

Carbon 3D uses a totally new technology called CLIP to print parts with excellent mechanical properties, resolution and surface finish.

CREDIT: CARBON 3D

3D printing update

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This is not the first time that this magazine has written about 3D printing, the familiar name used to indicate a wide range of technologies also known as additive manufacturing or AM. We covered the subject extensively in 2104 and again in 2015; two years later it looks as if the revolution of digital manufacturing and Industry 4.0 is eventually gathering steam with unprecedented impacts on the way we conceive manufacturing.

To put that in the correct perspective, we begin with a quote. In a predictive statement delivered on a TV show in 2016, Erik Sprunk, Nike's Chief Operating Officer, said: "Imagine this scenario: You log into your computer, fire up the Internet and purchase a file from Nike.com. The file contains data for a specific type of shoe that's a custom fit to your foot with the exact design and colour you want. From there, you download the file and feed an at-home 3D printer with the necessary material for said shoe. A few hours later, just like that, you've got a new pair of shoes ready to be worn."

These few words summarise the disruptive potential of the combination of 3D printing and customisation, highlighting a completely new scenario in terms of relationships between consumers and manufacturers. It's a scenario that Karl Marx would certainly applaud when he stated that "manufacturing means belonging to the masses". It is here now. 3D printing, together with a wealth of other digital technologies, will eventually give consumers power that was never previously imagined, transforming each of them into a 'maker' of their own products. What role there will then be for traditional manufacturers and bricks and mortar retailers is all to be discussed. Nevertheless, reasons for concern, if companies do not realise and adjust to the changes, are more than justified. And all this stems mainly from the advances we can see in the domain of additive manufacturing.

The technological developments in this area in the last two years have been tremendous. More than the specific achievements attained, what has changed, however, is the common perception that we are getting closer (just to stay with quotations) to what Ray Kurzweil, a well known visionary, calls a 'singularity'. This is a point in the curve that describes the evolution of a certain technology where its development speed tends to increase in an uncontrolled manner. In this update we will introduce the latest advances in AM technologies concluding with some important case studies that clearly show where it is leading us.



LATEST DEVELOPMENTS

3D printing has expanded into various industries, such as automotive and medicine. Many say that with 3D printing we are at the door of a revolution, with bioengineers testing alternative uses of the method, which can potentially save lives in the future. So far, human organs and body parts (e.g. the ear and nose) have been successfully created by 3D printing biomaterial although they have not yet been transplanted into a real person. On the other hand, alternative uses of 3D printing in medicine do exist and are being applied today. One of the main uses of the method in surgery is when patients' organs are scanned and then printed so that doctors can examine the model of the organ and prepare for the operation. In many cases, in order to understand a patient's problem, they need to undergo surgery. With 3D printing, the issue could be discovered beforehand.

The automobile industry is testing the boundaries of the technology with the first car ever to be 3D printed that was launched in 2010. An almost entirely 3D printed car is the Strati by Local Motors, released in 2014. The vehicle is completely functioning and entirely 3D printed using ABS plastic and carbon fibre except for the power train. 2014 was also the year when Swedish company Koenigsegg announced their new eco-friendly model One:1, which is among the most famous cars designed with the technology. Seven of these have been produced and all of them sold—a clear

shift from 3D's original domain of rapid prototyping. As we know, AM processes differ in the way the layers are printed to create the final object. An updated list of 3D printing AM technologies showed, until only a few years ago, seven main types of technologies:

Stereolithography (SLA): SLA is recognised as the oldest 3D printing process and the first to be commercialised. It is a laser-based process that works with photopolymer resins that react with the laser and cure to form a solid in a very precise way and produce very accurate parts. Stereolithography is generally accepted as being one of the most accurate 3D printing processes with excellent surface finish, using up most of the material and creating less waste.

Digital Light Processing (DLP): DLP is a similar process to SLA except that here the 3D printing process works with photopolymers. It also uses a more conventional light source such as an arc lamp, with a liquid crystal display panel or a deformable mirror device (DMD) which is applied to the entire surface of the vat of photopolymer resin in a single pass, generally making it faster than SLA.

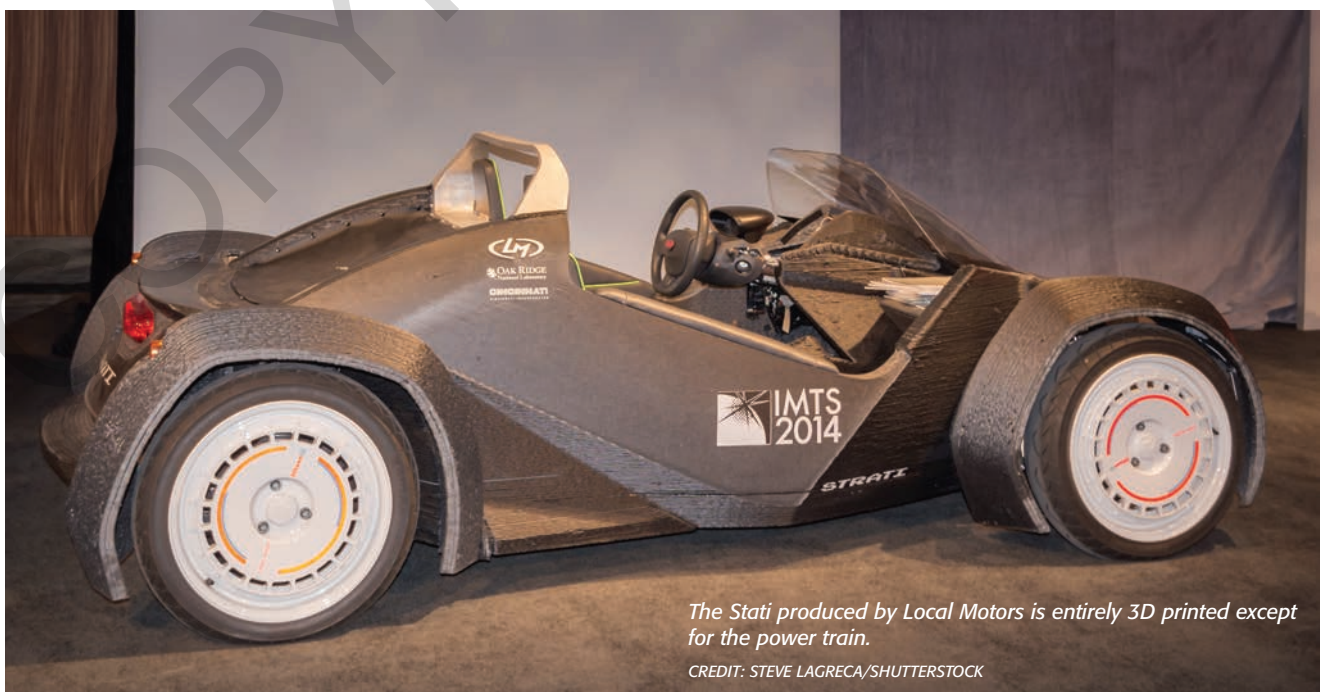
Fused deposition modelling (FDM): 3D printing machines that use FDM technology build objects layer-by-layer from the very bottom up by heating and extruding thermoplastic filament. Each layer hardens as it is deposited and bonds to the previous layer.

Selective Laser Sintering (SLS): This is a technique that uses laser as a power source to form solid 3D objects. The main difference between SLS and SLA is that it uses powdered material in the vat instead of liquid resin. This technology helps in generating the most intricate geometric shapes using material only where it is required. This reduces the quantity of material needed without compromising the strength of the product, but still making it durable and lightweight.

Selective laser melting (SLM): SLM is a technique that also uses 3D CAD data as a source and forms 3D objects by means of a high-power laser beam that fuses and melts metallic powders together. Unlike SLS, the SLM process fully melts the metal material into solid 3D parts.

Electronic Beam Melting (EBM): EBM is another type of additive manufacturing for metal parts. The same as SLM, this 3D printing method is a powder bed fusion technique. While SLM uses a high-power laser beam as its power source, EBM uses an electron beam instead, which is the main difference between these two methods.

Laminated object manufacturing (LOM): In LOM processes, layers of adhesive-coated paper, plastic or metal laminates are fused together using heat and pressure and then cut. It is one of the oldest 3D printing techniques, which has recently been revitalised by a small group of new vendors.



The Strati produced by Local Motors is entirely 3D printed except for the power train.

CREDIT: STEVE LAGRECA/SHUTTERSTOCK

TWO NEWCOMERS

In this already crowded playground, two recent newcomers are shaking the confidence of all the other incumbents of the sector: Carbon 3D and Hewlett Packard.

Carbon 3D is a start-up company with a totally new technology called CLIP. Established (presumably) in 2013, after two years of stealth mode it made its first public announcement in March 2015 when it unveiled something called DLS (Digital Light Synthesis) enabled by its proprietary CLIP technology. This is a breakthrough process that uses digital light projection, oxygen permeable optics and programmable liquid resins to produce parts with excellent mechanical properties, resolution and surface finish.

3D printed parts are often inconsistent, and their mechanical properties vary depending on the direction the parts were printed due to the layer-by-layer approach. Parts printed with DLS are much more like those that have been injection-moulded. DLS produces consistent and predictable mechanical properties, creating parts that are solid on the inside. The DLS process, driven by Carbon's CLIP technology and programmable liquid resins, uses digital light projection in a combination of oxygen permeable optics.

Traditional additive approaches to photo polymerisation typically produce weak, brittle parts. Carbon overcomes this by embedding a second heat-activated programmable chemistry in the materials. This results in high-resolution parts with engineering-grade mechanical properties. In addition to that, the building process is reported to be much faster than any other traditional method, overcoming one of the main limitations AM technologies still suffer from: low productivity. Yet the current evidence suggests that this speed goal has not been completely achieved as yet, despite the clear advantages that the Carbon 3D seems to have with respect to all its competitors. It is, however, the technology selected by adidas for its Futurecraft 4D project.

Hewlett Packard is a well known player in the ICT field, famous for its personal computers and, more than anything else, its printers. Recently, the company started harvesting its consolidated experience in ink jet



Futurecraft 4D uses a digital component creation process that eliminates the need for traditional prototyping or moulding.

CREDIT: ADIDAS/HYPEBEAST

printing to print, layer by layer, thin slices of different materials in a natural evolution from 2D to 3D printing. Their new process, called Multi Jet Fusion technology, is actually much more complicated than simple ink jet printing. HP Multi Jet Fusion technology offers speed advantages as well as control over part and material properties beyond those found in other 3D printing processes.

As with many 3D printing processes, HP technology starts by laying down a thin layer of material in the working area. Next, the carriage containing a thermal ink jet array passes from left to right, printing chemical agents across the full working area. The layering and energy processes are combined in a continuous pass of the second carriage from top to bottom. The process continues, layer-by-layer, until a complete part is formed. At each layer, the carriages change direction for optimum productivity. Using ink jet arrays with a high number of nozzles per inch, HP's proprietary synchronous architecture is capable of printing over 30 million drops per second across each inch of the working area.

This new technology can enable the full potential of 3D printing to be achieved through the production of

highly functional parts by placing precise and minute quantities of multiple types of fluids. This offers a versatility and potential not found in other 3D printing technologies. In addition to fusing and detailing agents, additional agents to transform properties at each volumetric pixel (or voxel) can be used. These transforming agents, deposited point-by-point across each cross-section, allow HP MJF to produce parts that cannot be made by other methods. For example, taking advantage of HP's in-depth knowledge of colour science, Multi Jet Fusion printers could selectively print a different colour at each voxel with agents containing cyan, magenta, yellow, or black (CMYK) colourants producing multi-coloured objects that are hardly achievable with any other system, whether by 3D printing or moulding.

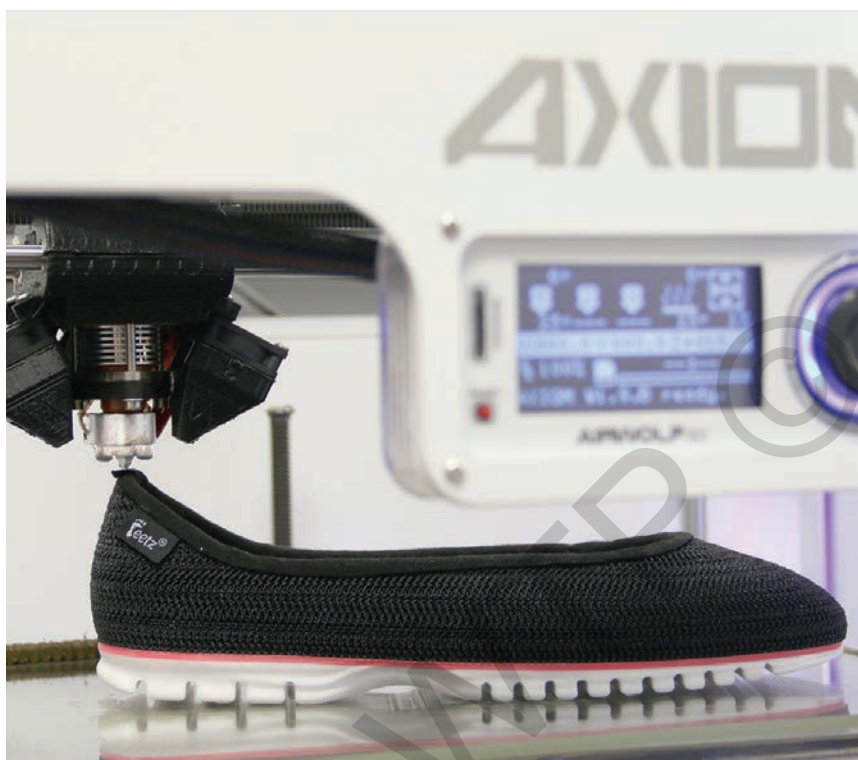
ADIDAS AND CARBON 3D

German company adidas has been experimenting with 3D printing to produce functional parts for its running shoes for quite a while now, as have many other big names in the sports shoe sector. This research exercise goes under the name of Futurecraft and fits together with other explorations the company is making in the area of new manufacturing processes that have

resulted in its Speedfactory, an ultra modern, highly automated and robotised facility the company is building in Germany for the manufacture of hybrid shoes, incorporating 3D printed parts together with more traditional components. The first pilot plant will be followed by others in other countries (namely the United States) through which adidas aims to bring back part of the production that was outsourced to distant suppliers in past years. In April adidas unveiled its collaboration with Carbon 3D for the development of a very futuristic shoe concept called Futurecraft 4D.

Futurecraft 4D is a fruition of adidas Futurecraft, the brand's journey to define the future of craftsmanship through exploring new technology, design and collaboration in order to provide the best for each athlete. Its midsole design is based on 17 years of running data and brought to functional reality through a pioneering digital footwear component creation process that eliminates the necessity of traditional prototyping or moulding. The new running shoe in fact has a very special lattice structure midsole that is entirely produced with additive technologies. With this, adidas now operates on a completely different manufacturing scale and sport performance quality, officially departing from 3D printing and bringing additive manufacturing in the sports industry into a new dimension.

Futurecraft 4D is adidas's first application of Carbon 3D and represents the brand's step into athlete-data driven design and manufacturing. With an ambition to create the ultimate running shoe for all, the company analysed its library of running data to shape functional zones into a specific midsole design. Unlike any traditional manufacturing technology the new approach precisely addresses the needs of each athlete in regard to movement, cushioning, stability and comfort with one single component. Carbon's unique programmable resin platform offers the required performance with respect to material durability and elastomeric responsiveness. Three hundred pairs of Futurecraft 4D were released this April for friends and family, to be followed by more than 5,000 pairs for retail in Fall/Winter 2017 with further scaling in coming seasons.



A pair of Feetz shoes can be manufactured in slightly under four hours with no manual work, no stitching and no lasts or lasting.

CREDIT: FEETZ

FEETZ

A further example of the progressive penetration of 3D printing in footwear manufacturing is Feetz. It is possibly also the best example because it perfectly combines the benefits of customisation for each individual consumer with the unlimited possibilities of a shoe that is entirely 3D printed. The company moved last year from its original location in Chattanooga to Silicon Valley in the heart of the high tech district of America where it settled in a brand new manufacturing facility that does not have anything in common with any traditional footwear company. Feetz shoes can be ordered online through a smartphone app and in a few selected physical sale corners. Customers can scan their feet using special software that transforms their phones into accurate foot scanners, then select the model they like and chose the specific configuration options they desire. All this data is then transferred to company servers where they are elaborated to generate the unique shoe design and size for each consumer.

Every Feetz shoe is made of two parts. One is an upper-like component with a lattice structure that mimics the flexibility and the transpiration

properties of typical shoe materials. A special algorithm was developed to generate these intricate geometries and to create the g-codes that are then sent to 3D printing machines. The other is an outsole with the necessary resistance to withstand the typical wear and tear of daily usage. No stitching or adhesive is needed to assemble the two elements as the materials from which they are made are fully compatible, so they are simply melted together.

Feetz uses a special FDM 3D printer specifically developed for the company and they process materials also customised for their needs and fine-tuned after several years of research. Such materials are also thought to be recyclable allowing the company to almost fully re-utilise waste or returned shoes. Their highly automated print farm can manufacture a pair of shoes in slightly under four hours with a daily capacity of approximately 30 pairs, with no manual work, no stitching, no lasts and no lasting. It's a complete paradigm change that takes us very close to the vision anticipated by Nike's COO and gives us a clear understanding of the full potential of 3D printing. 🌀