Desmear and Plating Through Hole Considerations and Experiences for Green PCB Production

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Abstract

With the latest legislations from RoHS and WEEE dominating the horizon of the PCB landscape there is a need for manufacturers and their suppliers to understand their impacts. The requirement to remove lead from the industry and therefore the need for lead-free soldering operations means a large amount of stress is placed on the PCB substrates. The laminate material suppliers are responding to the new legislation by introducing newer varieties of materials that have better heat stress handling capacities as well as some added benefits like reduced z-expansion. Another concern for the laminate manufacturers is the need to remove halogen based, flame retardants like bromine from their resin systems. This paper will discuss the relevant legislations and the impact of these on the desmear and plating through hole processes. We will introduce and discuss the changes that are taking place in the laminate materials sector needed to meet the newer requirements. We will discuss the most significant advances in the halogen free as well as Pb-free capable materials. The significance of the changes and their influence on the desmear and PTH processes will be highlighted. Test results from investigations and experiences with the newer materials will be presented and compared to results normally found for the more standard materials. We will propose options for handling the various issues arising from these new materials and so help to prepare PCB manufacturers for the coming turbulence in the industry being generated by the new legislative demands.

Introduction

At the moment there is a strong increase in the desire for flex and flex-rigid PCBs (FPCs) due to certain market sectors. The increased technological demands from the latest handheld devices containing cameras and new high resolution screens as well as the newer mobile phones means that there is a surge in the requirement for flex-rigid panels and multi-flex panels. The need to mass produce these panel types and to reduce the cost of manufacture, as always has driven the development of newer methods of processing.

Technically the materials involved in flex / flex-rigid board manufacturing generate a large number of issues. One key concern is the large variance of materials in one board build-up as well as the exotic nature of some of the commonly used materials and the inherent issues they raise. We will discuss some of the differences in common materials used as well as common board build-ups and relate this to processing issues. We will provide examples for several common flex / flex-rigid board constructions and will show some of the processing answers to the various issues raised. Lastly we will integrate new developments in processing whilst explaining the benefits each one brings.

Material Considerations

To have an idea of the requirements and issues associated for PTH processing of FPCs it is necessary to consider the materials being used and their characteristics. For most FPCs the choice of materials are shown in table 1:

Table 1 – Typical Flexible Dielectric Materials

Substrate (Selection)	**Tg [°C]**	**Moisture Absorption**	**Remark**
Polyimide (PI, Kapton)	220…390	1…3 %	Standard resin for flexible printed circuits. Good resistance against strong acids, organics, but poor against strong bases.
Polyester (PET, Mylar)	90…110	< 0.4 %	PET is a low cost, optically clear substrate that is suitable for many applications. Good resistance against strong acids, organics, but poor against strong bases.
Polyethylene Naphthalate (PEN)	approx. 120	< 0.5 %	PEN is a low cost substrate designed to offer properties ranging between polyester and polyimide. PEN also has excellent resistance to solvents and chemicals.
Composite (Epoxy/Glass etc.)	90…165	< 3 %	Good resistant against strong acids, organics, but fair against strong bases. Lower flexibility than other substrates.

The use of other materials like Liquid Crystal Polymers is also becoming increasingly popular due to their different electrical and physical properties.

Also to be considered are the adhesives that are commonly found with flexible build-ups and laminates. A general list of the most popular types are in table 2.

Table 2 – Typical Flexible Adhesive Materials

Adhesive (Selection)	**Tg [°C]**	**Moisture Absorption**	**Remark**
(FR*) Acrylic	30…40	4…6 %	Standard adhesive for flexible printed circuits because of the relatively low cost and their ease of processing. Acrylic adhesives have a higher resistance to soldering conditions than polyesters and modified epoxies
(FR*) Polyester (PET)	90…110	1…2 %	PET adhesives are used in applications where there are no extremes of temperature or forces that will significantly stress the circuit.
Epoxy (modified) (B-Stage)	90…165	4…5 %	(Modified) Epoxies are generally less flexible than other adhesive systems but they can be modified by the addition of other polymers. They possess excellent resistance to high temperatures and modified grades offer excellent bond strength and material compatibility.
Polyimide (PI)	220…260	1…2.5 %	PI adhesives have a very low coefficient of thermal expansion, which makes it a good choice for use in demanding multilayer circuits.
Phenolic Butyral	NA	NA	This is special adhesive that has some application in selected areas.

Processing has to be tailored to the different mixtures of materials. These are typical build-ups for flexible boards:

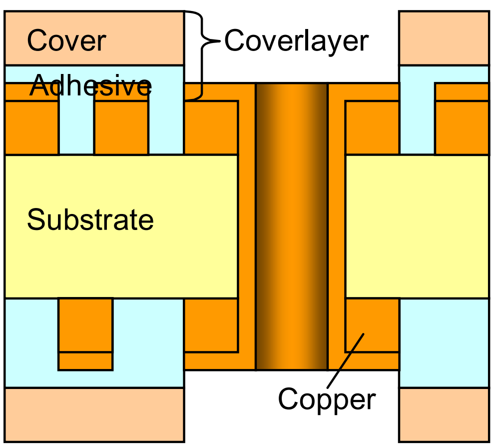


Figure 1 - Adhesiveless Flex Core

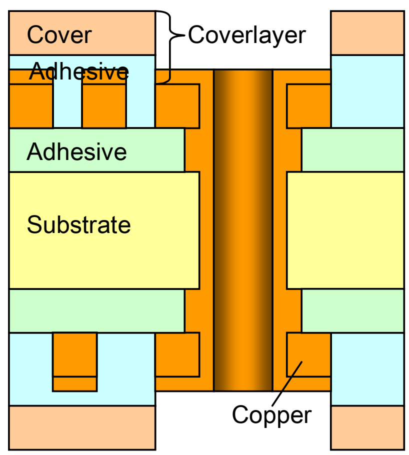


Figure 2 - Adhesive Based Flex Core

The main characteristics of these materials that have to be overcome are:

- Moisture retention
- High alkalinity / High Temperature susceptibility
- Adhesion
- Stretching, inherent structural weakness
- Adhesives

Moisture Retention

To reduce the influence of moisture retention on processing and also the final FPC quality the use of baking is regularly employed. This has the advantage of not only removing moisture from the flexible substrates but also to help to cure adhesives and resins and so improving their performance.

High Alkalinity / High Temperature Susceptibility

A lot of PTH systems require the use of alkaline cleaners or other active steps and also high temperatures. To be able to process materials such as acrylic adhesives the temperature or alkalinity of a system should be reduced as much as possible. Another option is to make the contact time with the hot alkaline solution as brief as possible. The use of a horizontal system, flooding devices and with the support of ultrasonics is a good way to treat acrylic adhesives even with higher temperature solutions that have a high pH.

Adhesion

Materials like Polyimide are notorious for low copper adhesion, this makes the adhesion in through holes, but especially on bare polyimide surfaces, troublesome. To combat this the conditioners in any direct plating system have to be designed to give maximum adhesion whilst maintaining good coverage. For electroless copper systems the conditioning and pre-treatment is important but the choice of a low stress, high adhesion electroless copper bath is more critical for blister free performance.

Stretching, Inherent Structural Weakness

As flex panels tend to be thin, typically around 50 - 100 µm, then the option of brushing them after drilling to remove burrs is not an option. A suitable alternative is of course a strong etch and doing this horizontally with flooding devices once again enhances the removal process.

Adhesives

Adhesives like acrylic are susceptible to being drawn-out from the surface of a hole during drilling and so can end up as a type of smear or even a 'worm' in the hole. This is of course not good for quality and should be removed. The most effective ways to remove these are of course with plasma, but when this is not available and a permanganate desmear is not suitable then another method must be sought. The use of an ultrasonic supported cleaner in horizontal mode with strong flooding devices is a suitable alternative. When this is combined with an etch cleaner then the deburring or copper removal can also be performed.

Figure 3 - Transverse Section with Adhesive 'Worms'

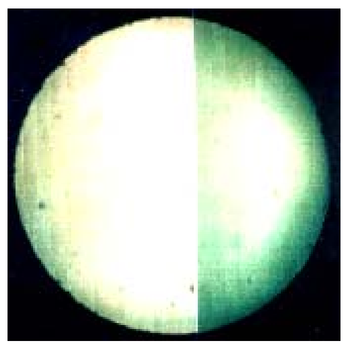


Figure 4 - After Cleaning Process

PTH Solutions

Desmear

Due to the time and expense of using plasma desmear there is a lot of activity to generate a suitable permanganate desmear solution for FPC production. Due to the large amount of material differences and panel build-ups a general process for all FPCs will be difficult to achieve. For some of the more common mass production FPCs, however, it is worthwhile to develop a desmear system. Some of the issues with desmearing are the high attack on low Tg adhesives like acrylic as well as the potential to damage even the higher Tg polyimide dielectrics. Some horror pictures from desmearing flex-rigid boards show some of the problems associated with FPC permanganate desmear:

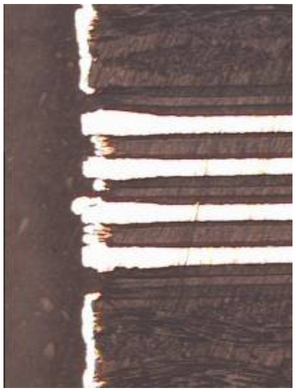
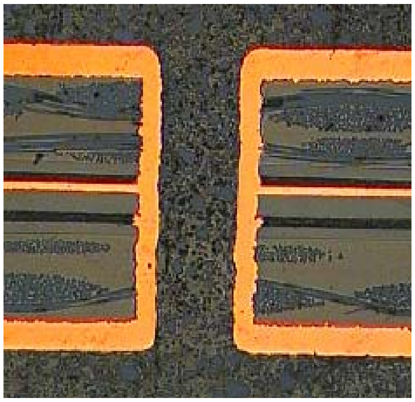


Figure 5 – Plasma Desmeared + Electroless

Figure 6 – Permanganate Desmeared + Electroless

Figure 6 shows the strong attack of the acrylic adhesive and even damage to the polyimide dielectric by a standard permanganate desmear whereas the panel desmeared with plasma (figure 5) shows good coverage and no damage. With the correct settings and the correct material choices and build-up it is possible to use a permanganate desmear for FPCs. Figures 7 and 8 show FPCs that have been desmeared with permanganate and electroless copper, but showing good results.



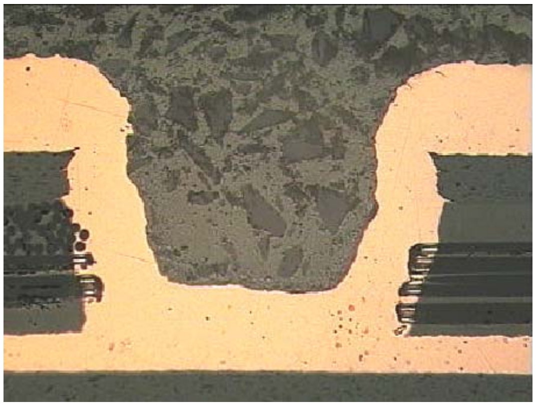


Figure 7 – Flex-rigid permanganate desmeared

Figure 8 – Blind microvia flex permanganate desmeared

Direct Plating

Direct plating is a popular technique for producing FPCs. The main reasons being that they are generally cheaper to run than electroless copper systems and also are more suited to the mix of different exotic materials. The Neopact process from Atotech is our most suitable process for FPCs. This is due to its good conditioning and the low temperatures and pH's employed. The process sequence for flex production is:

Table 3 – Neopact Horizontal Flex Process

Process	**Temp. (°C)**	**Time (s)**
Etch Cleaner	30	30-60
Cleaner 902 Flex	50	30
Neopact Conditioner	50	90
Neopact Pre-dip	RT	15
Neopact Conductor	50	100
Neopact Post-dip	30	40
Neopact Selector	30	40

Table 4 – Neopact Vertical Flex Process

Process	**Temp. (°C)**	**Time (min)**
Etch Cleaner	30	1-2
Cleaner 902 Flex	50	2
Neopact Conditioner	50	5
Neopact Pre-dip	RT	1
Neopact Conductor	50	5
Neopact Post-dip	30	2
Neopact Selector	30	2

Both horizontal and vertical systems are proven in sheet form and reel to reel processing.

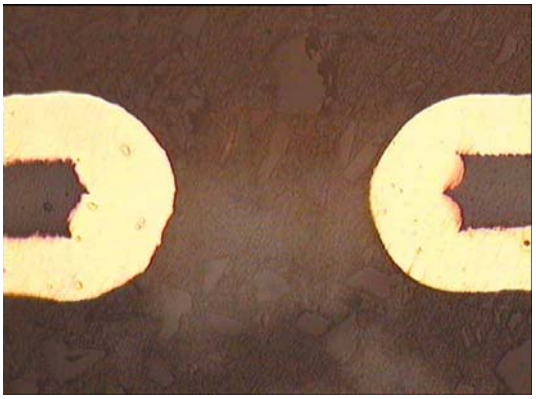


Figure 9 – Neopact Processed Rogers LCP

Figure 10 – Neopact Processed Flex-rigid

Electroless Copper

To get good, repeatable results with an electroless copper system the key criteria that need to be met are:

- Good cleaning and conditioning
- Sufficient activation
- Good coverage
- Good adhesion

A general electroless copper system is set-up to be able to reach these criteria for normal production. For flex production special care is needed due to the mixtures of exotic materials involved. The following figures show the benefits that can be achieved by focusing on key areas of the electroless copper process and optimizing them for flex production.

By choosing the correct cleaner for the electroless system we can improve the adsorption of palladium from the activation system and therefore improve the electroless copper coverage on polyimide and flex materials.

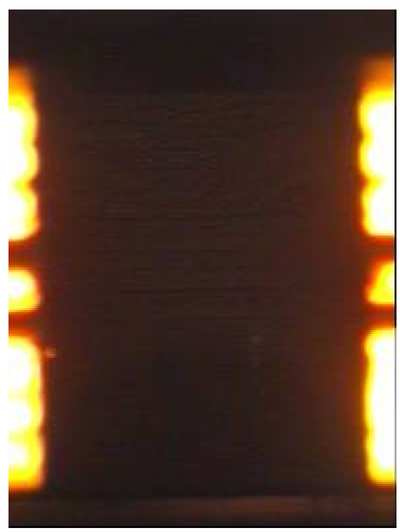


Figure 11 – Backlight for Standard Cleaner

Figure 12 – Backlight for Flex Cleaner

Even a minor change in the Reduction stage of the electroless copper activation process can increase the coverage on polyimide and other such materials. Figures 13 and 14 show the benefits of choosing the correct Reduction products, where the coverage shown to be poor with the original reducer is perfect once the flex reducer is used.

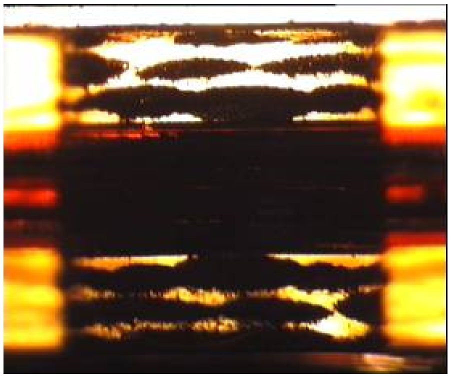


Figure 13 – Backlight for Original Reducer

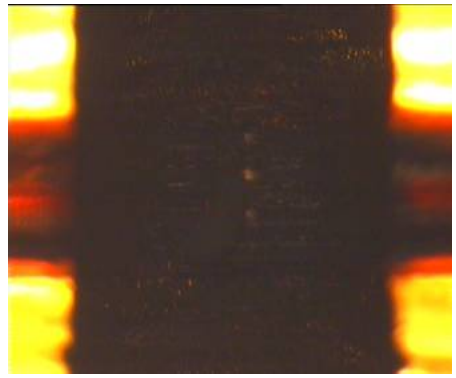


Figure 14 – Backlight for Flex Reducer

To achieve good adhesion on materials like Polyimide requires firstly good pretreatment. With a good rough surface made from plasma desmearing good adhesion on hole walls can be achieved with most electroless copper systems. To get good adhesion on exposed polyimide surfaces is not always easy. When the plasma desmear system is not used at all then to achieve good adhesion on exposed polyimide surfaces requires a very low stress electroless copper bath with advanced adhesion properties. One of the new electroless copper systems from Atotech has been especially designed for the modern materials of today and the future and so features low stress as well as superior adhesion. The superior adhesion is clearly shown in figures 15 and 16 where exposed polyimide layers are processed in Atotech's Printoganth P and Printoganth PV electroless and without any issues with blisters.

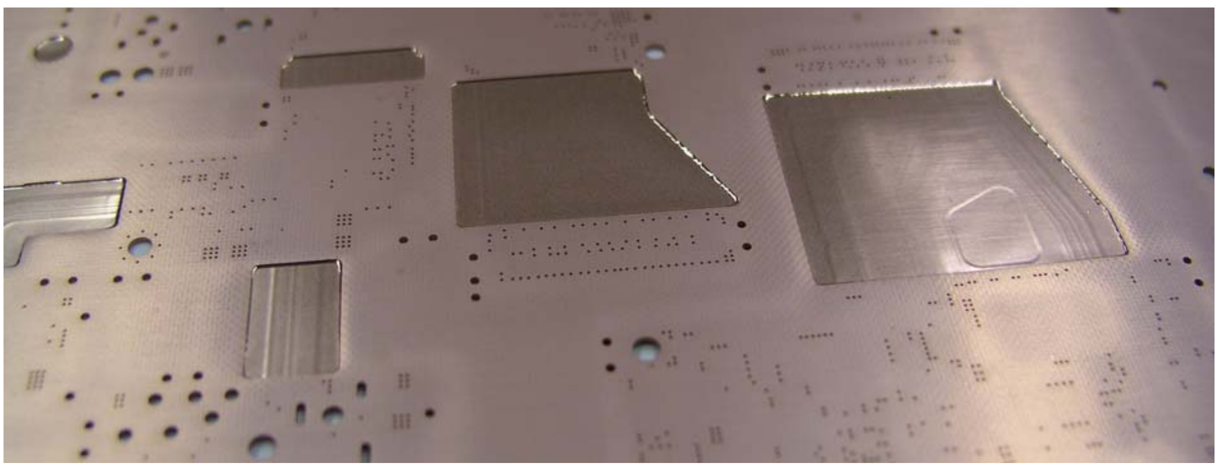


Figure 15 – Printoganth P Horizontal Electroless on Exposed Polyimide Surfaces

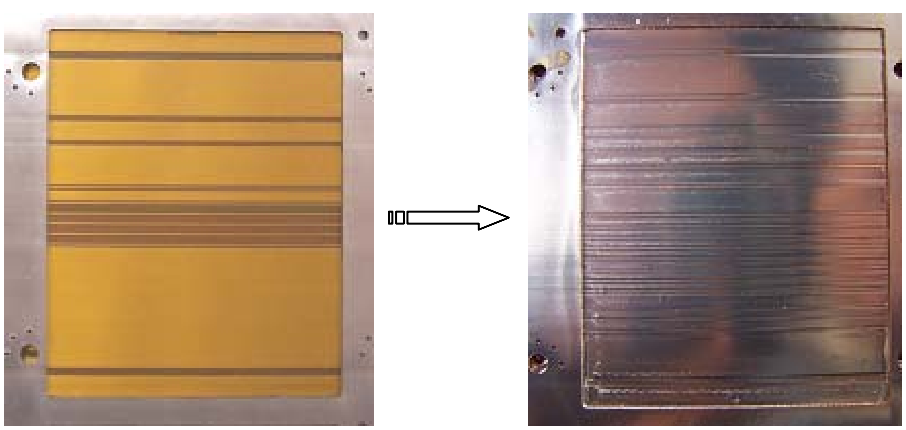


Figure 16 – Printoganth PV Vertical Electroless on Exposed Polyimide Surfaces

Conclusions

In order to meet today's demands for lower cost, mass production of flex and flex-rigid panels standard PTH has to be modified. The desire to remove the plasma process requires some innovative ideas for new permanganate desmear or alternative pre-treatment for multilayer panels. For some material types and panel build-ups this is already achievable and is currently in use for mass production. To ensure good coverage the pre-treatment system has to be optimized especially when the support from plasma desmearing is removed. For treatment of flex double sided materials the need for burr removal and adhesive removal requires extra steps and specific line designs to ensure good coverage even on the occasionally badly drilled panels. For reproducible coverage and blister free performance on exposed, smooth, polyimide surfaces the use of a low stress, high adhesion electroless copper system is necessary.

With the correct process, and optimized parameters, the demands of the latest flex boards and markets can be easily fulfilled.