Implementing “Green” PCB production processes

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Abstract

The impacts of the moving to green electronics on the PCB production process are multi-faceted. New solder alloys lead to a dramatic increase of reflow temperatures and cycle times, impacting formulations of base materials and requirements for solderable and bondable final finishes. This paper discusses the impact to the various production processes, ranging from inner-layer processing to surface finishing.

Up to now, there has been only little work done to determine the effect of the move to green electronics on the inner-layer manufacturing process. This paper will outline the results of comprehensive testing using different inner-layer bonding systems. Results will be obtained with the new halogen-free materials and will be referenced with those from standard FR4 materials. In addition, the impact of the lead-free soldering profiles will be investigated.

The higher soldering temperatures for lead free assembly lead to greater stresses on the printed circuit board, resulting in new quality requirements for interconnections and barrel plating. Additionally, low CTE materials are introduced to cope with that situation.
The paper will discuss the impact of those changes to the electroless and electrolytic metallization processes.

The halogen-free requirement puts significant challenges to the formulation of advanced dielectrics for PCB production. Sufficient Tg value and low water uptake are major aspects for the development of next generation materials. The paper will discuss a new materials solution for RCF, which can offer state-of-the-art properties with a halogen-free composition.

As the final finish of the PCB is in direct contact with the lead free assembly process, the effects need to be well understood. Additionally, the industry is rapidly moving towards HASL alternatives as immersion tin of immersion silver. The paper will present a summary of test results obtained over the last years, focusing on those new immersion processes, as well as ENIG (Electroless Nickel Immersion Gold).

Introduction

In electronics the most common soldering technology uses solder alloys containing lead. This technology has been widely used and optimized for billions of assemblies over the past decades. All printed circuit board (PCB) materials are adapted to this technology and therefore to its parameters.

Standards, test methods, specifications and experience concerning quality and reliability are based on this lead containing solder technology.

The number of the existing specifications related to this technology gives a good idea of the engineering work involved in the past.

Banning lead as stipulated by the RoHS directive (restriction of the use of certain hazardous substances in electrical and electronic equipment) will challenge most of the PCB materials and processes involved as an effect of a changed solder technology.

The impact of the restrictions touches more the solder technology, than the PCB material.
As by definition, PCB materials, have always been lead free, but not all are compatible to lead free technology.

The new solder technology favour so called SAC alloys (tin, silver and copper), which require a substantial increase in soldering temperature compared to eutectic tin lead solder alloys.

The defined task is, to achieve the same performance under the new solder alloy regime. Ensuring at least the same results often requires the use of high temperature polymers and PCB laminates and moisture resistant materials.

To get prepared, substantial man power and engineering is necessary to keep up with latest product designs of PCB laminates, reflow profiles or used soldering flux systems.
A head start in know-how and collection of reliability data provides opportunities for well prepared suppliers to gain market share in the new solder alloy regime.

MULTILAYER BONDING OF HIGH-PERFORMANCE DIELECTRIC MATERIALS

There is a need for new substrates with higher glass-transition-temperature and absence of halogen for a completely “Green” product.
Higher soldering temperatures result in higher z-axis expansion, which will affect PTH reliability and inner-layer-bonding integrity.

However, no work has been done on the effect of these higher assembly temperatures on the inner-layer bonding system.

In this paper the synergy of an Intergranular Etch (IGE) or Oxide Alternative with the white oxide will be examined.

The synergy of these two systems yields a process that has all the advantages of both systems: High peel strength, excellent thermal reliability, no pink ring or wedge voids, and ease of horizontal processing, but none of their weaknesses.

Hybrid Process Description

<u>Cleane</u>r
Developed primarily for aggressive cleaning applications for such residues as dry film resist and heavy fingerprints prior to the Etch process step.

<u>Initiator</u>
Provides improved treatment in subsequent Etch process step by providing protection of Etch bath against contaminates and providing the proper surface potential for the Etch to etch.

<u>Etch</u>
The Etch is a modified sulfuric acid/hydrogen peroxide microetch that provides the surface topography by etching the copper crystals at their grain boundaries. This etching provides the necessary surface roughness for mechanical bonding. The resulting structures have high shear strength of copper metal rather than the low shear strength of copper oxide crystals.

<u>Enhancer</u>
Consequently, the etched copper surface is coated with tin and subsequently laminated.

Test Vehicle

The primary test vehicles are a 6-layer and 12-layer printed circuit board treated with an Oxide Alternative bonding process.

The panel contains 35μm copper foil layers, constructed with various substrate materials. These panels were used for multiple reliability tests.

Test Methods and Responses

In this case several more intensive and quantifiable tests were done with peel strength being measured with each test lot for reference.

After initial adhesion strength was measured samples were subject to multiple Lead-Free Infrared Reflow cycles. After which the adhesion was measured again to determine the change in adhesion.

It is believe that this data reflects what happens within the PCB during lead-free assembly.

Results

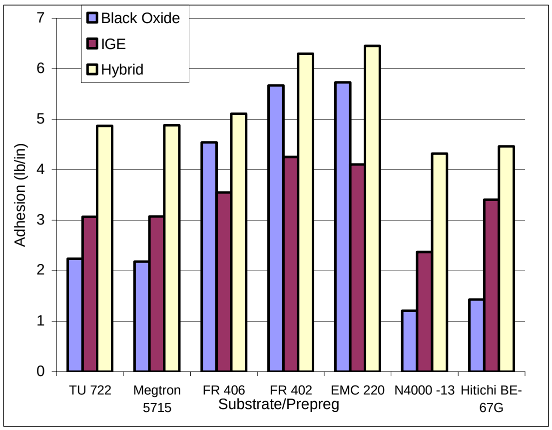

Fig. 1: Adhesion (lb/in) by Substrate/Prepreg After Lamination

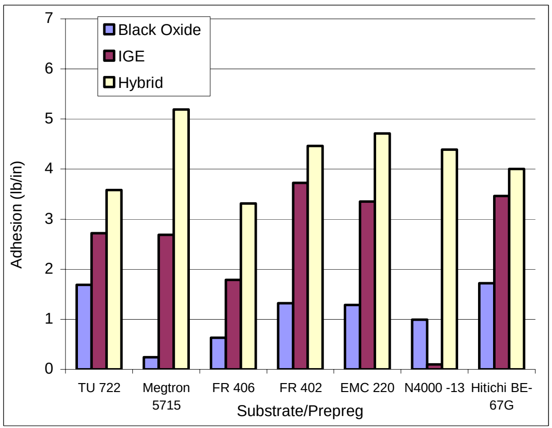

Fig.2: Adhesion (lb/in) by Substrate/Prepreg After 3 x Lead-Free Infrared Reflow

Also in compliance with lead-free solder initiatives samples were subject to a lead-Free re-flow profile then subjected to T-260 and T-288 testing.

The lead-Free re-flow conditions chosen were that of "standard" lead-free thermal profile. After 10 cycles samples were then T-260 and T-288 Tested.

Material	Sample Layers	T260 (Minutes)	T288 (Minutes)
Hitachi	12 Layer	8.78	0.17
N4000-6		21.85	1.46
GETEK		36.46	4.46
FR408		> 40	5.62
FR402		6.13	0.00
Hitachi	6 Layer	8.52	0.39
N4000-6		3.36	0.00
GETEK		>40	7.53
FR408		>40	8.5
FR402		7.41	0.75

Fig. 3: Thermal Mechanical Analysis Results

Discussion / Conclusion

The Hybrid process has proven to be very robust.

The DOE samples were processed while the Hybrid bath was at "steady-state" operation for standard production simulation.

The results are as expected.

Black oxide displayed superior performance pre-Reflow for both standard FR4 as well as the Halogen free material. However, pre-thermal stress adhesion strengths are not what's important but rather the adhesion after thermal stress.

In this case, the superior adhesion of Black Oxide could not withstand multiple Pb-free Reflow cycles and suffers a loss of adhesion greater than 50%.

Similarly the Alternative Oxide or IGE, the Alternative Oxide +Enhancer, and the Hybrid Oxide all experience adhesion loss. However, the Hybrid Oxides loss is minor in comparison to the other oxide coatings.

The Hybrid suffers only a 6% loss in adhesion with the Halogen Free material compared to 28% and 54% losses with standard Alternative Oxide and Black Oxide respectively.

We also find the Hybrid process can withstand multiple Lead-free IR-Reflows using various substrates materials with more than acceptable T260 times. In the case of the T288 testing the primary failure was due to material failure.
It would appear that perhaps the T288 test is not very reliable as a test method due to the extreme temperatures and subsequent prepreg breakdown.

This enhanced performance is due to the diffusion of tin with copper occurs to create an intermetallic film. The initial 0.25μm layer of pure tin is completely transformed into an intermetallic film during the lamination cycle.

Heating causes micro structural changes in the copper/tin layer.
The tin layer density decreases with time as the intermetallic layer grows and becomes thicker, while scattered micro void formation also occurs near the copper/tin boundary.

All these results indicate tin diffusion into the copper layer. The growth of the intermetallic creates prolific fingerlike structures at the copper/intermetallic interface for enhanced mechanical bonding (figure1).

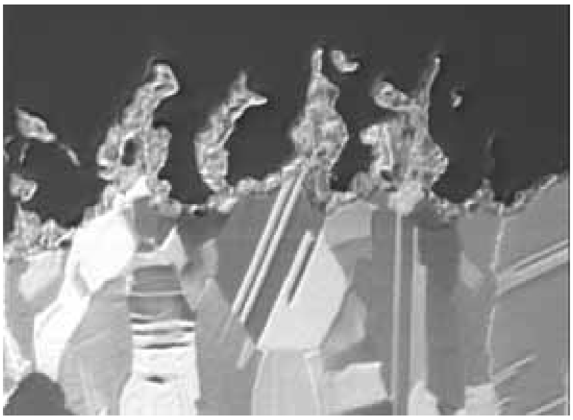

Fig. 4: Intermetallic Growth at Interface

The chemical bond between metal and epoxy is more difficult to characterize, and many theories have been proposed over the years.
It should be recognized that the surface of a copper circuit is composed of copper oxides, whether it has been treated with black oxide, reduced black oxide, or an oxide alternative.

Unless the oxide surface is formed and kept in a vacuum, some of the copper oxides will hydrate when exposed to ambient humidity to form hydroxyl groups, and these hydroxyl groups interact with the epoxy in a weak acid-base reaction to form a chemical bond.

The variation in adhesion strength observed with different metal oxide surfaces can be attributed to the surface charge, defined by the isoelectric point of the surface, or IEPS.

Using Halogen free or standard FR4 the Hybrid Oxide provides superior adhesion.

The higher adhesion strength after lamination although reduced after multiple IR-Reflows, remains greater than 4 lb/in of adhesion. Thus, the Hybrid provides better process stability when attempting to meet the impending lead-free requirements of tomorrow.

Further study of Lead-Free soldering will be investigated at a later time.
This testing will focus on isolation of the inner-layer-bonding systems i.e. samples without plated-though-hole for detail evaluation using T260 and T288 test methods.

DESMEARING AND PLATING THROUGH HOLE

The green processing of PCBs has several impacts on the desmearing and plating through hole (PTH) processes.

The main issues being:

- Halogen Free Base Materials
- Lead Free Capable Base Materials
- Cyanide Free Electroless Copper
- EDTA Free Electroless Copper
- Formaldehyde Free Electroless Copper

The requirement to remove halogens, especially bromine, from laminate materials poses some issues for desmear and PTH processes due to the requirement of laminate suppliers to generate newer formulations with alternative flame retardants, as well as the inclusion of fillers to maintain good functional capability.

These newer formulations mean that the materials have to be assessed once more and the best working practices and parameters need to be redefined.

This means a lot of work for the process suppliers as well as the PCB manufacturer. Another key issue is that of poisoning or premature aging of certain critical process steps.

The fillers, especially, give cause for concern and have been attributed to reducing the active age of desmear baths as well as steps like activation in electroless processing.
These again need to be assessed and require a lot investigation work.

For lead free capable base materials the main concerns of halogen free materials hold true in that the formulations are being altered from laminate materials commonly used today to achieve better functional capabilities like T_{260} and T_{288} time to delamination testing results.

A lot of the newer lead free capable materials being brought to the market are based on phenolic curing instead of dicyandiamide or require newer more exotic resin mixes.

Add to this the use of fillers again to achieve good CTE values and improved electrical properties and we see a repeat of the concerns for halogen free materials.

Again all the new materials need to be checked for their response to standard permanganate desmearing processes as well as their poisoning and sensitivity influence on critical process steps.
Atotech is in the middle of such a set of assessments. We have an exhaustive list of standard base materials as well as the newer breed of halogen and lead free capable materials.
These are all being tested to determine their response to and effect of:

- Standard and Aggressive Permanganate Desmear with 3 Sweller types
- Palladium absorption of the activation step
- Coverage and adhesion, especially for the electroless copper process
- Contamination of critical baths

Some results clearly show the wide variance of materials available and the need to assess each material individually.

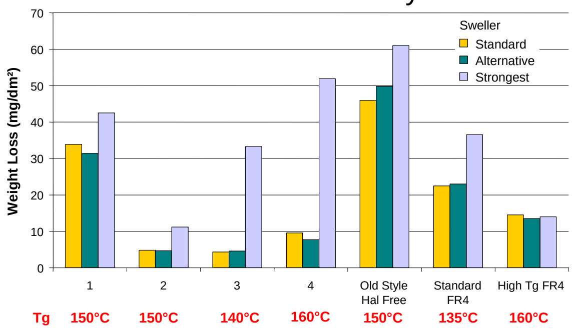

Fig. 5: Weight Loss Response to Different Swellers

Etch back After Standard Desmear

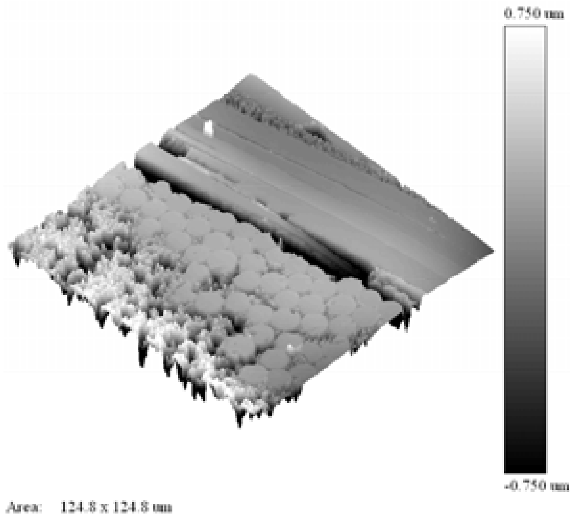

Fig.6: old style

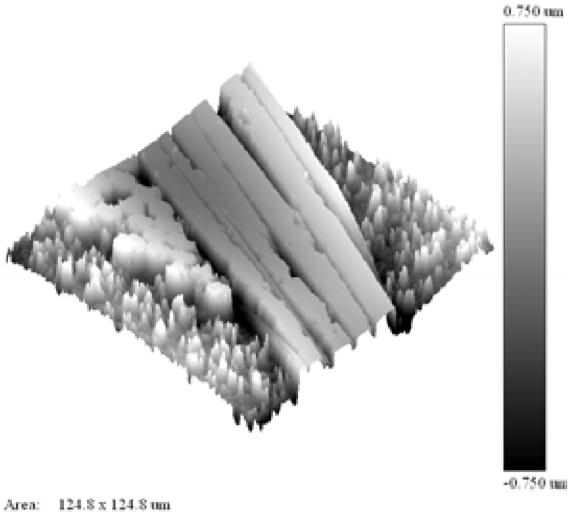

Fig.8: High filler content

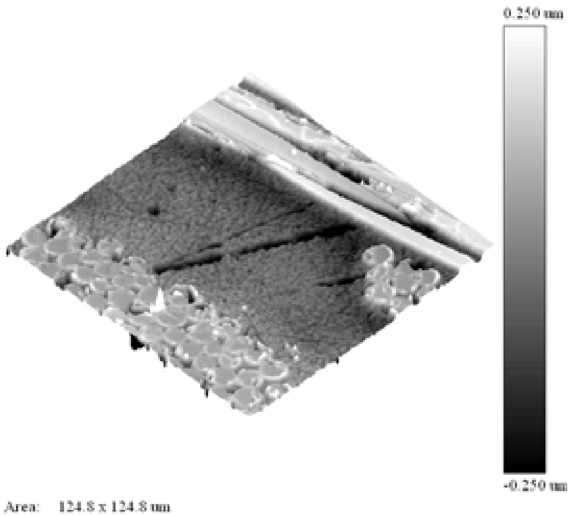

Fig.9: Low filler content

Cyanide Free Electroless Copper
Cyanide has long been used as one of the main stabilizer compounds in electroless copper baths.

Although the content of cyanide in most electroless copper baths is extremely small it is still a toxic substance and should be eliminated if possible.

Due to this reason the latest electroless products from suppliers, have been specifically engineered to completely remove cyanide.

Such new products are specifically engineered for horizontal processing and for vertical processing.

EDTA Free Electroless Copper
EDTA is a strong complexing agent that is commonly used in the industry for electroless copper baths.

This complexer is so strong that it can cause waste water issues due to its ability to complex other metals in the waste stream, including lead and other heavy metals.

If the complex is not sufficiently broken during treatment then there is a potential that this complexed heavy metal is released into the environment.

By completely removing EDTA from the process any potential danger is removed. The use of a weaker complexer like the natural product of grapes, Tartaric acid, is desirable as it is more readily treated and is biodegradable.

During the initiation phase of horizontal electroless system development it was decided to apply the environmentally friendly Tartaric acid system.

Since the first system installation in 1999 to the present day the horizontal electroless system has kept EDTA free, and will continue to do so.
This trend is catching on with all process suppliers.

Formaldehyde Free Electroless Copper –
Formaldehyde has recently been upgraded from ‘possibly carcinogenic to humans’ to ‘is carcinogenic to humans’.
This new hazard standard roughly means that it should be replaced with suitable alternatives as soon as possible.

There are many direct plating systems in the market that contain no formaldehyde but which do not have the large acceptance and wide range of use as electroless copper, therefore an alternative electroless copper process is required.

There are already one or two such alternatives already available but with limited application.
Latest generations of formaldehyde free system are being adapted for flexible board processing.

The topic of green PCB production affects desmear and PTH on many levels, the most critical to PCB manufacturers at the moment is the introduction of halogen free and lead free capable laminate materials.

Steps should be taken to introduce an assessment project of all such types of new materials into the factory and their effect on the current processes, ultimately to generate a new set of optimized production procedures.

ELECTROLYTIC METALLIZATION
Electrolytic metallization of printed circuit boards primarily involves depositing a controlled thickness of copper on the surface and through the holes of the dielectric substrate.

Both the pre-treatment process and the plating process must be adjusted to meet the base material characteristics such as aspect ratio or track line and space in pattern plating.
Equipment and processes to meet specific requirements are shown in reference [10].

The electroplated copper deposit should have good uniformity in terms of thickness and good physical properties such as ductility and tensile strength.
It must withstand all the subsequent processing steps so that the finished PCB exhibits good reliability as well as meeting the required standards in terms of product lifetime in service.

A new measurement technique for giving more precise quality assessment is shown in reference [11].

In comparison to traditional production processes "green" production process are characterized by the use of lead free soldering and the corresponding changes in this step can have a major impact on the electrolytic copper process.

The differences in the use of lead free soldering in comparison to conventional soldering can be summarized as follows,

- Approx. 30°C higher temperatures during soldering.
- Longer ramp up times and temperatures during soldering.

One result of these higher temperatures and longer dwell times at the elevated temperature will be an increased expansion of the base material and therefore an increased stress on the copper plated barrel of the through holes.
This increased stress on the plated hole can be compared to the traditional methods of measuring plated copper reliability.
Usually testing is carried out by solder float or solder dip at specified temperatures in standard eutectic tin lead solder as well as thermal cycle testing or now more commonly use of IST testing.

Tests have shown that the critical factors in the reliability of the copper plated PCB are in order of importance as follows,

1. Base material characteristics of the PCB including CTE (coefficient of thermal expansion).
2. Panel thickness.
3. Through hole diameter.
4. Electroplated copper thickness.

The base material used for the PCB has the largest impact on reliability and so it is to be expected that a similar influence on the capability for lead free soldering will be seen.

Investigation Of Lead Free Reflow Cycle On Electroplated Copper
To carry out first investigations of the reliability of copper deposit with lead free soldering a series of tests were carried out on sample panels.
Copper was deposited on the panels up to approx. 30µm in DC mode with pattern

plating in a conventional hoist type vertical plating line.

The test panel base material characteristics were as follows,

- Panel thickness 1.5mm, hole diameter 0.4mm and 1.2mm.
- Panel 6MLB pattern plate.
- Base material Tg1: 131.1°C, Tg2: 137.8.
- ΔTg 6.6°C.
- CTE (T<Tg): 58.3 ppm/°C
- CTE (T>Tg): 293.3 ppm/°C

The base material used was a standard FR4 type material with low TG, this material was chosen to try to show possible failures in the copper plating at an early stage in reliability testing.

The ΔTg 6.6°C (the difference between Tg1 and Tg2) shows that after production the material is possibly not completely polymerized and delamination after thermal excursion may occur.

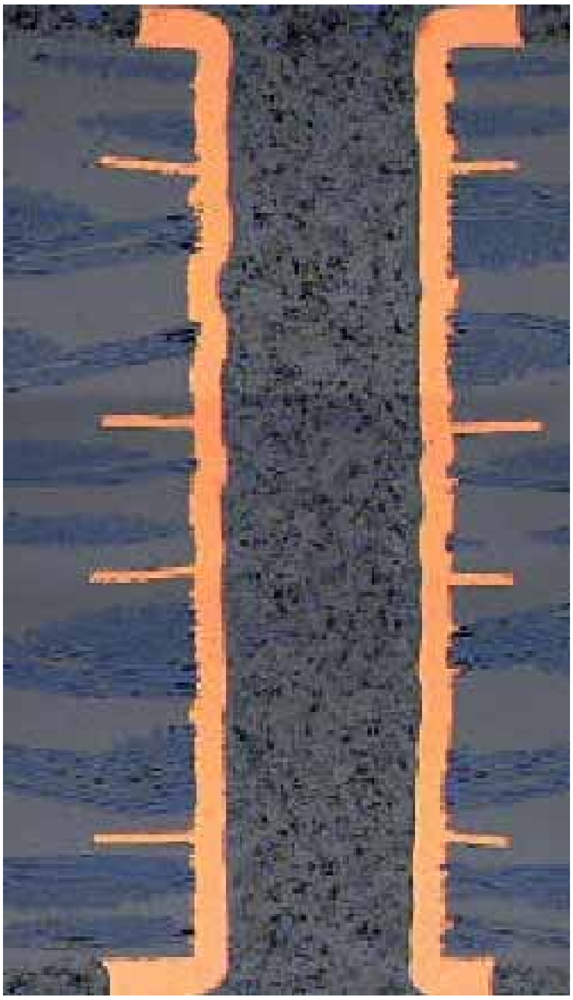

Fig. 10: Microsection of test panel after IST cycling showing multilayer build up and distortion of base material after thermal excursion

After plating test coupons were removed from the panels and solder float tested six times for 10 seconds at 288°C in conventional Sn/Pb followed by micro section investigation.

Parallel to this IST coupons were removed and tested with IST reliability cycle equipment. The remaining panels were then processed through a standard IPC Pb free solder profile with 1,2,3 and 4 times exposure, after this repeat solder float testing was carried out again six times for 10 seconds at 288°C.

Comparison was also made with IST coupons taken from the panels processed four times in the Pb free solder profile.

Microsections after 6 times 288°C solder shock after plating

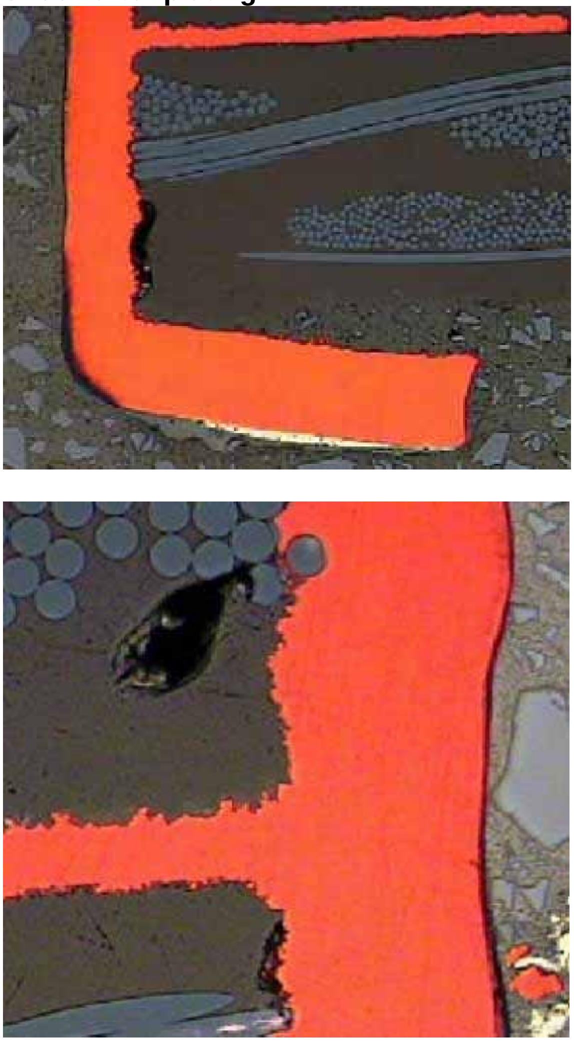

Fig. 11: The microsections show distortion of the base material and pad lifting with some resin voiding however there are no signs of cracks in the electroplated copper.

Microsections after 6 times 288°C solder shock after 4 times Pb free reflow cycle

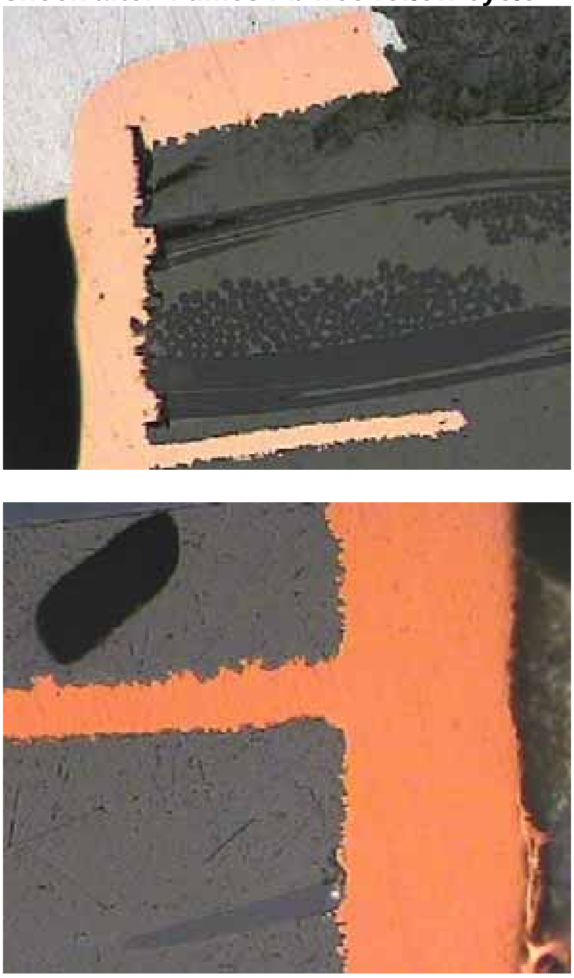

Fig. 12

The equivalent test after four times reflow also showed no signs of crack in the electroplated copper however further pad lifting and resin voids were seen.

Also loss of adhesion of the plated reinforcement copper to the drilled copper foil was seen, this fault can be attributed to the pre-treatment before electroless copper metallization and strike acid copper plating.

The IST cycle results were as follows,

- IST cycles without reflow 680 cycles achieved.
- IST cycle with 4 times Pb free reflow cycle 670 cycles achieved.

The IST cycle result within the scope of this testing did not show a significant difference between with or without reflow excursion.

The plated acid copper layer is not affected by up to four times Pb reflow cycle using the test panel as specified.

RESIN COATED COPPER FOIL

Resin coated copper foils (RCF) are widely used in the manufacturing of micro via layers in mobile phone boards.

Two main areas in pursuit of reduced environmental impact are addressed: the composition of the dielectric and the RCF manufacturing process itself. Atotech decided to address both issues simultaneously.

Environmentally friendly manufacturing process for RCF

The standard manufacturing process as it is practiced by the current suppliers of such a product consists of blending the formulation components (Resins, curing agents, additives, flame retardants) in an organic solvent, coating this mixture with precision coaters onto a copper foil and then evaporating the solvent in an oven.

We have now developed a solvent-less route whereby RCF may be successfully manufactured: Solid components are first blended and then homogenized in a melt extrusion process to yield a uniform a uniform dry powder thus the use of solvent is eliminated.

The manufacturing technology employed has been used for many years in products for decorative applications and is fully mature and well established. Subsequently the powder is applied directly on the copper foil using a proprietary coating technology.

By systematic modification of coating equipment it became possible to achieve very uniform distribution of powder over large Finally the powder is melted in an oven then cooled under controlled conditions to form a homogeneous coating. (Figure 13)

The surface of the coating produced using this process has a micro-topographical surface consequent on limited flow during the leveling phase. (fig. 14).
This ensures rapid and consistent air release during the final lamination step when the RCF is put to use

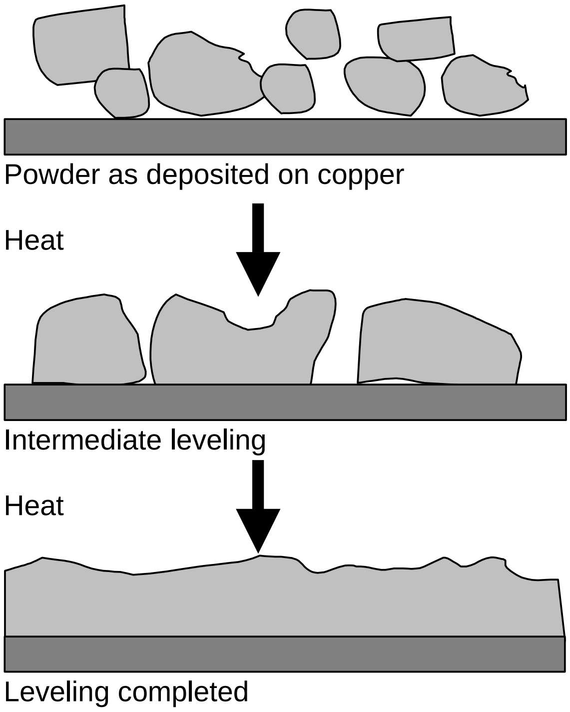

Fig.13: Melting and leveling

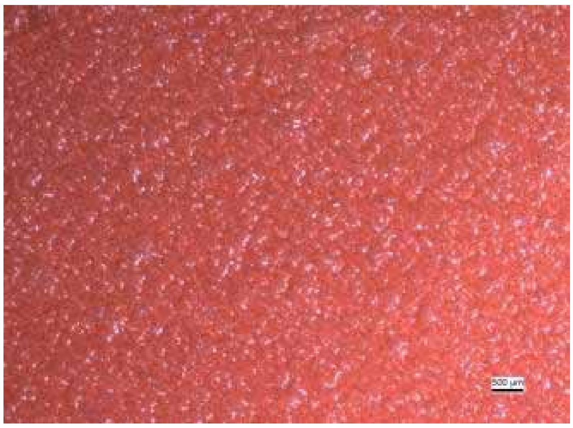

Fig. 14: Powder coated RCF

Halogen-free composition
In the past, brominated epoxy resins were the workhorses for formulators of laminates, prepregs and RCFs.

Since the implementation of the EU directives concerning “Restriction of the use of certain hazardous substances in electrical and electronic equipment” RoHS is approaching rapidly and such compounds must be replaced in all dielectric formulations.

Our newly developed dielectric is free of brominated epoxy resins and passes the halogen-free specification. A flame retardant based on a phosphorus compound is formulated into the powder.

Nevertheless no compromises were made concerning the material performance. In particular water uptake is at a low level.
The following table gives an overview of the material properties after lamination.

Property	Unit	Value
Tg	°C	155
CTE (TMA)	ppm/°K	50
Dk (1 GHz)		3.4
tan δ (1 GHz)	%	1.2
Tensile strength	MPa	70
Young’s modulus	GPa	2.6
Elongation to break	%	5.2
Flammability (according to UL 94 V0)		pass
Halogen-free (according to JPCA-ES-01-1999)		Yes
Cu Peel strength, 18 µm Cu	N/cm	11
Water uptake (IPC TM 650, 2.6.2.1)	%	1.6
Storage at room temp.	months	>3

Material properties of XA-2003

Summary
Atotech developed an environmentally friendly coating process for the manufacturing of RCF.
Combined with a halogen-free formulation for the dielectric this is a significant step forward towards greener materials and overall processes.

Very close thickness tolerance can be achieved over an extremely wide range of dielectric thicknesses providing a perfect micro via PCB construction tool for environmentally conscientious designers and producers.

FINAL FINISHES
This section compares surface wettability of final finishes applied on a PCB substrate, comparing the use of N_2 vs. air atmosphere during soldering.

Tested finishes were immersion tin and silver, OSPs, lead free HASL, medium and high P ENIGs and e’less nickel-palladium-gold (known as Universal Finish).

To distinguish suitability for lead free soldering, the diameter of solder paste after reflow soldering was measured.

As test vehicle a 1.6mm multi purpose test board (FR4 Tg170°C) with 30µm electroplated copper was used.

Layer thicknesses
Each finish was applied at its individual optimum thickness range for lead free soldering. The thickness ranges were verified in several investigations, described and published elsewhere.

Finish	Thickness [µm]
OSP (A)	~ 0,3
OSP (B)	~ 0,3
HASL (SnCuNi)	~5 – 20
Immersion Ag	0.21
Immersion Sn	1.21
Medium P ENIG	Ni 5.1 / Au 0.07
High P ENIG	Ni 5.0 / Au 0.04
E-Ni E-Pd I-Au	Ni 5.0 / Pd 0.16 / Au 0.02

Fig. 15: Final finish thicknesses

Reflow soldering
Reflow soldering was performed in a “REHM Nitro 2100” five-zone reflow oven.

As solder profile for this investigation, the time / temperature recommendation according to J-STD-020-C was chosen. Having 260°C peak on board / pad and total duration of reflow cycle of 10 minutes.

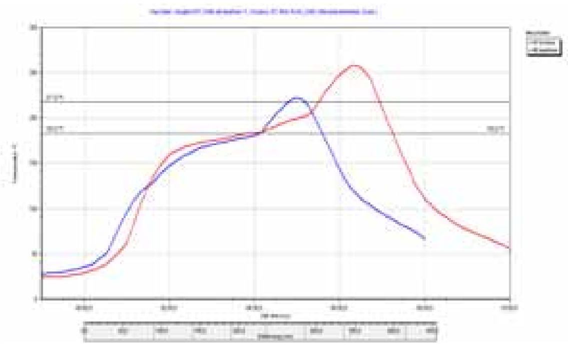

Fig. 16: Reflow profile according to J-STD-020-C (red) in comparison to historical eutectic tin-lead reflow profile (blue)

Soldering atmosphere

Two soldering atmospheres were investigated, N_2 (residual 100ppm O_2) vs. air (180 000ppm O_2) reflow.

Solder paste

Solderability tests performed, used “KOKI S3X58-M406 with Sn96.5Ag3.0Cu0.5”, and was applied by a “DEK 248” stencil printer using a stainless steel stencil with 125µm height.

Solder spread diameter

This method incorporates solder paste printing (1000µm diameter for this investigation) / reflow soldering / measuring the spread of the liquefied / solidified solder paste.

As the solder spread becomes greater, the more substrate / final finish is covered by solder. The resulting diameter indicates the wettability of the final finish.

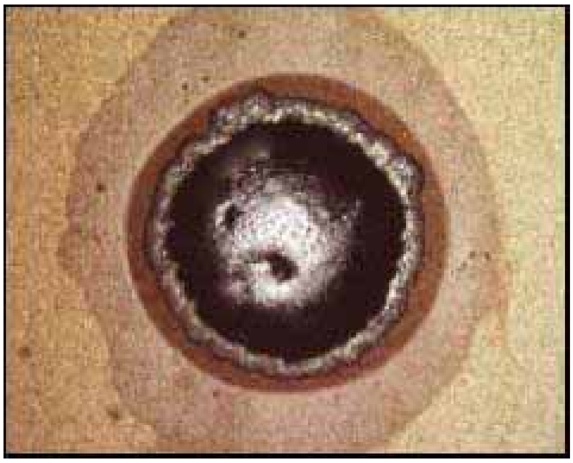

Fig. 17: Printed / wetted area 1000µm / 1100µm (diameter)

Fig. 18: Printed / wetted area 1000µm / 1400µm (diameter)

Fig. 19: Printed / wetted area 1000µm / 1760µm (diameter)

Surface conditions
For each finish the solder spread was determined for conditions as, “as received”, or after 1st reflow, or after 2nd reflow, or after 3rd reflow.
With each surface / condition 30 solder paste dots where reflowed and measured, in “X” and “Y” direction.
Reflow soldering and reflow ageing always being performed at both atmospheres (N_2 or air).

Results
Solder paste printed area always 1000µm diameter prior to reflow soldering

As received

Finish	"as received" diameter after soldering [µm]	
	air	N_2
OSP (A)	1008	1030
OSP (B)	999	1049
I-Ag	1063	1146
HASL (SnCuNi)	1396	2100*
I-Sn	1235	2100*
medium P ENIG	1456	1574
high P ENIG	1417	1695
E-Ni E-Pd I-Au	1465	3977

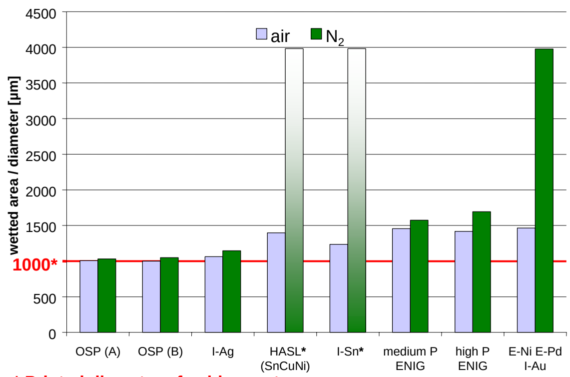

Fig. 20: Wetted area / diameter for all finishes in “as received” using N_2 (green) or air (blue) atmosphere during reflow soldering.

***Note:** for HASL and I-tin the diameter after reflow in N_2 (only for “as received“ samples) could not be measured, as no difference in appearance for the molten solder paste / surface could be detected.

After 1st reflow

Finish	"after 1st reflow" diameter after soldering [µm]	
	air	N_2
OSP (A)	1010	1082
OSP (B)	1026	1083
I-Ag	1030	1138
HASL (SnCuNi)	1010	1031
I-Sn	1035	1085
medium P ENIG	1395	1601
high P ENIG	1463	1530
E-Ni E-Pd I-Au	1392	2900

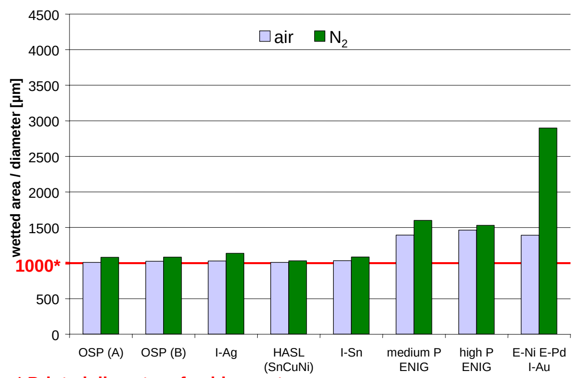

Fig. 21: Wetted area / diameter for all finishes after 1st reflow cycle using N_2 (green) or air (blue) atmosphere during ageing and reflow soldering

After 2nd reflow

Finish	"after 2nd reflow" diameter after soldering [µm]	
	air	N_2
OSP (A)	1005	1066
OSP (B)	1012	1030
I-Ag	1030	1193
HASL (SnCuNi)	978	1132
I-Sn	1035	1048
medium P ENIG	1375	1409
high P ENIG	1375	1419
E-Ni E-Pd I-Au	1398	2966

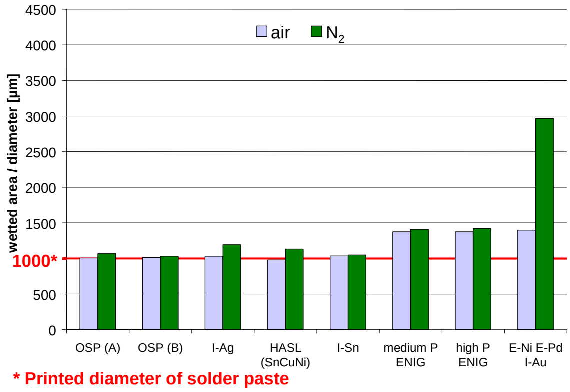

Fig. 22: Wetted area / diameter for all finishes after 2nd reflow cycle using N_2 (green) or air (blue) atmosphere during ageing and reflow soldering

After 3rd reflow

Finish	"after 3rd reflow" diameter after soldering [µm]	
	air	N_2
OSP (A)	998	1054
OSP (B)	1013	1012
I-Ag	1025	1150
HASL (SnCuNi)	990	1045
I-Sn	1015	1046
medium P ENIG	1367	1442
high P ENIG	1300	1370
E-Ni E-Pd I-Au	1383	2598

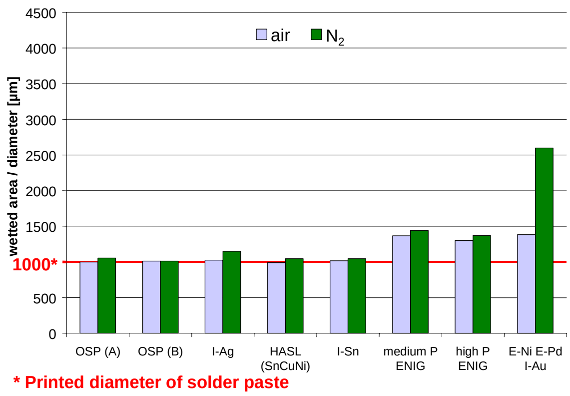

Fig. 23: Wetted area / diameter for all finishes after 3rd reflow cycle using N_2 (green) or air (blue) atmosphere during ageing and reflow soldering

Summary

Generally an improvement in wetted area / diameter is observed when using N_2 instead of air atmosphere during ageing and soldering.
The wetted area / diameter by soldering on an electroless nickel layer is generally greater than by soldering on copper.

OSPs: The improvement (N_2 vs. air) in wetted area is up to additional 70 µm in diameter.
When soldering in air atmosphere twice no spread of the solder paste was observed, indicated by 999 and 998µm solder area diameter after soldering.

Immersion silver: The improvement (N_2 vs. air) in wetted area is up to additional 160 µm in diameter. Compared to "as received" the impact of reflow soldering either in air or N_2 is minor.

HASL (SnCuNi): Air soldering: the spread of solder paste for the first reflow ("as received") was widest and reached nearly 400µm additional diameter. But this surface suffered during air soldering and the wetted area decreased after 2nd reflow (air) to less than the initial printed area.
N_2 soldering: for the first reflow ("as received") the wetting of the paste / surface could not be determined, as the surface after soldering did not show any difference in appearance between pad / solder. Starting with the 1st reflow ageing the additional wetted area was maximum 45µm diameter plus.

Immersion tin: The improvement (N_2 vs. air) in wetted area is dramatic for "as received".
Doing N_2 soldering, the wetting of the paste / surface (for "as received") could not be determined, as the surface after soldering did not show any difference in appearance between pad / solder.
Additional reflows, to "as received", the impact of reflow soldering either in air or N_2 is minor.

Medium P ENIG: The improvement (N_2 vs. air) in wetted area is up to additional 200 µm in diameter. Compared to “as received” the impact of reflow soldering either in air or N_2 is minor. The wetted areas / diameters for just air soldering remain always above or around 1400µm.

High P ENIG: The improvement (N_2 vs. air) in wetted area is up to additional 280 µm in diameter. Compared to “as received” the impact / amounts of reflow soldering either in air or N_2 are minor, where the wetted areas / diameters for just air soldering where around 1300- 1400µm.

E-Ni E-Pd I-Au: The improvement (N_2 vs. air) in wetted area is dramatic. Wetted areas / diameters for soldering in air atmosphere is comparable to those of medium / high P ENIG.
But when it comes to soldering in N_2 atmosphere the wetted area / diameter nearly quadrupled from 1000µm (diameter) “as printed” to 3977µm (diameter) after soldering. After the 3rd reflow cycle the spread of the wetted area in terms of diameter measurement still increased to nearly 2600µm, which is almost the double compared to the other ENIG systems and 2.6 timer more compared to HASL and its alternatives.

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