Multi-Depth Laser Drilled Blind Vias for Increased Circuit Density

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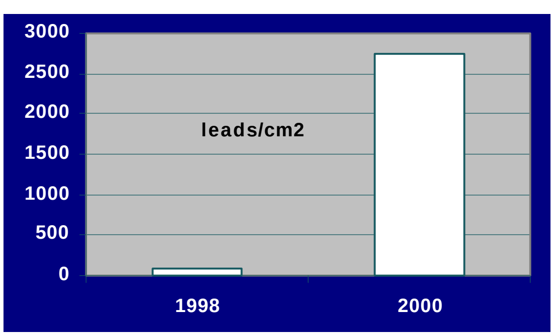
Abstract

The tried and true method of mechanically drilling "Z" axis interconnections is now sharing responsibility with laser drilling blind vias and other blind via technologies. Electronic component densities continue to increase each year. The introduction of microBGAs (μBGAs), Quad Flat Packs (QFPs) and other fine pitch components have forced the development of PWB interconnect technologies to match this demand. One of the great contributions to increasing PWB densities is Microvia-in-Pad technology. This paper will present the results of a project that presents a step by step path for the introduction of laser drilled microvia-in pad technology into traditional multilayer fabs.

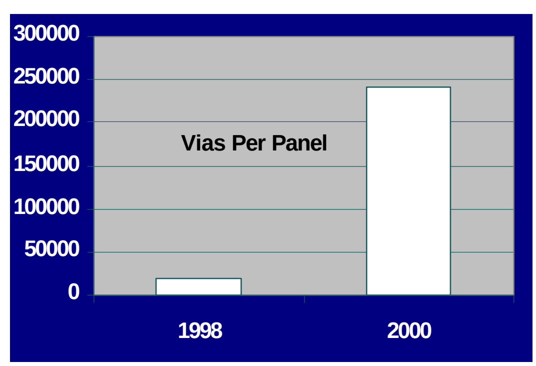
Key Words: Multi-depth, Laser, BGAs, QFPs, Microvia-in-Pad

Introduction

The projected growth in the density of electronic component leads or interconnections is presenting Designers, Fabricators and Assemblers with unprecedented challenges. With electronic component interconnections per square centimeter at an all time high, conventional multilayer design and fabrication techniques are approaching their practical limits. The following charts have been created from data presented in the September 1997 article of Electronic Engineering Times:



- 1998: 495 leads/sq.in. (77 leads/cm²)
- 2000: 17,760 leads/sq.in. (2753 leads/cm²)



- 1998: 20,000 vias per Panel
- 2000: 240,000 vias per Panel
- (from EE Times Sept.97):

Fig. 1 Interconnection Growth for the Next Three Years

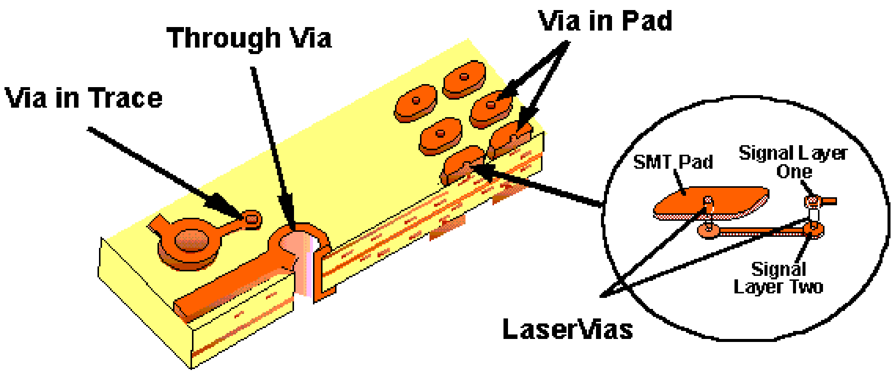


Fig. 2 Via in Pad

The phenomenal growth projected in leads or interconnections per square centimeter resulting in a 12 times growth in vias per panel over a 3 year period, clearly put the pressure the circuit board fabrication industry to develop and introduce blind and buried vias to meet this interconnection density. One such cost effective approach to use laser technology to produce blind vias and more specifically produce blind vias that interconnect at more than one level deep. Several methods for producing multi-depth blind vias are currently being evaluated within the circuit board industry. One method that is being used is that of build up technologies. This method while quite effective for interconnecting is expensive as process steps are re-produced in order to make staggered vias.

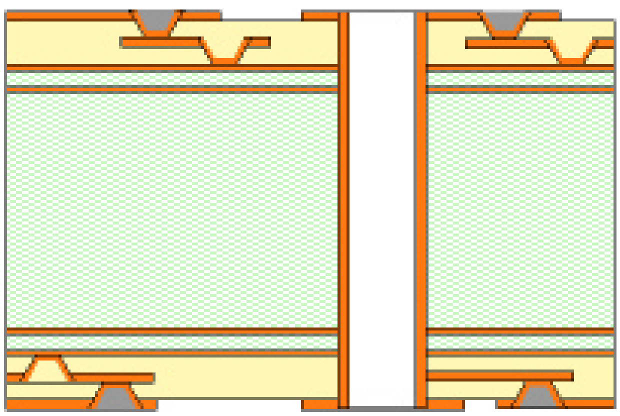


Fig. 3 Buildup Technology with Staggered Vias

The advantage of laser drilled blind vias are in its unique ability to drill multi-depth blind microvia interconnections as part of the multilayer process without using build up technologies. These multi-depth blind vias are stacked rather than staggered as depicted in the drawing below:

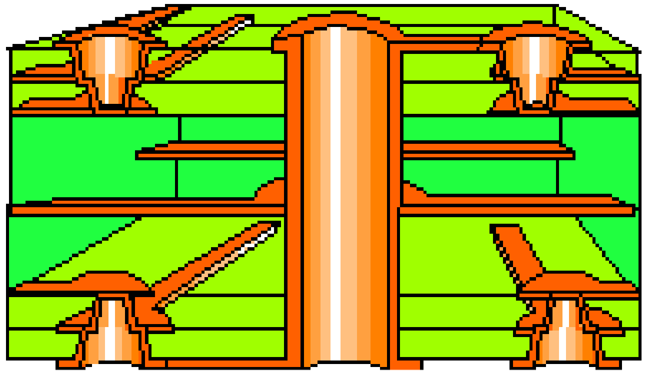


Fig. 3 Three Level Laser Drilled Blind Vias

Design

Today's circuit board designs with over 495 interconnections per square centimeter are forcing designers to reduce trace and space geometry's shrink via sizes and increase board layer count in order to complete all of the interconnections. Surface mount devices, by their nature require all interconnections to be made on the surface layer of a board. Obviously, all connections cannot be made on these surface layers requiring large numbers of via holes to enable signals to access inner routing layers where the majority of interconnections are made. The problem arises when a high percentage of available via locations are used before all interconnections have been made. This phenomenon, known as "via starvation", is an indication that even smaller geometry's will be needed to successfully complete the routing task.

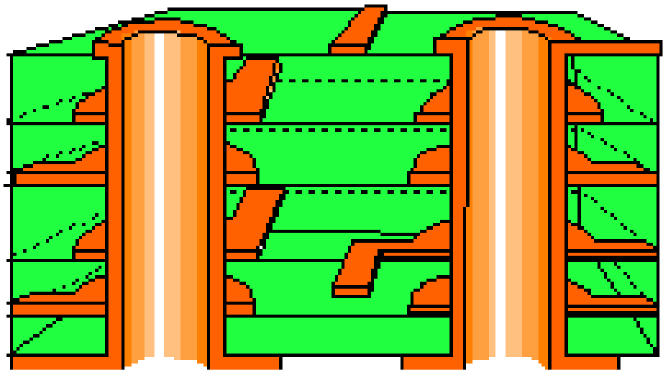


Fig. 5 Via Starvation

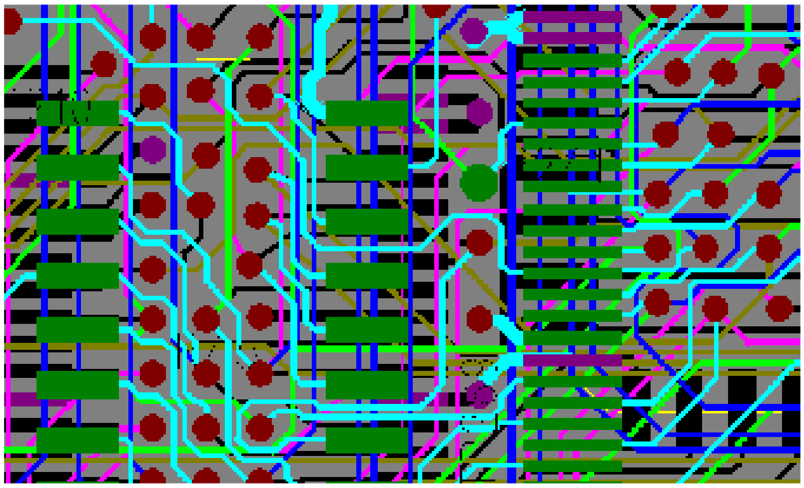


Fig. 6 Via Starvation at the Design Stage

Reducing traces below 0.005" and drilling plated through holes smaller than 0.010" however, causes fabrication costs to skyrocket and dramatically reduces the number of board vendors capable of building such boards. An alternate but emerging fabrication technology, laser drilled microvias, can offer greatly increased routing capability without requiring further decreases in feature or drill sizes.

The fact that the laser vias may be placed within the pads of the SMT devices themselves that plays the greatest role in eliminating the via starvation problem. Interconnecting from the outer layer down one layer creates an advantage and results in increased circuit density and a reduced cost per function. The cost savings on a per function basis are however significant when the interconnections are made down three levels, where the primary interconnections are made between the second and third level on either side. Panels of eight or ten layers can be designed in four layers, thus reducing the design and fabrication costs and circuit complexity.

From the design standpoint, one remaining point needs to be made, that is that the laser blind vias do not extend beyond the third layer, the through hole vias penetrate through all layers of a board. The advantage of using LaserVia™ Technology in this context is within the interconnections of the first three layers of a multilayer board; the corresponding layers on the opposite side of the board are non-perforated and available for mounting an additional circuit. The opposite side of a through via board, however, would be already filled with via pads and through vias and largely unavailable for additional circuitry.

The Machine

The machine designed to introduce this technology comes out of the joint venture between MicroPak Labs, bringing 15 years experience in laser applications to the PCB world and Pluritec, backed by a strong 20 years old reputation in production drilling equipment. The laser chosen, high power RF excited CO_2, has the advantage to enable the highest productivity in the market: 974 vias per second on a grid. The CO_2 laser, reflected by the copper, is highly absorbed by the dielectric, so that a single pulse is sufficient to create the blind via. This technology, though, requires windows be pre-etched on the external layers of the board before laser processing.

Fig. 7 Laser Drilling Machine

The Test Coupon

A test coupon the size of a typical business card has been designed to allow the fabricators to take confidence with this technology and to understand how it can be smoothly inserted in their existing fabrication process. The experience of building this board has proved beneficial to the fabricator in terms of process control and understanding its limitations, by bringing true challenges in terms of alignment and plating.

Test coupons have been fabricated by two Italian companies:

- FCE, Moncalieri (TO)
- Corona, Leini' (TO)

Additional tests on plating parameters to increase yield have been performed by Alfachimici, Moncalieri (TO)

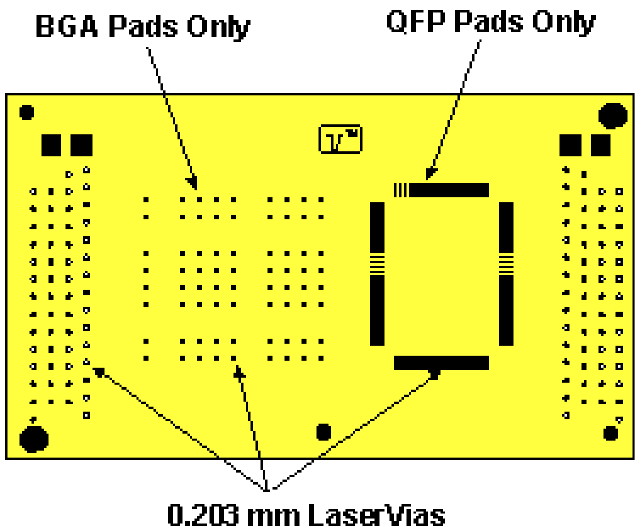


Fig. 8 BGA BizCard Test Coupon

Fabrication

The CAM operation to bring the circuit design into the fabrication area is rather straight forward for producing laser drilled blind vias, however, it is necessary to make sure the outer layer is fabricated with etched windows that act as a mask for rapid laser drilling.

There are two methods for producing these windows and they can be different as defined as:

1. Foil Lamination - where copper foil is used in the same fashion as Mass Lamination; or
2. Core Cap Lamination, where the outer layers are treated as if they were innerlayers and the windows are etched on the outer surface and the traditional circuits are etched on the inner surface.

The preferred method for building blind via circuits for interconnections down to a third layer is the Core Cap Lamination technique. With Core Cap Lamination the critical registration between the outer window and layer two donuts can be best aligned with innerlayer alignment techniques. The pad on layer three can be adjusted in size to match the alignment capabilities and material movement knowledge, of the fabricator. Figures 5 and 6 show the typical material layup for each method.

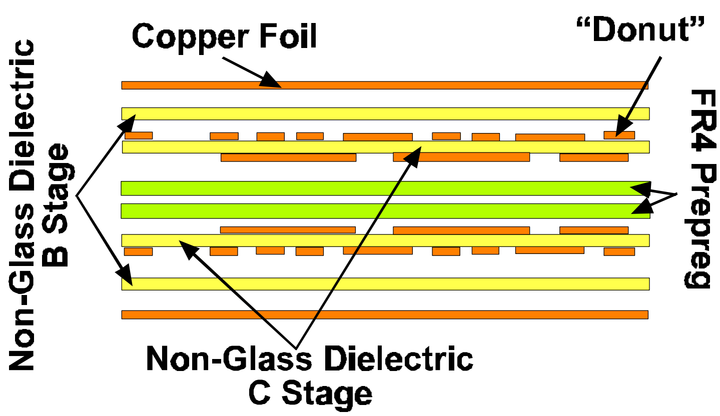


Fig. 9 Foil Lamination

These two methods for producing a conformal mask for drilling blind vias with a laser can work with any number of layers. The two diagrams within this paper are designed around a six-layer board design. It is generally not necessary to design blind via boards for less than four layers, with the best value or payback for boards in the six and up layer count.

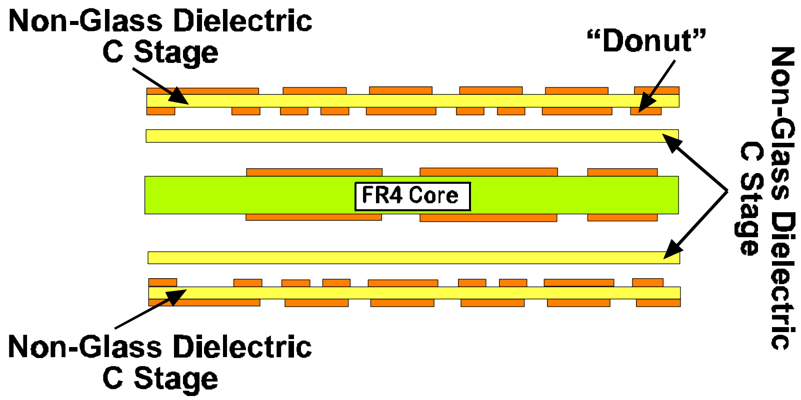


Fig. 10 Core Cap Lamination

The test design, containing both a Ball Grid Array (BGA) and a fine pitch Quad Flat Pack (QFP) is available for use in evaluating the fabrication process capability for the introduction of laser drilled blind vias to multi-depths. The design has all nets interconnected so that a simple continuity test can be preformed to check the entire circuit or to find an open area. The interconnection scheme is defined in the manner displayed in the two drawings that follow. Both drawings depict only one side of the circuit board. Figure 7 shows the interconnecting scheme for the BGA and Figure 8 the interconnecting scheme for the QFP.

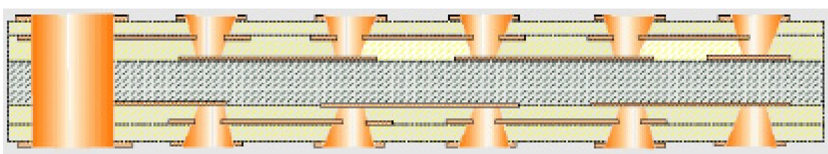


Fig. 11 Multi-Depth Interconnections

Fig. 11 shows how the section of the board appears after laser processing, where vias are ablated with a single pulse, without stopping the axes, though they go down to level 3.

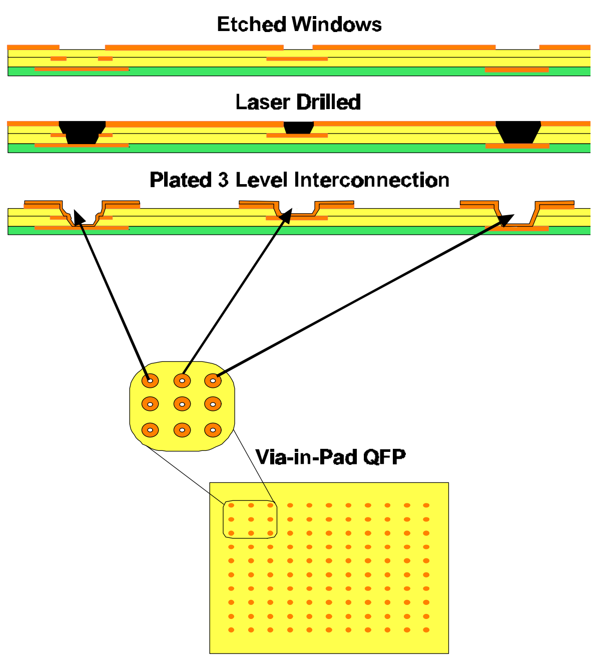


Fig. 12 BGA Multi-Level Interconnections

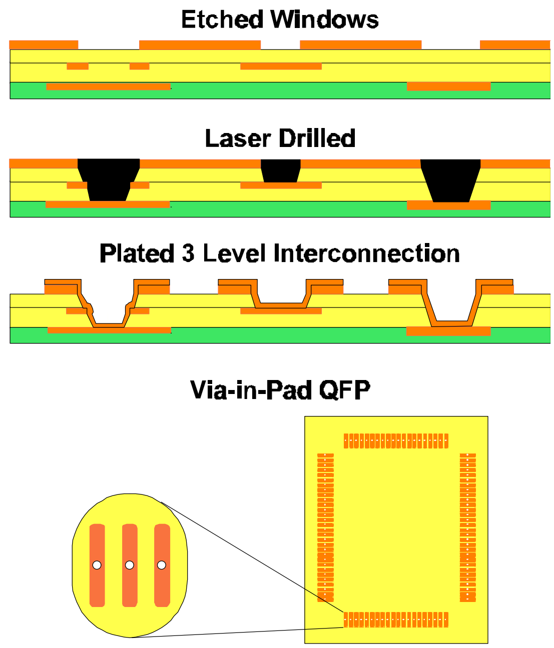
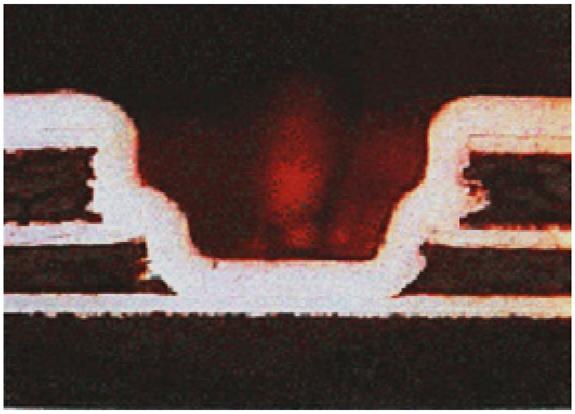


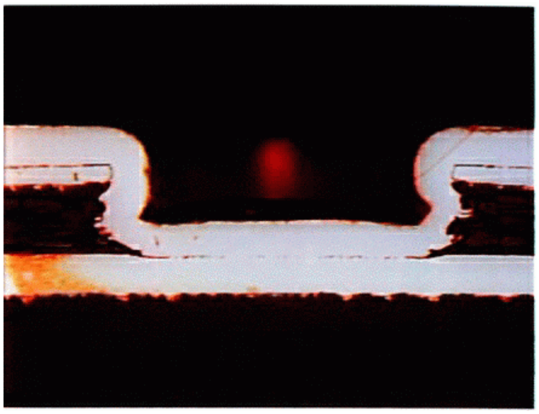
Fig. 13 QFP Multi-Level Interconnections

Early results obtained by the fabricators involved in the test have showed which are the critical steps of this technology:

1. Consistent photo etching of 0.12 diameter windows, that can bring to reduce panel size
2. Difficulty for the registration of the innerlayer two to the outer layer, that proved to be the most difficult task in the process
3. Plating, because of the small diameter of the via and its blind nature.



Multi Level Interconnection



Single Level Interconnection

Fig. 14 Cross-Sections

Conclusion

The advantages of multi-depth blind via interconnections saves significant time for the circuit board designer, easing his layout, and routing effort. The most significant savings however comes in the time saved, allowing more circuit boards to be designed by a given circuit board designer.

Component densities are only going to grow over the next few years, placing more demand on the circuit board to make the necessary interconnections. The circuit board designer will not be able to meet the increasing interconnect demand with out the use of blind via-in-pad technology.

All of the elements now exist including the design CAD tools, knowledgeable circuit board designers, fabrication processes and now production lasers to meet the current and upcoming rapidly advancing dense interconnect demand. Circuit board fabricators have recently become open to developing new technologies and are testing new advanced dielectric materials to help the up coming microvia technology movement.

In field application of the technology has shown encouraging results both in high volume production potentiality and process consistency, demonstrating that LaserVias are the most cost-effective path to microvia-in-pad technology.

Biography

Larry W. Burgess has over thirty years experience in the interconnect packaging disciplines. He holds a Bachelor's Degree in chemistry and has held Management and Engineering Management positions at fortune 100 electronic companies. He is President and Chief Technical Officer at MicroPak Laboratories, Inc., where he has licensed technology to Sandia National Laboratories. MicroPak has recently formed a joint venture with Pluritec. Currently, Mr. Burgess has opened the first in a series of Laser Drilling Centers in North America to support the upcoming demand for laser drilled blind microvias.

Fabrizio Pauri holds an advanced engineering degree (Laurea in Ingegneria Meccanica) from Politecnico di Milano. Since 1995 he has been employed at Pluritec Italia in the Research and Development Department as the Project Manager of laser microvia drilling machines. Currently he is developing processes and new techniques for laser drilling existing and new circuit board dielectric materials.