3D Printing the Future of Healthcare

Additive manufacturing, or 3D printing, is fast-tracking developments in the medical device industry

By Geoff Giordano

The escalating adoption of 3D printing (3DP) is spurring increasing development of new plastics, some of them specifically for medical and dental applications.

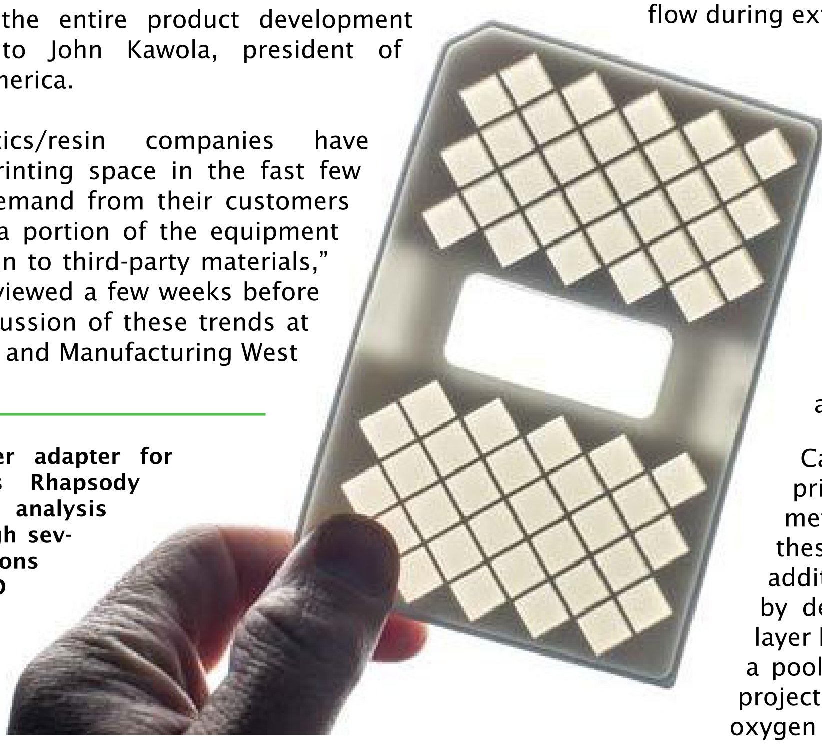
In its earlier days, 3D printing, also known as additive manufacturing, relied largely on generic resins developed for pre-3DP applications. But as 3DP gains a firmer foothold in manufacturing beyond the rapid generation of part prototypes, industry-leading companies are crafting plastics for specific medical uses.

Plastics companies have begun pursuing collaborations with these 3DP leaders to invent materials that can be used throughout the entire product development cycle, according to John Kawola, president of Ultimaker North America.

"Numerous plastics/resin companies have entered the 3D printing space in the fast few years … due to demand from their customers and the fact that a portion of the equipment market is now open to third-party materials," says Kawola, interviewed a few weeks before his scheduled discussion of these trends at the Medical Device and Manufacturing West conference in Anaheim, Calif., on Feb. 5.

"Manufacturers who use plastic for production—molding, extrusion machining—are finding opportunities and demand to explore using 3D printing, and there is appeal to having the materials used for 3D printing match up with materials being used for conventional processes," Kawola adds.

Generally, he says, plastics for 3DP are quite similar at the chemical level to resins for traditional processes. In the case of filament used in the fused deposition modeling process Ultimaker employs, additives akin to lubricants, as well as others materials, are incorporated to improve flow during extrusion.



This hemocytometer adapter for Becton Dickinson's Rhapsody single-cell genomic analysis system went through several design iterations to optimize it for 3D production using Carbon's MPU 100 medical polyurethane. Courtesy of Carbon

New Material for a New Part

When healthcare giant Becton, Dickinson and Co. of Franklin Lakes, N.J., needed an alternative to injection molding to make a critical component of a gene-analysis system, Carbon of Redwood City, Calif., had the answer.

Carbon has pioneered a proprietary additive manufacturing method called Digital Light Synthesis (DLS). Unlike other common additive methods that build parts by depositing powder or filament layer by layer, DLS builds parts from a pool of resin that is subjected to projected light and saturated with oxygen to manipulate polymerization

A "smart" medication monitoring pill bottle made with Carbon's MPU 100 medical polyurethane (above). A surgical tool handle, left, and ligating clip holder made with Carbon's MPU 100, a medical polyurethane (left). Courtesy of Carbon

and create an overlapping continuum of material.

In September, the company introduced a new material for life sciences applications called MPU 100, a medical polyurethane.

One struggle in growing adoption of its resins for medical manufacturing was that they were black to facilitate Carbon's photochemical process, explains Steven Pollack, Carbon's senior staff research scientist. "When you use light as your chisel, you'd like to be able to control how deep the light gets into the part—and black is a great light-stopping pigment."

MPU 100 took about a year to develop and addressed concerns such as use in a surgical environment, where healthcare personnel would not know if a black-pigment device had been cleaned or not. Once this new white resin was developed, Carbon sent it to BD to see what they could achieve with it.

More importantly, MPU 100 possesses the temperature and solvent resistance, smooth surface and non-porous properties ideal for a hospital setting, unlike other resins 3D printed with photochemistry.

"In our dual cure concept, we use photochemistry to create the shape, then use a thermosetting chemistry to create the mechanical properties," Pollack says. "After the part is built, you bake it—and that baking essentially turns on a thermosetting reaction. You can make a polyurethane, a polyepoxy, a silicon chemistry. MPU has a latent polyurethane chemistry; baking turns it on, and it goes from a material that is mechanically weak to a material with the mechanical properties of ABS or unfilled nylon."

BD has been one of Carbon's earliest adopters since the latter's founding in 2013. When the BD Life Sciences—Genomics group based in Menlo Park, Calif., began working on the BD Rhapsody single-cell genomic analysis system, one of the toughest parts to produce was the hemocytometer adapter. The microfluidic holder is made up of numerous square recesses set at 90º angles and requires trapped negative space for the slide holder, undercut structures, and a window for optics.

With this system, genomic sequencing can be done cell by cell. "You're not just taking a tumor or other biopsy sample and averaging the genomics over all the cells of the sample," Pollack explains. The BD system isolates cells in the hemocytometer adapter's microwells, each of which is bar coded. The adapter then slides into the reader.

Given the limited number of adapters that made to be made, 3D printing was the ideal process. And MPU 100 was the perfect material. "It's got the right mechanical properties, surface feel and texture," Pollack notes.

BD and Carbon experts worked together to refine the part's design to minimize resin use and maximize print speed. Rotating the honeycomb structure by 45º, for instance, made the walls self-supporting and reduced resin usage by 7 percent per build. A custom print script reduced print time by 55 percent.

Ultimately, the project was successfully completed from development to part production using the same Carbon printers. Injection molding the part would have entailed prohibitive costs for complex molds to produce about 1,000 parts a year.

MPU 100 has also been used by Biolase of Irvine, Calif., as a replacement material for cast urethane parts and reduced by 70 percent the time between design and final part.

Dental Discovery

In recent months, dentistry-specific materials have also some to the fore. Dental applications have long been suited for 3D printing to perfectly customize implants and surgical guides for patients.

3D Systems of Rock Hill, S.C., has bet big on demand for digital dentistry, launching the NextDent 5100 printer in 2018 to accompany its portfolio of 30 dental resins. Offered in a range of colors, the resins can be used by dental labs and clinics to closely match patients' teeth and gums.

"All of our NextDent materials are biocompatible as well as FDA listed and CE-certified, making them suitable for a wide range of prosthodontic and orthodontic applications," says Rik Jacobs, vice president and general manager for 3D Systems dental operations.

Several of the company's dental resins have earned Class IIa certification, which Jacobs says means that "for the first time in dental history" multiple long-term applications such as splints, denture bases, crowns and bridges can now be manufactured for long-term use in the oral cavity using 3D printing technology.

"NextDent Ortho Rigid material enables production of splints for long-term use in the patient's mouth," Jacobs explains. "NextDent Base material was specifically developed for the printing of denture bases." Mostly recently, NextDent C&B MFH (Micro Filled Hybrid), developed to produce crowns and bridges with high strength and wear resistance, received the certification.

Increased manufacturing speed and minimizing human error are key drivers in developing these new resins, Jacobs explains. For example, it can take 14 hours of lab work to go from an initial impression of a patient's mouth to a final set of dentures. After that, models are shipped back and forth between the lab and dentist's office. Patients make an average of five visits to be fitted for the device, Jacobs adds.

"The process also results in significant material waste in the form of plaster and wax that is used in all iterations of the models working toward creation of the final product," he notes. "With 3D printing—specifically the NextDent solution—the entire process can be accomplished up to four times faster than other available solutions while reducing material waste and capital equipment expenditure as well as reliance upon milling centers."

At press time, 3D Systems was planning to add NextDent Denture 3D+ to its dental repertoire by the first quarter of this year. The material, aimed at producing removable dental bases, could secure Class IIa certification by March. "This material has significantly lower shrinkage compared to standard denture base materials resulting in production of excellent-fitting denture bases," Jacobs says.

Continued development of dental-specific 3DP resins is not only a function of manufacturing efficiency but patient safety, Jacobs adds. Allergic reactions are a danger.

"The biggest challenge experienced with traditional photopolymer resins are allergic reactions resulting from cytotoxicity," he explains. "When a traditional dental photopolymer reacts with a patient's saliva, the resin can begin to break down and release monomers (the individual molecules that create the photopolymer). These monomers can cause soreness and a burning sensation in the mouth."

3D Systems' new dental biocompatible photopolymers are monomer-free and being validated with testing institutions. "From early results, we anticipate almost no allergic reactions to the materials."

Carbon, too, has seen a surge in dental demands for new additive materials, Pollack notes. Dental applications have grown to such an extent that Carbon has broken out a growing team specifically to meet those needs.

"We are seeing a huge uptick in adoption of our machines in dental laboratories by the people who fabricate things like dental models, surgical guides for patients who need implants, and more recently a huge growth in digitally fabricated dentures at lower cost than typical devices," Pollack explains.

The NextDent 5100 high-speed 3D printer from 3D Systems is powered by Figure 4 technology combined with the broadest portfolio of dental materials. Courtesy of 3D Systems

NextDent C&B Micro Filled Hybrid is developed to produce crowns and bridges with high strength and wear resistance (left). 3dsystems-NextDent-Denture3D-Plus: NextDent Denture 3D+ is suitable for printing all types of removable denture bases and has significantly lower shrinkage versus standard PMMA denture base materials and is available in multiple colors (center). 3dsystems-NextDent-OrthoRigid: NextDent Ortho Rigid from 3D Systems is developed for digital manufacturing of splints (right). Courtesy of 3D Systems

Plastics in the dental space are "a very odd thing," he says, because the FDA regulates the liquids or solids that become devices. Generally, the FDA regulates the final product. (Pollack came to Carbon after 10 years running the FDA's Office of Science and Engineering Laboratories.)

Carbon has partnered with a number of companies that have developed 3D-printable resins and has validated those resins to work on Carbon machines to produce dental models. Those companies includes Dentca of Torrance, Calif., and its denture resins; Germany's Dreve and its gingiva guide; and Whip Mix of Louisville, Ky., and its surgical guide-compatible resin.

"We've opened the resin store for third-party resins in the dental space," Pollack concludes.

Future Applications

While 3DP is gaining ground in numerous industries, traditional manufacturing processes dwarf its impact. But Ultimaker's John Kawola foresees huge opportunity in the next five or more years.

"If you take just take one segment—medical devices—including all the plastic components being used in probes or medical equipment or other such equipment, the percentage being produced using 3DP in the world today is much less than 1 percent in terms of end-use parts," he explains. Injection molding output, by comparison, is worth "hundreds of billions of dollars of plastic parts… That's why most of us are optimistic that there's real opportunity (to grow 3DP) from 1 percent to 5 percent."

To that end, Ultimaker has started a Materials Alliance Program with a number of plastics companies. "We have a platform that allows quick development of the parameters and profiles that are needed for specific materials," Kawola says. "The customer benefits by having an expanding choice of materials to use and equipment that has been qualified and tested for these materials."

That collaboration is helping bring new investment and brain power from more established plastics and chemicals giants like BASF, Dupont, Clariant, and SABIC into the heretofore more insular world of 3DP startups.

"3D printing has matured over the years without the participation of the large plastics companies," Kawola explains. "The nature of closed hardware platforms meant that these companies were rarely part of the ecosystem. Now that the market is more open, we are starting to see much faster innovation and application development. In the past, the 3DP hardware companies had materials science capability and developed their own materials. These products were good, but the scope of investments and the collective people working on it in the industry was limited."

With 3DP, "simulation is evolving and processes are improving," he says. "The goal is that engineers in the future will be able to accurately predict and design the (material) properties required."

ABOUT THE AUTHOR

Geoff Giordano has been a contributor to Plastics Engineering since 2009, covering a range of topics, including additives, infrastructure, flexible electronics, design software, 3D printing and nanotechnology. He has served as editor-in-chief of numerous industry magazines and is founder and chief creative officer of content marketing firm Driven Inbound. He can be reached at geoff@driveninbound.com.