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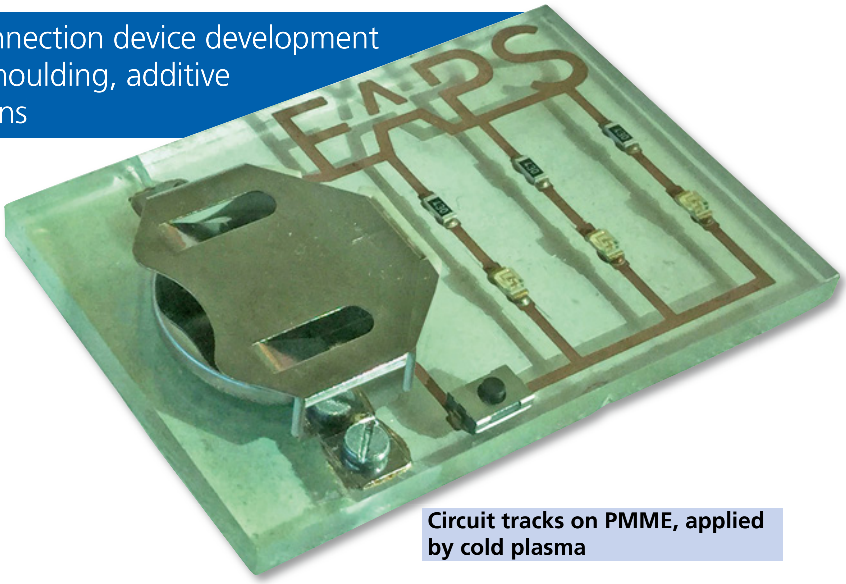
Building a future with bioplastics

Prof Jörg Franke: Increasing diversity in 3D machatronic integrated device technologies

Hanns-Peter Knaebel: The future of medical device manufacturing lies in an increased level of automation

Increasing process and materials diversity for mechatronic devices

3D moulded or other mechatronic interconnection device development continues. **David Vink** reviews, injection moulding, additive manufacturing and thermoforming solutions



Circuit tracks on PMME, applied by cold plasma

While laser direct structured (LDS) injection moulding may have been strongly represented at earlier editions of the 3D-MID Moulded Interconnection Devices Congress, at the 2018 edition last September, alternative solutions were out in full force.

The biannual congress was being organised for the 13th time by the 3D-MID research association at Erlangen-Nuremberg University FAPS factory automation and production systems institute and, as always, was run by association chairman and FAPS institute head Prof. Jörg Franke.

LDS, which a few years ago had been a 'sort of hype' according to Franke, was now shunted aside in favour of developments such as circuit track application with Aerosol Jet or Nano Jet printed nano-silver conductive pastes, a direct write method suitable for the fast and flexible production of conductive tracks; cold plasma spraying of SnAgCu alloy on e.g. injection moulded PMMA or injection moulded ceramic parts instead of plating; and the use of additive selective laser sintering (SLS) or 3D printing processes for substrate production. As Franke observed: "Mobile phones could be completely printed in future and we are working on this".

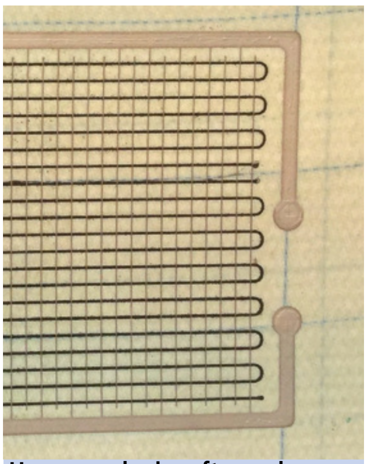
The developments have put Franke in a quandary, as the congress is still called a "moulding" event, despite the growing interest in additive processes and the fact that the tracks applied to films were not necessarily back injection moulded onto rigid plastic mouldings. He said thought should be given to a new congress name, without frightening off or alienating the moulding or additive manufacturing communities.

Prof. Jörg Franke: "Increasing diversity in 3D mechatronic integrated device technologies"

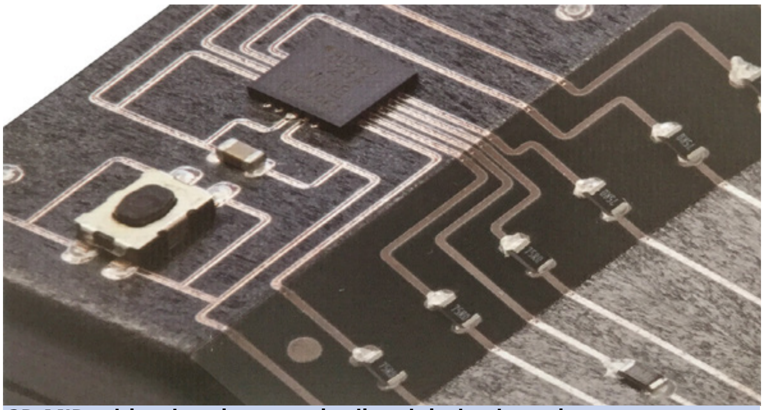
Calling MID "not a technology, but a solution", Franke noted that 3D-MID could refer equally well to 3D "mechatronic – rather than just moulded – integrated devices", and he subsequently alternated handily between the two terms. In fact, the title of his congress paper was "Generative mechatronic functionalisation of spatial devices", in which he discussed the OPTAVER project for the aerosol jet printing of optically conductive structures on MIDs. **FAPS** showed in the congress exhibition a 3D Aerosol-Jet printing with nano-silver ink of a helix antenna with a milled PVC substrate.

Neotech AMT, a Germany-based company developing systems for 3D printed electronics, displayed, among other things, nano-silver printed tracks for sensors on polycarbonate film. The company was also one of the three participants in the FeVediS project, – the other two were FAPS and the PYCO division for polymer materials and composites at Fraunhofer IAP – which aimed to develop 3D printed electronics for data and power supply on lightweight honeycomb aircraft panels. The technology used was Aerosol-jet printing.

Neotech also showed a 3D printed polylactide (PLA) heater with printed circuit tracks, developed within the €4.7m 2017-2020 Hyb-Man EU project on Hybrid 3D Manufacturing of Smart Systems. Eleven partners from the Netherlands and Germany, including Philips Lighting as project leader, Fraunhofer Institute IFAM, Henkel, Robert Bosch, Eindhoven University, TNO Applied Sciences Institute and Xenon Automatisierungs-



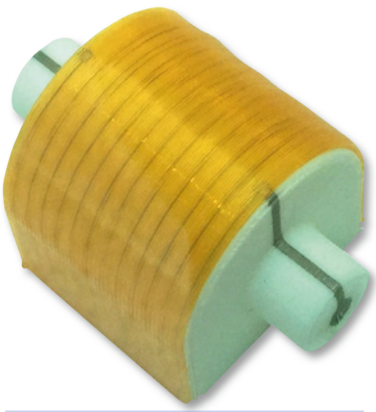
Honeycomb aircraft panel with printed circuit tracks



3D MID with printed nanoscale silver ink circuit tracks

technik, are collaborating within this project on the development of additive manufacturing methods to enable flexible, first-time-right production of smart systems for lighting and automotive applications – LED luminaries and automotive adaptive sensors.

Prof. Toshiki Niino, from the industrial science institute at **Tokio University**, talked about his team's work on LDS activation on 3D parts produced by SLS, prior to selective electroless circuit track plating.



Hyb-Man project 3D printed PLA heater with printed circuit tracks

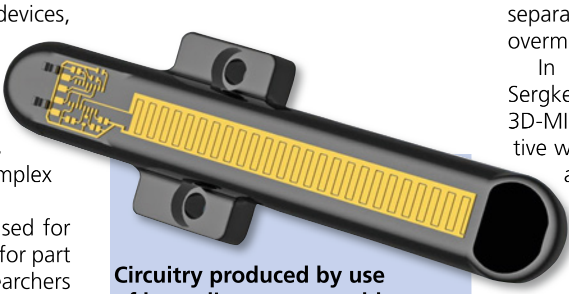
Niino favours SLS, as the technology allows high strength parts to be produced in a wide range of materials and with true three-dimensionality, as opposed to limited "2.5D" injection moulded integrated devices, or lower strength 3D printed ones with limited material choice. LDS activation during part formation on surfaces hidden from laser access in final parts enables more complex 3D-MIDs, he said.

Fibre lasers are normally used for LDS activation and CO_2 lasers for part sintering. The Tokio researchers sought to find out whether a CO_2 laser could be used for both tasks. Work was performed on a PA2 grade of PA12 from Aspect in Japan, compounded with 3wt% copper chromite (CuCr2O4) and a catalyst to provided LDS activation. While the activation was initially worse when using a fibre laser , it improved with 3wt% active carbon in the compound. The sharpness came closer with 30wt% glass fibre reinforcement in the modified PA2, although track density fell from 78% to 56%. The flow of molten plastic during activation favours high relative density, but reduces sharpness, unlike GF reinforcement, Niino revealed.

Thomas Mager of **Fraunhofer IEM** institute for mechatronic systems design talked about LDS-structurable lacquered surfaces on conventional plastics, as opposed to plastics containing an LDS activation agent. He said some plastics, such as Ultem 9035 polyetherimide (PEI) from Sabic, need treatment addressing surface energy and to level surface roughness and pores, while PA6 coats well without treatment.

Mager showed a dip pipe with an integrative capacitive sensor, produced by laser sintering PA6, and by sterolithography 3D printing (SLA) of FLGPCL03 methacrylic ester from **Material Formlabs**, with circuit tracks formed with LDS-activated lacquer use.

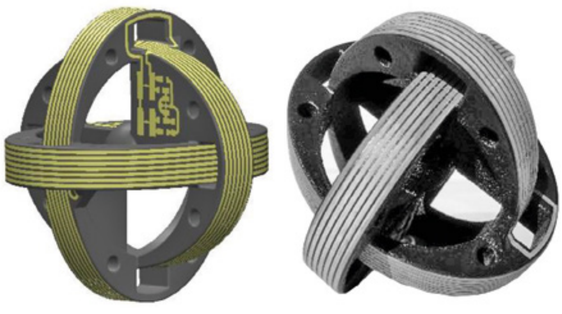
Although Mager concluded that the process additively manufactures functionalised MID components, he said topology is more limited than with conventional printed circuit boards, which can provide, in multilayer form, a number of circuit track layers with vias (through-connection paths). Despite success with LDS-structured lacquer, Mager commented that "new direct metallisable AM [additive manufacturing] materials are necessary for a more efficient manufacturing process".



Circuitry produced by use of laser direct structurable (LDS) lacquer

Antennae in automotive, mobile phone and RFID devices are still the main 3D-MID application area. However, Dr Maël Moguedet of **S2P Smart Plastic Products** in France, a spin-off with industrial shareholders from the **IPC** plastics industry technical centre, said he also saw potential in emergency services and police pagers with low frequency 3D antennae.

Moguedet described a 3-year €2.79m "Armature" project that started in June 2015 for development of housing antennae circuitry for 10,000 pagers/year, moulded in LDS-activated plastic, printed on a flexible substrate or deposited by plasma.



3D-MID circuitry for omni-directional inductive wireless power transfer

S2P's first approach was a 3D-MID laser-structured cover injection moulded in Xantar LDS 3710 (PC/ABS) from **Mitsubishi Engineering Plastics**, which was still under evaluation. Its second approach was "In-mould Electronics" (IME), in which conductive ink-based flexible circuitry, produced roll-to-roll, was thermoformed in an injection mould and overmoulded in an in-mould labelling process with the cover in Covestro Makrolon polycarbonate. Prototyping for this one-shot process was done by separate thermoforming and PC/ABS overmoulding stages.

In a separate S2P presentation, Sergkei Kamotesov talked about 3D-MIDs for omni-directional inductive wireless power transfer by using an LDS 3D-MID receiver consisting of three resonant elliptical coil inductors and circuitry for rectifiers and capacitors. It was plated to form 100µm

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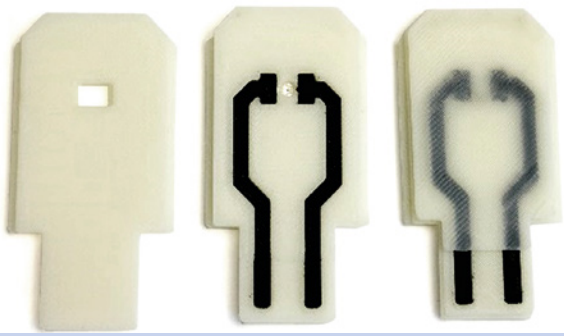
thick tracks in electroless and electroplated copper, followed by electroless tin. Kamotesov said there is potential to develop 3D-MID receivers with six inductors.

In a presentation on integration of electronic components in the thermoplastic processing chain, Manuel Morais of **Fraunhofer ICT** institute for chemical technology talked about using the APF Arburg Plastic Freefomer drop-on-demand 3D printer in a 2-component process with a combination of Terluran GP 35, an ABS from **BASF**, as a structural material, with carbon nanotube (CNT) filled PC/ABS blend as a conductive component.

Morais showed an USB LED light stick with embedding of circuitry and a LED, as well as capacitive sensors with embedded printed electrodes and printed shielding against electromagnetic and radio frequency interference (EMI/RFI) on one side.

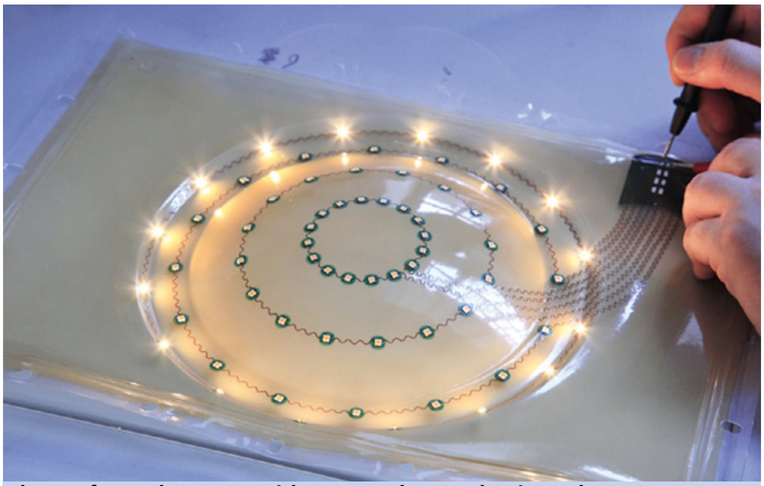


Fraunhofer ICT 3D printed light stick with embedded LED and circuitry, shown at Fakuma 2018

Aside from the aesthetic freedom and corrosive environment protection offered by the use of hidden conductive paths, Morais said this additive technique could in future enable "complete geometrical freedom in all three dimensions and be integrated with injection moulding". ICT also has injection moulding equipment, and a filament extrusion line for 1.75 mm and 2.85 mm filaments used on its fused filament fabrication (FFF) equipment.

An interesting presentation from Victor Zaderej of **Molex** in which he reviewed thirty years of MID technology, ended with a look at recent "application specific electronics packages" or ASEP as "the next generation MID".

ASEP involves insert injection moulding e.g. liquid crystal polymer (LCP) onto stamped roll-to-roll conductor strips which can handle high currents and associated high heat transfer, with support from thermally conductive plastic. Such packages integrate circuitry, connector and heat sink functions into one device, enable multilayer circuitry and involve 90% lower water consumption than with conventional printed circuit board (PCB) production.



Thermoformed 3D-MID with a TPU substrate laminated to PC or PMMA

Zaderej showed an ASEP "LIN" (local interconnect network) light module produced in automated continuous flow with 16 process steps, as opposed to 36 steps with conventional PCBs. A 200 Amp DC-to-DC converter ASEP reduced footprint 21%, weight 46% and electrical resistance 82% (for reduced heat development). An ASEP micro power distribution box reduced volume from 122.5cc to 51.5cc and weight from 64g to 50g.

Christine Kallmayer of **Fraunhofer IZM** institute for reliability and micro-integration described a manufacturing concept with stretchable circuitry using a thermoplastic polyurethane (TPU) substrate, with either meander-shaped metal conductors or printed conductive TPU conductors, laminated to rigid non-stretchable thermoplastics, e.g. PC, PMMA. High-pressure thermoforming on **Niebling** equipment then forms a 3D-MID with embedded components, e.g. LEDs.

Karolis Ratautas at the **FTMC** centre for physical sciences & technology at **Vilnius University**, Lithuania described SSAIL "selective surface activation induced by laser" that prepares surfaces of standard thermoplastics without organic-metal LDS activation agents to be electroless plated with circuit tracks, after chemical activation.

SSAIL uses a picosecond laser, as the required effect of creating oxygenated function groups, rather than just surface roughness, is not obtained with nanosecond lasers, as used in conventional LDS, Ratautas stated.

He showed equipment, material and processing costs, with lower €2/kg material cost for PC/ABS than €8/kg for PC/ABS containing LDS activation agent. This is the main reason why a Fiat 500 glove box demonstrator cost €0.93 to produce by SSAIL with Covestro T65 XF standard PC/ABS, compared with €3.25 when using PC/ABS containing LDS activation agent.

SSAIL also provides better mechanical properties, lower signal distortion and damping than compounds containing 4-8wt% of LDS metal-based additive, Ratautas added.

Yamaha SMD mounting equipment for 3D-MIDs also uses a 3D-MID

Notable among congress exhibits was part of a Yamaha S10/S20 i-Pulse surface mounted device (SMD) component mounter displayed by **ANS Answer Elektronik** on behalf of **Yamaha Motor Europe**. This mounts ("stuffs") SMDs onto both conventional flat as well as more complex 3D-MID circuitry.

The key SMD mounting heads themselves consist of an LDS 3D-MID, moulded by MID specialist Sankyo Kasei in an LDS thermoplastic for Johnan Manufacturing of Nagano, Japan. Johnan launched its 3D-MID manufacturing service in January 2018 at the Internepcon electronics production fair in Japan, claiming its system to be "the first Japanese automated pick-and-place system for 3D component mounting".