3D-HiPMAS

Pilot Factory for 3D High Precision MID Assemblies

Today's challenges

Due to the high potential of miniaturization and integration, with regard to the innovation degree, quality and sustainability requirements, the 21st century looks forward to the integration of new functions on plastic parts to produce smart plastic products, as markets are requiring traceability, security, communication as well as ergonomics.

So called "Molded Interconnected Devices" (MID) basically combine all the features of molded plastic parts with electrical conductive circuitry and electronic components assembly directly on the plastic packaging. MID lead finally to highly integrated multimaterial and multifunctional 3D compact systems.

With a 20% of growth per year since 2008, MID is tomorrow's converging technology for electronics and plastics.

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Introduction

Objectives

To achieve advanced high precision and high quality 3D micro systems, EU industry is facing the following MID bottlenecks:

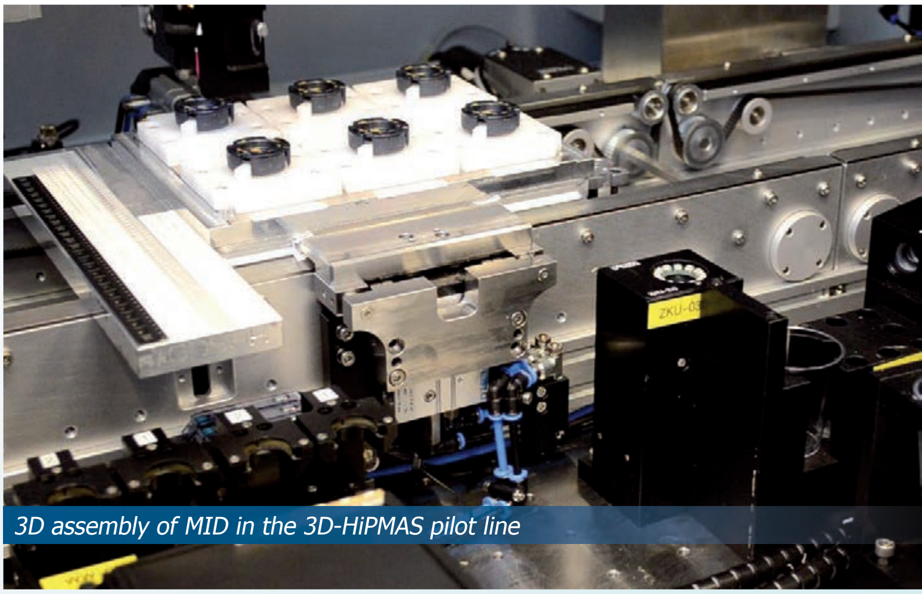
- to be able to manufacture high precision 3D micro-parts integrating plastics and electronics, including 3D plastic system carrier, 3D-conductive tracks and 3D electronics component assembly,
- to be able to significantly reduce the manufacturing cost in order for EU industry to be competitive with low-wage countries,
- to provide the industry with reliable, robust and in-line controlled manufacturing processes for plastics and electronics converging technologies.

The 3D-HiPMAS project will offer the industry a pilot factory able to provide customised solutions in terms of technical and economical performances.

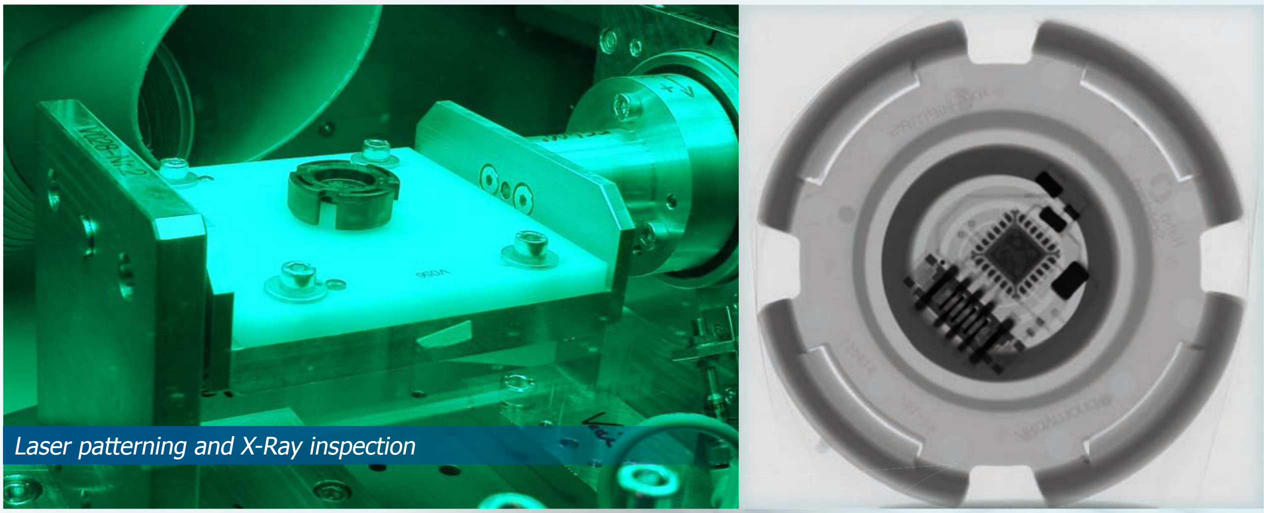
Flexible 3D high precision MID platform

In 3D-HiPMAS a 3D high precision MID R&D and manufacturing platform has been established which provides a maximum amount of flexibility to industrial customers. The 3D-HiPMAS technology focuses mainly on the building blocks "3D system carrier", "3D metal patterning" and "3D high precision assembly". All relevant process steps are available at Hahn-Schickard in Stuttgart, Germany. The customer has access to either the complete process chain or just single process steps. Therefore the 3D-HiPMAS pilot line supports small companies with no MID-manufacturing equipment at all. But it is also partner to larger companies which extend their own capabilities by one or several process steps from the pilot line. Four demonstrators developed in the project by PRAGMA, SONOVA, RADIALL and RAYCE were used to set up the pilot line processes and to demonstrate advanced 3D MID production on the pilot line.

The platform includes design, mould making, injection moulding, laser structuring, cleaning, metal plating, assembly and test combined with quality control and inspection tools. A flexible system for handling the parts allows to not only produce large quantities but also small and medium series. Within the project, the key technologies could be improved in a way that the pilot line provides leading performance in new LDS materials and processes for fine pitch MID, advanced 3D assembly and X-Ray inspection. The coordination of the pilot line also after project end is carried out by Hahn-Schickard.



3D assembly of MID in the 3D-HiPMAS pilot line



Laser patterning and X-Ray inspection

3D system carrier

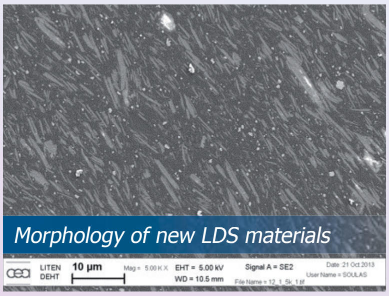
High-performance plastics for laser direct structuring (LDS)

Production of 3D micro parts by laser direct structuring requires plastic materials with well-defined material properties. To meet the thermal requirements in MID processes, high temperature polymers as PPA, LCP and PEEK are chosen. These polymers are suitable for lead-free soldering processes. By incorporation of special fillers and additives, thermal expansion of the carrier material is reduced. At the same time adhesion of metal lines after laser direct structuring is enhanced leading to higher reliability of the MID.

By development of the new thermoplastic compounds named TECACOMP® LDS (brand of Ensinger) within the 3D-HiPMAS project it is now possible to manufacture ultra-fine structured micro-parts with pitches of 70 µm and below. Fine-pitch capability was achieved by realizing a fine and homogeneous morphology in the polymer material. Edge and surface roughness was significantly reduced compared to state of the art LDS plastics.

For applications with high requirements on thermal management e.g. LED or high power electronics, special plastic materials with enhanced thermal conductivity have been developed. With thermal conductivity 5-10 times higher than conventional plastics, the new materials can play an important role in functional integration of electronic components.

Fine metal lines on TECACOMP® LDS



Morphology of new LDS materials

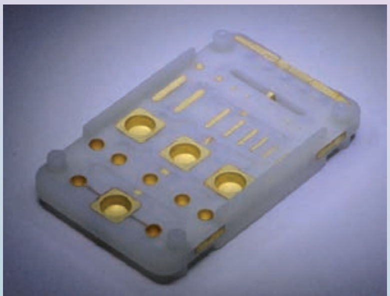
2 Shot injection moulding process for fine metal lines

Using a two-shot injection moulding process, the objective in 3D-HiPMAS project was to create MID parts with very fine dimensions conductive tracks:

- fine pitches below 0.4 mm (0.2 mm line and 0.2 mm space)
- fine vias below Ø 0.5 mm

Two-shot moulding consists in the injection of a plastic part made of 2 different polymers. A first one is plateable and the second one is not plateable and acting as a mask during the electroless metallization process of the part. The specifically designed test vehicle enables testing of a wide range of metallic shapes, e.g. lines, dots, squares, vias and connections. The design includes lines and spaces down to 0.15 mm and vias down to Ø 0.15 mm.

One of the main challenges is the selection of the good couple of materials: a non-optimized overmoulding process may lead to inacceptable distortions of the first injection moulded plastic part. Optimal results were obtained with a catalyst doped LCP and PC. Furthermore, additional processes as heat & cool technology (conformal cooling and variotherm) and vacuum in the mould cavities greatly enhance the quality of the final parts.



Test vehicle with specific design after plating (copper / nickel / gold)

Detail of the test vehicle (vias down to Ø 0.15mm, specific shapes for adhesion measurements, lines and dots with different dimensions down to Ø 0.15 mm)

3D metal patterning

Ultra-fine pitch LDS technology

An injection moulded part made of a doped plastic serves as a basis for LDS. Selected surface regions are activated by laser radiation and copper and additional metal layers (such as nickel and gold) are deposited on the activated areas by chemical metallization processes. State of the art LDS can achieve a pitch of 300 µm, i.e. line and space of 150 µm each.

In the 3D-HiPMAS project boundary conditions, technical prerequisites, and possibilities associated with the production of ultrafine conductor structures were studied. With a modified laser processing unit and tailored materials, the process can generate structures in production with a pitch smaller than 70 µm on 2D substrates and smaller than 150 µm on 3D substrates. For some substrate materials even a pitch of 50 µm is feasible.

Technological Challenges and Solutions

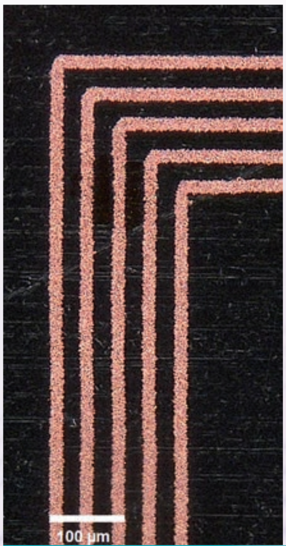
For a miniaturized high-precision MID, high-precision injection moulded blanks made out of a suitable polymer and exhibiting outstanding surface quality are required. Currently, all plastic-additive combinations have been optimized for laser activation in the near-infrared range.

The laser wavelength plays a key role, especially with respect to the focusing ability. Thus, the effect of various wavelengths on the LDS materials was investigated, and a wavelength of 532 nm was found to be suitable for the desired structure widths. For LCP, PPA, PEEK, and a few thermosetting plastics, the new LDS process is already ready for production.

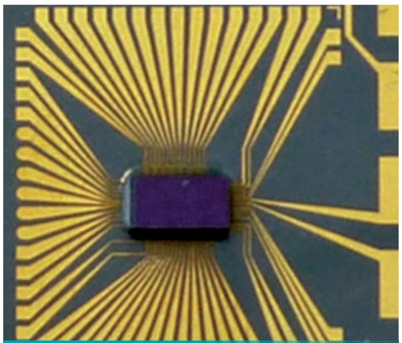
In terms of system technology, a special laser source, a new, highly dynamic scanner, and optimized optical elements deliver the required precision and performance. A camera in the beam path enables visual inspection of the structuring results during the process. The scanning field is limited to 60 x 60 mm², smaller than that of standard LDS systems.

For chemical metallization, the proven bath chemicals and processes are still useable, but a silver or palladium/gold finish is preferred over nickel/gold, to avoid line broadening of nickel plating. However, ultra-fine conductor applications present new challenges: inaccurate metallization and debris can quickly lead to short circuits. CO_2 snow jet cleaning solves this problem: it removes ablation products from the surface and reduces the surface roughness of the generated structures to produce also surfaces suitable for chip assembly.

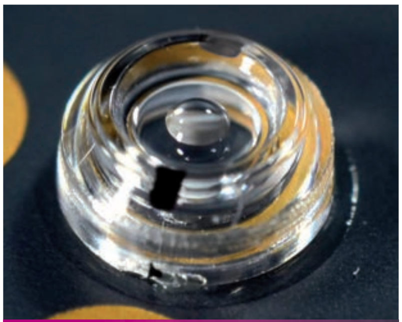
LDS machine



Ultra-fine pitch LDS



Flip chip assembly on MID substrate



Molded micro lens assembled on MID substrate

3D high precision assembling

Joining processes on advanced 3D MID system carriers

The new technology with fine pitch metal lines enables the assembly of smaller components like fine pitch bare dies and the high accuracy assembly of micromechanical and micro optical devices. Several processes have been developed at Hahn-Schickard. Flip chip assembly on MID substrates using chips with Au stud bumps with 160 µm pitch as well as using chips with Ni/Au bumps with 80 µm pitch could be successfully demonstrated.

If fine pitch SMD have to be assembled on MID substrates, processes for dispensing small depots of solder paste and accurate part handling have to be available. In 3D-HiPMAS needle dispensing of solder paste with depots < 400 µm and assembly of 0201 devices and 500 µm pitch QFN could be demonstrated. Beside oven reflow soldering also laser soldering could be applied.

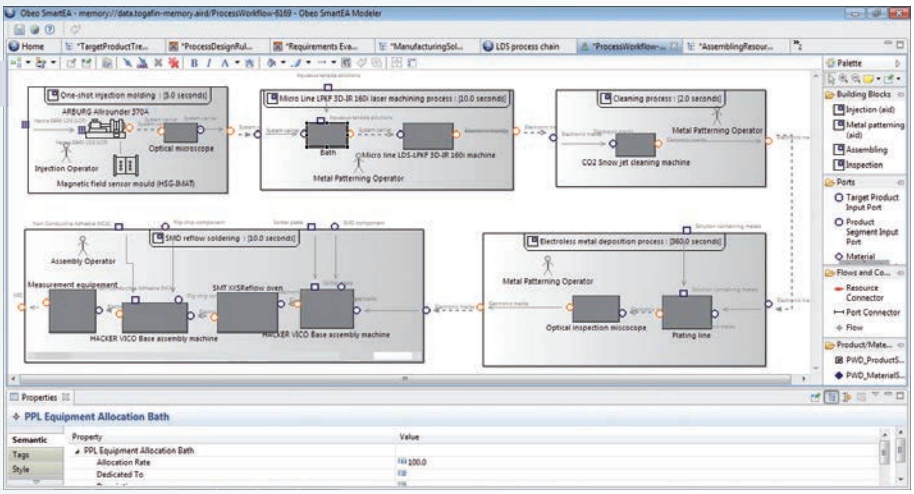
High accuracy assembly of micro optical components needs improved strategies. Therefore in 3D-HiPMAS strategies and options for improvement of camera based referencing were developed. High accuracy assembly of moulded micro lenses with deviation of 5 µm ± 3 µm could be verified on MID substrates as an example.

Online process and quality control

3D-HiPMAS workbench

The 3D-HiPMAS workbench is a web based software designed to help engineers to develop MID in a collaborative way. When a new MID is defined, the product specifications are analyzed in real time to propose the best manufacturing solutions based on user-defined knowledge bases. It is designed to facilitate the collaborations between experts using different viewpoints and advanced graphical tools like flow charts. Using the user data, the software produces early validation services (cost estimation, process advisors, validations rules, etc.) to optimize the development phase.

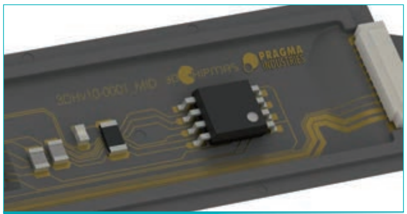
Process flow chart



Online process and product quality control

Improving the quality of MID is an economic and technological challenge for the 3D-HiPMAS pilot line. An analysis based on a Design Of Experiments was done to identify easily the most influent operating parameters for MID quality criteria. The statistical response was modeled and compared to experimental results from tests performed at Hahn-Schickard. The method can be transferred to any MID in order to develop an online process and product quality control on the pilot line.

Demonstrators



MID assembly for fuel cell

- **Fuel cell**

LDS technology offers new perspectives in electronic integration. Pragma Industries use this powerful process to push electronic functions directly into the fuel cell core for the first time on this domain.

- **Sensor devices: Capacitive pressure sensor and strain gauge**

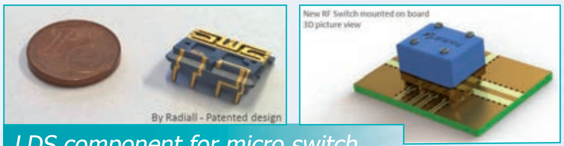
In automotive applications there is more and more demand on sensors and their integration into the connector parts. The first generation sensors are made separately and assembled to the measurement line by screwing or clipping. Thanks to MID, in collaboration with Hahn Schickard, Rayce developed a pressure sensor integrated in a fluid connector that allows better performance and cost optimization. Furthermore MID enable the realization of strain gauges directly on the polymer part for design validation and monitoring of next vehicle generation in composite.

MID based pressure sensor

Strain gauge on LDS part

- **3D Micro switch**

The new RF switch developed by Radiall team is a RF component based on MID technology. It's a power RF micro switch using SMT integration process (Surface Mounted Technology). The RF performances are extended up to 15 GHz compared to the existing product. The life cycle of the new switch is better than 2M of cycles and it will be qualified for harsh environment.

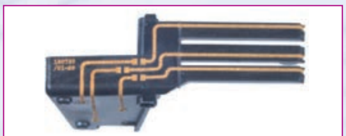


LDS component for micro switch

- **3D Micro hearing aid device**

Sonova developed an MID based connector for a miniature FM receiver to a hearing instrument and by doing so realized a highly integrated part. By developing the connector in MID technology rather than using conventional electronic interconnection technology Sonova was able to combine five individual parts (frame, three springs, flex print) into only one part thus reducing several manual assembly steps.

Concept of connector based on MID technology



3D Micro hearing aid device in LDS technology

CONSORTIUM

UNITED KINGDOM
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FRANCE
RADIALL / PEP / CEA / PRAGMA INDUSTRIES / PLASTIPOLIS / RAYCE

SWITZERLAND
SONOVA

GERMANY
HAHN-SCHICKARD / LPKF / HAECKER / ENSINGER

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