The Smart Lighting[1] conference took place on May 14 -15, in Frankfurt, Germany. The event brought together 150 attendees from academia, research institutes, industry, government to discuss the latest scientific and technological developments. Besides technological aspects, the two other major themes of the conference were related to the identification of opportunities and challenges related to business as well as design aspects. Across the three themes, the conference featured up to 50 high level speakers from all over the world who shared their view on the rise of more intelligent lighting systems in the near future.

The Smart Lighting conference aims to distinguish itself from other events in the domain of lighting by focusing the program on innovative approaches, products and solutions with a significant impact on the industry's future. The main focus of the conference is on intelligent lighting systems & solutions which make better and more efficient use of the combined functionalities and interfaces.

New lighting technologies based on LED and OLED enable new levels of design freedom in lighting systems and solutions. At the same time, digital additive manufacturing (3D printing) technologies offer virtually unlimited freedom of design and manufacturing of luminaires and lighting fixtures. **In a dedicated 'freedom of design' session we aimed to explore opportunities that emerge when new lighting technologies are combined with digital freeform fabrication capabilities of additive manufacturing technologies.**

This interactive session aimed at introducing the key actors in lighting industry to the emerging field of 3D printing and additive manufacturing. In doing so, a number of experts from leading institutes and companies active in the field of 3D printing and additive manufacturing were brought together in a dedicated session in this conference to shed light on selected aspects of this emerging technological field and the opportunities it could bring to the future of the lighting domain.

With the aim of stimulating the interactions between the two technological communities, the executive committee of Smart Lighting 2013 also collaborated with the EU funded Diginova project to develop a joint plenary session where a keynote speech was organized accordingly for topics of common interest to the attendees. The joint plenary session, proceeded the dedicated session on the freedom of design and featured a keynote speech "The business drivers to additive manufacturing- stimulating technology adoption" by Dr. Phil Reeves, managing director of Econolyst, UK.

[1] Smart Lighting is about advanced lighting systems, solutions and services. Such solutions and services will be enabled through the emergence of semiconductor based digital light sources such as high-brightness light emitting diodes [LEDs] and organic light emitting diodes [OLEDs]. This allows lighting functions to become dynamic in color and intensity, interactive in control and adaptive on demand, i.e. to become more intelligent. This multidisciplinary field is emerging because integration of intelligent functionalities and interfaces at three complementary levels is becoming possible. The first integration level is the lighting engine or light source itself [embedded level], the second level is in luminaries and lighting systems [system level] and the third level is in complete lighting solutions [component level].

Summary of the keynote speech:

In his keynote speech, Dr. Reeves initially clarified the term additive manufacturing as the manufacture of 'end-use' component parts using Additive Layer Manufacturing (ALM) processes. He further emphasized that while different adjectives are being used (e.g. Generative, Constructive or eManufacturing) to describe this emerging field, the term additive manufacturing is the best way to highlight the difference of this new development in manufacturing technology in relation to previous ways of manufacturing such as subtractive, fabricative and formative manufacturing methods. He explained that the differentiation with previous generations of manufacturing technologies comes from the fact that in additive manufacturing material is manipulated so that successive pieces of it is combined to make the desired object.

Dr. Reeves provided a detailed historical overview of the developments in this field and argued that while the concept of additive manufacturing may not be new as such the rapid advances in the recent years show that many industries are actually adopting this new manufacturing technique from 2011 onwards. He also highlighted the new possibilities for using multimaterial – multi functional systems as a key driver for the rapid pace of adoption of the technology across variety of different industries.

In the main part of his speech Dr. Reeves explained how the following six core business drivers have been applied to the Smart Lighting sector by highlighting concrete instances of ongoing developments and ongoing projects: 1) Increased freedom of design, 2)Economic low volume production, 3)Product personalization, 4) Improved environmental sustainability, 5) Opportunity of new supply chains and retail models and 6) Increased part functionalities and cost reduction realized at the same time.

The final part of the speech focused on visions and expectations of additive manufacturing and 3D printing and highlighted future possibilities that could be achieved through technology convergence.

Dr. Reeves also actively participated on the panel discussion at the end of this plenary session where provided the opportunity to the key stakeholders active in the lighting domain to pose their specific questions. One issue that was raised during the plenary discussion was related to how additive manufacturing could actually be applied in the lighting domain to add value to current products and at the same time also enable mass manufacturing. Dr. Reeves in response articulated that in fact in other domains such as automotive and dental implants high volume production is already being realized with additive manufacturing techniques. The key point he highlighted was the opportunity to realize freedom of design, at the same cost level, even when high volumes have to be realized. The example of dental implants were highlighted to explain that every single product could have a different geometry tailored to the requirements the user while large volumes of the products have to be realized on annual basis.

The interactive session: “Freedom of design & manufacturing for the future of lighting”

The dedicated Diginova session included four presentations by experts in the digital manufacturing domain.

Introducing the EU funded Diginova Project
Marcel Slot, Chairman of the Session and Director Technology Planning & Partnerships, Océ-Technologies B.V

This presentation mainly focused on introducing the aim of the EU funded Diginova project. The purpose and working scheme of the Diginova project was explained in detail. In turn it was highlighted that the project aims to map key material innovation and application domains, identify key technology challenges and new business opportunities in different areas. This then linked up with how this particular session was organized during the Smart Lighting conference. In the remaining time slot, a concrete example of a research project at Océ Technologies was elaborated upon.

How Digital Printed Optics can enable LED Lighting OEMS to customize their offering
Richard van de Vrie, Chief Executive Officer, LuxExcel

This presentation started by pointing to the challenges that are faced by the LED lighting OEM community. The main message was that the key actors in the lighting industry are often using the same components and designs of products and are mainly focused on achieving incremental improvements in the Price/Lumens/Watt –Ratio in order to keep pace with the competition. The presentation then showed a number of clear examples of problems with illumination in variety of different settings and argued that digital manufacturing offers variety of opportunities to eliminate those problems. The remaining of the presentation offered a detailed view on how LuxExcel’s digitally fabricated optical products could bring added value to the lighting domain. The benefits to the lighting OEM were articulated as faster product introductions, quick product upgrades, flexibility of design and “just in time” production. The benefits to the lighting designers were articulated as rapid prototyping and testing, small volume but customized production, totally new designs, digital design and open online library and new business models. Finally the presentation showed a variety of applications of digitally printed optical solutions to make the possibilities tangible for the audience.

Additive manufacturing of lighting designs
Tom Craeghs, Research Project Manager, Materialise NV, Belgium

This presentation delved more deeply into the concept of Additive Manufacturing and explained that a broad range of techniques are being utilized to enable digital manufacturing processes. The presenter explained three core competences of the Materialise to be 1) Additive manufacturing, 2) Digital CAD and the more sophisticated 3) Medical image based engineering and manufacturing. It was argued that these core competencies bring together production of new products, software development and services in one company together. In the sequel the presentation focused on detailed explanation of three different manufacturing processes that would be most interesting to the lighting community, i.e. Selective Laser Sintering, Stereo-lithography and Fused Deposition Modeling. For each of these manufacturing processes concrete examples of applications were shown and the advantages were articulated. The introduction of the MGX brand by Materialise showed that ways of cooperation across the value chain are possible, for instance between lighting designers and engineers Materialise in this context. The presentation ended with a future outlook, for instance, the possibility to print conductive circuits in lighting designs and further possibilities to increase functionalities.

Freedom of design for integrated products by hybrid Additive Manufacturing
Frits Feenstra MSc, Senior Project Manager, TNO, The Netherlands

This presentation focused on more advanced forms of additive manufacturing, first probing into the possibilities to use multi-materials in additive manufacturing processes. Furthermore, the presentation detailed how TNO is taking the next necessary steps to enable a high volume manufacturing process. In the first part of the presentation there was a focus on how TNO has been dealing with the challenges related to material jetting and showed that already free form multi-material 3D products have been demonstrated. The following part of the presentation delved into the issue of moving additive manufacturing from a batch manufacturing process to a continuous one. This was exemplified through an R&D project that was carried out in TNO where high adjustment platforms are being realized. The platform will then include different steps of manufacturing e.g. different print heads (for different materials), curing units and pick and place possibilities. The final part of the presentation focused on the topic of freedom of design and explained that not only complex geometries could be realized (as was shown in the previous presentation), but in the future integration of different functionalities will also drive new possibilities to develop smart systems with additive manufacturing technologies. Some concrete examples were shown to the audience on the final slides.

Interactive discussion chaired by Marcel Slot

In order to understand the needs and ideas of the stakeholders in the lighting domain Marcel Slot prepared two guiding questions which linked up with the issues that were already discussed during the conference. Below the main issues that were raised during the discussion in the Diginova session are highlighted:

1) **During the conference many different speakers pointed to the fact that LED technology (as a key SSL technology) is now becoming mature in terms of performances. The speakers of the conference thus pointed to the fact that the focus of the industry should be to reduce costs and/or add value to lighting products. The talks in this specific session pointed out many different opportunities that Digital Fabrication could bring to your industry such as, flexible production, customized production etc. Do you think that these value propositions really apply to your industry?**

- Focusing on the residential lighting market, the response of the audience was very encouraging. It was argued that additive manufacturing will enable lighting designers to design new products in the future. More importantly, the audience agreed that additive manufacturing could bring added value to users and designers at the same time in the lighting industry. Designers would be capable of developing more advanced, sophisticated and customized products and offer these on the internet with new business models that do not require upfront investments. Concurrently, these developments would allow users to become more involved in the developments of lighting products and match technological possibilities to their specific needs. This will create a whole new user experience in the future of lighting.
- Personalization, speed and quality were seen as the main denominators determining demand in the lighting industry. The combination of the new possibilities offered by the LED technologies and new design possibilities enabled by added manufacturing and the rise of new business models where no upfront investments are required will change the future of demand in the lighting industry entirely.
- More generally the audience also discussed the future shaping and structuring of supply chains and how companies that are active in the additive manufacturing domain could actually become key players in the lighting value chain. It was envisioned that companies such as Materialise and LuxExcel could be collaborating in the future as a part lighting value chain to deliver new highly added value products to the lighting market.

2) **If you want to exploit freedom of design, LED technology already allows this to occur and in the future possibilities will increase as OLED technologies enter the lighting domain. If additive manufacturing is to play a role in the lighting market, what will be the opportunities and what will be the barriers:**

Opportunities:

- The audience generally recognized that Digital Fabrication brings new opportunities. In addition to design possibilities also customized solutions were seen as an opportunity (e.g. the optical solutions as was presented by Luxexcel).
- The possibilities that were shown in the presentation of TNO for multi-material jetting (enabling multi functionality) and high volume production were also recognized as important opportunities for adoption of additive manufacturing in the future.
- Besides Freedom of Design, a key opportunity recognized by the audience had to do with the Access to Designers community. This will be playing a key role in shaping the lighting industry as the experience economy is materializing rapidly. It was generally recognized that additive manufacturing would enable the lighting design community to become more active in developing new business models to serve new needs of customers.
- Allowing the end users to become involved in designing and creating their own products will eventually increase the value of the products of the customers of lighting products. However, the audience also pointed to the fact that within the lighting industry one needs to differentiate between industrial clients and residential clients. For industrial purposes highly knowledge intensive firms such as LuxExcel and materials will have to play a role in the design process of lighting solutions.

Barriers:

- Costs will be a barrier to adoption but the audience agreed that customers will be inclined to pay for added value that this manufacturing technology can bring, and especially because of personalization of products.
- A key barrier from a producers perspective related to the distributed expertise along the lighting value chain (such as reflectors, drivers, sockets, light sources and system integration). The audience questioned how such comprehensive and sophisticated design teams could be easily replaced outside current value chain actors. This might happen, but transition strategies will be required to achieve complete customized products. Perhaps the first steps will be to have customized designs of lamps and then start adding functionalities.
- The issue of market surveillance was mentioned as a potential barrier and similarities with LED market was drawn where many products are not really compliant to EU regulations and standards. However, business models that were shown by Materialise, for instance, creating a brand MGX where Materialize will determine design rules were seen as potential solutions to this problem.

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