Novel Approach for a Non-Etching Adhesion Promoter for the Next Generation of IC Substrates

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Abstract:

Targeted for meeting the requirements of advanced IC manufactures for a Non-Etching Adhesion Promoter (NEAP) in the manufacture of sub 10 / 10 µm line and space, the Secure™ HFz process represents an innovative approach to enhancing the bonding of Ajinomoto Build- up Film (ABF) materials and comparable films as well as solder masks while not significantly etching the copper conductor to promote adhesion but rather using Silane based chemical adhesion promoters.

A complete description of the process and its operating parameters will be presented. As this technical paper will demonstrate, this process achieves superior bonding strength and thermal reliability for not only ABF materials but also high-performance substrates and prepregs in comparison to more traditional copper roughening treatment methods.

A complete process characterization has been done to illustrate the merits of Secure™ HFz. The surface was characterized using Scanning Electron Microscopy (SEM), Laser Interference Microscopy (LIM), and Atomic Force Microscopy (AFM) techniques. While the adhesion and thermal performance was done using standard industrial methods such as peel strength.

Introduction:

Currently, in order to ensure adhesion between the copper conductors/surfaces and an insulation layer, copper surface treatments are used to create micro roughness (figure 1) for adhesion and to ensure thermal performance. However, these methods are reaching their capability limits.

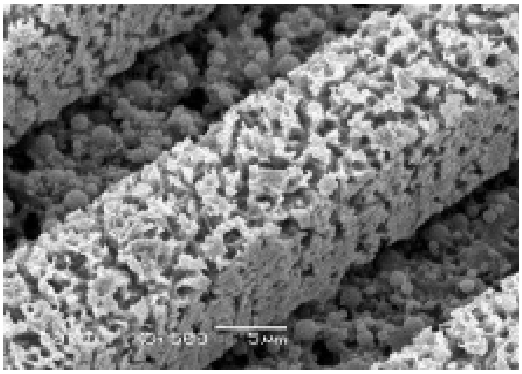

Figure 1. 12 µm line treated with micro roughening chemistry for adhesion.

As lines and spaces move below 10 / 10 µm it is becoming a challenge to concurrently achieve excellent adhesion, ensure thermal performance, while minimizing surface roughness.

Secure™ HFz is an innovative idea based on the “white oxide” process concept. The “white oxide” process was the first commercially successful large-scale conveyorized oxide alternative for conventional multilayer bonding. During the initial release the process had limited success, as the concept was too radical. Chemical bonding, an invisible adhesion promoter on the surface, was an advanced concept when the industrial standard for multilayer bonding was Black Oxide, a visible black coating, based on mechanical bonding. However, we now re-explore white oxides potential as a “non-etching” adhesion promoter. Currently market demand and a genuine need to move away from etching chemistries and roughening now outstrip the antiquated chemical bonding skepticism.

Process Description:

Process	Time	Temp
Alkaline Cleaner	30 s	50 °C
Rinse		RT
Acid Cleaner	30 s	40 °C
Rinse		RT
Immersion Tin	30 s	35 °C
Rinse		RT
Anti-Drag In		RT
Silane Filming	20 s	30 °C
Drying		60 °C

Table 1. Secure™ HFz process flow

Alkaline Cleaner

Alkaline Cleaner is used primarily for aggressive cleaning applications especially for the removal of organic residues like dry film resist and oily fingerprints.

Acid Cleaner

Acid Cleaner is used primarily to remove heavy oxides, anti-tarnishes or detergents from the surface prior to immersion tin deposition.

Immersion Tin

The immersion tin process is designed to deposit 0.08 – 0.15 µm of pure tin onto the copper surface. The tin oxide represents a more suitable interface since stronger polar bonds can be formed between the 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.

Silane Filming

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

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

The organosilanes of the following general structure were found to be suitable couplers:

These organosilanes form strong bonds with the metal oxides.

- Sn – O – Si – R' –

During the lamination process, strong covalent bonds are formed between the Silanes and the 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 impendence requirements.

$(OH)_{4-n}$ – Si – (R-R')n (n=1-3)

Where
R = Organic Bridge
R' = Functional Terminal Group

Results:

Prior to processing all samples were measured using LIM to determine average conductor width/space and height (thickness) before processing through the various adhesion promoters.

- Sn – O – Si – R' – Resin

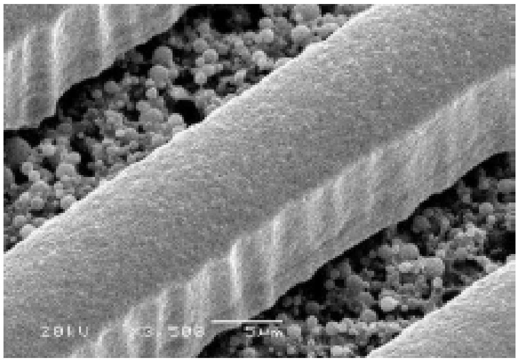

Figure 2. 12 µm line treated after ½ etching.

As LIM is a nondestructive test the samples could be processed and measured again as well as surface characteristic by AFM. The changes in conductor height, width and roughness are tabulated in tables 2, 3 and 4.

Process	R_a	R_{ms}	R_z
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 2. Tabulated AFM surface analysis readings in µm.

Process	Width	∆ Width
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 3. Tabulated conductor widths with LIM surface analysis readings after treatment in various adhesion promoters.

Process	Height	∆ Height
Before Treatment	16.4±0.57	[redacted]
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 4. Tabulated conductor height with LIM surface analysis readings after treatment in various adhesion promoters.

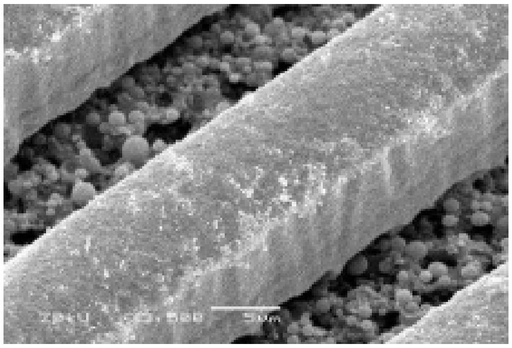

Figure 3. 12/12 μm line and space after treatment with Secure™ HFz process

After Secure™ HFz process, the conductor surfaces are statistically non-etched and maintain excellent shape characteristics for high frequency application.

The adhesion characteristic was also very robust with excellent peel strength (Figure 4 & 5) before and after Highly Accelerated Stress Testing (HAST).

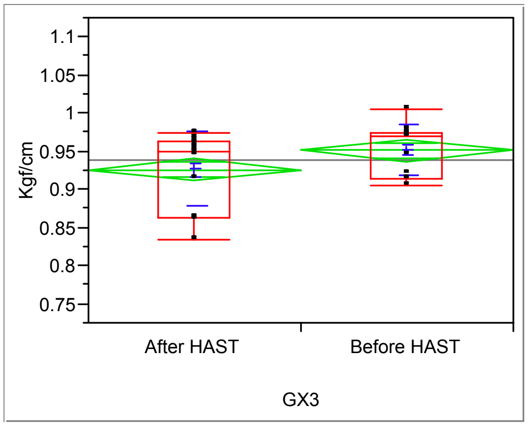

Figure 4. Oneway ANOVA of adhesion using ABF GX3 before and after HAST.

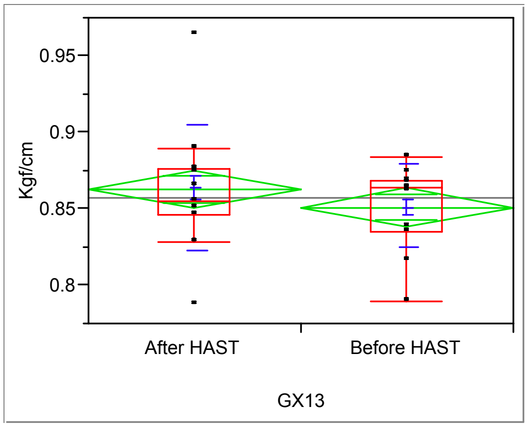

Figure 5. Oneway ANOVA of adhesion using ABF GX13 before and after HAST.

Summary & Conclusion:

The Secure™ HFz process characterization demonstrates that it is a viable "non-etching" adhesion promoter. The SEM, AFM, and LIM analysis clearly illustrates that conductors down to 12 μm can be fabricated with excellent shape characteristics for favorable electrical performance. Having R_a values less than 0.05 μm, and statistically no loss of conductor width or height after processing. The Secure™ HFz also could achieve excellent adhesion with current and advanced ABF materials as well as thermal functionality in terms of HAST.

Secure™ HFz appears to be 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.

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