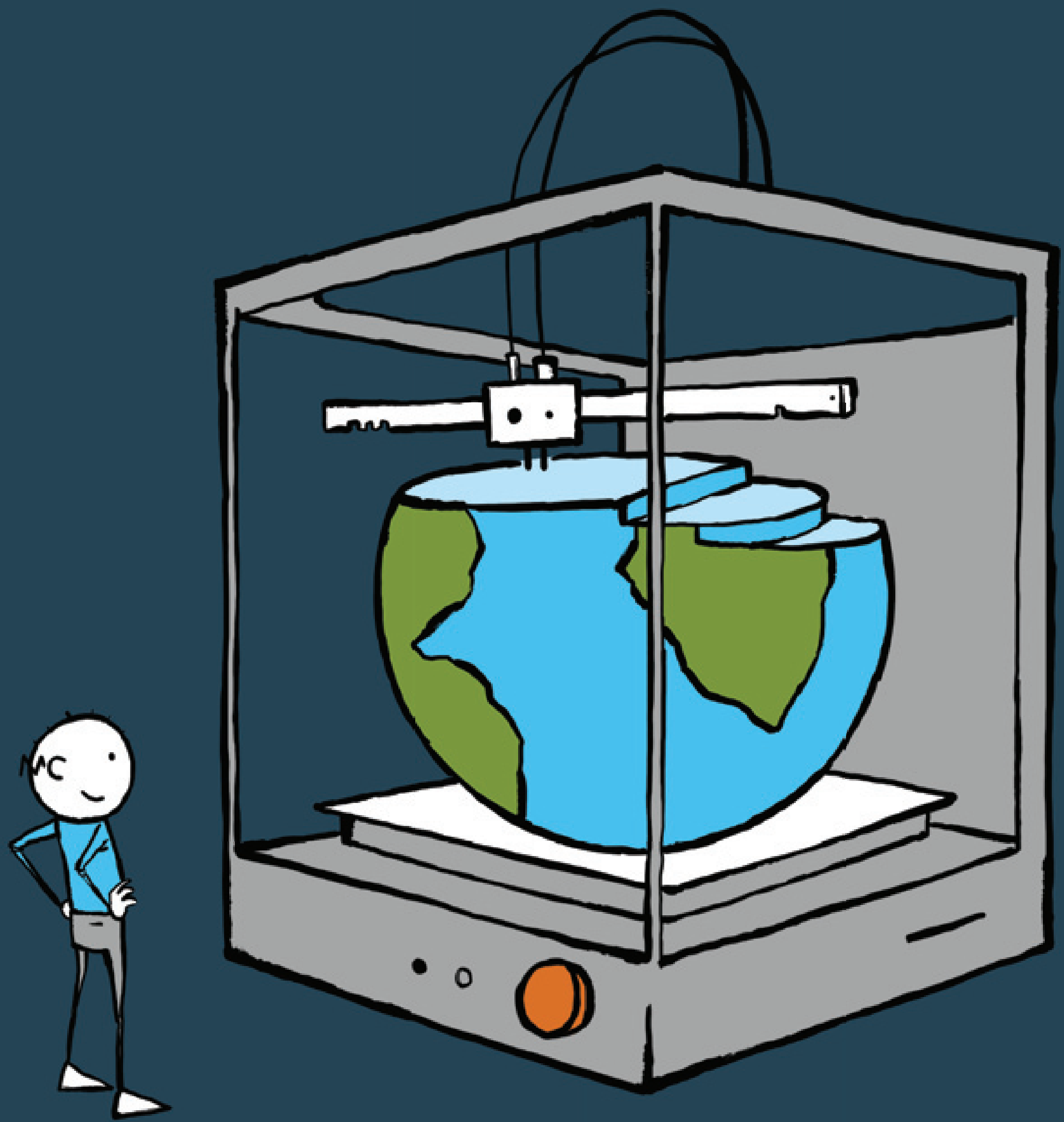
Issue 51

ROI DIALOG

SILENT REVOLUTION

3D Printing in Manufacturing



ROI MANAGEMENT CONSULTANTS

ROI DIALOG OVERVIEW – ISSUE 51

PAGE 3 **Silent Revolution**
Ignoring it is not an option: 3D printing is changing industry
Additive manufacturing is still seen as a limited technology in relation to overall production volume. And yet there are many indications that 3D printing will gain a firm place in industry as a production method and will change established forms of organization and process.

PAGE 4 **Additive Manufacturing Ecosystem**
An illustration of the value stream of 3D printing in industry
How does the industrial 3D printing ecosystem look like and which are the elements influencing the value stream of additive manufacturing directly and indirectly? We are giving an overview.

PAGE 5 **3D printing: Strong Momentum**
Fresh impetus for the future development of additive manufacturing
Rapid software development, topology optimization for functional parts and new printing materials are only a few examples of the momentum of 3D printing technology. Taking the key raw material metal as an example we illustrate which future developments are of particular importance.

PAGE 6-8 **"3D printing offers virtually infinite possibilities…"**
Interview with Christian Kirner, Chief Operating Officer (COO), EOS GmbH
In an interview, Christian Kirner outlines the most important prerequisites, milestones and obstacles for additive manufacturing – and the strategic directions shaping the next few years.

PAGE 9 **Potential for Creative Transformation**
More than just gimmicks – the use of 3D printing components in industry
Industrial 3D printing is claimed to significantly reduce production times and costs while making the supply chain more flexible. The technology has great potential to creatively transform traditional production processes across all sectors.

PAGE 10-11 **"Opportunity for Germany as a Center for Technological Innovation"**
Interview with Dr. Thomas Jüngling, CEO, H.C. Starck Surface Technology and Ceramic Powders GmbH
In an interview, Dr. Thomas Jüngling explains why the market for additive manufacturing has picked up speed and what trends and opportunities companies should be aware of.

PAGE 12-14 **Multi-dimensional Circuit Carriers using Additive Manufacturing**
Beta LAYOUT: Prototypes for new printed circuit boards developed with EOS technology
PCB specialist Beta LAYOUT faced a number of different challenges when manufacturing customized prototypes for interconnect devices. A workpiece produced using additive manufacturing that receives its functionality via direct laser structuring provided the solution.

PAGE 15 **From Prototyping to Manufacturing**
Guidelines for using 3D printing within a company
Companies can now use 3D technologies to replace conventional production methods like milling, molding, drilling and turning. We list checkpoints for digitalized production and approaches to additive manufacturing.

SILENT REVOLUTION

3D printing has already started to change industry. Ignoring it is not an option

By Hans-Georg Scheibe, Member of the Management Board,
ROI Management Consulting AG

Numerous studies forecast that global expenditure on 3D printing will double or even treble over the next four years, with hardware, powder materials and software accounting in equal parts for this growth. Industry analysts and leading manufacturers of industrial 3D printing equipment and materials like metal powders are feeling the growing demand and expect the integration of additive and traditional manufacturing to increase. After all, 3D printing only requires one tenth of the raw materials of conventional production, enabling cost-effective and high-quality manufacturing of unusual geometries and small series as well as guaranteeing an extremely high degree of flexibility. This is why today automotive, healthcare, defense and aerospace industries – and not only these – are investing in additive manufacturing equipment and systems.

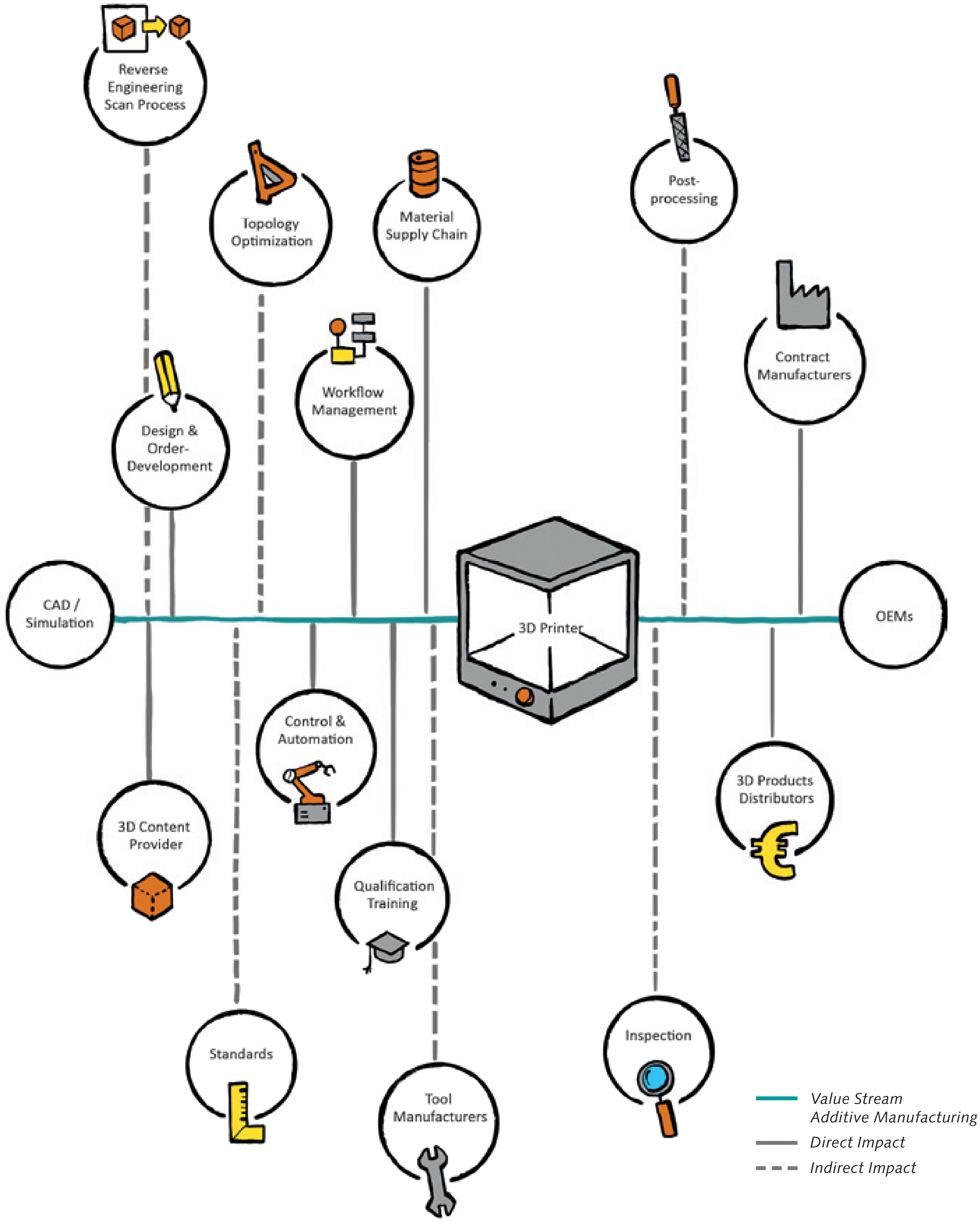
However, at this point people often enough dismiss this growth as being primarily generated by prototyping and the production of expensive or highly complex components. They continue to add that additive manufacturing, in relation to the overall volume of production, is still a negligible market segment, limited to specific production tasks and driven by grand visions and insignificant results. And that additive manufacturing on an industrial scale is a rather capital-intensive and sophisticated technology that wouldn't work at the "flick of a switch".

There is an element of truth in this, but we shouldn't just take the easy road since the real picture is changing radically, and there is increasing evidence for this. There are many reasons to believe that large-format 3D printing will gain a firm hold in industry as a manufacturing process and that many established forms of organization and process as well as profitability calculations and supply chains will be challenged. For companies that systematically engage with the new technology, 3D printing has already found entry into the design stages and is influencing the value chain from procurement through to after-sales service. In relation to the extend and planning of the integration process, the impact of the technology on an organization will be distinctly felt – for example through the elimination of entire production steps and the localization of manufacturing, the shortening of value chains through increased vertical integration, new qualification requirements and team structures, or the emergence of new process-based, technical interfaces to customers.

Nevertheless, the fact that a purposeful and well planned deployment of 3D printing provides tangible benefits is just one side of the coin. The other side of the coin is that the technology allows us to take a completely new look at supposed invariants. The question here is, for example, whether classical series production needs really large factory buildings. From the perspective of overall costs doesn't it pay off more to opt for small, local production sites with 3D technology instead of outsourcing or bought-in parts? Is it possible to devise an extremely customer focused production process without extensive investments in new infrastructure? Can fully automated 3D foundries be set up by combining additive manufacturing and other Industry 4.0 technologies? Is it possible to operate outside of typical hierarchies and team structures in production?

Of course, many solutions based on 3D printing are currently too slow or too costly in order to break up structures across the whole of industry. However, they show that these fractures are in principle possible, while the technology grows more cost-effective and powerful by the year. In other words – scenarios counting on an extensive integration of additive manufacturing are currently not an imperative for every segment of the value chain or for every company. But at the same time, it is not an option to avoid thinking about such scenarios.

ADDITIVE MANUFACTURING ECOSYSTEM



3D PRINTING: STRONG MOMENTUM

Fresh impetus for the future development of additive manufacturing

Additive manufacturing is fascinating in particular because of the virtually infinite range of products. Apparel, mountings for jet turbines, automotive bodywork components, titanium implants for human bones and many other innovative products are impressive proof of the range of possible applications in almost all areas of life. However, anyone wishing to understand the development potential of the technology should direct his gaze beyond the products range to the extensive ecosystem that supports 3D printing. Factors like design & order development and workflow management have a direct effect on the evolution of 3D printing, while factors like standardization have an indirect effect (see figure on p. 4).

"As in any ecosystem, also in additive manufacturing the complexity and momentum of many elements make it difficult to predict the next stage of development. However, some trends are becoming more noticeable," says Anselm Magel, expert for 3D printing at ROI Management Consulting AG. "Simulation software, for example, is playing an increasingly important role for melt pools and the process of powder bed-based laser melting. Thanks to the software it is possible to simulate tension, distortion and the microstructures of metal parts on a computer and as a consequence eliminate errors long before manufacture."

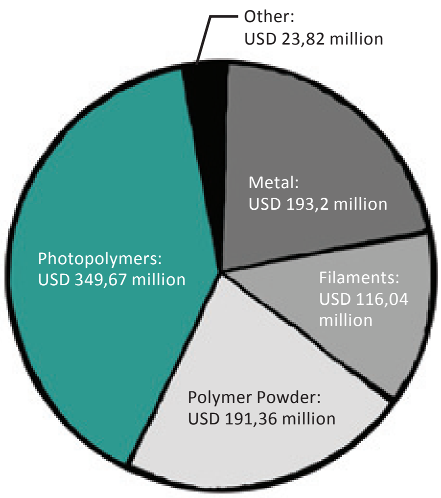
Other core trends include topology optimization of functional parts or the new technology of electrolytic metal powder production, which is significantly more cost-efficient than gas or plasma atomization that predominates nowadays. The standardization of a new file format by the 3MF Consortium intended to replace the outdated STL format is also having a positive effect.

High Development Potential: Metals

"Besides the currently dominant polymers, metals are the key raw materials for the next development steps of the technology," Magel emphasizes. "Five process variables will determine the design of the production process: metal powder characteristics, jet performance, the speed at which the jet travels, the layer height or speed of material feed, local geometry and the temperature of the parts at the melting point." Here, the switch from empirical to simulation-driven additive manufacturing becomes essential. Process simulation helps modelling the structural characteristics of the selected metal like heat build-up, displacement, residual tension and crystalline structure.

"Also exciting are the possibilities of in-line quality and process monitoring and control that will soon be available. Metal processing additive manufacturing systems are currently not fitted with any sensors, or only with thermal elements in the thermal chamber, and products are made using a linear feed method. In the next few years it will be possible to measures the temperature, the precision of the geometry and the state of the powder bed before and after the melting process, i.e. during the production process. These data can then be used to correct the construction job during the process, vastly improving quality and production speed," Magel explains.

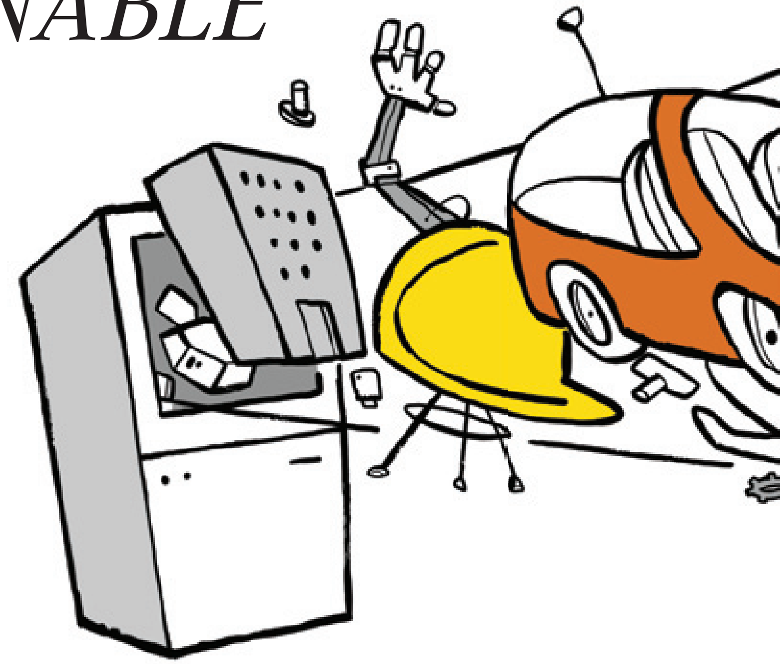
In future, Magel expects to see repeatable production processes, reproducibility on other equipment and high-quality production results as a consequence of the interplay of future innovations, like in material powders or in manipulating material microstructures and porosity. We can also assume an exponential increase in the speed of manufacturing 3D-printed products. "Optimizing manufacturing process variables will make it possible to achieve four- to five-fold growth in production speed for metal process systems – and, depending on the object and size of the series, the decrease in costs per part is likely to be in the double-digit range."



Market size of 3D printer materials in 2015: approx. USD 874 million (source: ROI, Wohlers Assoc.)

“3D PRINTING OFFERS VIRTUALLY INFINITE OPPORTUNITIES OF IMPROVING OUR LIVES AND MAKING THEM MORE SUSTAINABLE”

Interview with Christian Kirner,
Chief Operating Officer (COO), EOS GmbH



DIALOG: *Mr. Kirner, additive manufacturing is seen as one of the most promising emerging technologies. EOS has been on the market for over 25 years now. What are the main reasons for additive manufacturing attracting such huge attention in recent years?*

CK: After finding widespread use primarily in prototype construction in the first 20 years, where it significantly speeded up product development, the technology has now reached a level of maturity allowing customers to produce end parts in series. Leading global corporations and DAX-listed companies have begun qualifying this technology for pilot production around five years ago. And now there are the first genuine series applications, for example in the aerospace and medical sectors. The general hype around “3D printing” has been huge in recent years, and interest in the technology has continuously and massively increased.

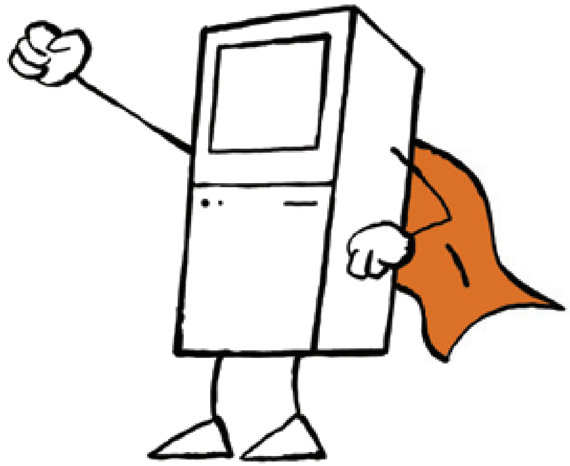
DIALOG: *What do you consider to be the most important milestones in the development of 3D technology over the last 25 years?*

CK: Of course we can only speak for ourselves here as it’s difficult to speak about “the one method of 3D printing” in such a diversified market. There have been many milestones in our company history that helped us take the next step: the first major customer, BMW, for whom EOS supplied a stereolithography system, and the recommendations to other companies that followed on from this; the decision to quit stereolithography and to concentrate solely on the higher quality, powder-based laser-sintering process; the decision to also develop the metal process alongside the plastics process. And finally the move into series applications that are today primarily based around metallic materials.

DIALOG: *What are the biggest obstacles preventing the widespread proliferation of the technology, and what can manufacturers do to break down those obstacles?*

CK: We currently consider the topic of knowledge development among customers to be the biggest obstacle. Our technology is still quite new. Customers need to take a number of decisions beforehand in order to ultimately achieve real added value with our technology. What is the right component and the right application for using EOS technology? What engineering guidelines need to be considered in order to make optimum use of all the degrees of freedom offered by additive manufacturing? What needs to be changed in a company's organizational structure? How would customers need to modify their business models based on the technology? And finally, the machine operators need to be trained up perfectly and expertise developed in order to produce high-quality components using this cutting-edge technology. Additive manufacturing remains highly complex since you can't just create a component at the press of a button. In all these matters, EOS will support its customers with extensive consulting services.

> "Additive manufacturing remains highly complex since you can't just create a component at the press of a button."



DIALOG: *Companies like "Local Motors" are demonstrating that even automotive industry concepts can be re-thought through 3D printing. Do you believe that the propagation of 3D printing is likely to bring major changes to industrial value chains in the coming years?*

CK: Additive manufacturing is already changing the way in which design and production is performed for many applications. The next few years will see the growing integration of conventional and additive processes as production becomes increasingly digitalized. Instead of replacing one technology with another, the best of both worlds will be used to achieve the best possible result. This will allow additive manufacturing to enrich and extend the prospects of industrial value creation.

"The next few years will see growing the integration of conventional and additive processes as production becomes increasingly digitalized."

Christian Kirner,
Chief Operating Officer
(COO), EOS GmbH

DIALOG: *Where will this take EOS and what strategic direction will you follow in the next few years?*

CK: While pursuing the EOS strategy of introducing additive manufacturing methods to all industrial sectors, we have, for example, developed a groundbreaking metal system, the EOS M 400-4. The system is the perfect addition to our system portfolio for industrial deployment. It eliminates all the previous limits on manufacturing as it meets the very highest demands of our industrial partners in terms of efficiency, scalability, ease of use, and process monitoring. And what is more, since the system is based on a modular platform designed for 3D printing. It can be integrated into existing production environments and is, at the same time, designed to enable future innovation at the customer's end.

DIALOG: *You yourself have been accompanying and observing global technological trends for a number of decades. What does 3D printing mean personally for you? What is so intriguing about it?*

CK: I consider the potential that additive manufacturing offers to be really huge. 3D printing provides virtually infinite and yet unknown possibilities of improving our lives and making them more sustainable. In the context of Industry 4.0 and the Internet of Things (IoT), 3D printing will become a historic milestone over the medium term not just for the industry but ultimately for society as a whole. The technology and its benefits will be firmly embedded in our thinking and actions, just like smartphones and 2D printers today.

About EOS

EOS is the global technology and quality leader for high-end additive manufacturing (AM) solutions. The company enables its customers to manufacture high-quality and innovative products based on the industrial 3D printing processes. Founded in 1989, EOS is a pioneer and global leader in the area of direct metal laser sintering (DMLS), and also a provider of a leading polymer technology.
www.eos.info

POTENTIAL FOR CREATIVE TRANSFORMATION

More than just gimmicks – the use of 3D printing components in industry

Passengers with Dutch airline KLM can enjoy a very special service. Up in the skies the cabin crew serves ice-cold beer from a beer trolley that was made by a 3D printer. However, the "BrewLock Keg" the will remain a "3D printing gimmick" for the foreseeable future due to its high cost of manufacture. It remains to be seen whether series production will be cost-efficient.

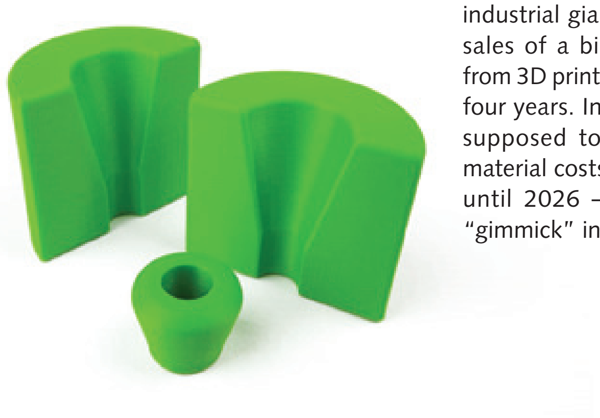
However, this example of use demonstrates quite clearly how the subject of "additive manufacturing" is perceived today. While the public often see exotic printed products like mini portrait statues, or now beer kegs, as expensive one-off fabrications without the potential for series production, industry has already moved significantly farther. For example, the cabins of two A350 XWB passenger airliners that Airbus delivered to Qatar Airways at the end of 2014 each contain over 1,000 parts made from thermoplast that were produced by 3D printing. Besides making the supply chain more flexible, this is meant to significantly cut production times and costs.

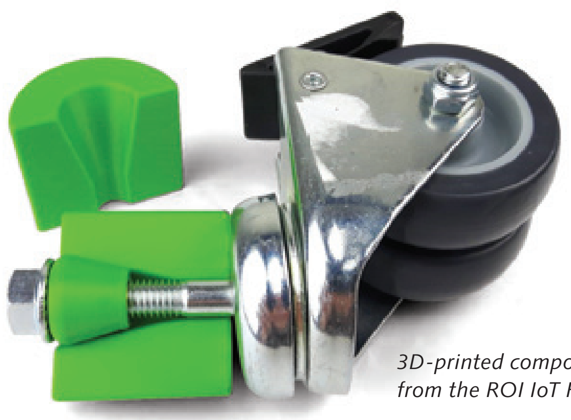
These and other benefits are of course attractive not just for aerospace companies alone. The semiconductor industry, the automotive sector and medical engineering are already among the growth markets for 3D printing methods. "3D printing has the potential for the creative transformation of traditional engineering and manufacturing processes – even in key industries that have so far seen the subject as exotic or of limited interest," says Anselm Magel, expert for 3D printing at ROI Management Consulting AG. "There are various scenarios of application along the value chain that may be a suitable point of entry. Two areas of application can be profitable in particular – design optimization and lightweight construction design of components, as well as shortening paths in the supply chain."

It is crucial to focus on the functional benefits and cost drivers for components. What superior functionality can be designed? What parts are particularly complex and therefore expensive to manufacture or maintain? Are there high fixed costs, e.g. for tools? Which components are produced in small numbers? How can individual customer requirements be met? Switching to additive manufacturing can open up significant opportunities in all these areas – opportunities that you will recognize when you are open for change and prepared to experiment.

Additive manufacturing also shortens the supply chain. Critical parts for the manufacturing process may be produced in house instead of purchasing them from a single source of supply. With just-in-time production of parts using a 3D printer on premise may in future avoid long delivery times for spare parts that cause high downtime costs.

"Current developments entailing repeatable manufacturing processes, reproducibility on other machinery and higher-quality results will trigger further market growth," Magel points out. The future viability of the technology is confirmed by the market entry of a global company like General Electric (GE). The industrial giant plans to generate annual sales of a billion dollars with products from 3D printing processes within the next four years. In addition, the technology is supposed to reduce the corporation's material costs by up to five billion dollars until 2026 – which is anything but a "gimmick" in terms of the bottom line.





3D-printed components from the ROI IoT Fab

"OPPORTUNITY FOR GERMANY AS A CENTER FOR TECHNOLOGICAL INNOVATION"

Interview with Dr. Thomas Jüngling, CEO, H.C. Starck Surface Technology and Ceramic Powders GmbH

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DIALOG: *Dr. Jüngling, global sales of products and services in the field of additive manufacturing remained constant at a relatively low level for almost three decades – something which is typical for a niche technology. However, the market has picked up speed at an incredible rate in the last three to four years. What are the reasons for this?*

TJ: The technology of additive manufacturing has now reached a stage that allows complex components to be produced with high and repeat precision. Compared to conventional manufacturing the additional design possibilities are resulting in technical progress and delivering new solutions that create potentially high competitive advantages.

DIALOG: *H.C. Starck has been involved not just in the manufacture of technology metals and metal powder solutions but also in advanced ceramics and thermal spray powders for additive manufacturing for decades. What direction is the demand for 3D printing base materials taking and what trends do you anticipate over the next few years?*

TJ: Demand is currently concentrated on titanium alloys, nickel-based super alloys, high-strength steels and stainless steels, as well as a range of customer-specific special alloys based on refractory metals. These may well also be joined hard metal allows in future.

DIALOG: *Technologies like desktop production performed by end users are still at a relatively early stage. What's your opinion on the chances of these methods and to what degree are you looking into them?*

TJ: This concept is likely to be promising for components that are required in low numbers or which are needed in many locations far apart from eachother. From our point of view, the supply chain delivering to operators of the equipment can be easily organized and is comparable to thermal spraying logistics in other markets. We have a great deal of experience helping us to develop market-specific concepts.

DIALOG: *Does 3D printing have the potential to change the basic premises of industrial manufacturing?*

TJ: Additive manufacturing will not be able to replace conventional means of production. It is more likely to complement them and enable innovative technical solutions that may have considerable importance in conserving resources and raising energy efficiency.

DIALOG: *How is the growth of the 3D printing market affecting your own company? Where is your main focus for research and development and what structural adjustments are required?*

TJ: We are building up a market-focused sales team in our company that acts as a point of contact for all market players, from plant manufacturer and service office to plant operator and manufacturing company. We have test facilities for testing new alloys where small batches of alloy can be accurately produced and optimized already using the subsequently required mass production technology.

DIALOG: *As always with technology hype, there is a danger of overheating and excessive expectations. On which promises will 3D printing not be able to carry through and where are the limits to growth?*

TJ: The technology of additive manufacturing is certain to continue to develop in terms of efficiency and design possibilities. Applying functional components to conventionally manufactured parts and integrating additive manufacturing into production lines make significant growth potential possible. The cost-efficient production of high-quality, custom powder raw materials will play a major role for successful growth.

DIALOG: *Many of the raw materials that H.C. Starck produces and which are needed for the metal powders used in 3D printing come from politically unstable regions. How is your company addressing the issue of supply reliability?*

TJ: H.C. Starck's strategy for procuring raw materials is based on two principles: the continuous expansion of recycling activities, and the purchase of raw materials exclusively from suppliers with environmentally and socially sound business practices.

The stringent, globally applicable procurement guidelines detailed in the Responsible Supply Chain Management System (RSCM) guarantee that H.C. Starck buys raw materials only from suppliers who comply with strict requirements with regard to environmental protection, occupational safety and social responsibility. Here H.C. Starck refers, among other things, to the positions set out by the Electronic Industry Citizenship Coalition (EICC) and the Organisation for Economic Co-operation and Development (OECD). And H.C. Starck won't budge a single inch from this stance, even when faced with a shortage of resources, export quotas, and price fluctuations.

H.C. Starck's tantalum and tungsten supply chain has been declared free of "conflict minerals" following an independent audit by a third-party auditor commissioned by the Conflict Free Sourcing Initiative (CFSI), a joint effort by the EICC and the Global e-Sustainability Initiative (GeSI).

DIALOG: *And finally a personal question: What do you find so fascinating about 3D printing technology?*

TJ: The new possibilities for engineers to design technically innovative systems. I think we can look forward to a great many solutions that would not be conceivable or feasible with conventional methods. Anyone acting quickly with a good idea can gain significant competitive advantage. This is indeed an opportunity for Germany as a center for technological innovation.

Dr. Thomas Jüngling, CEO, H.C. Starck Surface Technology and Ceramic Powders GmbH

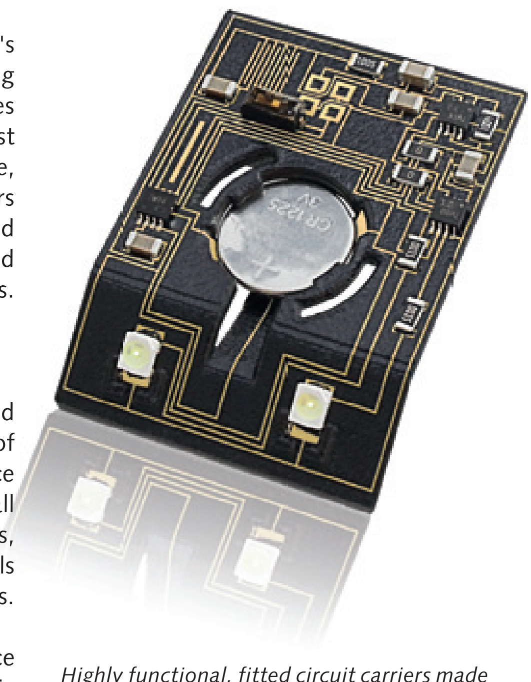
About H.C. Starck Surface Technology & Ceramic Powders

The H.C. Starck Surface Technology & Ceramic Powders GmbH offers a wide variety of thermal spray powders and complementary coating technology materials, as well as the most extensive non-oxide ceramic powder portfolio for advanced ceramics and high-end applications and also atomized metal powders for a broad scope of innovative technologies.
www.hcstarck.com

MULTIDIMENSIONAL CIRCUIT CARRIERS USING ADDITIVE MANUFACTURING

Beta LAYOUT: Prototypes for new printed circuit boards (PCBs) created with EOS technology

At the beginning of 2016, many people were writing about the end of Moore's Law, anticipating that the performance of computer chips would no longer be doubling every two years. The reason for this is that the structures on the processors themselves are already within a few nanometers of what is possible. Further reductions are almost impossible from a technical point of view. In order to continue improving performance, manufacturers are working on the architecture, which stacks multiple structural layers on top of one another. A similar approach has already been established within the field of circuit carriers. The German firm of Beta LAYOUT GmbH has successfully harnessed EOS technology to manufacture and test the prototypes for these innovative carriers.

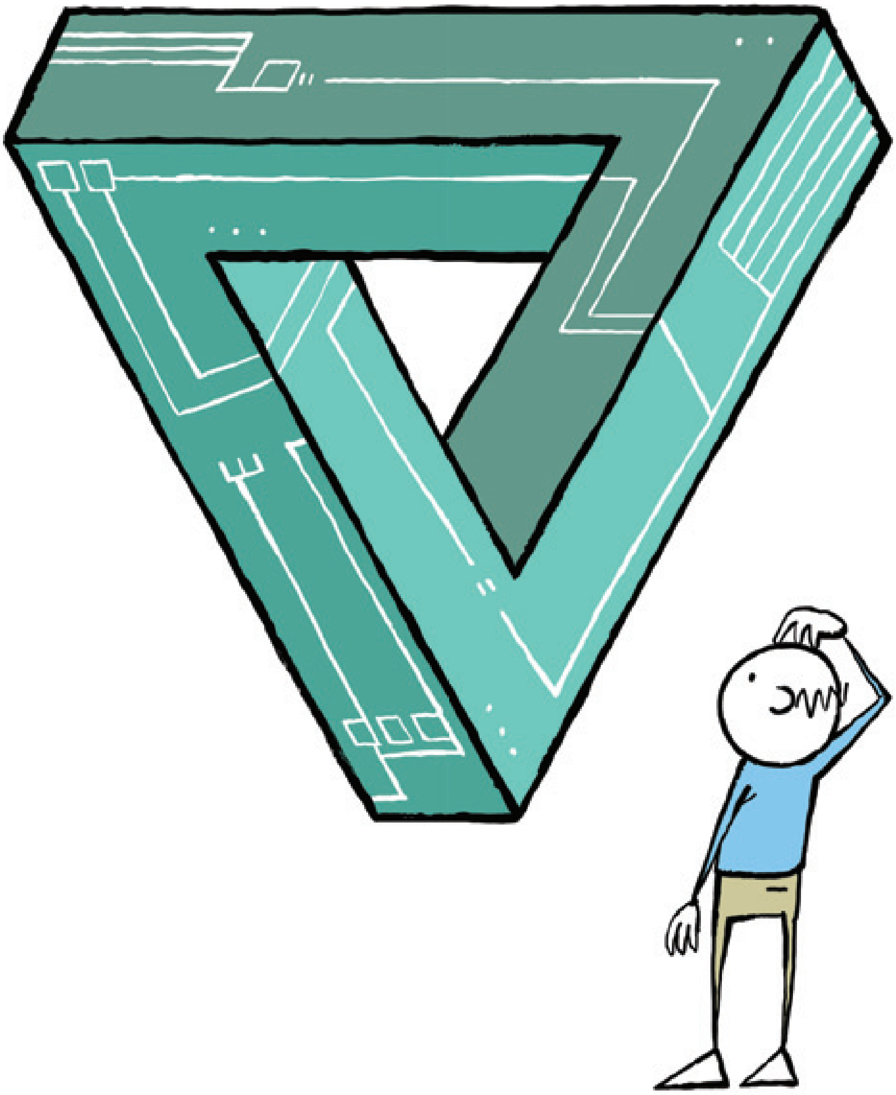


Highly functional, fitted circuit carriers made of PA 3200 GF by using additive manufacturing technology (source: Beta LAYOUT)

Challenge

Circuit carriers and traditional PCBs have always been a little overshadowed by the microprocessors that operate on them. This is somewhat unjust because, of course, having the best brain is of little use without the benefits of a high-performance central nervous system. It's a similar story in the microelectronics sector: almost all contemporary devices require a circuit board in order to incorporate one or more chips, plus the additionally required electrical components. This creates a network that fulfills a range of tasks, from supplying of electricity, circuitry, through to the output of signals.

In new devices, there is often only a very small amount of installation space available for conventional circuit boards. One reason for this is that a lot of electronic equipment is becoming ever smaller; and even when the form itself is larger, there tends to be very little space left over for the actual electronics. The existing volume is required for housing screens, for example, more and more interfaces and output points, as well as larger batteries. The time when a simple lab PCB was sufficient for the experimental construction of new circuitry are now, in most cases and most sectors, long gone. Alongside the available installation space, weight is a key factor – compact, three-dimensionally constructed circuit boards also have an important role to play here.



With contemporary electronic products, the circuitry often has to compete for the limited space within the housing. When conventionally stacked, PCBs can no longer accommodate all of the necessary components, so that the aforementioned three-dimensional circuit carriers become the solution of choice. Here again, the ever-shorter life cycles of many devices pose additional challenges: injection molding is far too expensive to manufacture prototypes. For this reason, Beta LAYOUT GmbH decided to search for a cheaper, high-performance alternative.

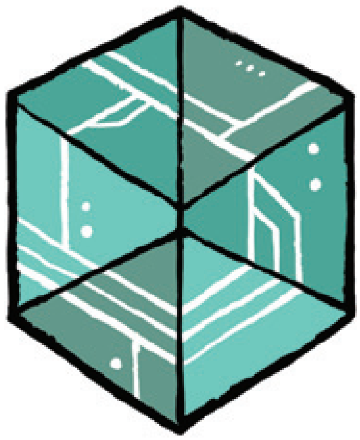
Solution

There is no technology better suited to the demands of multi-layer architecture than additive manufacturing. This is because it uses a laser to build up a component, layer by layer. This is why Beta LAYOUT relies on the technology and uses plastic parts manufactured by 3D printing. The innovation takes place after the printing process itself; once they've been made, the models are coated with a special finish that is furnished with an additive. The subsequent so-called 'laser direct structuring' (LDS) generates layouts, which can be turned into conductor tracks by activating the finish.

The laser triggers a physical-chemical reaction that creates metallic spores while simultaneously roughening the surface. After laser direct structuring, the models are placed in a copper bath free of electric current. There, copper particles are deposited on the previously activated areas to create conductor tracks. After copper coating, the conductor tracks can undergo further copper plating through galvanization, or be directly furnished with a surface finish. After this, Beta LAYOUT then adds the individual components to the unit in the company's internal assembly department. The finished pieces serve as initial prototypes and models, allowing function testing and a check of design layouts.

"We offer manufacturing of 3D-MID (mechatronic integrated devices) as prototypes for diverse companies," explains Manuel Martin, Product Manager 3D-MID at Beta LAYOUT GmbH. "Working with EOS' FORMIGA P 110, we are in a position to deliver high-quality products to our customers fast. What's particularly practical in all this is that we are even able to deal with orders of 3D models via websites and online shops. Additive manufacturing has enabled us to successfully expand our business model."

Results



Whether for individual developers or large established companies, additive manufacturing ensures that custom-made circuit carriers can be used for the prototypes of new electronic devices. The plastic components can be produced quickly and at an attractive price. The process simultaneously offers the nessary level of precision and high component-quality, allowing the required basic body to be manufactured as if it were already a close-to series product – an aspect that should not be underestimated, particularly with test runs.

The EOS technology also provides a high degree of flexibility: the machine used is able to process various materials, including, for example, PA 3200 GF which is filled with glass beads, or the aluminum-filled polyamide Alumide. High-performance polymers such as PEEK and various metals are also available. The crucial point is that all the materials are capable of withstanding high temperatures, a limitation of the injection-molding process in series production. Because of this flexibility, Beta LAYOUT is able to fulfill the various individual requirements of its customers, for example, by responding to the particular characteristics of the intended purpose of the circuit carrier. In this way, the company can develop individual, optimized solutions, be this in terms of lower costs, a higher degree of temperature resistance, or any other specific requirements.

Besides these advantages, additive manufacturing also offers another additional bonus: "Ultimately, what we are experiencing here is a democratization of advanced technology. Without innovations such as this, we would not be able to offer 3D-MID as a service at all," says Manuel Martin. "This would mean that many smaller companies and development houses would have no chance of realizing such prototypes. Consequently, the much talked-about innovation and creative power of small and medium-sized companies would lose momentum and the research and development sector would be a lot less dynamic." Additive manufacturing is a catalyst for further innovation– and, in this way, perhaps a point of departure towards establishing a new Moore's Law.

Manufacturing steps for mechatronic integrated devices (MID) via laser direct structuring (source: Beta LAYOUT)

About Beta LAYOUT

Beta LAYOUT GmbH is a leading manufacturer of printed circuit boards and 3D-MID prototypes, and a provider of 3D printing services.
www.beta-layout.com

FROM PROTOTYPING TO MANUFACTURING

Guidelines for using 3D printing within a company

BMW used 3D printing to manufacture prototype parts for concept cars as far back as the early 1990s. Because the technology enabled ideas to be visualized significantly faster and less expensively than with plywood, molded or polystyrene models. This 'prototyping' function of the technology has now developed far beyond the boundaries of R&D. Conventional technologies like milling, molding, drilling and turning can be replaced by 3D printing.

Networked with 3D printer: Arduino boards with sensors for measuring light, temperature and movement in the ROI IoT Fab

"3D printing technologies are creating opportunities for companies as 'manufacturers' to shape their production structures more openly and flexibly," says Hans-Georg Scheibe, Member of the Management Board of ROI Management Consulting AG. "Effects of scale are a thing of the past. 3D printing is overhauling conventional manufacturing logic, according to which a product only becomes profitable in large series. At the same time, less material and energy are being wasted as there is no machining waste as in drilling or milling operations." Companies should focus on customer requirements and follow the steps set out below when developing 3D printing sample construction solutions:

- Create a proof of concept (PoC) for the desired parts with all the key factors such a size, properties, surface, form, tolerances. Strictly observe a period of five weeks to complete the process.
- Divide PoC and implementation work into small experiments with explicitly defined tolerances.
- Systematically develop the required skills in a cross-functional core team with few hierarchy levels.

The core team should bundle all the required skills from the beginning of the first project and should possibly involve external service providers. Particularly important competencies are: design expertise in digital direct manufacturing and know-how in machine operation for in-house manufacturing, materials expertise, supply chain expertise, quality management, product management and training skills for digital direct manufacturing. Skills bought-in from outside can then be gradually replaced with internal skills as the number of projects and the share of additive manufacturing grow.

"How quickly and how well 3D printing can be implemented will of course depend on the degree of expertise already available in the company," says Anselm Magel, expert for 3D printing at ROI Management Consulting AG. "When only little experience is present, a core team should start defining just a couple of basic elements of digitalized production and approaches to additive manufacturing. It will soon become clear what can be realized quickly with the customer – and what needs to be deferred for the time being as vision."

Checklist: nine checkpoints for digitalized production and approaches to additive manufacturing.

1. Examination of active tools, functional parts and sub-assemblies. What can be produced using additive manufacturing and what are the benefits in terms of cost, time, quality and functionality?
2. Design optimization and lightweight construction design. How can functional parts and subassemblies be improved?
3. Simulation-driven additive manufacturing. How can tools, functional parts and sub-assemblies be produced without empirical tests?
4. Design certification. How can functional parts and sub-assemblies be certified before they are generated?
5. Object procurement. Can the desired design object be purchased on the market?
6. License management. Is a secure object search ensured as well as a transfer to printer and other systems?
7. Local production. What printers are required and available at which locations?
8. In-line process & quality control. How will produced parts be tested during the process?
9. Automation of post-processing. How can the automated manufacturing of parts be successfully completed with full traceability?

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Person responsible for content under German press law:
Hans-Georg Scheibe

ROI Management Consulting AG
Infanteriestraße 11, D-80797 München
Phone: +49 (0) 89 12 15 90 0, E-mail: dialog@roi.de

Management Board: Michael Jung, Hans-Georg Scheibe