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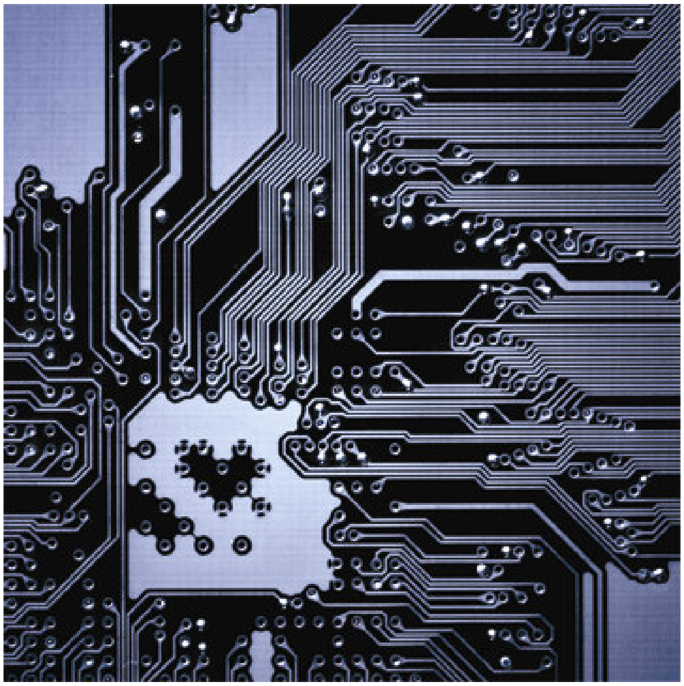

ADHESION PROMOTION TECHNOLOGY FOR SEMI-ADDITIVE PROCESS

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Rohm and Haas Electronic Materials

The increased functionality of today's advanced electronics, such as multi-function mobile equipment, is driven by semiconductor technology development. The added functionality of semiconductor and passive devices increase circuit density and decrease the available assembly space in the device. Packaging substrates are controlled by semiconductor trends. As semiconductor chip performance improves, the substrates and packaging technologies must keep pace.

This paper discusses a unique Adhesion Promotion Process designed for the semi-additive fabrication of advanced flip-chip packaging substrates. In these applications, 2-D measurements, such as Ra (average roughness), have been the traditional parameters specified to control surface quality. In this article we will explore how 3D parameters can be employed to provide greater insight into surface finish and performance. [1] In particular, we will focus on characterizing the effects of carrier films surface at each step of the adhesion promotion process, using 3-D surface profile parameters.

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INTRODUCTION

This paper discusses a unique Adhesion Promotion Process for semi additive process in advanced flip chip packaging substrate fabrication. A clear understanding of the parameters that affect the metallization process is necessary to obtain stable adhesion of the circuit pattern. Permanganate has been adopted due to its highly oxidative nature and its ability to produce the proper texture on resin surfaces. The adhesion promotion process consists of the following steps: i) swelling of resin with an alkaline solvent solution, ii) oxidation and removal of the swelled resin with an alkaline permanganate solution, iii) neutralization and removal of permanganate residues. Resin etching properties and adhesion is directly linked to the insulating resin and its properties. Proper optimization of process conditions is necessary for each individual resin.

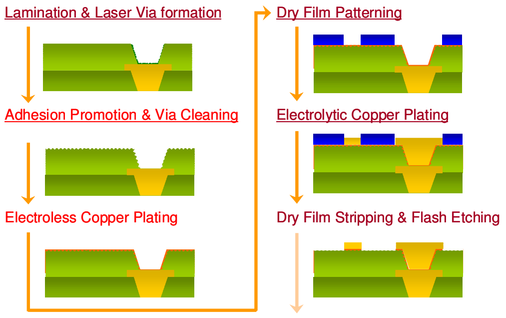


Fig.1 Semi-Additive Process flow for the package substrate insulator

Currently, average roughness (Ra), is the parameter specified for controlling surface quality. The influence of surface average roughness (Ra) does not correlate well to peel strength between epoxy substrates and plated copper. In this article, we will use 3-D roughness parameters to provide a better insight into the relationship between peel strength and surface roughness.

EXPERIMENT

Two types of carrier films were investigated in this study. Carrier films are used to transport the substrate to vacuum lamination. During the pressing step, the carrier film roughness will impact the roughness of the substrate after lamination.

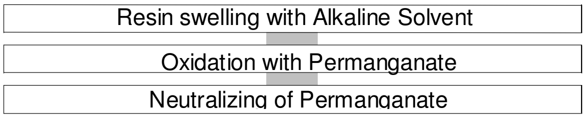
A single dielectric material was investigated in this study, Ajinomoto Build-up Film ABF-GX13.

Process Evaluation:

Adhesion Promotion Process

After laminating and curing the build-up resin, the dielectric is chemically treated to form the desired microstructure on the surface and remove smear from the bottom of the blind vias. The microstructure is formed by oxidation of the insulator resin and simultaneously removing filler particles in the insulator. The removed resin and filler form microscopic pits on the surface which are later utilized as anchors for the electroless copper. Fig. 2 is a typical process flow.

Fig.2 Process Flow of Adhesion Promotion on Insulator



Electroless copper plating process

After the adhesion promotion process, a conductive seed layer is formed using electroless copper. Fig.3 demonstrates a typical process flow.

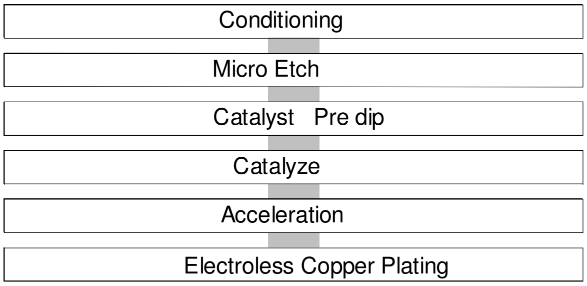


Fig.3 Process Flow of Electroless Copper Plating

In order to observe the effects of carbonate by-product in the Promoter step (generated by the reaction of hydroxide with the carbon dioxide formed when resin is attacked by permanganate), we fixed the bath concentration and process parameters and then allowed the by-product concentration to increase by processing panels.

Test Matrix:

Test no.	1	2	3	4	5
Sweller					
Bath Strength. (%)	100				
Alkali (N)	0.25				
Temperature (^oC)	65				
Dwell Time (min.)	10				
Promoter					
$NaMnO_4$ (g/L)	60				
Na_2MnO_4 (g/L)	7				
NaOH (N)	1.2				
Na_2CO_3 (N)	**0.06**	**0.53**	**1.15**	**1.81**	**2.42**
Specific Gravity	**1.09**	**1.111**	**1.161**	**1.2**	**1.245**
Temperature (^oC)	83				
Dwell Time (min.)	15				
Neutralizer					
Bath Strength (%)	100				
Acid Normality	0.3				
Temperature (^oC)	45				
Dwell Time (min.)	5				

Measurement:

Surface Profiler: In this paper, the surface profile measurements were made with a Wyco® NT8000 Optical Profiler.

Surface Parameter Definition:

Ra (Roughness average): is the main height as calculated over the entire measured length or area. It is quoted in micrometers or micro-inches. Ra is calculated per the ANSI B46.1 standard.

Sds (Density of Summits of the Surface): This is the number of summits of a unit sampling area, which relies on the eight nearest neighbor summits definition.

Sdr (Developed Interfacial Area Ratio): This is the ratio of the increment of the interfacial area of a surface over the sampling area. The developed interfacial area ratio reflects the hybrid property of surfaces. A large value of the parameter indicates the significance of either the amplitude or the spacing or both

Sm (Peak Materiel Volume of the Surface): the peak material volume is defined as the material portion enclosed in the 10% bearing area and normalized to unity.

Sc (Core Void Volume of the Surface): The core void volume is the void portion enclosed from 10% to 80% of surface bearing area and normalized to the unit sampling area

Sv (Valley Void Volume of the Surface): The valley void volume of the unit sampling area is defined as a void volume at the valley zone from 80% to 100% of surface bearing area.

X-SM(the mean peak spacing): Sm is measured by selecting an evaluation length (X) from the roughness curve, and determining a width of each peak and calculating the mean value of the width

Peel strength: in this paper the peel strength measurement is done by Zwick® Universal test machine.

RESULT AND DISCUSSION:

Carrier Film Roughness Comparison:

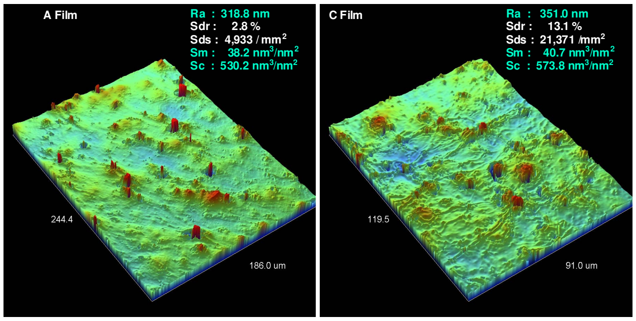


Fig.4 Carrier Film Surface Profile Comparison by 3-D Measurement

Carrier Film A	Carrier Film C
Ra : 318.8 nm Sdr : 2.8 % Sds : 4,933 / mm2 Sm : 38.2 nm3/nm2 Sc : 530.2 nm3/nm2	Ra : 351.0 nm Sdr : 13.1 % Sds : 21,371 /mm2 Sm : 40.7 nm3/nm2 Sc : 573.8 nm3/nm2

A significant difference was found between the surface profiles of Carrier Films A and C. Film A differs from Film C in both Sdr (Developed Interfacial Area Ratio) and Sds (Summit Density) value from C Film. While the Sdr and Sds values of Film C are more than 4 times greater than those of Film A, the Ra values for the two films are very similar.

"As Is" ABF GX13 Surface with different carrier film Lamination Comparison:

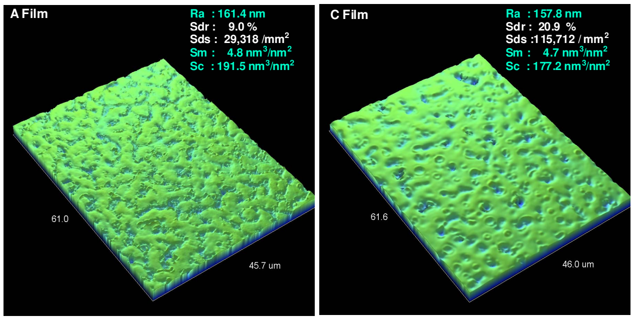


Fig.5 Effect of Carrier Film Type on ABF-GX13 Surface Profile by 3-D Measurement

GX 13 Surface by Carrier Film A	GX 13 Surface by Carrier Film C
Ra : 161.4 nm Sdr : 9.0 % Sds : 29,318 /mm2 Sm : 4.8 nm3/nm2 Sc : 191.5 nm3/nm2	Ra : 157.8 nm Sdr : 20.9 % Sds :115,712 / mm2 Sm : 4.7 nm3/nm2 Sc : 177.2 nm3/nm2

When different types of carrier films are used in lamination, the resulting ABF surface structures differ significantly in both in Sdr (Developed Interfacial Area Ratio) and Sds (Summit Density) value.

“After Adhesion Promotion” ABF GX13 Surface with different carrier film Lamination Comparison:

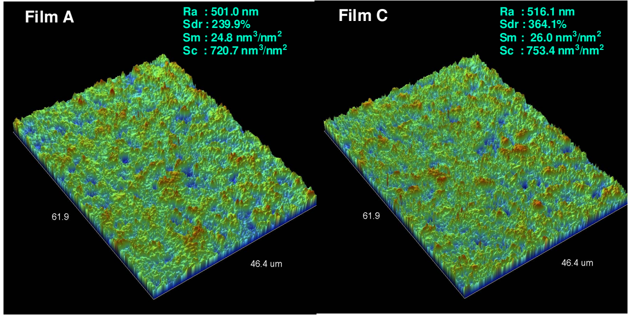


Fig.6 ABF GX13 Surface Profile with different carrier film lamination after adhesion promotion comparison by 3D measurement

GX 13 Surface by Carrier Film A After Adhesion Promotion	GX 13 Surface by Carrier Film C After Adhesion Promotion
Ra : 501.0 nm Sdr : 239.9% Sds : 185,955 /mm2 X-Sm : 1767.7 nm Sm : 24.8 nm3/nm2 Sc : 720.7 nm3/nm2	Ra : 516.1 nm Sdr : 364.1% Sds : 237,749 /mm2 X-Sm : 1528.0 nm Sm : 26.0 nm3/nm2 Sc : 753.4 nm3/nm2

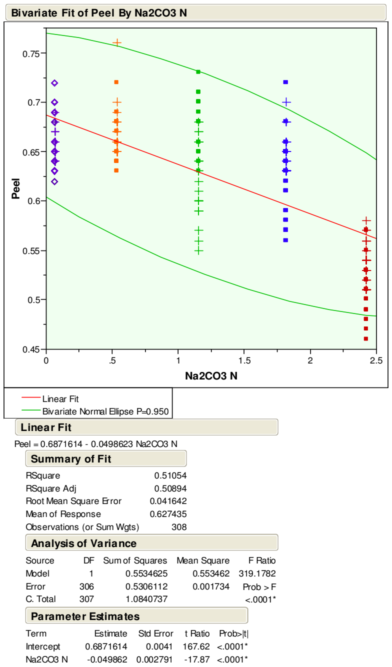
Even after the adhesion promotion process, the effect of different carrier films on Sdr and Sds can still be clearly observed.

Once more, the values of Ra for the two different carrier films are quite similar. Based on the above evaluation of carrier film effects on surface profile, both after lamination and after adhesion promotion, we can clearly see that Sdr and Sds are much better measures of surface roughness differences than Ra.

The type of carrier film used has a significant impact on the surface roughness after the adhesion process.

Correlation between Peel Strength and Sodium Carbonate Normality

In the Fig. 7 there is significant Correlation between Peel Strength and Sodium Carbonate Normality. If Sodium carbonate normality exceeds 1.5 N Peel Strength begins to decreases, and if 2.0 N is exceeded, it will decrease greatly.



Bivariate Fit of Peel By Na2CO3 N

Linear Fit
Bivariate Normal Ellipse P=0.950

Linear Fit

Peel = 0.6871614 - 0.0498623 Na2CO3 N

Summary of Fit

RSquare	0.51054
RSquare Adj	0.50894
Root Mean Square Error	0.041642
Mean of Response	0.627435
Observations (or Sum Wgts)	308

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.5534625	0.553462	319.1782
Error	306	0.5306112	0.001734	Prob > F
C. Total	307	1.0840737		<.0001*

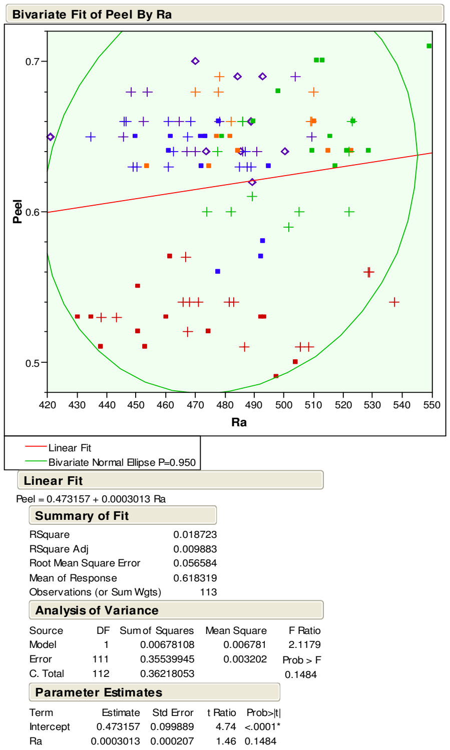
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.6871614	0.0041	167.62	<.0001*
Na2CO3 N	-0.049862	0.002791	-17.87	<.0001*

Fig.7 Correlation between Peel Strength and Sodium Carbonate Normality

Correlation between Ra Value and Peel Strength

From the Fig 8, it is clear to see there is no correlation between Ra and Peel strength.



Bivariate Fit of Peel By Ra

Linear Fit
Bivariate Normal Ellipse P=0.950

Linear Fit

Peel = 0.473157 + 0.0003013 Ra

Summary of Fit

RSquare	0.018723
RSquare Adj	0.009883
Root Mean Square Error	0.056584
Mean of Response	0.618319
Observations (or Sum Wgts)	113

Analysis of Variance

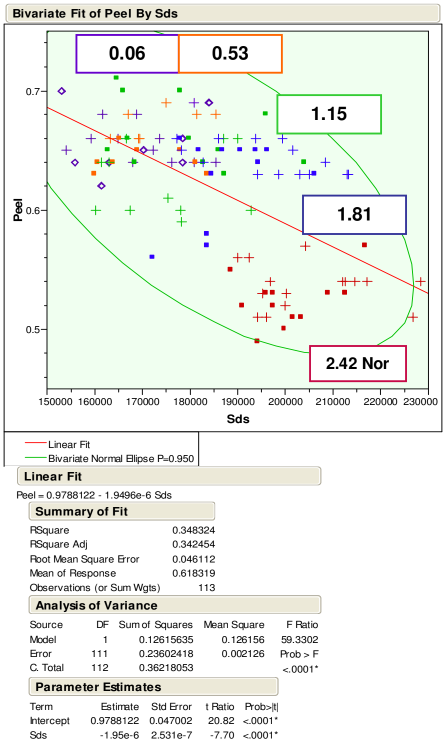
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.00678108	0.006781	2.1179
Error	111	0.35539945	0.003202	Prob > F
C. Total	112	0.36218053		0.1484

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.473157	0.099889	4.74	<.0001*
Ra	0.0003013	0.000207	1.46	0.1484

Fig.8 Correlation between Ra Value and Peel Strength

Correlation between Peel Strength Value and Sds value (3D) (Summit Density)



Linear Fit

Peel = 0.9788122 - 1.9496e-6 Sds

Summary of Fit

RSquare	0.348324
RSquare Adj	0.342454
Root Mean Square Error	0.046112
Mean of Response	0.618319
Observations (or Sum Wgts)	113

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.12615635	0.126156	59.3302
Error	111	0.23602418	0.002126	Prob > F
C. Total	112	0.36218053		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.9788122	0.047002	20.82	<.0001*
Sds	-1.95e-6	2.531e-7	-7.70	<.0001*

Fig.9 Correlation between Sds, and Peel Strength

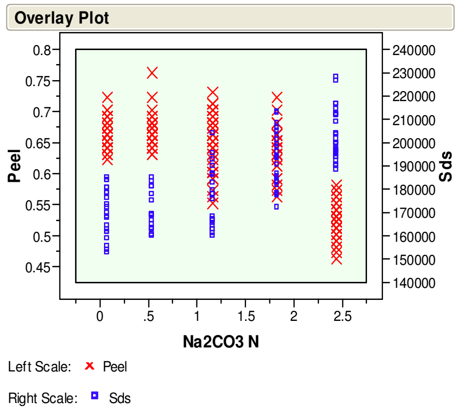


Fig.10 Correlation between Sds, and Peel Strength

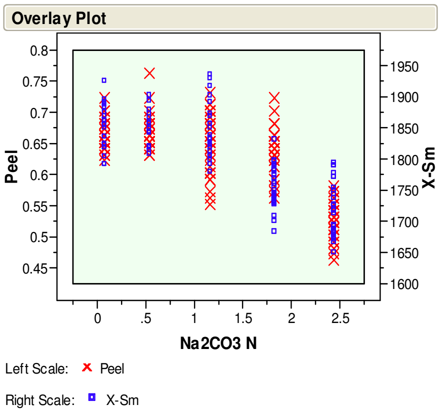


Fig.11 Correlation between X-Sm, and Peel Strength

Figures 9 and 10 show that peel strength decreases are associated with increased values of Sds. At sodium carbonate normalities over 2.4N, values of Sds increase to 190000/mm3 or more. At this range of Sds values, peel strengths are observed to decrease significantly. Figure 11 show that peel strength decreases are associated with decreased values of X-Sm. At sodium carbonate normalities over 2.4N, values of X-Sm fall to 1800nm or less. In this range, peel strength decreases significantly.

Overall, if values of either Sds and X-sm fall outside of an optimum range, a sharp decrease in peel strength is observed. The exact numeric values of Sds, Sdr and X-Sm identified in this study are not absolute indicators of performance. Differences in dielectric and lamination materials and process variables such as carrier film type, vacuum lamination parameters and curing conditions are expected to affect these values. However, the overall trends seen in this study are likely to be applicable to a wide range of conditions.

CONCLUSION

3-D surface profile analysis provides more detailed information than 2-D measurements, such as Ra. In particular, values of Sds and Sdr are shown to be very valuable for analysis of the effects on dielectric film surface properties of different carrier films, curing processes and vacuum lamination conditions.

For bath control purposes, values Sds and X-Sm are shown to correlate to peel strength values. Both parameters demonstrate threshold behavior, with peel strength values decreasing greatly beyond a particular value.

In order to maintain consistent performance of a SAP adhesion promotion process, many factors need to be controlled, including carrier film type, vacuum laminator, dielectric material curing and the sodium carbonate concentration in the promoter bath.

While no significant correlation is seen between Ra and peel strength, 3-D parameters provide useful insights into surface finish and performance.

REFERENCES

[1] Mike Zecchino, Characterizing Surface Quality: Why Average Roughness is not enough. *ADVANCED MATERIALS AND PROCESSES* 2003, VOL 161; PART 3, pages 25-30