# Microvia forming using UV laser

*By Bernd Lange, LPKF Laser & Electronics AG, Garbsen, Germany*

The continuing trend of miniaturization in electronic packaging demands smaller and smaller structures in conductive materials such as copper, nickel and gold. Vias in PCB's are becoming as small as 60µm and for packaging interposers and High Density Interconnect boards (HDI) the industry roadmaps predict microvias with 50µm to 30µm diameter for the near future.

An increasing number of reliable interconnections between the layers of HDI boards require smaller microvias and higher quality standards for the forming process of microvias.

For reliable interconnection the main requirements to microvias are:

- Clean vias without residue
- No delamination of copper and substrate
- Tapered sidewalls without undercut
- Big land diameter for robust interconnection to the inner layer
- No perforation of the inner layer

There are primarily four methods of microvia formation:

- Mechanically drilled vias
- Photo via formation / etching
- Plasma-etching
- Laser ablated vias

Mechanical drilling is well known to the PCB community and the machine providers try hard to control the drilling depth in order to qualify their machines for blind via formation. Nevertheless this method is limited by throughput and efficiency as well as by its accuracy especially when it comes to glass-fiber reinforced materials.

Photo via forming process is limited to photo imageable dielectrics. The expose and etch reliability, low copper adhesion and changing dielectric thickness together result in low yield. This method is usually not economical for small and mid size board houses.

Plasma etching is also limited to certain substrates and requires substantial capital investment, which makes it only attractive for very high volume production. The quality of the micro vias is a function of the exact process control.

It is not surprising that laser ablation with its flexibility and versatility quickly became the leading method for microvia forming. Two types of lasers are generally suitable to perform well in this field although they have very different characteristics and applications.

## *$CO_2$ Laser*

$CO_2$ lasers are emitting infrared light with a wavelength between 9.3μm to 10.6μm.$CO_2$ lasers are primarily used to drill bare substrates due to their inability to cut through copper. Recent developments of special absorption foils should also allow the ablation of very thin copper layers eventually.

$CO_2$ lasers are available with a wide range of output power, providing the necessary margin for fast drill processing in circuit board substrates.

As vias are becoming smaller another shortcoming in the use of $CO_2$ lasers emerges. The relatively long wavelength limits the minimal focus diameter in a given working field area. The formation of vias with diameters less than 75μm reaches the physical limits of this technology.

The practical use of $CO_2$ lasers requires a long chain of process steps within very tight tolerances. The copper layer typically has to be opened by etching, which causes a number of additional alignment challenges. To address this the design usually needs to provide larger pads on the inner layer. Although $CO_2$ lasers are perfectly capable to ablate organic substrates they can't guarantee residue-free holes as the laser light reflects on the inner copper and thus reduces the energy absorption. This requires chemical desmear or plasma etching as another consecutive process step to clean the bottom of the via from eventual residue.

In an attempt to remove all residues completely with a $CO_2$ laser it requires so much laser energy that this typically results in under cutting and delamination.

## *UV Laser*

The other type of laser used for micro via formation is a solid-state laser emitting ultraviolet light. Looking at the absorption spectra of copper, epoxy, polyimide and glass it shows that ultraviolet light with a wavelength of 355nm will be absorbed from all those materials. In addition this light will be emitted with very short high-power pulses. Precisely focused to a small spot the extreme high power density creates very concentrated plasma that allows pinpoint ablation of the material.

This creates a number of significant advantages for the drilling of printed circuit boards.

1. Both copper and substrate can be drilled with the same laser using only one piece of equipment without the need of photochemical etching of the outer copper layer.

2. UV lasers are capable of removing the copper layer to expose the fiducials for proper alignment between drill pattern and artwork of the inner layers.

3. Microvias with superior quality, large and clean bottoms that are textured and won't require desmearing.

4. The energy exposure in a very small spot for a very short time limits heat spread-out to the dill hole's environment. This also reduces the danger of delamination of mushroom shaped holes.

5. UV lasers have a very small focus. This allows creating of microvias with diameters as small as 30μm with a high aspect ratio.

6. UV lasers allow production of "stacked vias" that connect three layers of the board with one another.

Other benefits of UV laser formation of microvias are:

1. The excellent alignment to the inner layer circuitry by using fiducials on the inner layer allows the use of smaller land pads.

2. The capability to form stacked vias, connecting three layers reduces the SBU steps.

## *New Challenges*

Recently HDI circuits were used mostly in consumer handheld devices. RCC foils are perfectly capable of being laser drilled and meeting the performance requirements of such products.

The automotive and computer industry's demands for HDI PCBs with extended temperature range and superior mechanical stability requires microvias formed in reinforced materials. Woven glass fibers bedded in epoxy provide the necessary material characteristics but they are also more difficult to drill with lasers because of their inhomogeneous absorption of laser light. The glass has a higher absorption threshold than the epoxy and it also has a relatively uneven distribution over the area.

## *New Possibilities*

In the past most of the UV laser-drilling machines were limited by their laser output power and were very limited in their use with FR4 substrates. Resin coated copper (RCC) and similar non-reinforced materials were the materials of choice and numerous results of laser via formation in these materials were reported.

New laser sources especially developed under the requirements of the microvia formation process ensure excellent results in glass reinforced materials and accelerate the formation process. The following pictures show drilling results in FR4 with 1080 glass fiber. The micro via formation has been made with MicroLine Drill 600 of LPKF Laser & Electronics.

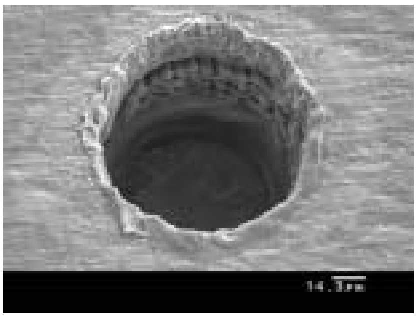

Fig. 1: 700x magnification of a microvia in FR4.
(Photo: LPKF)

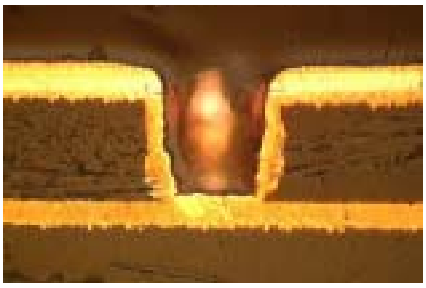

Fig. 2: Microvia in FR4 with 1 layer of 1080 glass reinforcement.
(Photo: Fachhochschule Stralsund - University of Applied Sciences)

Fig. 3: Flawless connection throughout the entire bottom of the via.
(Photo: Fachhochschule Stralsund - University of Applied Sciences)

Fig. 1 is a SEM picture of a microvia in FR4 with one layer of 1080 prior cleaning. The via is drilled with an LPKF MicroLine Drill 600 with UV laser. The bundles of glass fibers are cleanly terminated and epoxy is ablated at the same location allowing flawless plating. The bottom of the via is residue free and textured. Fig 2 shows the cross section of a 100µm diameter microvia after plating. The walls are well tapered and the sidewalls are plated continuously. Fig. 3 shows the bottom of the same microvia with a flawless connection and evenly deposition of the copper at the inner layer.

Test boards with 60 000 vias of different diameters from 50µm to 300µm formed by UV laser have been plated without desmearing and subjected to cycles of thermal shock. The electrical test revealed excellent resistance results and yield.

## *Literature Sources:*

IPC: National Technology Roadmap for Electronic Interconnections 2000
K. Vollrath, B. Lange: A versatile laser machine for PCB production, to be published
S. Raman: UV laser drilling of multilayer blind vias, technical paper at IPC 1998, S17-1
S. Venkat: Laser processing of flex, PC FAB 2-2001, p. 28ff
C. Vaucher: Current alternatives to direct imaging / patterning, CircuitTree 7-2001, p. 46f
T. Rapala-Virtanen: Experience gained manufacturing HDI PWBs, EIPC2001, II.2.1ff