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New Materials for HDI Interconnect Applications

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Abstract. A study was conduced to see if faster laser ablation rates, improved fracture resistance and better copper adhesion after electroless plating could be engineered into existing Resin Coated Foils (RCF) with out diminishing any thermal, electrical or mechanical properties -- all while staying cost competitive. That the main factors that can influence ablation rates and fracture resistance are possibly thru base resin chemistry while the improved adhesion of electroless platted copper is believed to be more influenced by the surface roughness and morphology of an etched circuit board.

Introduction The past decade has seen a huge growth in the sales of personal electronic devices: cell phone, pagers, game-boys to name but a few. As these electronic devices have gotten smaller and smaller, the need for new High Density Interconnect (HDI) materials and processes has emerged, and this in turn has challenged PWB shops and suppliers to meet the demanding need for smaller microvias, and better process ability for closer circuit traces. All this while maintaining current production equipment and raw material costs.

The challenge was to find one panacea that would meet the targets just mentioned while maintaining all other electrical, mechanical, processing properties and cost. This study took three approaches:

1. Doping the resin with an agent with the intent of adding toughness, providing more surface area and or roughness aiding in the deposition of electroless platted copper and perhaps increasing absorption of the laser energy.
2. Modify the base resin chemistry such that it is more susceptible to processing chemicals and thereby altering the surface morphology while at the same time increasing the IR absorption in the same region as the CO_2 laser.
3. Varying the surface treatment of the substrate copper in an attempt to modify the surface morphology of the etched laminate. Various combinations of these treatments were made.

Table 1 shows the modification to the RCF samples reported here. All samples were treated on various coppers having different surface treatments. Not all samples tested were reported here.

Table 1 - Sample Modifications and Rational

Sample ID	Modification	Rational
A	Control	----
B	Resin Modification	More susceptible to processing chemistries
C	Phosphorous Doped	$(PO)_4$ Compounds strongly absorb in the same IR region as a 9.3 um Laser[1]
D	Resin Change and Green Dye	Some evidence that materials doped with a complimentary dye increases that laser's absorption[2] Same base resin as sample "B".
E	Silica Doped	Si containing compounds also strongly absorb in the same IR region as a 9.3 um Laser[1]

Materials and Methods

All RCF samples used in this study were two pass coated with resin to a nominal thickness of 66 microns; the first 33 microns being "C" staged to ensure dielectric thickness and the second 33 micron pass "B" staged ensuring proper trace and via filling. The copper substrates coated were from several different vendors, each with their own unique pre-treatment coating on the matt surface of the copper. The nominal thickness of the copper used was 18 microns, or a weight of ½ oz. copper per square foot.

Test boards for laser drilling were prepared by laminating each coated foil sample to a .014" clad with ½ oz. copper treated with an AlphaPREP™ surface treatment. The outer layer of copper was removed via standard cupric acid etch and the test panel then re-laminated with the same sample of coated foil, again with the outer layer of copper removed via acid etch. This resulted in a test board with a nominal 125-135 um coating of fully cured resin.

An Excellon 9.3 micron CO_2 laser was set to supply 150 mJ per pulse with a pulse duration of 10 microseconds. The 9.3 laser is a "T" type laser whose crossbeam temperature is uniform and ablates material in a stepwise manner. All samples were de-smeared using standard permanganate chemistry prior to analysis. The drilling test pattern consisted of 120 holes per "field" with each field having 4 rows of holes with 30 holes per row. The holes were 200 um in diameter. Field one had one laser pulse, field two had two laser pulses and so forth.

For analysis of laser ablated hole wall quality and depth, each sample was potted and cross-sections prepared. For samples that were not ablated to the capture pad only depth measurements were taken. Samples that did reach the capture pad the volume of material removed was calculated. A Gage R&R study variation of 17% was recorded for measuring these laser ablated holes well with-in the 9-30% requirement for an acceptable gage.

Test panels for impact toughness were prepared by laminating each RCF sample onto a 4”x12” cold rolled steel panel. This was cured is a lab scale press for 90 minutes at 350F under 100 psi pressure. The sample was then acid etched to remove the copper. The final test panel had a nominal 66-micron coating of fully cured resin. The test panels were then impact tested as per ASTM D2794-93. This test drops a 2 Kg. weight at varying heights and records the Kg.-cm. of impact before resin failure. Also tested was the neat resin’s tensile elongation and modulus.

Samples for electroless copper adhesion were prepared as per standard industry practices: RCF samples were laminated onto standard 0.014” laminates, acid etched, surface prepped, permanganate swelled, neutralized then electroless copper flash plated onto the surface followed my an electro plating to a nominal thickness of 35 microns. The boards were thermally cycled as per standard PWB processing and the copper peel strength measured as per standard IPC methods.

Results

After laser ablation, hole depth and volume of material removed were calculated. At one and two pulses none of the samples were ablated to the landing pad. Each RCF sample measured seven holes with the greatest depth. All but one sample required three pulses to reach the bottom of the hole. Figure 1. and 2. show the box plots of hole depth at one and two pulses of energy. Analysis of variance shows this data to satisfy a 95% confidence level for a difference of means between samples. Only sample “B” showed a consistent 10% increase in hole depth compared to control sample “A”. Sample “E” consistently fared much worse than the control.

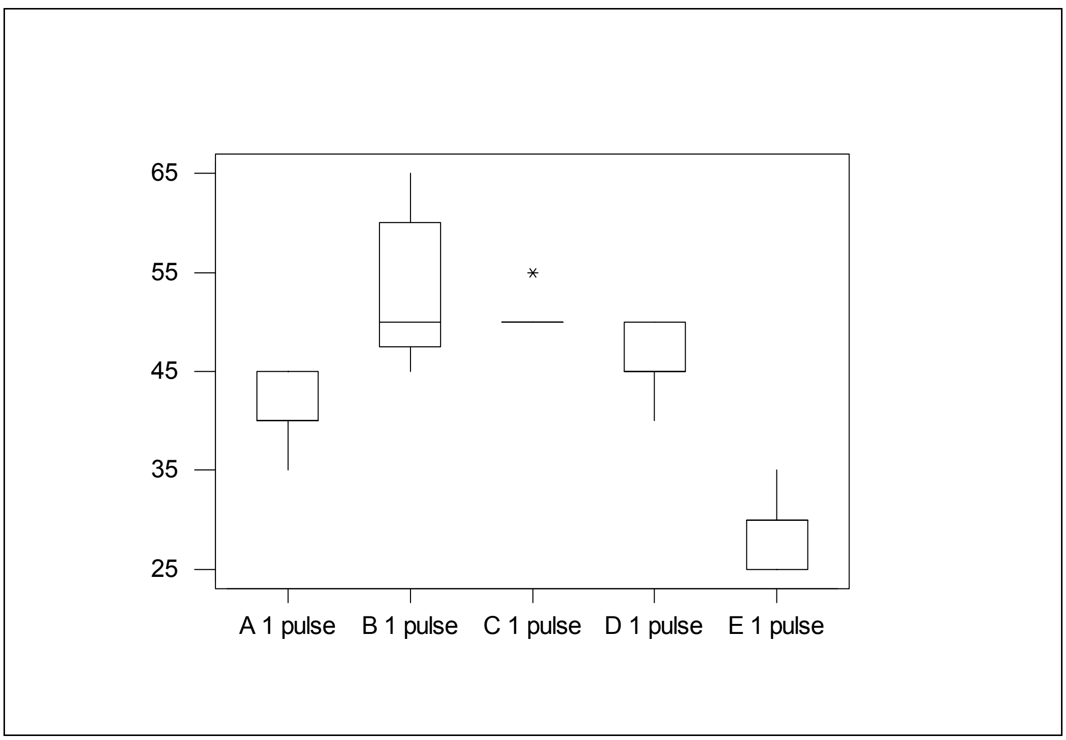

Figure 1 - One Pulse Data 9.3 Laser

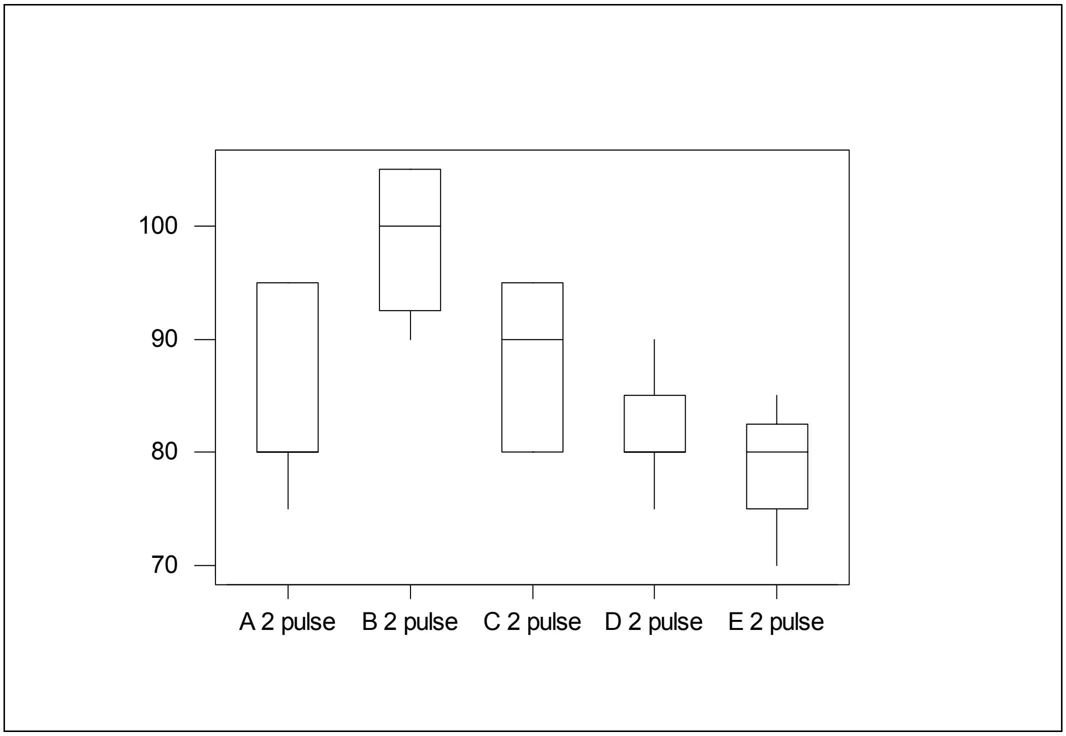

Figure 2 - Two Pulse Data 9.3 Laser

For the 3 pulsed laser set the volume calculations again show that samples “B” and “C” had a >11% increase in material ablated compared to control sample “A”. Samples “D” and “E” fared much worse compared to the control. See Table 2.for the calculations.

Likewise for toughness and impact resistance, all samples, with the exception of the Silica doped sample, had much improved impact resistance as compared to control sample “A”. This study found no correlation between Tensile Modulus, Elongation or Fracture resistance, this probably due that to different approaches were take, a base resin modification and the addition of dopant into the base resin. See Table 3 for the toughness data.

Table 2 - Volume Calculations for 3-pulse Laser Ablation with a 9.3 um Laser

Sample code	Modification	Volume calculation 10^{-13} M^3	%Δ Compared to control
A	Control	79.4	----
B	Resin Change	89.1	+12%
C	Phosphorus Doped	88.2	+11%
D	Resin Change / Green Dye	71.2	-12%
E	Si Doped	66.0	-20%

Table 3 - Tensile and Impact Value Data

Sample	**Tensile Modulus** (Mpsi)	% Elongation	**Impact Results** (Kg-cm.)	%Δ Compared to control
A	0.437	5.6	57.5	---
B	0.389	7.0	161	180 %
C	0.391	3.9	103.5	80%
D	0.379	7.0	161	180%
E	0.463	6.0	46	-20%

As for finished board copper peel strength; both samples “B” and “E” had significantly higher values than the control sample “A”, see Figure 3. This improvement is most likely attributed to the surface roughness of the etched panel, due to the roughness of the copper that was etched off, than any resin modification. This is more clearly seen in Figure 4.

Finally Figure 5. shows the relative change in all properties tested, ablation rates, toughness and peel strength, as compared to control sample “A”. Sample “B” clearly had the best overall improvement of properties.

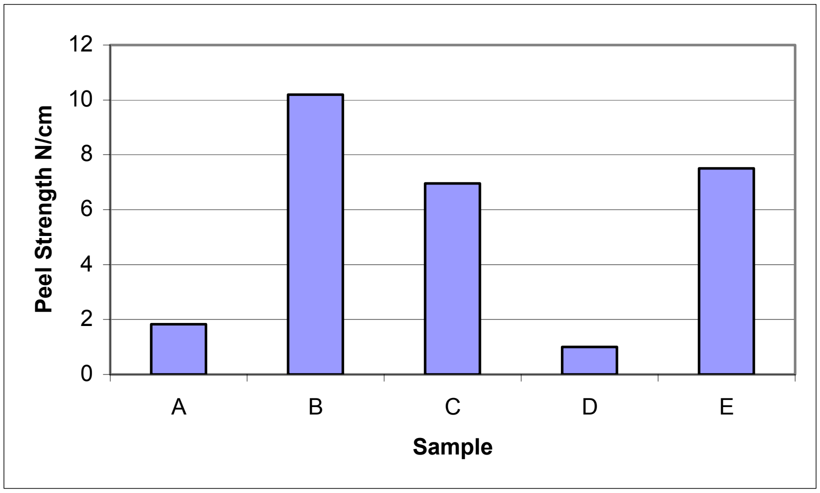

Figure 3 - Copper Peel Strength Results

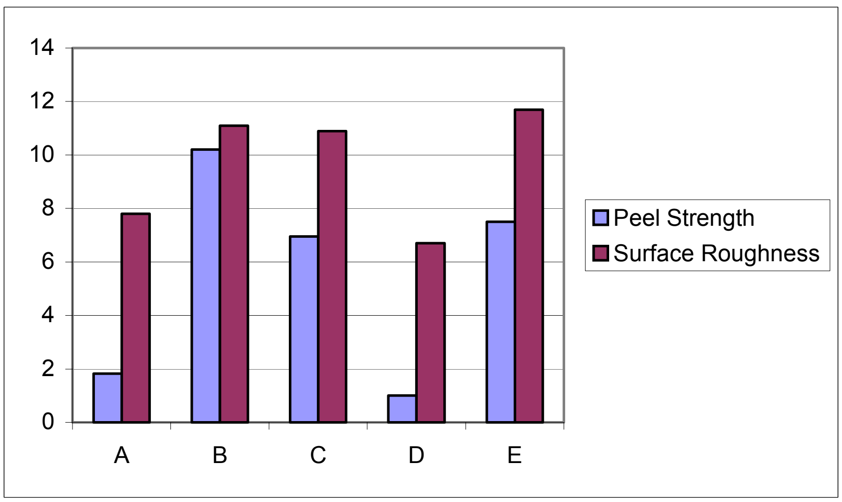

Figure 4 - Copper Peel Strength Results and Surface Roughness of Each Sample

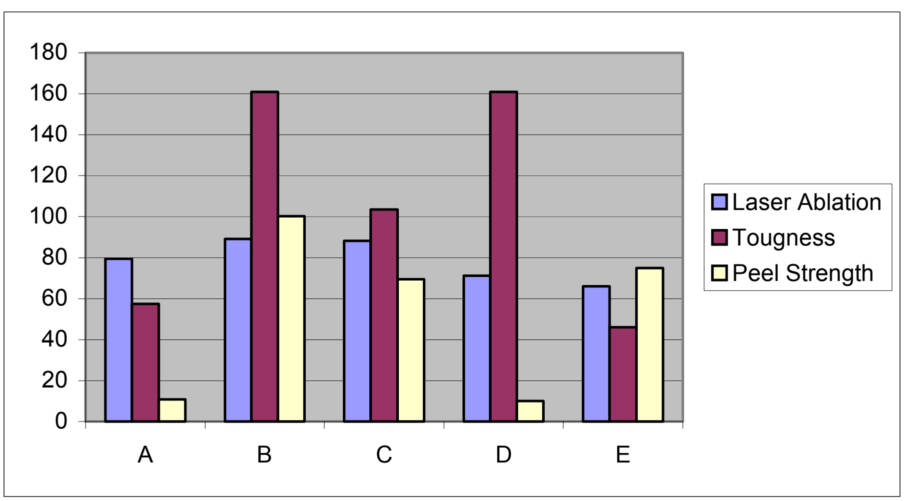

Figure 5 - Relative Comparison of all Properties Tested per Sample

Discussion

This study shows that for RCFs, the main contributors to increased laser ablation and improved fracture resistance are had through base resin modifications and that final copper peel strength is more greatly influenced by surface morphology than resin chemistry.

Laser ablation was shown to improve via two factors, base resin chemistry and by the addition of a Phosphorous dopant. In this study there is no evidence that a dye improved the absorption of the laser and thereby the ablation rate of the resin. Likewise toughness was also shown to improve through a base resin modification, this was true both with or with out the addition of a dye to the resin. The addition of a Silica dopant hurt fracture toughness and decreased the laser ablation rates.

And finally with all the resin modifications and treatments, the main contributor to increase ultimate copper peel strength was found to be influenced by the surface morphology of the resin prior to electroless platting. Samples that contained a dopant, when coated on copper with a higher surface roughness, did not have as high a peel value as the neat resin sample, this probably because with a dopant there was physically less resin available for the copper to adhere to. The rougher the copper treatment, and therefore the rougher the resin surface after acid etch, the higher the ultimate Copper peel strength.

Acknowledgements

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