

The latest challenge for the electronics assembly industry has surfaced around lighting technology. How to reliably separate individual circuits from the panel – when the panel is made from metal?

Introduction.

The advent of new technologies have been driving the electronics industry for decades, mobile telephony, PCs to Laptops, Tablets and GPS. Each creating demands and forcing advances in machinery and processes used to manufacture the product.

Substrates have changed to meet the signal and power requirements of the smaller more compact circuits but are in large part the same materials they have been for many years. A sandwich of FR4 and copper layers. The FR4 being the greater percentage of the mechanical structure supporting the electronics. A Material that is relatively easy to cut using mechanical cutting mechanisms.

The advent of high power LEDs and a shift away from incandescent based lighting systems has created another reason for process and machinery evolution. Contrary to some opinions LEDs are not without operational challenges, they do not last forever and the light output does decay. Each of the issues listed can be controlled or mitigated through thermal management. When an LED is powered to produce the Photons we see as light – they create a great deal of heat. That heat unchecked will proportionally reduce the performance of the device over time. Consequentially the work in developing solutions to the thermal problems have been significant – the primary method being the use of a Metal substrate with a laminate layer mounted on its surface. The substrate backing layer typically being Aluminum.

The use of a thermally efficient pathway is very beneficial to the performance of the finished product but it does create issues for the last operation in the manufacturing line. PCB singulation. Aluminum, the metal of choice, is a ductile metal, relatively soft and quick to bind to cutting tools unless it is actively cooled and moved out of the cutting path under pressure – typically a jet of cooling fluid. Using an active cooling system [Wet] in an electronics environment is simply un-acceptable. Cutting aluminum dry is difficult exercise whether it be using a router type cutter or a Saw blade. The cut particles bind to the blade and fill the cutting flutes blunting the cutting faces. The management of the particles demands very high level of vacuum to ensure there is not contamination of electrical pathways.

"V score" panel designs appear to make sense, most of these panels can be laid out as a grid. However the usual methods of separating V score boards do not work well with an Aluminum substrate they have a tendency to imply immense stresses as the panel is "worked" by an operator to encourage the individual circuits to part company from their connected neighbors. The solution lies in the use of Laser cutting systems.



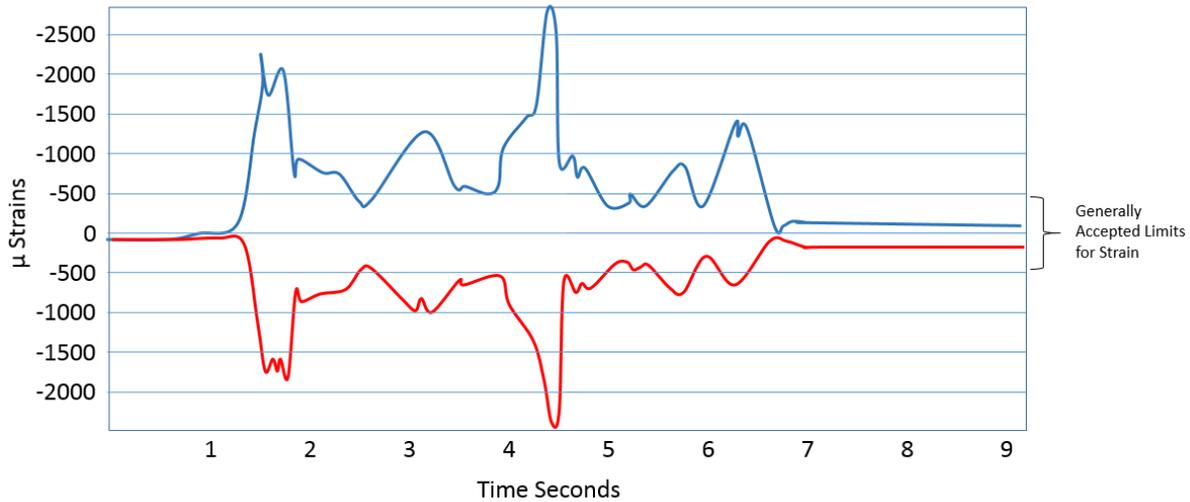


Figure 1 When a panel does not break along its V score line and it is manipulated back and forth the stress induced across the panel exceeds the approved limit by as much as 7X

Laser Background.

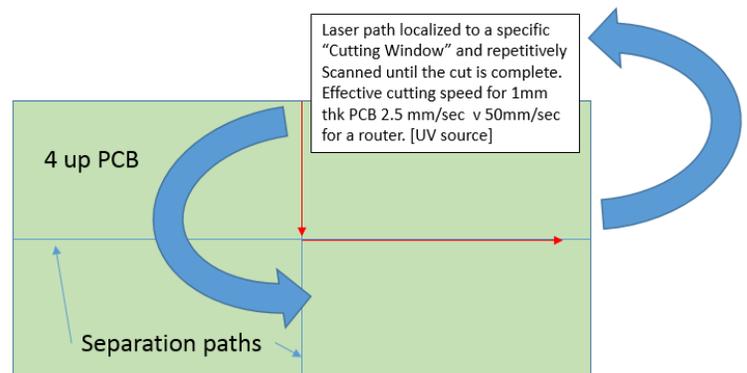
Lasers have long been looked at as the obvious next technology step in PCB singulation, they simplify tooling requirements, increase flexibility and have no consumable parts requirements. However they have **not** significantly advanced machine design or process development because they don't actually work that well with the materials we deal with on a daily basis. Laser types [wavelength] need to be appropriately selected to achieve best material interaction, this being more difficult for FR4 which is a combination of two or more diverse materials (commonly being Fiber laminate, Copper, Resin, etc.) The process of using a laser to "Cut" is actually described as Ablation. Laser ablation is completely described thus. [Courtesy Wikipedia]

Laser ablation is the process of removing material from a solid (or occasionally liquid) surface by irradiating it with a laser beam. At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates. At high laser flux, the material is typically converted to a plasma. Usually, laser ablation refers to removing material with a pulsed laser, but it is possible to ablate material with a continuous wave laser beam if the laser intensity is high enough. The depth over which the laser energy is absorbed, and thus the amount of material removed by a single laser pulse, depends on the material's optical properties and the laser wavelength and pulse length. The total mass ablated from the target per laser pulse is usually referred to as ablation rate.

The Effective cutting depth of Lasers is very short and the pulse rates [power transmission] extremely sensitive. Consequentially it is necessary to scan a particular area multiple times, each scan over the area removing a thin layer of material.

This results in a process that is typically very slow

when compared to traditional mechanical cutting systems, routing, Sawing or punching. Increasing power



or pulse duration results in a significant and instant buildup of heat and burning of the cut path, in some cases dramatic delamination of the substrate results. Balancing power and cut speed has not been achieved to a satisfactory degree such that routing and other mechanical systems can be made obsolete.

Today Laser systems are used where mechanical systems are either too harsh or the substrate too difficult to handle in a fixture or gripper. (Ultra-thin substrates or Flex circuits). The effective cutting focal depth of most lasers used today is 0.6mm making them suitable for cutting flex or ultra-thin PCBS. But, anything that has a thickness of > 0.6mm is much more difficult. Thicker materials can be cut but the effective "Conical Profile" of the laser will exhibit itself in an angled edge, and the cycle time increases significantly. The Laser Source used for PCB is usually UV. The flexibility inherent in these panels make them difficult to handle because they have inadequate mechanical stiffness and flex under normal cutting forces. Laser is a non-contact mechanism and allows a Flex circuit to be supported using a simple flat plate or a vacuum fixture, making the process easy to setup. UV as a source, however, is expensive and so green lasers have crept into the market as a compromise of laser capability for lower capital outlays.

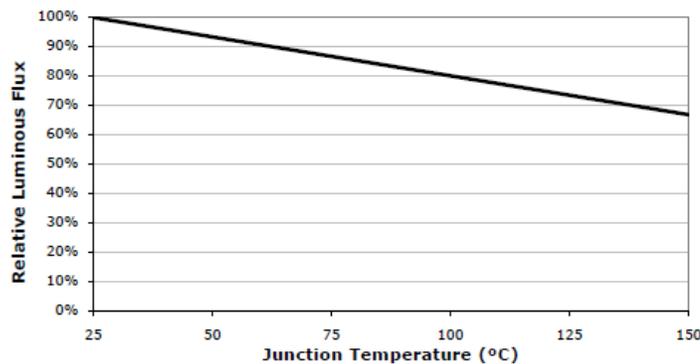
CO2 and similar wavelength lasers are available and they can be used under strict process control where the local metal inner layers do not cross the cut path. I have mentioned burning or carbonization as a side effect of the process and with CO2 it is almost inevitable that some degree of edge burning will occur – it is not pretty to look at but the bigger issue is it being a conductive path, it is in effect a carbon trace from point A to B. If these two points are isolated – the issue is a moot, if however either point is a signal/power path a direct short may result.

So how does any of this translate to the lighting industry?

LED and Lighting Manufacture.

The lighting market has evolved at a phenomenal rate with the advent of power LED packages. Today LED appears in residential, commercial and automotive applications either as an indicator, an accent or a primary source of illumination. The later creating exponential demands for LED products. However while an

Relative Flux vs. Junction Temperature ($I_f = 300$ mA)



appealing alternative to traditional light sources LED is not without issue. Issues with heat have been described previously and the correlation LED life and light output is well documented. The chart below is courtesy of Cree and shows the relationship of temperature and light output.

Various mechanisms have been tried to manage thermal conduction of locally generated heat resulting in the use of Aluminum substrate.

Routers offer no benefits, Saws are better but not ideal, cutting tools blunt and break, cut edges become burred and poorly defined, fixturing is complicated - Laser appears to be the only solution. A UV or Green Laser solution requires multiple passes and consequentially is too slow. A longer wavelength laser source is a better solution, it provides extremely high power capabilities, is readily available, comparatively inexpensive, compact with extremely long life. Using a 1032nm pulsed fiber laser results in a machine with a footprint no larger than a machine using mechanical cutting technology. A Pulsed Fiber laser does not require any optical guidance mechanism, it simply moves with the X, Y gantry.

The technology is not new, it is common place in the metal fabrication industry, the scale of the systems has been the issue. The migration of the Laser Systems into the PCB industry does not demand a technology development exercise – the issue is one of integration.

Process Control.

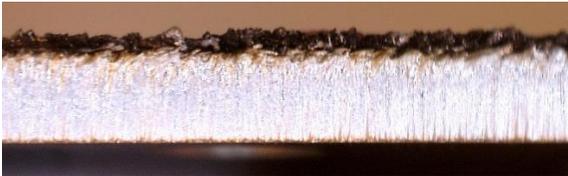
The power delivered by a Laser is a consequence of the Focal Spot x Pulse length x Source Power and feed rate. Determining the best possible pulse rate and power delivery is subject to the materials being cut and effective thickness, addition of inert gas may be considered both as a cooling agent and to minimize any charring of the glass laminate layer. The Heat Affected Zone [HAZ] around the laser is remarkably small and does not present an issue to components in close proximity to the cut path. Typically at a distance of 1.0mm substrate temperatures do not exceed 120 deg C.

Effective PCB thickness needs to be understood. If a 1.6mm has previously been V scored to a depth of 25% the effective thickness of the circuit is now 1.2mm. This is in itself an interesting observation, cutting or breaking a section of aluminum close to 1.2mm thick is not a simple task, the metal bends, it does not break and the tendency is to bend against the break line multiple times. Every reversal in direction creates a strain across the circuit in the plane the LEDs are mounted, effectively "Peeling" them off their pads.

Burning of Aluminum does not occur and Aluminum Oxide is an electrical insulator anyway. However the Glass layers of the substrate do have the potential to burn/carbonize and create a conductive pathway, as mentioned previously, to prevent this the area immediately surrounding the Laser /PCB interface is inerted with a N2 gas injection. The elimination of the local Oxygen significantly mitigates the carbonization of the glass layer. [See images.]



Edge of panel from manufacturer. This shows a clean aluminum substrate, a thin synthetic material layer on top. This is prior to assembly or singulation operations.



Post Laser Singulation where the process has NOT been controlled well. Too much power has caused the Aluminum to overheat locally and while it has been cleanly cut – the top layer of the substrate has been severely carbonized.



Post Laser Singulation where the process has been controlled appropriately. The quality of the cut is obvious and the degree of expansion and charring of the top layer is zero. Cut speed for this operation was >35mm/second with a single pass. This results in an effective cutting speed of >35mm/sec.

Cost.

The cost of Lasers when compared to a Router or a Saw are higher, but this often reverses when the tooling costs are considered. A fixture for a Saw or a Router must hold the PCB firmly prior to cutting, and retain each individual circuit as it is released from the panel. It must mitigate cutting forces and withstand the lateral loads without allowing the PCB to “slip.” Fixtures are sophisticated systems in their own right and consequentially expensive. Laser is non contact process and as a result demands less complicated fixturing that is less expensive. When the cost of the Laser is looked at alongside the lower cost of the fixtures, the “Solution” may work out to be the least expensive of the alternatives being considered. Add to the simplified fixturing, a Pulsed Fiber Laser has a life of ~100k hours. So there are no costs for cutting tools and significantly reduced fixture costs making the cost of ownership very low.

Conclusion.

Laser cutting in the circuit board industry is not an answer to every situation, routing and sawing still have the majority position in terms of numbers of machines and miles of material cut. However newer materials and increased number of thin substrates demand new solutions. Lasers are ideally suited to these materials and design outlines. The good news is that laser cutting solutions today are compact and very reliable. Could a single machine be equipped with a router and a Laser source?? Possibly. Today such a machine does not exist – will it in the coming year[s] ? Quite probably.

Getech Automation was established in 1992 to focus on developing and manufacturing machines and systems to meet key needs of the PCBA and Semi-conductor industries. Today Getech Automation is the world leader in PCB singulation technology producing Stand Alone and fully automated In-Line systems. The cutting systems used include traditional Router bit cutters for Tab removal, Diamond Saw cutting for PCBs with long continuous Tabs and Laser cutting for exotic materials.

END.