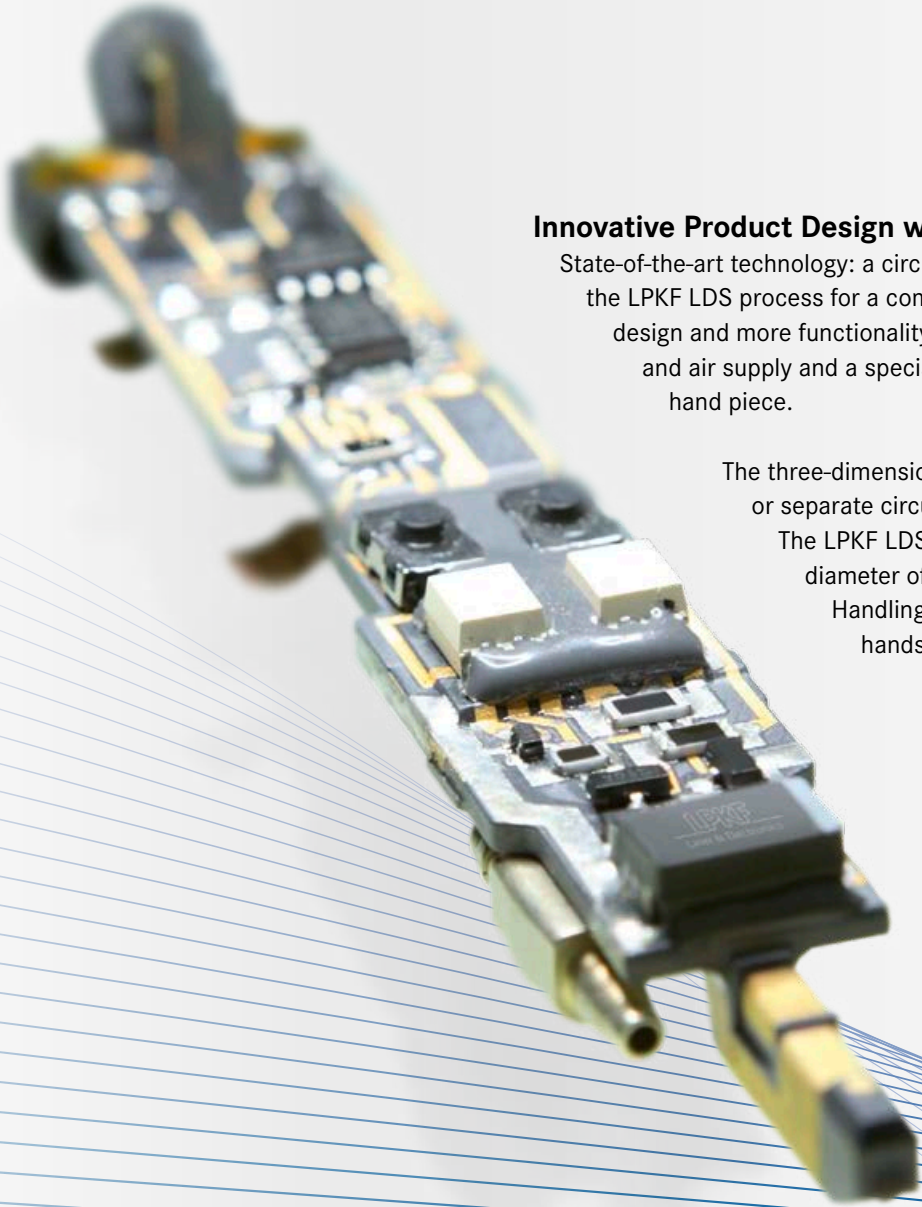


Three-Dimensional Circuits
LPKF LDS: Laser Direct Structuring for
3D Molded Interconnect Devices





Innovative Product Design with MID Technology

State-of-the-art technology: a circuit carrier was designed according to the LPKF LDS process for a complex dental tool. This makes a compact design and more functionality possible. The control for the warm water and air supply and a special lighting device are integrated in the hand piece.

The three-dimensional circuit comes about without cables or separate circuit boards directly on the plastic carrier.

The LPKF LDS process reduces the weight and diameter of the tool. That improves the ergonomics: Handling is pleasant and the manual stress on the hands is lowered.

Component for dental hand piece
(Manufacturer: KaVo Dental GmbH)

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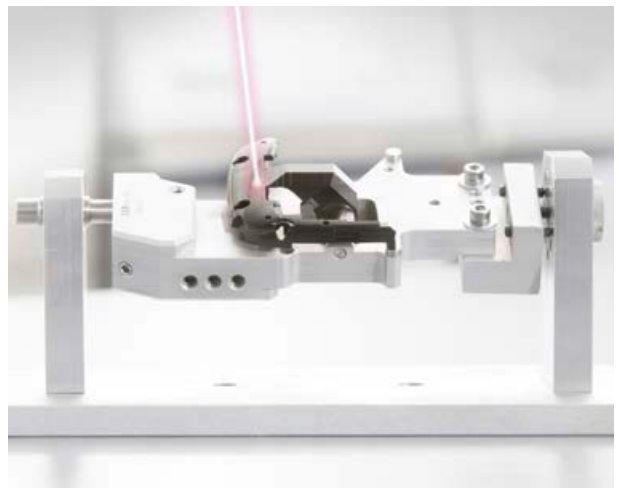
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More Functionality – New Possibilities

Since 1997, LPKF has been working on three-dimensional circuit boards and has developed a laser-supported process for producing three-dimensional MIDs (molded interconnect devices): the LPKF LDS process. Circuit layouts can be created on complex three-dimensional carrier structures using LPKF laser direct structuring.

The laser beam inscribes the layout directly on the plastic component. The weight and dimensions of the component can thus be noticeably reduced. Developers profit from complete 3-D capability on free-form surfaces and additional freedom in changing the circuit design. LPKF LDS opens up new possibilities.

Laser direct structuring takes place immediately after single-component injection molding of the carrier. A laser beam requires only a few seconds to transfer the circuit layout directly from the computer to the plastic carrier – without tools or masks. The subsequent metallization and SMD assembly lead to high-quality developed products.



Smartphone antenna structured with the LPKF Fusion3D 1100

Laser-structured and metallized
finger tips for a robot hand
(Source: Citec, Bielefeld University)

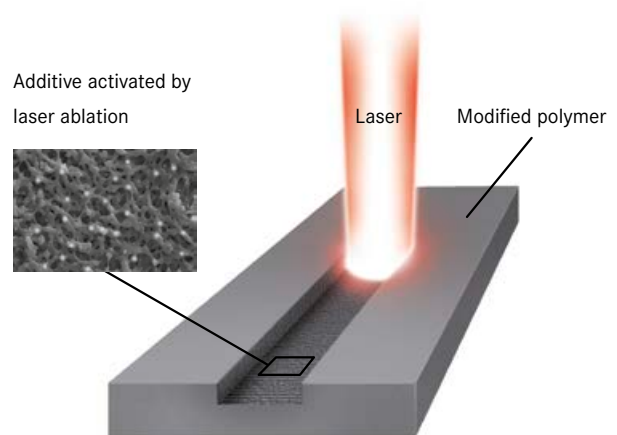


Flexible Solution for Three-Dimensional Circuits

One of the substantial advantages in processing materials with the laser is the combination of a clearly defined energy input on the material and a high processing speed. The layout of the circuit is not predetermined by the geometry of a special tool. This makes a shorter development time and a higher degree of flexibility possible.

A Better Product at a Lower Cost

Two-component injection molding and hot stamping are recognized methods in producing MIDs (molded interconnect devices). Both processes are bound to product-specific tools in integrating conductor structures to a component. Thus close-to-production prototyping is virtually impossible. The increasing miniaturization of circuits on MID components is leading to a clear rise in the set-up time and the costs. The LPKF LDS process prevents these problems and increases cost-effectiveness in prototyping and series production.



The LPKF LDS Process

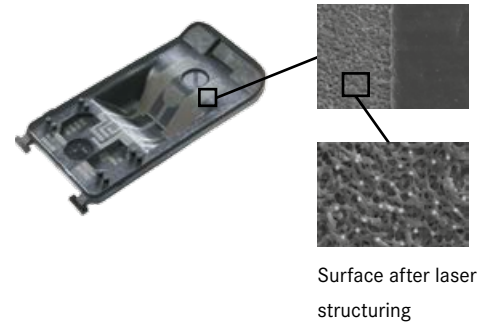
1. Injection Molding

The parts are produced in single-component injection molding from commercially available thermoplast provided with additives. In comparison to two-component injection molding, only one simple tool is required and the molding process is quicker. You can find further information about the large LPKF portfolio of LDS-suitable materials on page 14.



2. Laser activation

Activation of the thermoplastic material is done by laser beam. A physical-chemical reaction creates metallic seeds – that is the activation process. In addition to activation, the laser forms a micro-rough surface on which the copper is firmly anchored during the metallization.

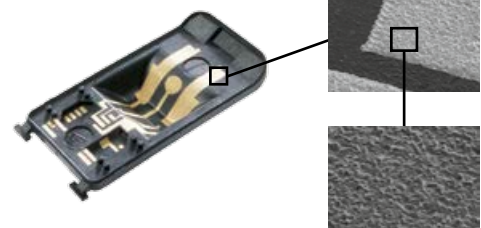


Surface after laser structuring

3. Metallization

Metallization of the LPKF LDS parts begins with a cleaning step. After that, an additive track build-up takes place in copper baths, typically in a range of 8 to 12 $\mu\text{m}/\text{h}$. Finally, as a rule a deposition of nickel and a thin layer of gold takes place.

Even application-specific coatings such as Sn, Ag, Pd/Au, OSP, etc., can be applied in this process.



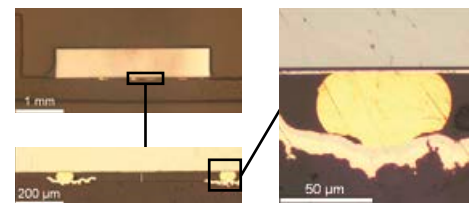
Surface after metallization

4. Assembly

Many laser-activatable plastics with a high level of heat resistance such as LCP, PA 6/6T or PBT/PET blend are reflow-solderable and thus compatible with standard SMT processes. When applying soldering paste, dispensing is the standard process if different height levels have to be achieved. There are now several providers of technical solutions for three-dimensional assembly.



Bond pad on currentlessly metallized pad with Cu/Ni/Au



Stud bonds on metallized pad with Cu/Ni/Au



Tomorrow's Technology in Today's Production

The increasing use of electronics is a challenge for many industries and markets. Industry requires technologies that reduce the dimensions and weight of components. At the same time, production of prototypes has to be simplified and the time until market launch has to be shortened. The LPKF LDS process meets these requirements exactly.

LPKF LDS in Automotive Engineering

Modern vehicles require a multitude of sensors and electronic assistants which increase the comfort and safety of the vehicle passengers. At the same time, the number of components used and the manufacturing costs should be clearly reduced. Injection-molded molded interconnect devices (MIDs) in combination with suitable connection and assembly technology are outstandingly suited for achieving these goals.

Typical electro-mechanical functions such as keys, plugs and other connection elements can thus be integrated side by side in a component that serves as a molded interconnect device.

Deciding in favor of LPKF LDS expands the design options, speeds up change of electronic components and leads to less expensive development and production.

Steering wheel controls
(Manufacturer: TRW
Automotive for BMW)



Telecommunication – Staying in Contact

A multitude of types, design, miniaturization and cost reduction characterize the development of portable electronic devices. End users expect more and more functions in up-to-date compact enclosures.

The LPKF LDS technology has a large potential for miniaturization of components. At the same time, it offers a high level of flexibility when it's a matter of change and improvement of functionality – especially if features are supposed to be variably adapted for several products. Antennas in mobile phones and laptops produced with LPKF LDS technology have proven this millions of times.



For a New Generation of Medical Devices

Smaller dimensions, more functions – these market requirements apply to many medical devices. New capabilities and technologies are pushing this trend: due to the rapid development in software and chip technology, new diagnostic procedures are constantly opening up. Small diagnostic devices help improve millions of patients' lives. The patients can carry small diagnostic and monitoring devices for drug application, such as blood sugar measuring devices.

In connection with widespread wireless communication technology, personal physician visits could be limited to a minimum. This development requires a new and higher stage of intelligent functional aggregation. The laser-based LPKF LDS process exactly meets these requirements with its precision and high level of reliability.

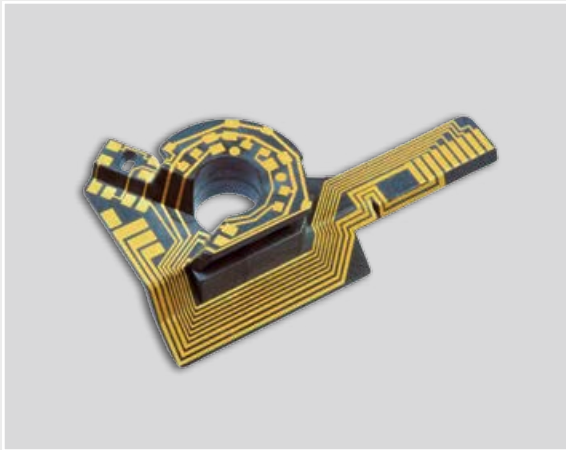


MID technology makes medical devices even more comfortable. A classic LPKF LDS application: hearing aids that are light and compact (Manufacturer: Siemens Audiologische Technik [Siemens Hearing Instruments])

Inspiration for New Layouts

General electronics, medical technology, automobiles, telecommunication, consumer products – LDS components are found in many devices and systems in many different areas of application and solve a whole range of demanding problems.

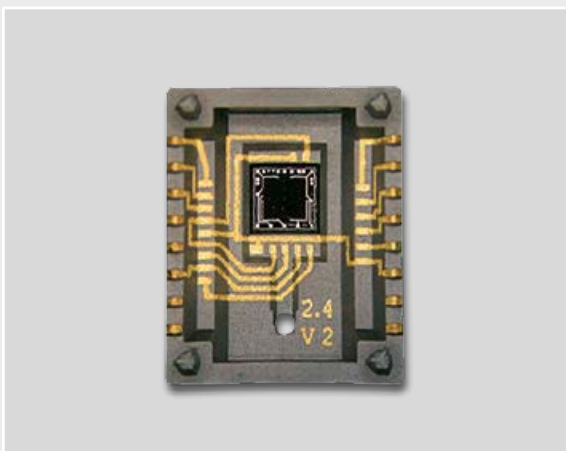
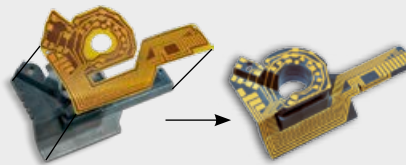
What is more convincing than projects that others have already successfully implemented? In the following, some applications represent the respective technical challenge. They illustrate how theoretical approaches have become real components – and show the potential for LDS technology to develop in completely different markets.



Combining flex circuit and plastic component into one component (Manufacturer: Harting AG)

Replacing Flex Circuits

If the available installation space is limited, LPKF LDS prevents problems that occur with flex circuits such as complex handling or limited bending radius.



Pressure sensor for industrial applications. The ASIC is integrated; mechanical connections are part of the enclosure (Manufacturer: Harting AG)

Replacing Chip Carriers

Changes to the circuit layout can be easily implemented by a change of the laser program. LPKF LDS technology thus opens up additional platform strategies for sensor enclosures. With suitable chip sets and circuit layouts, different products are developed on the basis of a common injection molded component.

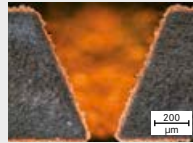
The LPKF LDS process allows assembly with unhused chips, e.g., through wire bonding or flip-chip technology. The process creates the smooth metal surfaces required for reliable assembly.



Component for hearing aid (Manufacturer: Siemens Audiologische Technik GmbH [Siemens Hearing Instruments], Harting AG), images right: HSG-IMAT

Through-Hole Plating

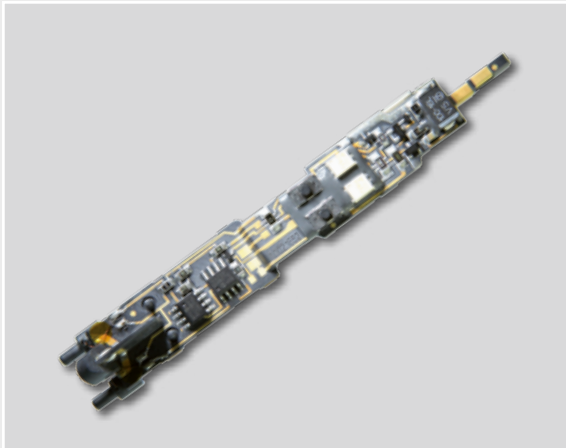
Reliable through-hole plating can be produced with LPKF LDS technology in order to connect the surfaces of MIDs. This expands the possibilities for the layout. So applied, a 3D molded interconnect device serves to fix microphones in hearing aids according to the latest technology.



LDS through-hole plating
(Angle = 70°)



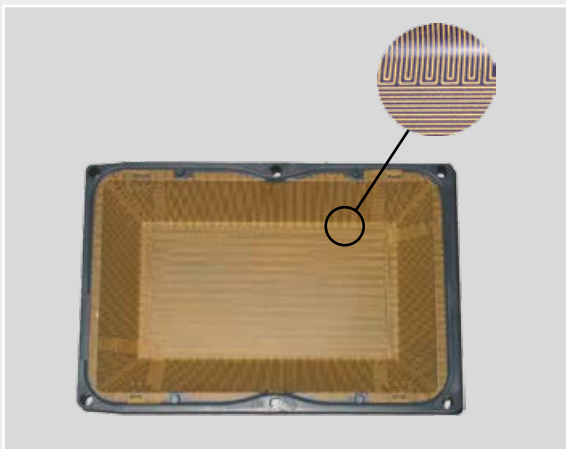
Diameter = 240 µm



Dental hand piece (Manufacturer: KaVo Dental GmbH)

Compatible with SMT

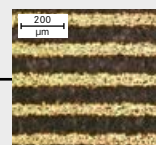
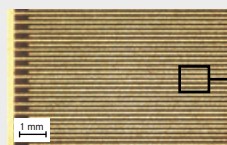
Products produced with LPKF LDS are completely SMT-capable. Components on even surfaces of the same level can be mounted by automatic assembly. Meanwhile, serial systems are also available on the market for assembly of 3D components.



Top: safety enclosure (Manufacturer: Harting AG)
Right: sensor structure on LCP Vectra E820i-LDS, lines and distances: 75 µm / 75 µm (3 mil / 3 mil) (Source: HSG-IMAT)

Fine and Ultra-Fine Structures

LPKF LDS implements extremely small track gaps. Track widths of 150 µm (6 mil) and gaps of 200 µm (7.9 mil) have proven themselves as standard in practice. But also noticeably narrower tracks and gaps were already implemented in series production. The combination of small gaps and a computer-controlled layout of complex circuits expands the design possibilities of every developer.





Steering wheel controls (Source: TRW Automotive for BMW)

Reliable Contact

LDS components instead of wiring harnesses – with LDS components additional cabling can be omitted. Along with the costs of cabling, the assembly outlay is also reduced. If electronic components are soldered directly onto LDS components or attached by means of a conductive adhesive, additional circuit boards can often also be omitted.



After a short chemical metallization, a smooth copper layer up to 35 μm (1.4 mil) thick comes about through classic galvanization

Galvanic Reinforcement

New developments for new markets: with galvanic reinforcement, components come about that also withstand high mechanical and thermal stresses or are well suited to bonding due to their smooth metal surfaces.



The LDS enclosure connects the sensor and evaluation electronics

Sensor Technology

With chip stacking, a LDS housing can take over the required contact between the components involved. A high packing density results with the slight pitch and the option of also using the outside of the housing or enclosure for tracks.



Clip N'Slide LED light (Source: HomeLights/Molex)

LED Clip System

Contact, attachment and heat conduction in one component. The functional components are arranged on a disk-shaped base medium. Two magnets hold the components, a metal layer on the bottom is for heat dissipation and LDS tracks supply the high-power LED with electric energy.



LEDs on metallic bodies: a convincing answer to thermal problems in the LED area

LED Retrofit

Tracks on metallic bodies? Covering with LDS PowderCoating creates a structurable surface. The layout options of LDS technology can thus be combined with the characteristics of metallic materials – an outstanding combination for demanding LED lighting applications.

From the Idea to the LDS Prototype

With the new LDS Prototyping solution from LPKF, 3D prototypes can be quickly and economically produced by laser direct structuring. LPKF is closing the gap between design and series production with the complete prototyping line.

Prototyping begins with a 3D print of the molded interconnect device from the layout data at your location or at a service provider's location. The printing process plays a decisive role: good LDS results require smooth surfaces.

The printed part is covered with LPKF ProtoPaint LDS which contains LDS additives. LPKF ProtoPaint LDS is delivered in a special spray can and activated before the first painting. Then a single thorough painting is usually sufficient for a good coating. The paint is dried for approx. three hours at 70 °C (160 °F) in the oven – then an LDS-capable basic component is available.

The LPKF ProtoLaser 3D is available for laser structuring. The compact laser system uses the proven ProtoLaser platform and can be moved on rollers through any lab door. The ProtoLaser 3D has a height-adjustable working platform for structuring parts with different dimensions. The working area is 300 x 300 x 50 mm (11.8" x 11.8" x 2"); the scanning area is 100 x 100 x 25 mm (3.9" x 3.9" x 1"). Structures on different component angles can be seamlessly joined together by a pilot laser and a sophisticated vision system.



- Close-to-production LDS prototypes
- Cost-effective entry into LDS technology
- Economical, fast, simple
- No chemical knowledge required

LPKF ProtoPlate LDS is for currentless metallization of structured LDS parts. It consists of a protective enclosure for process guidance and a fully prepared combination of bath chemicals as consumable materials. The metallization process does not require any chemical knowledge: just pour the bath solution from a canister into the ProtoPlate system's beaker, heat it to ca. 42 °C (107.6 °F) and add the activator.

Then the parts are immersed in the bath solution. LPKF ProtoPlate LDS creates copper layers in the standard range of 3 µm to 10 µm (0.12 mil to 0.4 mil). The original canister for the bath solution receives the used metallization liquid and is prepared for disposal with a label that is also included. From the idea to the 3D prototype in just one day.

The LDS Prototyping Process at a Glance



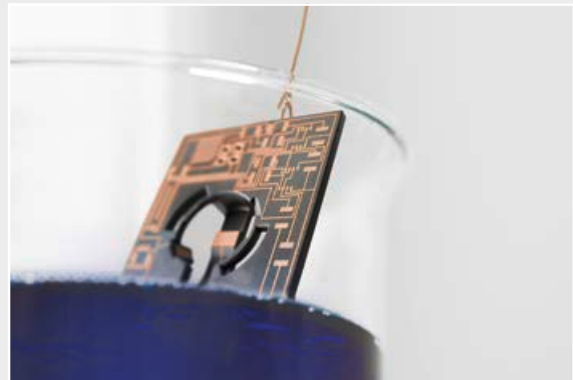
1. Creating the three-dimensional part



2. Painting the part with LPKF ProtoPaint LDS



3. Structuring the circuit tracks with the LPKF ProtoLaser 3D



4. Selective metallization with LPKF ProtoPlate LDS

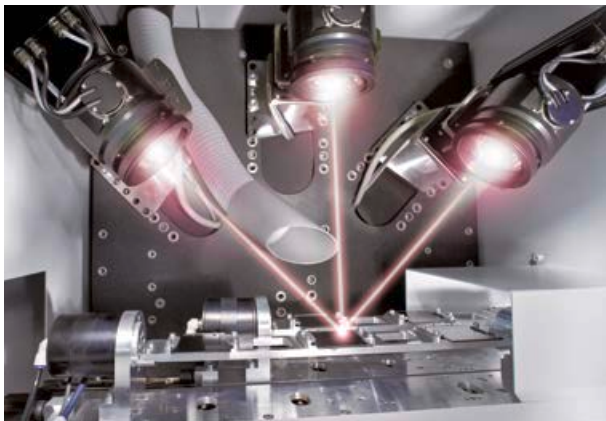
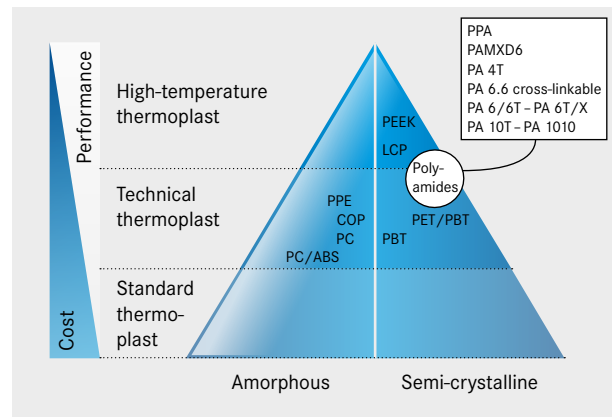
The Advantages at a Glance

So that the advantages of the LPKF LDS technology can be implemented even more easily, LPKF is making available proven and tested solutions for all process steps, and qualified support based on extensive practical experience with various applications.

Large selection of materials

Every production process requires adapted materials. The main material characteristics such as processing temperature, dimensional stability under heat, mechanical and electrical characteristics as well as flowability and of course costs are to be considered. Nearly all well-known manufacturers offer LDS-doped variants. That guarantees the availability of laser-absorbable series materials for nearly every application imaginable.

The diagram shows the most frequently used classes of LPKF LDS thermoplasts, without any claim to completeness.



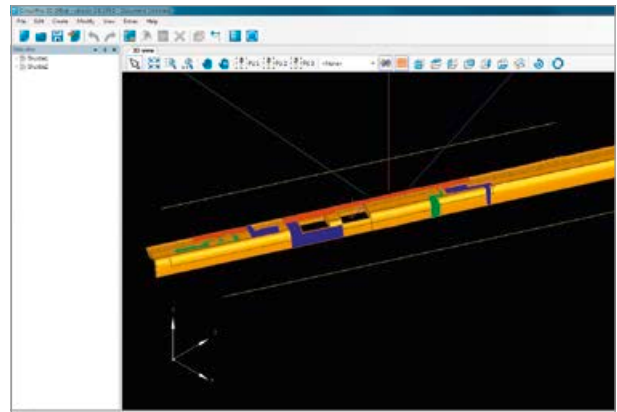
3D Technology as Benchmark

The LPKF Fusion3D platform is a laser system specifically developed for structuring three-dimensional molded interconnect devices.

The LPKF LDS process is extremely fast – practically regardless of how complicated the circuit layout is: the laser beam structures in a contactless fashion over free-form surfaces. The capability of the device ensures reproducible results and efficient manufacturing.

Cross-Linked by Irradiation and Colored

Modern plastics make LDS technology even more attractive: colored plastics, those with special characteristics and now also materials cross-linked by irradiation which can be soldered for a short time up to 400 °C (752 °F). The growing range of materials is opening up new possibilities to product developers.



Design Rules at a Glance

A process-optimized design of molded interconnect devices is decisive for optimally utilizing the advantages of the LPKF LDS technology. A few simple rules ensure high quality in MID manufacturing.

Tracks and Gaps

One of the most important characteristics of three-dimensional molded interconnect devices is efficient use of the available surface. Track widths $\geq 150 \mu\text{m}$ (6 mil) and track gaps $\geq 200 \mu\text{m}$ (7.9 mil) have proven themselves in practice. Depending on the application, narrower tracks and gaps can also be obtained.

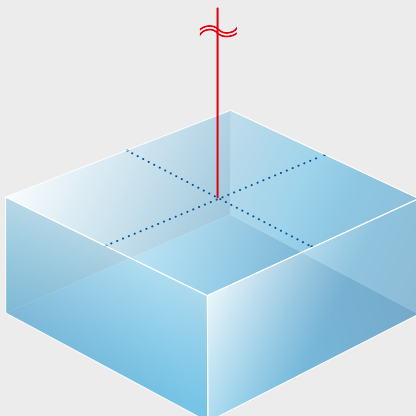
The size of the Workpiece

The area in which the component can be processed is limited by the scanning area of the laser. The scanning area of the LPKF Fusion3D laser system is a truncated cone with a base area diameter of 160 mm (6.3"), a height of 70 degrees between the sleeve surface and the base line. Within these dimensions, a workpiece is processed without turning or shifting.

Angle of Incidence

Activation of the polymer is done by a laser. The laser's angle of incidence in relation to the surface to be structured is to be considered for reliable activation. The angle of incidence is the angle between the perpendicular of the surface to be activated and the laser beam. Angles of incidence that exceed 70 degrees are reduced by rotation of the component during processing. Thus circuit layouts can also be created on surfaces that are separated by angles of 90 degrees.

Tilted-out, centered laser beam



Panels and Ejector Pins

Tracks should be designed so that they do not directly touch the panels. In the case of panels with an angle of 45 degrees, a space $\geq 150 \mu\text{m}$ (6 mil) is recommended; in the case of steeper panels with angles of 70 degrees, spaces $\geq 250 \mu\text{m}$ (9.8 mil) make sense. In planning, a sufficient gap between tracks and ejector pins is to be taken into account.

Optimal Throughput Times

The shorter the throughput time for the parts, the higher the cost advantages of the LPKF LDS process are. The throughput time consists of the handling time and the time for the structuring. The duration of the structuring is proportional to the surface of the circuit layout. The processing time is mainly determined by the number of positions into which the component has to be brought. Minimizing the number of positions and the layout surface during the design of the component provides for optimal throughput times.

Through-Hole Plating

In order to process the inner walls of drill holes for metallization with the laser, the through-hole plating on one or both sides must be conical. With larger wall thicknesses, sufficient inside diameters of the holes are required so that the laser beam reaches all surfaces. The ratio for a one-sided conical execution is 1:1, for a two-sided conical execution 2:1.

HOLDERS and Connection Seams

The three-dimensional components must be secured during laser structuring and assembly. The holders required must not cause any damage to sensitive parts such as the tracks, contact pads or surfaces of components. Tracks should not be allowed to go over connecting seams of the plastic component.

Global Support

LPKF LDS users have service centers close by in Europe, the USA and Asia. Experts in the application center in Germany use their expertise to provide practical and knowledgeable advice including the production of samples.



The global LPKF network for service and distribution:

- Headquarters
- LPKF Group
- LPKF Distributors

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