Laser Drillable E-Glass Multilayer Materials…

An Overview of Laser Enhanced Materials

by **BOB FORCIER**

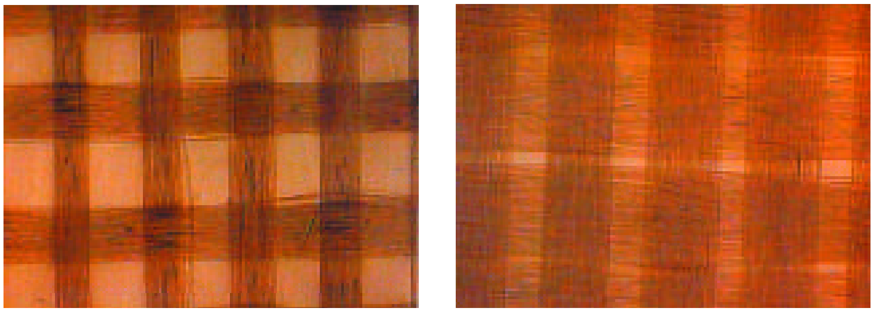
LASER DRILLABLE MATERIALS TECHNOLOGY

One key factor of a new family of materials that enables easier laser drilling is the weaving and post-weaving processes implemented by the glass fabric suppliers. By careful formation of the glass fiber bundles, the glass manufacturer can provide a flatter bundle in both the warp and the fill directions as compared to the rounder bundles usually associated with standard E-Glass weaving technologies. Included in this new process is a spreading of the glass fibers to achieve a more even glass distribution across the entire area of the fabric. In this manner, the fabric has a smaller range of highs and lows in glass density.

With standard materials, the area where two fiber bundles overlap has a high glass density and is more difficult to laser drill. By spreading out the fibers, these high-density areas of glass fibers have a lower glass content and can be laser machined with less laser pulses. Of course,different glass manufacturers utilize slightly different processes to achieve this spreading of the fibers, but the different glass manufacturers arrive at the same resulting glass distribution characteristics. Figure 1 illustrates the differences between a standard E-Glass fabric and a fabric that has been optimized for laser drilling.

Utilizing this enhanced glass fabric and a compatible resin technology, the laminator can produce a multilayer system that has many advantages compared to resin-coated copper technology or to laminates made with conventional E-Glass fabrics. These laser-drillable fabrics are currently available in limited glass styles, but are gradually becoming commercially available in more standard glass fabric styles.

The first materials to be utilized in the industry are presently thin fabrics, which are prepregged with high-Tg resin systems for the chip packaging applications. Although the fabric provides a building block for this technology, the resin systems utilized have to complement the glass finishes to achieve optimum performance in laser drilling.


Standard E-Glass Fabric

Laser Drillable E-Glass Fabric

Figure 1. Standard E-Glass Vs Laser Drillable E-Glass.

MATERIAL PROPERTIES OF LASER-DRILLABLE FABRICS

Table 1 provides the typical properties of laser-drillable multilayer materials as compared to both resin-coated copper and standard materials. As outlined in the table, fiber-reinforced materials with this enhanced glass fabric can provide numerous advantages to the HDI designer and the printed circuit including improved thermal and mechanical characteristics of the finished interconnect.

PRINT-THROUGH AND SURFACE SMOOTHNESS

One of the key benefits of this technology is the reduction in “print-through” of the internal circuit image on the outside of the multilayer board after the pressing operation. It is not uncommon, with thin external dielectrics and thin external coppers, for the image of Layer 2 or Layer N-1 to be transferred to the outer surfaces. This print-through topography can reduce outer layer circuitry formation yields when fine lines are predominant. Resin coated copper type materials can sometimes show more of the print-through than conventional materials depending on the design, the copper weights, and lamination process.

The use of laser-drillable fabrics reduces print-through because of the glass reinforcement and good surface planarity compared to standard E-Glass or resin-coated copper

Table 1. Comparative Benefits of Laser Drillable Multilayer Materials.

Property	Resin Coated Copper	E-Glass Advanced Materials	Laser Drillable LD™ Advanced Materials
Print Through	Moderate	Good	Excellent
Outer Dielectric Tolerance	± 15%	±10%	±10%
Maximum Laser Drillable Dielectric Thickness	80 micron	240 micron 2,3 ply constructions	240 micron 2,3 ply constructions
Laser-Drilled Hole Geometry and Plateability	Good	Fair	Excellent
Dimensional Stability	Moderate	Good	Excellent
Resin Cracking	Possible	No	No
Typical Laser Drilling Speed (500 Hz TEA CO_2 Laser 75-micron Dielectric)*	50 micron: 1 pulse 80 micron: 1 pulse* *Application dependent	50 micron: 4–5 pulses 80 micron: 6–8 pulses* *Application dependent	50 micron: 3–4 pulses 80 micron: 5–6 pulses* *Application dependent
Material Options (volume availability)	Epoxy High Tg Epoxy	Epoxy High Tg Epoxy Low Loss Epoxy Low CTE Epoxy APPE Polyimide Low Loss Polyimide Cyanate Ester	Epoxy High Tg Epoxy Low Loss Epoxy Low CTE Epoxy APPE Polyimide Low Loss Polyimide Cyanate Ester
Z-Axis Range	+5.0%	1.7% –4.5%	1.7% –4.5%
X-Y CTE Range PPM/°C	30–40	10–16	10–16
Tg Range °C	130–170	130–250	130–250
Plasma Compatibility	Yes	No	No
Optimum Layer Counts	2–12	2–50	2–50
Minimum Copper (microns)	5	5	5
BGA Rework	Fair	Excellent	Excellent
Low Dk Resins	Yes	Yes	Yes N4000–13, N6000
Chip Packaging	Yes	Yes	Yes

dielectric technologies. In addition to reduced print-through, the laser-drillable materials have inherently lower surface roughness as measured with a surface profilometer, when compared with standard E-Glass dielectrics.

DIELECTRIC THICKNESS CAPABILITY AND RESIN FILLING

Another benefit of this technology is thickness uniformity and resin filling. Most resin-coated copper technologies are somewhat limited in outer layer dielectric thickness capability due to the process of manufacturing resin-coated coppers.

Because of this limitation, certain applications of impedance control and buried via designs are more difficult to achieve. Laser drillable prepregs and laminates offer some alternatives to enhance these types of designs.

Since resin-coated coppers are relatively thin by their nature (80 microns and below), it is difficult to achieve standard impedances without very fine lines (100 microns) externally for microstrip applications. To complicate the issue, resin-coated coppers have slightly worse thickness tolerances compared to standard prepregs, a characteristic that does not assist in tight impedance control.

This is not the case with laser-drillable glasses, where higher overall thickness can be achieved with tighter thickness tolerances. With the thicker dielectrics provided by the laser-drillable materials, 50 ohm impedances can be targeted with standard external line geometries, such as 125-micron lines and spaces, thereby providing better final interconnect yield possibilities.

In addition, HDI manufacture is often associated with buried vias, which require resin filling during the fabrication process. Usually resin-coated copper technologies have difficulty in filling buried via pairs due to the thin nature of the product. Also, with resin-coated copper, it is sometimes difficult to guarantee a minimum insulation thickness over circuit lines after the relamination.

With LD materials, insulation of 40 microns or greater is possible, with the glass fabric acting as a spacer to guarantee the insulation between the layers.Figure 2 illustrates a micrograph of a multilayer blind and buried via board, which utilizes laser-drillable fabrics both internally for the buried vias and externally for the microvias. Notice the excellent filling of the buried vias by the laser-drillable prepreg.

Another benefit of the laser-drillable material technology is its ability to be supplied as a core for buried-via applications. This will

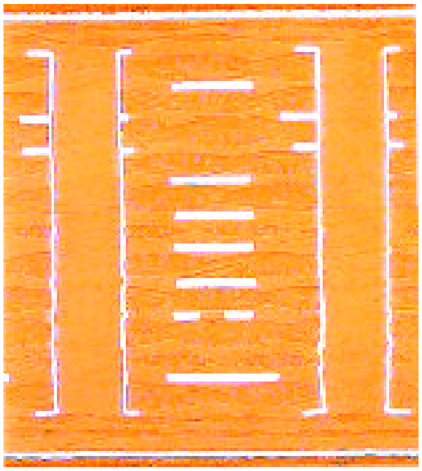


Figure 2. Buried Via 14-Layer Resin Filling Utilizing Laser-Drillable LD Materials (Layer 1–2 and 13–14 fabricated with LD Technology).

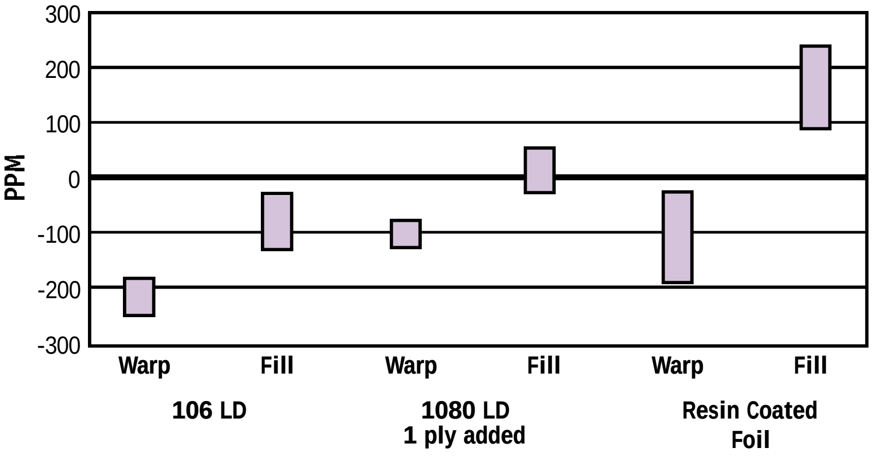
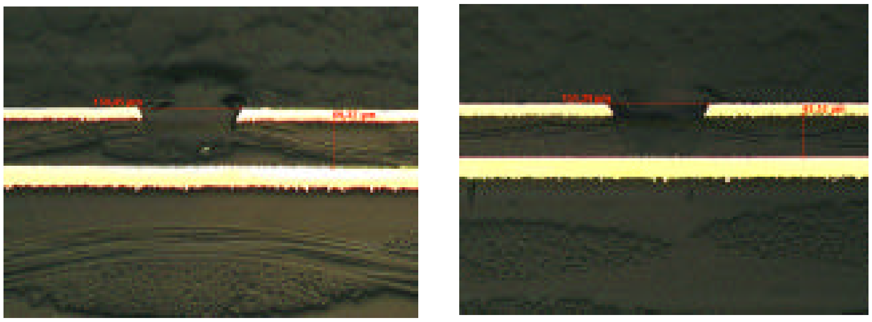


Figure 3. DIM STAB on 4 Layers (106 LD and 1080 LD types Vs Resin Coated Foil).



Conventional 1080 Dielectric

LD™ Dielectric

Figure 4. Comparison of LD and Standard Dielectrics. (4 pulses, 500 Hz TEA CO_2 laser).

enable fabricators to create vias generated by laser ablation from Layer 1 and n to Layers 3 and n-2. This cannot be accomplished using resin-coated copper technology.

DIMENSIONAL STABILITY AND X-Y CTE

Because of the glass reinforcement, dimensional stability during processing and of the final multilayer are improved with the laser-drillable fiberglass-reinforced materials compared with resin-coated coppers. As shown in Table 1, the X-Y CTE for glass reinforced materials is considerably improved over resin coated copper. A key factor in this improved X-Y CTE is the low CTE of the glass fabric itself. Figure 3 illustrates the tighter range achieved on dimensional stability ppm movement when utilizing the laser-drillable material set.

LASER DRILLING ROBUSTNESS

Figure 4 contains two micrographs comparing standare E-Glass laser-drilling of a microvia to the new laser-drillable dielectrics utilizing a CO_2 laser. Even after four pulses of the dielectric,some residual resin is left behind at the bottom surface of the microvia of the conventional materials, which will disrupt the integrity of the plating process. In addition, the circumference of the resulting hole is not uniform due to the glass rich bundles associated with conventional fabrics. However, the LD materials have clean laser-drilled holes with clean lands at the bottom of the microvia formation.

Several laser drilling equipment manufacturers now utilize multiple frequency lasers that provide sequential processing of the laser formation of the hole. By tailoring the frequency of one laser to remove the copper foil, the alternate laser can have a different frequency and pulse configuration that allows fast and clean removal of the glass fibers and resin, thereby forming a reliable microvia hole. These laser machines all use galvo technology for speed enhancement and provide software programming of the process to optimize the hole texture.

As the technology of laser drilling and microvia processing progresses, thicker dielectric substrates, such as 1080 and 2113 became viable candidates for blind and buried via formation. With the laser-drillable prepreg and laminate materials and the new technology of laser drilling machines, the laser process can be adjusted to provide approximately 25 percent improvement in laser drilling speed while simultaneously providing a rounder, more plateable internal surface geometry. Since the LD materials don't have as many glass-rich areas, the possibility of glass wicking is reduced considerably.

RESIN TECHNOLOGY

Although very popular, the resin types and thickness ranges of resin-coated coppers are somewhat limited. For example, most resin-coated coppers have just two generic FR-4 resin technologies: a) 130–140°C Tg and b) 150–175°C Tg. There are a few higher performance resins that have been applied to resin-coated copper and SBU approaches. Although these products have excellent technical merit,they are not being used in high-volume non-reinforced applications at this point in time.

The weaknesses of non-reinforced resin technology may not be readily apparent at

Table 2. Advanced HDI Material Properties for LD Systems.

Resin Type	Fiber Type	Application	Tg °C DSC TMA *DMA	X/YCTE -40C +125°C PPM	Z CTE –50°C to +260°C %
Resin Coated Copper	None HDI	135–140	155–170	30–40	5.0%+
Epoxy	N4000–2 LD	Broad Spectrum	140	12–16	4.5
Epoxy	N4000–6 LD	Low CTE	180	10–14	3.8
Epoxy Low CTE	N4000-7 LD	Low CTE	155	10–14	3.7
Epoxy Low Loss	N4000–13 LD	Low Dk 1-5 Ghz	210	10–14	3.5
BT	N5000-32 LD	Telecom	180	10–14	3.8
BT JEDEC	N5000 LD	PBGA, HDI	*190	10–14	3.6
APPE	N6000 LD	1–10 Ghz	*210	10–14	3.5

*by DMA

the lower layer counts. As you move up in layer count however, a number of factors give a compelling argument to consider fiber-reinforced options and more importantly, laser-drillable materials. Higher layer-count designs require lower expansion rates due to the higher overall thickness involved and to satisfy concerns over via reliability or pad lifting on the external circuitry.

Laser-drillable prepregs and laminates allow many options for laser microvia formation in a conventional multilayer process.

Also, with more complex designs, buried vias are being used more often in conjunction with blind vias to increase density. Buried vias often are designed as the second or third dielectric into the HDI board, as illustrated in Figure 2. Because of their location in the multilayer structure,they require more dimensional stability and better via-filling capability.

The options for laser-drillable resin systems are listed in Table 2. Perhaps the biggest advantage of utilizing fiber-reinforced materials is X-Y-Z CTE.

The benefits of laser-drillable E-Glass reinforced materials include faster laser processing, cleaner hole formation, lower thermal-mechanical expansion rates, better hole-wall adhesion during the metalization process,uniformity of material in the multilayer structure, easier UL approval of new products, and better fill of buried via stacks. Laser-drillable material technology provides other options to the fabricator and to the OEM end-user, including a broad spectrum of available resin systems. ■

SUMMARY

Laser-drillable prepregs and laminates allow many options for laser microvia formation in a conventional multilayer process. Backplane technology with high overall thickness designs can easily benefit from this approach because of the need for the lower z-axis expansion afforded by fiber reinforced dielectrics.

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