Integrated Functionality in High-Temperature LDS Assemblies

The added value solution in electronics

Integrated Functionality in High-Temperature LDS Assemblies

Laser Direct Structuring gives designers an effective new way to manufacture MIDs, and offers many performance advantages.

By Ir. Paul Potters, DSM Engineering Plastics

Published June 2011 in ConnectorSupplier

Molded Interconnection Devices (MIDs) include a critical thermoplastic part, the 3D substrate for conductive tracks. A wide array of processes exist to manufacture these devices. Some are based on full metallization of plastic parts, with removal of the plating in a secondary step by etching or photo-resist processes. Others create conductive circuits directly on the parts, using either advanced printing processes or high temperature dispensing. Often a secondary curing operation is required. A third type of MID production includes a structuring step where the differentiation between conductive and insulative areas is determined. Two-component molding technology, which uses two distinct types of thermoplastics - one being plateable - is another well-known method of production, and Laser Direct Structuring (LDS) is an emerging technology that will likely come into greater use.

In LDS, molded compounds are exposed to a laser beam in all three dimensions. During this direct laser writing, chemical activation through ablation of the exposed polymer surface eases the proper adhesion of copper in standard electroless plating. Just a few straightforward process steps are needed: molding, lasering, and plating. In this way, LDS offers a highly flexible design solution. By simply making software adjustments, electronic circuits are quickly varied without any substantial new investment.

Trends in Electronics

As we see everywhere, the consumer market is asking for smaller and lighter products with more functionality. The miniaturization of electromechanical components like connectors and sensors requires reflow soldering technologies, because the contact pitch becomes so small. A consequence of this is the need for high-temperature-resistant materials (up to 280°C). Another route to miniaturization is through the integration of functionalities in the components or (sub)systems by conversion or disruptive technologies.

The industry’s growing environmental focus is another key trend. A few pioneers set their green targets independently, and as trendsetters, they influence the content of the future standards. Most companies, however, follow regulations set by governments or international associations.

MID accommodates both these trends by enabling smaller components with lower weight. A lower mix of materials in lower volumes is used. Carbon footprint is reduced in both production and operational stages. And the LDS process is environmentally friendly, as no etching or aggressive chemicals are used.

LDS Product Segmentation

As the LDS technology aligns perfectly with these market trends, it has great technical and commercial potential. In some segments, the technology is already applied in high volume production; for example, in cell phone antennas. In choosing the right material, a split has to be made in high and non-high temperature applications. Typically, long-term, high-temperature resistance of the material is required, for example, in electronic devices that are positioned close to automotive combustion engines or in lighting applications. A short but very high-temperature resistance is required in reflow soldering techniques. In infrared and convection-heated ovens, components have to withstand multiple passes of 260°C for 10 seconds.

Two groups of applications can be distinguished. The LDS carrier material can be a three-dimensional part functioning as a “3D PCB.” Small electronic components can be soldered onto the surface. Mounting and soldering equipment has been developed to automate the production in reflow assembly lines to reduce manufacturing cost. These designs are typically larger parts with a lot of 3D design functionalities. The material must perform well in the injection molding process. Furthermore, mechanical requirements are important to function as a structural part and to allow freedom in fixation solutions.

The second group consists of LDS parts, which are electronic components being soldered onto a PCB. Although the design is compact, a lot of functionality can still be integrated on a miniature scale with low-pitch electronic tracks. These parts require micro-molding capabilities and good electrical properties of the base material.

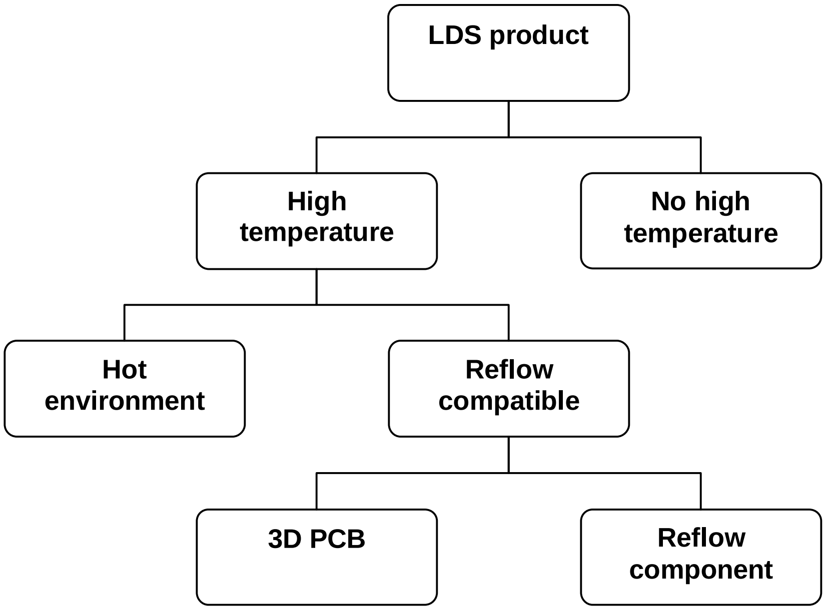

Figure 1 – Segmentation of Laser Direct Structuring (LDS) parts

Disruptive Design Solutions

With the emergence of the LDS technology, the focus is mostly on replacing a PCB or on creating electronic traces on a 3D embodiment. In specific situations, this gives enough benefits, versus more traditional solutions. To become really competitive, numerous functionalities should be integrated into the design. It requires a non-conventional and creative approach on a system or sub-system level. Engineers from multiple disciplines have to be involved. These disruptive solutions will be most successful when designs are made from scratch and are initiated above the component level. Only creativity, courage, and management support in development departments will overcome technical challenges and lead to competitive solutions. Unfortunately, we often see some hesitation or even reluctance, due to newness of the technology (product and process), or doubts in quality and reliability of the electronic interconnections. This is understandable, but not necessary at all.

Electrical Functionalities

In talking about the integration of functionalities, it is interesting to list a number of primary and secondary functionalities created by LDS technology. Of course, LDS devices combine electrical conductivity and insulation, that is the base principle of MID. Electronic and electrical circuits on the base material surface create design freedom. Vias, either injection molded or cut by the laser, allow connections through the material thickness. Width of the traces and distance between them can be tuned to meet high-speed data transfer in signal transmitting configurations. Large component areas with plating can secure EMI shielding, replacing metal shields. If sufficient plating thickness is applied, tracks can also transfer power. Track layout can be optimized for voltage and current applied.

Thermal Management

More and more often, thermal management is the challenge in electronic devices; sometimes in power applications, but very often in lighting (LED) or other miniaturization applications. Some LDS grades conduct heat slightly better than standard material. In critical designs, this can reduce local temperatures marginally, but not as well as real thermo-conductive polymers. However, tracks can conduct and transfer heat from their sources. Vias conduct heat through the material. Figure 2 shows a thermal simulation on a 1mm thick circular device with a heat source of two watts on the upper side in the center. Ambient air temperature is considered 20°C. Figure 1 reflects the temperature distribution in a cross section with pure plastic. In figure 2, the bottom side is plated with copper. In the third case, a plated via is added. The differences in maximum temperature illustrate the potential in thermal control with selective plating. The via brings a huge temperature reduction. For reference, the temperature in a fully aluminum plate would be 31.4°C. Of course, the plating might have optical or electrical functions at the same time.

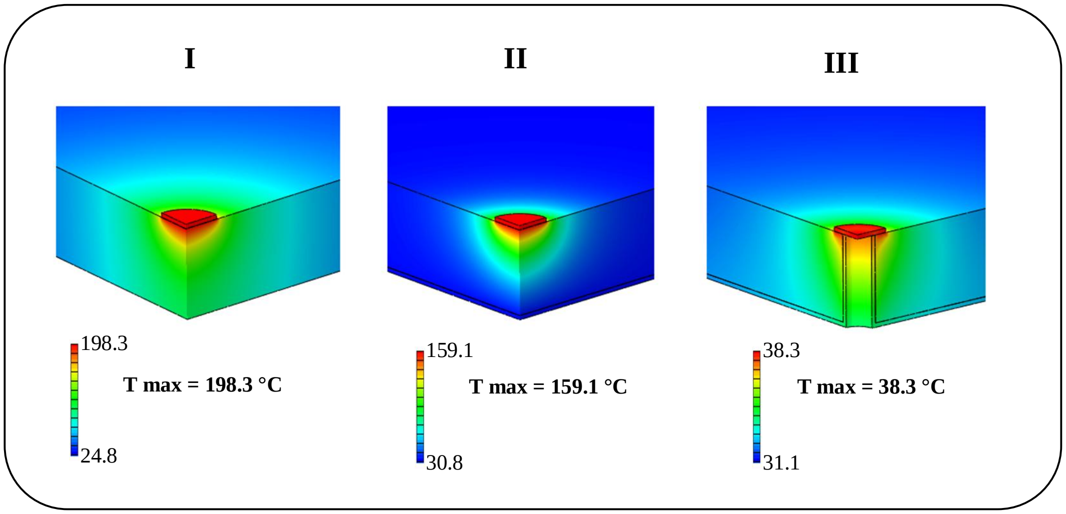

Figure 2 – **Temperature comparison with different layouts**

3D profiles, which are easily integrated into a molded part, increase the cooling surface to facilitate improved air cooling by natural or forced convection (figure 3). Integrating these options in an LDS electronic circuit might save other design measures for thermal control.

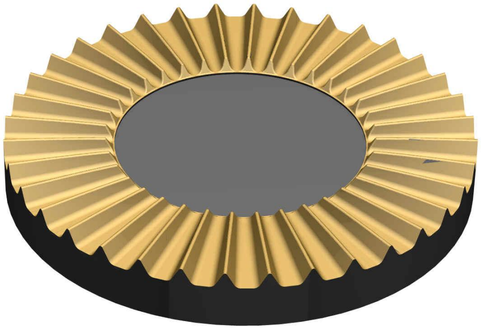

Figure 3 – **Molded ribs with plating improve air cooling.**

Vision

Depending on the plating, the reflection of light can be defined. In lighting applications, the effect on efficiency is obvious when a shiny silver-plating finish is applied, at least above a specific wavelength. Roughness of the surface defines the diffraction of light. A specular (“mirror”) reflection can be obtained with a very smooth surface. A matte surface shows diffuse (uniform) reflection. Contrasts in reflectivity can be accurate recognition for vision inspection systems, like in pick-and-place modules in automatic soldering lines identifying LDS components. When the LDS part is a component carrier, small plating spots can function as fiducial marks.

The laser in the LDS process can easily define text or a logo on the product. The marking arises during the plating process and is very readable by the lucidity and the contrast. It can be used for product identification or user functions. Last but not least, the plating can be an attractive cosmetic feature.

Mechanical Performance

Maybe unexpectedly, the selective plating creates design freedom in mechanical performance. Even with a thin surface layer, a strong metal substance increases stiffness and strength. This is due to the relatively high mechanical strength of metals versus the plastic base material. Specifically for thin parts, the increase is incredible. The stiffness of a 0.5mm thick beam increases by 50% if a copper layer of only 5 microns is designed in. With 50 micron copper, a five-times-higher level of stiffness is reached! Figure 4 gives the mechanical performance as function of the thickness, where the total thickness is kept constant. Perfect bonding between metal and plastic is assumed. With these dimensions, typical contact forces of 0.4 N can be reached with 0.1mm deflection, while stresses in both metal and plastic remain far below yield strength. Of course, soldering two parts together during the reflow process is another method to permanently and firmly attach them, mechanically and electrically.

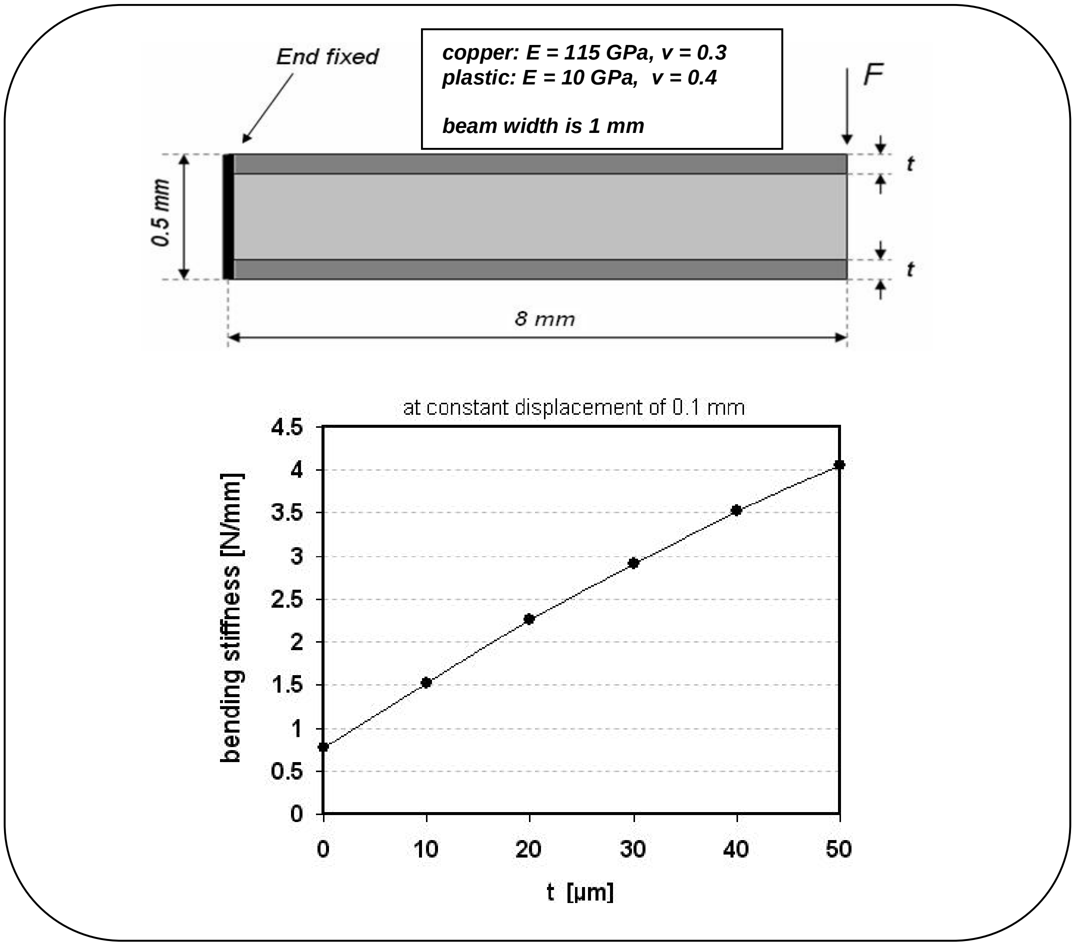

Figure 4 – **Increase of mechanical performance by plating**

Interconnections

The challenge is not only to design the LDS component, but to make the interconnection with the environment in which it will operate. The electrical current in the tracks on the part must run to other devices. The interconnection might either be permanent or releasable. Stripped wires can be directly attached to plated areas by several soldering techniques. Connector contacts, both header pins and receptacle terminals, can also be jig soldered in a separate manufacturing step. With appropriate terminal design, the contacts can even be processed in the automatic reflow assembly line.

The most basic interconnection is a contact spring of the external device being pressed against the plated surface of the metalized plastic. The reliability depends on the surface finish of both parts. The plating, type and thickness, and the level of roughness, determine wear and contact resistance.

A spring element can be an integral part of the LDS component. However, the long-term stress relaxation of the plastic determines the applicability. With good geometry and selection of high performing material, the stresses can be constrained and a reliable connection will be established. Another solution is to use a secondary elastic (metal) support. For example, in an EMI-shielded application, multiple contacts on low pitch are required to secure a closed, all-around shielding. All individual spring members can be supported by only one simply mounted, standard circular spring to secure sufficient contact force over time (figure 5).

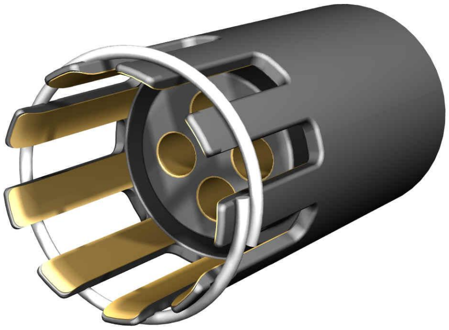

Figure 5 – **Spring supported circular interconnection**

Furthermore, traditional electrical and mechanical connection methods can be combined with LDS technology. Screws for high forces and glands for 360-degree circular contacts create rigid mechanical fixations with low electrical contact resistance.

Material

To fully benefit from the design freedom, a high performance base material is needed. With the best high-temperature material in the market, DSM Engineering Plastics offers a solution for high demanding applications where reflow and mechanical performance are required. Its high melt and glass transition temperature and unique heat deflection behavior make this possible. On top of that, the electrical performance (high CTI) allows for further design miniaturization and for use in high voltage (power) applications. Within its ForTii™ family, DSM has developed UL HB and V0 flammability LDS grades, with an excellent plating index to match specifications for consumer, industrial, and automotive applications.

A very flat SMT LVDS connector and the world’s smallest SiP, where EMI shielding and ESD protection are integrated, is a good example to illustrate the strong combination of LDS and ForTii™.

Sometimes materials are not suitable. PCBs with LEDs in automotive lighting can be replaced with a LDS solution, but LDS grades of Liquid Crystal Polymers (LCP, e.g.Vectra) are not passing reflow soldering.

Cost

The best timing for LDS design is early in the concept phase. Most optimum is a moment where redesign is done on system level but not at component level; for example, when developing new generation platforms. Then creative engineers will be able to design highly added value products. Technically, the technology has become mature. Business justification is a rather complex study. Internal lasering and plating equipment require high investments. Outsourcing is a good alternative, but also costly. However, in many situations, smart LDS designs will create sufficient added value to justify investment and manufacturing costs. Under the right conditions, the LDS solution is highly competitive and cost effective.

Conclusion

With a good component design using reliable interconnection methods, a high level of functional integration can be established with LDS technology. Designers will manage building a cost-competitive design. The base technology is proven. The trends in electronics on miniaturization and high (temperature) performance match the technology and materials developed by DSM. So the future is open: It’s up to the creative development engineers to take the next step.

Since 2010, Paul Potters has served as business development manager of Stanyl® ForTii™ at DSM Engineering Plastics. Before joining DSM, he worked for 15 years at FCI, a leading connector manufacturer. As engineering manager, he led the European product development group of the electronics division. He previously held engineering and project management positions in connector development.

Potters holds a master’s degree in mechanical engineering from the University of Eindhoven, and participated in a management program at the ESCP business school in Paris and Berlin. He holds more than 15 patents in connector designs. Contact him at Paul.Potters@DSM.com or +31651357490.

Visit DSM Engineering Plastics online: www.dsmep.com