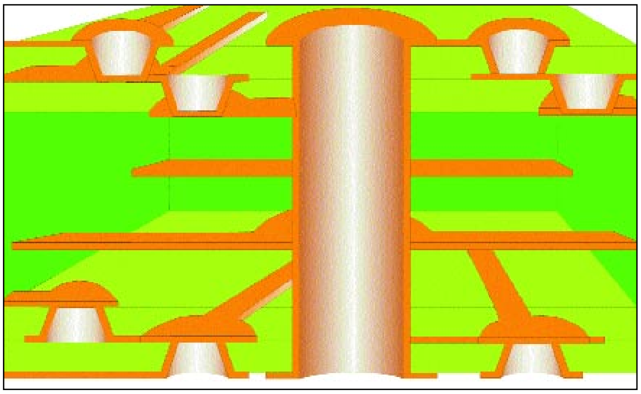

FIGURE 1. A typical buildup process yields a staggered blind via interconnect. Compare this to the variable-depth construction in Figure 3.

'Material' MATTERS

The economics and dynamics of laser-drilled blind microvias for interconnecting to the third level. by LARRY W. BURGESS

The most dramatic change in the board fabrication industry during the past five years has been the explosive growth in demand for blind microvias and the corresponding increase in the use of laser drills to create these blind microvias. For several years, growth and volume build of blind microvias has taken place in Southeast Asia, where the dominant technology for blind microvias has been a technological match with the materials of choice and laser technology.[1] North America has been slow to adopt blind microvias, suggesting instead that it is a technology best suited for cell phones and that the production market is clearly in Asia.[2]

What must be realized, however, is that the volume of panels produced with blind microvia technology is not the only factor to consider. Instead, it is the volume of blind microvias that is the clear bottleneck to making cost-effective circuit boards. The object, then, is to understand the bottleneck and then find a solution to cut the costs for this bottleneck, in this case, the fastest, most cost-effective laser drilling technology.

The preferred dielectric material for blind microvias is resin coated foil (RCF).[1] A trend is emerging, however, toward epoxy aramid materials such as DuPont's "Thermount." These materials have been shown to work well with what is today the dominant laser technology, CO_2. The Asian market has for some time adopted CO_2 as its laser of choice. The reasons are simple:

- Removing copper and FR-4 can be extremely slow. In some cases the blind microvia count on a panel can reach over 150,000, which can take up to and over 7 hours per panel to remove the copper and FR-4.
- Etching the "windows" (openings in the outer surface), while sometimes a difficult task, is a common batch process; therefore, once registration processing is worked out, window etching is very cost-effective.
- It has been reported that a single laser technology can drill dielectric material with a single pulse, or multiple vias with a single pulse when in fine-pitch configuration.[3]

Another way to understand the reason behind the CO_2 laser's dominance is to understand the approach that marries or naturally blends the various physical technologies that make up the key components for producing laser-drilled blind microvias. The key component choices in this case are:

- Lasers: Infrared (CO_2) or ultraviolet (Nd:YAG or Nd:LIF) emitter.
- Windows: Chemically etch or laser drill copper.
- Dielectric: Match wavelength of laser beam or control laser beam energy by using high-energy short pulses.

When one starts with a simple and general understanding of physics, the idea of marrying the mechanisms is obvious. First, match the laser and dielectric wavelengths so that the laser is most effective. A very quick study shows the the CO_2 laser absorption characteristic of the non-woven aramid creates a natural "partnership" for efficiency. Another way to understand this partnership: Consider the low energy from the laser beam that is needed to remove the material (and the epoxy or polyimide) as opposed to the high energy required for removing the glass weave and/or copper. Second, look to the other dielectric component – the binding material – most often epoxy or polyimide. Because the epoxy or polyimide is partially transparent to the CO_2 laser, it is the beam absorption characteristic of the non-woven aramid, the binding material, that dominates the physical characteristics.

This demonstrates that if a low-energy source (low-fluence laser beam[4]) can readily remove the combination of

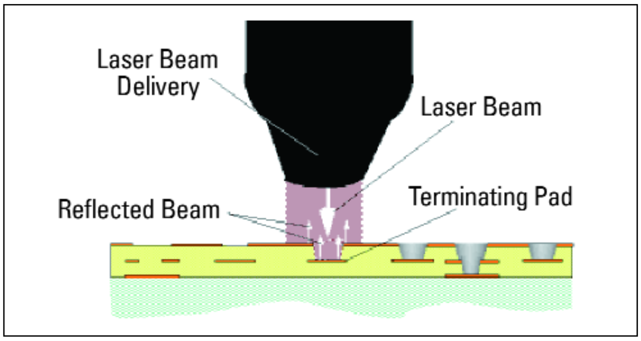

FIGURE 2. Positioned over every "window" etched through the top copper surface, the low fluence CO_2 beam ablates the dielectric and is reflected from all copper layers without oxidizing their surfaces.

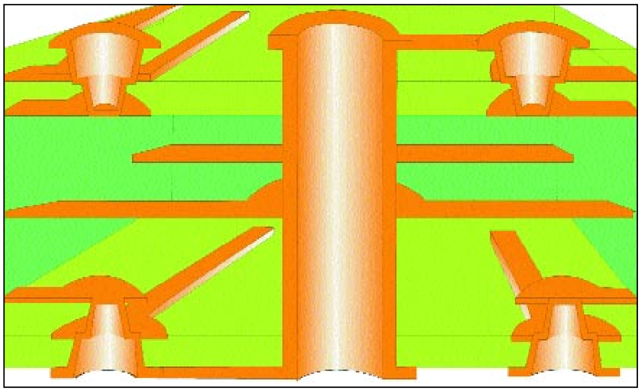

FIGURE 3. Although the results are strikingly similar, a significant difference between the variable depth and build-up methods lies in their constructions. Some buildup methods require fabrication and subsequent joining of two PCBs. The novel process (shown here) does not.

non-woven aramid and the binding material, epoxy or polyimide, and use the natural reflective surface of the copper at the surface (etched window) and bottom (bounce pad) of the laser drilled blind via, a very efficient or quick process time will be accomplished. In addition, a wide process window will help with improved quality and high yields, where the laser parameters may vary in several directions such as focus and pulse width.

On the other side of the comparative process is the narrow process window, in which the high-energy laser beam from a UV (Nd:YAG) laser is set to laser-drill materials like copper or glass weave (FR-4). The process must be devised to remove the high-energy-demand elements such as copper and FR-4 while avoiding low-energy-demand elements such as epoxy or polyimide that would otherwise create cavities and other damage that catch solutions during plating. This is one of the reasons for the recent surge of electromigration, or conductive anodic filament (CAF).[5] In addition, even though tremendous efforts have been made to control the UV laser beam to prevent it from damaging copper, it lacks the natural reflective characteristics of the CO_2 laser beam and therefore has to be tightly controlled to terminate at the copper bounce pad.

The aforementioned comparison becomes even more contrary for laser-drilling blind microvias down to the third level. There are two methods for this advanced interconnect scheme: variable-depth or buildup. Buildup requires separate but nearly complete boards to be made in order to form a single-level interconnect. Variable-depth uses a more conventional multilayer methodology similar to what is commonly used for mechanical drilling. So, with variable-depth laser-drilled interconnections, the alignment of three circuit levels is controlled by managing material movement as one would when mechanically drilling.

Multiple vs. Variable-depth

One accepted buildup technology* includes the laser drilling of a non-copper-clad dielectric material for blind microvia, the deposition of a conductive material and/or an additive or semi-additive plating process, followed by another round of laser drilling a non-copper-clad dielectric material so that there is a staggered blind via interconnect (Figure 1). This technique yields a very dense interconnect package, but can also increase the costs of the multilayered blind microvia, since two separate boards are fabricated. Interestingly, the dielectric material of choice for this process is an epoxy non-woven aramid.

An alternative to this buildup process is a newly patented[6] laser-drilling method with a new laser drilling system that permits a variable interconnect to be made with a single pulse (Figure 2). The density characteristics of buildup and variable-depth interconnections are similar in terms of board real

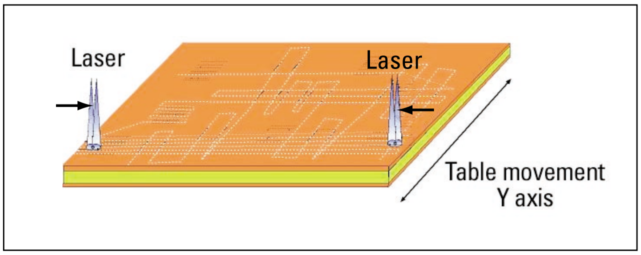

FIGURE 4a. The novel method uses a scanning movement in which the laser beam travels on a split X axis and the table moves on the Y axis.

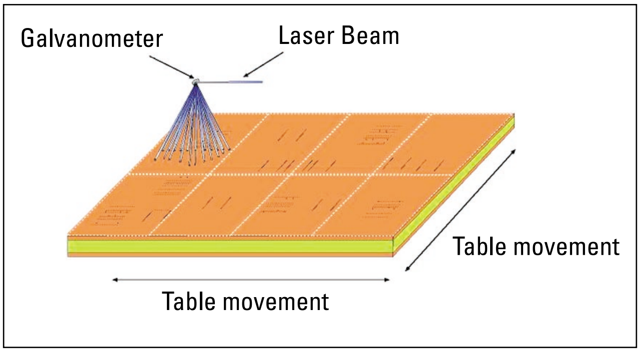

FIGURE 4b. Traditional point-to-point laser drilling uses a galvanometer through which the beam is deflected, and the table moves on the X and Y axes.

estate. The novel variable-depth interconnection method** uses a single board, however, and thus eliminates duplicate rounds of plating, imaging, etching, and a second lamination (which also has to be plated, imaged, and etched).

Another interesting and not-so-obvious aspect of some buildup methods is that the laser has to perform almost twice as much work: It first drills the innerlayers and then drills the outer layers to complete the interconnected "daisy chain" at the third level. By contrast, the variable-depth interconnection can be made with a single pulse using the newly patented laser and method (Figure 3).

The top hat Gaussian Curve of the laser beam emitted from the novel system permits the beam to maintain a rather consistent beam energy into the via as it reflects off of the bounce pad (Figure 4). With the beam energy consistent as it hits the reflective copper surface at the second level, and, similarly, as it bounces off the third level, the dielectric material is removed in a clean manner with a single pulse. The via wall has no carbonization or HAZ.

Cell phones require 250,000 to 650,000 blind microvias per panel.[2] Data now suggest other types of applications will require 150,000 or more blind microvias per panel. To understand the dynamics and economics for making third-level laser-drilled interconnections, compare the increases in material costs with cost savings achieved by laser drilling. If the blind microvia laser drilling costs were $0.001 (1/10th of a cent) per via, the laser drilling costs for a panel with 5,000 blind microvias would be $5. If the panel had 50,000 laser-drilled blind microvias at the same per via cost, the costs would be $50. Now assume a 15 percent increase in material costs. For a 14-layer panel with FR-4 innerlayers ($62) and "Thermount" outerlayers ($19), a net savings of $31 ($50 less $19) would be achieved. However, the time it would take to laser drill an all-FR-4 panel could raise the drilling costs by more than five times, making the savings even greater. ○

*"ALIVH" (Any Layer Interstitial Via Hole") (Matsushita Corp.)
**"LaserVia" (LaserVia Corp.)

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