



3D print developments target volume markets

Large volume custom manufacturing is on the horizon for 3D printing processes and new developments in compounds are playing a major role. Mark Holmes reports

The range of compounds suitable for 3D printing – or additive manufacturing – continues to grow and formulations are increasingly being developed with specific 3D print production processes in mind. Many compound producers are collaborating with specialist suppliers of 3D printing materials and with machinery manufacturers to optimise the performance and processing of new materials. A great deal of this development work is intended to take 3D print manufacturing technologies to the next level, supporting the move from the prototyping environment through to production of one-off and customised products and, ultimately, to high volume tailored manufacturing.

LyondellBasell, for example, has recently launched Beon3D, a range of polypropylene (PP) compounds intended for production of complex,

high quality 3D printed objects in one step. The company says the Beon3D materials are intended to advance the adoption of additive manufacturing in markets such as transportation, industrial and consumer goods, building and construction.

While often associated with the production of single items, 3D print technologies are also suitable for large-scale custom manufacturing. However, the choice of polymers has been restricted due to processing challenges. PP compounds, for example, are the material of choice for many industrial-manufactured parts due to their good mechanical properties, scratch and chemical resistance, light weight, as well as resource efficiency. But the polymer is not easy to process in extrusion-based 3D print processes such as fused deposition modelling (FDM) and fused filament fabrication (FFF). ➤

Main image: 3D print compounds are increasingly being developed for volume production and specific production techniques. The latest Repsol introductions are pitched at FDM and FFF equipment



IMAGE: BRASKEM

Above:
Braskem is working with Advanced Laser Materials to develop PP powders for SLS manufacturing systems

“The key challenges in extrusion-based additive manufacturing of common PP are the typically pronounced warpage and adhesion problems of PP on common printing substrates,” says Joan Miravittles, Marketing Manager at LyondellBasell. “The Beon3D range is specifically designed for 3D printing to overcome these challenges. Therefore, we offer industrial customers solutions for the additive manufacturing of PP that enable fast, precise, and reliable manufacturing at the highest level.”

The Beon3D product family is currently focused on extrusion additive manufacturing techniques that use filament materials. “Our materials are specifically designed to be processed with all common printer systems and also to allow reliable scaling for customers,” Miravittles says.

“Extrusion-based additive manufacturing is a robust and cost-competitive technology that allows the application of various polymers, and especially polymer compounds, to produce functional multi-colour and multi-material parts in a single process step. Additionally, extrusion-based additive manufacturing is exceptionally flexible in producing customised parts over a wide size range and in any quantity. Consequently, it is complementary to conventional processing techniques and allows for a unique integrative combination for tailored mass production,” he says.

LyondellBasell claims that its Beon3D products provide fast, precise and reliable processing even at high volumes. “Beon3D products are chemical and temperature resistant and create durable, low-density parts,” says Miravittles. “It is due to our expertise in various industrial markets such as transportation, electrical and electronics, as well as building and construction, that we are able to bring the Beon3D product family to our customers providing them with innovative and efficient 3D printing solutions.”

Bright future

While the use of PP compounds in the 3D print sector is still emerging, leading additive manufacturing industry experts predict a bright future for the polymer. According to Prof Dr Rolf Muelhaupt, additive manufacturing expert at the University of Freiburg in Germany, the combination of materials such as LyondellBasell’s Beon3D PP compounds with current additive manufacturing technologies will enable new material properties previously unthinkable in the sector. “Producing sustainable finished products in one-step has become a reality through the combination of design, digitisation and manufacturing,” he says.

Spain’s **Repsol** has also expanded its range of PP compounds for 3D print applications, with two new grades formulated for production of high mechanical performance components using FFF and FDM techniques introduced this year. The compounds join the current three grades launched in 2020.

Isplen P3D820FM is a highly mineral filled medium flow PP that offers high rigidity and dimensional stability and low warpage together with good impact performance and optimal surface appearance. It is UV stabilised and is said to offer good scratch resistance, making it suitable for outdoor use. Repsol Isplen P3D630FV is a glass fibre reinforced PP indicated for applications that require very good impact resistance, high rigidity, and low deformation and shrinkage. It is also UV stabilised.

Also targeting PP but in the different area of powder-based technology, **Braskem and Advanced Laser Materials (ALM)**, a leader in materials development for additive manufacturing, have introduced a PP powder for selective laser sintering (SLS) industrial 3D printing. The two companies began their partnership in 2018, focusing specifically on the development of polyolefin-based powders for SLS. The new PP powder is the first commercial product launched under the joint collaboration.

SLS uses thermal energy from a laser to selectively sinter polymer powder layer-by-layer to produce a three-dimensional, solid geometry. It is used in industrial applications in automotive, aerospace, packaging and consumer goods. The launch of the new PP powder is said to bring a number of enhanced benefits to the SLS additive manufacturing process. These include lighter weight, moisture resistance, durable living hinge capabilities, improved recyclability, chemical resistance and enhanced processing stability, as well as an elongation at break and flexibility that is comparable to injection moulding PP grades. ➤

Right: Infinam PEEK 9359 F is a new 3D printable filament based on PEEK from Evonik

Thinking big

Bioplastics producer **Natureworks** has long held a foothold in the 3D print space, where its PLA-based Ingeo polymers have proven to run well on filament-type production systems. The latest addition to its offering is Ingeo 3D700, an amorphous grade formulated for large-format 3D print applications where the company says high rates of polymer deposition can result in excessive warpage with materials such as ABS or significant shrinkage with polyolefins or “general-purpose” PLA grades.

“As the 3D printing space expands into larger, more complex applications, we are seeing an increased need for printing materials that are tailored for a specific application or process,” says Dan Sawyer, Business Development Leader for NatureWorks. “With significant growth in large-format additive manufacturing for industrial applications, we saw the opportunity to develop a new Ingeo biopolymer grade specifically designed to minimise the loss of time and material due to failures in large format prints.”

Part warpage in large parts is typically controlled by using compounds containing mineral fillers or glass, carbon, or cellulosic fibre reinforcement, which can make processing more challenging. Natureworks says that because the Ingeo 3D700 resin has been designed for low shrinkage, it is possible to use less reinforcing content and still achieve quality large-format parts.

In trials carried out by extruder and large-format printer component maker Dyze Design, Ingeo 3D700 showed significant shrinkage and throughput improvements over Ingeo 3D850, an existing Natureworks 3D print grade. “Our tests showed

that a large-format part printed using Ingeo 3D850 demonstrated a shrink rate of 1.25%. In comparison, the same part printed with Ingeo 3D700 had a shrink rate of less than 0.25%,” said Dyze CTO Philippe Carrier. “Because Ingeo 3D700 also has a higher throughput rate, we were able to successfully print at the lower temperature of 190°C without seeing shrinkage or warping in the part.”

Natureworks says Ingeo 3D700 is available for use as pellets for direct resin-to-print processes or as filament for the FFF process in the US, Asia, and Europe.

The latest additive manufacturing development from **Evonik** is a 3D printable filament based on PEEK. This high-temperature and chemical-resistant ready-to-use material is said to be particularly well suited for additive manufacturing of demanding industrial plastic parts due to the high-performance polymer’s suitability for processing in common

extrusion-based 3D printing technologies such as fused filament fabrication (FFF) or fused deposition modelling (FDM).

Evonik has launched the new filament under the Infinam PEEK 9359 F name. The natural-coloured PEEK filament, which has a diameter of 1.75mm, is wound on 500g spools suitable for direct use in standard FFF/FDM 3D printers for PEEK materials. Its properties include high mechanical strength, hydrolysis resistance and inherent flame retardancy. The company adds that it is well suited to production of lightweight and high-performance 3D parts for the aerospace, automotive, and the oil and gas industries.

Compared to stainless steel, 3D parts made of Infinam PEEK 9359 F are said to be approximately 80% lighter and 30% tougher. They also offer very good fatigue resistance and this combination of properties makes the compound a good option for metal replacement in demanding lightweight applications. The new resin also offers good wear resistance and low sliding friction and can withstand long term exposure to temperatures of 250°C or short term exposure to temperatures of more than 300°C.



IMAGE: EVONIK

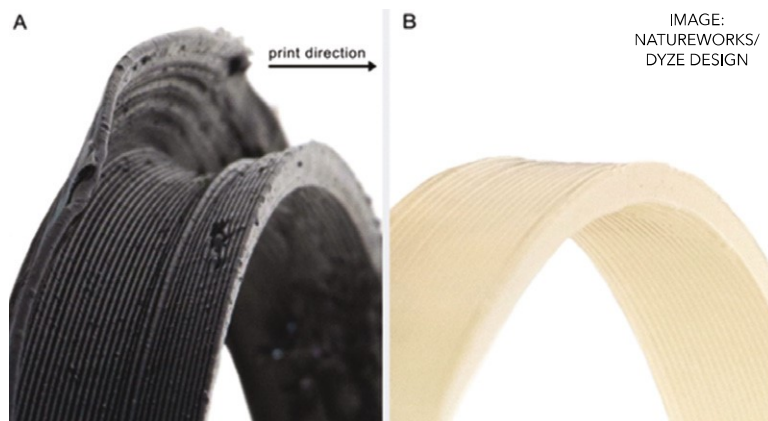


IMAGE: NATUREWORKS/ DYZE DESIGN

Images show the difference in side wall warpage in the same part produced in black PP (left) and Ingeo 3D700 (right) from Natureworks

Flexible option

Together with HP, Evonik has developed a 3D-printable thermoplastic elastomer for the latter’s Multi Jet Fusion technology. The elastomer is a flexible high-performance speciality powder based

Right: Evonik and HP have developed a 3D-printable thermoplastic elastomer for HP's Multi Jet Fusion technology

on a thermoplastic amide (TPA). The two companies have a long-standing industry partnership and this new elastomer is optimised for the Multi Jet Fusion technology.

The new TPA powder is a flexible, lightweight-construction material with a low density of 1.01 g/cm³ and a Shore A hardness of 91. The high-performance powder is intended for production of functional high-tech 3D plastic parts – prototypes as well as series products – that require high extensibility and energy return; Evonik cites sports equipment and automotive components as prime examples.

Underlining its commitment to additive manufacturing, Evonik recently opened a new technology centre for 3D printing in Austin, Texas, US. The company says the site will play a key role within its global innovation network in the development of ready-to-use materials for powder bed fusion based on the Structured Polymers technology it acquired in 2019.

The new Centre for Structured Polymers Technology comprises an application technology laboratory with 3D printers and a processing area, a research and development laboratory, production rooms and associated office areas, as well as meeting rooms.



IMAGE: EVONIK

The Structured Polymers technology is based on polymer granulate that is processed into fine powder material in various steps. Polymer powders can be produced in controlled particle sizes with a diameter range of 0.1-400 microns. The first ready-to-use powder materials

– two thermoplastic elastomers based on copolyesters – were introduced to the market in late-2019. Both products exhibit high elasticity and flexibility combined with good resilience, remain tough and flexible after printing, and are said to yield good surface quality.

In a separate move, Evonik has acquired a minority stake in Chinese company UnionTech through its Venture Capital unit. The Shanghai-based company is active in the field of stereolithography (SLS) 3D printing. In the SLS process the part is “pulled” from a bath of light-curing liquid resin with a laser or display light source curing the photopolymer layer-by-layer to create a three-dimensional product. Using this method, it is possible to produce complex workpieces with a much smoother structure than with other 3D print processes. Typical markets include automotive and aircraft manufacturers as well as industrial parts or special footwear products. ➤

Maintaining filament consistency

The Liad Smart ColorSave-Micro from **Ampacet** is a gravimetric colour and additive feeder designed to meet the needs of companies producing filaments for the 3D printing industry.

The company says filament producers face a common challenge in maintaining consistent colour quality during extrusion, which can

lead to high scrap rates or customer complaints. This can be due to use of short screws without mixing elements or not using micro pellets or quick melt colour masterbatches, but also due to inaccurate hand mixing.

According to the company, the Liad Smart ColorSave-Micro gravimetric feeder provides precise feeding of

colour masterbatches to eliminate the inaccuracies of hand-mixing resin and colour or additive masterbatches. In addition, it avoids the possibility of segregation of colour and virgin resin during the feeding process.

The feeder uses a single vibrational-protected inner channel to eliminate exterior vibration and consistently deliver an accurate dose. It operates in a continuous extrusion mode and ensures a consistent let-down ratio of the colourant relative to the extruder throughput rate.

The ColorSave-Micro can accurately dispense materials – including flowable, non-dusty powders or granules and micro pellets – at rates as low as 0.1%.

➤ www.ampacet.com

Left: The filament format is one of the most popular for 3D print materials but production raises specific challenges dosing for formulators and producers, according to Ampacet

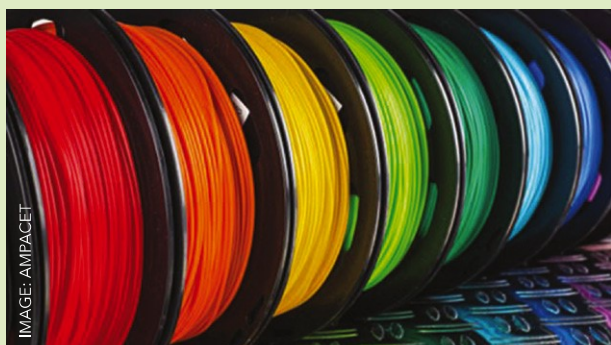


IMAGE: AMPACET

PEEK performance

Another key player in the high performance additive manufacturing sector is **Victrex**. The company says that incumbent PEEK materials used in most 3D print applications are based on grades originally designed for conventional manufacturing methods such as machining and injection moulding, while its Victrex AM 200 filament is specifically developed for this new production technology.

Victrex says that while the good mechanical properties of PAEK are in demand for high-performance 3D printed parts these could often not be realised with existing PEEK and PEKK choices. The company says repurposing injection moulding PEEK into filament fusion additive manufacturing, for example, typically results in weak parts because of poor interlayer bonding. Its new material is designed to address this weakness.

The first 3D printing equipment supplier to offer Victrex's new AM PAEK filament is China-based Intamsys. It reports that in its manufacturing equipment the Victrex AM 200 filament delivers higher Z-axis strength and has shown up to 80% strength in the X-Y direction with a better fused filament forming (FFF) printing adaptability than existing PAEK materials.

"Our test results to date have shown that the Victrex AM 200 filament has a better interlayer adhesion than other PAEK materials on Intamsys machines," says Charles Han, Founder and Chief Executive Officer of Intamsys. "Compared with unfilled PEEK, it is designed with slower crystallisa-



IMAGE: VICTREX

tion, lower melt temperature and a viscosity fine-tuned to the filament fusion process, such as easier flow in the build chamber after leaving the nozzle. Higher flow in open air (low shear rates) also promotes interlayer bonding and stability during printing. All of this contributes to an improved interlaminar adhesion, easier printing (less shrink and warp), and a better suitability for FDM 3D printing, compared to other similar options, based upon the testing we have done at Intamsys up to this point."

The Intamsys tests were performed on a number of different printers including its smart dual nozzle Funmat Pro 410 3D Printer. This industrial-grade, high-temperature 3D printer can print parts up to 305mm by 305mm by 406mm and can handle a variety of complex structures. It can print a number of materials, including PEEK, carbon fibre reinforced PEEK-CF, PEKK, PC, PC-ABS.

Intamsys is also part of Victrex's filament fusion network, which aims to facilitate the use of high-performance Victrex AM materials based on PAEK

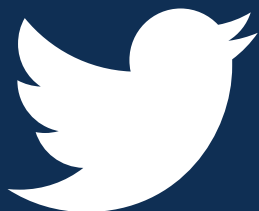
Left: An engineering component produced in Victrex AM 200 PAEK filament

Below: This shoe insole was printed by SLS using a partially bio-based thermoplastic polyurethane from Covestro



IMAGE: COVESTRO

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Emery Oleochemicals has developed binder systems for metal and ceramic 3D print part production



IMAGE: EMERY OLEOCHEMICALS

Additive manufacturing – more than just plastics

3D printing is not all about plastics. Emery Oleochemicals' Green Polymer Additives business unit has developed a binder system for 3D printing of sinterable metals and ceramics using extruded filaments and FDM machinery.

The company's technical group developed its first binder system for metal injection molding in the early 1990s. Since then, applications have developed from powder injection molding (PIM) and powder extrusion to the current stage of additive manufacturing using filaments made from sinterable feedstock. These filaments typically contain more than 80 wt% of metal or ceramic powder.

According to the company, the metal or ceramic feedstock filaments can be processed using a standard FDM printer with just a modified print head. After filament 3D printing, parts go through several post-processing steps involving solvent removal and thermal treatment steps to create finished full metal or ceramic components.

According to Emery, its binder and feedstock systems provide parts with improved part strength and lower shrinkage. The company says the same binder system can be used for both 3D print prototyping and volume powder injection moulding.

> <https://greenpolymeradditives.emeryoleo.com/3dprinting>

polymers. These materials are designed for use in applications requiring high temperature resistance and good mechanical properties. Victrex says the materials also offer good resistance to wear, fatigue and chemicals.

Sustainable ideas

The latest additions to the **Covestro** 3D print materials line up are focused on sustainability and include pellets and filaments containing recycled content, including some post-industrial waste from the company's manufacturing facilities. One of these new additions is a polycarbonate blend suitable for applications that require high temperature resistance.

Covestro is also developing partially bio-based products for 3D printing in which almost 50% of the carbon content is derived from biomass. One such material is a TPU that has already been used to print a shoe insole using selective laser sintering (SLS). Other building blocks for sustainable TPU materials include the Cardyon polyols, which are partly-derived from CO₂.

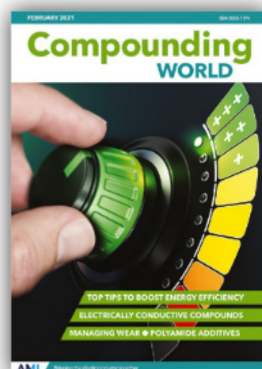
Lubrizol Corporation has introduced three Estane 3D TPU grades for fused filament fabrication (FFF) 3D printing applications for users of Ultimaker equipment. The new grades include Estane 3D TPU F94A-055 or HH PL, Estane 3DP TPU 98A and Estane 3DP TPU F70D. Ultimaker offers a material library called the Marketplace in Ultimaker Cura, which allows partner raw material suppliers to upload profiles for grades that are compatible with Ultimaker printers. Lubrizol's three latest Estane 3D TPU grades meet requirements for printing industrial jigs and fixtures, prototypes, end-use parts, and flexible parts such as orthopaedic insoles.

Three new **Kimya** ABS compounds have been qualified for the Method X 3D printer from MakerBot, which is a subsidiary of Stratasys. The new materials include Kimya ABS Kevlar for parts requiring high strength, abrasion resistance, and

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IMAGE: LEHOSS GROUP



Above: TÜV Süd has certified the combination of Luvocom 3F filament from Lehvoss Group and Ultimaker printing technology

dimensional stability; Kimya ABS-ESD, which protects against electrostatic discharges; and Kimya ABS-EC, which is electrically conductive.

Kimya says that cost savings of up to 80% have been demonstrated compared to traditional manufacturing methods by 3D printing tools and fixtures using the ABS Kevlar material in its own production facilities. With a heated build chamber that can maintain temperatures up to 110°C and that provides the ability to control the speed at which parts cool during the printing process, Method machines are claimed to be able to print high strength manufacturing-grade parts from advanced engineering materials more successfully than traditional desktop 3D printers. The company says users can also produce parts that have internal structures or complex geometries on Method machines when printing with Stratasys SR-30 soluble supports.

The new Kimya materials are designed to print on the Method X 3D printer equipped with MakerBot's new Labs Gen 2 Experimental Extruder. This is optimised to handle more abrasive third-party composites and polymers and features a number of upgraded components, including hardened gears and a metal filament switch designed to reduce wear.

Performance PA

MakerBot has also added a PA 12 carbon fibre reinforced grade to its range. The material offers very good physical and thermal properties and can be used to print metal replacement parts for some applications. It is described as a resilient carbon fibre-reinforced PA that is optimised for high strength and stiffness. Compared

Right: A bottle mould produced using the new xPEEK147-Black grade from Henkel on Nexa3D's NXE 400 machine

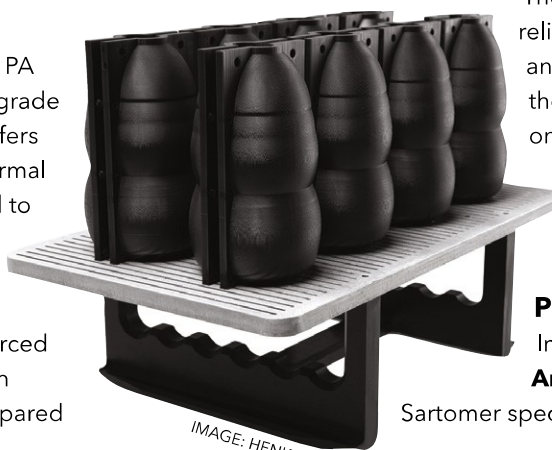


IMAGE: HENKEL

to PA6 and PA66, the PA12 base polymer offers a lower moisture absorption and, as a result, it better retains its performance in high moisture environments.

The PA12 carbon fibre grade has been formulated to process well in MakerBot's 3D print equipment. With a tensile modulus of 6000MPa, it is said to be suitable for applications that require high rigidity, such as automotive brackets or inspection gauges, functional prototypes, and lightweight parts for the aerospace, manufacturing, and automotive industries.

Commissioned by **Lehvoss Group** and Ultimaker, German testing house TÜV Süd has certified the 3D printing combination of the former's Luvocom 3F PA^{HT} 9825 NT filament and Ultimaker printer. The certification is based on TÜV Süd's Reproducible 3DP Construction process test specification, which references existing and emerging 3D printing standards.

The specification includes material property analysis and production of test specimen parts – including dimensional tolerances – as well as the manufacture of the filament. In addition, emissions are measured during the printing process. According to TÜV Süd, the combination of the LehVoss material and Ultimaker printing process meets the requirements in all respects. The Luvocom 3F PA^{HT} 9825 NT unreinforced high-performance PA and Ultimaker S5 Pro Bundle is the first FFF system to be certified by TÜV Süd.

On the basis of its current range of more than 30 FFF materials, Lehvoss Group is now supplying four materials as its own filament. Work is underway on certification of all four variants, with the focus on development, production and distribution of materials that can be marketed in filament form by established manufacturers under their own brand names.

"This is an important step for the industrialisation and scalability of FFF," says Dr Thiago Medeiros Araujo, Business Development Luvocom 3F.

"The certified system increases reliability in parts production and is intended to accelerate the use of 3D printing to put it on a par with already established production processes, such as injection moulding."

Photo finish

In the photopolymer area, **Arkema** has expanded its Sartomer specialty resins product offering

in 3D printing with the acquisition of Colorado Photopolymer Solutions. The company, which is based at Boulder, Colorado, US, specialises in photopolymer formulation for 3D printing in areas such as medical, composites, construction and consumer goods sectors.

Arkema has also strengthened its partnership with Continuous Composites, creator of the Continuous Fiber 3D Printing technology (CF3D). This US-based start-up aims to advance development of 3D composite manufacturing technologies for production of lightweight structures and offers a complete solution that includes software, hardware, material and motion platforms. Through its Sartomer Business Line, Arkema is developing a new generation of solutions for the CF3D process. Following the signing of a Joint Development Agreement in 2019, the two companies say they have hit some key milestones with the development of N3xtDimension photocurable resins for the process.

Adaptive3D is another US start-up that Arkema has invested in. The company sells photopolymer resins to enable additive manufacturing of tough, strain-tolerant, tear-resistant rubbers. Adaptive3D printable photo-resins are optimised for high-throughput manufacturing of functional complex three-dimensional plastic and rubber parts in a wide range of applications in the consumer goods, healthcare, industrial, transportation and oil and gas markets.

A collaboration between **Henkel** and Carbon aims to develop and validate the former's Loctite-branded formulations for use with Carbon's additive manufacturing process. As part of the collaboration, the newly introduced Loctite 3D IND405 Clear material is immediately available to Carbon customers.

The partnership agreement allows industrial customers to access Henkel's single-component (1K) technologies for use with the Carbon Digital Light Synthesis (Carbon DLS) 3D printing process. The Loctite 3D

IND405 Clear grade certified for Carbon printers is a clear, tough, semi-rigid, 3D printable material. The one-part liquid is said to be easily printed and is suitable for applications including enclosures and housings, light pipe prototypes, bottle prototypes, and jigs and fixtures.

Henkel is also working with Nexa3D, which makes production photopolymer-based 3D printers, and has developed three new functional polymers for durable prototype, production tooling and functional end-use parts with extended UV weathering stability. The partnership aims to move additive manufacturing towards mass production of functional parts across multiple industries using Nexa3D's NXE 400 manufacturing process.

The new photopolymer materials include xPP405-Black, which is a tough semi-rigid high-strength plastic resin providing a modulus similar to PP, 130% tensile elongation at failure and good UV weathering stability as characterised by ASTM G154 testing. xPP405-Black has an industrial black finish and is suitable for production of end-use parts such as piping, large housings and enclosures. The xPP405-Clear grade combines clarity, toughness and impact strength with a heat deflection temperature between 50-60°C. It can be finished for clarity and is suitable for production of packaging, light guides and luminaire components, and micro-fluidics.

The xPEEK147-Black grade is a tough material with good surface finish and dimensional stability and a high heat deflection temperature. It is suitable for production of tooling and functional end-use parts for automotive under-the-hood applications. xPEEK147 provides a temperature resistance of up to 230°C together with high stiffness and dimensional stability, long term thermal stability, and good solvent resistance.

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IMAGE: HENKEL

Right: Fluid ducts printed in Henkel's Loctite 3D IND405 Clear grade using the Carbon DLS process

Additional reporting by Chris Smith