



LDS-MID Design Guide

Technical Information

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LPKF
Laser & Electronics



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Version 2.1

English

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1 Introduction

Developing *MID* components (moulded interconnect devices) is a complex procedure no matter which process or technology is used. This guide helps especially the developer of *MIDs* that are based on the LPKF laser direct structuring process (**LPKF-LDS[®] process**) in the interdisciplinary development process.

To avoid errors or designs unsuitable for production, a very close cooperation between all participants in the individual processes is required already in the early stages of the project.

This applies not only to the **LDS** process steps injection moulding, laser structuring, and metallisation that are discussed in more detail in this document, but extends to the area of mounting and bonding of electronic components in case of populated *MIDs*.

2 Materials

Nowadays, a whole range of thermoplastic materials is available for manufacturing **LDS MID** components.

2.1 Material types

The following materials can be used in the **LDS** process:

Table 1: Materials

| Type | Material |
|---------|---|
| LCP | liquid crystal polymer |
| PA 6/6T | polyamide |
| PBT | polybutylene terephthalate |
| PBT/PET | polybutylene terephthalate/polyethylene terephthalate blend |
| PPA | polyphthalamide |
| PC | polycarbonate |
| PC/ABS | polycarbonate + ABS blend |

2.2 Suppliers

LPKF has tested and approved materials for the **LDS** process from various producers. The following material types are available from the listed producers:

Table 2: Suppliers

| Producer | Type |
|---|---------|
| BASF AG | PA 6/6T |
| | PBT |
| LANXESS | PBT |
| | PET/PBT |
| TICONA GmbH | LCP |
| RTP Co. | PC/ABS |
| | PC |
| | LCP |
| | PPA |
| DSM Engineering Plastics B.V. | PC/ABS |
| Mitsubishi Engineering-Plastics Corporation | PC |
| EVONIK INDUSTRIES | PBT |
| WAH HONG Industrial Corp. | PC/ABS |

Table 2:

| Producer | Type |
|---------------------------|--------|
| SABIC Innovative Plastics | PC/ABS |
| | PPA |



Note

A detailed list of the approved materials can be downloaded from the **LPKF** website at <http://www.lpkf.com/lds-plastics>.

2.3 Material selection criteria

As material development advances continuously, **LPKF** updates the list regularly.

Selecting the material depends on the requirements of the application of the **LDS MID** component. Depending on the application, the coefficient of thermal expansion, water absorption, mechanical properties, solderability as well as other steps of further processing (laser welding etc.) can be important selection criteria. Always consult the material data sheet of the producer and tap their processing knowhow when selecting the material for the **LDS MID** process. The plastics producers will gladly support you during the design stage providing Moldflow studies and practical hints on dimensioning your **MID** components.

3 Design rules

The following design rules (DR_XXX_LDS_MID_) help you to achieve optimum results when designing *MID* components.

3.1 Overview of LDS MID design rules

The following table shows for which process and for which material each design rule applies.

Table 3: Design rules

| Design rule | General | Injection moulding | Laser Processing | Metallisation | Assembly and connecting |
|--|---------|--------------------|------------------|---------------|-------------------------|
| DR_001_LDS-MID_Nextra MID module | X | X | - | - | X |
| DR_002_LDS-MID_critical areas | X | - | - | - | X |
| DR_003_LDS-MID_component carriers | X | X | X | X | X |
| DR_004_LDS-MID_fiducial marks | X | - | X | - | X |
| DR_005_LDS-MID_avoid gate at critical area | - | X | - | - | - |
| DR_006_LDS-MID_hot-runner systems | - | X | - | X | - |
| DR_007_LDS-MID_weld lines | - | X | X | - | X |
| DR_008_LDS-MID_positioning ejector pins | - | X | X | - | X |
| DR_009_LDS-MID_material shrinkage | - | X | - | - | X |
| DR_010_LDS-MID_coefficient of thermal expansion | - | X | - | - | X |
| DR_011_LDS-MID_laser processing time | - | - | X | - | - |
| DR_012_LDS-MID_scan field volume | X | - | X | - | - |
| DR_013_LDS-MID_width and spacing of conductive paths | X | - | X | X | X |
| DR_014_LDS-MID_datamatrix or barcode | X | - | X | X | X |
| DR_015_LDS-MID_thickness of copper layer | X | X | - | X | X |
| DR_016_LDS-MID_bond connections | X | - | X | X | X |
| DR_017_LDS-MID_plated vias | X | X | X | - | X |
| DR_018_LDS-MID_conductive-path passages | X | X | X | - | - |
| DR_019_LDS-MID_mechanical vias | X | X | X | - | X |
| DR_020_LDS-MID_detachable connection | X | X | X | - | X |
| DR_021_LDS-MID_edge radius | - | - | X | X | - |
| DR_022_LDS-MID_positioning conductive tracks | - | - | X | X | X |
| DR_023_LDS-MID_angle of incidence of laser beam | X | - | X | X | - |
| DR_024_LDS-MID_ventilation | X | X | - | X | - |
| DR_025_LDS-MID_fastening the plastic components | X | X | - | X | - |

Table 3: Design rules

| Design rule | General | Injection moulding | Laser Processing | Metallisation | Assembly and connecting |
|---|---------|--------------------|------------------|---------------|-------------------------|
| DR_026_LDS-MID_recessed conductive paths | X | X | - | X | - |
| DR_027_LDS-MID_SMD assembly process | X | X | X | - | X |
| DR_028_LDS-MID_turns of paths | X | - | X | - | X |
| DR_029_LDS-MID_tombstone effect | X | - | X | - | X |
| DR_030_LDS-MID_maximum component size | X | - | X | - | X |
| DR_031_LDS-MID_distance to solder pads | X | - | X | - | X |
| DR_032_LDS-MID_fiducial marks | X | - | X | - | X |
| DR_033_LDS-MID_redundant conductive paths | X | - | X | - | X |
| DR_034_LDS-MID_reflow soldering method | X | X | X | - | X |
| DR_035_LDS-MID_encapsulating | X | - | - | - | X |

3.2 LDS-MID design rules

This chapter describes the design rules in detail.

DR_001_LDS-MID_Nextra MID module

In **CAD construction** of *MID* components, it is advisable to use tools that bridge the gap between MCAD and ECAD, as this is the only way to enable a flexible and efficient development of *MID* components.

The *Nextra*[®] *MID module* offered by *FlowCAD* (www.flowcad.de) is a platform that can be used to produce three-dimensional STEP data sets containing closed outlines of the conductive path geometries that can be processed by the structuring software of the laser systems **LPKF MicroLine 3D** or **LPKF Fusion 3D**.

DR_002_LDS-MID_critical areas

Define all "critical" areas on the component, i.e. functional surfaces like conductive paths, landing pads, electrode surfaces, contact pads etc.

DR_003_LDS-MID_component carriers

Provide defined **handling/clasping** facilities for the **LDS MID** component that enable e.g. laser processing or subsequent mounting of electronic components.

DR_004_LDS-MID_fiducial marks

Use **alignment** or **registration marks**. The registration marks are required for laser processing or for *vision systems* in the subsequent mounting of electronic components.

DR_005_LDS-MID_avoid gate at critical area

Avoid positioning gates at critical areas when **designing the tool**.

DR_006_LDS-MID_hot-runner systems

If feasible and the costs are justifiable, choose a hot-runner system over film-gate or direct-gate systems to avoid extraneous metallisations at the break or shear edges that are produced when removing the sprues.

DR_007_LDS-MID_weld lines

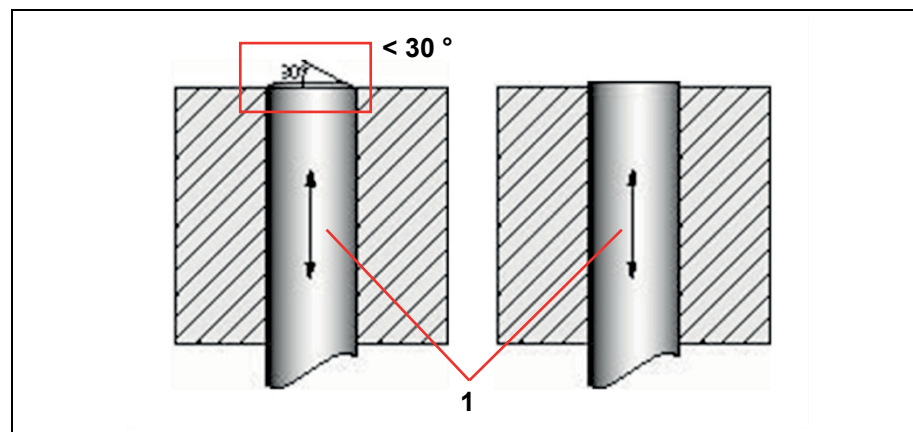
Avoid weld lines on critical surfaces.

The conductive pattern should not be placed over the weld lines, because this can have critical effects on the conductive paths especially under mechanical stress or temperature variation stress. Pay special attention to conductive patterns and weld lines when employing LCP-type *MID* materials.

DR_008_LDS-MID_positioning ejector pins

Avoid ejector sites at critical areas e.g. conductive paths. If this absolutely unavoidable, bevel the ejector pin's \perp circumference with a maximum angle of 30° .

Fig. 1: Beveled ejector pin



\perp ejector pin

DR_009_LDS-MID_material shrinkage

Pay attention to shrinkage of the component during processing and optimise the injection moulding parameters to minimise shrinkage. Ensure that jetting is avoided when the material is injected into the mould as this leads to undesirable anisotropies when processing the *MID* components in thermal processes such as soldering.

Using a moldflow simulation can be of good service before producing the final mould.

DR_010_LDS-MID_coefficient of thermal expansion

Pay attention to possible anisotropic material characteristics such as the coefficient of thermal expansion (CTE).

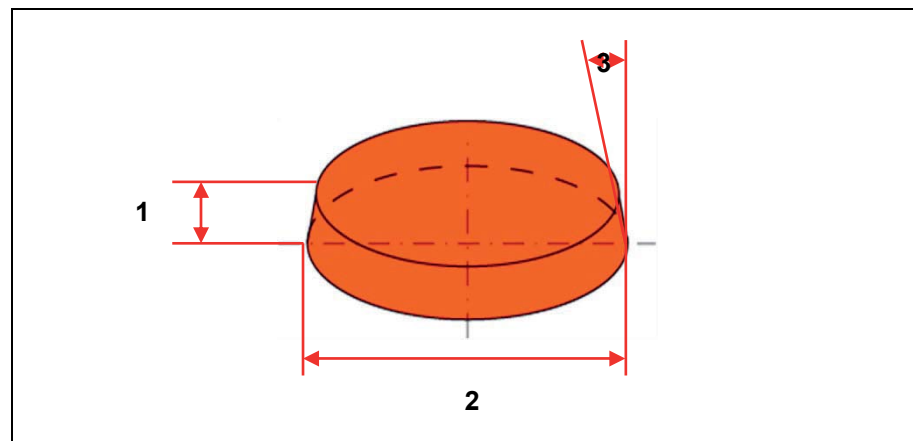
DR_011_LDS-MID_laser processing time

When designing the *LDS MID* component, keep in mind that a low count of clamping steps or processing positions reduces laser processing time and thus enables economic production.

DR_012_LDS-MID_scan field volume

Observe the maximum possible scan field volume (truncated cone with a base diameter of 160 mm, a height of 24 mm, and an angle of 77.4° between the base and the lateral surface in the *LPKF MicroLine-3D 160i*).

Fig. 2: Scan field volume



/1/ height = 24 mm

/2/ diameter = 160 mm

/3/ angle towards the vertical Z-axis = 12.6° max

DR_013_LDS-MID_width and spacing of conductive paths

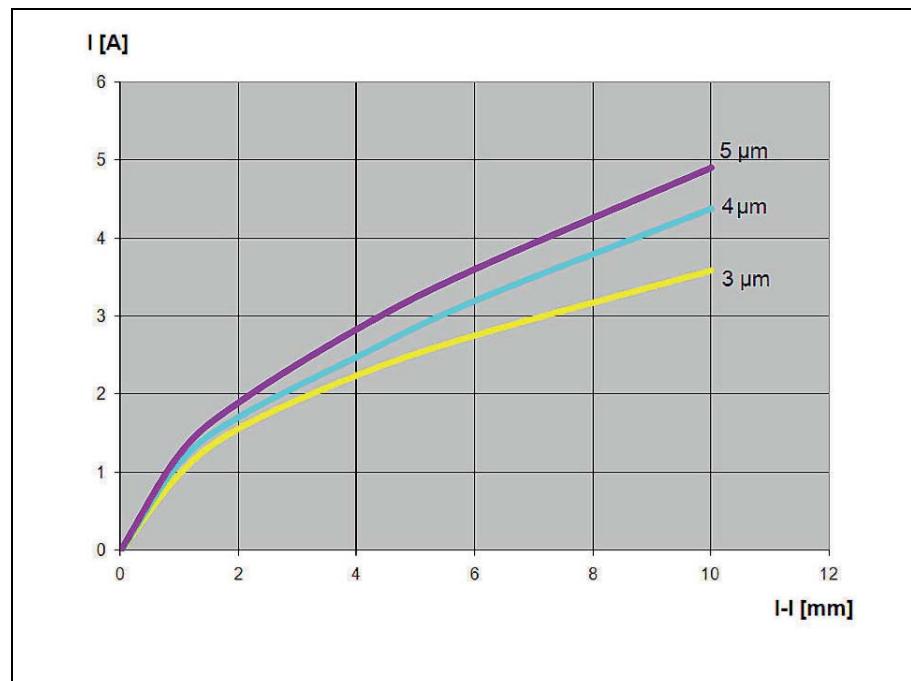
Observe the minimum width and spacing of conductive paths:

- recommended conductive path width $\geq 150 \mu\text{m}$
- recommended conductive path spacing $\geq 200 \mu\text{m}$

Consult all parties involved in the process (laser processing, metallisation, and assembly) if you wish to use lower values (such as $100 \mu\text{m}$ width and spacing of conductive paths).

When considering the dimensions of conductive paths dependent on the application of the *MID* assembly, observe that the conductivity of solely chemically deposited copper layers is only approx. 60% of that of solid copper. As the dimension "height of the conductive path" is limited, sufficient current rating can only be achieved by adequate width of the conductive path. The following figure provides an indication for the current rating of chemically deposited conductive copper paths depending on width and thickness with a permissible heating by 40 Kelvin:

Fig. 3: Dimensions of conductive paths



I [A] = current in amperes

$l-l$ [mm] = width of conductive path in mm

DR_014_LDS-MID_datamatrix or barcode

The structuring software for the **LDS[®] process** provides an option in the process step "laser structuring" for tracking the *MID* components. For this option, the conductive paths and a serial data matrix code or barcode have to be activated at the same time. The subsequent metallization guarantees good legibility.

DR_015_LDS-MID_thickness of copper layer

For economic reasons, we recommend to limit the thickness of the chemical copper plating that follows laser structuring to $\leq 8 \mu\text{m}$ for **LDS MID** components that cannot or are not intended to be galvanically reinforced.

For general electronics applications or solder mounting, we recommend electroless nickel/phosphorus or gold plating. Other finish layers such as chemically deposited tin or silver or organic protective passivations can be employed and have to be consulted with the metallisation service provider.

If a sufficient layer thickness, e.g. for a required higher current rating, cannot be achieved or is not economically sensible using chemical deposition, the chemical copper plating can be subsequently reinforced by galvanic copper plating. This requires of the layout design that all conductive paths have to be joined at a common contact area. This can be e.g. a surface area on the component that is separated mechanically after metallisation, thus disconnecting the electrical connections of all conductive structures.

DR_016_LDS-MID_bond connections

Applications of "chip on MID" attract more and more interest where the electrical connections between the substrate and the chip that is glued directly onto the substrate have to be made by bonding.

There are two general bonding technologies:

1. ultrasonic wedge-wedge bonding using Al/Si wire and
2. thermosonic ball-wedge bonding using Au wire

The following two prerequisites have to be met to successfully bond **LDS MID** components:

1. A smooth-as-possible bonding surface on the substrate with only rare nodules and an R_z value of $10 \mu\text{m}$ max. This requires great care when selecting the laser parameters but also when selecting the bath chemicals and in process control of the metallisation.
2. Selecting the correct finish surface for successfully creating bond connections.

Due to the inherent surface roughening of the **LDS[®] process**, only ultrasonic wedge-wedge bonds using Al wire have been publicised up to now. Approaches that enable **LDS MID** components for thermosonic ball-wedge bonding by introducing an additional planing step in the areas of the bonding pads have only recently been tried.

The most common finish surfaces are:

1. electroless Ni / immersion Au (EN-IG)
2. electroless Ni / electroless Pd/immersion Au (EN-EP-IG)
3. electroless Ni / immersion Au/electroless Au (EN-IG-EG)
4. electroless Ni / immersion Pd/immersion Au (EN-IP-IG)

and most recently:

5. auto-catalytic Ag / immersion Au (ASIG)

The following table lists the compatibility of finish surfaces for various applications, among them bonding methods:

Table 4: Finish surfaces

| Application | EN-IG | EN-EP-IG | EN-IG-EG | EN-IP-IG | ASIG |
|----------------------------------|-------|----------|-------------|----------|------|
| conductive adhesive bonding | + | + | + | + | + |
| multi-step soldering (lead-free) | + | + | (+) | + | + |
| contact pads | + | + | + | + | + |
| ultrasonic bonding | + | + | (+) | + | + |
| thermosonic bonding | - | (+) | + | + | + |
| ease of process control | (+) | - | + | + | + |
| costs | + | (+/-) | - | + | + |
| Pd thickness in μm | / | 0.2 | / | 0.03 | / |
| Ag thickness in μm | / | / | / | / | 0.2 |
| Au thickness in μm | 0.1 | 0.1 | > 0.5 total | 0.03 | 0.1 |

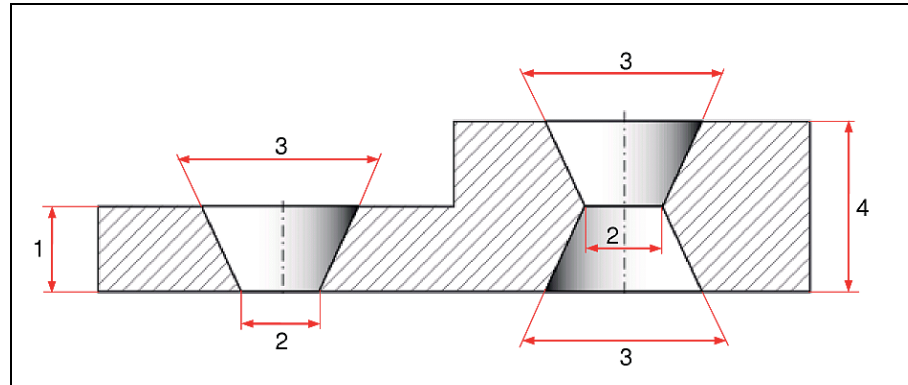
legend:

- + compatible/economic
- incompatible/uneconomic
- (+) compatible to a certain extent
- (+/-) costs are adequate

DR_017_LDS-MID_plated vias

Observe prerequisites for single-cone or double-cone design when designing via holes.

Fig. 4: Via holes



/1/ wall thickness 300 μm max.

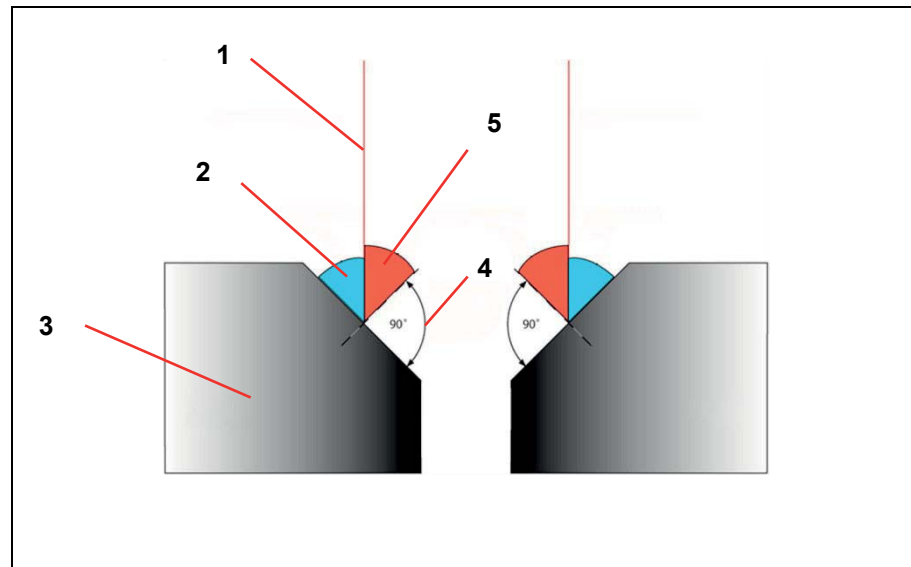
/3/ angle 50° min.

/2/ hole diameter 300 μm min.

/4/ wall thickness 600 μm max.

Enlarge the diameter of via holes in case of enlarged wall thickness /1/ or /4/. Ensure that the bevel angle of the via holes does not exceed the maximum angle of incidence of the laser beam even at the far edges of the scan field volume (see DR_018_LDS-MID_conductive-path passages on page 19).

Fig. 5: Laser beam



/1/ centre of laser beam

/4/ perpendicular to the surface to be structured

/2/ 50% of the angular aperture

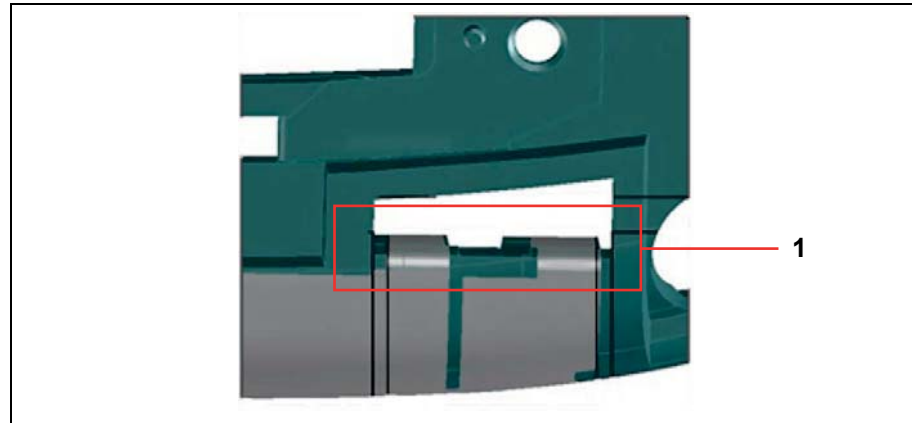
/5/ angle of incidence

/3/ LDS substrate

DR_018_LDS-MID_conductive-path passages

In antenna design, via holes are often replaced by wide passages using a core in the moulding tool.

Fig. 6: Passage



/1/ passage

Observe that all conductive paths in the passage must be accessible to the laser beam for activation and design the width of the passage accordingly.

DR_019_LDS-MID_mechanical vias

Another option for creating through connections is using hollow rivets according to standard DIN 7340 - type A, using a suitable rivet press and suitably injection-moulded holes.

The tubular copper rivets are available with diameters of 0.6 to 1.2 mm.

The benefit of this solution is the option to reliably solder wires to the *MID* component.

Only the *MID* material LCP allows via holes (that can be metallised) with diameters down to 150 µm and an aspect ratio of 1:6 to be produced using laser drilling. The **MicroLine 3D** software provides a corresponding tool for spiral drilling or percussion drilling.

DR_020_LDS-MID_detachable connection

Use the diverse design options creatively for detachable electrical connections of *MID* components to "the outside world".

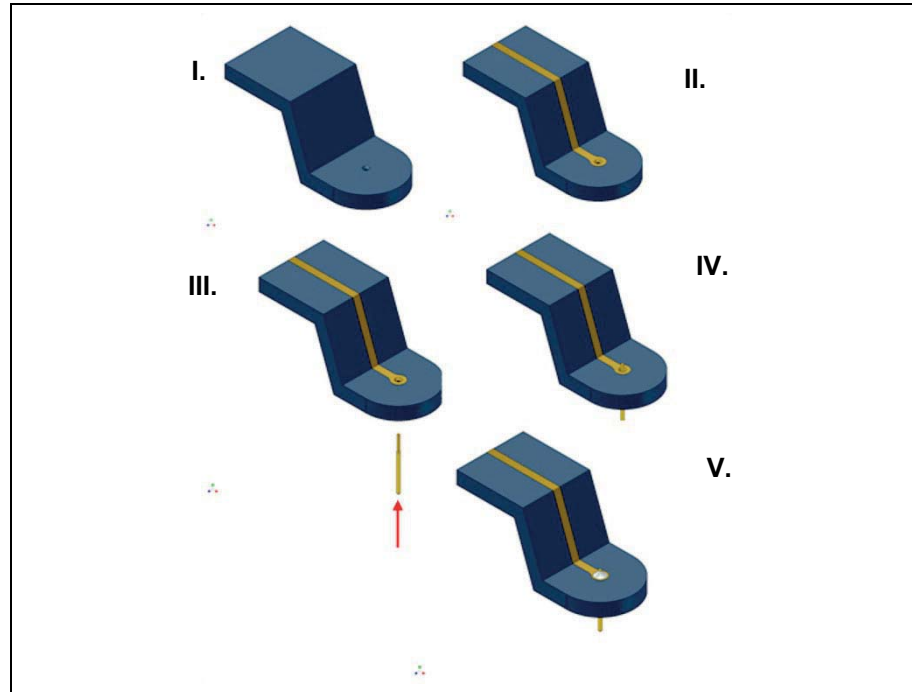
- There is a wide selection of SMD connectors on the market that are the best option to connect **LDS MID** components to PCBs, flex-PCBs and cable harnesses.

Select types that possess additional soldering lugs for bonding the connector body thus allowing that the connector is mechanically fastened at the same time as its pins are soldered. Include these additional bonding surfaces when creating the layout for laser

structuring.

- Another option is press-fitting connector pins of circular or square cross-section into accordingly designed holes in the *MID* component and subsequent soldering in the assembly process (see Fig. 7: Press-fit connector pin).

Fig. 7: Press-fit connector pin



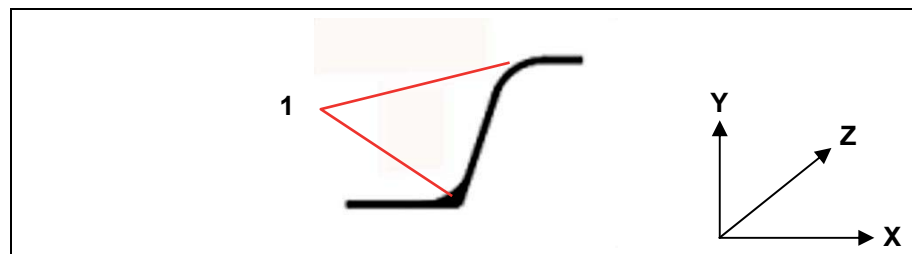
DR_021_LDS-MID_edge radius

Avoid sharp edges where structures are to be metallised.

recommended edge radius: $\geq 150 \mu\text{m}$

Using values of $100 \mu\text{m}$ is possible but consult all parties involved in the process (laser processing and metallisation).

Fig. 8: edge radius



/1/ edge radius

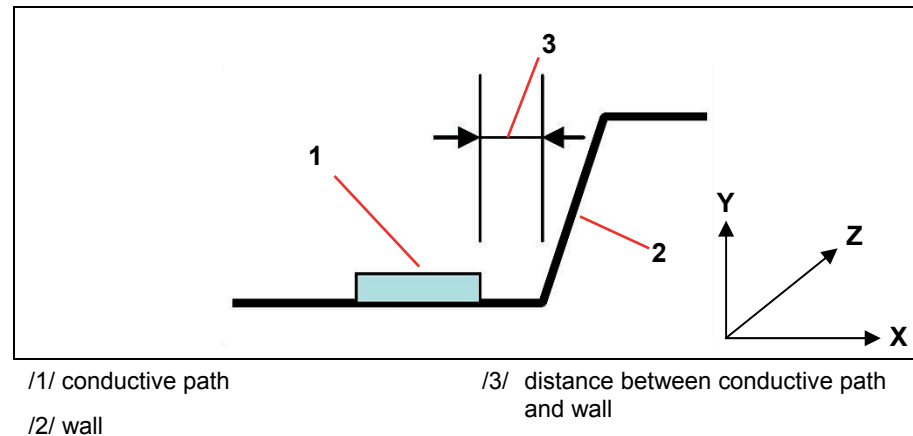
DR_022_LDS-MID_positioning conductive tracks

Design conductive paths in such a way that they do not border immediately on walls. This reduces the risk of debris deposits caused by ablation products and of extraneous metallisation on the wall. Set the distance to the wall the larger the steeper the angle of the slope:

≥ 150 µm at 45° inclination

≥ 250 µm at 70° inclination

Fig. 9: distance of conductive path



Using lower values is possible but consult all parties involved in the process (laser processing, metallisation, and assembly).

DR_023_LDS-MID_angle of incidence of laser beam

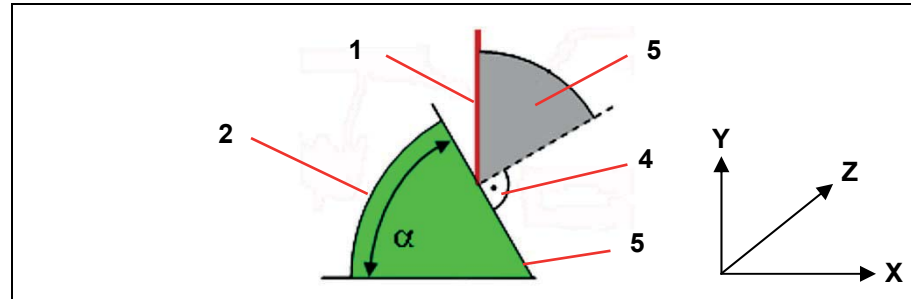
Observe the maximum possible angle of incidence to the surface to be structured to ensure reliable activation. The angle of incidence is defined as the angle between the perpendicular to the surface to be structured and the laser beam.

Also observe that the angle of incidence of the laser beam to the horizontal increases with increasing distance from the centre of the scan field.

- Recommended angle of incidence: ≤ 70°
- Maximum angle of incidence of the laser beam to horizontal at the borders of the scan field: ≤ 13° (*LPKF MicroLine-3D 160i*)

The same angles apply to all processing units of the multi-head laser system *MicroLine Fusion 3D*.

Fig. 10: angle of incidence



/1/ laser beam

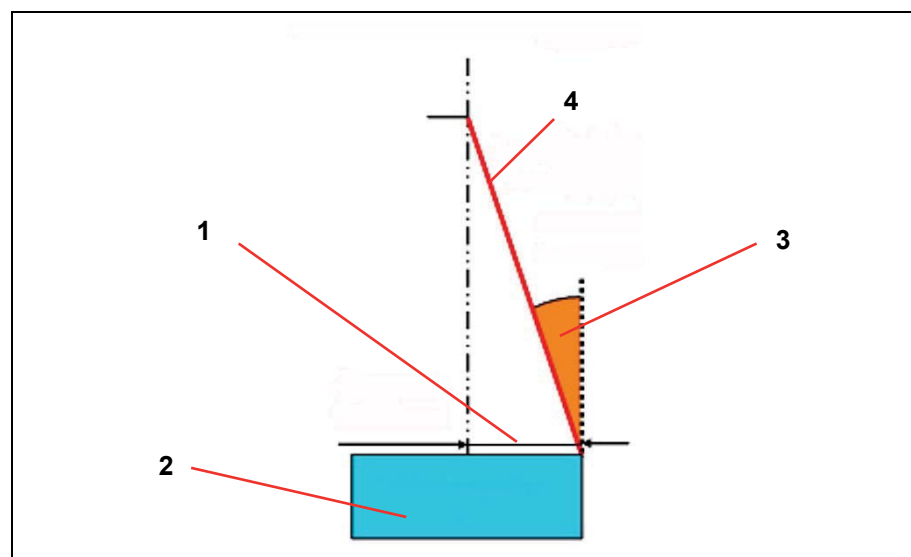
/2/ component

/3/ wall

/4/ perpendicular to the surface to be structured

/5/ angle of incidence

Fig. 11: scan field



/1/ distance to centre

/2/ scan field

/3/ angle of incidence (13 °) to the horizontal

/4/ deflected laser beam

DR_024_LDS-MID_ventilation

When designing the *MID* component, provide ventilation for hydrogen bubbles that are generated during metallisation. Observe the orientation of the component on the rack (if using rack metallisation) and create a design that ensures unhindered release of these hydrogen bubbles thus ensuring that metal layer growth is not impaired.

For economic reasons (increased expenses for wastewater management), do not design components with cavities that have openings only on one side. Avoid e.g. blind holes.

DR_025_LDS-MID_fastening the plastic components

If the components cannot or are not intended to be retained in drums or baskets, provide clasping facilities e.g. ears, pickup holes, or undercuts for fastening the plastic components to the racks in the metallisation process.

DR_026_LDS-MID_recessed conductive paths

When metallising **LDS MID** components as loose material, devise recessed conductive paths if possible, thus preventing damage caused by grinding among the components especially on edges. Spacers on the *MID* component such as bumps or domes can prevent sticking together in drums.

Devise the geometrical design in such a way that the components cannot jam each other in the drum process.

DR_027_LDS-MID_SMD assembly process

If the *MID* components are intended for surface mounting, observe the following basic design rules for mounting and connecting techniques:

- Place components on flat surfaces; these surfaces may even be on different levels. Reserve the slopes that connect the mounting surfaces for conductive paths. Other design concepts are possible but consult your assembly service provider or his systems manufacturer on this matter.
- Provide sufficient spacing of the landing pads towards the *MID* component edges and walls to ensure freedom of movement for the solder paste dispenser and the vacuum pick&place tip.
- Do not exceed tolerance measures of $\pm 50 \mu\text{m}$ for planar mounting pads when designing for dispenser or mounting systems without automated measuring of the component position. This imposes high demands on the quality of the injection moulded component.

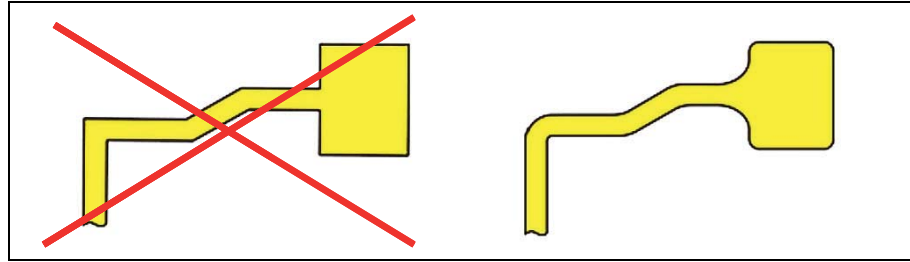
DR_028_LDS-MID_turns of paths

Avoid sharp-edged turns of conductive paths. Design turns with sufficiently wide radii (see Fig. 12: Optimal conductive path and pad on page 24) to reduce stress on the *MID* component in use. Especially the default settings of classic PCB routing programs are unsuitable for designing the conductive paths on **LDS MID** components.

Observe the following items already when designing:

- Design smooth transitions of conductive paths to SMD component pads instead of abrupt transitions that are common in PCB technology. This applies especially if a solder-resist mask cannot be used or only with great effort (as is often the case with *MID* components) for this measure reduces the capillary effect that causes solder outflow from the pads to the conductive paths when the solder paste is melted.
- Round off the corners of *SMD* pads to reduce the risk of peeling under the thermal stress that impacts the *MID* assembly during the soldering process.

Fig. 12: Optimal conductive path and pad



DR_029_LDS-MID_tombstone effect

Solder leaking from the pad and the resulting problems in reflow soldering such as the tombstone effect can be prevented by applying a line of suitable solder-resist lacquer across the conductive path near the pad using a dispenser. Pad printing is another method for applying solder resist.

DR_030_LDS-MID_maximum component size

Do not use SMD resistors and SMD capacitors exceeding component size 1206 as the difference in the coefficient of thermal expansion between the plastic substrate and the conductive paths is larger in *MID* components than in FR4 circuit boards which can cause higher defect rates due to alternating thermal stresses.

Due to the lack of solder resist masks, we recommend to allow only one conductive path between two pads for components of the size 1206.

DR_031_LDS-MID_distance to solder pads

Provide sufficient distance between solder deposits and non-solder functional surfaces (e.g. contact pads) so that solder run-over along the connecting conductive paths to the functional surface is reliably prevented.

DR_032_LDS-MID_fiducial marks

Usually, automated processes are used for assembling and connecting in mass production. This requires that the location of dispensing and mounting positions have to be recognised and monitored accurately using *vision systems*. Provide for integrating suitable fiducial marks for the assembly process already in the circuit design phase. Consult your electronic manufacturing service provider on the contrast of the fiducial mark in relation to the plastic base material.

DR_033_LDS-MID_redundant conductive paths

Make use of the option to devise redundant conductive paths at critical spots (see DR_002_LDS-MID_critical areas on page 12). For this, the **LPKF-LDS® process** provides ideal conditions.

DR_034_LDS-MID_reflow soldering method

Also keep in mind the selection of the reflow soldering method already when designing the component.

- Watch out for possible hot-spots at elevated structures or at walls facing the heat sources when employing infrared or convection reflow soldering.
- If you are using the vapour phase soldering method, which is generally recommendable for *MID* technology, provide good drainage for the soldering medium (Galden) to prevent long evaporation periods after the reflow process.
- Another option is selective laser soldering using optical process control.

DR_035_LDS-MID_encapsulating

Depending on the application of the fully assembled **LDS MID** components, one of several options for encapsulating the finished assembly can be selected.

- Various producers offer several potting resins and protective lacquers that can either provide full protection or, if applied partially, protection of selected circuit areas.
- Hot-melt potting is an interesting manufacturing option to protect the *MID* assembly from environmental impact.
- A very interesting option for hermetically encapsulating *MID* assemblies is also laser welding if a laser-transparent material is selected for the "shell". Further information on process technology is available from our business unit plastic welding in Erlangen, Germany (www.laserequipment.de).

4 Injection moulding

4.1 Tool design

4.1.1 Material

Do not use injection moulding tools made of aluminium to avoid tool-related extraneous plating during metallisation of the **LDS MID** components. Steel grades that can be through-hardened like 1.2343 or 1.2767 have proved suitable for processing **LDS** materials.

4.1.2 Tool surface

A standard surface finish ($R_z \leq 5 \mu\text{m}$) is sufficient, polishing the surface usually is not necessary. However, for areas of the *MID* component which will be used for bonding, we recommend a partial polish of the tool using specific laser parameters for bonding areas. When designing the tool, ensure that tool temperature can be kept even over time and over the all tool surfaces.

4.1.3 Design rules for sprue and gate

Observe the following rules for designing sprue and gate:

1. Preferably use direct conical runners to the centre of the component.
2. Place the gate at the thickest wall of the component.
3. Always provide a means for intercepting the cold slug.
4. Devise the sprue bushing wider than the thickest component wall.
5. Provide a gate width of at least 50% of thickest component wall.
6. Prevent jetting by employing a large-diameter gate and shooting against a wall.
7. If more than one gate is required, observe the forming of weld lines!

When using multi-cavity tools, use sensors measuring the pressure inside the tool that are linked to the moulding system's control to ensure consistent quality over all cavities.

4.2 Injection moulding process

Before injection-moulding an **LDS MID** lot, thoroughly remove residues of previous injection moulding processes to avoid contamination. Do not use mould release agents, especially those based on silicone for injection moulding. Avoid using lubricants for ejector pins or only use very sparingly.

Observe the process window specified by the granulate manufacturers in the processing information as well as the instructions for pre-drying of the material. Avoid process interruptions to ensure consistent quality.

4.3 Handling, packaging, and storage

4.3.1 Handling

Avoid damage and contamination (e.g. metal or skin contact, scratches) especially on critical areas when handling **LDS MID** components.

4.3.2 Packaging and storage

Provide adequate trays for the components removed from the mold and adequate packaging for further transport. Deep-drawn plastic trays have proved to be best and can form the basis of a consistent transport concept. Bear in mind the possible effects of packaging materials on subsequent processes (laser processing, metallisation, soldering, conductive adhesive bonding etc.). Prevent any water absorption of the **LDS MID** components during storage.

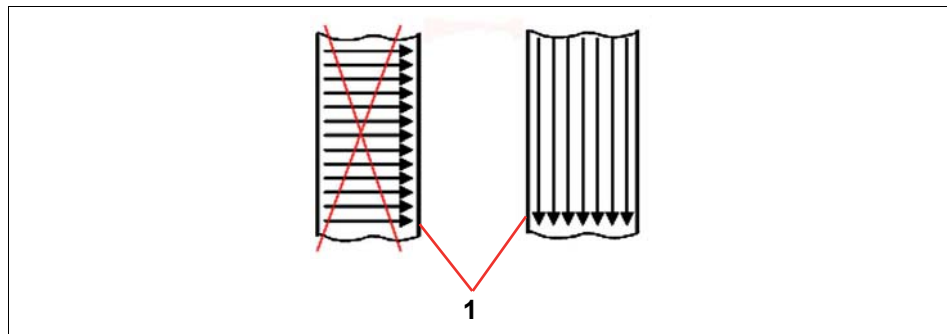
5 Laser Processing

5.1 Data Preparation

5.1.1 Avoid short fill vectors

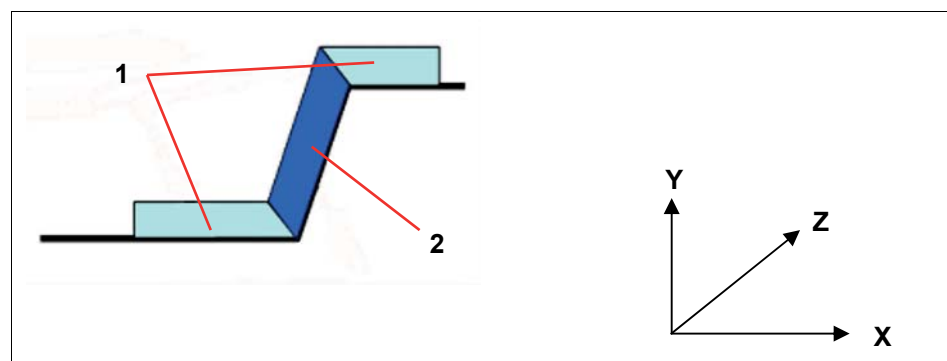
Avoid short fill vectors. Fill narrow conductive paths lengthwise instead (see Fig. 13: Fill vectors). If an *LDS MID* component is to be structured with different slopes, different laser parameter sets may be necessary for the different areas to achieve reliable activation (see Fig. 14: Parameter sets). Observe, though, that the dynamic range of the optical Z-axis is not exceeded.

Fig. 13: Fill vectors



/1/ outline of conductive path

Fig. 14: Parameter sets



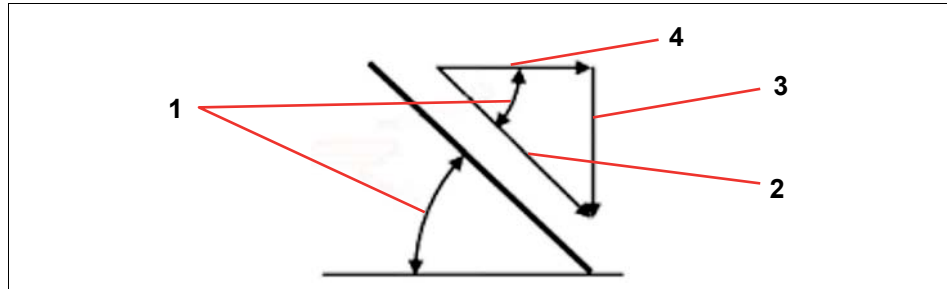
/1/ parameter set 1

/2/ parameter set 2

5.1.2 Laser parameters

The frequency is also limited by the maximum focus-tracking speed in Z-direction: The more inclined the slope the faster the focus has to be adjusted in Z-direction when processing. The maximum focus tracking speed of a **MicroLine-3D 160i** system of 1,000 mm/s results in a maximum travel speed of 1,500 mm/s on a 45° slope (see Fig. 15: Travel speed).

Fig. 15: Travel speed



/1/ angle of the slope = α

/3/ speed Z-direction = v_z

/2/ resulting speed = v

/4/ speed X-direction = v_x

The calculation formula for the speed on the slope is:

$$v = \frac{v_z}{(\sin \alpha)}$$

For $v_z(\max) = 1,000 \text{ mm/s}$ and $\alpha(\max) = 45^\circ$, the resulting speed v on the slope is:

$$v = \frac{1,000 \text{ mm/s}}{(\sin 45^\circ)} = \frac{1,000 \text{ mm/s}}{0.707} = 1,414.4 \text{ mm/s}$$

5.1.3 Other process parameters

Observe the instructions of the laser system's manufacturer when computing the suitable process parameters for average laser power and longitudinal and lateral inclination

For the laser data preparation, we offer comprehensive training and training videos for the 3D software **CircuitPro 3D** to our customers of the new **LPKF Fusion 3D** system.

5.2 Laser Processing

5.2.1 Fixture

If possible, employ plastic fixtures or clamping devices for laser processing of the **LDS MID** component to prevent extraneous plating during metallisation. If the components have to be clamped several times in different positions for laser processing, provide recesses on the fixture or clamping device to prevent damaging areas that are already activated when clamping in the subsequent position.

5.2.2 Positioning

Using an optical system (vision system) for aligning the conductive pattern on the component can compensate tolerances that can be caused by the fixture/clamping device, scanner mirrors, positioning systems etc.

Fixture design rules help construct specific component fixtures. They are available to our laser system customers at no charge.

5.3 Handling, packaging, and storage

5.3.1 Handling

Avoid damage and contamination (e.g. metal or skin contact, scratches) during and after laser processing especially on activated areas when handling **LDS MID** components (see chapter 4.3 Handling, packaging, and storage on page 28).

We recommend using lint-free cotton gloves for manual loading and unloading of the components to be structured or already structured and to clean the gloves regularly. Prolonged usage of gloves or finger cots made of latex has a critical impact on quality in the metallisation process as sweat tends to diffuse through the gloves or finger cots and thus creates residues on the components.

5.3.2 Packaging

Do not use paper containing sulphuric compounds as packaging for transport to the metallisation process step. Avoid direct sunlight and use silica gel for storage as humidity and temperature can affect activation.

5.3.3 Storage

Storing the laser-activated components for several weeks before metallisation poses no problem for the metallisation process if normal storage conditions (10 – 20° C, ≤ 65 % relative humidity) maintained.

Avoid storing the components in conditions where condensation in combination of temperatures below 0° C can occur or in industrial (corrosive) atmosphere. Store only for as short as possible if these conditions cannot be avoided.

6 Metallisation

6.1 Component retainers

Consider the suitability for your component and consult your metallisation service provider when deciding on the metallisation method (drum, basket, or rack metallisation) and on the type of rack or mesh size of drums or baskets. When using racks or baskets, use types that are fully insulated with thermoplastic fluorinated hydrocarbon compounds (*Halar*[®]) in a whirl-sintering process and clean them of extraneous metallisations regularly.

6.2 Cleaning LDS MIDs

It is essential that the ablation products of the laser structuring that are highly activated and can cause massive problems in the form of extraneous plating are removed to ensure trouble-free further processing. Removal can be achieved in ultrasonic baths, using high-pressure water jet, or – if utmost cleanliness is required – by using CO₂ snow-jet cleaning (for details on this technology refer to the web site of acp-micron: www.acp-micron.com) and can be done directly after laser processing or – more typically – before the plating steps.

Common media for cleaning in ultrasonic baths (recommended frequency: 40 kHz) are aqueous tenside solutions such as *Mucosol* or *Tickopur* (both only available in Europe) as well as aqueous alcoholic tenside solutions (e.g. *Tickopur* + isopropyl alcohol). As the market for cleaning agents is structured regionally, we recommend consulting your supplier of the copper/nickel/gold chemicals for selecting the suitable cleaning chemicals.

Please observe that the chemical properties of the cleaning agent can have negative effects on the platability of **LDS MIDs**. Conduct a series of tests investigating such effects.

6.3 Electrolytes for metallisation

Observe the storage and operating instructions provided by the producers of the electroless plating chemicals (see overview of known electroless copper baths suitable for the **LDS[®] process**). Consider the transport chain and determine whether temperature-controlled transport is necessary.

Observe shelf life and service life of the electrolytes.

The following table shows the applicability of the individual copper baths for:

- 1 applicable as a copper strike bath for PC and PC/ABS in a two-stage process
- 2 applicable as full-build copper bath for PC and PC/ABS in a two-stage process
- 3 applicable as a single-stage copper bath (for LCP, PA, PBT, PBT/PET, PPA)

Table 5:
Applicability of
copper baths

| copper bath | producer | 1 | 2 | 3 |
|---|--|------|-----|-----|
| Circuposit 4500 | www.rohm-haas.com | no | yes | yes |
| Cuposit 71-HS (formerly XP 6870) | | yes* | yes | yes |
| M-Copper 85 | www.mac-dermid.com | yes | no | no |
| Macuplex MID Copper | | - | yes | yes |
| Macuplec 85 MX- LDS | | yes* | yes | - |
| MID Copper 100 | | yes | yes | yes |
| Cupralux INI | www.ato-tech.com | yes* | yes | yes |
| Enplate MID Select 9070 | www.cookson-electronics.com | yes | no | no |
| Enplate Cu 872 | | no | yes | yes |
| Enplate LDS 400 (under development) | | yes* | yes | - |
| Cupro-Coat 100 | www.aimt-group.com | - | yes | yes |

*under special conditions

6.4 Metallisation Process

6.4.1 Processing order

Avoid unnecessary storage times after laser processing by metallising those components first that have been laser-processed first (first-in-first-out principle).

Consult the electrolyte producer's processing information to determine the process window. Monitor by analysis and add the individual bath chemicals regularly to ensure a reproducible initial plating and constant deposition.

Provide for sufficient movement of the components. Operate the baths at optimum load, especially for chemical copper deposition. We recommend a filter cycle for each bath using filter cartridges of pore sizes $\leq 5 \mu\text{m}$.

6.4.2 Metallisation processes/process steps

Execute the individual metallisation steps wet-on-wet, while providing good rinsing after each process step to preserve the service life of the individual baths.

We recommend to devise the last rinsing step after the metallisation processes as a hot rinse (approx. 90°C with conductivity $< 1 \mu\text{S/cm}$, i.e. de-ionised water) and dry the components in circulating air to ensure spotless drying of the components for trouble-free assembly.

The following list shows the most important process steps for a standard **LDS** metallisation:

Table 6: Steps in metallisation

| Step | Description |
|------|--|
| 1 | Pre-cleaning as described in section 6.2 Cleaning LDS MIDs |
| 2 | Copper bath or baths as a single- or two-stage process (strike + full build) – copper process depending on LDS material and bath chemicals used |
| 3 | MicroEtch |
| 4 | Pd activation |
| 5 | nickel bath (two-stage if necessary, depending on layer requirements) |
| 6 | gold bath |
| 7 | hot rinse |
| 8 | drying |

Insert an adequate static and flow rinsing combination after each process bath (active bath) listed.

LPKF provides laser system customers who are interested in entering the metallisation of **LDS** components with detailed design recommendations for entire metallisation systems for prototyping as well as for mass production. Please ask the LPKF sales representative.

6.5 Thermal conditioning

In many cases, a thermal conditioning of the *MID* components after metallisation and before mounting and connection processes can achieve a better strength of the metal-plastic bond.

A thermal conditioning at 120°C for one hour has proved good results for consolidation of the metallised *MID* component except for PC/ABS materials. Condition PC/ABS thermally at temperatures < 85°C but for a longer period.

6.6 Handling

Avoid damages as well as contaminations (e.g. scratches, metal and skin contact) especially on metallised spots when handling metallised **LDS MID** components. Provide suitable packaging, depending on the component with component separation (e.g. deep-drawn trays). Pay attention possible effects of packaging materials on subsequent processes (soldering, gluing etc.). Avoid electrostatic charging by the packaging material, especially before mounting the **LDS MID** components. The decision whether to use ESD packaging depends on the circuit technology of the assembly and its ESD susceptibility; consult your service provider for mounting and bonding.

7 Quality assurance

We recommend developing a process FMEA before planning the production process steps in order to derive and define the necessary gates for quality assurance measures.

The **LDS** QA matrix indicates possible test methods for manufacturing **LDS MIDs**. These as well as images of defects in the individual process steps are part of the system documentation in the delivery of **MicroLine-3D** laser systems.

8 Appendix

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8.3 List of abbreviations

| | | |
|----------|-----------------|---|
| A | ABS | acrylonitrile butadiene styrene |
| | Ag | silver |
| | Al | aluminium |
| | ASIG | auto-catalytic silver immersion gold |
| | Au | gold |
| C | CAD | computer aided design |
| | CO ₂ | carbon dioxide |
| | CTE | coefficient of thermal expansion |
| | Cu | copper |
| D | DIN | Deutsches Institut für Normung (German standards institute) |
| E | ECAD | electronic CAD |
| | EG | electroless Au |
| | EN | electroless Ni |
| | EP | electroless Pd |
| | ESD | electrostatic discharge |
| F | FMEA | failure modes and effects analysis |
| I | IG | immersion Au |
| | IR | infrared |
| L | LCP | liquid crystal polymer |
| | LDS | laser direct structuring |
| M | MCAD | mechanical CAD |
| | MID | moulded interconnect devices |
| N | NiP | nickel-phosphorus |
| P | PA | polyamide |
| | PBT/PET | polybutylene terephthalate/polyethylene terephthalate blend |
| | PC | polycarbonate |
| | PCB | printed circuit board |
| | Pd | palladium |
| | PPA | polyphthalamide |
| Q | QA | quality assurance |
| S | Si | silicon |
| | SMD | surface-mounted device |
| | Sn | tin |

8.4 Conversion tables

Distance

| | | | |
|------|--------------|--------------------|----------------------------|
| 1 cm | = 0.3937 in. | 1 inch (in) | = 25.4 mm |
| 1 mm | = 39.37 mil | 1 mil = 1/1000 in. | = 2.54×10^{-2} mm |

Area

| | | | |
|-------------------|------------------|---------------------------------|--------------------------|
| 1 cm ² | = 0.1550 sq. in. | 1 sq. inch | = 6.4516 cm ² |
| 1 m ² | = 10.7639 sq.ft. | 1 sq.ft. = 144 in. ² | = 0.0929 m ² |
| 1 m ² | = 1.19599 sq.yd. | 1 sq. yd. = 9 ft. ² | = 0.8361 m ² |

Temperature

| | | |
|---------|----------|----------------------|
| - 20 °C | = - 4 °F | °F = °C * 1.8 + 32 |
| 0 °C | = 32 °F | °C = (°F - 32) / 1.8 |
| 100 °C | = 212 °F | |

