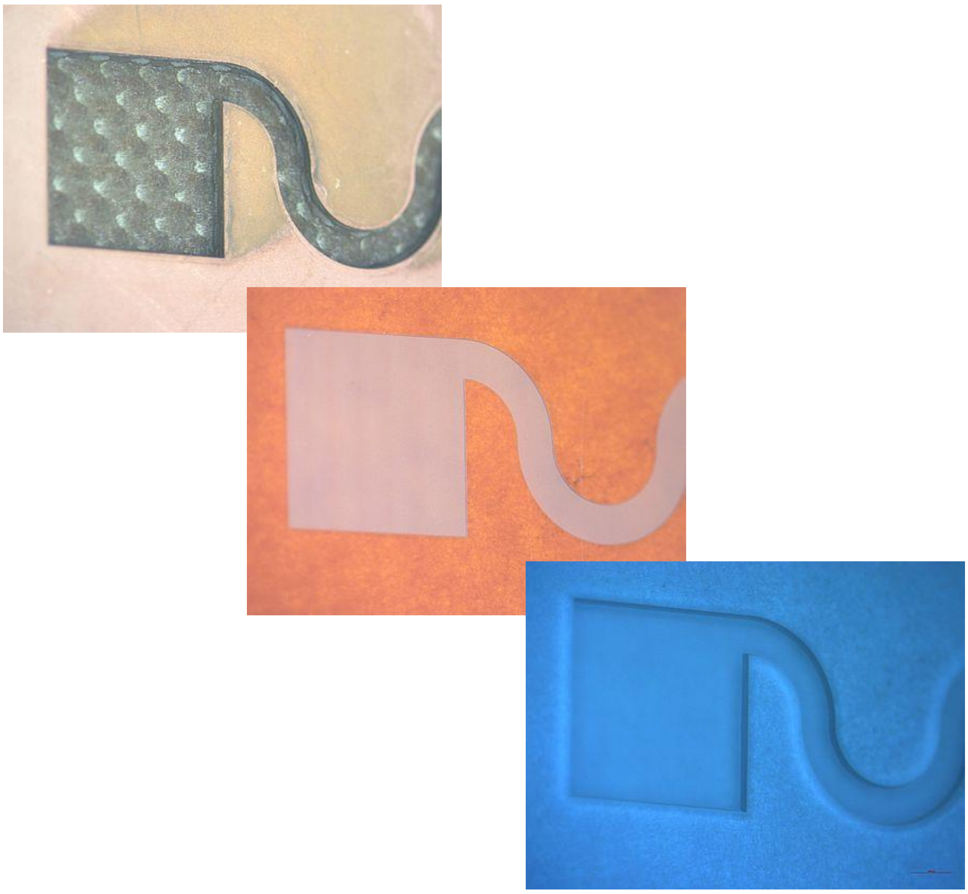
PCB Laser Etching and Pocketing in a Single Step

Laser Depth Engraving with the LPKF ProtoLaser



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Blind openings in printed circuit boards (PCBs) are sometimes needed for a variety of reasons: for keeping assembled board heights low, for connecting components directly to specific signals or power layers without stacking vias, for creating recessed/embedded chips, which require shorter wire-bonding connections for chip-on-board assembly, or for executing edge connectors with better mechanical stability and lower profiles. Pocketing is also used to expose RF antennae on inner layers of multilayer designs, to apply optical fibers or connections to boards, or simply to access inner layers at certain locations. Utilizing such pockets or cavities can increase the complexity of the PCB and the assembly process; therefore, these features are usually associated with HDI boards and special applications. For this report, the possibilities of laser depth engraving and the resulting surface quality were examined with two different LPKF ProtoLaser systems.

Depth-controlled milling may appear to be an obvious solution, but it is limited by the diameter of the smallest tool. For HDI PCB boards, especially in a prototyping environment where laser processing is already a logical choice, a laser is an ideal tool for making cavities with extreme precision in all dimensions.

Laser wavelengths that are effective in drilling and cutting PCBs are also effective in processing cavities. One primary advantage of a laser tool is its ability to stop at different materials such as a Cu layer, for instance. In addition to pocket creation, another application in which stopping at various material layers proves to be beneficial is the blind via drilling process, which can be performed with all LPKF ProtoLaser systems.

More unpredictable is the processing of pockets in substrates containing different materials such as the fiberglass and resin combination in FR4. For an overview and a better understanding of laser pocketing, three common double-sided PCB materials (Isola's standard FR4, Panasonic's Megtron 6, and Rogers RO4003C) as well as a homogeneous glass (SHOTT AF 32 glass), a polyimide (Kapton®), and ceramic (LTCC® from Dupont™ and Al_2O_3) substrate materials were selected.

The Sample Design and Job Preparation

The test layout consists of a square measuring 5 mm by 5 mm, a circle with a diameter of 5 mm, and a curved line with a width of 1 mm between them. This simple design, which is small yet large enough for individual material behavior to be recognized, is very informative for the operator; processing is done along the major axis and arcs. The sample has overall dimensions of 24 mm x 7 mm; the engraved or pocket area (white area inside the red area in Figure 1) has dimensions of 22 mm x 5 mm and an area of 110.5 mm^2.

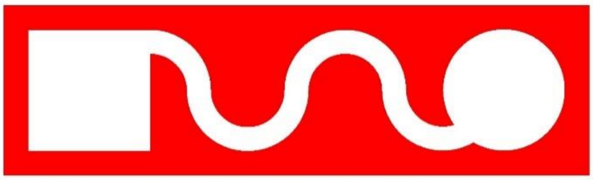

Figure 1: CAD of test layout

The simple design geometry was created in the Layout section of LPKF CircuitPro PL. It could also be imported from vector-based formats such as DXF, Gerber, or similar. The workflow for a such a sample is easy, as it only consists of laser ablation of the surface metal. X/Y or X-only strategies were used across processed materials. Laser tool parameters differ for different materials. Frequency, power, and laser movement speed are typically

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optimized for the material type, while the number of repetitions defines the engraving depth. Of course, parameters will also vary in relation to the various laser wavelengths and pulse widths available in other ProtoLaser models – for that reason, this set of data is not treated in this report.

Figure 2: LPKF ProtoLaser U4

Equipment Selection

The top-selling, all-purpose LPKF ProtoLaser U4 is expected to be able to deal with most, if not all, selected materials. The main aim of the application test was to discover if the LPKF ProtoLaser R4 could do it better. The ProtoLaser U4 uses a UV nanosecond laser source, while the ProtoLaser R4 uses a green picosecond source. The R4 model also has a smaller focused beam spot, offers excellent absorption, even in transparent materials, and can operate within the so-called cold ablation regime. This provides an advantage for precise laser etching of relatively small design features and eliminates overheating of the material. Cold ablation typically contributes to slower processing speeds, and the smaller-diameter laser beam requires more passes to remove the same area, so longer processing times can be expected.

Figure 3: LPKF ProtoLaser R4

Process Setup and Measurement

Since the selected material for this experiment was not a multilayer design that would allow us to stop at a specific target layer for pockets, the target depth was defined as half of the material thickness. The focus of the test was on surface quality in terms of roughness and colorization (carbonization).

Samples were processed several times on each material to yield optimal parameters and the desired cavity depth. The sample was then reproduced, and measurements were done in each case. Surface analysis was performed with the Keyence VK-X210 laser microscope at the section of the design where the square feature transitioned to the channel feature. The processing time was measured by the CircuitPro PL software. The results are shown in Table 1. The processing time was influenced by the material and the cavity depth – approximately half the material thickness.

	Surface roughness Rz [um], index			Processing time [mm:ss], index		
Material	**ProtoLaser U4**	**ProtoLaser R4**	**U4/UR**	**ProtoLaser U4**	**ProtoLaser R4**	**U4 / R4**
FR4, 1.55 mm	84	92	0.91	08:20	10:16	0.81
Megtron 6, 0.54 mm	83	28	2.96	02:55	07:16	0.40
Rogers 4003C, 1.0 mm	66	31	2.13	02:08	06:44	0.32
Glass AF 32, 0.5 mm	44	18	2.44	08:51	16:33	0.53
Kapton, 0.125 mm	15	7	2.14	00:52	01:49	0.48
Al2O3, 0.55	22	9	2.44	44:00	08:02	5.07
LTCC, 0.1 mm	33	9	3.67	03:09	01:35	1.99

Table 1: Surface roughness values for processed pockets and processing times on ProtoLaser U4 and R4, respectively, as well as resultant indices, where an index below one indicates superiority of ProtoLaser U4 and an index above one indicates superiority of ProtoLaser R4 for the given parameter

Results

The overview of measurements in Table 1 indicates that the common PCB materials FR4, Megtron 6, and RO4003C, each of which is based on a fiber structure and resin, are easy and fast to process by laser but have poorer surface quality due to their inhomogeneous substrates. The different substrates have different compositions because they are designed for different target applications, so the results were expected to differ between them. The worst surface roughness was achieved with the lowest-cost FR4, which was used more as a reference than as a target material. A quick comparison of numbers between both systems on FR4 shows a slight advantage of the ProtoLaser U4 over the ProtoLaser R4, which is 23% slower and provides 10% lower quality. To provide a better understanding of the surface roughness (Rz) parameter, a comparison with mechanical milling was made: Rz = 29 µm with the LPKF ProtoMat S104 using an LPKF 0.8 mm end mill at 80,000 rpm and a max. feed rate of 44 mm/s. At this point, milling shows a clear advantage over laser processing in terms of surface quality and speed, but in the multilayer case, where milling should stop at a thin (18 µm) internal copper layer, mechanical tools may fail.

Laser processing of advanced Megtron and Rogers substrates already displays an advantage for the ProtoLaser R4 picosecond system in terms of the surface quality, at the cost of a longer processing time. Considering the different thicknesses of the different base materials and the fact that the pocket depth should be about half of the material thickness in this application test, it can be calculated that the ProtoLaser U4 nanosecond UV system processes Megtron as fast as FR4 (~10 mm^3/min) and RO4003C 2.5 times as fast (~25 mm^3/min) as FR4 and Megtron.

The cavity surfaces are shown in the photos in Table 2. In each case, the microscope was tilted and focused to a part of the sample for better visibility of the cut depth.

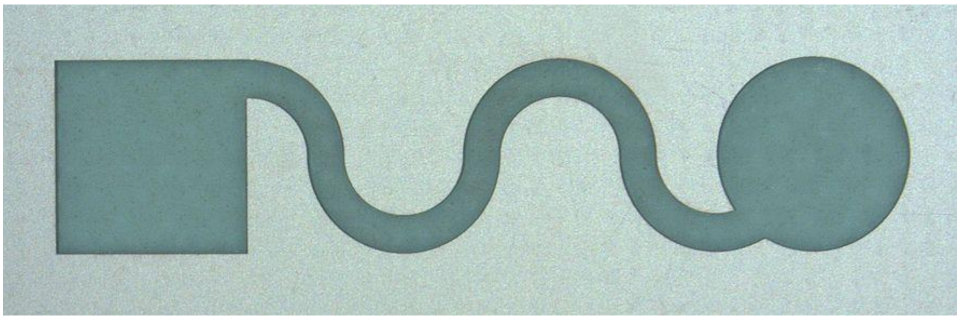


Figure 4: Top view of depth-engraved sample design in Rogers RO4003 material processed by the ProtoLaser R4

In the case of a chip-on-board application, in which the signal layer is also etched by a ProtoLaser, processing the pocket in the same process step and using the same equipment provides a clear advantage in terms of precision of the design and due to the reduction in handling time.

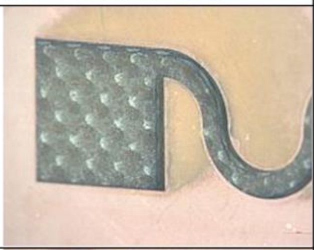
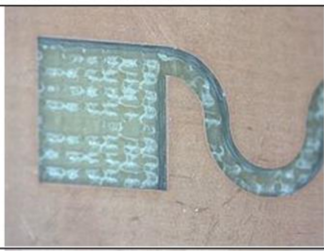
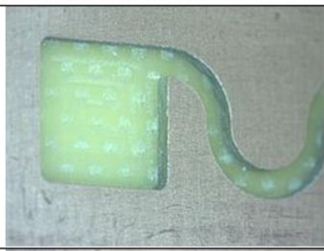
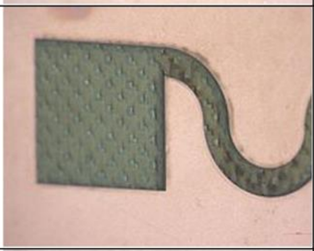
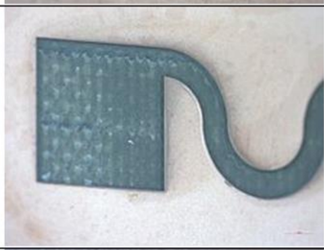
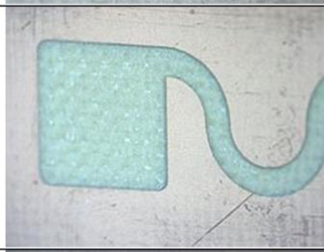
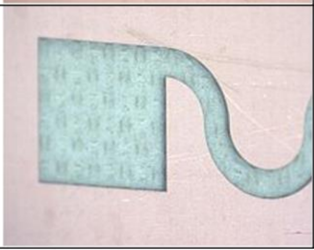
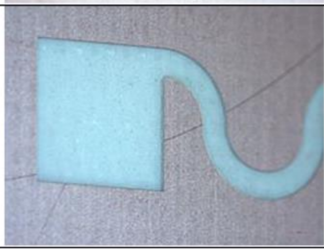
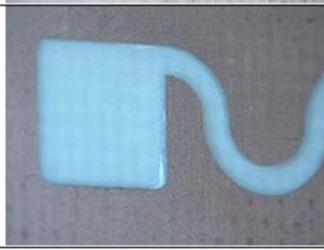
Material\System	LPKF ProtoLaser U4	LPKF ProtoLaser R4	LPKF ProtoMat S104
FR4 (1.55 mm)			
Megtron 6 (0.54 mm)			
RO 4003C (1.0 mm)			

Table 2: Overview of depth-engraved samples of selected substrates processed by both ProtoLaser systems as well as mechanically milled ProtoMat samples (included for reference purposes)

The second group of tested materials cannot alternatively be mechanically processed. The common solution for these substrates is laser processing. These materials are used not only in electronics, but also in such fields as microfluidics. As the substrate materials are homogeneous and solid, the surfaces after laser depth engraving are also smoother. With all four materials in this test, roughness is significantly lower on the samples produced with ProtoLaser R4. Surprisingly, the processing time for both synthetically generated ceramic materials, i.e., alumina and LTCC, was much shorter with the ProtoLaser R4. Visual results are shown in Table 3. As the materials are thinner, edges are as visible as with the typical PCB materials displayed in Table 2.

Conclusion

The experiment demonstrated the successful realization of laser depth engraving of various popular electronics substrates using the LPKF ProtoLaser U4 and ProtoLaser R4 with the standard laser tool setup in the integrated CircuitPro software. There is always a certain amount of surface roughness after laser ablation. Once the target depth is reached, it is possible to perform an additional step using different laser tool parameters to smoothen the surface further, if necessary. Such laser polishing could lead to overheating of the material and thus discoloration of the surface, which should be avoided as much as possible. Based on the results for the selected materials, the behaviors of many similar electronics substrates on the market can be predicted. Also, it is important to note that it is possible to laser-etch a PCB design and produce openings or pockets in the same process step without moving and realigning the PCB; this guarantees exact matching of tracks and pads to cavities and vice versa.

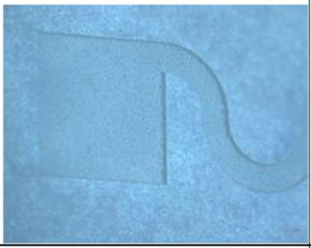
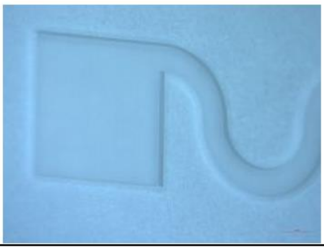
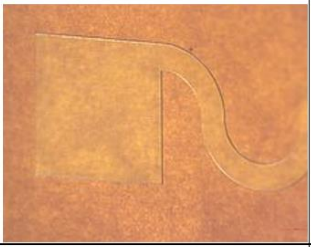
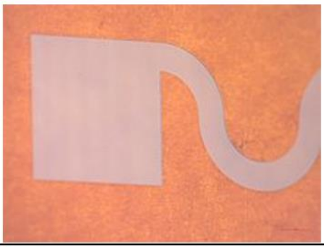
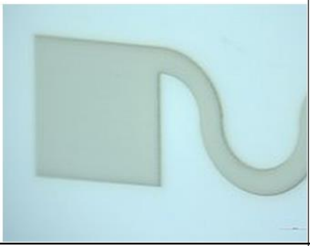
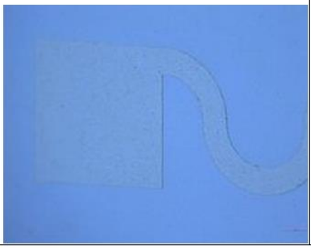
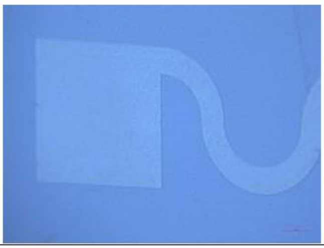
Material\System	LPKF ProtoLaser U4	LPKF ProtoLaser R4	LPKF ProtoMat S104
Glass AF 32 (0.5 mm)			not possible
Kapton (0.125 mm)			not possible
Al2O3 (0.55)			not possible
LTCC (0.1 mm)			not possible

Table 3: Overview of depth-engraved samples of selected substrates processed by both ProtoLaser systems

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