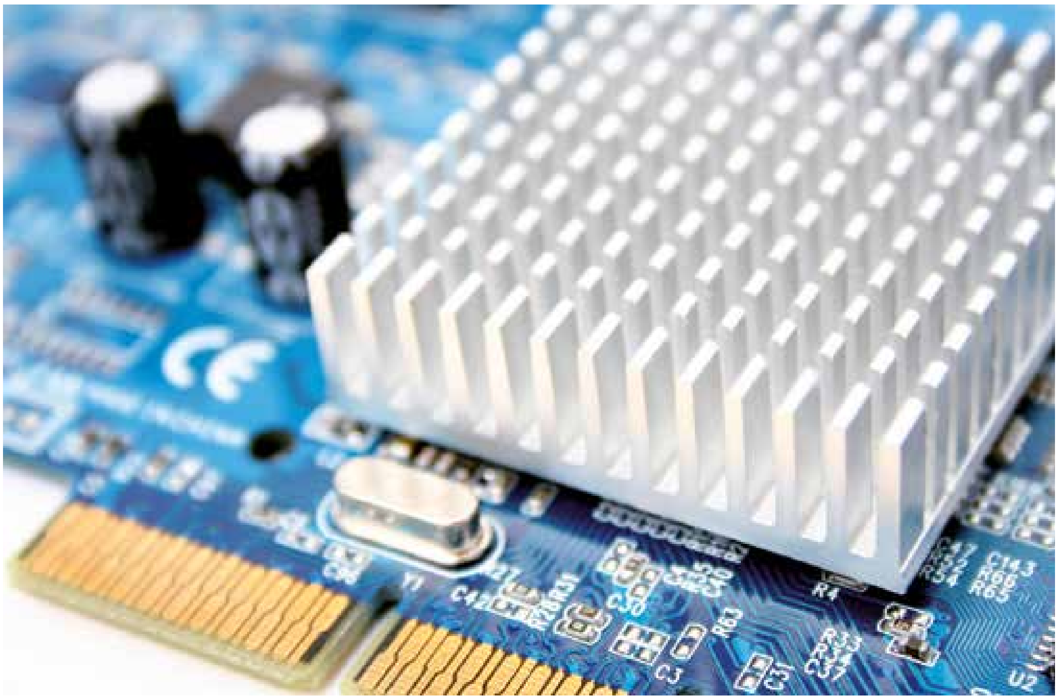

Electronic component made from thermally conducting polyphthalamide compound (figures: Ensinger)

Heat-Resistant and Heat-Conducting

Tailor-Made Compounds for 3-D Micro-Components

Polymers have now advanced to the stage that they can support the printing or etching of small conducting structures onto three-dimensional micro-components. Heat-conducting compounds based on heat-resistant polymers make suitable materials for meeting demanding challenges in this field.

Molded interconnect devices (MIDs) consist of printed conductors and electrical circuits integrated directly into three-dimensional plastic components that can be molded in virtually any shape. The housing and printed circuit board serve as the work-pieces. Companies can use MIDs to develop components that are smaller, lighter and less expensive than would be possible with conventional printed circuit boards. What is more, three-dimensional MID systems can integrate additional functions. Forschungsvereinigung 3-D MID e.V., Nuremberg, Germany, is a research association that pools the expertise of international industrial companies and research institutes and is the driving force behind the development of MID technology. Ensinger Compounds, a business division of HP Polymer GmbH, Lenzing, Austria, and a specialist in high-performance plastics has been a member of the EU-funded project "Pilot Factory for 3D MID High Precision Assemblies" (3D HiPMAS) since 2010. This research project is being coordinated by the Institute for Micro Mounting of Hahn-Schickard, Villingen-Schwenningen, Germany, which is a leading R&D service provider in the field of housing, build-up and joining technologies for micro-technical components and systems.

Research and Application

The MID production process is complex and involves several steps. It starts with the development of the base material and is followed by injection molding, metallization and assembly, before ending with quality assurance. Eight international companies and four institutes are jointly working on a project to develop a European pilot plant for 3-D micro-components by 2015. They have set themselves an ambitious goal: to slash current production costs by than 50 %.

Specifically, they are seeking to miniaturize the two-component injection molded 3-D plastic carrier to accommodate very narrow conductive paths just 150 µm wide. They are also hoping to make further advances in laser direct structuring (LDS) and new coating technologies with a view to increasing the precision of selective metallization and creating pitch widths (track width plus gap) of 150 µm in 3-D. They are also examining the scope for attaining alignment accuracy of less than 10 µm during assembly of the electronic components. Finally, the participants are working on devising a reliable online monitoring and a quality testing system. »

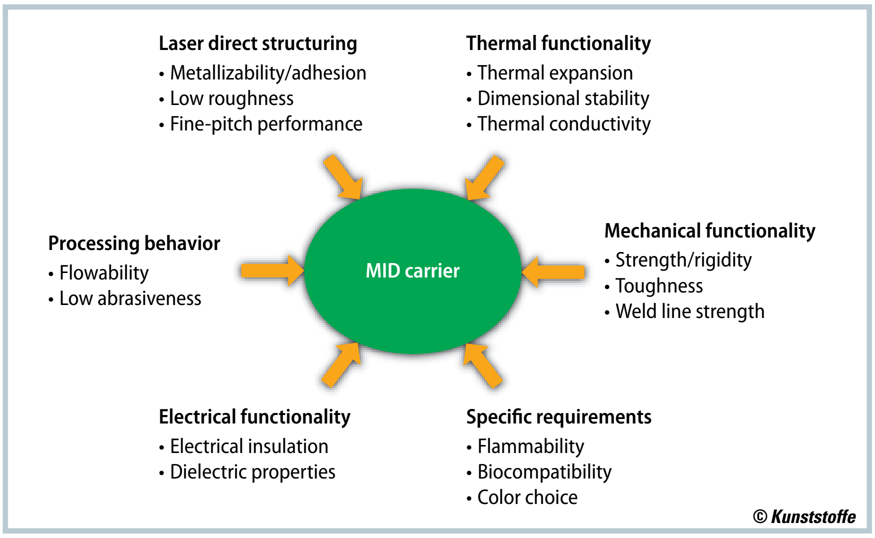

Fig. 1. Extensive requirements imposed on an MID carrier

The EU-funded project will develop and operate a pilot plant for producing four three-dimensional prototypes for the alternative energy, electrical engineering, mobility, and medical sectors. This work involves:

- Further miniaturization of a micro fuel cell and integration of an electronic function directly onto the component. Reduction in the number of parts and a further step towards mass production of "plug-and-play" fuel cells.
- An improved connector for an FM system used in a micro-hearing aid. This will lower production costs because just one MID component will replace various electronic and mechanical components.
- A micro-switch that can be manufactured and assembled more cost-effectively thanks to MID technology. The high design freedom supports a higher frequency range and a better RF performance.
- Development of a rugged pressure sensor with an integrated temperature sensor display and a smaller housing.

Focus on Laser Direct Structuring

Conductive paths are most commonly incorporated into three-dimensional MIDs by two-component injection molding, hot embossing, or laser direct structuring (LDS). LDS process lends itself to miniaturization and functional integration of plastic components and has achieved the greatest success on the market, and so the 3D-HiPMAS team has focused on it. Laser direct structuring supports the design of three-dimensional MIDs and the attainment of the narrowest conductive paths. In addition, the technology is much more flexible than that of printed circuit boards: circuit layouts can be changed relatively easily during the production process.

Laser direct structuring is performed on polymers which have been treated with additives and injection molded to form a plastic carrier. The structures of the conductive paths are written onto the polymer with a laser that follows a CAD layout. The laser energy causes a structural change in the polymer. Then, the conductive paths are applied in metallization baths and the electronic devices mounted.

Compounds that Meet High Demands

Hardly any technology imposes such diverse demands on a compound as MID. For LDS, the compound must have good heat resistance, good isotropic component behavior and especially be highly suitable for metallization (**Fig. 1**).

The task of Ensinger Compounds in the 3D-HiPMAS project is to look after the first stage, namely the development of the three-dimensional plastic carrier made from high-performance thermoplastic compounds. The company has decades of experience in the compounding of high-performance polymers and runs one of the most modern and versatile compounding operations in Europe.

Materials development is focused on narrowing the conductive path widths and improving thermal expansion and thermal conductivity. This focus limits the choice of polymers to polymers that are highly heat resistant. For its matrix polymer, Ensinger has chosen polyether ether ketone (PEEK) and liquid crystal polymer (LCP). LCP is characterized by very good dimensional stability and rigidity, even at very high temperatures. In addition, this

The Author

Matthias Wuchter, M.Sc., is head of compound development at Ensinger GmbH, Germany.

Service

Digital Version

- A PDF file of the article can be found at *www.kunststoffe-international.com/1039321*

German Version

- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de*

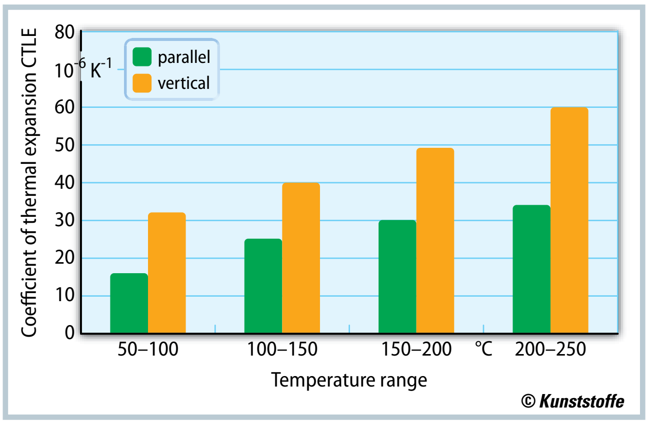

Fig. 2. The heat-conducting LCP compound has the lowest thermal expansion

high-tech polymer possesses good chemical resistance and flame retardance. Its thermal expansion is the smallest of all thermoplastics, and the extent and directionality of the thermal expansion have been reduced with fillers (**Fig. 2**).

The soldering process is one of the most challenging in 3-D micro-component production. Temperatures during reflow soldering can be has high as 260 °C. However, LCP and PEEK are equal to the task because of their high heat resistance. Ensinger conducted a battery of tests to establish the optimal compounding components. This included tailoring the type, geometry and size of fillers to the specific requirements. As a result, Ensinger was able to optimize both the thermal expansion of the material and the fine-pitch behavior as well as the adhesion of the conductive paths.

Very narrow conductive path layouts are needed for use in the miniature range. The microstructure of the polymer substrate must be prepared for precision metallization. The fillers must be chosen carefully because they have a significant impact on coating quality and the functionality of the conductive paths: current will not flow across breaks in the paths. Blurry edges give rise to arcing between the conductive paths. Both Tecacomp PEEK LDS and Tecacomp LCP LDS are optimized for extremely narrow conductive paths and can accommodate complex circuits in a small space. They have been specially modified (fillers, additives and compounding technology) to achieve closely spaced conductive paths. **Figure 3** shows how coating quality can be significantly improved by the correct choice of fillers and additives.

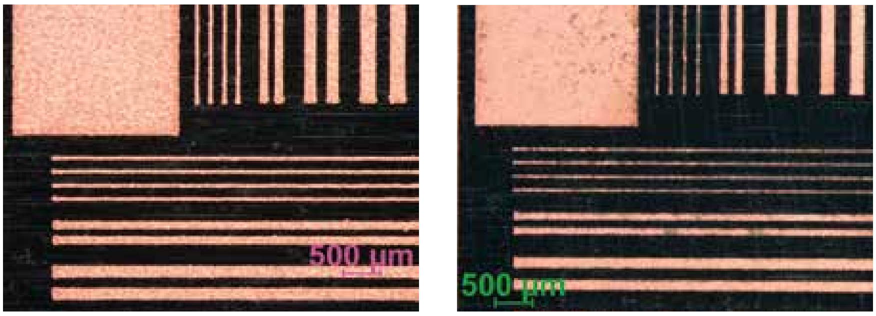

Fig. 3. Coating quality can be significantly improved by the right choice of fillers and additives: PEEK with mineral filler (left), PEEK with silicate nano-tubes (right)

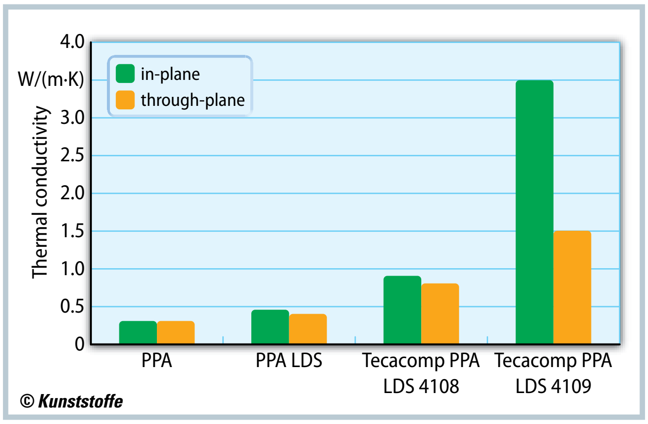

Fig. 4. Comparison of thermal conductivities of laser-structurable heat conductive PPA Compounds

Fig. 5. Three-dimensional micro-component onto which very fine interconnect structures have been applied by laser direct structuring (figure: LPKF)

Fillers Dissipate Heat

A further compound developed by Ensinger is Tecacomp PPA LDS. Based on a partially aromatic polyamide, it paves the way for further steps to integrate functions: PPA compounds treated with heat-conducting fillers dissipate heat generated in an electrical component and provide an additional cooling function. This material can also be structured by the LDS method.

Ensinger has other heat-conducting materials in its portfolio. The resultant components can be provided with electric circuits by means of other technologies. Components made from Tecacomp TC offer many advantages over metallic heat-sinks: they can be injection molded in any shape and open up new scope for designing effective cooling elements and encapsulating complete assemblies with a stable, heat-dissipating housing. A single, polymer body equipped with ceramic fillers is capable of fixing, cooling and electrically insulating several electronic components at once and of protecting them against environmental influences. Ensinger offers specific solutions, e.g. based on the polymers PP, PA, PBT and PPS, for various applications in the lighting, electrical & electronics and automotive fields. The components have a thermal conductivity of 1–20 W/m/K, the exact figure depending on the filler system, and can be imbued with further functions such as flame retardance and light resistance.

Conclusion

The current state of MID technology supports smart integration of various functions in a three-dimensional micro-component. This opens up new options in the manufacture of mechatronic assemblies. Laser direct structuring is now able to reproduce very narrow conductive path structures and to further miniaturize components (**Fig. 5**).

New Tecacomp LDS high-performance polymers modified for LDS support fine pitch structures and are even more reliable on account of their optimized thermal expansion behavior. 3-D micro-components made from compounds containing heat-conducting fillers can also take on tasks in heat management. ■