC

MS2®
Molten Solder Surfactant

A New Dross Elimination Process from P. Kay Metal

THAT WORKS

PK METAL

Dan Feinberg
Apex/Expo 2009

U.S. and Global Patents Pending

Introducing Two Revolutionary New Products

MS2® 100PB

Dross Eliminator for Leaded Solder

MS2® 200LF

Dross Eliminator for Lead-Free Solder

There Are Three Equal but Different Reasons to use this process

- Significant and Meaningful Savings in Solder Purchases

- Improved Solder Joint Quality, Reduced Solder Related Defects

- Overall reduction of Hazardous Waste

Dross, A Costly Issue

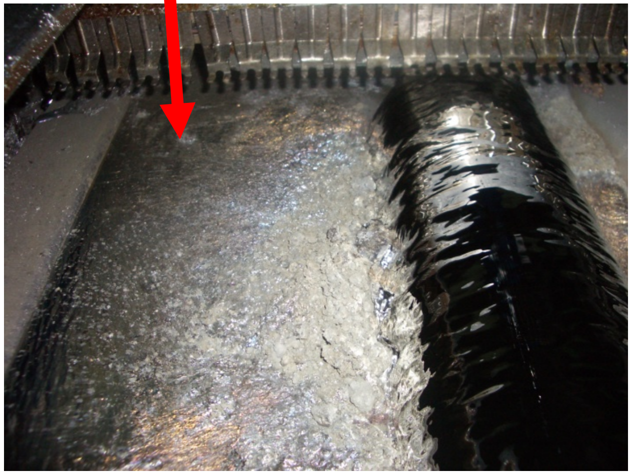
- **Cost of Metal to Replace Dross**
  - Much higher with RoHS
- **Reduced Efficiency**
  - Down time to remove and clean
  - Constant wave calibration
- **Reduced Quality**
  - Shorts and skips
  - Bridged circuits over solder mask
- **Hazardous Waste Generation**
- **Storage, Handling, Accounting, Manifesting, Cash Flow.**

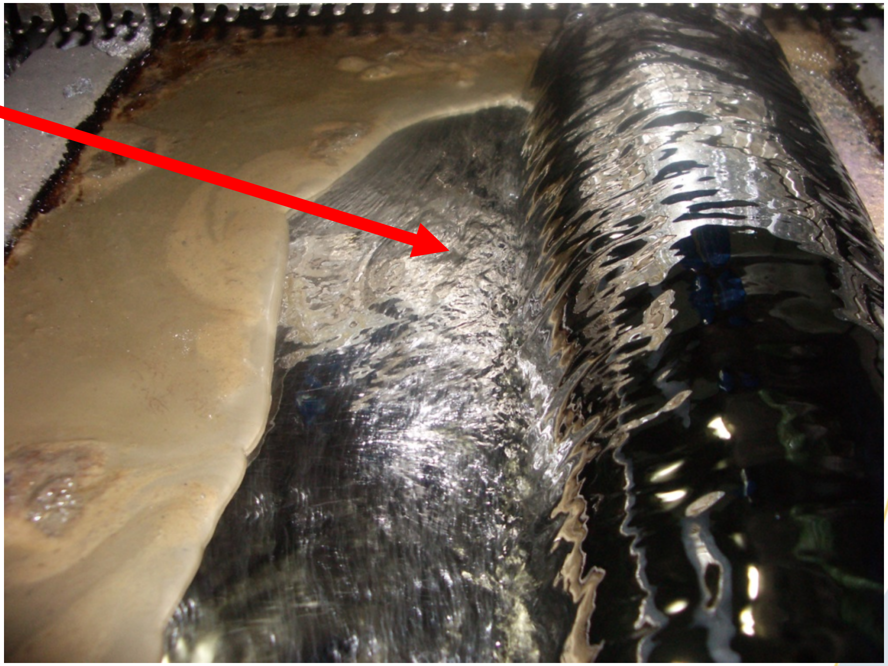
This Material Totally Eliminates Dross

- It reduces virtually all costs associated with dross- related hazardous waste
- No need for manual or mechanical dross removal (reduced down time)
- It reduces solder purchases by **40%** to **75%** based on production volumes
- It **DOES NOT** mix with the metal, it only affects the dross
- There are no fumes or odor

The Material Eliminates Dross

Typical Views of a Wave Before (L) and After (R) Addition of MS2





Dross after one hour of production (2.7 lbs) shown on the left. Shortly after the material is incorporated into the process (picture on the right) there is no measurable dross. ***All dross has had its metal constituents converted back into useable solder.***

No Other Process Changes Necessary

- No change in process fluxes or process parameters are necessitated by the use of the MS2 process
- The small amount of spent MS2 that is generated can be shipped back to P. Kay Metal for recycling
- The material does NOT mix with the metal

The Economics of Dross

In a typical wave solder machine, dross generated after one hour of production is 2.7 lbs.

Up to 70% of solder added can be due to the need to replace metal tied up in dross.

At the subject facility solder purchased per month: 2000 lbs of SAC305 @ $20/lb which equals $40,000 (total for four (4) wave solder machines).

- If this facility generates 50% (Which is conservative) dross that would equal 1,000 lbs of dross per month which they sell to a scrap broker for $7/lb for $7,000.
- Their net cost for solder is therefore ($40,000 minus $7,000) or $33,000 per month.

Cost of solder per month

2,000 lbs x $20/lb = $40,000

1,000 lbs of dross per month @ $7/ lb = $7,000

NET COST FOR SOLDER:

$40,000 - $7,000 = $33,000

When using this material, they would only have to purchase 1,000 lbs (2,000 lbs minus the 1,000 lbs that is wasted as dross) or a CONSERVATIVE 50% reduction.

Monthly solder purchases of 1000 lbs at $20/ lb = $20,000. This equals a $20,000 monthly savings of solder purchases compared to current net cost of solder while producing dross.

By using the material, Solder usage per month becomes;

2,000 lbs – 1,000 lbs (dross) = **2,000 lbs**

1,000 lbs x $20/lb = $20,000 (cost of solder per month)

MONTHLY SAVINGS IN SOLDER PURCHASES:

$40,000 - $20,000 =

$20,000/Monthly Savings

You must add in the cost of the material, which in this scenario to eliminate 1,000 lbs of dross would be $2,600.

$20,000 Solder Savings - $2,600 monthly cost of material = $17,400 monthly savings.

$17,400 monthly savings x 12 months = $208,000 Annual Savings.

This Equals a 47% Net Savings Compared to Current Usage of Solder and Producing Dross.

* For Tin /Lead using the same scenario the savings would be $52,800 annually or 30% net savings.

Additional Savings

In addition to the cost to replace solder lost to dross you must consider:

- Down time to clean dross from the unit
- Down time to calibrate wave or fountain due to dross clogs
- Labor costs to remove dross
- Safety issues caused by scooping hot dross from the unit
- Cost of dross-related rework on the assembly
- Cost of storage and shipment of dross to the scrap broker

More Savings

- Dramatic Reduction in Solder Related Defects
- Higher Throughput

The Assembler saves money on solder, achieves a lower defect rate, improves throughput (efficiency and line speed) and reduces hazardous waste.

Everyone Wins! Except your solder manufacturer and dross recycler!

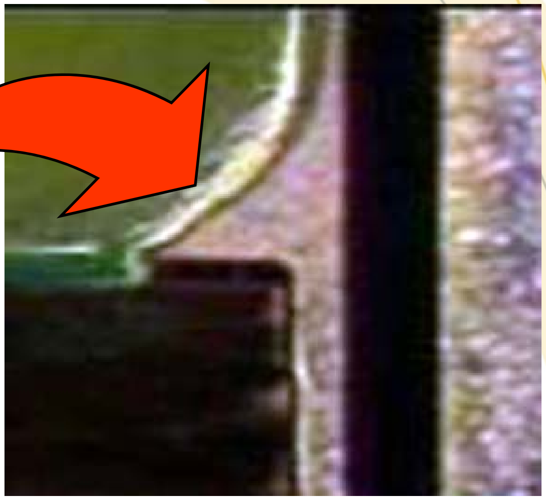
Reliability & Improved Quality

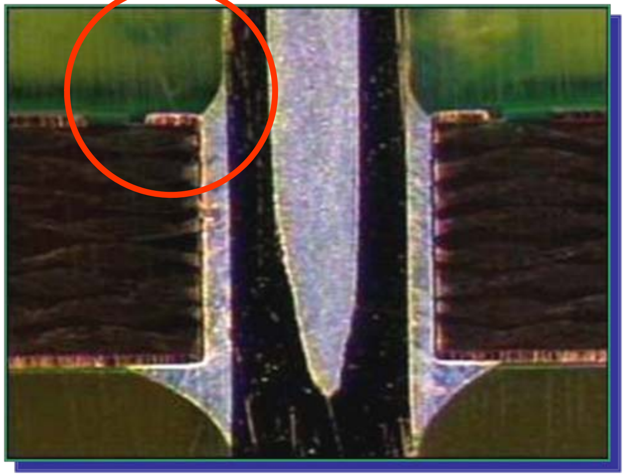
After two years in full production......

There is now statistically valid data *available that shows MS2 contributes to improved quality and throughput*

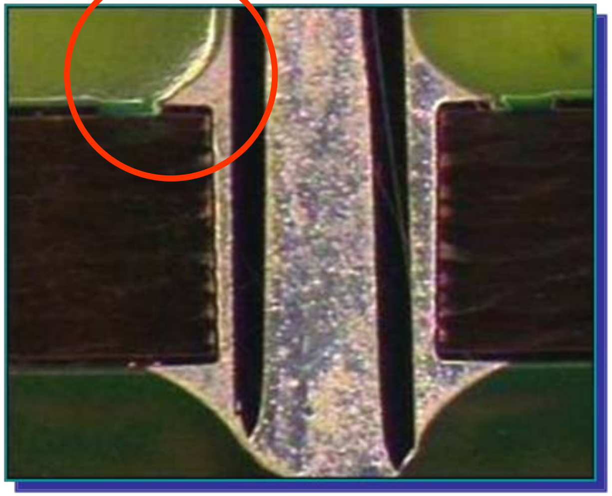
"The conclusion that can be drawn is that the samples with MS2 have hole fill that is as good or better than without MS2"

Kola Akinade PhD, Cisco/Scientific Atlanta



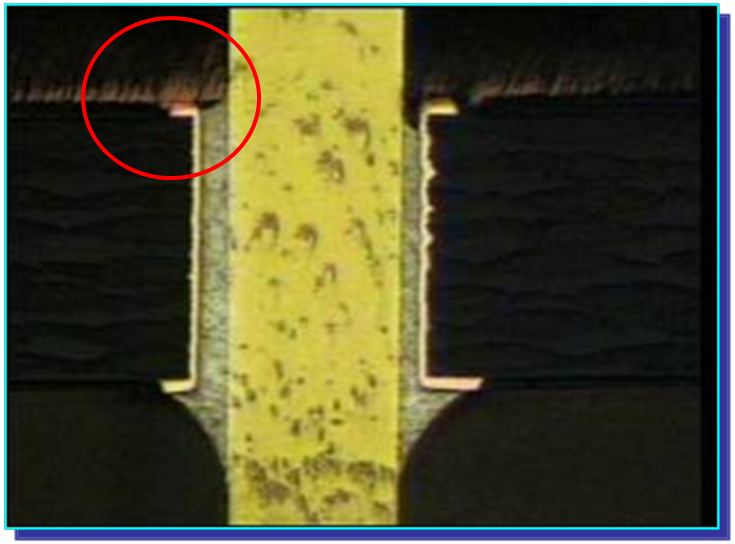


Standard Process

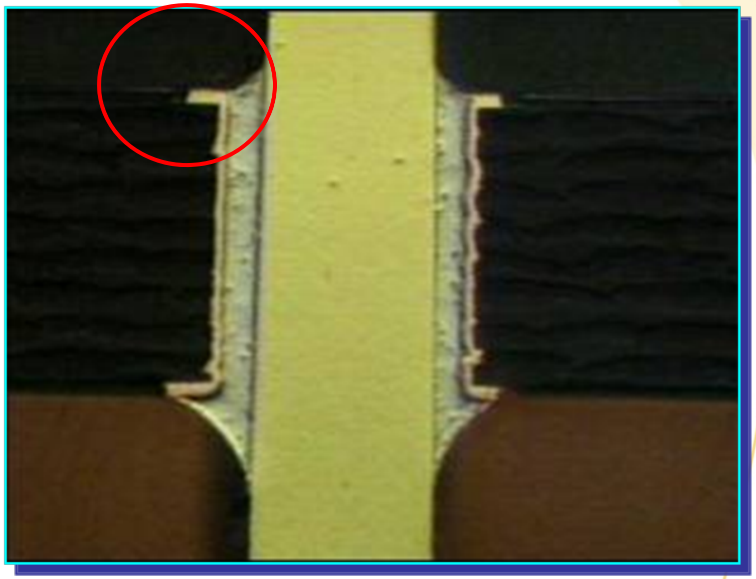


Standard Process With MS2

Additional Examples



Standard Process



Standard Process With material

Reliability

Significant reliability testing has been undertaken at various 3rd party test and reliability facilities such as Engent Labs, Foresite, STI, and the University of Toronto as well as at beta now numerious production sites

There have been no issues with reliability or contamination. All tests conducted to date for SIR electrical performance and ion chromatography testing have passed with levels well above the limits of $1E^8$ ohms of resistance which is the SIR criteria of J-STD-001C No change in grain structure has been found between the boards processed with and without MS2™

Training

The material is easy to use however as with any process chemical an effective installation and efficient use of the product is dependent on trained and knowledgeable sales and service personal and operators

The Supplier must provide:

- Training for its sales and distribution partners
- Installation and operation manuals and videos
- Factory direct service assistance

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There is data generated by testing labs and production users that shows cleaner, brighter solder joints and improved wetting as well as a measurable and significant reduction in solder process related defects and improved throughput.

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The cost savings are substantial