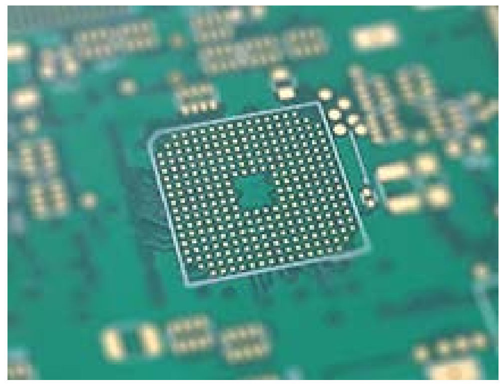
Via In Pad - Conductive Fill or Non-Conductive Fill?

"Which is the Best Choice for My Design?"

One of the most commonly asked questions when deciding how to fill mechanically drilled via-in-pad holes is whether or not to specify conductive or non-conductive epoxies. This brief paper will take up where our previous "Tech Talk for Techies" left off, with a look into the best practices and manufacturability of filling vias for via-in-pad structures.

<u>Smaller is Better</u>



In the early 2000s the first fine-pitch ball grid array devices became popular with designers looking to pack as much horsepower into as small a space as possible. "Smaller is better" became the rule and with that the mechanical drilling world became severely impacted by available drill bit sizes, aspect ratios, and plating methodologies. First of all, the diameter of the drill needed to be in the 0.006" or smaller range due to the reduction of pad size and spacing pitch. Secondly, the aspect ratio (depth to diameter) became limited by drill flute length, positional accuracy, rigidity of the tools (to prevent breakage), and the throwing power of acid copper plating systems. And lastly, the plating needed to close up the hole as much as possible, which led to problems with voiding, incomplete fill, and gas/solution entrapment.

Laser drilling technology and microvia plating systems rapidly advanced to take the place of very small mechanical drills in fine-pitch BGA structures. This allowed a natural separation of mechanical and laser diameters based on which were best in their application. Mechanical drill diameters were designated down to where laser via technology took over—typically at 0.006" diameter and smaller. And today the process has matured for 0.5mm pitch BGAs and tighter using microvias and larger devices having greater diameter pads that allow mechanical drilling (with the limitations on annular ring and aspect ratio accounted for).

<u>Finished Hole Diameter and Aspect Ratio</u>

The best practice for epoxy filled vias is to have a <u>FINISHED</u> via hole diameter between the sizes of 0.008" and 0.018" (easy to remember!). The main reason is that the viscosity of the epoxy fill (accounting for both conductive and non-conductive varieties) allows for it to be pushed completely through a hole as small as 0.008", but will not readily run out of a hole as large as 0.018”. The associated aspect ratio is best if the depth to diameter is less than 10:1 (to maintain a minimum ‘industry standard’ fill of 97%).

Annular Ring

For annular ring considerations, the IPC standard persists for Class 2 and Class 3 minimums, so the associated pad diameter must be sufficiently large to accommodate the mechanical drill size that ultimately will plate DOWN to the finished diameter. Let’s look at an example: For an 0.008” FHS (finished hole size) the drill will likely be 0.010” (to allow 0.001”/side plating in the hole minimum). That means that for a Class 2 design the pad would typically be 0.018” or larger, and for a Class 3 design 0.020” or larger (to allow minimum annular ring in the finished board). ***As you can see, mechanically drilled via-in-pad structures are for larger pitch devices due to the necessary pad diameter to meet minimum annular ring per specification.***

The BIG Decision: Conductive or Non-Conductive Epoxy Via Fill Material?

What are the available VIP fill material options?

Conductive: Conductive via fill material is popularized by two main companies’ products—DuPont CB100 and Tatsuto AE3030. They are both of the ‘silver coated copper particle’ filled epoxy matrix, which provides some electrical and thermal conductivity in a cured state. The difference between the two materials is in the overall particulate size and finished CTE (coefficient of thermal expansion)—the CB100 has a larger particle size with a higher CTE, and has been available for much longer making it a better known material.

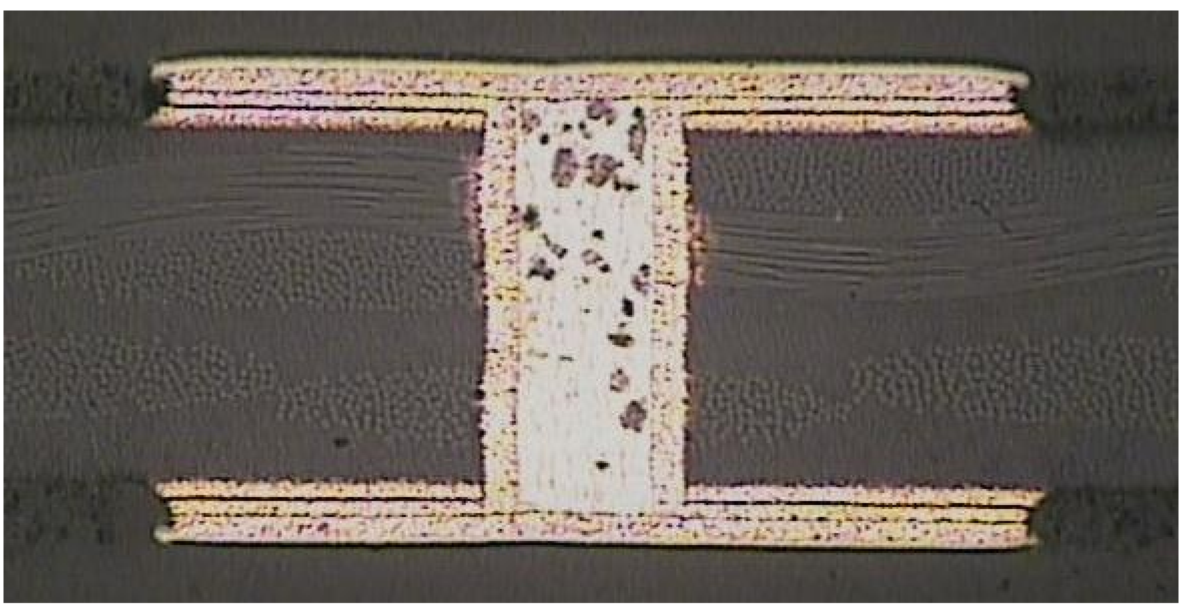


Figure 1 - Dupont CB100 Conductive Via Fill

Non-Conductive: The non-conductive products are similarly popularized by two products—Peters PP2795 epoxy and San-Ei Kagaku PHP-900 epoxy. In this case the Peters product has been available for a longer time but in recent years the San-Ei product has taken the lead due to a better CTE match with standard PCB laminates. Due to overwhelming demand, Advanced Circuits uses only the San-Ei Kagaku material for in-house VIP processing.

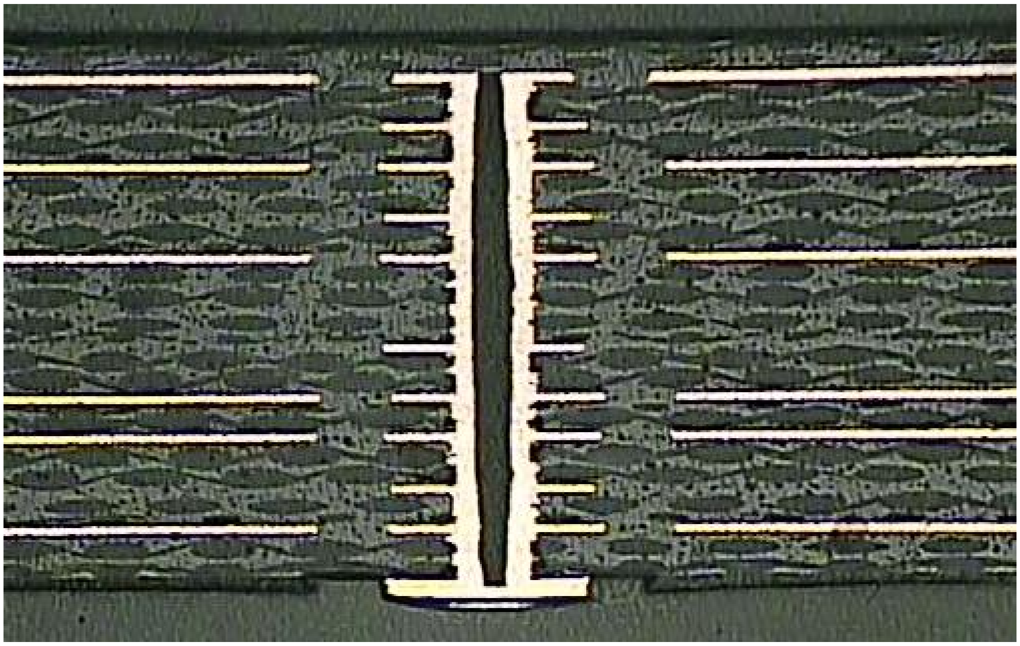


Figure 2 - San-Ei Kagaku PHP-900 Non-conductive Via Fill in Blind Via

Making Your Decision

Match the CTE of the VIP fill material and Laminate

The first consideration (and only consideration in some designs) is to try to match the CTE with the surrounding laminate material. Why is that important? Because as the board lives out its life in an on/off and heating/cooling state the expansion and contraction of the padstack structures move either with or against the adjacent board laminate material, which can lead to stress fractures and possible electrical opens in the very worst cases.

This consideration naturally favors the **non-conductive epoxies** as their CTE is a better match with the laminate therefore making a more reliable overall structure. And the industry has followed suit—likely 90% or more products today specify non-conductive epoxy, making it a more popular and therefore less expensive option as well.

But this begs the question—why or where would it be necessary to select a conductive epoxy fill?

<u>Conductive epoxy</u> is used for thermal vias and for legacy products. Thermal vias (vias used to conduct heat away from a component) have been shown to marginally benefit from a conductive fill as the entire structure helps transmit thermal energy out and away from the source. High pin count BGAs that run hot could benefit from the use of conductive VIP epoxies. Another common application is to add thermal vias in a grid matrix directly beneath a flat-pack SMD.

Legacy or older established designs from companies that have been running for a decade or more often specified conductive DuPont CB100 as the via fill because it was the most commonly used option in the past. These board assemblies have long ago been characterized and lifecycle properties are well known.

<u>Fact or Fiction?</u>

One myth to put to rest is that a conductive fill is required for a solid via-in-pad structure—some assume incorrectly that it must be conductive in order to plate over the cap of the hole barrel when the plated pad is formed. This is not the case! The board fabricator always runs the cured/planarized epoxy filled holes through electroless copper followed by an electrolytic strike plate, which effectively seals the hole and prepares it for the final pattern plating operation when the surface pad is plated.

<u>Wrap</u>

It must be stated that for all of these via-in-pad structures a continuous WRAP of copper plating is required (by IPC and customer specification) from the barrel of the hole out onto the surface pad, thus providing seamless continuity of the structure which helps hold it together during normal expansion/contraction during the lifecycle of the PCB. This however is another very complex story altogether, and is beyond the scope of this article (will likely be covered in a future edition of "Tech Talk for Techies"!).

Conclusion: Design and Intent of the PCB

So in the end it is the design and intent of the PCB that determines the need for conductive or non-conductive epoxy fill. Advanced Circuits' Product Engineers can assist you with the decision to select one based on the key points of your design. Additionally, the specifications including CTE can be obtained either on the manufacturer's websites or by requesting them from our engineers who can provide specific information on how best to proceed!

We hope this brief paper helps guide you in the selection of the available options for your design—please contact us if you have further questions.