Thermal Reliability of Laser Ablated Microvias and Standard Through-Hole Technologies as a Function of Materials and Processing

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Abstract

High Density Interconnect (HDI) technologies are being used widely in Asia and Europe in consumer electronics for portable wireless communication and computing, digital imaging, and chip packaging. Although North America lags behind in developing process capability for this technology, HDI will become a significant business segment for North America. For this to happen, the printed circuit board shops will have to become process capable in fabricating fine lines and spaces, and also be capable in forming and plating microvias.

This two-part paper will look at the thermal reliability of microvias and standard vias in relation to the materials and processes in which by they are created. The reliability of the interconnect is measure using several different techniques including standard thermal shock, Interconnect Stress Testing (IST™), and air to air thermal cycling.

Introduction

Part I of this paper will address the materials used and the method of via formation, and the subsequent effect on reliability. Part II will address the processing of the materials and the effect that the processing has on the reliability of the finished product.

Materials Evaluated

The materials evaluated in this study were FR-4 (140°C nominal Tg) and un-reinforced resin coated copper (RCC®).

Typical Redistribution Dielectric Structures

A redistribution dielectric suitable with via drilling can be one of the following:

- FR-4 laminate or prepreg with foil cap
- Resin coated foil
- Aramid laminate, or prepreg with foil cap (lasable prepreg)
- Polyimide film-based laminate
- PTFE-based prepreg
- Liquid or dry film based lasable dielectric coatings

A designer or fabricator's selection will in part depend on the via drilling approach. For example, inorganic reinforced materials will not plasma etch. Polyimide film is expensive, exhibits dimensional stability sensitivity and is chemically different than the substrate, making processing difficult. PTFE is also very expensive and chemically different than the underlying substrate. Lasable dielectric coatings run into plating issues (variable thickness) and difficulty in fabricating fine lines.

FR-4, Lasable Prepreg, and RCC are particularly attractive for several reasons: Their resin chemistries are similar to the substrate materials, which reduce problems with UL recognition, and their homogeneity facilitates fabrication steps. They are also the most cost-effective materials, and shops are quite familiar with their use.

RCC offers surface smoothness, thin dielectric, standard laminating steps, and ease of ablation due to its non-reinforced composition. Lasable prepreg also lends itself to relatively high laser speeds and clean holes. FR-4 has not been widely acknowledged as suitable for redistribution layers because its ablation characteristics were considered minimal with the laser. The ability to add a sufficiently thin dielectric of high integrity (smoothness, uniformity, etc.) was also questioned. However, today many shops are able to lay up and laminate panels with 12 micron copper foil and one ply of FR-4 prepreg as thin as 1.7 mils. The laser suppliers have demonstrated the ability to drill vias through glass reinforced dielectrics at relatively slow speeds.

Material Properties

The two materials compared in this evaluation are 18-35-35 Resin Coated Copper and FR-4 1080 Prepreg. Below are the material descriptions and properties for RCC and FR-4 materials.

RCC

RCC is a unique, thin dielectric for multilayer high density interconnects. It consists of specially engineered layers of resin, supported on electrodeposited copper foil. It is designed to serve as an insulating layer while encapsulating the circuitry and also acting as an outerlayer conductor.

RCC is supplied with a polyliner protecting the B-staged resin. This liner, along with its uniquely toughened resin matrix, reduces cracking, and eliminates resin flaking and epoxy spots due to handling.

The 18-35-35 RCC consists of 18 micron copper (1/2 oz.), a 35 micron (1.4 mils) C-Stage (fully cured) epoxy resin coating, and a second coating of 35 micron (1.4 mils) B-Stage (partially cured) epoxy resin. Its unique structure allows RCC to be used with rigid laminate as a cap layer or sequential build up product. The elimination of glass reinforcement allows the mass formation of blind microvias by means other than mechanical drilling. Both plasma and laser ablation have been used effectively.

FR-4 Prepreg

The FR-4 1080 prepreg consists of a 140°C Tg tetra-functional epoxy resin system, impregnated into a 1080 style woven fiberglass fabric. With a resin content of approximately 65% by weight, the prepreg acts as a bond ply between the subassembly and the foil cap layer. The resulting dielectric spacing is approximately 65 to 70 microns (2.5 to 2.8 mils)

Microvia Drilling Process

FR-4 and RCC can be lased to form microvias. The question becomes the cost to drill and subsequently reliably plate the materials. FR-4 can by lased at fairly low speeds, however it may require a glass removal step prior to plating. RCC products lase at a much faster rate and do not require any glass removal to insure a clean hole wall.

Below in Figure 1, the laser ablation rates in holes per second are displayed. The microvias formed were 150 microns in diameter and varied in depth dependent on the material thickness. The laser used to ablate the microvias was a TEA CO2.

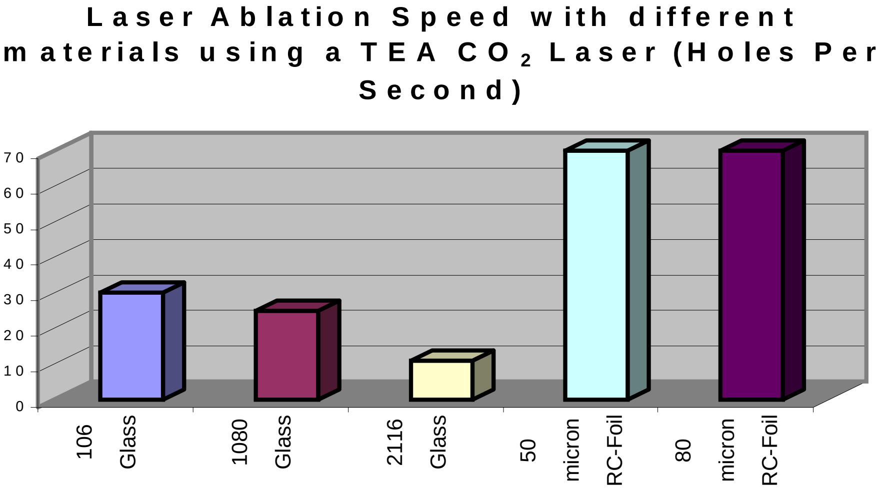


Figure 1

Not only does the RCC drill faster, it yields a much more consistent via hole. This is due to the fact that the RCC is glass free. The laser has only to drill through the homogeneous resin.

FR-4 1080 prepreg, consists of a somewhat open weave fabric fiberglass fabric (See Figure 2), and thermosetting epoxy resin. The fiberglass fabric is impregnated with the epoxy resin to make the prepreg. In the areas were the glass fibers cross or stack on top of each other, the laser will have a more difficult time ablating through this area. In spaces between the glass strands, (resin rich areas) the laser will ablate the material very quickly. This difference in ablation characteristics will cause intra-hole variation in the microvia drilling process.

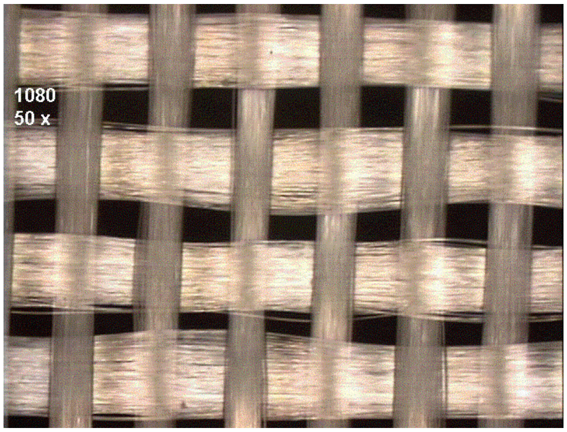


Figure 2 – 1080 Woven Glass

Microvia Costs

With the cost of building a PCB being roughly 70% processing cost and 30% material cost (15% laminate and prepreg, 15% chemistries, dry film etc.) the gains to be made are with overall yield improvement. However, the raw materials will always be scrutinized and the lowest cost solution will be used.

Of the six microvia solutions listed in this paper, The FR-4, RCC and lasable prepreg (not evaluated in this study) materials offer the most cost effective solutions for most PCB shops. All three solutions can be laid–up and pressed using standard FR-4 lamination procedures. The differences in the materials play out further in the outerlayer process.

Laser drill speeds (noted in Figure 1) is the first area to address. If the shops microvia volume is fairly low and the number of microvias to drill per side of the PCB are relatively few (<5,000 per side) then the FR-4 material may be adequate for this (non-laser drill constrained) situation. Where the microvia volume is relatively high and the number of microvias per side of the PCB are high (>5,000) the RCC may work best for this (laser drill constrained) situation.

Hole wall prep and plating is the next area to address. Both the RCC and FR-4 materials can be desmeared and plated utilizing standard chemistries. However it should be noted that the desmear process for the RCC will have to be modified to optimize the hole wall and capture pad cleaning/preparation. Typically the desmear needs to be slightly more aggressive, to attack the high Tg resin systems used in the RCC.

Plating issues arise with the size and shape of the microvia. The small diameter and dead end geometry makes it difficult to adequately plate a seed layer down into the interconnect. In the standard electroless process, hydrogen gas is evolved, and due to the microvia geometry, is often difficult to eliminate. Direct metalization of the microvia using a colloidal graphite system, Shadow®, has proven to yield much more reliable microvias.

The formation of fine lines and spaces is another area to look at. RCC helps enable the formation of fine lines and spaces (≤ 75µm/3 mil). Because RCC products are free of woven fiberglass, their surface topography after lamination is much smoother, allowing for a cleaner etch during line formation. RCC also enables fine lines by reducing epoxy spots due to pinhole in thin coppers (< 12µm/3/8 oz.) This is accomplished due to the fact the RCC's C-staged resin is coated and cured void free without the use of pressure. This effectively “plugs” the pinhole in the copper, so that no resin can flow through during the high pressure lamination of the PCB.

All of the above factors affect HDI PCB yields. Material costs must be weighed against the value they bring to each individual PCB shops processing technology.

Part II of this joint presentation describes advancements made in a graphite based direct metalization process. The process is utilized to fabricate high reliability through hole and blind via printed wiring board substrates and interconnection devices. The process is well documented in several publications and in the patent literature. However, several improvements and process modifications have been developed recently, and are detailed in this paper.

With the advent of direct metalization and HDI, questions of long term reliability and performance of vias have surfaced. In addition, the relationship of the vias fabricated with RCC type foils and standard FR-4 versus metalization technique (direct vs. conventional electroless copper) may influence the reliability of the interconnect. A number of factors may affect overall via reliability: (1) uniformity of the electrodeposited copper in the hole, (2) overall plating thickness of the copper, (3) thickness of the plated copper on the capture pad of the microvia, (4) adhesion of the plated copper to the interconnect and (5) any other factors which may interfere with the uniform deposition of plated copper. Subsequently, there are questions as to the reliability of vias fabricated with RCC and FR-4. Other concerns as to the plated copper quality on a surface catalyzed with the graphite system versus standard electroless copper have arisen.

Methodology

In order to measure the reliability of microvias, a standard test vehicle was designed. The design considerations included input from materials suppliers, end users and fabricators involved in HDI. The design included through holes and microvias of various diameters to best reflect the state of the current technology. The panels had both IST™ and AT&T coupons designed in for reliability testing. The plan included the following basic steps:

1. Selection of a test appropriate to the task of demonstrating microvia interconnect reliability under circumstances acceptable to the industry.

The objective included a demonstration of whether production-derived plated microvias and through holes are capable of performance in thermal cycling equal to plated through vias. And if found comparable, to extend the measurement looking for the failure point, although not beyond normal expectations.

The testing medium selected was IPC TM 2.6.26 (proposed), DC Current Induced thermal cycling test, commonly known as IST. This is a relatively new approach to reliability testing, which offers flexibility in coupon design and speed of test, while resulting in failures mechanisms that replicate the more conventional air-to-air testing.

2. Design a test coupon that represents the density and feature sets to be found in HDI/BUM boards. The final coupon incorporates both blind microvias and through vias; it also has two sizes of microvias and through vias. These parameters extend the data to capture a larger population of board features and potential sources of defects. This design is outlined below.

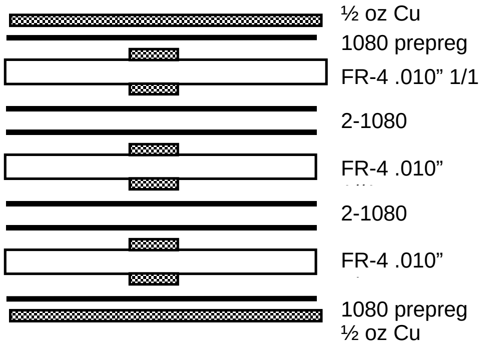
Coupon Feature	**Target Size**
RCC dielectric thickness	50 µm (0.002”)
FR-4 dielectric thickness	60 µm (0.0024”)
Thru via diameters	335µm (0.0135”) & 1,000µm (0.040”)
Pad diameters (thru vias)	700µm (0.028”) & 1350µm (0.054”)
Blind microvia diameter	75µm (0.003”) & 150µm (0.006”)
Pad diameter (capture pads)	300µm (0.012”)
Grid pitch	2500µm (0.100”)
Plating thickness in thru vias	Target 0.5 mil and 1.0 mil
Plating thickness in microvias	Target 0.5 mil and 1.0 mil

The features of the BUM test coupon and panel were selected to complement and build on the partners’ expertise and experiences, keeping consistent with attainment of maximum benefits from the specified testing.

Shown below is the actual construction of the reliability test vehicle coupons.

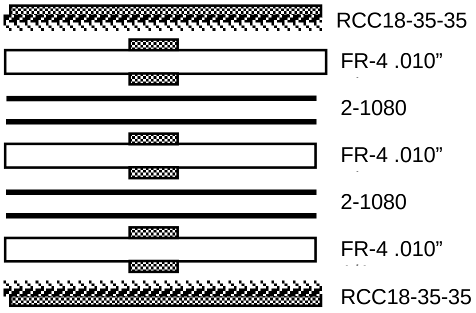
BUM Type A, Material Build

a. Layer count: 8 layers
b. Structure:
  - Innerlayers (2/3, 6/7): FR-4 0.010” (0.25mm)Cu 1/1
  - Innerlayers (4/5): FR-4 0.010” (0.25mm Cu 1/1
  - Cap layers (1, 8): FR-4 1080 pp + Cu foil 1/2 oz
  - Bond layers: 2x FR-4 pp 1080
c. Overall thickness: 0.054±0.004” (1.37 mm)



BUM Type B, Material Build

a. Layer count:	8 layers
b. Structure:	
- Innerlayers (2/3, 6/7):	FR-4 0.010” (0.25mm)Cu 1/1
- Innerlayers (4/5):	FR-4 0.010” (0.25mm)Cu 1/1
- Cap layers (1, 8):	RCC18-35-35 (resin coated foil)
- Bond layers:	2x FR-4 pp 1080
c. Overall thickness:	0.054±0.004” (1.37 mm)



Desmear Process

Work began with conventional permanganate parameters; including a solvent-based sensitizer and a high pH potassium permanganate etch. Weight loss testing was used, looking for a response of approximately 0.3 mg/cm^2, which is considered representative of sufficient desmear of most drilled holes.

FR-4 redistribution layers responded in typical fashion, and no special steps were required. Some RCC products on the other hand exhibited low weight loss; the high cross-linkage chemistry of the dielectric resin required some process refinement to reach an acceptable level of weight loss. Other RCC types are less chemically resistant and can be considered equivalent to FR-4 for process compatibility, although they also have lower Tg’s, which may not match up with the performance of the substrate material. The table below lists the parameters used to desmear the FR-4 material.

FR-4

		0.3-0.4 mg/cm2 wt loss
Hole Swell	Commercially available or butyl caustic mix	**2 minutes/175^o C**
Permanganate	80 g/l $KmnO_4$ 45 g/l NaOH	10 minutes/175^o C
Neutralizer	Commercially Available	5 minutes/115^o C

In order to resolve the issue with the more chemically resistant RCC foils, a new approach to sensitizer chemistry was developed. This patented system was engineered through a careful selection of bio-degradable solvents with a specific range of solubility parameters. By carefully matching the solubility parameters of the solvent(s) to the resin system, optimum penetration was achieved. Through optimum solvent/resin interaction, the permanganate was more efficient at micro-roughening the topography and removing sufficient amount of resin. Standard commercially available systems did not meet the strict criteria of topography enhancement. Thus, the new system had to be developed for resin removal on RCC foils to be successful. Figure 3 and 4 show the results of the standard system and the modified solvent sensitizer. It is quite evident that the modified solvent swell system is necessary for adequate texturing and resin removal for some of the more chemically resistant RCC materials. The table below also shows the degree of resin weight loss utilizing the standard solvent system and the modified process.

RCC-Standard Solvent System

		0.1-0.12 mg/cm2 wt loss
Hole Swell	Commercially available or butyl/caustic system	2-3 minutes at 175^o C
Permanganate	80 g/l $KMnO_4$ 45 g/l NaOH	10 minutes/175^o C
Neutralizer	Commercially available	5 minutes/115^o C

Note: Weight loss with butyl/caustic system on RCC material less than optimum. SEM of figure 3 reflects poor topography.

RCC- Modified Solvent System

		0.25-.32 mg/cm2 wt loss
Hole Swell	Modified Solvent System	5 minutes/160^o C
Permanganate	80 g/l $KmnO_4$ 45 g/l NaOH	15 minutes/175^o C
Neutralizer	Commercially available	5 minutes/115^o C

Note: The modified solvent system improved penetration on the RCC material, enabling the permanganate to increase the degree of resin removal and sufficiently roughen the resin to enhance the subsequent adhesion of the metalization layer. (figure 4)

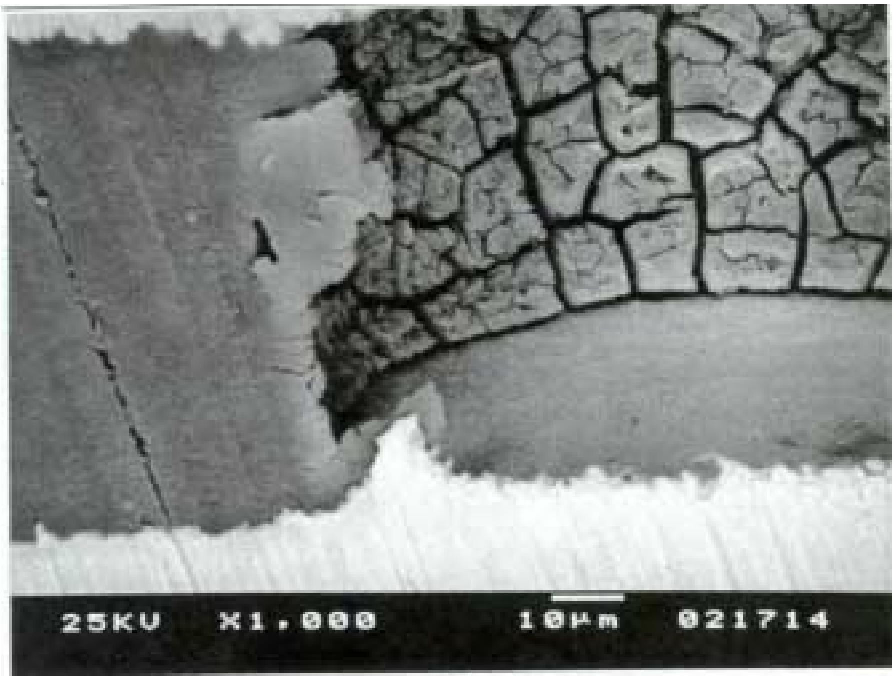


Figure 3 - Incomplete Desmear/Micro-Roughening of RCC Resin with Standard Desmear Process

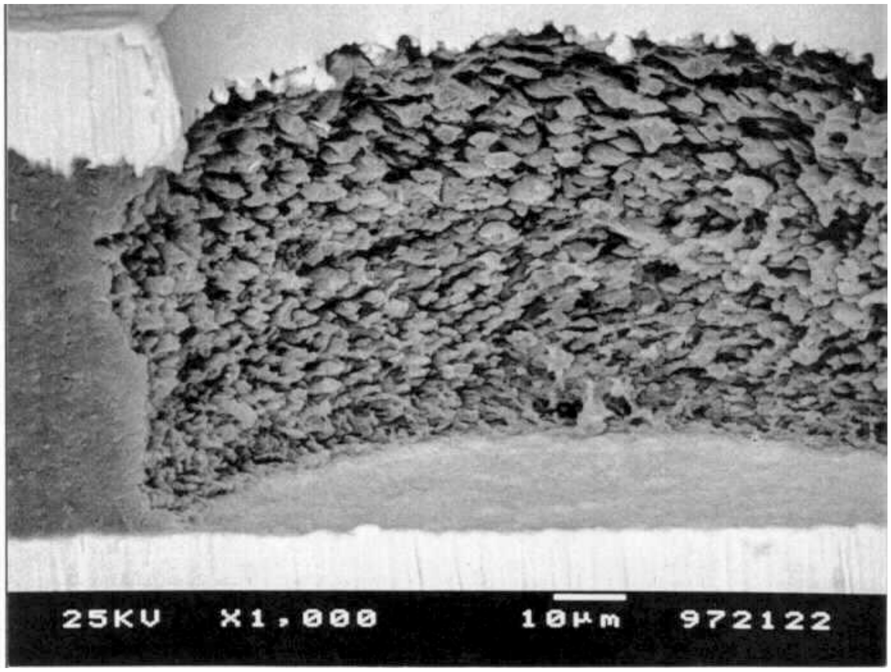


Figure 4 - Optimum Desmear and Micro-Roughening with New Solvent Conditioning System

Direct Plating versus Conventional Electroless Copper Deposition

A direct plating approach was chosen early on, because conventional electroless was known by prior experience to have some limitations with small hole geometries. The main limitations were considered to be related to small through holes and microvias and the relationship of thin or voided plating deposits resulting from the evolution of hydrogen gas. Hydrogen gas is a by-product of the electroless copper deposition process. (See Figure 5) The tendencies for gas bubbles to lodge themselves on the capture pad and along the walls of the vias has been blamed on voiding and thin plating instances. In addition, electroless copper maintains several barriers between the interconnect (capture pad/interlayer foil) and the subsequent electrodeposited copper. These barriers can lead to a weak bond, that can go to failure after thermal stress. With the graphite based metalization, there is a direct copper to copper bond, as there are no barriers between the foil and the electrodeposited copper metal. (This assumes that proper desmear and direct metalization parameters were followed.) The colloidal graphite technology was the primary metallization approach for the reliability testing phase. The performance of this direct plating system appears to be well suited for blind microvia metallization, with good adhesion, complete coverage, and uniform deposition, while readily removable from panel surfaces of the panel. In particular, direct plating resulted in copper thickness in the via comparable with surface thickness, relative to that achieved with electroless.

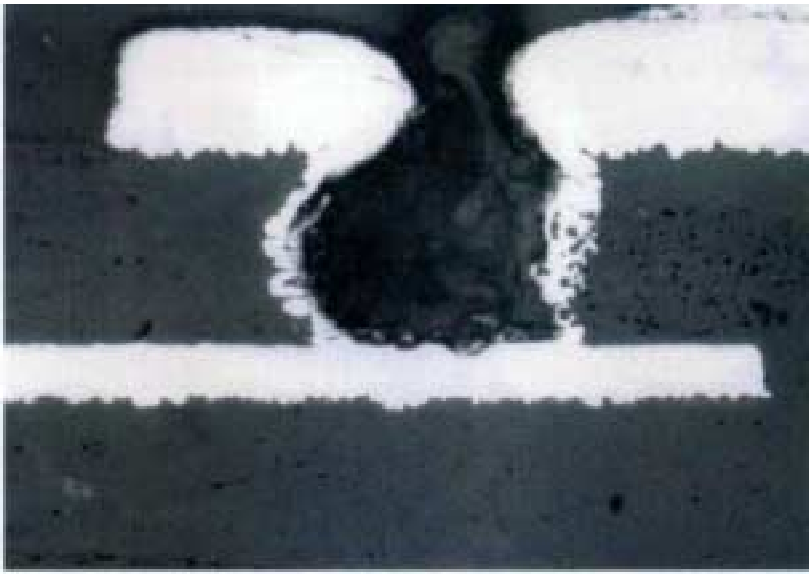


Figure 5 - Micro-Section of Microvia Plated with Conventional Electroless Copper-Note Thin Plating Due to Hydrogen Gas Bubble Formation

For this study, a well-known proprietary electroless copper process was chosen as the metalization technique to compare the performance of the test vehicle to the graphite based metalization process. In this multi company team project, one company supplied the materials, another company provided the direct plate system, and the third team member (a very large printed wiring board fabricator) manufactured all the test vehicles and carried out all of the processing (including metalizing one set of test vehicles with their current electroless copper system) and finishing operations necessary on the test vehicles, with the exception of applying the direct metalzation coating. However, all acid copper electrodeposition was performed at the fabricator's facility.

Description of the Graphite Based Direct Metalization Process

The process described herein is based on a very fine and stable aqueous dispersion of graphite. The graphite particle, by virtue of its crystalline structure, is highly conductive and has been demonstrated to enable the uniform electrodeposition of copper from acid sulfate electrolytes. And, despite earlier setbacks associated with the use of graphite, significant advances in the overall process and in the dispersion itself has rendered the process viable for the metalization of plated through hole multilayer and double-sided printed wiring boards. Earlier problems such as voids on the resin and occasional poor adhesion have been eliminated. Anionic dispersion agents aid in maintaining the stability of the graphite suspension.

Cleaning and Conditioning

This process step is critical in preparing the glass and resin to receive the graphite dispersion. The slightly alkaline chemistry contains a cationic polyelectrolyte with multiple positive charges. The highly charged polyelectrolyte provides a net positive charge on the glass and the resin, aiding in the electrostatic attraction of the graphite particle.

Graphite Conductive Colloid

After cleaning and conditioning the glass fiber bundles and the resin, a room temperature rinse follows. Then, the substrate is treated with a specialized dispersion of graphite. The graphite is highly conductive and suitable for subsequent metalization of plated through hole printed wiring boards. The graphite for this process is dispersed in an aqueous medium with a pH in the range of 8.5-9.6. The choice of graphite may be either a synthetic or a naturally occurring entity. For reasons of superior conductivity, synthetic graphite is preferred.

Graphite is often compared erroneously to carbon black, a semi-conductive form of carbon. Carbon black is the main ingredient of another direct metalization system. When one compares the structure of these two forms of carbon, one notes that graphite has a highly crystalline structure, while carbon black is amorphous. The crystalline structure enables the graphite to have higher conductivity than carbon black, which is a significant advantage in electroplating small holes in very thick printed wiring boards.

Another key component of the graphite dispersion is the inclusion of a water-soluble binding agent. The binding agent is designed to coat the graphite particles and aid the particles in adhering to the hole walls of the plated through hole printed wiring board. The water-soluble binding agent can be selected from a variety of polymers, resins, and other acrylate compounds.

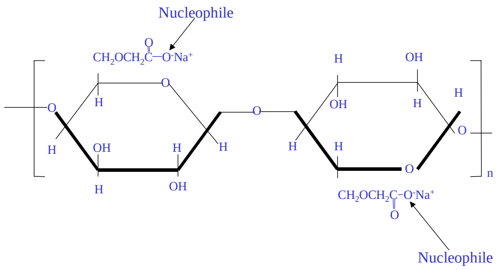
An anionic dispersing agent is added to the graphite dispersion. The preferred agent would have a molecular weight less than 1000 Daltons, so that it is substantially smaller than the binder agent. The anionic dispersing agent has a hydrophobic end and a hydrophilic end. The hydrophobic end functions by attracting the hydrophobic region of the binding agent; while the hydrophilic (anionic end) portion of the dispersing agent sticks out into the aqueous region the water medium. This action helps to prevent the graphite particles from being attracted to each other and forming some type of agglomeration. In addition, the negative charges surrounding each bound graphite particle provide the attractive forces that allow the particles to adhere to the positively charged resin and glass bundles. As was disclosed earlier, the cationic polyelectrolyte, a key ingredient in the cleaning/conditioning step, coats the glass and resin, providing a very high positively charged surface.

The resulting composition of the aqueous dispersion of graphite is capable of depositing a uniform, adherent and highly conductive coating on the non-conductive surfaces of the hole wall.

As we have learned from extensive testing and reliability data; the fixer step is probably the most important and critical aspect in producing of highly reliable vias and through vias. The fixer is a proprietary acidic solution that is used at typically 120° ± 5°F. The fixer provides protons (hydrogen ions) to the neutralizer and the anionic charged binder surrounding the graphite particles.

Once the charge is neutralized the colloidal graphite becomes insoluble so only a thin tightly coherent coating is left, which is attracted and partially polymerized to the conditioner. Because of the action of the fixer on the binder, the excess neutralized colloidal graphite can be rinsed away and the insoluble, partially polymerized conductive coating is left behind.

Typical Binder



Once the excess coating has been removed, the drying step is applied. This step is critical in that the drying will drive out any excess moisture from the partially polymerized graphite coating. The coating now becomes completely polymerized. This step leaves a very conductive pathway through the PTH and microvia, thus enabling the electrodeposition of copper to take place.

The fixer step is critical in that, excess graphite could remain on the face of the copper interconnect or on the capture pads of small blind vias. This is most critical for long term thermal reliability of plated through holes and microvias. Fixer ensures no excess material remains, compromising interconnect integrity.

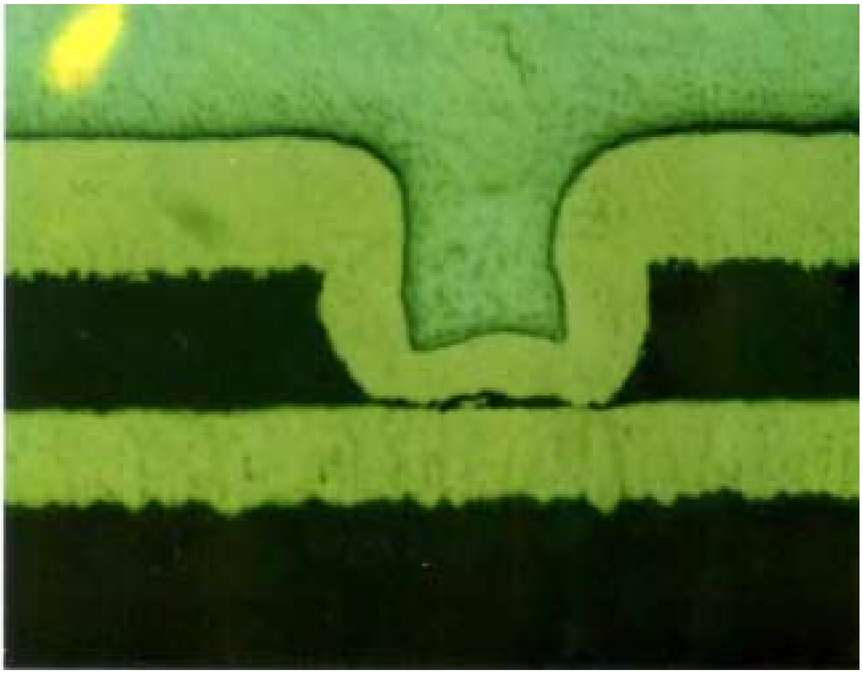


Figure 6 - Microvia without Fixer Step – Excess Material on Capture Pad

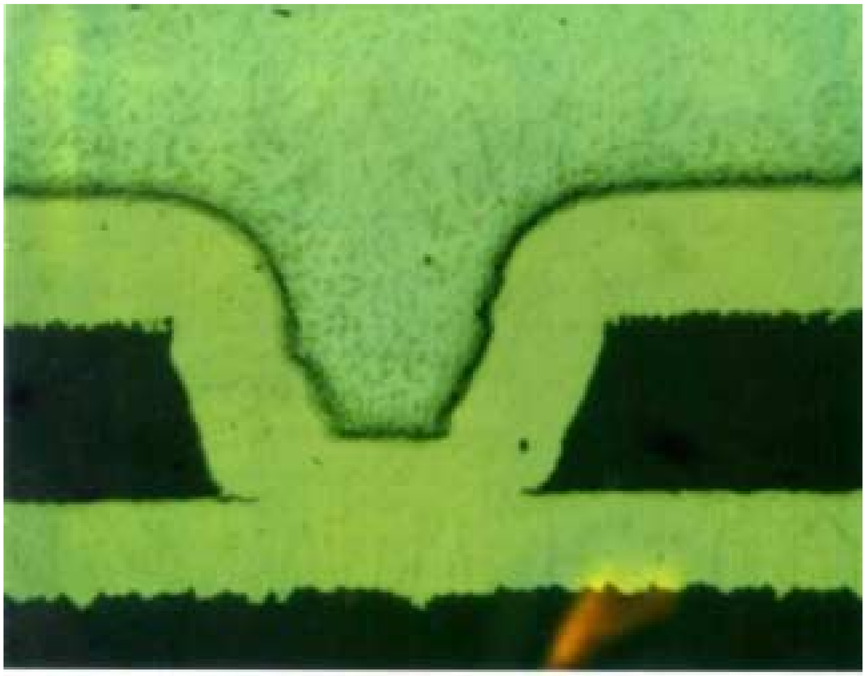


Figure 7 - Microvia with Fixer Step – Copper to Copper Bond – Clean Copper to Copper Bond

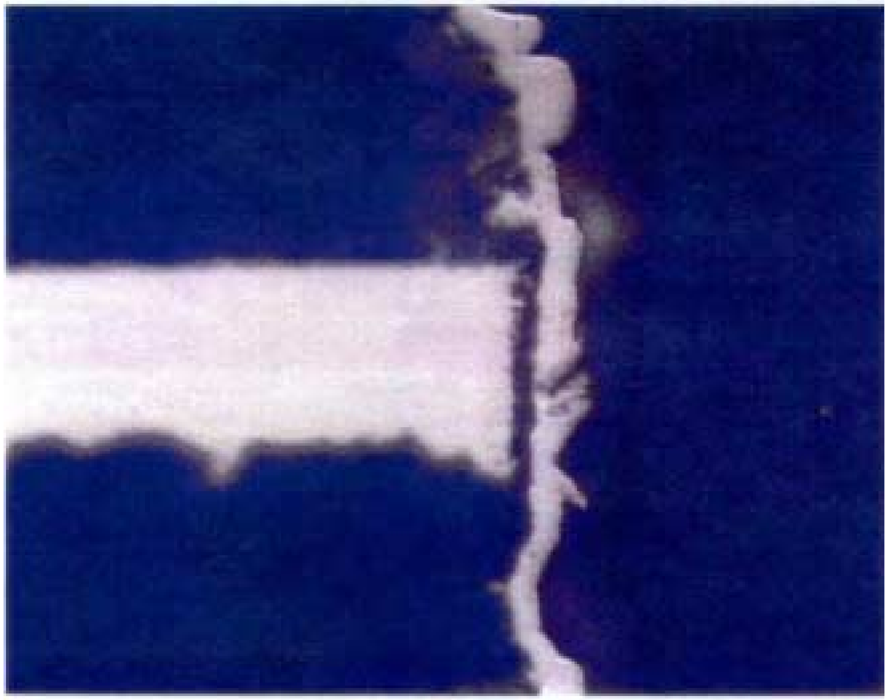


Figure 8 - PTH without Fixer Step

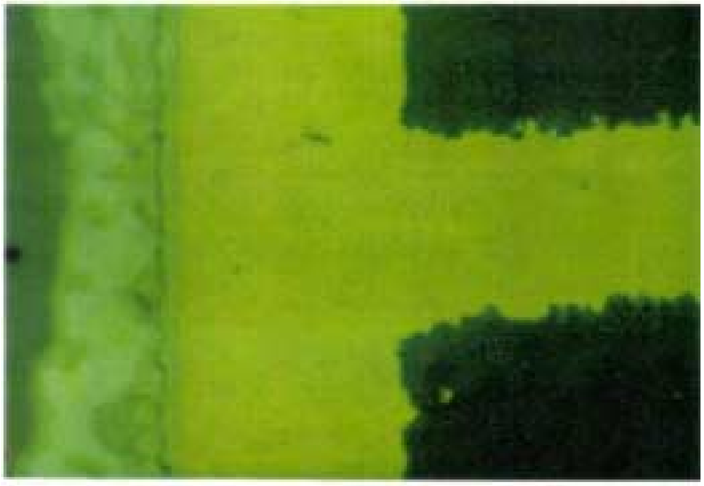


Figure 9 - PTH with Fixer – Copper to Copper Bond

Prior to electroplating of copper, the dried coating must be removed from the copper interconnects and the surface. A micro-etch step employing either hydrogen peroxide-sulfuric acid or sodium persulphate is utilized to accomplish this. The micro-etch serves an additional purpose in that the action of the micro-etch imparts sufficient roughening of the copper surface to enhance photoresist adhesion without the need for scrubbing. For increased productivity, it is desirable to feed panels directly after the micro-etch step into a cut sheet laminator. Or, as in some cases, the panels can be fed directly into a horizontal acid copper plating system. Regardless, hold times after micro-etch will not affect the conductivity of the colloid, whether the panels will be plated as full panel plate or with a pattern. However, an anti-tarnish is recommended for hold times longer than eight hours between the application of the colloid and lamination of a photoresist. This is more for cosmetic reasons, than for plating purposes.

Process Sequence

With the exception of the application of the direct metalization process, all test panels were fabricated through lay up, lamination, via formation, desmear, pattern plate copper, metal etch resist, photoresist strip, etch, strip, apply solder mask, and routing of test coupons at the fabricator team member. After the test coupons were routed, the samples were sent for reliability testing. The two primary test methods were Interconnection Stress Testing (IST™) and air to air thermal cycling. We anticipate that by utilizing two different reliability methods, greater understanding on failure modes could be achieved. This is currently being evaluated and the results will be available at the 2000 IPC Show.

Interconnection Stress Testing

IST™ employs DC current to the internal interconnect of a PTH or via. The DC current directly heats the interconnect, causing stress both through the interconnect and the barrel. The test vehicle described above in this paper contains two independent circuits that are monitored simultaneously. The interconnect circuit and the PTH circuit are continuously heated and cooled by the application of the DC current. Switching the current on and off creates thermal cycles between room temperature and the designated temperature within the sample. This thermal cycle induces cyclic fatigue strain in the plated through holes or blind vias and the interlayer interconnects. The cycling will eventually precipitate a primary failure mode, either in the plated barrel or at the interconnect. IST™ monitors both circuits simultaneously and determines where the primary failure occurred. Typically, the stress testing is discontinued once the PTH circuit reaches a resistance change of 10% from the first hot cycle. At this point, the cycles to failure are recorded, and the resistance at the interconnect is measured. While no specific failure criteria has been established for interconnect failure, typically a resistance increase of 15 milli-ohms from the first hot cycle is considered a post failure. In this investigation, microsections were completed on several of the test vehicle coupons for correlation to the actual stress testing. Microsection analysis is useful for critical failure analysis. In this may, the exact locations of interconnect defects, plating barrel defects, etc. can be precisely determined.

Air to Air Accelerated Reliability Testing

Air to Air Thermal Stress Testing was also utilized as part of this project to help gain further insight into failure mechanisms associated with small microvias and through holes. Ideally, attempts to correlate IST™ results to Air to Air Reliability testing data is desirable.

In the air to air test, the methodology in IPC-SM-785 is followed. The thermal profile for the test procedure is as follows:

- -40°C to +125°C
- 30 minute dwell times at the two temperatures
- Transition time between temperatures < 5 minutes
- Total test cycles- 1000
- Monitor resistance with a Glitch Detector

The Glitch Detector will record the time at which the failure occurred. Sections will be taken on coupons that both failed and passed for the entire 1000 hours.

List of Evaluated Laminates and Plating Thicknesses

For all Reliability Testing the following laminates and plating thicknesses were used:

- FR-4 one ounce copper pads – Target Plating 0.5 mils.
- FR-4 half ounce copper pads – Target Plating 1.0 mils
- FR-4 half ounce copper pads – Target Plating 0.5 mils
- RCC one ounce copper pads – Target Plating 0.5 mils
- RCC one ounce copper pads – Target Plating 1.0 mils

- RCC half ounce copper pads – Target Plating 1.0 mils

IST Results

The IST results demonstrate two trends. The first trend is seen when the data is sorted by metallization process.

IST Cycles to Failure from All Tests

Cycles Average							
Metalization	3 mil. vias	6 mil. vias	3 and 6 mil. vias	13.5 mil. through-vias	40.0 mil. through-vias	13.5 and 40.0 mil. through-vias	Average from all tests
Colloidal Graphite	380	798	**589**	331	489	**410**	**500**
Electroless Copper Site 1	157	566	**62**	272	442	**357**	**359**
Electroless Copper Site 2	171	611	**391**	354	418	**386**	**388**

This data clearly shows the higher reliability that can be achieved when plating the microvias and through-holes with the colloidal graphite process.

The second trend that is somewhat less obvious is the difference in the plating processes by material type.

IST Cycles to Failure from FR4 Microvia Layer

Cycles Average							
Metalization	3 mil. vias	6 mil. vias	3 and 6 mil. vias	13.5 mil. through-vias	40.0 mil. through-vias	13.5 and 40.0 mil. through-vias	Average from all tests
Colloidal Graphite	340	660	**500**	308	431	**370**	**435**
Electroless Copper Site 1	220	660	**440**	216	394	**361**	**372**
Electroless Copper Site 2	144	660	**402**	351	381	**366**	**384**

IST Cycles to Failure from RCC Microvia Layer

Cycles Average							
Metalization	3 mil. vias	6 mil. vias	3 and 6 mil. vias	13.5 mil. through-vias	40.0 mil. through-vias	13.5 and 40.0 mil. through-vias	Average from all tests
Colloidal Graphite	410	935	**673**	348	533	**440**	**557**
Electroless Copper Site 1	109	492	**300**	315	503	**409**	**355**
Electroless Copper Site 2	200	570	**385**	357	446	**401**	**393**

This data shows a slight difference in the reliability delta between the FR4 and RCC material by plating process. The RCC appears to plate more reliably using the colloidal graphite than the standard electroless. The delta between the two processes is larger for the RCC than the FR4.

Conclusion

Microvias can be fabricated using mainstream manufacturing procedures. Microvia structures are thermally and electrically as or more reliable, than traditional through-hole technology. The key to building a reliable via is the ability to plate the small hole/dead end geometry with a minimum of 0.8 mils (20µm) of copper. Less than 0.8 mils (20µm) of copper deposited in the microvia, leads to premature failure of that microvia. To be able to effectively plate a microvia, an aspect ratio (dielectric thickness/hole diameter) of 1:1 (or less) must be maintained. This allows the plating chemistry to effectively plate the microvia.

Colloidal graphite direct plating has been demonstrated to have a significant benefit over electroless copper in plating these small hole geometries. The RCC un-reinforced dielectric materials exhibit more consistent ablating and plating characteristics than does the FR-4 materials.

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