

## Permanent Non-Etching Adhesion Promotion System for Solder Mask Applications

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### Abstract

With the constant drive for miniaturization in the IC substrate market, and the increasing performance demands being made on completed assemblies, the use of etch based adhesion promoter systems is coming into question. Unlike the current technology, Atotech's Secure™ HFz process enhances the adhesion between a Copper conductor and a solder mask with no etching to the conductor itself. This unique approach is designed to meet the current and future market requirements typical to ultra fine line IC substrate manufacturing (sub 10 / 10 µm line and spaces can be achieved).

This work details the Secure™ HFz process and discusses testing carried out, in which, the adhesion properties are attained for treated surfaces and a range of solder mask materials. The tests show that surfaces treated with this non-etching chemistry exhibit comparable or greater adhesion strength when compared to a traditional etching based system. Long term reliability is also evaluated through HAST (Highly Accelerated Stress Test) where again overall performance is equivalent to, or better than the current etch based process.

The summary of this work is that Copper surfaces treated with the Secure™ HFz process offer a technical advantage in ultrafine line and space applications due to their improved adhesion to solder mask materials with no changes, critically reduction, in overall track geometry.

### Introduction

Currently, in order to ensure suitable adhesion between Copper conductors and an insulation layer, Copper surface treatments are used, these create a level of micro roughness that gives an anchor effect, thus ensuring thermal performance. (Figure 2) However, these methods are reaching their capability limits.

As line and space features move smaller than 10µm, it is becoming a challenge to concurrently achieve excellent adhesion, ensure thermal performance, and minimise surface roughness.

Secure™ HFz is based on the "white oxide" process concept. The "white oxide" process were the first commercially successful, large-scale, conveyorised oxide alternative, for conventional multilayer bonding.

However, during their initial release, these processes suffered from limited success. The concept of chemical bonding through the use of an invisible adhesion promoter, was viewed with scepticism in an industry where the standard for multilayer bonding was Black Oxide, a highly visible black coating, routed in mechanical bonding. However, we now re-explore white oxides potential as a "non-etching" adhesion promoter. Currently, the market demand coupled with a genuine need to move away from etching chemistries makes this capable technology more attractive than previously.

While the process has obvious benefits for bonding or lamination, where a smooth surface is desired for high frequency applications, in order to be fully used within the IC substrate arena, it also has to give acceptable performance with solder mask materials.

### Process Description

#### Alkaline Cleaner

The Alkaline cleaner is used primarily for aggressive cleaning applications, especially for the removal of organic residues such as dry film resist and oily fingerprints.

#### Acid Cleaner

An Acid Cleaner is used to remove heavy oxides, anti-tarnishes or detergents from the surface prior to the Immersion Tin deposition.

#### Immersion Tin

The Immersion Tin process is designed to deposit 0.06 – 0.09 µm of pure tin onto the copper surface. Compared to Copper, Tin is a more suitable interface as stronger polar bonds can be formed between its oxide, and the polar groups within the substrate. The Tin hydroxide serves as a convenient anchor for further chemical modifications to build strong covalent bonds to the organic resins.

#### Activation

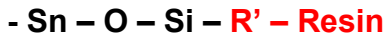
The Activation process is designed to stabilise the surface for Silane Filming step

#### Silane Filming

Once an even Tin-oxide layer has been formed, an aqueous solution of organosilanes is then applied.

The organosilane adhesion promoter has the ability to form strong covalent bonds to the Tin hydroxide (Sn-OH) as well as to the organic resin, which results in a strong interface linking the two materials.

The organosilanes of the following general structure



were found to be suitable coupling agents.

These organosilanes form strong bonds with the metal oxides

During the imaging process, strong covalent bonds are formed between the Silanes and the polymer resin.

As described all adhesion is derived from the organosilane mixture. As such no etching or roughening of the Copper is required to achieve adhesion. This is ideal for high frequency applications, reducing signal losses and meeting more stringent controlled impedance requirements.

## Results

In order to characterise the nature of features produced with the Secure™ HFz process, sample parts were processed through a standard SAP type process. The resulting features were then treated with the Secure™ HFz process and compared to parts through etch based adhesion systems.

Prior to processing with either adhesion promoter, all samples were measured using Laser Interference Microscopy (LIM) to determine average conductor width/space and height (thickness) before processing through the etching and non-etching processes.

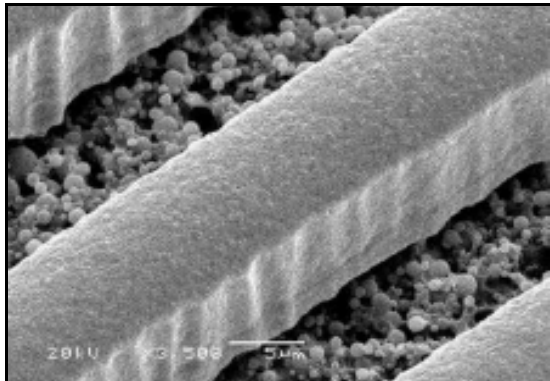


Figure 1

12 μm Line After Treatment With Differential Etch.

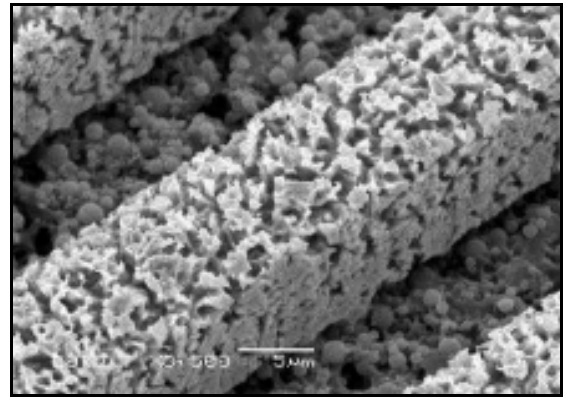


Figure 2

12 μm Line (After Differential Etch) After Treatment With Micro Roughening Chemistry.

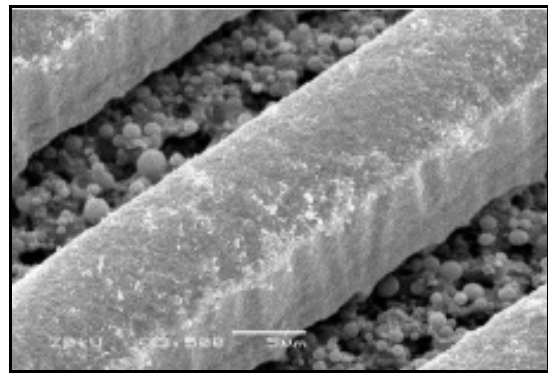


Figure 3

12 μm Line (After Differential Etch) After Treatment With Secure™ HFz process.

As LIM is a non-destructive, test the samples could be processed and measured again as well as surface characteristic by Atomic Force Microscopy (AFM). The changes in conductor height, width and roughness are tabulated in Tables 1, 2 and 3.

Process	R <sub>a</sub> (μm)	R <sub>ms</sub> (μm)	R <sub>z</sub> (μm)
Before Treatment	0.03	0.04	0.28
BondFilm®	0.41	0.39	2.94
Secure™ HTg	0.39	0.35	2.61
Process of Record	0.22	0.27	1.61
Secure™ HFz	0.05	0.06	0.30

Table 1

Surface Roughness Analysis After Various Surface Treatments

Process	Width (µm)	Δ Width (µm)
Before Treatment	12.3±0.68	
BondFilm®	10.3±0.65	2.0 µm
Secure™ HTg	10.4±0.65	1.9 µm
Process of Record	9.8±0.53	2.5 µm
Secure™ HFz	12.1±0.38	0.2 µm

Table 2  
Initial Conductor Width and Measured Width Change After Various Surface Treatments

Process	Height (µm)	Δ Height (µm)
Before Treatment	16.4±0.57	
BondFilm®	15.7±0.41	0.6 µm
Secure™ HTg	15.6±0.61	~ 7 µm
Process of Record	14.2±0.94	2.1 µm
Secure™ HFz	16.2±0.32	0.1 µm

Table 3  
Initial Conductor Height and Measured Height Change After Various Surface Treatments

As can be seen, after treatment with the Secure™ HFz process, the conductor surfaces are statistically the same as before treatment, however the etch based system shows noticeable reduction in track size.

For performance testing with solder masks, treated parts were coated with solder masks before being subjected to HAST exposure (HAST, JESD22-A118, 130C, RH85%) and subsequent peel testing.

From Figures 4 and 5 it is clear that the adhesion strength of the solder mask remains high even after long term HAST exposure, and is comparable to an etch based technology.

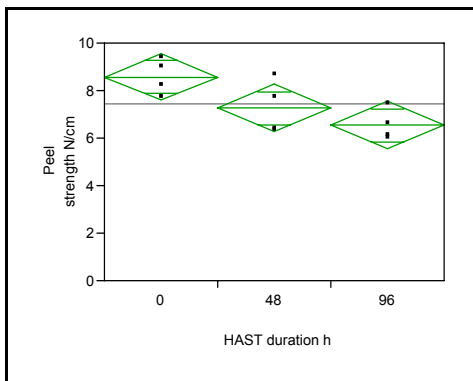


Figure 4  
One-way ANOVA Showing Adhesion Performance Under Different uHAST Exposure Times.

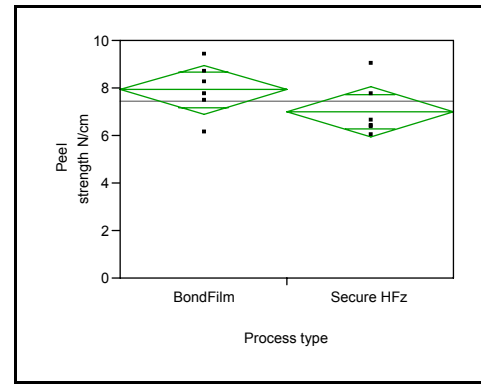


Figure 5  
One-way ANOVA Showing Adhesion Performance With Different Treatment Processes.

Figure 6 shows comparable peel strengths for two different solder masks applied to Secure™ HFz treated surfaces, it is clear that both mask materials perform acceptably with comparable adhesion.

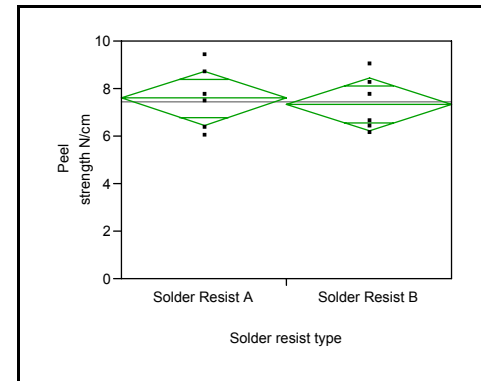


Figure 6  
One-way ANOVA Showing Adhesion Performance With Different Solder masks.

## Summary & Conclusion

The Secure™ HFz process is offered as a non-etching adhesion promoter for multilayer bonding and solder mask applications.

Characterization of Copper features treated with this novel process confirms the non-etching claim with no discernable change noted on track shape or size. Further it has demonstrated that conductors down to 12 µm can be reliably fabricated.

Testing Secure™ HFz with solder masks has been shown to be not only achievable, but yields adhesion strength comparable to etch based chemistries and resistant to long term HAST exposure.

Secure™ HFz is the technology that can concurrently achieve excellent adhesion, ensure thermal performance, and minimize surface roughness for the next generation of advanced PCBs and IC substrates.