3dpbm | Insights

Consumer AM

From shoes to eyewear and beyond

March 2021

3dpbm

About
3dpbm is a leading media company providing insights, market analysis and B2B marketing services to the AM industry. 3dpbm publishes 3D Printing Media Network, a global editorial website that is a trusted and influential resource for professional additive manufacturing.

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Hello

Welcome to our third eBook of 2021 and our second edition exploring the world of consumer applications for additive manufacturing.

From shoes, to eyewear, to sports equipment, to jewelry: the possibilities for consumer 3D printing continue to grow, especially as high-volume technologies gain prominence and new materials hit the market. At this point in time, we are seeing a number of 3D printing companies solidify their positions in the consumer AM market, leveraging production-grade solutions and sophisticated workflows to create consumer products with efficiency and at a competitive cost. In terms of its adoption, AM is becoming increasingly popular for applications that require a high degree of customization (such as insoles and eyewear) as well as to create new, higher-performance designs (as evidenced with the adidas lattice midsoles). AM is also unlocking new opportunities in consumer segments that had previously been limited by manufacturing, such as smartglasses.

In this eBook, we delve into many corners of the consumer AM segment, spotlighting the growing influence of high-speed photopolymerization, a truly captivating chat with German manufacturer OECHSLER and 3D printing company Carbon, an enlightening Q&A with lens 3D printing specialist Luxexcel about smart eyewear and a detailed map of consumer AM players.

Tess Boissonneault
Editor in Chief, 3dpbm

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ANALYSIS

The high-speed photopolymerization race for production 3D printing is on

A tangible trend taking hold around the world

Image: LuxCreo

In early 2021, Stratasys bought Origin, and Desktop Metal bought EnvisionTEC. These acquisitions were not casual: they were strategic decisions made by companies that, for different reasons, had some cash to bet on the next 3D printing growth area and decided to go for high-speed photopolymerization technology. EnvisionTEC's founder Al Siblani invented and patented the technology for high-speed, continuous DLP but never thought much of its potential; Origin's Programmable Photopolymerization (P^3) is one of the technologies that went after the potential of these processes for digital mass production through durable photopolymerizable materials.

They are not alone in this race. The trailblazer is Carbon, a company that, through the vision of its founders, single-handedly created this AM hardware segment and then went on to demonstrate that million-part applications were not only possible but also made economic sense. Carbon's Digital Light Synthesis (DLS) technology is now used by adidas to produce millions of serially manufactured, generatively designed midsoles for the Futurecraft brand. It is used by Ford as well as by Lamborghini for final automotive parts and components. And it's breaking through the dental segment as well. The Carbon DLS process uses digital light projection, oxygen-permeable optics and programmable liquid resins to rapidly-produce durable parts with strong mechanical properties, resolution and surface finish. Before Carbon, speed was never a real issue for DLP technology since the photopolymer resins used were not durable enough to make final products. Carbon's co-founder Joe DeSimone had the intuition of mixing durable thermosets, such as polyurethane, with enough photopolymerizable material to enable the curing, additive reaction. At this point, and with these materials, it started to make sense to go faster. Carbon did, building up a significant lead on all competitors.

Back to the industry

Carbon's technology, however, is not that revolutionary. The real revolution is in the materials. In fact—and as mentioned—EnvisionTEC's Al Siblani was the first to patent it. However, EnvisionTEC's products cater to a somewhat restricted group of very high-end adopters who, for various reasons, need resolution and precision more than speed and durability. This meant EnvisionTEC resisted marketing this technology until Carbon came out with its products and showed that there was a large potential market for series production. EnvisionTEC then released the cDLM series of high-speed photopolymerization printers but never fully believed in pushing them into large-scale production segments. Now that EnvisionTEC has been acquired by Desktop Metal, a company that made digital serial and mass production (of metal parts) its battlecry, all this may change.

Image: 3D Systems

Perhaps one of the most innovative, alternative high-speed photopolymerization technologies comes from a company that was built upon—and in fact invented—SLA photopolymerization: 3D Systems. The high-speed photopolymerization technology in 3D Systems' Figure 4 systems combines speed and accuracy through UV and heat-based curing processes. According to 3D Systems, this yields the world's fastest additive manufacturing throughput and time-to-part. Recent data highlights Figure 4 production print speeds of up to 65 mm/hour, and prototyping speeds of up to 100 mm/hour, and part accuracy and Six Sigma repeatability

> “Figure 4 materials address applications in functional prototyping, direct production of end-use parts, molding and casting“

(Cpk >2) across all materials. The range of Figure 4 materials addresses a wide variety of applications needed for functional prototyping, direct production of end-use parts, molding and casting. They are durable and can display thermoplastic-like behaviors, as well as rubber-like, castable, heat resistant and biocompatible properties. However, they are not final thermoset materials like Carbon’s.

The West Coast hub

A lot of other companies have also presented their own versions of high-speed photopolymerization. The most talked about lately is Origin, which was acquired by Stratasys in an effort by the additive industry market leader to capitalize on the expected photopolymer production 3D printing craze. The San Francisco startup (Silicon Valley is the main hub for high-speed photopolymerization, probably due in part to Google’s early investment in Carbon, also based in Silicon Valley) created its Programmable Photopolymerization (P^3) technology specifically for high throughput, repeatability and straight-up on-demand production. Their production idea is based on small footprint modular printers that maximize production capacity per available surface.

Also in California is Nexa3D, a company promoted by former 3D Systems CEO and AM industry pioneer Avi Reichental, through his XponentialWorks venture investment, corporate advisory and product development company. Reichental is the co-founder, chairman and CEO of the company founded in 2016 together with Andrea Denaro, Gianni Zitelli and Luciano Tringali.

Today, Nexa3D is emerging as a leading manufacturer of high-speed photopolymerization 3D printers, thanks to its proprietary Lubricant Sublayer Photo-curing (LSPc) technology and patented structured light matrix. This process reduces 3D printing cycles from hours to minutes while maintaining a high level of quality and precision. Nexa3D’s NXV printer reaches a record speed of up to 1 centimeter per minute.

Also on the West Coast, just a few miles north, Vancouver-based NewPro developed the NP1 high-speed photopolymerization 3D printer leveraging Intelligent Liquid Interface (ILI) technology. This process is based on a transparent wettable membrane between the photo-curing resin and the light source. The membrane is chemically designed to enable faster movement between cured layers. This eliminates the mechanical processes used on conventional 3D printing techniques allowing to grow objects at high speed. The ILI process can be used with a wide variety of materials for several

Image: NewPro 3D

In early 2021, Stratasys acquired Origin, whose Programmable Photopolymerization technology is intended for digital mass production.
Image: Origin | Stratasys

applications, however the company is currently focusing primarily on the medical segment, collaborating with universities and hospitals, where the accelerated rate of additive manufacturing contributes to better communication and procedures in radiology and dental departments.

A high-speed photopolymerization bridge to Asia

With headquarters in the San Francisco Bay Area and in Beijing, LuxCreo is another high-speed photopolymerization company targeting smart factory additive production capabilities and Digital 3D Production Lines to bring new ideas to market faster. LuxCreo’s Digital 3D Production relies on the company’s LUX3 ultra-fast 3D printers, which leverage the company’s LEAP (Light Enabled Additive Production) high-speed DLP technology, as well as on materials and software to provide a connected, agile and scalable 3D printing production network. With Digital 3D Production, LuxCreo’s clients can gain instant access to Smart Factory 3D printing production scale.

Acting as a high-speed photopolymerization bridge between America and Asia, LuxCreo brings us to two other Asian companies that have developed high-speed photopolymerization systems to work with durable materials. Korean company Carima was actually one of the very first to do so, launching 3D printers

based on proprietary C-CAT (Carima-Continuous Additive Technology) in 2015. The New C-CAT released in 2020 has been improved and developed to print faster and with more accurate continuous layers.

Addressing the issue of using an oxygen layer to release force, which causes the layer to become thinner or disappear due to the inflow of resin, the new C-CAT approach improved the disjunctive surface technology so that it can be less than 1/100th lower than the existing film and thus minimize dissipation. Carima also increased the option to choose output layer thickness. Due to its weak release force, continuous molding is possible during printing, allowing to print output up to 60 cm per hour. Supported industrial materials include Tough BLK and Rigid BLK, as well as third-party photopolymers.

Backed by Taiwan's New Kinpo Group, XYZprinting has been democratizing 3D printing for nearly a decade. The company's latest high-speed photopolymerization 3D printers can use both DLP and SLA processes. Based on UFF Technology (Ultra-Fast Film), the systems can boost the printing speed by replacing Teflon film with Ultra-Fast Film. It works by reducing the separation force and allows the build platform to move quickly, similarly to the oxygen layer in other layerless photopolymerization processes. UFF brings not only speed but also smooth part finishes through quick and precise layer release from the film.

As each of these companies advances its own technology and materials, photopolymerization 3D printing keeps evolving. We can't wait to see what's on the horizon. ◆

Nexa3D's high-speed photopolymerization 3D printers are based on its proprietary Lubricant Sublayer Photo-curing technology.
Image: Nexa3D

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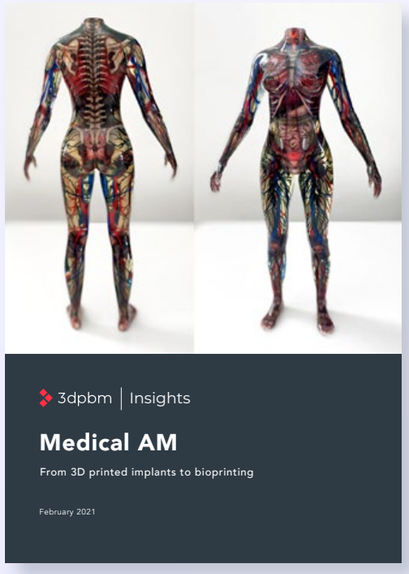

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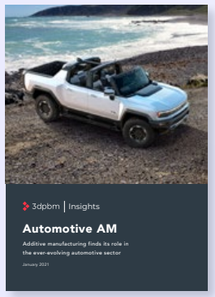

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INTERVIEW

OECHSLER and Carbon, a powerhouse team in polymer 3D printing

How the companies are achieving production rates of over a million 3D printed parts a year

Founded in 1864, Germany-based OECHSLER has well over a century of experience in the production of plastic parts and products. This long-running practice has provided a strong foundation for the company's current offering, which consists of one of the most robust polymer 3D printing production chains in existence.

Eager to find out more about how OECHSLER got to this point—and how its journey with 3D printing has evolved—we spoke to Markus Bischoff, OECHSLER AG's Vice President of Sales, Sporting Goods and Additive Manufacturing. We also had the opportunity to hear from Joe Batdorf, Director of DLS Production at Carbon, the company that has been pivotal to OECHSLER's AM pursuits.

A brief introduction

OECHSLER was founded by Mattias Oechsler in Ansbach, Middle Franconia, and was initially focused on the production of buttons. Over the years, it grew from these more humble roots to become one of the world's leading plastic technology companies, providing parts and end-to-end services to customers across many sectors, including automotive, sporting & consumer, medical and industrial. The company today operates six production facilities (in Germany, China, Romania, Mexico and Vietnam) and employs roughly 3,000 people globally.

Though the bulk of OECHSLER's production over the decades has relied on injection molding processes, additive manufacturing has become something of a game-changer in recent years. "As a plastics processing company, we have been involved with the topic of 3D printing since an early stage," Bischoff explains. "It started more than 15 years ago, but for a long time it was limited to rapid tooling and rapid prototyping."
In 2016, however, OECHSLER partnered with a company that would change its perspective on 3D printing and its ambitions surrounding the technology. "Carbon was introduced to OECHSLER by a global sporting goods OEM and we made the decision to collaborate with the scale-up of a high-volume manufacturing project," Batdorf reveals. "Over time, Carbon transferred DLS manufacturing technology to OECHSLER, and we've worked together to industrialize the manufacturing process."

An AM power couple

The Carbon Digital Light Synthesis™ (Carbon DLS™) process proved to be something of a turning point for OECHSLER, marking the first time the company truly saw serial production potential for polymer AM. Bischoff elaborates: "On a technological level, OECHSLER is a series/mass producer, so we always analyze the scalability of technologies. Once we understood the mass production potential of Carbon's DLS technology in 2016/17, we started to invest time, effort and resources. Fortunately, our efforts at that time were accompanied by a promising customer project."

Carbon's DLS technology fits the bill for production for a number of reasons. As Batdorf explains: "The DLS process allows engineers and designers to iterate faster, deliver projects with less risk and radically reimagine their products by introducing consolidated parts, impossible geometries and programmable lattices. The technology produces consistent and predictable isotropic mechanical properties, creating parts that are solid on the inside like injection molded parts. In addition, Carbon technology produces fully dense parts."

"All these factors have been integral preconditions for mass production," adds Bischoff. "Additionally, the process is super competitive in terms of printing speed and product quality." The combination of Carbon's technology and OECHSLER's manufacturing experience proved to be powerful, and the companies successfully built a robust and scalable solution for series production. "Achieving this was only

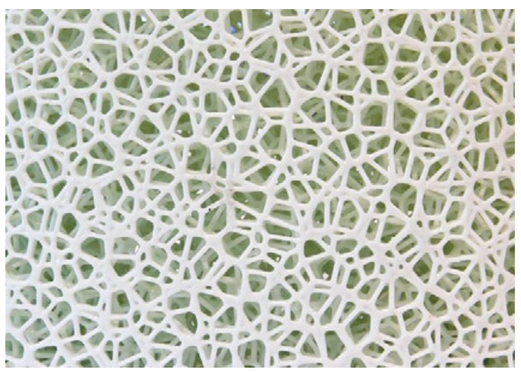
Image: OECHSLER AG

> “To scale from 100 to 100,000 is the challenge; scaling from 100,000 to 1 million is business as usual for OECHSLER nowadays”

possible by building mutual trust and sharing know-how,” Bischoff continues. “Carbon and OECHSLER employees worked together in inter-company teams to pursue one key goal: the realization of one of the largest series productions in polymer-based additive manufacturing.”

Today, OECHSLER runs over 150 3D printers globally and has continuously produced over 1 million 3D printed components a year since 2019. “OECHSLER fundamentally understands additive manufacturing as a series production process,” Bischoff says. “This means that we are currently in a position to offer our customers all services along the entire value chain, from product idea, product, process and material development to global series production.”

Image: Carbon, Inc.



The challenges of series production

Of course, it was no walk in the park to attain this level of series production. Both Carbon and OECHSLER worked tirelessly to validate and optimize the production process so that millions of parts were viable. “The main challenge was to scale and stabilize the production process,” Bischoff notes. “While before the process was designed for the production of several hundred parts, it had to be rethought to achieve the production of millions.

“The actual printing process accounts for around 50% of the production chain. This meant we had to redesign the pre-and especially post processes. As OECHSLER has deep knowledge in setting up and scaling productions and Carbon has a deep knowledge of their technology and process, we benefited a lot from the collaboration and synergies. Ultimately, the main challenge was to transition from a ‘proof-of-concept’ to serial production. To scale from 100 to 100,000 is the challenge; scaling from 100,000 to 1 million is business as usual for OECHSLER nowadays.”

The bulk of this groundwork was undertaken at OECHSLER’s German facilities, where teams specialize in process development. Once the workflow was established and stable there, it was implemented in the Chinese factory in Taicang on an even larger scale. Today, OECHSLER runs three AM sites in Germany and China. “Our mass production facilities have been

OECHSLER operates six production facilities around the globe, in Germany, China, Romania, Mexico and Vietnam, and employs roughly 3,000 people.
Image: OECHSLER AG

completely redesigned and adapted to the needs of additive manufacturing,” Bischoff adds. “Honestly, you might think you’re in outer space when you walk through the production rooms, as we use state-of-the-art technologies.”

From your head to your toes

In terms of its output, OECHSLER has a diverse portfolio and has become a key production partner to Carbon in Europe and China. As mentioned, the company supplies 3D printed parts to a global sporting goods OEM, but it also serves customers in the automotive, medical, industrial and sporting sectors. “In each of these markets, we have identified and are realizing serial projects,” Bischoff tells us. “One of the most recent product lines is the American football helmets we produced for Riddell.” (Most of our readers will be familiar with this project, which was unveiled by Carbon in late 2019 alongside the launch of its L1 3D printer.)

Having such a broad manufacturing capacity—spanning not only 3D printing but also injection molding—means that OECHSLER has the opportunity to find products that would be best suited for additive manufacturing. In other words, it knows where the technology has the biggest benefits and potential.

"The DLS process allows engineers and designers to iterate faster, deliver projects with less risk and radically reimagine their products by introducing consolidated parts, impossible geometries and programmable lattices. The technology produces consistent and predictable isotropic mechanical properties, creating parts that are solid on the inside like injection molded parts."

Joe Batdorf
Director of DLS Production at Carbon.

Image: OECHSLER AG

"Products with a high number of variants, but also those with a specific design only achievable with 3D printing, benefit most from the technology," Bischoff notes. "We also see that a combination of injection molding with AM provides huge potential. You can use IM for standard parts and AM for complex, individualized parts."

Batdorf adds: "Both Carbon and OECHSLER's business development teams are engaged with many different OEMs at the moment, developing applications to scale up into production. Carbon and OECHSLER plan to capitalize on our experience gained over the last few years and commence the production of more exciting new products for our customers. We've demonstrated that we can quickly scale up manufacturing capacity when needed and we look forward to the continued expansion of DLS manufacturing capacity and capabilities."

A big part of why the partners are well equipped to handle such a broad variety of applications is Carbon's material portfolio. With material options that include rigid polyurethane, flexible polyurethane, elastomeric polyurethane, medical-grade polyurethane, epoxy, cyanate ester and silicone, Carbon and OECHSLER can meet the needs of many customers—both for prototyping and end-use applications. Since 2019, OECHSLER has reportedly consumed more than 500,000 liters of Carbon resins per year.

For your serial production needs

Ultimately, the collaboration between OECHSLER and Carbon has not only been a mutually beneficial one: customers from across many industries can take advantage of the production framework the companies have built. And thanks to the easily scalable nature of the Carbon DLS production line and OECHSLER's steady infrastructure, they are always on the lookout for new partners.

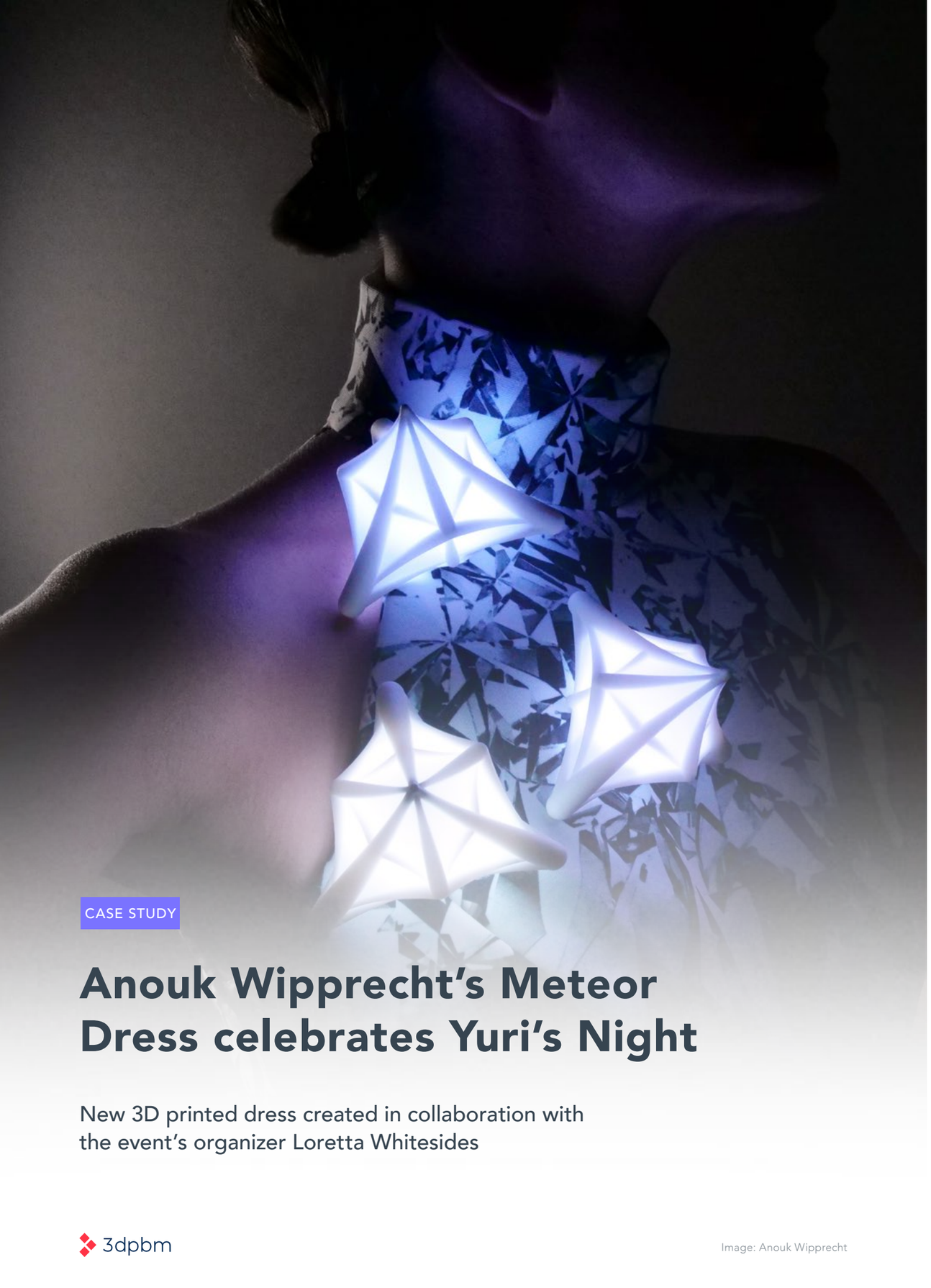
Carbon and OECHSLER are producing 3D printed parts at scale for customers in a number of key industries, including sporting goods and automotive.
Image: Carbon, Inc.

Carbon has a broad materials portfolio for the DLS process, including rigid PU, flexible PU, silicone and more.
Image: OECHSLER AG

"We understand ourselves as a one-stop-shop and are happy to support customers from the very first idea," Bischoff says. "The customer can expect the highest AM expertise in the value chain of additive manufacturing. Generally, we are searching for products that really benefit from the technology: we're not just printing because it's fancy."

From Carbon's perspective, Batdorf emphasizes how significant the partnership with OECHSLER has been for the evolution of its technology. "This collaboration has proven out Carbon's vision of the factory of the future. There were a lot of lessons learned along the way which have enabled us to develop repeatable processes for future expansion. We have demonstrated that it is possible to run multiple product lines with different materials, simultaneously at scale in the same factory. We have developed processes to speed up technology and application transfer to the customer, which OECHSLER has used to bring products to market in previously unthinkable timeframes."

"There is no limit," Bischoff concludes. "Increasing the capacity further can be realized quite easily. In the end, we use AM only for products where it makes sense to exploit the advantages of the technology, like design freedom, customization, and fast adoption." ◆



CASE STUDY

Anouk Wipprecht's Meteor Dress celebrates Yuri's Night

New 3D printed dress created in collaboration with the event's organizer Loretta Whitesides

We've come to know Anouk Wipprecht for her innovative use of 3D printing for creating advanced, interactive dresses that give us a glimpse of what the future holds for smart, wearable consumer products.

Her newest Meteor Dress is an illuminating, star-gazing garment with 3D printed parts that light up every time a meteoroid falls through the night sky, through a sampling of past real-life meteor data.

The dress—which shows the data through 3D printed triangle-shaped geometries and integrated light pulsations—was created for the world space party 'Yuri's Night', organized by Loretta Whitesides, Zero-G flight director and founding astronaut at Virgin Galactic.

Anouk's ultimate goal is to make fashion an immersive experience, combining garments with electronics and robotics, equipped with sensors. She strives to engineer a new generation of wearable robotics and electronic wardrobes that listen to the wearer's body and surroundings.

In this quest, her creativity has sometimes come to terms with the needs of actually wearing the dresses in more casual settings, thus reconciling extreme use of technology with a more comfortable style. As 3D printing and materials evolve they will eventually meet consumer habits, bringing smart, customized wearable products to the masses.

Meteor Physics

The Meteor Dress is the designer's first space-data project. "I wanted to take data from space, such as the meteors in this case, and display it in a dress. Meteors fascinate me: a small body from outer space enters Earth's atmosphere, becoming incandescent as a result of friction and appearing as a streak of light. We try so hard to engineer our way towards space, while these bits of space fall effortlessly toward us." The dress runs a Python script that generates meteors at the given rate and the correct brightness distribution, as it would have been observed in the sky. To create it, Anouk contacted Denis Vida of Global Meteor Network and learned what data she might be able to use.

Vida is a meteor physics postdoctoral researcher and is building a global network of video meteor-recording cameras through his Global Meteor Network "The goal of the GMN project is to observe meteors, by a global network of cameras pointed at the night sky. Each camera is connected to a Raspberry Pi running open-source software for video capture, compression and meteor detection," he explained.

The collaboration with Anouk Wipprecht started out of this shared passion for exploring the boundaries of technology and making them more accessible to a global audience. The Meteor Dress represents an ideal meeting point for space, 3D printing technology and a wearable consumer product.

"Creating it was fun", Anouk exclusively told 3dpbm. "it was less 'fully robotic' and more like a wearable, everyday dress. It was the first time I had to ship something off without physically being there for either fitting or demo sessions. So, I took this fun, minimal approach: all the wires are built into the dress, with the computer board and mini battery pack in the back. It's very minimalist chic!"

Yuri's Night is an international celebration held every April to commemorate milestones in space exploration. It is named after the first human to launch into space, Yuri Gagarin, who flew the Vostok 1 spaceship on April 12, 1961. Yuri's Night was created in 2000 by Loretta Hidalgo Whitesides and her husband, as part of their commitment to making space cool and training the next generation of space leaders. Loretta was super enthusiastic about displaying the dress at Yuri's night: "The audience can make a wish every time it blinks," she said: 'I am super excited to share this custom high-tech space-data-driven dress!' ◆

Image: Anouk Wipprecht

SPOTLIGHT

Everything you need to know about prescription smartglasses

Luxexcel illuminates the challenges and opportunities for smart eyewear and 3D printing

3dpbm × Luxexcel 3D printed lenses

Image: Luxexcel

Though smart eyewear technology has had its ups and downs over the past decade or so, it seems we are entering a new era, where demand for the technology and the advancement of the wearable devices will finally coincide. The fact that corporations like Facebook and Amazon are preparing to launch their own smartglasses is further indication that the technology is readying itself for broad consumer adoption. Dutch lens technology specialist Luxexcel has recognized this and has strategically positioned itself as a key partner for smart eyewear developers with its unique ability to 3D print prescription lenses with embedded technology .

In the following piece, the lens 3D printing company spotlights the challenges that have hindered smart eyewear technology up until now and illuminates the opportunities for smart eyewear and 3D printing.

Q: Why aren't more people wearing smartglasses today?

A: There are many setbacks to smart eyewear currently, which explain why they haven't been widely adopted. We can look at it from multiple perspectives, but what is clear is that smart eyewear should meet three main functions. First, like traditional eyewear, smartglasses should function as a fashion item. Second, they must meet the criteria as a medical aid. And third, they are wearable technology that gives the user access to augmented reality.

The main problem with smartglasses on the market today is that they have put the primary focus on the last function, falling short on the first two. In other words, they are wearable devices. And hurdles to their adoption have been fairly basic: even though glasses are used to help people see, smartglasses do not have built-in prescription lenses, thus falling short on one of their primary functions. Additionally, they are not as fashionable or lightweight as traditional frames, and their bulky design can be uncomfortable to the wearer.

Q: As a person who wears prescription lenses, what are my options for smartglasses?

A: Looking at what is already on the market: the options for prescription wearers are not great. Even though 7 out of 10 adults need some sort of prescription lens to see clearly, most smartglasses currently on the market do not come with the option for prescription lenses. Instead, people have had to settle for adding prescription inserts to their smartglasses. These inserts, made using traditional lens manufacturing processes, are worn underneath smart glasses, which can be cumbersome and heavy for the wearer.

Another option that exists is to glue display technologies onto traditional lenses. This, again, adds unnecessary weight to the frame, making it uncomfortable to wear for long periods. And that's not to mention the bulky aesthetic of integrating these add-ons. Guido Groet, Chief Strategy Officer at Luxexcel, sums it up well: "The devices look like helmets or sci-fi goggles—it certainly doesn't look like fashionable glasses that consumers have become accustomed to wearing."

Q: Does an alternative exist?

A: The short answer is yes. Luxexcel's technology has presented a compelling solution that can solve not only the issue of prescription smart lenses, but also the design and comfort problems. The company's unique 3D printing technology is capable of printing ophthalmic lenses with smart features embedded in them. This means that smartglasses can integrate lenses with prescriptions and smart devices, eliminating the need for add-ons. Critically, this reduces the weight and bulk of the eyewear. In fact, Luxexcel's 3D printed smart lenses are up to 50% thinner (and thus lighter) than smart lenses with multiple components glued together. "We combine prescription and smart devices into a slim profile that fits into a frame that looks and feels

much like traditional eyewear," adds Groet, Chief Strategy Officer Luxexcel "The lens delivers the user's best vision, as well as smart functionality. We're making the world's first truly integrated prescription and augmented reality lenses available today."

Q: How does 3D printing smart prescription lenses work?

A: At the center of Luxexcel's ability to print prescription lenses is its VisionPlatform™, a proprietary solution consisting of hardware, software and ink materials. The 3D printing system is based on inkjet technology that precisely jets billions of micro droplets, gradually building up the lens structure on the build platform. The technology is also unique in that it does not require any supports or post processing: what comes off the printer is a finished lens that can easily be snapped into a frame.

The printer uses a proprietary material called Luxexcel VisionClear™, which is specially formulated to create high-quality, transparent objects. The entire 3D printing process is controlled by the VisionMaster™ software. To date, the VisionPlatform™ has been used to produce over 50,000 lenses for customers. To add smart functionalities to its lenses, Luxexcel has the ability to directly embed smart devices into the printed lenses, including waveguides, holographic foils, flexible displays, active filters and liquid crystal technology. "A smart device such as a waveguide is encased in the printed material and prescription power is printed on top or around it," Groet explained. "The waveguide, which projects images into the eye, is fully embedded in the prescription lens."

This approach also better protects the smart devices. For example, because waveguides are incredibly fragile, encapsulating them within the durable lenses will help keep them safe from dust, humidity and impact. It is also worth mentioning that Luxexcel's printed lenses have obtained ISO, ANSI and FDA certifications.

Q: Where does Luxexcel fit into the smart eyewear market?

A: Luxexcel is not a smart eyewear manufacturer. Rather, the Dutch company is positioned to work with smartglasses developers (OEMs /ODMs) by providing its 3D printing platform for prescription smart lens production. The company is thus offering a B2B solution that any smart eyewear company can benefit from.

Recently, the company partnered with WaveOptics, a manufacturer of waveguides and light engines. The goal of this collaboration is to develop a module that integrates 3D printed prescription lenses, waveguides and projectors: the three main components needed for AR smartglasses. Prototype samples of these lenses will become available as soon as Q2 2021.

At the end of the day, Luxexcel is aiming to fill a gaping hole in the $1+ trillion smart eyewear market and find a solution for the many consumers that require corrective lenses. ◆

Image: Luxexcel

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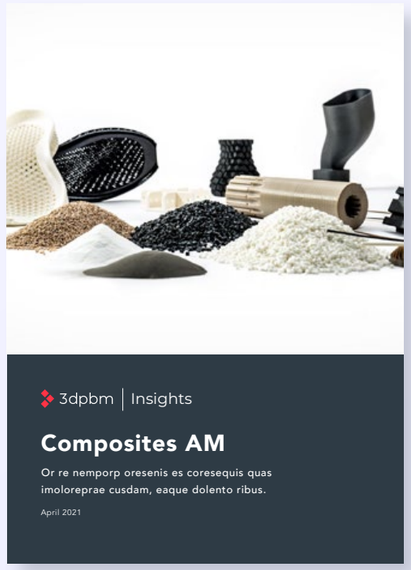

APRIL 2021 **Composites AM**

In this upcoming eBook, 3dpbm explores the ever-evolving and highly innovative area of composites in additive manufacturing.

- ✓ Analysis
- ✓ Interviews
- ✓ Case Studies
- ✓ Mapping

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2021 Calendar

JAN	Automotive	JUL	Maritime
FEB	Medical	AUG	Post-Processing
MAR	Consumer	SEP	AM Services
APR	Composites	OCT	Metal
MAY	Sustainability	NOV	Ceramics
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MAPPING

The AM companies behind 3D printed consumer products

An overview of major players in the AM consumer segment, from hardware to materials and services.

Printing giant HP launched its Multi Jet Fusion 3D printing tech in 2016, and several companies now use the production-ready technology for consumer goods. In January 2020, HP announced a collaboration with insole brand Superfeet and sportswear company New Balance that will see the companies produce and market customized 3D printed insoles based on customers' biometric data. HP also has an ongoing partnership with sunglasses brand Oakley, which uses HP's Multi Jet Fusion 3D printing technology to improve its product design process and prototyping. A popular material for consumer goods is HP's PA 11 thermoplastic, which is suitable for prostheses, insoles, sports goods, snap fits and living hinges. HP's Metal Jet process is also finding applications in the consumer segment. In 2020, the company joined forces with golf brand Cobra Golf to 3D print a metal lattice component for the KING Supersport-35 putter.

German AM leader EOS has a firm foothold in the lifestyle market, with its printing systems used to develop and manufacture products such as jewelry, watches, footwear and sports equipment. EOS has worked with metals company Cookson Precious Metals (CPM) to develop 3D printed products made from gold. Its AM systems have also been used by bicycle equipment companies Kappius Components and RaceWare Direct. In October 2019, EOS and lattice specialist nTopology launched Digital Foam, a program that enables the production of highly tuned 3D foam patterns that can be used in products like 3D printed protective headgear, individualized orthotics and performance footwear. Notably, EOS has been a long-time partner of HEXR, a company pioneering the use of 3D printing for custom bicycle helmets.

Carbon

California-based 3D printing company Carbon, whose proprietary DLS (Digital Light Synthesis) process has made a huge mark on the AM industry, has worked with a number of sportswear and sports equipment companies. Market leader adidas, an early investor in Carbon, uses the company's 3D printing technology for midsole production, while Eric Liedtke, a former Executive Board Member at adidas, now sits on Carbon's Board of Directors. Carbon also has partnerships with bicycle manufacturers Specialized and fizik, with whom it has developed 3D printed bike saddles, and FinMan, a fishing equipment company. In October 2019, Carbon took its first foray into eyewear, working with Japanese brand J of JINS to create the Neuron4D line of sunglasses. The company's technology is also used to print American football helmets for Ridell as well as exclusive perfume bottles for VIKTOR&ROLF. Read our full interview with Carbon on Page 12.

A leader in polymer 3D printing, Stratasys has brought to market a number of 3D printing solutions suitable for consumer applications. Chief among them is the Stratasys J750 machine based on its PolyJet technology. This multi-material, multi-color technology has found many uses in the fashion industry, where designers have explored printing directly onto fabric. Recently, Google used Stratasys PolyJet printing to create the Jacquard Tag, a wearable device that senses motions, like swiping or tapping, allowing wearers to perform actions such as pausing music, taking a photo or answering a phone call. Stratasys' PolyJet platforms are still largely limited to prototyping, but now that Stratasys has acquired Origin, its activity in series production for the consumer sector may increase.

Image: Cobra Golf

PRODWAYS

French industrial leader Prodways develops and markets AM production systems that serve a number of industries. Its DLP resin printers are widely used in the jewelry industry, and in January 2019 the company launched its SolidscapeDL 3D printer, which is used to make castable wax models to facilitate jewelry production. Prodways also sells a proprietary thermoplastic polyurethane (TPU) material that is ideal for the production of 3D printed midsoles, while its MOVINGLight AM technology (and associated material) is capable of printing resistant composite molds that can be used to inject or compress a series of final outsoles with tailored designs and complex textures.

DWS

DWS Systems, an Italian SLA specialist, develops and manufactures 3D printers for the gold jewelry industry. The company's product line includes rapid prototyping and manufacturing systems capable of producing between 10 and 3,200 models per day. DWS also develops several 3D printing materials in house, including nanoceramics and resins for casting and molding. In November 2019, DWS partnered with global chemical company Huntsman to develop and launch a new polyurethane-based resin called IROPRINT R 1801. The SLA material, characterized by its soft and flexible properties, has applications in the footwear market.

sisma

Leading Italian laser manufacturer Sisma sells a range of metal and resin AM systems, and its Everes range of DLP machines are widely used in the jewelry industry. The machines are designed for the manufacturing of extremely thin filigrees, and compatible materials include extremely high fusible resins with a similar burnout cycle to wax. Several of the company's MYSINT SLS AM systems can also be used for jewelry. To create a one-piece custom jewel or to try out a new material, users can switch from the printer's standard 100 mm platform to a smaller 34.5 mm version with a reduced laser spot (30 µm). The machines are compatible with precious metals such as white and red gold, silver and platinum.

formlabs

Massachusetts SLA specialist Formlabs has worked with a number of high-profile companies to develop printed consumer products. In September 2019, having worked together for two years, Formlabs and sportswear company New Balance debuted their second sneaker model, the FuelCell Echo Triple. The shoe was produced using the innovative TripleCell footwear 3D printing platform, which combines Formlabs' SLA technology with a custom material called Rebound Resin. Formlabs also worked with razor company Gillette to develop a limited-edition 3D printed razor, the Razor Maker Apollo. The company's SLA machines are also widely used in the jewelry industry and for audiology products like earplugs.

Image: HEXR | EOS

BASF

BASF, the world's leading chemical company, develops a range of 3D printing materials including TPU powders, polymers and filaments. The company's Ultrasint TPU01 thermoplastic material, developed specially for HP's Jet Fusion 5200 3D printer, is suited to applications in the automotive, footwear and sports markets because of its abrasion resistance, toughness and flexibility. BASF says it is developing 3D printing solutions in response to the manufacturing sector's demand for scalable industrial solutions for customized consumer goods such as eyewear, footwear and accessory articles. To this end, it is currently focusing on seamless compatibility between software, hardware and printing materials.

materialise

Belgian 3D printing service provider Materialise has a strong foothold in consumer goods. The company offers mass customization and personalization options to businesses and sole traders, giving them the ability to deliver bespoke products to customers. One business using Materialise's services is Phits Insoles, which was the first company in the world to directly translate gait analysis into custom, dynamic 3D printed insoles. Phits provided the dynamic measurement foot scan solutions, while Materialise used its 3D printing software and manufacturing expertise to fabricate the insoles. Materialise also worked with adidas on the Futurecraft 3D sneaker, generating a lightweight structure for the 3D printed midsole to keep the shoe at a comfortable weight.

OECHSLER

Founded back in 1864, Germany-based OECHSLER is a major plastics manufacturing company. In recent years, the company has embraced 3D printing and has been responsible for creating one of the largest polymer AM production lines. At the core of its polymer 3D printing capability is Carbon's DLS technology. Today, OECHSLER and Carbon produce over a million 3D printed products a year, for customers in sporting goods, automotive, medical and other industries. Read our full interview with OECHSLER on Page 12.

Lubrizol

Ohio chemical company Lubrizol has developed several TPU materials for additive manufacturing. Its ESTANE 3D TPU portfolio is engineered to meet strict market requirements for 3D printed parts and comes in formats for PBF systems (MJF, SLS, HSS) and FDM machines. The company's TPU M95A TPU powder was developed specifically for HP's Jet Fusion 4200 series 3D printing solution, and offers excellent elongation and tensile strength, good energy rebound, high impact absorption, low abrasion rate and good compression. The material is suitable for footwear and other consumer-focused parts.

SHAPEWAYS

3D printing service provider Shapeways, headquartered in New York City, acts as a gateway for smaller companies bringing their 3D printed consumer products to market, by allowing those companies to sell customizable printed versions of their products—manufactured by Shapeways—in a range of 42 materials and finishes, including plastics and metals. Shapeways' Marketplace, a platform where 3D designers can sell their products, is especially popular with designers of 3D printed jewelry and accessories.

Let's Partner

In 2021, our eBook series will look at 12 key AM topics. In our monthly publications, we'll cover important technical advancements, market trends and industry announcements relevant to each area.

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We look forward to working with you in 2021!

CASE STUDY

Reinventing the frame: the McLaren Vision Collection

A luxury brand, eyewear designer and company of innovators find an entirely new solution for creating high-end 3D printed metal eyewear.

3dpbm × materialise

Image: L'Amy Group

When a brand such as McLaren, known for its luxury automotive engineering, takes on a new project, customers expect the highest quality as well as for the marque's essence to be captured in the new product. For McLaren, this means employing supercar imperatives and cutting-edge technologies to guarantee ultimate performance. In the case of the collaboration with leading eyewear manufacturer L'Amy, designer Sébastien Brusset and 3D printing innovator Materialise, this culminated in the highly acclaimed McLaren Vision Collection. Lauded as the Frame Technological Innovation of the year at the 2018 Silmo d'Or Awards in Paris, this collection of eyewear and sunglasses fully represents the McLaren ethos: innovation, endurance, no compromises.

In order to rise to the challenge of meeting the McLaren standard in precision manufacturing, L'Amy and Sébastien Brusset turned to Materialise to support them in bringing their ambitious vision to life: creating a high performance, high endurance, fully customizable eyewear collection with metal 3D printing.

A vision comes into focus

The concept behind the McLaren frame that ultimately won a prestigious Silmo d'Or Award was a long time in the making, over 20 years in fact, when the original concept first came to designer Sébastien Brusset. At the time, the trained optician-turned-eyewear designer found it surprising that lenses were set in very rigid structures that created tension between the lens and frame, thus making the product less resistant to shock and less comfortable for the wearer. In an effort to create eyewear that is more lightweight, more durable and better adapted to human physiognomy, Sébastien set an ambitious challenge for himself: "rethinking from scratch what a frame is and how it is constructed."

The designer envisioned a strong, lightweight structure, organic and minimalistic in terms of its aesthetic, with blades that fit the customer's nose bridge perfectly.

But even as this notion of deconstructing and completely rethinking eyewear came to him, Sébastien also knew that the idea was not feasible using the conventional manufacturing solutions available to him at the time. Achieving the shape he was looking to create—as well as the level of wall thickness required—would have meant significant production costs and large amounts of wasted materials. Or that would have been the case had he gone with any type of technology other than 3D printing.

"The big advantage of 3D printing is that it gives you the freedom to achieve unusual shapes and work with your material of choice efficiently," he says. From the beginning of this project, he understood that 3D printing was an integral part of turning his idea into a tangible reality. Fast forward two decades, to his partnership with Materialise, and what started as a pipe dream is now an eyewear collection that has earned a global award for innovation and technology.

Pushing the limits of metal 3D printing

When Sébastien Brusset and L'Amy began the co-creation process with Materialise for the McLaren Vision Collection, they initially embarked on a focused journey centered around plastics, specifically PA 12 Nylon for selective laser sintering (SLS). As the partners dove deeper into the concept of the collection, however, Brusset and Materialise's experts agreed that they had the opportunity to take their idea even further, by creating eyewear frames that are entirely 3D printed in metal.

"This project took us beyond what was previously possible with metal 3D printing. It challenged us to create an eyewear-specific post-processing chain that guarantees more reproducibility, repeatability and traceability," says process engineer Philip Buchholz. "Through the collaboration with McLaren and L'Amy, we created the ecosystem that now enables us to apply metal 3D printing for eyewear."

"For the McLaren Vision Collection, we had 3D printing in mind as the only possible production technology from the very beginning of the initial design process."

SÉBASTIEN BRUSSET
EYEWEAR DESIGNER, JAW STUDIO

Innovation meets craftsmanship

"For designers and brands, the two big advantages afforded by 3D printing are freedom of design and freedom of production," explains Alireza Parandian, Head of Global Business Strategy for AM Wearables at Materialise. "Brands that are bringing premium products to market won't risk having backlog stock that doesn't sell. 3D printing in metal guarantees flexibility for production, so that frames can be manufactured on demand."

A further manufacturing imperative for premium eyewear is ensuring that every single frame meets the highest quality standards. In order to rise to the challenge, the Materialise Metal Competence Center in Bremen, Germany combines the possibility to scale and multiply quality that is afforded by 3D printing innovation with the handcrafted care and attention to detail of a traditional atelier.

"The Materialise advantage is that we have a panoramic view of a given project," Philip Buchholz explains. "No other service provider has access to this kind of knowledge of software, coupled with our own additive manufacturing production facility. Thanks to the application-specific technology we have developed, we can apply the same level of attention to detail throughout the entire process flow, which culminates with an in-depth quality check and artisanal hand finishing."

The perfect fit

For eyewear, the designer's most important requirements are always around the aesthetic and performance of the frame. The accuracy of dimensions is essential, as are factors related to interfaces for the temples and hinge assembly. As an answer to designer Sébastien Brusset's challenge of exploring "how little frame is possible," the lens is hung within the frame at just two contact points to minimize interference with the lens.

"We wanted this frame to be ultra-comfortable. Rubber is molded around a titanium core, hinges are rotatable, meaning the glasses fit the customer's face optimally but can also be folded compactly," Sébastien says of the award-winning design. "In many instances, the feeling of the fit will be affected when hinges are repeatedly folded: we were able to eliminate this drawback. Imagine the comfort of a plastic frame that is perfectly adapted to your face—no slipping down the nose, no gripping at the temples—but with the advantages of a very lightweight metal frame."

Titanium was a natural choice here: its mechanical properties and biochemical behavior are well suited for lightweight wearables. In contrast to a solid piece of titanium that has been milled, 3D printed titanium has a higher elongation at break, making it more flexible and resistant to breakage.

The McLaren Vision Collection frames are 3D printed from titanium. The metal was chosen for its mechanical properties and biochemical behavior.
Image: L'Amy Group

Looking forward

"A 3D printed product with this level of finishing on this scale of production is ground-breakingly innovative," says Parandian. To make Brusset's design come to life for the McLaren Vision Collection, Materialise developed a dedicated process for metal 3D printed eyewear that repeatedly delivers high quality, precision frames.

"To meet the highest quality standards and guarantee the McLaren seal of ultimate performance, we invested in operational excellence and delivered a major leap forward in scaling quality with metal 3D printing for the eyewear market," Alireza continues. "This is the level of commitment we offer to all of our customers. When you work with us, you tap into a company of innovators who will help you push the limits of design and production for your future collections."

For designers such as Sébastien Brusset and brands such as McLaren, a clear advantage of 3D printing is that it can change the way in which customers interact with their frames. The product is tailor-made to suit individual sizing needs and can be personalized according to end-consumer preferences (for instance, by adding text or your car's chassis number to the frame).

For eyewear manufacturers such as L'Amy, flexible, custom solutions afford more security in terms of adapting and scaling production, shorter time to market and higher cost benefits. For Sébastien Brusset of Jaw Studios, the future of eyewear design and production is bright: "Thanks to 3D printing, there are no more generic products—with mass customization, each product is truly made for you." ◆

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