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

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Abstract

Driven by the need for a Non-Etching Adhesion Promoter in the manufacture of sub 10 µm features in IC substrates, the Secure™ HFz process represents an innovative approach to enhance the bonding of Ajinomoto and similar build up films, as well as solder masks while *not significantly* etching the Copper conductor. This novel process makes use of a silane based chemical treatment to replace the more traditional etch based systems in order to improve surface adhesion characteristics.

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

A complete process characterization has been carried out in order to illustrate the merits of the Secure™ HFz process. The surface of the test vehicle was characterized using Scanning Electron Microscopy (SEM), Laser Interference Microscopy (LIM), and Atomic Force Microscopy (AFM) analysis. Adhesion and thermal performance was evaluated using standard industrial methods such as peel strength and HAST (Highly Accelerated Stress Testing).

Introduction

Currently, IC substrate manufacturers are facing a challenge in producing the next generations of sub 10 µm IC substrates. The present technology uses Copper surface treatments in order to create a micro-etched surface that ensures sufficient adhesion and thermal reliability between a Copper conductor surface and the insulation layer. However, it is widely recognized that these technologies will eventually become obsolete in the production of future IC substrates.

As IC substrates continue to follow the trend of Moore's law, the lines and spaces below 10 µm have increasing difficulties in maintaining excellent adhesion and reliable thermal performance while also minimizing their surface roughness. Tests have shown that high frequency signals travel on the conductor surface, (skin effect) so it is becoming more vital to have a smooth surface conductors in such applications, where a micro-etched roughened surface will exhibit a loss of signal integrity.

Secure™ HFz is targeted to provide a smooth conductor surface that is essential in the high frequency application of future IC substrate. The conventional micro-etching based treatment creates a roughened surface that serves as micro-anchors to ensure excellent bonding and adequate thermal reliability. Contrary to the widely accepted technology, Secure™ HFz solely uses chemical bonding to provide superb bonding and exceptional thermal reliability without tampering with the conductor dimensions.

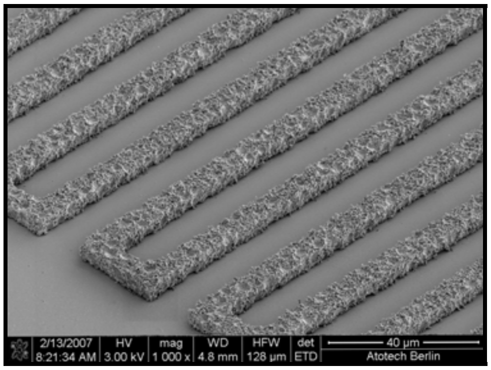

Figure 1. 10 µm line and space treated with micro roughening chemistry

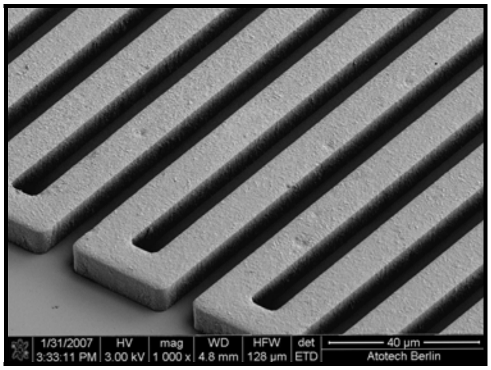

Figure 2. 10 µm line and space treated with non-etching adhesion promoter chemistry

Process Description

Secure™ HFz is 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. 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 Sequence

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 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 stabilize 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.

- Sn – O – Si – R’ -

The organosilanes of the following general structure were found to be suitable coupling agents. These organosilanes form strong bonds with the metal oxides

- Sn – O – Si – R’ – Resin

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 impendence requirements.

Experiment

A typical SAP board was chosen as the test vehicle for the experiment. The sample boards were treated with Secure™ HFz and various etch based chemistries such as a widely accepted oxide replacement process by the industry. The initial circuit features were characterized using LIM, the average conductor width, height, and spaces were recorded.

After the test boards were processed with each surface treatment processes, they were characterized by using SEM, LIM, and AFM analysis. The adhesion and thermal performance was shown using standard industrial methods such as peel strength measurement and HAST.

Results

When the conductor dimension after the Secure™ HFz process (Figure 5) is compared to the original conductor features (Figure 3), the SEM pictures clearly show that the conductor surface is not roughened by the process. In contrast, the etch based process shown in Figure 4 exhibits the roughened conductor surface that is not ideal for high frequency applications.

AFM analysis has shown Secure™ HFz is a flat process with no roughness created on the surface. When compared to the process of record for the etching based process, the Ra is reduced by 77%, Rms is lower than 78%, and Rz has decreased by 81%.

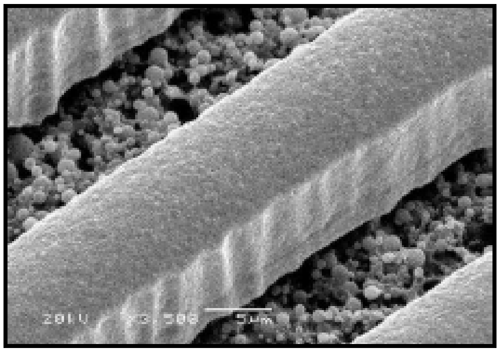

Figure 3. 12 µm line (after differential etch) after treatment with micro roughening chemistry

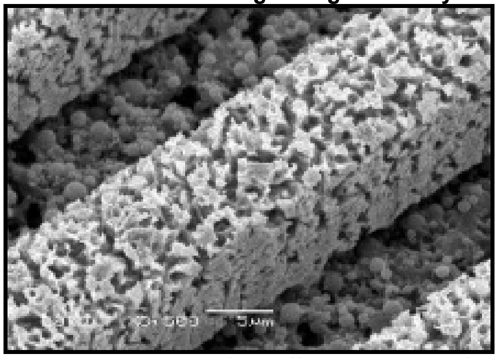

Figure 4. 12 µm line (after differential etch) after treatment with micro roughening chemistry

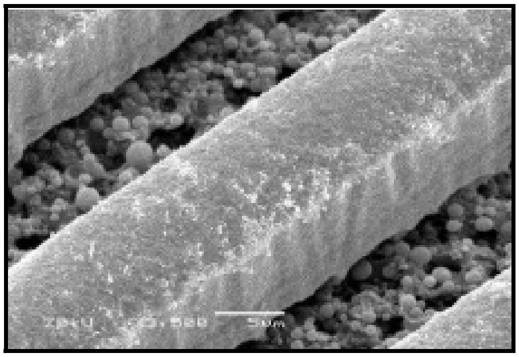

Figure 5. 12 µm line (after differential etch) after treatment with Secure™ HFz process

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

Table 1. AFM analysis on surface after various treatments

Process	R_a (µm)	R_{ms} (µm)	R_z (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 2. Analysis of measured conductor width change vs. initial conductor width after various treatments

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

Table 3. Analysis of measured conductor width change vs. initial conductor height after various treatments

Process	Height (µm)	ΔHeight (µm)
Before Treatment	16.4 ± 0.57	-
BondFilm®	15.7 ± 0.41	0.6
Secure™ HTg	15.6 ± 0.61	0.7
Process of Record	14.2 ± 0.94	2.1
Secure™ HFz	16.2 ± 0.32	0.1

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

Figure 6 shows the peel strength results for Copper surfaces treated with Secure™ HFz and then bonded to build up type films that were subsequently subjected to HAST conditions for 48 and 96 hours. The results show that even the exposure to extreme humidity and heat does not cause a significant reduction in the peel strength.

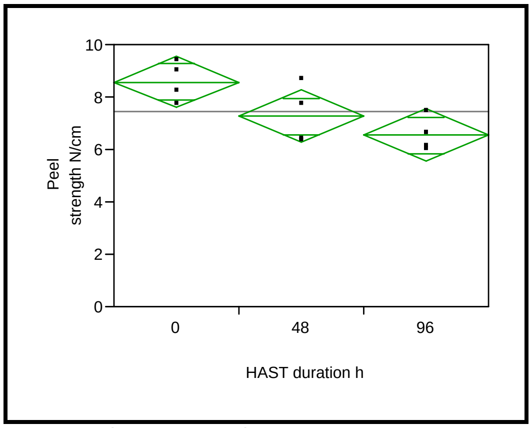

Figure 6. One-way ANOVA showing adhesion performance under different HAST exposure times

Despite a lack of micro-etched surface acting as an anchor for mechanical bonding, the chemical bonding by Secure™ HFz provides superb bonding ability for a smooth conductor surface. Figure 7 shows that the non-etching adhesion promoter has a peel strength that is comparable to the etch based process.

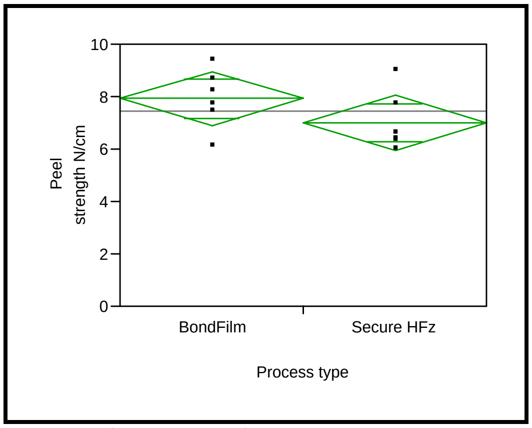

Figure 7. One-way ANOVA showing adhesion performance with different treatment processes

The non-etching adhesion promoter is also suitable as a pre-treatment for solder resist applications. Figure 8 shows smooth conductor surfaces treated with Secure™ HFz after coating with solder resist.

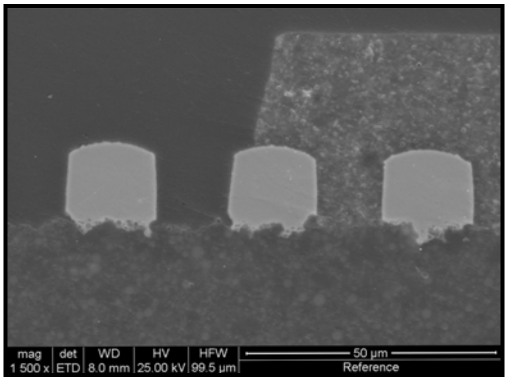

Figure 8. 10 µm line and space treated with non-etching adhesion promoter chemistry

The peel strengths measured for two solder resists typical to an IC substrate application have also shown sufficient values (Figure 9). The experimental results prove that the chemical bonding from Secure™ HFz is robust enough to bond the smooth surface and the solder resist.

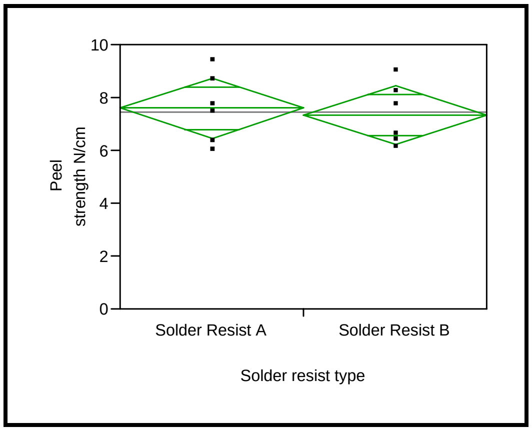

Figure 9. One-way ANOVA showing adhesion performance with different solder masks

Summary & Conclusion

The future of outer and inner layer bonding for IC substrates is undoubtedly moving in the direction of non-etching adhesion promoters. Secure™ HFz has proven that it can provide the superb bonding and excellent thermal reliability for a smooth conductor that is essential in a high frequency IC substrate application.

The Secure™ HFz process characterization demonstrates that it is a viable “non-etching” adhesion promoter. The SEM, AFM, and LIM analysis clearly illustrate that conductors down to 12 µm can be fabricated with the excellent shape characteristics required for favorable electrical performance. Having R_a values less than 0.05 µm and statistically no loss of conductor width or height after processing.

Secure™ HFz is in a unique position, where it can offer the future PCB and IC substrate industries the non-etching solution for excellent bonding and outstanding thermal reliability.