

"Back to the Future" -- Foil Lamination for the 21st Century

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Introduction

Historically, cost-conscious PWB design engineers realized that it was possible to do PWB layouts using foil lamination instead of laminate cap construction, and through that simple expedient to save money in the manufactured cost of bare boards. This is "old" technology, even for me, though I've only been in the business 20 years. Most designers and PWB fabricators take it for granted and take advantage of it whenever possible, which is much of the time. That might lead you to think that foil lamination, like "your father's Buick," is somewhat passé and only marginally relevant to the high tech world of personal telecommunications and high speed data transfer. Wrong! There is a whole generation of high density interconnect (HDI) boards that not only use foil lamination, but in which the foil laminated surface layer is essential to the function and performance of the design.

The Old

First let's look at some of the issues associated with the historical foil lamination process which involved nothing more complicated than adding a surface layer to a multilayer PWB by using prepreg and copper foil on the outside of the layup (see Figure 1) rather than a piece of copper clad laminate, which was referred to as a "cap layer" (see Figure 2). Its primary purpose, as mentioned above, was to reduce cost. Which it did. There were some issues associated with foil lamination, some of which are still relevant to the new generations of foil lamination applications. Let's briefly look to the past for a historical perspective.

There have been hiccups in the foil lamination process over the years. As it turns out, the copper foil used to bond to some of the high performance resin systems such as polyimide are not the same ones used to bond to standard FR-4, which has led to "low copper peel" results whose source was not always intuitively obvious. After all copper is copper, right? Wrong. So Lesson #1 (which the "old timers" who have been using foil lamination for many years already know) is: Use the right copper foil for the resin system you are laminating. Your laminate and prepreg supplier will be able to guide you in the right direction, since in all likelihood he also uses that foil to get proper bond

performance. Is this a design or a fabrication issue? Our experience has been that the designer needs to be aware of fabrication issues because if it turns out not to work, guess who is going to get the "credit!"

Lesson #2 and corollary to Lesson #1 (and the designer should be aware for the same reasons) is that when you are producing a PWB you are not laminating under exactly the same conditions of time, temperature and pressure being used by your laminate supplier, which means that you will have to do some work to optimize your lamination cycle to achieve acceptable copper bonds without otherwise messing up your boards. Remember that changing pressure, heat-up rate, etc. will impact such intangibles as layer registration, resin flow and fill, flatness and parallelism of the overall MLB, etc., etc. Some of these will impact functional performance of the board. If you or your fabricator can't or won't do the necessary work to avoid those problems, then Lesson #2a is "Go back to cap lam designs."

When the now defunct MIL-S-13949 military specification for laminates was in force, DESC (Defense Electronics Supply Center for those too young to remember or who have worked in commercial PWB facilities all your lives) decided that PWB houses doing foil lamination were de-facto acting as their own laminate suppliers, and had to meet the same copper peel requirements as their suppliers, including getting qualified, doing lot testing to confirm the achievement of acceptable copper peels under all the various conditions, and maintaining the same records as laminators. MIL-S-13949 is now extinct -- but the reason its requirements were passed along to PWB fabricators (see Lesson #1 and Lesson #2 above) remains valid. You still need a robust copper peel value if you are going to do foil lamination and in new generation foil lam products this can be even more critical as we will see.

...And the New

In recent years a whole new application for foil lamination has evolved in which designers have taken advantage of newer materials and processes allowing them to design HDI (High Density Interconnect) MLB's that are thinner, lighter and in many cases less costly than their predecessors. Taking advantage of materials that can be laser drilled or plasma ablated to form surface microvias between layers 1 and 2 (and even 1, 2 and 3 with some planning) designers have been able to realize thinner PWB's that have much higher interconnect density for applications, such as phone boards that must be low cost, light, thin, and handle a plethora of functions.

Foil lamination is integral to this process. There are at least three approaches to surface microvia materials that are in use or are coming into use:

1.) Resin Coated Copper Foil

Resin Coated Copper Foil (RCC, aka RCF, Resin Coated Foil) can be laminated directly on top of a multilayer PWB providing a dielectric layer (the resin on the coated foil) that

can subsequently be laser drilled to form microvias between layers 1 and 2, permitting efficient signal distribution and higher interconnect density.

RCC products are available as simple B-stage in coated thickness of 50 to 100 microns (2 to 4 mils for those of you like myself who are still English units dinosaurs) or in a more sophisticated version, as a C-stage/B-stage combination that provides better flatness and parallelism and greatly reduces any chance for accidental punch-through of a copper feature that might cause premature shorting.

This is at present by far the most widely and successfully used method of surface microvia formation worldwide. Issues occasionally reported with RCC, depending of course on the user, fabricator and application, include low copper peel values, excessive “footballing” causing lack of flatness and parallelism, and resin shrinkage resulting in registration issues as well as occasional resin cracking. In addition, since coating copper foil becomes increasingly more difficult as the foil gets thinner, the cost of RCC in very thin copper, such as 9 micron that is needed for formation of very fine lines and spaces, can be considerable. (Lesson #3 is to make sure that the material you select for foil lamination in microvia applications works for you in your own application when your chosen board fabricator provides finished product.)

2.) Non-Woven Aramid Prepregs

The use of 50 micron or 100 micron epoxy prepreg (0.002” and 0.004”) based on Thermount® as the basis for a foil lamination process has found a considerable following among those who have encountered issues with RCC and/or where multiple layers of microvia interconnect are desirable or necessary. Thermount® and Thermount®RT™ are Dupont aramid paper reinforcements composed of fibers of para-aramid bound together by a meta-aramid binder. Designed for PWB applications, Thermount is 100% organic, lightweight and provides a thin, dimensionally stable, flat platform for microvia applications.

Figure 3 illustrates a typical surface microvia hole drilled in an epoxy-aramid MLB with a surface layer based on Thermount®.

The thin aramid product provides improved flatness and parallelism, while the fiber reinforcement provided by the aramid inhibits the formation and propagation of resin microcracks. Because Thermount® products are provided using standard high performance epoxy resin systems, cure times and temperatures are within the normal parameters of most PWB fabricators. In addition, because products based on Thermount® are available as both laminate and prepreg, it is possible to design using more than one Thermount® layer and to make laser via interconnections between layers 1, 2 and 3 as can be seen in Figure 4.

Two issues that must be considered by the board fabricator, assembly house and the OEM have historically troubled Thermount®, despite its many advantages. First is moisture uptake, in that products based on Thermount® absorb more moisture than do

standard glass-epoxies and therefore may require some baking or desiccation prior to lamination and solder reflow. The development of second generation Thermount®RT™ products with lower water absorption mitigates this issue somewhat, but it remains a concern especially in high humidity areas.

The second area of concern for Thermount® products has been low copper peel values due to the inherently low cohesive strength of the Thermount product. One ounce copper peel values at or under 5 lb/in were common with early generation Thermount® products, which resulted in a mixed reception for the material in applications such as hand held phones, PDA's and laptop computers in which a requirement exists for interconnections to survive a variety of drop impact tests. In the mind of many OEM designers that low peel value is a "drop dead" issue in choosing a material for HDI designs.

Newer generation Thermount® based products such as Arlon's 55ST have attempted to overcome the low peel problem by forming an interpenetrating polymer network (IPN) between the Thermount® and the resin system itself, permitting 1 oz. peels as high as 10 lb/in -- double that of the previous generation of products -- and half ounce peels (in foil lamination applications) over 7 lb/in. Progress is also being made in the area of water absorption, but there is still need to be careful with drying of these materials.

3. "Flat Glass" (and Better Lasers)

New to the foil lamination arena is the use of so-called "flat glass" which is special fiberglass fabric that lies very flat and is easier to lase cleanly than traditional glass weaves. The idea here is that a "premium" glass epoxy prepreg can possibly be made to do the job now being done by RCC or nonwoven aramid products. The cost performance of these new glass materials is still in the process of being evaluated.

On another front, although not a subject for detailing in this article, improving laser technology may well help this and other materials achieve microvias faster and more cleanly -- both of which are still issues with trying to form quality microvias in glass fiber based products.

Back to the Future

For the future a wider variety of materials and designs will want to take advantage of foil lamination for surface microvia formation. Applications requiring higher frequencies will need materials that can be laser drilled yet which have low dielectric constant and loss characteristics for handling microwave and FR signals. Large optical backplanes will utilize materials that can act as light ducts at the board surface -- and while this is not "foil lamination" as we currently know it, the newer technology will add a level of complexity to the interconnection between surface copper foil and the multilayer board beneath. A variety of thermoplastic film materials may well be used in surface microvia applications -- materials such as LCP (liquid crystal polymers) are already being considered for related applications.

The challenge for the board designer and fabricator as we go forward will be to integrate some of these newer concepts in surface microvia materials and cope at the same time with the fact that they don't all process "just like FR-4." And yet it is exactly these emergent technologies that will open new vistas for board performance, continued size reduction and density increase.

Note: Thermount® and Thermount®RT™ are tradenames of the Dupont Company, Wilmington, DE.

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Additional information about Arlon, including the text of "Everything You Ever Wanted to Know..." can be found at www.arlonmed.com

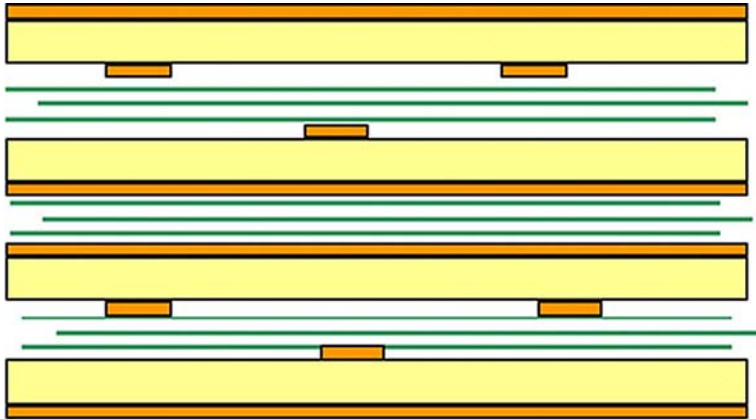


Figure 2 -- Traditional Cap Lamination uses a copper clad laminate for the top or cap layer with prepreg as bonding material.

Cap Lamination – Cap is Clad Laminate

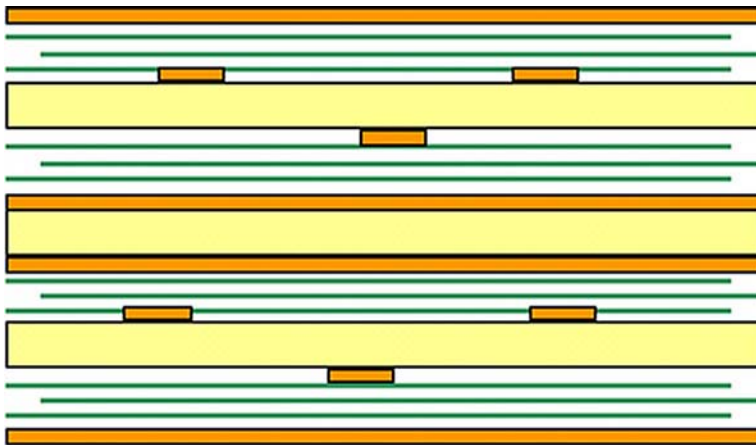


Figure 1 -- Foil Lamination uses prepreg and copper foil at the surface, and the designer adjusts all the other layers accordingly.

Foil Lamination – Cap is Preg + Foil

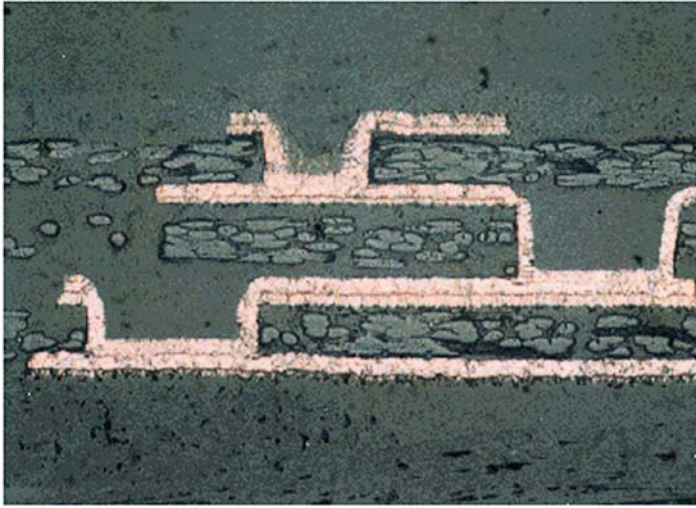


Figure 4 -- Microvia interconnections using laminate and prepreg based on Thermount® aramid material. Photo courtesy of Dupont Company.

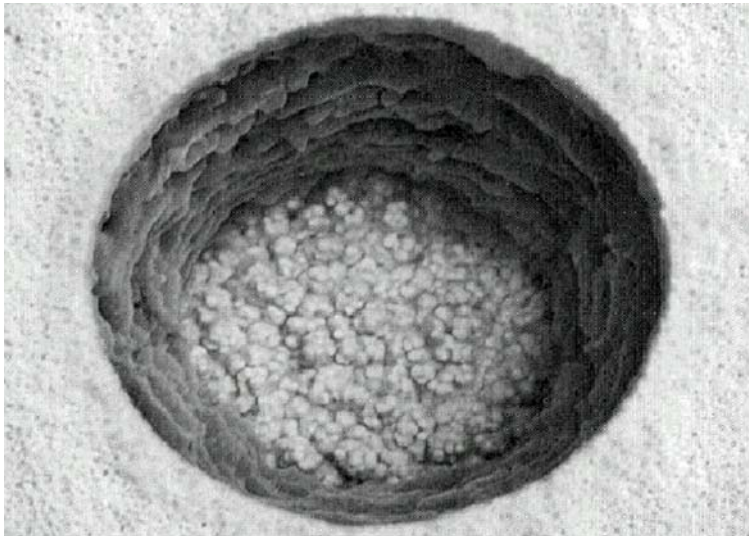


Figure 3 -- Laser microvia drilled in Thermount® based foil laminated layer. Laser stops at the copper stop-pad. Photo courtesy of Dupont Company.