MID-Technology: New Applications, Materials, Plating Concepts

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The MID-technology (**M**oulded **I**nterconnect **D**evices) is a relatively new technology for the manufacturing of components with integrated electrical and mechanical functions. The electrical functions are achieved by partial metallisation of the plastic substrate. Two important substrate materials (LCP, **L**iquid **C**rystal **P**olymer, and polyamide) are presented and the different concepts for selective plating by electroless plating technologies (Copper, Nickel) are discussed. The end finish is generally built up by electroplating e.g. copper or tin or by electroless nickel / immersion gold.
New MID- applications for mechatronics are presented.

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Introduction

The MID-technology (**M**oulded **I**nterconnect **D**evices) is a relatively new technology for the manufacturing of components with integrated electrical and mechanical functions. The integration yields new design freedom and high cost reduction potentials. The bodies of MIDs are made by injection moulding of thermoplastic materials, the electrical functions (e.g. circuit tracks) are achieved by selective metallisation. Key markets are the automotive and telecommunication industry.

There are three main processes for the manufacturing of MIDs (see also [1,2]):

- Hot embossing: a specially prepared copper foil is embossed into the moulded plastic substrate
- Laser Imaging: Metallisation of moulded plastic parts with electroless and galvanic copper is followed by plating etch resist / laser structuring of etch resist, etching copper and finally surface finishing
- Two-shot moulding: Combination of plateable and non-plateable materials by two-shot moulding; the electrical functions are realized by selective plating of the plateable areas

Table 1
Main MID-Processes: Features

	Geometry of MID	Miniatu-risation/ fine pitch	costs
Hot Embossing	Comparably simple structures / 2.5 D	no	low
Laser imaging	(Restricted by laser technology) 3 D	yes	high (batch processes)
Two-shot moulding	Fully 3 D	yes, depends on material	Comparably high (tool and thermoplastics costs)

Two-shot moulding is the most flexible of the processes with regard to geometry and design of the MIDs. Depending on the thermoplastics used, miniaturisation of the electrical and mechanical structures is possible. There are three main variations of the two-shot moulding process, see figure 1.

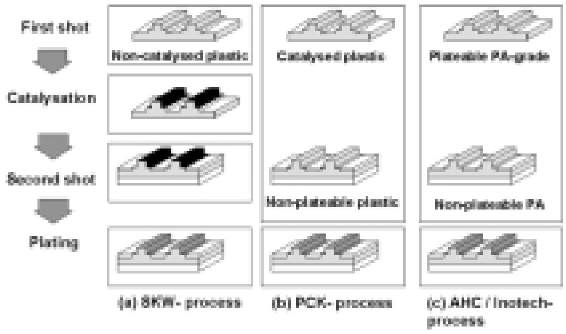

Figure1 - Two-Shot Moulding processes for MID technology

The SKW (Sankyo-Kasei-Wiring-Board)-Process requires the chemical treatment (activation and metallisation) of the thermoplastics between the first and the second shot and is therefore very difficult to handle. The PCK (Printed-Circuit-Board - Kollmorgen)- and AHC/Inotech- Processes are easier to handle with regard to the injection moulding, but require a very careful adaptation of the electroless plating processes involved.

Selectivity and starting behavior of the electroless plating processes are the key features for the electrical functionality of the MIDs. The plateability is due to the use of Palladium-compounded thermoplastics (PCK-process) or inherently plateable thermoplastics (AHC/Inotech-process), e.g. PA 6 or PA 6.6, respectively.

This paper deals with applications of both the PCK- and the AHC/Inotech-process. Two important substrate materials (LCP, **L**iquid **C**rystal **P**olymer, and polyamide) are presented and the different concepts for selective plating by electroless plating technologies (Copper, Nickel) are discussed.

Materials

Normally, low-cost thermoplastics such as polyamide (PA), Polycarbonat + Acryl-Butadien-Styrol (PC/ABS) are used for MID applications. However, if high thermal stability (> 150°C, max. up to 240°C) and fine structures (< 200 µm) are required, high temperature thermoplastics, e.g. Liquid Crystal Polymer (LCP) or polyetherimide (PEI) are used. LCP has excellent heat and dimension stability and can be used for fine pitch applications, the minimal circuit or insulator width

being 100 µm. Conventional soldering processes can be applied.
A disadvantage of LCP is the high price of the material (24 US Dollar per kilo for the Pd-compounded LCP-type), so LCP is not used for big sized parts like housings.
Polyamide is a technical thermoplastic (price 2.5 – 4 US Dollar per kilo) with high dimension stability and high dynamic load. Some special types are reflow solderable.

Plating concepts

There are different metallisation concepts for LCP and PA.

Polyamide

Certain sorts of PA, e.g. PA 6 and PA 6.6, are inherently plateable by the following process: After pretreatment (swelling and etching), activation is performed with a Palladium-containing solution. After reduction of Palladium, electroless plating starts readily on the activated surface areas. A specially developed electroless nickel ("Ni strike electrolyte") is used for the first step of the metallisation. Further metallisation can be performed by electroless or galvanic plating (see figure 2).

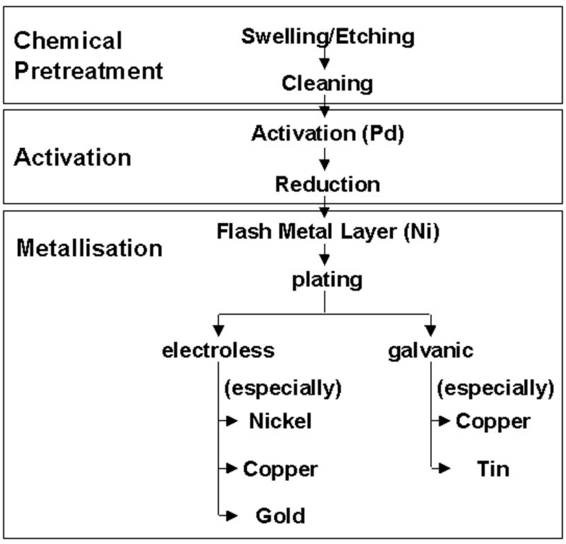

Figure 2 - Metallisation of Polyamide

The plateability of PA 6 and 6.6 is mainly due to a micro surface roughness after the pretreatment in a swell and etch process, which allows the adsorption of ionogenic Palladium catalyst.
The adhesion strength of the metal layers on PA is typically 1 N/mm (peel test).

LCP

For the metallisation of MIDs based on LCP, a different plating concept is necessary. LCP is not inherently plateable. The plateability is achieved by compounding small amounts of Palladium (≈50 ppm) into the material with very small Palladium concentrations resulting on the surface. As electroless nickel is inactive on the surface, the more active electroless copper process has to be used.
The process steps for the metallisation of Palladium-compounded LCP are: swelling / etching and electroless copper (see figure 3). The selectivity of the plating process is achieved by the presence of Palladium on the plateable surfaces.
„Selectivity" in this case means, that electroless plating has to start reliably on the plateable LCP, and has to be inactive on the non-plateable thermoplastics (e.g. partly aromatic polyamide or LCP). As the plateable LCP-component contains very low concentrations of Palladium, a very active electroless process is needed to get a good starting behavior. However, the process also has to be very stable to prevent unwanted plating of the non-plateable surfaces.
A special electroless copper process had to be developed to meet the demands concerning activity / starting behavior, plating speed, bath stability and - very important for the electrical function of the MID - selectivity.
The adhesion strength of the metal layers on LCP is typically between 0.7 and 0.9 N/mm (peel test).

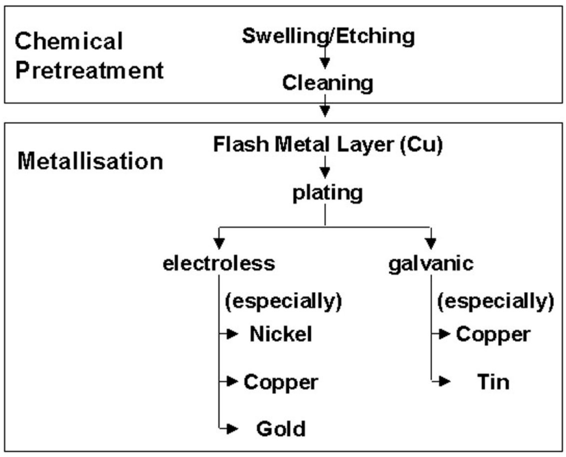

Figure 3 - Metallisation of LCP

After the plateable areas have achieved full coverage with copper or nickel, further plating both on LCP and PA can be performed depending on the layout, application and assembly demands of the MID.

Table 2 gives some examples of surface finishes that are commonly applied. Usually electroplating is preferred, depending on the layout of the circuits.

Table 2
Surface Finishes for MIDs

Process	Layer Thickness	Purpose
Cu/Sn (electroplating)	5 – 40 µm Cu 4 – 10 µm Sn	Circuit tracks / soldering
Cu / Sn (electroless)	5 – 20 µm 1 µm Sn	Circuit tracks / soldering
Cu / Ni (electroplating)	3-5µm Cu 2 µm Ni	shielding
Ni / Au (electroless)	5 – 15 µm Ni 0.05 – 0.1 µm Au	wear resistance/ soldering/ corrosion /

Examples

Figure 4 shows a PCB-connector for brake modules (automotive).
Material: PA 6 / Nylon 12
Metallisation: Cu/Ni/Sn

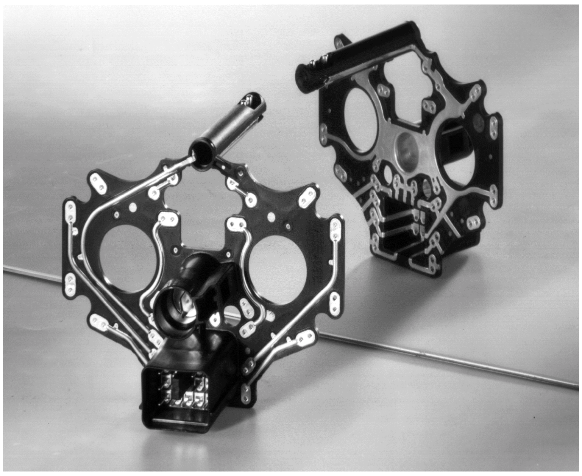

Figure 4 - PCB-Connector for Brake Modules (Automotive) (PA)

The entire subassembly component was successfully tested according to the following scheme (see table 3)

Table 3
Component Tests for PCB-Connector

Constant humid warmth	40°C / 93 % / 56 days (DIN IEC 68-2-3)
Temperature shock test	10 cycles –40°C to +155 °C (JED-647)
Chemical resistance	Lubricating and gear-oils, brake fluid, cleaning liquids, fuels
High-voltage tests	1 kV
Vibrations	

Figure 5 shows a MID-component of a control gear of an electric motor (250 V).
Material: PA 6 / PA 12
Metallisation: Cu/Ni/Sn

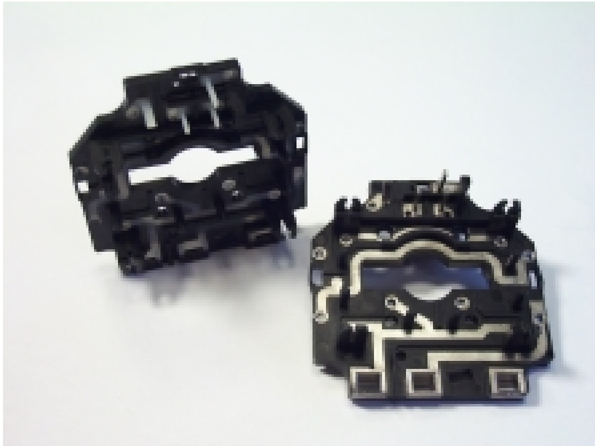

Figure 5 - MID-Component of a Control Gear (Electric Motor; 250 V), PA (by Courtesy of J. Stehle + Söhne AG)

Figure 6 shows a MID-antenna of a mobile phone.
Material: PA 6 / PA 12
Metallisation: Cu/Ni/Au

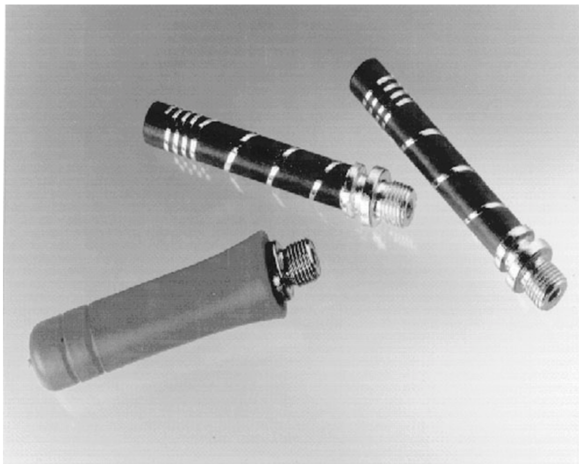

Figure 6 - MID-Antenna (Mobile Communication), PA

Figure 7 shows an application in electronic industry.
Material: LCP
Metallisation: Cu/Ni/Au (all electroless)

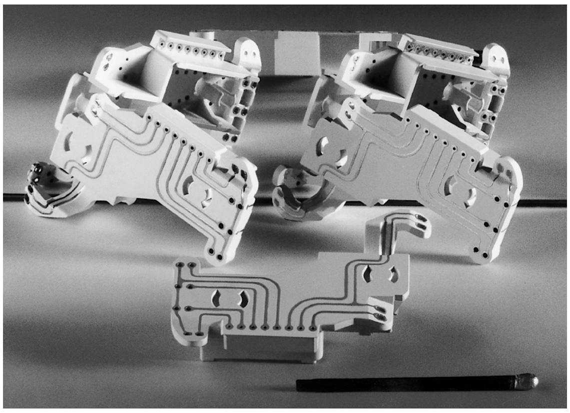

Figure 7 - Application in Electronic Industry, LCP (by Courtesy of Buss-Werkstofftechnik GmbH & Co KG)

Conclusions

Two-shot moulding is a very flexible technology that allows the manufacturing of high performance MIDs. Different plating concepts for LCP and PA as two important substrate materials allow the reliable metallisation of both materials. Some examples are presented as interesting MID applications.

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