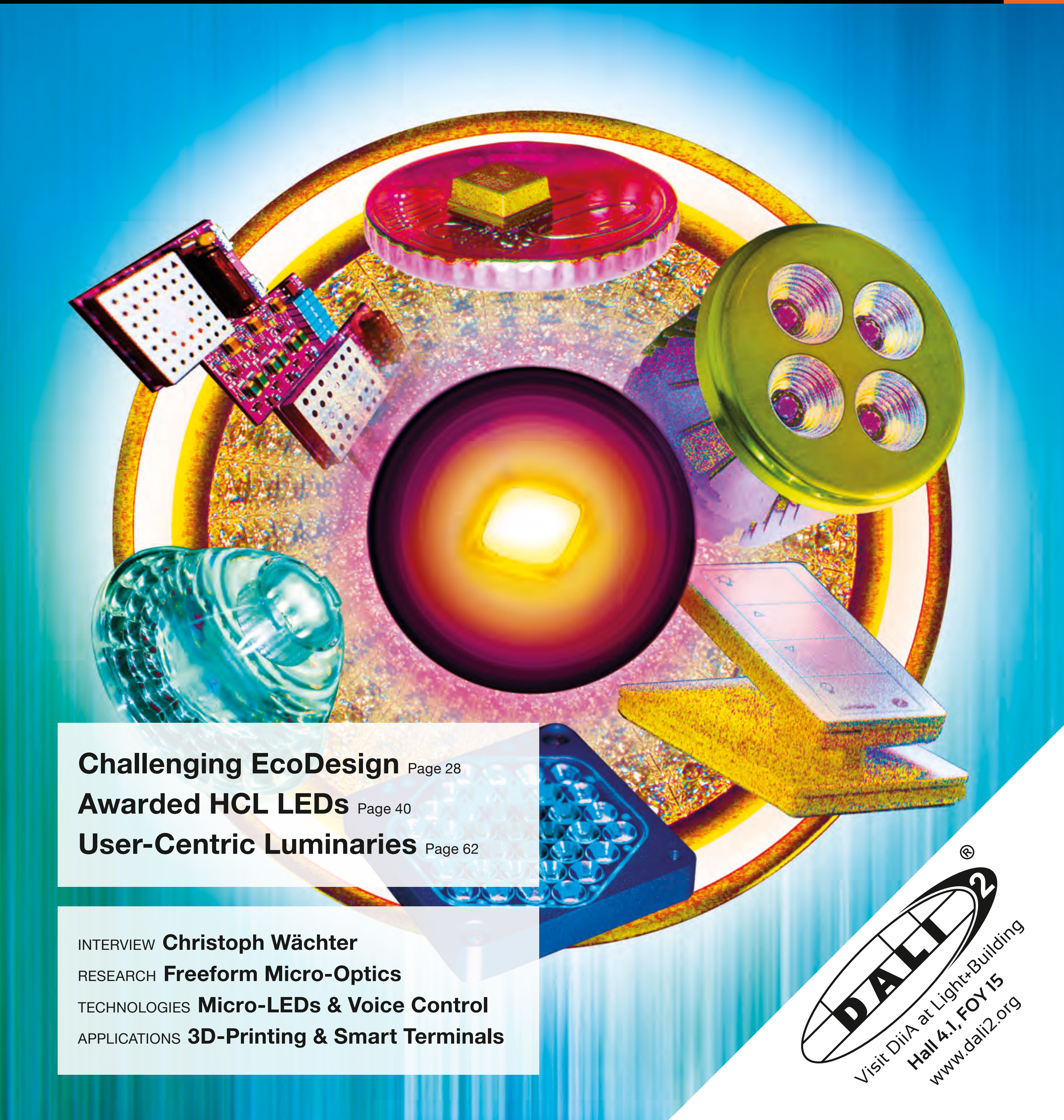
LED professional

www.led-professional.com
ISSN 1993-890X

Review

LpR
The Global Information Hub for Lighting Technologies
Jan/Feb 2020 | Issue 77



Light for the Third Industrial Revolution

The third industrial revolution is in full swing, characterized by three major technological advances occurring almost simultaneously: new energy sources, new communication channels and new transport options. Renewable energy sources such as solar energy, wind energy etc., the world of the Internet and IoT and self-propelled traffic on land and in the air show these developments in concrete terms.

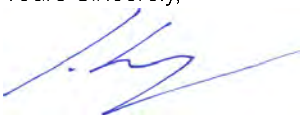
The third industrial revolution inevitably goes hand in hand with concrete solutions to protect nature and the environment at its core, to guard our habitat for future generations as well as for ourselves. This is a major challenge. Economic development and sustainability must be closely linked in the future. Applied to the topic of light the question is how and with what the light sector – Photonics – can contribute. From my point of view, the light sector has significant influence on the future development of our planet.

In lighting, the major application areas are Human Centric Lighting, Automotive Lighting, Horticulture Lighting, and UV/IR Applications – all in terms of Internet/IoT networked systems. Miniaturization is currently making a quantum leap with Extreme Ultra Violet Light (EUV) in which future semiconductor structures can be reduced by factors. High-energy pulsed lasers also open up completely new application possibilities. Light, in all its technological and application diversity, holds enormous opportunities and potential. In combination with the development of sustainable systems, we can make a major positive contribution to the future.

We touch on some of these topics in this issue and throughout the year we will also be covering the ones mentioned above.

In closing I'd like to wish all our readers a great start to the New Year. May 2020 be successful for you in all aspects of your lives.

Yours Sincerely,



Siegfried Luger

Luger Research e.U., Founder & CEO
LED professional, Trends in Lighting & Global Lighting Directory
LpS 2020 & TiL 2020
Photonics21, Member of the Board of Stakeholders
Int. Solid-State Lighting Alliance (ISA), Member of the Board of Advisors

3D Printing: New Disruptive Fabrication Technologies for a Novel Design Approach

Some manufacturing technologies and tools that were only used in pre-production or prototyping for a long time have become state-of-the-art for mass production. 3D printing is one such technology. Lighting designer, Ruairí O'Brien, stated that, in his opinion, this could be a risk for the business of traditional luminary manufacturers if they don't adapt. In response, we asked the specialists in this field, Claudio Pucci, designer, and Eng.D. Enrico Cozzoni (PhD), senior scientist and aerospace engineer at Grado Zero Espace to write an article to explain what state-of-the-art really is, what is possible, where the current limits are, and what the prospects are.

Rapid production, and its different forms, has been moving steadily toward a mainstream manufacturing technique. It is a disruptive technology that has the potential to affect a range of industries, introducing and extending the limitations of the actual Design & Production paradigm. In addition, it can easily produce customized and personalized objects, starting from any type of digital model, also and especially objects that were previously mere design concepts.

General Introduction to Rapid prototyping and Production

There has been ample research on rapid production in areas like materials and processes (Norton 2001), but previous studies have not paid sufficient attention to increasing the understanding of what the aspects beyond manufacturing are that need to be addressed in order to successfully adopt novel rapid production technologies. For instance, Bogue (2013) points out that 3D Printing technology is being used in a variety of applications, which basically fall into two broad categories: Rapid Prototyping and Component Manufacturing. While it is possible to consider rapid production as an effective transition in the product manufacturing, it is also fundamental to decompose it into five consecutive evolutionary steps that should be understood, to capitalize on the potential associated with rapid production technologies.

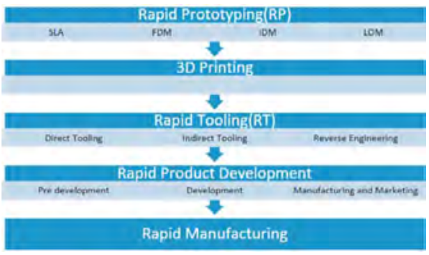


Figure 1: Evolutionary steps in Rapid Production (courtesy of Muita et Al. 2015)

We will examine three of these evolutionary steps.

Rapid Prototyping (RP)

The first domain we will introduce is that of Rapid Prototyping (RP), where this term is used to describe the process of rapidly creating a system or part representation before final release or commercialization (Gibson 2010). In product development, Rapid Prototyping refers to technologies that create physical prototypes from digital data simulations. Furthermore, it allows users to test prototypes of different versions of the models before full-scale manufacturing. Prototyping is an essential part of the product development and manufacturing cycle required for assessing the form, fit, and functionality of a design before a significant investment in tooling and production is made (Pham & Gault 1998). Rapid prototypes, i.e., goods derived from Rapid Prototyping, are mostly applied in design and development, product evaluation, production and process analysis, and manufacture tooling fabrication.

The application fields for Rapid Prototyping, that span from Electronics to Consumer Goods, are growing, overcoming the previous limited use of the technologies, mainly due to a gap in the quality, strength, and volume of the goods produced using the available Rapid Prototyping technologies. The main reason is that Rapid Prototyping processes have already shortened turnaround times and lowered costs, against a growing quality of the final product. These factors bring about significant time and cost savings in product testing and development, enhancing the competitive advantage of a firm.

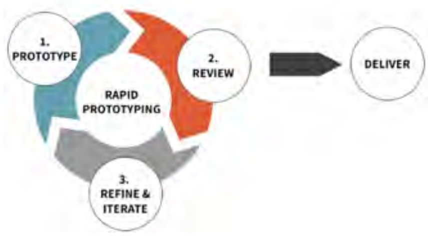


Figure 2: Rapid Prototyping cycle

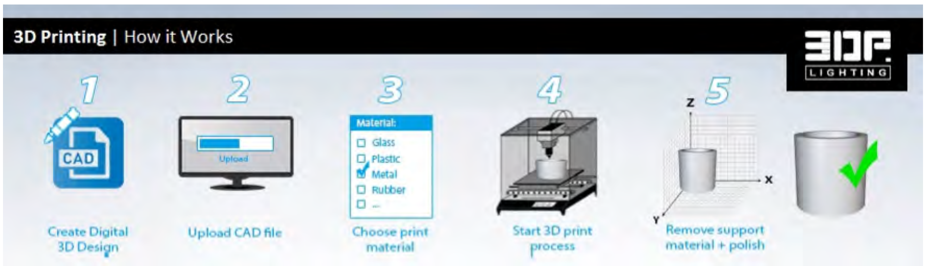


Figure 3: 3D Printing steps (courtesy of 3DP-Lighting)

Rapid Prototyping comprises several different processes that can be categorized into ten main categories (Labgraph 2014). Stereo lithography (SLA) is notably the most popular Rapid Prototyping process, because it is perfect for fit and form testing or show models. Selective Laser Sintering (SLS) and Selective Laser Melting (SLM), is a family of layer-wise material addition techniques that allows generating complex 3D parts by selectively consolidating successive layers of powder material on top of each other, using thermal energy supplied by a focused and computer-controlled laser beam. SLS and SLM are commonly used for prototyping and production applications. Fused Deposition Modeling (FDM), which works on an additive principle by laying down material in layers, is also commonly used for modeling, prototyping, and production applications. Inkjet Material Deposition (IDM) is an emerging technique in which inkjet technology is used to deposit materials on substrates. In Laminated Object Manufacturing (LOM), layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter.

3D Printing

3D Printing or Additive Manufacturing (AM) is used to convert a 3D model into a three-dimensional object through additive processes in which successive layers of material or droplets are laid down under artificial intelligence. The 3D Printing process is quite simple: in fact, 3D Printing is based on the idea of adding material: building up a product “layer-wise”, or for precision manufacturing, such as printed optics, even with “droplets-on-demand”. This method is used rather than starting with a solid block or sheet of material and then removing the material that you don’t want, such as machining.

The material used for this purpose is called 3D printing material. 3D printers can use a wide range of materials, including plastics, resins, metals, ceramics and many more. Today, the most popular material is plastic, and most of the desktop style printers print objects using plastic. However, some of the higher-end printers are capable of printing using many different materials. Currently printers support over 100 different materials.

Using 3D Printing equipment today, you can already choose from a great variety of materials, those presented above, to create your objects, with many more new materials on the rise. Having a digital CAD file that specifies the exact shape contours and complexity of the product to be printed is only one step from the digital design process towards the real end product.

In contrast, current manufacturing processes use a subtractive approach that includes a combination of grinding, forging, bending, molding, cutting, welding, gluing, and assembling (CSC 2012). The use of 3D Printing in a variety of sectors is rapidly gaining momentum; for example, it provides a fast and cost-efficient means of fabricating parts of machinery and instruments with customized design (Bogue 2013). 3D Printing’s rapid evolution can be attributed to mainly two features:

- Control of how the ingredients are deposited
- Its flexibility to manufacture different products, contrasting it to traditional manufacturing methods, in which the production line must be customized and tailored if the product line is changed, requiring expensive investment in tooling and long factory down-time (CSC 2012)

There are various machines that can be used in 3D Printing. The main difference between them is related to how the layers are built up. Unlike a laser that draws a single line to convert material, 3D printers leverage their raster scan print head architecture to increase the amount of converted material (Bak 2003). Each layer

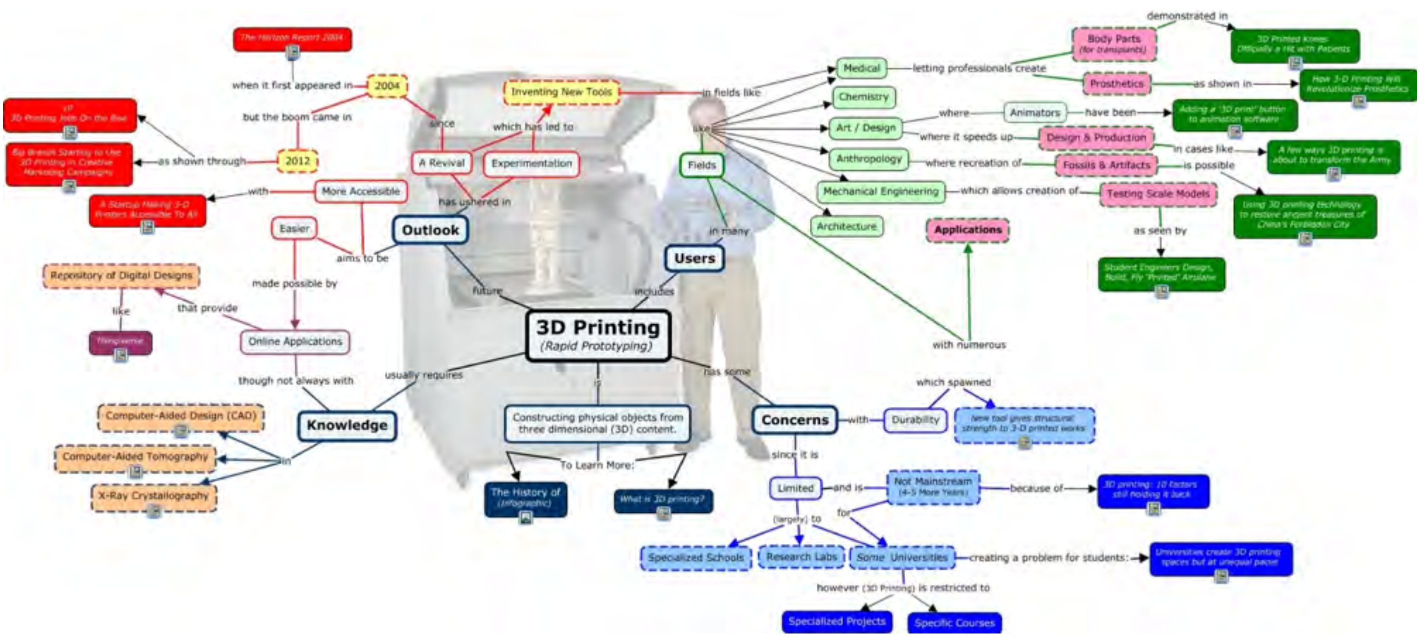


Figure 4: 3D Printing conceptual map


Figure 5: 3D Printing of metal housing for a pendant solution (courtesy of Grado Zero Espace, Repro-Light project)


Figure 6: 3D Printing one-piece heat sinks for lighting applications

is added until the object is fully printed or 'manufactured' with an extruder (fused filament), chemical agent (binder), or a laser (sintering/melting) changing the state of the material (Birtchnell & Urry 2013). In the manufacturing context, the technologies are particularly well suited to the production of components with complex geometries such as internal passageways, undercuts, and other features that are difficult or even impossible to manufacture with conventional techniques (Bogue 2013). Berman (2012) suggests there are two aspects that make 3D printing different from other rapid prototyping technologies:

- It enables small quantities of customized goods to be produced at relatively low costs
- It allows seamless integration with Computer Aided Designs (CAD) and other digital files like Magnetic Resonance Imaging (MRI)

In addition, 3D printing changes the logistics chains by providing a platform for local production instead of large-scale and centralized manufacturing. This enables collaboration that is accelerating innovation and disruption in the material world, just as the Internet fostered collaboration, innovation, and disruption in the digital world (CSC 2012).

Rapid Manufacturing

Rapid Manufacturing is the ultimate view of Rapid Production. It is commonly viewed as a new philosophy providing an industrial revolution for the digital age. Hence, genuine Rapid Manufacturing systems employ additive processes to deliver large masses of finished goods directly from digital data and effectively eliminating all tooling (Bak 2003). According to Labgraph (2014), the main processes that lead towards rapid manufacturing, in sequential order, are considered to include:

- **Product design** – it includes the product definition, material choice, Rapid Prototyping process selection, marketing evaluation, value-estimation, optimizing design, choosing packaging, and preparing the handbook.
- **Rapid product development** – it includes the rapid prototyping, rapid tooling, and prototype evaluation, small batch production in order to test standards, assembly definition, production cycle, and investment analysis.
- **Marketing** – it involves the formulation of market research that includes start-up plans, break-even analysis, advertising, pricing strategies, and strategic market approaches. International agreements

These are activities that involve the distribution of goods and access of outside markets to capabilities that will facilitate production and distribution of goods and services to target market.

Regarding the adoption and future possibilities of Rapid Manufacturing, Cloud-based Design and Manufacturing (CBM) provides interesting opportunities. It is a networked manufacturing model that exploits on-demand access to a shared collection of diversified and distributed manufacturing resources (Dazhong et Al. 2014). It signifies the evolution of manufacturing and allows for optimal resource allocation in response to a customer's variable task. Moreover, it optimizes processes by forming temporary production lines, thus saving cost, increasing speed, and reducing turnaround time for clients. CBM combines many elements of new technologies, including cloud-based services, CAD, and rapid production.

In 3D Printing, additive processes are used, in which successive layers or droplets of a certain material are laid down under computer guidance. The printed objects can be of almost any shape or geometry, since in the most processes a removable supporting material is printed along with the structures. They are produced from a 3D model or other electronic data source.

3D Printing (also known as Additive Manufacturing, AM) is any of the various processes used to make 3D-objects. 3D Printing Lighting is a next revolution in the world of making, also referred to as the 'third industrial revolution'.

3D Printing – in the term's original sense – refers to the process that sequentially deposits material onto a powder bed with inkjet printer heads. More recently the meaning of the term has expanded to encompass a wider variety of techniques such as extrusion and sintering based processes. 3D Printing Lighting products is expected to change the way half-fabricates and end products are made and set to change the supply chain. Technical standards generally use the term Additive Manufacturing for this broader sense.

There are several aspects in the lighting industry that 3D Printing can impact.

3D Printing Metal Housing and Components

Metal 3D Printing is a costly method as the metal printers use laser methods to manufacture any objects. Hence, metal materials are limited to high-end Lighting applications. Ceramics and others are affordable materials that are expected to have a high demand in future, for example to enhance fixture cooling. A range of other manufacturing materials can be used for 3D Printing that includes nylon, glass-filled polyamide, epoxy resins, wax, and photopolymers.

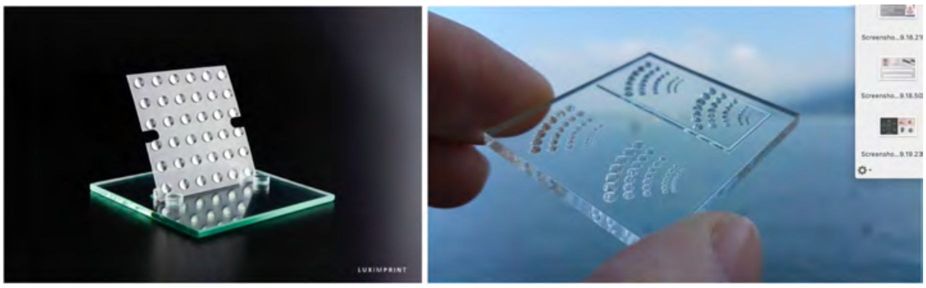


Figure 7: Digital fabrication of micro-lenses (courtesy of LUXIMPRINT)

For many manufacturers of Lighting equipment, natural convection of airflows remains the preferred method for cooling the electronic components of a given light fixture. This method is cheap, simple to maintain and produces no noise or electromagnetic interference. Natural convection, however, is limited in its scope. Metal 3D Printing opens up doors to design solutions that could help significantly to improve the efficiency of cooling bodies.

3D Printing Optics

3D Printing of optical performance parts (optics, lenses, reflectors) is a very niche technology in the Additive Manufacturing landscape. On the contrary, to more common technologies where mainly accuracy of shape matters, the parts also relate to a given function in its total optomechanical assembly. In addition to shape accuracy and form fitting, other factors like transmission values, refractive index, haze values come to play. Due to the deep skills needed to design and manufacture optical parts and understand their performance, only a handful of companies around the globe are in control of the process. One of these is the Netherlands-based LUXIMPRINT, a global leader in Additive Optics Fabrication.

3D Printing Personalized Components, Accessories and Services

3D Printing provides a more flexible, fast and more environmentally friendly way to manufacture luminaires and lighting devices. Signify, a company leader in the world in Lighting recently unveiled its facilities to 3D Print light shades and luminaires in the Netherlands. Over recent years, the company has perfected a highly flexible, digital, more sustainable form of manufacturing, using a 100% recyclable polycarbonate material. It allows luminaires to be bespoke designed or tailored to customer's exact needs and recycled at the end of their life, supporting a circular economy. The investment in 3D printing further illustrates the commitment to better serving customers while reducing their, and their company's, carbon footprint. A typical manufactured luminaire (excl. electronics and optics) using recycled materials and 3D Printing can reach a 47% lower carbon footprint than a conventionally manufactured metal luminaire. Nearly every component may be reused or recycled, supporting the concept of a circular economy.

With the EU H2020-FOF-2017 funded project Repro-Light (Grant number 768780 – `https://www.repro-light.eu/`), the company Grado Zero Espace from Italy, specialized in advanced materials R&D and innovative manufacturing technologies, has had the possibility to experiment the concept of 3D Printing customization and modularity strategy for Lighting luminaire manufacturing and installation packs. Starting from Repro-Light project ideas and installation requirements, the Company has developed integrated installation plans including 3D Printing elements, for linear and pendant solutions, highlighting and analyzing the importance of Eco-Design through concepts like Design for Disassembling, extended life cycle, maintainability, upgradability, etc., through the use of digital generative technologies.

Coverings (in 3D Printing in one piece and two pieces for housing), reflectors on shading covers (aesthetic and functional),

Figure 8: Infographic and tailored decorative luminaires (courtesy of Signify)

Figure 9: Coverings in 3D Printing metal and plastic (courtesy of Grado Zero Espace)

anti-glare components, connecting elements, and complementary accessories modules (projector, Bluetooth, etc.), have been experimented on within the Repro-Light project, as well as customizable installation packages configurable packages based on the type of installation for office, retail and industry spaces.

Based on the different types of installation, it is possible to define product specifications aimed at the specific scenario package and manufactured on-request through 3D Printing, for no stock for small production and on ad-hoc scale.

Conclusion

Novel rapid production technology, such as 3D Printing, is a disruptive innovation due to its potential to induce large-scale changes in multiple conventional industries, supply chains, and business models. It also promotes one to one relationships between customers and manufacturers. This is particularly interesting and true for the lighting industry, where it is crucial to understand how this revolution in manufacturing will have implications for not only the manufacturing processes, but also on the business model by seriously augmenting or replacing current systems of manufactured production and consumption, which may all occur at a distance. Rapid production has the potential to impact and revolutionize the business models and supply chains we know today. The creative evolution of rapid prototyping towards rapid product design and manufacturing and rapid product development will continue to generate a variety of new environments to design and manufacture products with broad capabilities for meeting customer expectations. (Bernard & Fischer 2012). Firms that do not adopt rapid production technology will be at a disadvantage, in the near future. With 3D Printing, the manufacture of individual lighting components, such as heat sinks, electrical traces, and LED optics, customizable accessories and installation packages, shading elements etc., could be customized, enabling the design of parts that cannot be manufactured today by traditional methods, improving both aesthetics and functionality. Research is still needed to advance the integration of 3D Printing into the lighting industry, beyond the current prototyping stage. Several projects such as the Repro-Light H2020-FOF-2017 project have been funded by the EC to conduct initial investigations into the potential for 3D

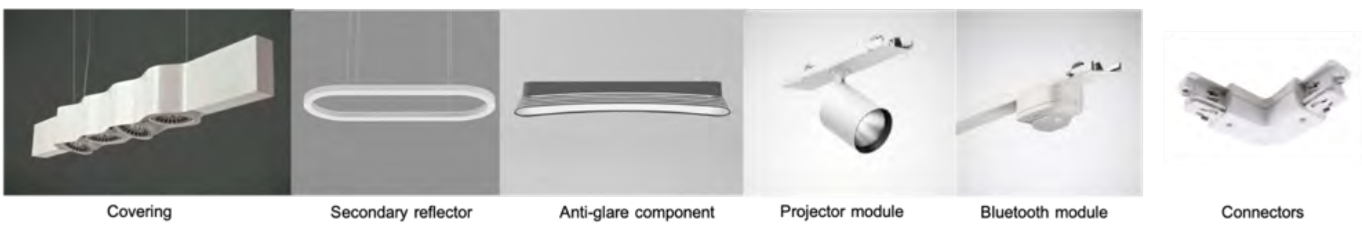


Figure 10: Complementary accessory modules by 3D Printing (Courtesy of Grado Zero Espace)

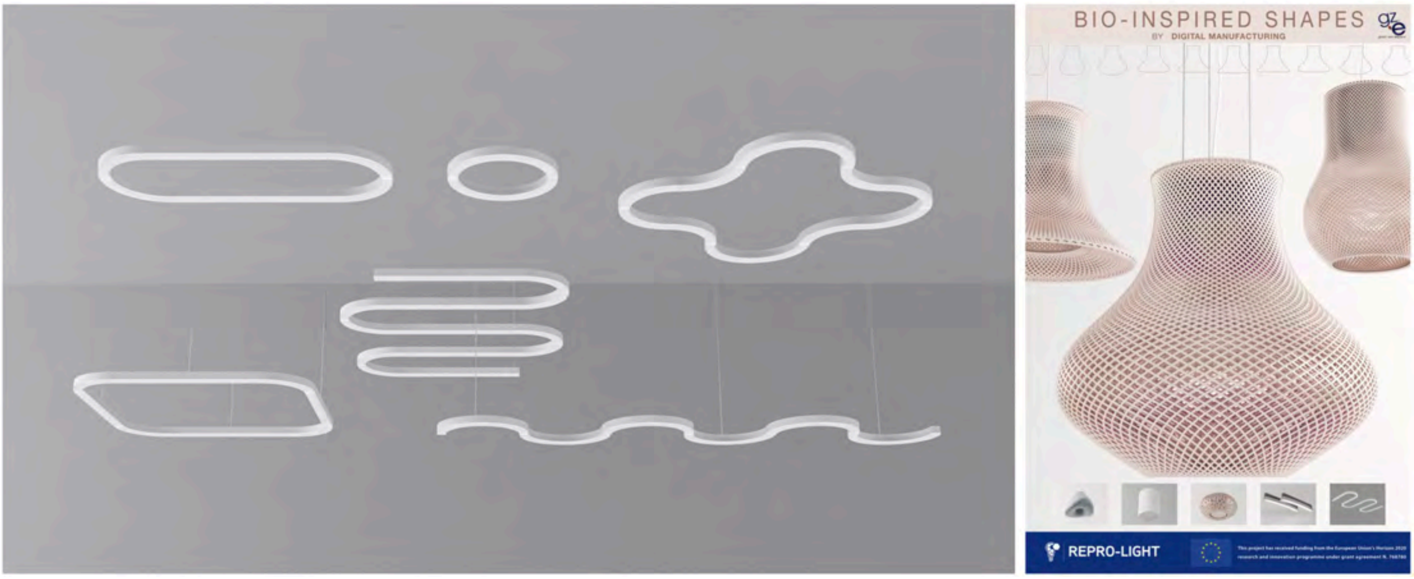


Figure 11: Modular connectors and bio-inspired shapes by 3D Printing (courtesy of Grado Zero Espace)

Printing aesthetic and functional components, for linear and pendant lighting systems. ■

Acknowledgement

This project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement No. 768780.

References

[1] Berman, B. (2012). 3-D Printing: The new industrial revolution. Business Horizons 55, 155–162.

[2] Bernard, A. and Fischer, A. (2012). New trends in rapid product development. CIRP Annals – Manufacturing Technology, 51(2), 635–652.

[3] Birtchnell, T. and Urry, J. (2013). 3D, SF and the future. Futures, 50, 25–34.

[4] Bogue, R. (2013). 3D printing: The dawn of a new era in manufacturing? Assembly Automation, 33(4), 307–311.

[5] Bradshaw, S., Bowyer, A., and Haufe, P. (2010). The intellectual property implications of low-cost 3D printing. Scripted, 7(1), 5–31.

[6] Bullinger, H-J., Warschat, J., and Fischer, D. (2000). Rapid product development: An overview. Computers in Industry, 42, 99–108.

[7] Canalys (2014). 3D printing market to grow to USD16.2b in 2018. http://www.canalys.com/newsroom/3d-printingmarket-grow-us162-billion-2018.

[8] CERAM Research Ltd. (2013). Rapid tooling. http://www.azom.com/article.aspx?ArticleID=1325

[9] CSC (2012). 3D printing and the future of manufacturing. Leading Edge Forum Fall 2012.

[10] Bak, D. (2003). Rapid prototyping or rapid production? 3D printing processes move industry towards the latter. Assembly Automation. 23(4), 340–345.

[11] FactoryOfFactories (2014). Science and technology of composite materials. http://www.factoryoffactories.com/composites.htm

[12] Gravelle, L-P. and Perron-Piche, J. (2013). 3D printing: Intellectual property rights beware. Scripted, 7(1), 5–31.

[13] Hilton, P.D. and Jacobs, P.F. (Eds.)(2000). Rapid Tooling: Technologies and industrial applications. Marcel Dekker Inc, New York.

[14] 3Ders (2014). Let the revolution begin: Key 3D patents expire today. http://www.3ders.org/articles/20140128let-the-revolution-begin-key-3d-printing-patent-expirestoday.html

[15] Labgraph (2014). Rapid prototyping. http://www.factoryoffactories.com/rapidprotot.htm

[16] Hopkinson, N. and Dickens, P. (2001). Rapid prototyping for direct manufacture. Rapid Prototyping Journal, 7(4), 197–202.

[17] Norton, A. (2001). Rapid product development and late customisation for manufacturing SMEs. Pera Knowledge, UK.

[18] Pham, D.T. and Gault, R.S. (1998). A comparison of rapid prototyping technologies. International Journal of Machine Tools and Manufacture, 38(10/11), 1257–1287.

[19] Society of Manufacturing Engineers (2014). Rapid Tooling Design. Fundamentals of Tool Design Study Guide Available at http://www.sme.org

[20] Trend Watching (2010). 10 New Business Models for This Decade. http://www.slideshare.net/oukearts/10-newbusiness-models-for-this-decade

[21] Wittbrodt, B.T., Glover, A.G., Laureto, J., Anzalone, G.C., Oppliger, D., Irwin, J.L., and Pearce, J.M. (2013). Lifecycle economic analysis of distributed manufacturing with open source 3-D printers. Mechatronics, 23, 713726.

ABOUT THE AUTHOR

Enrico Cozzoni, PhD: Dr. Cozzoni has a M.Sc. in Aerospace Engineering, Ph.D. in Industrial Engineering, B.Sc. in Mathematics & Computer Science. He has worked for more than 10 years directly in contact with the worldwide high-tech production & business domains dealing with Digital and Virtual Manufacturing, BC Techs. and AI, BDA, Cognitive Manufacturing and I4.0. Skills and competencies in Life Cycle and Systems Engineering. He was the lead Project Manager for more than 15 International projects, mainly at EU level, as leader for Product and Process R&D, Supply Chain and Production Management, and Product Life Cycle Management.