MAY 2022

ISSN 2053-7174

Compounding WORLD

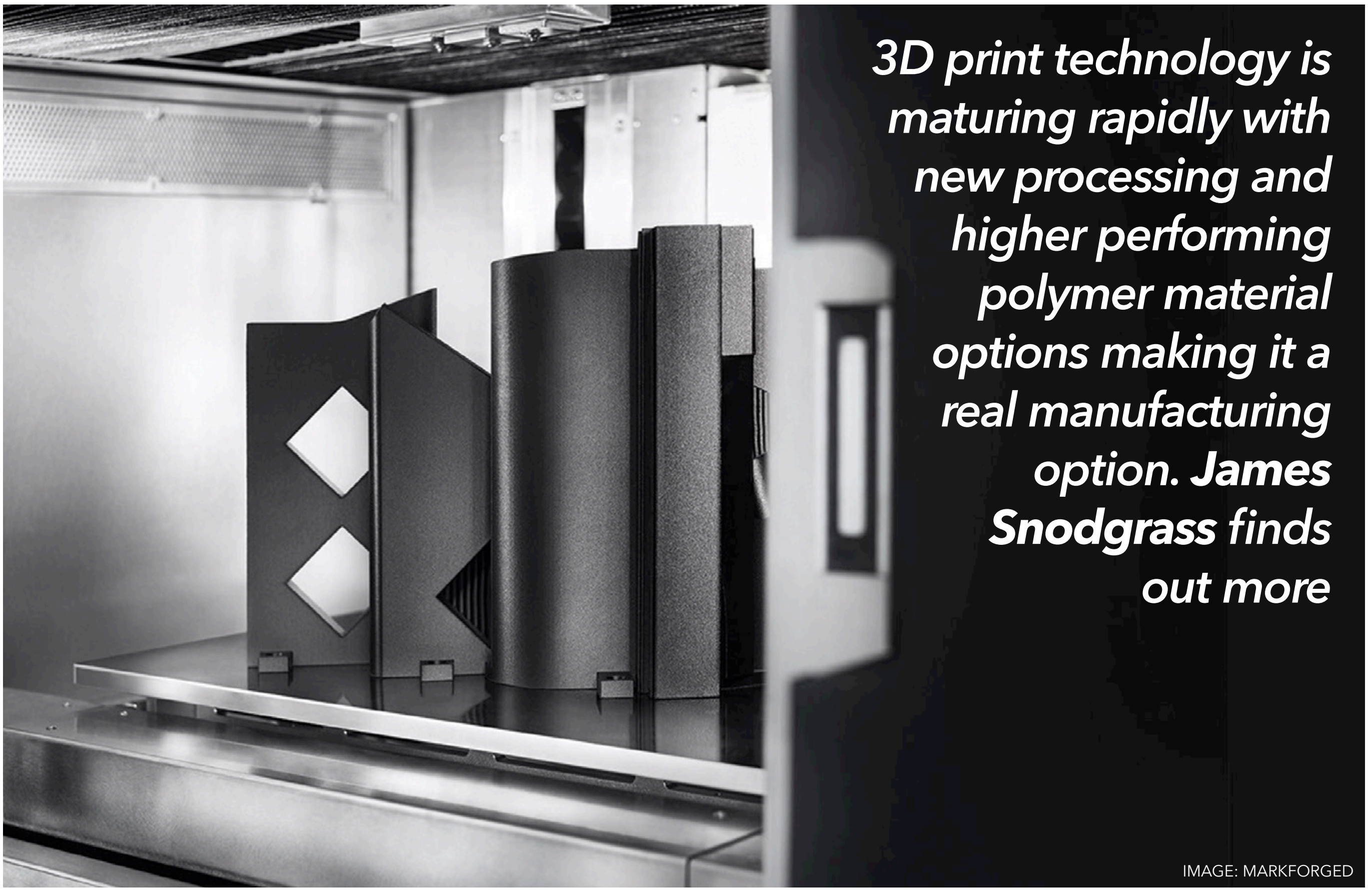
DEVELOPMENTS IN WIRE AND CABLE

USING NATURAL FIBRES AND FILLERS

COMPATIBILISERS ● 3D PRINT UPDATE

AMI Bringing the plastics industry together

3D printing toughens up



3D print technology is maturing rapidly with new processing and higher performing polymer material options making it a real manufacturing option. James Snodgrass finds out more

IMAGE: MARKFORGED

Look back just 10 years and the 3D printing landscape was very different from today. Setting aside the top end liquid stereolithography and powder-based SLS additive manufacturing systems for the moment, solid 3D print materials were principally filaments of either PLA (polylactic acid) or ABS (acrylonitrile butadiene styrene). And these filaments were largely produced by small start-ups operating to the 'homebrew' principles of the machines used to print them – typically open-source designs using stepper motors from inkjet printers and often built around a laser-cut plywood chassis.

In recent years, however, the 3D printing market has matured and most of the major polymer materials companies now supply 3D print compounds in one form or another. The technology is also pivoting away from prototyping and towards, if not mass manufacturing then, at least, medium volume manufacturing. The biggest evidence of this shift has been the emergence of print farms (equipped with hundreds or even thousands of machines in a single location working on the same parts, or several parts of a whole) and new, faster printing techniques such as SAF (more on that later).

A key area of development has been in build materials based on continuous fibre reinforcement. Belgian materials firm **Solvay** has been working with Switzerland-based advanced manufacturing solutions provider **OEM 9T Labs** to help bring additively manufactured carbon fibre-reinforced plastic (CFRP) parts to mass production. This joint effort uses 9T Labs' additive manufacturing technology to produce low-to-medium volume size parts for the aerospace, medical, luxury/leisure, automation, and oil and gas industries.

Solvay's contribution is its performance materials expertise, which includes carbon fibre-reinforced polyetheretherketone (CF/PEEK), CF-reinforced bio-based high performance polyamides, and CF-reinforced polyphenylene sulphide (CF/PPS) composites. As a result of the partnership, 9T Labs has been able to significantly expand the portfolio of neat and carbon fibre-reinforced materials it can offer to customers.

"With 9T Labs' innovative process and equip-

Main image: Markforged's FX20 is a high performance 3D print system capable of handling continuous reinforced high temperature polymers such as carbon PEI

IMAGE: MARKFORGED

Above: SABIC now offers a continuous carbon fibre PEI filament for Markforged's FX20 production system

ment and Solvay's high-performance thermoplastic materials, we are well positioned to address problems that have long plagued manufacturers in many industries trying to use advanced composites – namely high incremental costs, high scrap, and problems achieving repeatability and traceability at high volumes. We believe this collaboration will help solve many challenges and will open entirely new markets and mass production applications to CFRP materials," says Marco Apostolo, Director of Technology at Solvay.

"For the fabrication of structural parts, metals still prevail because the manufacturing of structural CFRP parts has not been cost-competitive," says Giovanni Cavolina, 9T Labs' co-founder and Chief Commercial Officer. "The Red Series platform in combination with Solvay's high-performance and recyclable materials will change this and make CFRP parts more sustainable, accessible and cost-competitive, especially at higher volumes."

9T Labs claims its hybrid manufacturing technology enables high-performance structural parts – in challenging small-to-medium size and thick sections – to be produced in carbon fibre-reinforced thermoplastic composites in production volumes ranging from 100 to 10,000 parts/year. By combining 3D printing (which offers design freedom, part complexity, and control of fibre orientation) with compression moulding in matched metal dies (providing rapid cycle times, high production rates, very good surface finishes with low voids, plus high repeatability and reproducibility) this hybrid production system offers a combination of both additive and conventional manufacturing.

Earlier this year **SABIC** introduced a 3D printing filament with continuous fibre reinforcement designed specifically to work with **Markforged**'s latest printer, the FX20. Markforged is best known for its metal and carbon fibre 3D printing product, The Digital Forge. Its new printer is designed specifically for printing with carbon fibre reinforced polymer. The FX20 can make flame-retardant, high-performance thermoplastic prints using Sabic's Ultem 9085 PEI filament in combination with Markforged's proprietary continuous fibre reinforcement technology to produce high-strength, heat resistant, and high performance parts that meet the needs of demanding industries such as aerospace, defence, automotive, and oil and gas.

The FX20 uses a heated build chamber capable of maintaining a temperature of up to 200°C temperature and has the capacity to print parts up to 525mm by 400mm by 400mm. It operates up to eight times faster than the default print settings on Markforged's existing line of composite printers and prints nearly five times larger builds than the company's next largest printer, the X7.

"Markforged continues to build on our innovative legacy and lead the way in composite 3D printing – the future of manufacturing. With the releases of the FX20 and continuous fibre reinforced Ultem 9085 filament, we're now fulfilling that promise to manufacturers who previously, in the most demanding environments, were unable to experience the benefits of the Digital Forge and our unique materials," says Shai Terem, President and CEO of Markforged.

Filament innovation

The technique most lay people associate with 3D printing today is that which builds objects using a molten, extruded polymer filament. It is a process many refer to as FDM (or fused deposition moulding) but as that name is a registered trademark of **Stratasys** it is also referred to by the generic acronym FFF (fused filament fabrication).

Brazil's **Braskem** has expanded its 3D printing product portfolio to include PE and glass fibre-reinforced PP filaments for FFF production, claiming that its products are easier to print, exhibit less warpage, display minimal shrinkage, and have better interlayer adhesion than comparable alternatives.

"Braskem continues to evolve its product portfolio for the rapidly growing 3D printing market. Braskem's polypropylene and polyethylene products have superior printing capabilities with minimum warpage and are the ideal solution for 3D printing," says Jason Vagnozzi, Braskem's Commercial Director for Additive Manufacturing. "Unlike other materials on the market, Braskem's PE is perfect for packaging and consumer applications and can be used anywhere HDPE would normally

Above: Makerbot has extended its Method qualified material list with three engineering grades from LehVoss

be used, while our new glass-fibre reinforced PP has added strength and durability which makes it a great solution for automotive, aerospace, medical, robotic, and industrial applications."

The FL500PP-GF glass fibre-reinforced PP filament is based on a co-polymer specifically developed for additive manufacturing. The formulation is designed to maximise printability, dimensional stability, and surface finish, while minimising warpage and bed adhesion issues. It is intended for automotive, aerospace, medical and robotic applications and is available in 1.75mm and 2.85mm diameters.

Glass fibre-reinforced PP filaments have a lower density than traditional FFF plastics; they are claimed to be 30% lighter than PLA and up to three times stiffer than ABS. In addition, PP filaments do not require drying before printing (unlike materials such as PA), which makes it more efficient to work with. Braskem says these properties, combined with PP's recyclability, make it an attractive material for a wide range of 3D printing applications.

PE filaments have historically been difficult to print due to warpage and shrinkage. Braskem says its 100% HDPE FL300PE filament has been specifically engineered for 3D printing applications. It offers easy printing and lightweight together with good chemical and moisture resistance. The company says it is well suited for packaging and prototyping, and for any industrial and consumer goods applications where HDPE resins are typically required.

This year, Stratasys group company **Makerbot** added three new high performance filament materials from **LehVoss Group** to its list of qualified materials for use with the LABS GEN 2 Experimental Extruder option on its Method and Method X 3D printers. The new materials include Luvocom 3F PA HT 9825 NT high-temperature reduced water uptake PA (suitable for continuous service at up to 100°C), Luvocom 3F PA HTCF 9891 BK (a carbon fibre reinforced version of the 3F PA HT 9825 NT grade offering even lower water uptake and continuous service up to 150°), and Luvocom 3F PET CF 9780 BK carbon fibre reinforced PET (offering temperature resistance up to 120°C). All are semi-crystalline materials optimised for the FFF process.

"The MakerBot Method and Method X machines offer unique heated chamber capabilities which allow semi-crystalline materials to have their full properties out of the printer, avoiding the need of post-processes," says Thiago Medeiros Araujo, Global Product Manager Luvocom 3F at LehVoss.

Powder alternative

Last year, **Stratasys** took full control of 3D print technology company Xaar 3D. The company, the 3D-printing spin-off of industrial inkjet printhead maker Xaar, was working on finessing the process of selective absorption fusion (SAF) invented by Xaar's Professor Neil Hopkinson. Stratasys had previously held a 45% stake in the company and had announced its intention to launch a family of machines using the technology. The first of these is the recently announced H350 Printer.

SAF aims to speed up 3D printing by using a powder-based technology that is more like conventional 2D printing. While there are companies using inkjet-style technology to extrude molten polymer onto a plate, SAF takes a different approach. It uses a series of printheads spanning the entire width of a bed of powdered polymer and which scan across it, depositing an "ink" that is actually an infrared sensitive liquid – a HAF (high absorbing fluid). The printhead path is followed by an infrared light and where the HAF has been deposited, the powdered polymer is fused. A new layer of powder is then added and the process repeated until the three

IMAGE: STRATASYS

Right: The Stratasys H350 is the first production system to use selective absorption fusion (SAF) powder technology

Right: IWK and Creamelt are involved in the "Closing the Loop" project to reuse ocean plastic in 3D print applications

dimensional form is complete.

Stratasys has remained tight-lipped about the compounds that will be compatible with the H-series, with no indication of their partner compounder. All a Stratasys spokesperson was prepared to say was that the launch material will be a "sustainable PA11".

Recycling ideas

Sustainability is as much a priority in the 3D print sector as it is elsewhere in the plastics industry and there is a developing interest in utilising waste streams. At this year's 24th annual SXSW Innovation Awards in the US, Israel-based **UBQ Materials** won the Speculative Design category for a waste-based 3D printing filament made from a material it simply calls "UBQ".

UBQ Materials claims to have a technology that takes household waste from landfill and transforms it into "UBQ" thermoplastic. The company divulges little about the composition of this material but its patents detail a mechanical process that is said to create a composite of non-meltable waste within a thermoplastic encapsulating matrix. It says its plant in Israel can produce 5,000 tonnes of UBQ material per year, most of which is currently used by local manufacturers.

A partnership with R&D company **Plastics App**, founded in May 2021, has led to the development of a 3D printing filament based on UBQ. The company claims its material is a "climate positive" thermoplastic that can significantly reduce the carbon footprint of additive manufacturing. "With this innovation, 3D printing may become the most environmentally conscious means of production available," says Jack "Tato" Bigio, co-CEO and co-founder of UBQ Materials.

Another initiative focused on plastics waste is Sweden's **Solaris Community**. It is targeting plastic waste in the oceans, specifically oceans in Asia, as a partner in the United Nations ESCAP (Economic and Social Commission for Asia and the Pacific) initiative, *Closing the Loop*. As part of a programme called the Ocean Plastic Project, Solaris and other social enterprises are harvesting plastic from the oceans of southeast Asia, using satellites and AI data to pinpoint areas of plastic pollution.

IMAGE: SOLARIS COMMUNITY/IWK

Below: Compounding of ocean-recovered material for 3D print filament production at IWK

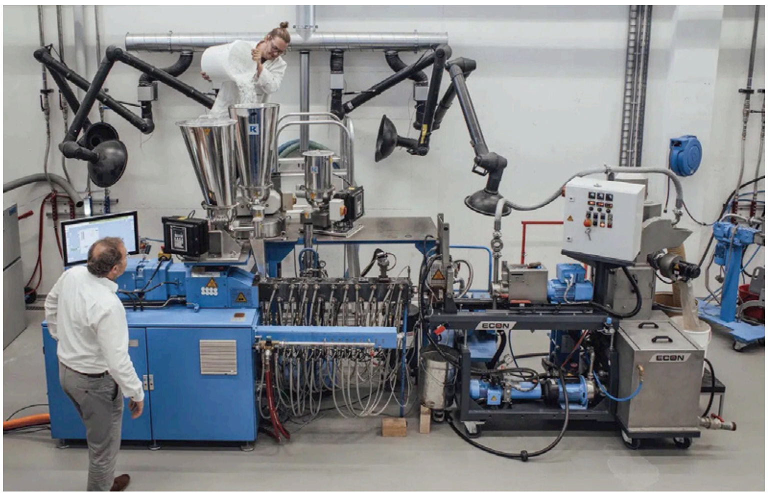


IMAGE: SOLARIS COMMUNITY/IWK

Solaris subsidiary Tide, based at Ranong in Thailand, co-ordinates the collection process and the collected waste is taken to one of five islands in the Andaman Sea where local fishermen have been employed to gather and sort it. The material is then registered, washed, and shredded in a social enterprise implemented by the Swiss non-profit Jan and Oscar Foundation and the International Union for Conservation of Nature (IUCN).

The shredded material is tested prior to compounding by project partner the Institute for Materials Technology and Plastics Processing (**IWK**) at the University of Applied Sciences in Rapperswil, Switzerland. IWK claims to have developed a means to reverse the damage caused by ultraviolet exposure and saltwater penetration. The upcycled polymer is then converted to filament and the end product sold by the Swiss 3D printing filament company **Creamelt** which, like IWK, is based in Rapperswil.

Thinking big

Large Format Additive Manufacturing (LFAM) is analogous to FFF, in principle. In scale, however, it is vastly different. Both systems extrude a molten polymer onto a print bed but while FFF extrudes from a filament in quantities measured in g/h, LFAM extrudes in kg/h. Extrusion rates of 50kg/h or higher are possible and at that ouput rate waste mounts up. Large parts that didn't quite print as expected can contain potentially hundreds of kilograms of waste polymer.

To tackle this waste, **SABIC** worked on a joint

IMAGE: 3D SYSTEMS

Right: Tooling cores produced using Accura AMX Durable materials on 3D Systems SLA equipment

study with Local Motors (the since-defunct US startup that aimed to build low-volume additive manufactured specialist vehicles) to validate the feasibility of recycling scrap thermoplastic parts and shavings from the 3D printing process.

The study aimed to explore more sustainable alternatives to landfilling for large, printed LFAM parts in anticipation of wider adoption. It included analysing the printability and mechanical properties of SABIC's LNP Thermocomp AM reinforced compound after being printed, reclaimed, ground and reprocessed into pellet form. The study determined that material from post-production parts and scrap could potentially be reused in LFAM or other processes, such as injection moulding or extrusion, at amounts up to 100%.

"As adoption of large format additive manufacturing accelerates, it is essential to find sustainable alternatives to landfilling large, printed parts," says Walter Thompson, Senior Applications Development Engineer at SABIC. "Our study showed great potential for reusing these materials and marks a first step in supporting reuse within the value chain."

There are challenges to reusing large, printed parts. No established value chain exists for reclaiming post-production LFAM parts and scrap. This complex sequence of steps includes managing the logistics of locating, collecting and transporting large parts to a facility capable of cleaning, cutting, regrinding and repurposing the material. Another challenge is the potential degradation from multiple heat cycles (grinding, re-pelletising, re-compounding). Each adds to the cumulative heat history.

The SABIC/Local Motors study included evaluations for printability, throughput and mechanical properties. Six material samples of LNP Thermocomp AM compound were prepared containing levels of reprocessed content at 0, 15, 25, 50, 75 and 100%, respectively. The samples were monitored for changes in throughput and melt flow rate on SABIC's Big Area Additive Manufacturing (BAAM) machine. Supplied by Cincinnati Incorporated – the pioneer, along with Oak Ridge National Laboratory in the US of LFAM – the BAAM machine is located in SABIC's Polymer Processing Development Center in Pittsfield, Massachusetts.

Each sample was used to print a single-wall hexagon, which is Sabic's typical test part geometry for processing and material characterisation. All printed well, with a smooth, shiny surface and straight, even layers that demonstrated no issues with material flow.

For the mechanical property evaluation, specimens were cut from each hexagonal printed part. These were tested for tensile properties using Test Method D638 and for flexural modulus using a three-point bend test following a modified ASTM D-790 test method. Results showed very good tensile properties in the part samples containing smaller percentages of regrind and only incremental declines in the samples that included larger percentages of regrind. The 100% regrind sample experienced just a 20% reduction in tensile properties in the X-axis and a 15% reduction in the Z-axis. For flexural properties, the same gradual trend occurred, with flexural modulus declining by just 14% in the X-axis and 12% in the Z-axis for the sample containing 100% regrind.

As expected by the study's participants, tensile and flexural testing showed decreasing mechanical strength as the percentage of regrind increased. This is typical of regrind used in other processes such as injection moulding and extrusion.

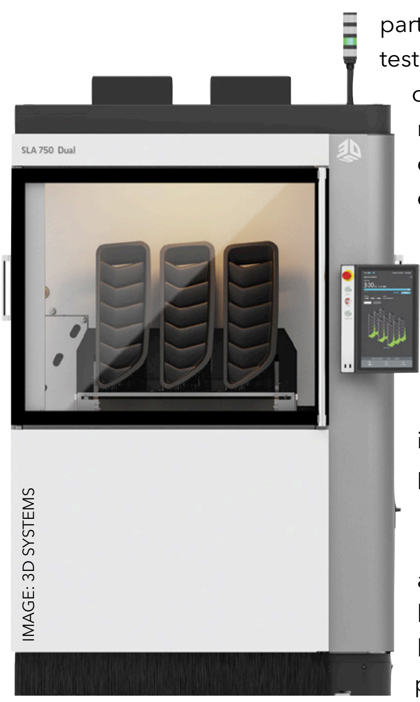


IMAGE: 3D SYSTEMS

Right: 3D Systems pioneered 3D printing; the SLA 750 Dual is one of its latest production systems

Back to the future

3D printing is considered a new technology by many but it is now 36 years since the invention of the first 3D printing process – stereolithography – and the process inventor **3D Systems** has introduced new machinery and new resins with the aim of lowering the cost of stereolithographic printing and post-processing. ›

The company's latest offering comprises three complementary technologies, its new SLA 750 and SLA 750 Dual machines (the latter being the first synchronous, dual-laser stereolithography printer) as well as the company's new Accura AMX Durable Natural material and the PostCure 1050 post-processing system. The company claims this system is optimised for cost-effective SLA batch part production at up to twice the speed and triple the throughput of comparable stereolithography systems.

Accura AMX Durable Natural resin is designed to withstand repeated high mechanical loads and shocks with a combination of mechanical properties including impact resistance, tear strength, and elongation at break. The new material is tested to ASTM D4329 and ASTM G194 standards and is claimed to meet indoor mechanical performance requirements for up to eight years and outdoor weathering for up to one and a half years. This material displays similar stress/strain toughness performance to standard thermoplastics and exhibits isotropic mechanical properties to help ensure part strength in any build orientation, according to 3D Systems.

One application that 3D Systems forsees for the new material is production of large and complex mandrel tooling cores that can be easily removed from convoluted tubing. Such components are said to be invaluable as manufacturing aids for large cooling ducts, pipes, and manifolds used in automotive, aerospace, energy, and consumer goods applications.

Additional reporting by Chris Smith

CLICK ON THE LINKS FOR MORE INFORMATION:

- **www.solvay.com**
- **www.9tlabs.com**
- **www.sabic.com**
- **www.markforged.com**
- **www.stratasys.com**
- **www.makerbot.com**
- **www.lehvoss.de**
- **www.ubqmaterials.com**
- **https://plastics-app.com/en/**
- **www.solariscommunity.com**
- **IWK**
- **www.creamelt.com**
- **www.3dsystems.com**