As electronic components become smaller and more complex, the challenges increase for developers of engineering thermoplastics. ***Peter Mapleston*** *finds out about new processes and offerings from materials suppliers*

Over-moulding electronics: making melts flow better

The need for efficient low-pressure encapsulation of electronics has never been as great as it is today. The Internet of Things (IoT) depends on a foundation of sensors and associated electronic connections and components to support all sorts of devices in the home, at work, and on the move. This trend has also led to increased network connectivity demands for data and power cables and connectors that function in the harshest environments. Sensors are also increasingly used in medical diagnostics and wearables. In a large number of these applications, the electronics need to be embedded in plastics to cushion them and protect them from the local environment.

The trick when trying to encapsulate electronics is to ensure that these often delicate elements are not moved or damaged as liquid polymer flows over them. It also helps if the process can be carried out quickly and economically. It's rather like squaring a circle.

But there are plenty of equipment and materials technology developers trying to make it happen. Quite a lot of the work going on is at the fringes of injection moulding, where it overlaps with other technologies such as extrusion, casting, and even additive manufacturing.

But what matters in the end is that the customer, whether they be producing cars or smart phones or robots, has a piece of electronics that works well, for a long time, often in difficult environments, at a price that they can afford.

X2F is a process developed by the company of the same name, based in Loveland, Colarado, USA, founded in 2014 by Rick Fitzpatrick (CTO) and Ron Leach (Chairman). X2F stands for Extrude to Fill. This gives an idea of how the process works, since it is not traditional injection moulding. The company says its process enables melt to move into a mould cavity without the pressures common to injection molding. But it is different from low pressure moulding, and it is not a traditional potting process either.

The company says its technology "leverages controlled viscosity and a patented 'pulse-packing' approach to create high-value components for a variety of industries." X2F says the process can achieve complex product geometries with improved operational efficiencies. Machines use a multizone screw that acts as a pump, delivering material that's been brought to its melt temperature in a static state.

According to the developers, the process "dramatically" reduces material degradation and moulded-in stress quite common in conventional moulding technologies. It is also said to offer faster development from prototyping to production-

Main image: Fraunhofer IPA demonstrator of customised sensor in which the PBT casing is 3D printed

scale, moulding of ultra-high-performance materials, and numerous operational advantages.

Initial target applications include polymer-based optics with improved properties, over-moulding of delicate electronics and circuitry, and highly filled engineering resins. Important for electronic applications, the X2F approach of using very low pressures allows for over-moulding on top of delicate circuitry without crushing circuits or melting solder.

Fitzpatrick has spent many years as an engineer in the plastics industry, including a period at Flextronics. In 2010, he set up Plasaver, to engineer and build various types of injection moulding equipment. A forerunner of X2F, Plasaver machines use a process that "allows us to more accurately set and control resin temperatures and this is done with the machine in a static state. [This] reduces the amount of force required to transfer the plastic into the injection mould and the clamp pressure required to hold the mould shut during injection. This leads to smaller machines moulding larger parts than one who is familiar with the conventional process would think possible. With an overall reduction of injection speed and forces, we are able to utilise sensor technologies to control and monitor the process in ways that conventional machines cannot. This approach makes the injection moulding process much more predictable and this leads to lower costs."

Mike Slowik is CEO at X2F. He says that whereas regular injection moulding machines operate at 150-300 MPa, X2F machines melt polymer with minimal pressure and fill mould cavities with pressures under 70 MPa – sometimes well under. This allows for the use of "minimalist" mould tooling. Typical shot weights are currently 0.1-300g and X2F owns IP on technology to increase shot size to multi-kilogramme quantities.

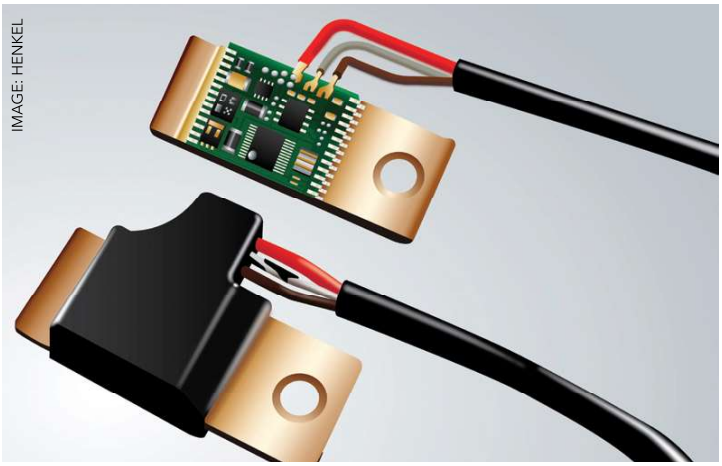
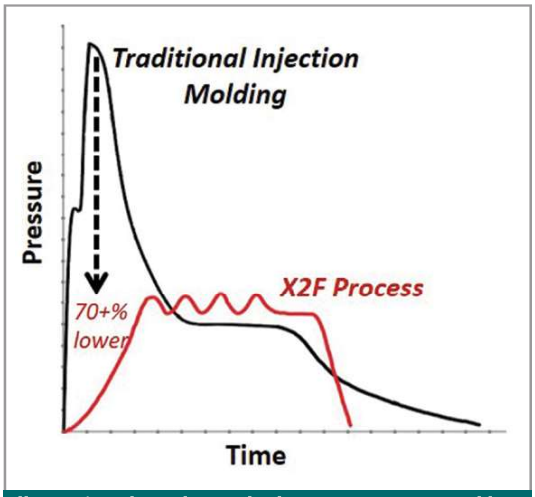


IMAGE: HENKEL

Above: Battery sensor circuit board before and after low pressure moulding process developed by Henkel. Electronic parts are protected against moisture, chemical exposure and high temperatures



Illustrative chart shows the lower pressures used by the X2F process compared with traditional injection moulding ***Source: X2F***

"We are getting good traction in the electronics market," Slowik says. He believes the technology has important advantages over other traditional encapsulation systems such as conformal coating and potting in terms of, among other things, speed, operator safety, and overall costs. Cycle times with X2F are normally under one minute. Additionally, X2F can easily process highly filled thermally conductive polymers.

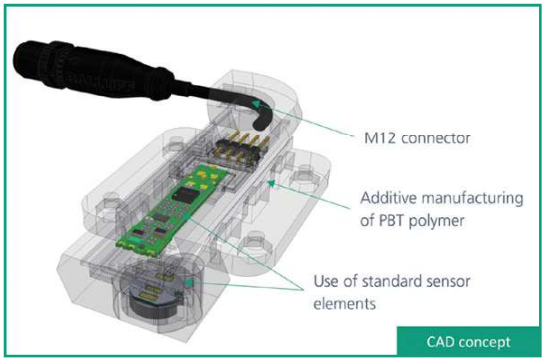
Furthermore, whereas alternative processes systems often work best with quite small parts – he cites USB drives – X2F can encapsulate complete computer boards. Also, while other LPM systems supplied by companies such as MoldMan Systems normally run with polyamide hot-melts, X2F can handle the full range of polymers aimed at E&E applications. "We are looking at applications that other LPM systems cannot handle, or are not so good at," he says.

X2F has placed systems with customers in the medical, industrial, automotive, and consumer electronics industries. Says Slowik: "We will design, prototype, pilot and produce parts in production quantities for customers or provide them our systems for production in their facilities."

The company's principal offering is the small-footprint E30V machine, with a vertical clamp system, which can be integrated into existing manufacturing cells with minimal changes to layout. "At 850 pounds [385kg], you can roll it off a pickup truck, plug it into a wall, and start making parts," says Slowik. It can be set up rather like a small vertical injection moulding system, with a turntable holding multiple lower mould halves.

X2F technology is a rival to one developed

IMAGES: FRAUNHOFER IPA



Demonstration model of customised sensor at different production stages: CAD concept (top left), after integration of the electronic components (top right) and as a finished demonstration model (bottom)

around 30 years ago by **Henkel** (when it was called Macromelt Molding), which itself is now raising the profile of its Low Pressure Molding technology for encapsulating electronic components in its Technomelt polyamide adhesive moulding compounds. Henkel says Technomelt LPM technology is increasingly being adopted for electronic components, power and industrial automation, HVAC, lighting, and also medical. It sees economic, process control, design and environmental advantages over potting with reactive resin systems and high-pressure injection moulding.

The technology is said to be particularly adept at encapsulating discrete areas in complicated assembly where wiring is attached to a PCB or other rigid component. One reason for this is that Technomelt resins, which are all unfilled, are resistant to high stresses and at the same time very flexible.

Matthew Hayward, Global Key Account for Power & Industrial Automation at Henkel, says he sees Technomelt as being particularly well suited to high-mix low-volume applications where throughput is key. "The ability to apply this material only where it is needed is a huge benefit. This enables one to 'skyline' an application (encapsulating only the components that require protection), or to significantly reduce the weight due to substantially less material usage."

Polyamide moulding compounds developed by Henkel are said to provide exceptional electrical insulation, as well as resistance to a broad range of chemicals, extreme thermal cycling across high and low temperatures, and vibrations. The internal electronics are fully protected against outside elements, including ingress of water and dust, and long-term UV exposure.

Michael Otto, Key Account Manager Engineering Adhesives for Low Pressure Molding at Henkel, says: "Unlike traditional two-component reactive potting compounds, the polyamides used in the Technomelt LPM process are single-component thermoplastics, moulding cycle times are shorter, and there are no emissions of volatiles. Whereas conventional potting can take as long as 24 hours to complete, our process has a cycle time that can be as short as 30 seconds. An additional important environmental feature of these polyamides, and one that is increasingly appreciated, is that they are largely bio-based, with up to around 80% of their content coming from renewable vegetable sources."

An advantage of LPM technologies in general over traditional potting systems is that they are much more economical in the amount of material they use in the finished part. In potting operations, the normal approach is to build a box around the component to be encapsulated, and then fill the box until the component is covered. With LPM as explained by Henkel, the component is placed into a mould that has a cavity geometry similar to that of the component, so that when the polyamide is injected, it forms a skin around the component that is more or less the same thickness at all points. This means that the amount of encapsulating material used per shot can be considerably less. The same, more or less, is true with X2F.

Costs of mould production are relatively low, especially as they are often made out of aluminium, which is much less expensive than tools made out of steel used in high-pressure injection moulding. In recent years, additive manufacturing techniques have also been adopted to make the moulds.

Henkel works in collaboration with partners manufacturing processing equipment around the world. Otto says: "Technomelt is a total system that

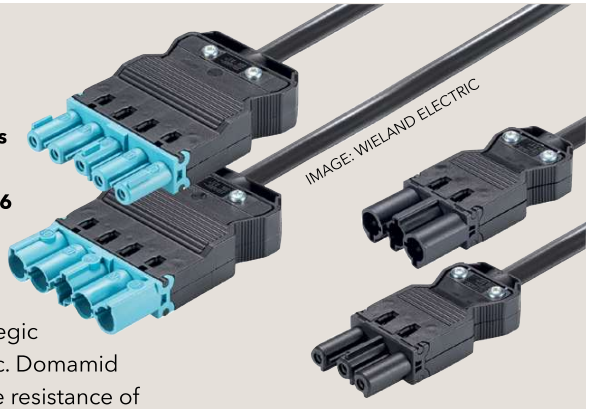
From PA6 to 66

German company Wieland Electric has **Domo Chemicals'** Domamid 6LVGT85 for its GST18i3 and GST18i5 installation connectors, which make up part of the "gesis" pluggable electrical installation system for buildings. Domamid 6LVGT85 is a low-viscosity PA6, certified V2 at 0.75mm with a UL Yellow card, matching the PA66 previously used for the housing shells, and top and bottom parts of the product.

Domo says the property profile with good flow and demoulding characteristics, as well as good particles crystallization, enables an optimised production process.

"After a short sampling phase we selected Domamid 6LVGT85, a solution that met all our mechanical and flammability specifications," says Matthias Gewecke, Strategic Buyer at Wieland Electric. Domamid 6LVGT85 has a glow wire resistance of 850°C on both test specimens and moulded parts, which were the specific values requested on the material characterisation.

"Since acquiring the Technyl brand [from Solvay] in February 2020, Domo has offered both PA6 and PA66 materials," says Andrea Rizzo, Sales Manager at Domo Engineered Materials. "Our philosophy is to provide customers with the best solutions for their applications and support them in gaining a competitive advantage in their field. In this case the PA66 substitution has provided multiple benefits as good flow and fast crystallisation have also resulted in better processability and cycle time reduction, not an easy achievement for a flame retardant solution with a glow wire resistance of 850°C down to 0.8mm."



Right: Wieland connectors make use of Domamid 6LVGT85 low viscosity PA6

brings together materials, machines, moulds, and technical service and engineering. Our partners have their own sales forces, which adds to our ability to access and assist the global market."

Bang up to date is a hybrid encapsulation system involving additive manufacturing and potting which has been the subject of a joint development involving a Fraunhofer institute and Arburg, with its Freeformer 3D printing system.

As the **Fraunhofer Institute for Manufacturing and Automation IPA** points out, 3D printing not only makes it possible to produce very complex shapes that would otherwise be virtually impossible to generate using conventional processes, but also enables small batch numbers to be produced on a cost-effective basis. But the integration of electronic components and the production of customised sensors has presented a challenge.

Standardised inductive proximity sensors in cylindrical metal casings are used in great numbers in automation technology for non-contact detection of metal objects. But the shape of the casings has prevented them from integration into specific environments such as robotic arm gripper fingers.

A research team from the Centre for Additive Production at Fraunhofer IPA asked if the sensor casing could be printed in plastic so that it could be manufactured in any shape. The answer 'yes' came back with the help of Arburg and the sensor and automation specialist Balluff.

A plastic with high dielectric strength and flame-retardant properties was required for the sensor casing. The experts opted for a PBT often used to injection mould electronic casings, but which had not yet been used for 3D printing. However, it could be used on the **Arburg** Freeformer, which works with regular granules.

The Freeformer was used to create components with cavities layer by layer, into which electronic components could be inserted during the printing process – the printer automatically stopped when coil, circuit board and plug needed to be integrated, very precisely. In a separate process, a dispenser was then used to produce the silver conductor tracks inside the casing. Finally, the cavities were then potted in polyurethane.

The team produced more than 30 demonstration models of customised sensors for testing to ensure they could withstand temperature changes and vibrations, that they were waterproof, and could pass an electrical insulation test. By optimising the design and manufacturing process, the tests were ultimately completed successfully.

The "Electronic Function Integration in Additively Manufactured Components" research project ran for eighteen months. Stefan Pfeffer, who led the project at Fraunhofer IPA, is currently working with Arburg on research into how conductive plastics can also be used in the future to tap into additional application areas.

Back in the world of regular injection moulding, polyamide and PBT thermoplastic polyester supplier **Lanxess** says it is expecting a sharp rise in demand for the flame-retardant variants of these plastics in E&E applications, due to factors such as increasing electric mobility and digitalisation in all areas of life. Lanxess has recently expanded its technical service offering in this area.

An experimental injection mould for an application-focused part was developed in one of the company's own labs. The mould reflects the typical challenges encountered during injection moulding of flame-retardant polyamide and polyester compounds.

"We want to use this mould for the realistic analysis of new flame-retardant as well as hydrolysis-stabilised materials," says Katharina Schütz, a project engineer at the polymer processing lab of the High Performance Materials (HPM) business unit. "First, our aim is to identify their special processing characteristics ahead of time so that we can adapt the formulations, where required, already during the product development stage. Second, we want to give processors of our flame-retardant plastics specific processing recommendations for serial production."

Most flame-retardant thermoplastics have a narrower processing window than standard products due to the additives that are used. If the process parameters are not chosen ideally, this can result in deposits on the mould or surface defects on the component. Non-ideal processing can also impair the mechanical properties of the compounds.

The injection mould developed by the Lanxess people is for a housing-like demonstrator part integrating numerous aspects from different areas of application. Its complex geometry exhibits sudden changes in wall thickness, openings, larger planar sections, ribs and rough imitations of plug connections. Various types of snap fits and screw bosses are also integrated.

The tests that HPM performs include drop tests, tracking resistance measurements in accordance with UL 746A (Comparative Tracking Index, CTI), and glow-wire tests in accordance with IEC 60695-2-11 to -13.

At **DuPont Mobility & Materials**, Nainish Sanghani, Global Strategic Marketing Manager, E/E, says the company may be unique in supplying E&E customers with non-halogen, flame retardant (NHFR) solutions that meet EIS (Electrical Insulation Systems) standards. DuPont tests these materials to generate data in support of various EIS standards covering Electrical Insulation Material (EIM) combinations. The company's portfolio for E&E applications is based mainly on PBT, PET and polyamides.

"We estimate that the testing we do in advance helps our customers decrease the time necessary to launch new electrical components by up to 18 months and reduces their costs. Testing costs can reach $100,000 depending on the device and where it will be sold," says Sanghani. The company reckons it has developed more than 400 solutions that meet EIS standards for moulders of E&E parts.

Nainish says there is growing interest in sustainable solutions such as the company's Zytel HTN high-temperature nylon products made with bio-based materials and protected with NHFRs. "These products are helping customers who mould, for example, SMT connector applications or USB connectors, to meet performance and safety requirements, demonstrated by UL-94VO ratings, as well as meet their increasingly tough sustainability goals." He says the company also sees demand for its bio-based products in applications such as soldering coil forms/bobbins.

Compounder **Eurotec** offers many Tecomid PA and Tecodur PBT compounds at various levels of flame behaviours, with the options that are halogen-free, halogen-free with red phosphorus content and RoHs-compliant halogenated. Several halogen-free Tecomid compounds, for example, comply with EN45454 R22 and R23, and so can be safely used in E&E parts in the railway industry.

Other grades have already been proven for fuse and distribution boxes, busbars and other electronic housing parts and come with UL Yellow Card certifications. Tecomid NB40 GR30 ORVXX HS and Tecomid NB40 GR30 ORVXX XA60 orange compounds with high thermal stability are ready

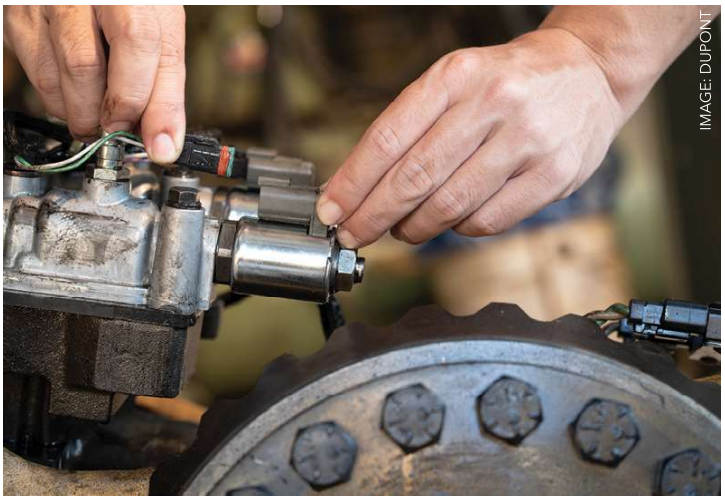


IMAGE: DUPONT

Above: DuPont says manufacturers of solenoids such as this one, part of a bulldozer transmission, benefit from its proactive materials testing to meet their end-use requirements

for use in high voltage connectors, plugs, sockets, and the like.

Eurotec says its Tecodur PBT products stand out with lower water absorption, high dimensional stability and high colour stability properties under heat. One grade, Tecodur PB70 GR30 GR105 QL, is a Yellow Card certified product that has PLC 1 tracking index and very good mechanical properties. It is used by a well-known OEM in automated switch fuses. Tecodur PB70 GR30 NL MS is a hydrolysis-stabilised grade.

Tisan Engineering Plastics compounds polyamide, PBT and polycarbonate blend materials for customers in the E&E sector. The company's Tislamid polyamide compounds are produced in standard and modified formulations for any customer's requirements. It highlights Tislamid PA6 with 20% glass fiber reinforced, heat stabilised, and improved flame retardant product (Tislamid A 20D03 F01 K02 R02) as an example of an electrical transformer application. Another example, Tislamid B 30D03 F01 Y01 R01 material, which is used in electrical switches, is a new generation of flame retardant compound based on PA66.

Tisan says PBT thermoplastic polyester has excellent electrical and mechanical properties, and resistance to chemicals and stress. For electrical wiring systems, Tisan has developed Tisester PBT 30D03 F01 K02 R01 compound which is glass fibre reinforced, heat stabilised and flame retardant.

The company says: "Tisblend compounds provide an ideal combination of strength, durability, chemical resistance, excellent impact resistance, heat resistance and visual performance by selecting material according to the relation between application, cost and performance." Tisblend HI UNR F02 R01 compounds are PC/ABS blends with improved halogen free flame retardant used for socket parts. Tisblend HF 30D03 F02 R01 is a PC/PBT blend with 30% glass fibre reinforced, heat stabilised, and improved flame retardant product which is designed for low voltage switch applications.

IMAGE: REALME

Right: Realme's phone has an extra-thin battery enclosure in a flame retardant polycarbonate copolymer compound from SABIC

The implementation of the International Electrotechnical Commission's new IEC 62368-1 safety standard for consumer electronics is prompting many manufacturers to seek higher-performing flame-retardant materials. Chinese smartphone maker Realme has selected **SABIC's** new LNP Elcres EXL7414 polycarbonate copolymer resin for the battery enclosure of its C25 phone, launched in March, to achieve UL94 V-0 FR compliance at 0.6mm, addressing the new IEC standard.

Additionally, says SABIC, the superior flame retardance of the new grade supports its potential use in ultra-thin-wall components to help save device weight and space in ever-thinner designs. It also delivers excellent flow for thin-wall moulding; ductility to resist damage from drops; and good chemical resistance to withstand ultraviolet-cured painting.

IEC 62368-1, which came into effect at the end of last year, replaces the previous IEC 60065 Audio