MID Technology: New Applications, Materials, Plating Concepts

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Molded Interconnect Devices (MID) technology is relatively new for the manufacturing of components with integrated electrical and mechanical functions. The electrical functions are achieved by partial metallization of the plastic substrate. In this edited version of a presentation from SUR/FIN® 2000—Chicago, two important substrate materials—liquid crystal polymer (LCP) 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/immer-sion gold. New MID applications for mechatronics are presented.

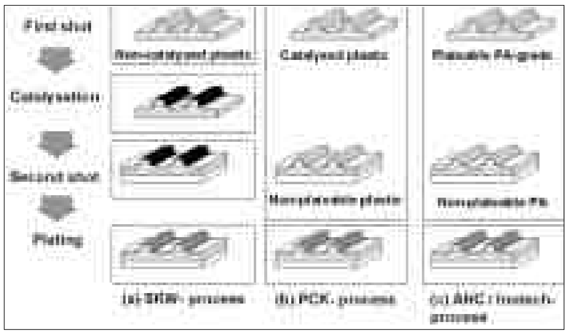

Fig. 1—Two-shot molding processes for MID technology.

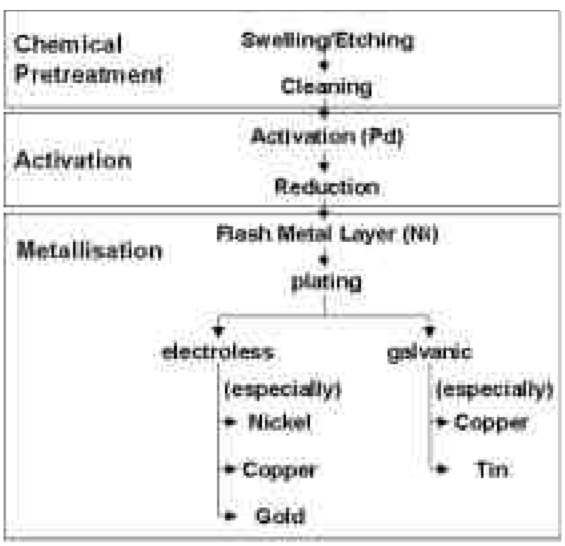

Fig. 2—Metallization of polyamide.

MID technology is relatively new 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 molding of thermoplastic materials, the electrical functions (*e.g.*, circuit tracks) are achieved by selective metallization. Key markets are the automotive and telecommunication industry.

There are three main processes (Table 1) for manufacturing MIDs:[1,2]

- Hot embossing: a specially prepared copper foil is embossed into the molded plastic substrate
- Laser imaging: Metallization of molded 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 molding: Combination of plateable and non-plateable materials by two-shot molding; the electrical functions are realized by selective plating of the plateable areas

Two-shot molding is the most flexible of the processes with regard to geometry and design of the MIDs. Depending on the thermoplastics used, miniaturization of the electrical and mechanical structures is possible. There are three main variations of two-shot molding (see Fig. 1).

The SKW Sankyo Kasei Wiring Board (SKW) process requires the chemical treatment (activation and metallization) of the thermoplastics between the first and the second shot and is therefore very difficult to handle. The Printed Circuit Board Kollmor-gen (PCK) and AHC/Inotech- processes are easier to handle with regard to the injection molding, 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 article deals with applications of both the PCK and the AHC/Inotech processes. Two important substrate materials—liquid crystal polymer (LCP) and polyamide—and the different concepts for selective plating by electroless plating technologies (copper, nickel) are discussed.

Materials

Normally, low-cost thermoplastics, such as polyamide (PA), Polycarbonate + 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

Table 1
Main MID Processes: Features

	Geometry of MID	Miniaturization/ 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 molding	Fully 3 D	yes, depends on material	Comparably high (tool & thermo-plastics costs)

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

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 & gear-oils, brake fluid, cleaning liquids, fuels
High-voltage tests	1 kV
Vibrations	—

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 per kilo for the Pd-compounded LCP-type), so LCP is not used for big-sized parts, such as housings.

Polyamide is a technical thermoplastic (price $2.5–$4 per kilo) with high dimension stability and high dynamic load. Some special types are reflow-solderable.

Plating Concepts

There are different metallization 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 metallization. Further metallization can be performed by electroless or galvanic plating (see Fig. 2).

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 metallization 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 metallization of palladium-compounded LCP are: swelling/etching and electroless copper (see Fig. 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).

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.

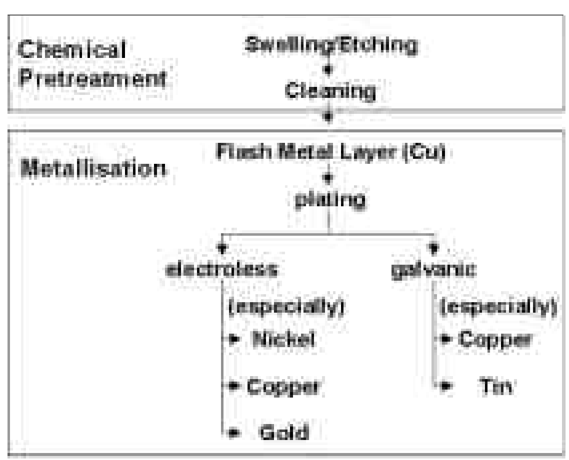

Fig. 3—Metallization of LCP.

Fig. 4—PCB connector for brake modules (automotive) (PA).

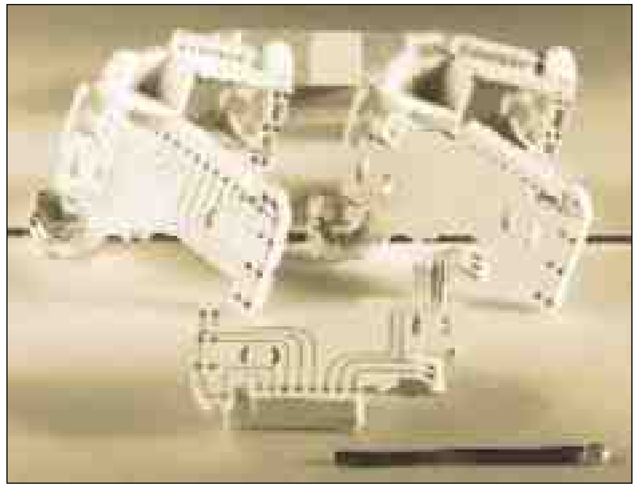

Fig. 7—Application in electronic industry, LCP (courtesy of Buss-Werkstofftechnik GmbH & Co KG).

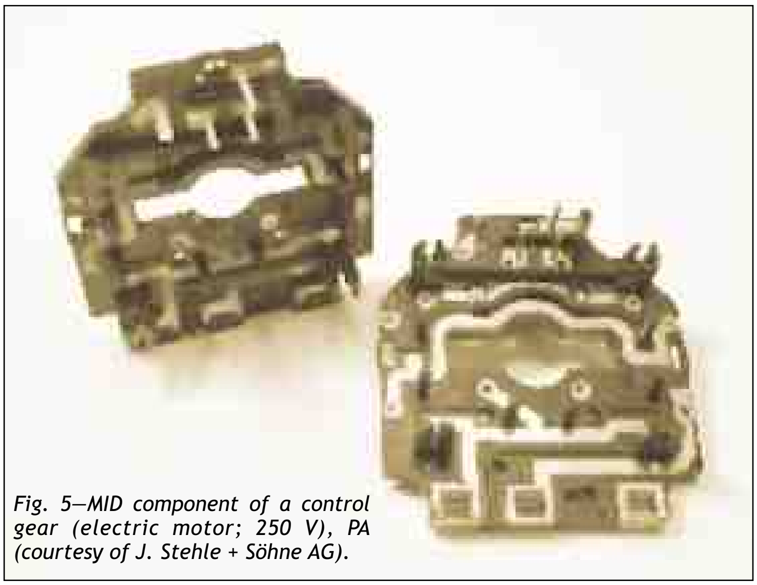

Fig. 5—MID component of a control gear (electric motor; 250 V), PA (courtesy of J. Stehle + Söhne AG).

Fig. 6—MID antenna (Mobile Communication), PA.

Examples

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

The entire subassembly component was successfully tested according to the scheme shown in Table 3.

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

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

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

Conclusions

Two-shot molding 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 metallization of both materials. Some examples are presented as interesting MID applications.

Acknowledgment

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