Three-dimensional circuits with LDS
Laser Direct Structuring and Metallization
for 3D Mechatronic Integrated Devices
Flexible Solution for Three-Dimensional Circuits

Since early 2000, LaserMicronics has focused on the production of three-dimensional Mechatronic Integrated Devices (MIDs; circuit carriers). As a manufacturing service provider, LaserMicronics has implemented the LPKF LDS process in real-life applications, reviewed further developments for feasibility, and in doing so realized a large number of circuit layouts on complex, three-dimensional components.

Innovative Product Design with LDS Technology
State-of-the-art: For a complex dental tool, a mainboard was drafted according to the LDS process and processed at LaserMicronics – after an intensive consult at the component layout department.

The 3D circuit is created directly on the plastic carrier, on both front and rear sides, including the required throughplating. The laser direct structuring (LDS) process reduces the weight and diameter of the handpiece. This improves the ergonomics for both the dentist and the patient. (Manufacturer: KaVo Dental GmbH)
The laser direct structuring (LDS) takes place on an injection-molded part: A laser beam transfers the circuit layout directly from the computer to the injection-molded part – without tools or templates. An electroless metallization results in sophisticated, high-quality products.

This allows the weight and dimensions of the component to be reduced significantly, and the number of components during assembly is reduced.

Developers benefit from full 3D designs on freeform surfaces and additional freedom when modifying the circuit design.

A simple prototyping process accelerates the development process; an LDS-capable powder coating turns even metal parts into circuit carriers – providing great potential for new developments.

The LPKF LDS Process

1. Injection molding: The molded parts are manufactured using a single-component injection molding process. For the LDS process, a simple tool is sufficient.

2. Laser activation: A laser beam activates the additives in the synthetic thermoplastic material. At the same time, a microrough surface is created, to which the copper adheres and bonds to during metallization.

3. Metallization: The metallization of the LPKF LDS components begins with a cleaning procedure. This is then followed by an additive construction of traces in an electroless copper bath (typically 8 to 12 μm/h). Finally, the protective surfaces can then be applied in an electroless fashion.

4. Assembly: Many laser-activatable plastics with a high thermal resistance are reflow solderable and compatible with standard SMT processes. There is already a wide range of providers of technical solutions for three-dimensional assembly.
Tomorrow’s Technology in Today’s Manufacturing

The increasing use of electronics is a challenge for many industry sectors and markets. The industry is looking for technologies which reduce the dimensions and weight of components. At the same time, the production of prototypes needs to be simplified and the time to market launch reduced. The LDS process fulfills exactly these requirements.

**LDS in Automotive Engineering**

Modern cars require a whole array of sensors and assistive electronics which increase the comfort and safety of the passengers in the vehicle. At the same time, the goal is to reduce the number of components used and significantly reduce manufacturing costs. Mechatronic Integrated Devices (MIDs) combined with the appropriate connection and assembly technology are perfectly suited for achieving these goals.

It allows typical electromechanical functions such as buttons, plugs, and other connecting elements to be integrated into a single module which serves as a molded interconnect device. Using the LDS process increases the available design options, accelerates modifications in electronic modules, and allows model variants to be produced in a cost-effective manner, ultimately resulting in more profitable development and manufacturing.

Steering wheel operating element (manufacturer: TRW Automotive for BMW)
**Telecommunications – Staying in Touch**

Model diversity, design, miniaturization and cost reductions characterize the development of wearable electronic devices. End consumers expect an increasing number of functions in the very latest, compact housings.

LPKF’s LDS technology possesses great potential for the miniaturization of components. At the same time, it offers great flexibility where the modification and improvement of functionality is concerned – in particular when features for multiple products need to be modified in a variable manner. Millions of antennas for mobile telephones and laptops manufactured using LDS technology have proven this time and again.

**A New Generation of Medical Equipment**

More compact dimensions, an increasing number of functions – these market requirements apply to many medical devices. New capabilities and technologies are driving this trend: The rapid development in software and chip technology constantly leads to new diagnosis procedures. Small diagnosis and monitoring devices help to improve the lives of millions of patients. They can now carry these devices with them, such as blood glucose meters.

Combined with widespread wireless communication technology, this allows visits to the doctor to be reduced to a minimum. This development calls for a new, more advanced manner of intelligently compressing more functions into a smaller space. With its precision and high reliability, the laser-based LDS process fulfills exactly these requirements.

MID technology makes medical devices even more convenient. A classic LPKF LDS application: Light and compact hearing aids (manufacturer: Siemens Audiologische Technik GmbH).
Traces on Metal Parts

In many areas, plastics have proven to be ideal materials for 3D components. They are light, easy to shape, and low-cost. However, they are unable to compete with metal carriers in at least one area: thermal conductivity.

This property is particularly crucial in LED applications. High-power LEDs need a reliable heat dissipation system. If the component temperatures are too high, the life expectancy of LEDs is shortened considerably, and the specified life expectancies of several tens of thousands of hours falls to a fraction of the nominal value.

**PowderCoating with LDS Additives**

With LPKF LDS PowderCoating, metal parts (or electrically conductive plastics) can be upgraded to become circuit carriers. The LDS additive is applied as a surface layer during an electrostatic powder coating process. The powder is electrically charged and deposits itself evenly on the grounded part. The application of LDS PowderCoating can be done by all service providers using all the usual processes. The paint layer polymerizes at temperatures between 170 °C and 200 °C and forms cross-links, such that subsequent plasticization no longer occurs at these temperatures.

**Two Variants**

The LPKF PowderCoating is available in two variants: PES 200 and PU 100. The semi matte PES surface is optimized for high mechanical stability, while the glossy PU 100 is prized for its robust chemical and thermal properties.
Both powder coatings offer good dielectric strengths in excess of 4 kV starting at a layer thickness of approx. 80 μm and 60 μm respectively. For the adhesion of the circuit pathways to the base material, a value between 90 N and 120 N is achieved – this is within the range of conventional PCBs such as FR4 PCB materials.

During soldering, PU 100 is approved for a 5-second soldering procedure at 270 °C, during which it is guaranteed to retain its stability, while PES 200 is limited to 240 °C. Both paint types are certified according to V-0 (UL-94) and hence flame-retardant.

LDS PowderCoating in Real-Life Applications
LDS PowderCoating provides a new production process that, particularly for LED lighting, allows for entirely new product layouts. Examples include retrofit LED lighting, but also lighting fixtures in automobiles. Test prototypes provide an impressive preview of the production process and the new product layouts.

Just like in the process for plastics: A test component (aluminum) for a daytime running light is first coated with LDS PowderCoating, after which it is structured and metallized, and finally finished with LEDs and a plug contact.

The metal component on the front, and a classic LDS plastic body in the rear. Already after a short period of time (left), hot spots have developed on the plastic component. After 24 hours (right) the metal body presents a homogeneous, low temperature, while the plastic unit is unable to dissipate the heat generated.
Inspiration for New Layouts

General electronics, medical technology, automobile engineering, telecommunications, and consumer products – LDS components are found in many devices and systems from numerous areas of application, where they fulfill widely differing and challenging functions.

What could be more impressive than projects that others have already successfully implemented? In the following, a number of applications will illustrate the respective technical challenges. They show how the theoretical approaches have been turned into actual components – and represent the potential for LDS technology in various markets.

Replacing Flex Circuits – More Precise Positioning
When the available installation space is limited, LDS avoids problems that occur with flex circuits, such as the complex handling, imprecise positioning on the carrier, or a limited bend radius. In this manner, LDS allows for the creation of sophisticated 3D circuits, and at the same time saves on the assembly step for flex circuits.

Model Variants with a Single Injection-Molded Part
Changes to the circuit layout can easily be done by modifying the laser program. With this, LDS technology unlocks additional platform strategies for sensor housings. By using the corresponding chipsets and circuit layouts, various products are created that are based on a single injection-molded part.

The LDS process allows for the installation of unpackaged chips, such as via wire bonding or flip chip technology. The process creates the smooth metal surfaces that are required for secure contacts.
Thin, Double-Sided Modules
This fingertip is mounted on a robot hand. There, it will sense the magnitude and direction of any occurring forces, giving the hand a sensitive grip. The LCP carrier contains twelve sensor fields on its outer side and is throughplated on the inner side, where it is connected to the evaluation electronics.

SMT-Compatible
Products manufactured using LDS are completely SMT-capable. Components on flat surfaces and on the same level can be mounted using automatic assembly. Series systems are currently also available on the market for the assembly of spatial modules.

Fine and Ultra-Fine Structures
LDS allows extremely small gaps between traces to be realized. Trace widths of 150 μm and gaps of 200 μm have been established as the standard in practice. But significantly narrower traces and gaps are already being used in series production.
Reliable Contacting
LDS components instead of cable harnesses – LDS components allow you to do away with additional wiring. In addition to the costs for wiring, the time and money required for assembly is also reduced. If electronic components are soldered directly onto LDS components or affixed by means of conductive gluing, this often also reduces the need for additional circuit boards.

Galvanic Reinforcement
New developments for new markets: With galvanic reinforcement, modules are created that are also able to withstand high mechanical and thermal stresses or which are ideal for bonding thanks to their smooth metal surface. HF applications also benefit from smooth surfaces at high frequencies. Reinforced layers also have a significantly improved current-carrying capacity.

Sensor Technology
For chip stacking, an LDS housing can be used to perform the required contacting between the components involved. The small pitch and the option of using the exterior surface of the housing for traces as well results in a high packing density and an efficient combination of bonding and soldering pads in the tightest of spaces.
LEDs on metal parts: An impressive solution to thermal problems in the LED sector

LED Clip System
Contacting, mounting, and heat dissipation in a single component. The functional components are arranged on a disc-shaped base carrier: Two magnets hold the components proper, a metal layer on the base is used for heat dissipation, and LDS traces supply the high-power LED with electrical energy. Even insert molded parts are elegantly integrated into the layouts.

Heat Management for High-Power LEDs
Traces on metal parts? A coating with LDS PowderCoating creates an insulating and structurable surface. This allows the layout options of LDS technology to be combined with the properties of metallic materials. Metal carriers are able to efficiently absorb and distribute locally generated heat – an indispensable characteristic for high-power LED lighting.

Complex HF Applications
3D circuits and antennas also equate to more creative freedom and designs for HF developers. The precision of the laser process and the additional third dimension make new applications possible, such as for communications systems in the automobile sector.

HF antenna on a roof fin. The HF properties were examined in a publication by the Institute of Radiofrequency and Microwave Engineering in Hanover (Manufacturer: hft).
From an Idea to an LDS Prototype

LaserMicronics produces LDS prototypes as part of feasibility studies and for the purposes of product optimization. When doing so, it uses the prototyping process, but also series systems.

With the new LDS prototyping solution, 3D prototypes can be manufactured quickly and cost-effectively using laser direct structuring. With its entire prototyping series, LPKF closes the gap between the draft and series production.

The prototyping begins with a 3D printout of the Mechatronic Integrated Device from the layout data. In this case, the printing process plays a decisive role: Good LDS results are achieved with smooth surfaces.

The printed base body is coated with LPKF ProtoPaint LDS, which contains LDS additives. ProtoPaint LDS is provided in a special spray can and activated before the first painting.

Once this is done, a single, thorough painting is usually sufficient for a good coat. The paint is dried for approx. three hours at 70 °C in the furnace – this creates the LDS-capable base part.

For laser structuring, LaserMicronics uses e.g. the LPKF Fusion3D 1200. The compact laser system can work with up to three processing heads simultaneously. The integrated round switching table reduces non-productive times, as removal/assembly takes place in one nest and the structuring of the component takes place simultaneously in the other nest.
• Series-capable LDS prototypes
• Low-cost adoption of technology
• Profitable, rapid, easy

After structuring, the electroless metallization of the LDS components takes place. For this purpose, a special prototyping process called LPKF ProtoPlate is used. It consists of a protective housing for carrying out the process and comes with a premixed combination of bath chemicals (consumables) for reliable and rapid metallization with copper.

LaserMicronics produces LDS prototypes as part of feasibility studies and for the purposes of product optimization. When doing so, it uses the prototyping process, but also series machines – e.g. during structuring or metallization.

LaserMicronics operates its own series metallization system with more than 25 baths and washing sinks. The qualified specialist personnel utilize their comprehensive experience from MID manufacturing, some of which go back to the beginnings of LDS. The metallization is optimized for LDS parts and, in addition to the copper layer, can also apply additional chemical surfaces or galvanically reinforce contacted copper layers. This allows parts characteristics to be manufactured during prototyping that already have the same surface characteristics as in series processes.

The LDS Prototyping Process at a Glance

1. Creating three-dimensional base part
2. Painting the base part with LPKF ProtoPaint LDS
3. Structuring with LPKF Fusion3D or LPKF ProtoLaser 3D
4. Metallization with LPKF ProtoPlate or series metallization
Overview of Benefits

In order to make it even easier to implement the benefits of LDS technology, LaserMicronics offers its customers proven and tested solutions for all process steps, comprehensive practical experience with various applications, and qualified support from the sampling stage to qualified series production.

Large Material Selection
Every manufacturing process requires specially adapted materials. The core material properties such as processing temperature, heat deflection temperature, mechanical and electrical properties, flowability, and of course the costs are deciding factors. Almost all notable plastics manufacturers offer LDS-doped variants. The diagram shows the most frequently used categories of LDS plastics (list is non-exhaustive).

Modern plastics make LDS even more attractive. Colored plastics, those with special properties, and materials that can be cross-linked with radiation which can be reflow soldered. The growing range of materials opens up new possibilities for product developers.

3D Technology as the Standard
The LPKF Fusion3D consists of laser systems developed specially for the structuring of three-dimensional molded interconnect devices. The laser beam structures freeform surfaces without any contact.

The high performance of the devices ensures reproducible results and efficient manufacturing – this system series forms the backbone of LDS production at LaserMicronics.

From a 3D Layout to a Component
Every LDS component begins as a CAD draft. The circuit pathways in the draft are deposited as surface layers. Manufactures of the base parts derive their design specifications from this data – and the CAM software calculates an optimal laser process from the surfaces.
About LaserMicronics

LaserMicronics is a specialist for micromaterial processing with lasers. At its offices in Garbsen (headquarters) and Fürth (Laser Welding division), laser systems developed by LPKF Laser & Electronics AG are used.

The range of products and services ranges from feasibility studies, process development, and process optimization to the manufacturing of prototypes and series production. Its wide range comprises laser plastic welding, LDS technology, laser cutting, laser drilling, laser structuring, TCO/ITO structuring, fuel cell technology, and micro cut parts.

LaserMicronics has been involved in LDS technology from the very beginning: As an application center for the manufacturer of the laser systems, during tests of new materials, during the further development of prototyping processes, and also as a reliable provider of (partial) services such as laser structuring or metallization.

LaserMicronics operates a comprehensive park of laser systems, a well-equipped laser laboratory, a series system for chemical metallization, as well as an experienced team of physicists and development engineers.

The fastest way to contact our LDS specialists: +49 (0) 5131-90811-0 or lds@lasermicronics.de
LaserMicronics – Your Service Partner
At its offices in Garbsen (near Hanover) and Fürth in Bavaria, LaserMicronics GmbH provides development and production services in the areas of laser micro-material processing and laser beam plastic welding. Apart from its comprehensive production service, LaserMicronics also consults on process development and optimization.

Other Products and Services by LaserMicronics

Challenging Cutting Applications
The laser systems used can process classic circuit board materials (circuit board repairs), but also invisible ITO layers, LTCC, or fired ceramics and micro cut parts made of metal.

Request a brochure:
info@lasermicronics.de

Laser Plastic Welding
Hygienic, safe, cost-effective: Laser plastic welding impresses with its high-quality welding results, the absence of particles, and low tool costs. LaserMicronics welds everything from tiny microfluidics to large automobile tanks — all with lasers.

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- Laser subtractive structuring (LSS) and metallization
- Laser plastic welding
- Solar technology
- TCO/ITO layer structuring
- Micro-drilling

- Structuring
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- Laser machining of ultra precision metal parts