Design of an Oled Lamp

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Ott-Design
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University of Twente
Industrial Design Engineering

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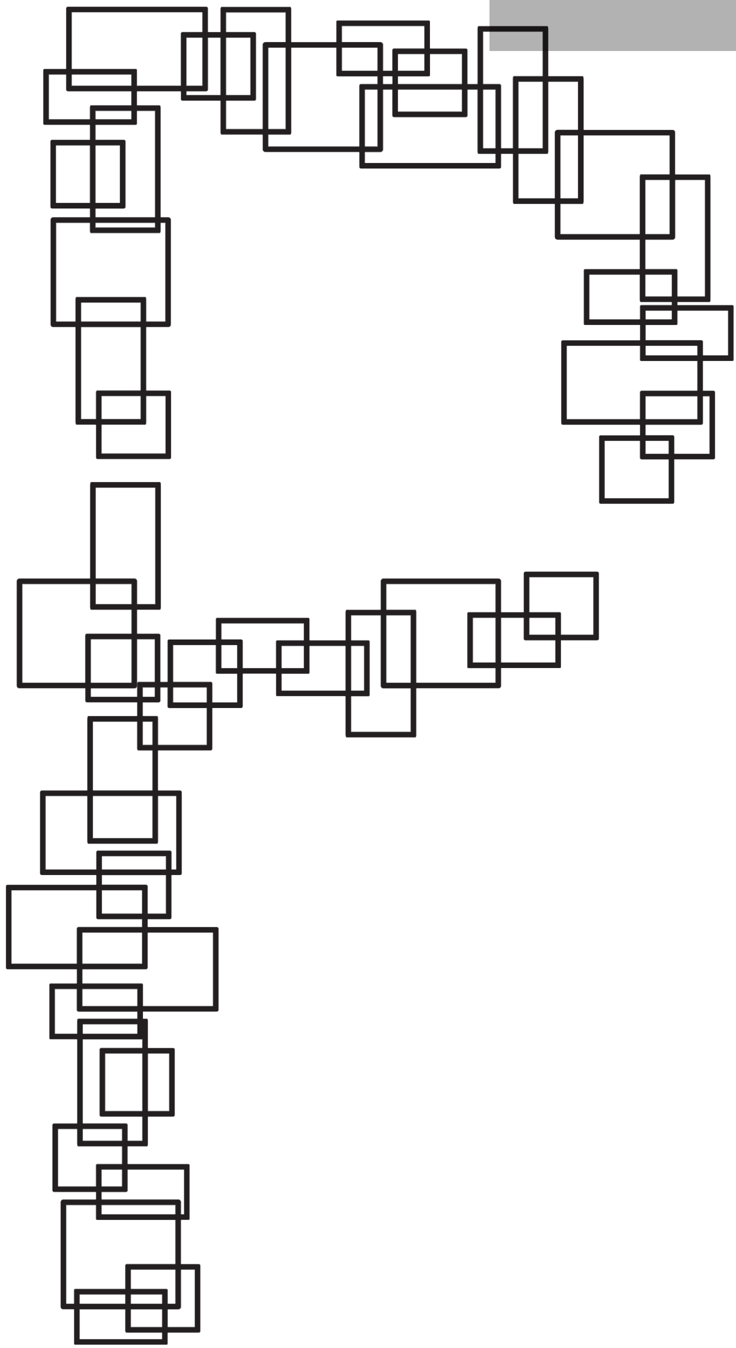


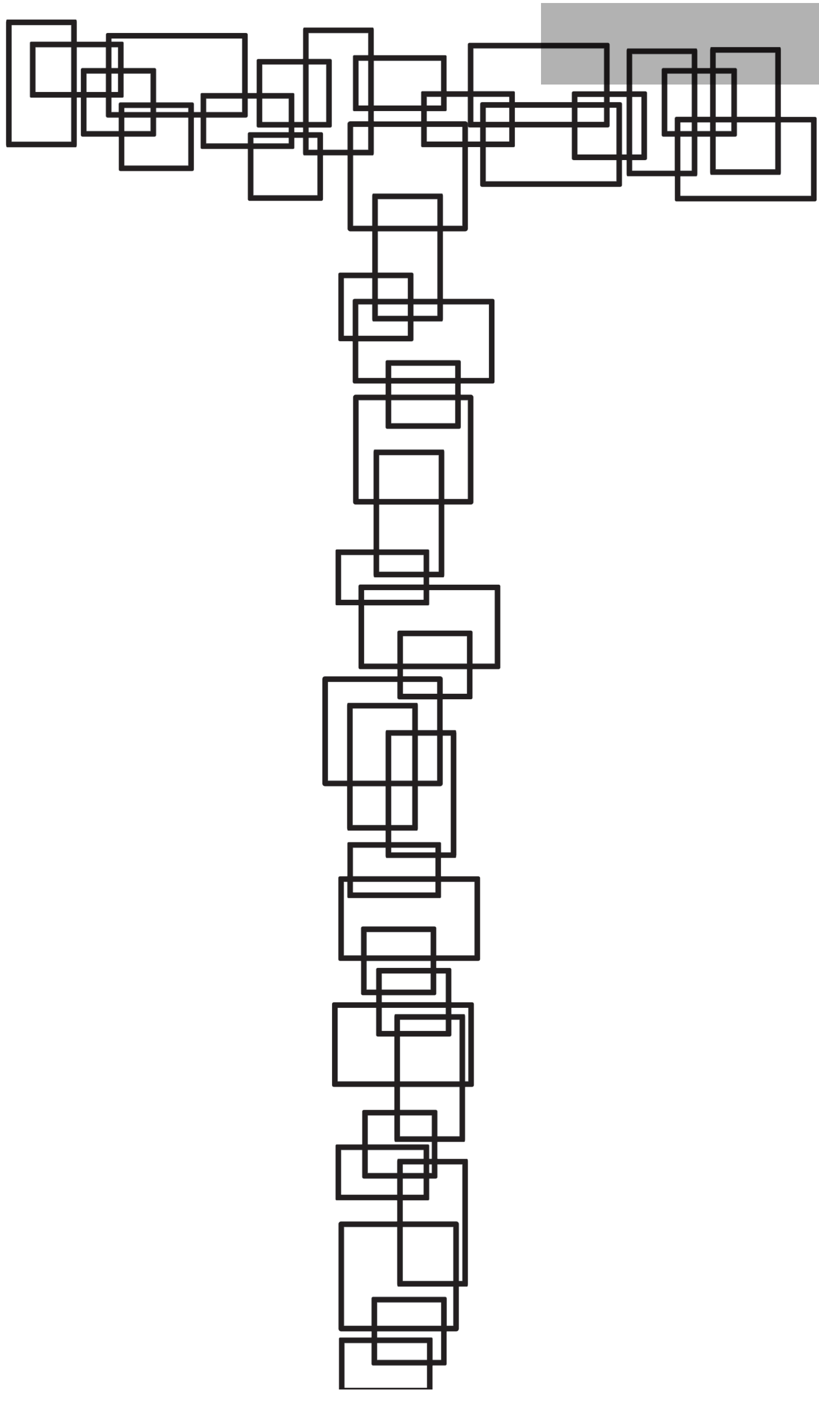
Preface

Writing a bachelor thesis is the final phase of the bachelor study Industrial Design Engineering at the University of Twente. This thesis can be carried out either for an external company or for the university itself and should last around 3 month.

I actually have a particular interest in interior and furniture design. I then have chosen to run a project dealing with furniture design in order to acquire more knowledge and experience in this specific area. Moreover I wished to write my thesis within an external company for getting to know the everyday working life. I aimed at improving my skills and the highest challenge was first to find a thesis within a company. It was obvious to have a look in East-Westphalia (Germany) where it is known that many companies from the furniture sector are located. At the same time I could discover the German design mentality which was a great input in addition to my Dutch design experiences.

The design office OTT-DESIGN offered me the possibility to write my thesis for their office. For this and for his support I want to thank Niko Ott, owner of OTT-DESIGN. I was not just able to write my thesis in the office but I also got a lot of knowledge regarding interior design. Moreover I also want to thank my supervisor at my university Hans Tragter for his remote support. Both supervisors gave me a lot of freedom so that I could work independently on my thesis but always supported me with tips so as to reach a higher level for my thesis and design.

Osnabrück, 16.05.2015



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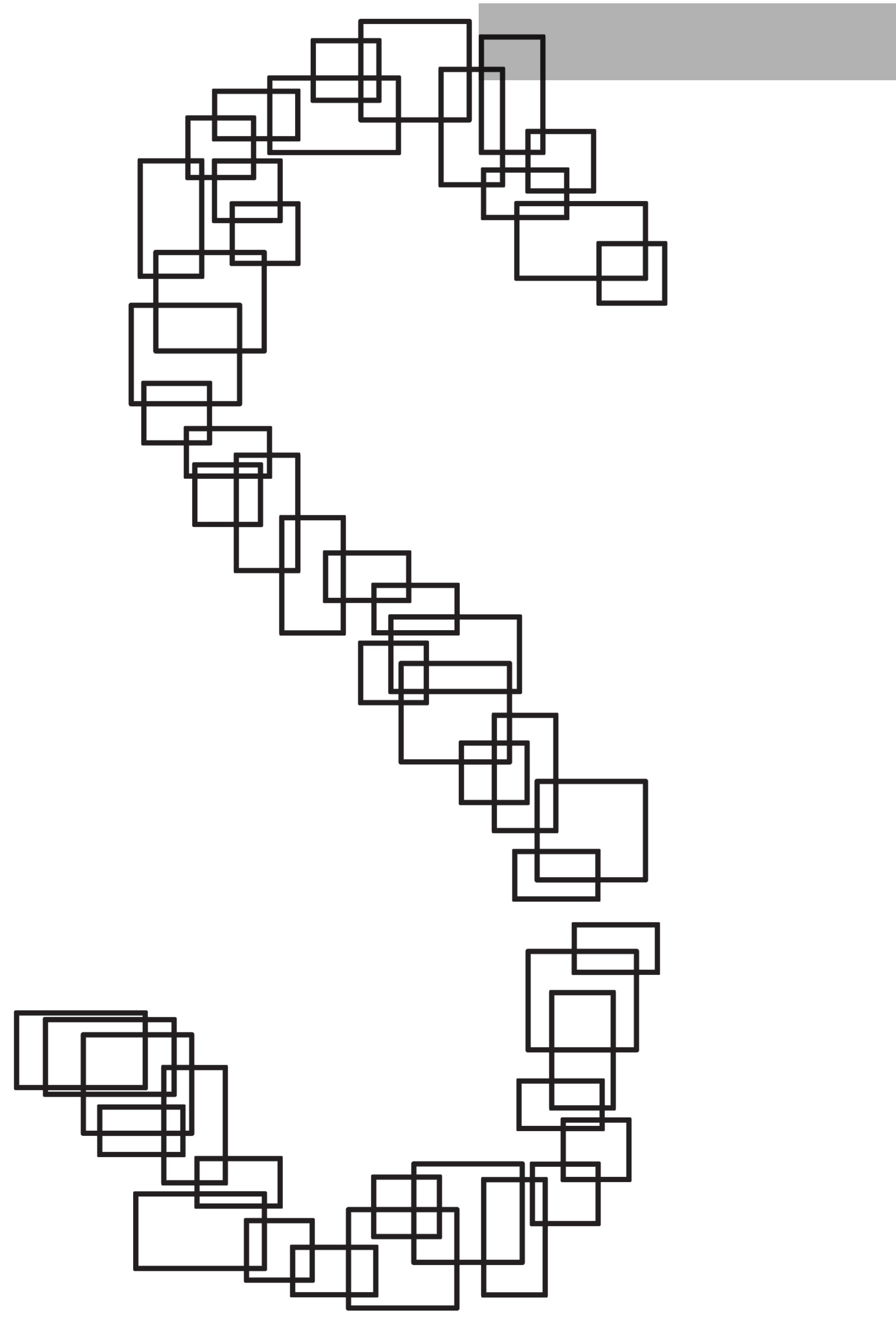


Summary

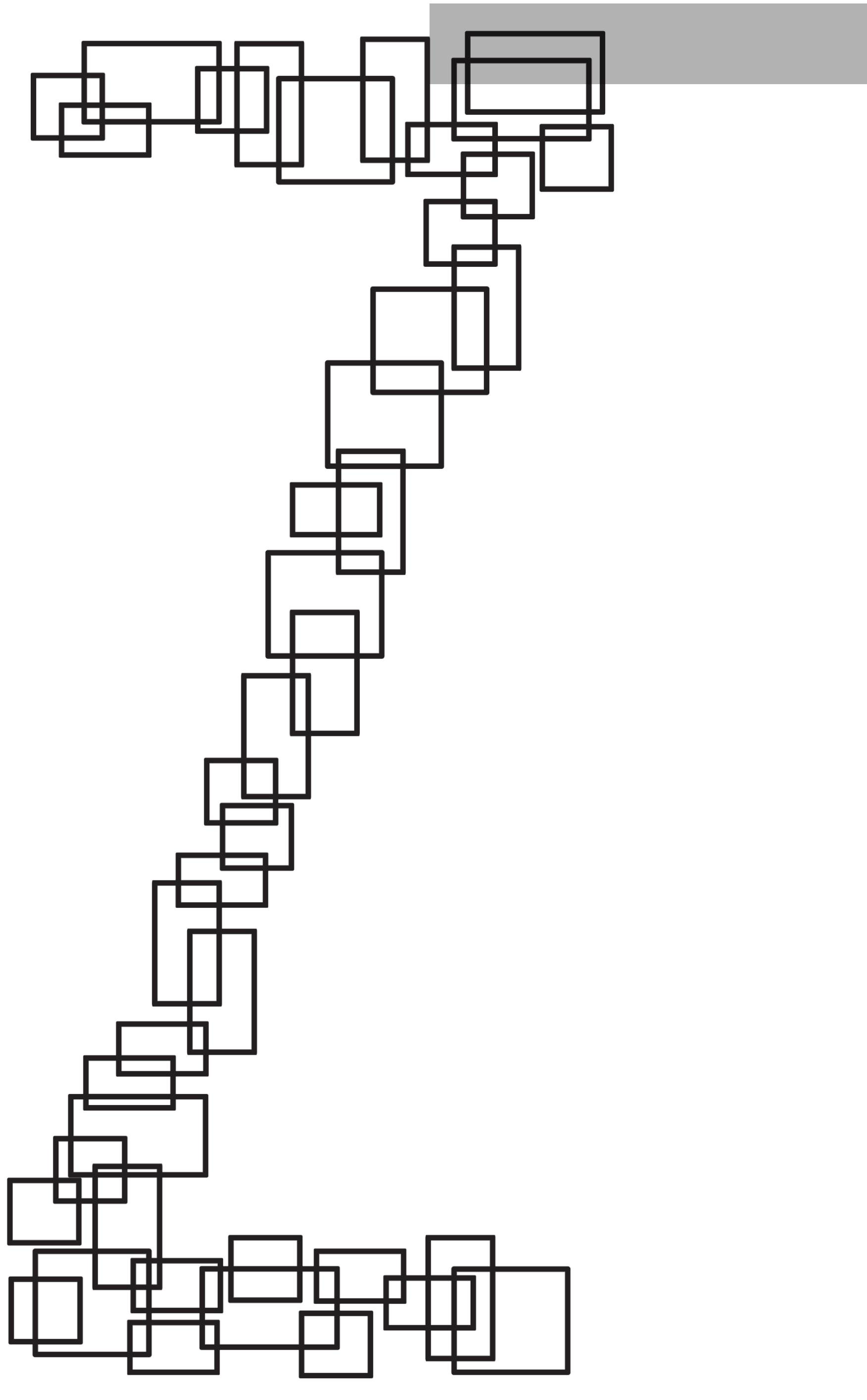
This bachelor thesis aims at acquiring specific knowledge about the current Organic Light Emitting Diodes (OLEDs) so as to find a suitable application for an OLED lamp and create a design guide for lamps with OLED panels. In addition a lamp with at least one OLED panel has been designed within this bachelor project

A thorough analysis is one of the essential requirements for this bachelor project. Light, the usage of light and its effects on the humans have been first studied. Then the OLED technology is examined to understand the characteristics of OLEDs for being able to use them in lamp designs. The results from both studies are essential for being aware of which purpose OLED lamps can be used for. Moreover the current market has been analysed via internet, magazines and fair trades. The visit of two fair trades in Cologne and Bad Salzuflen was used for getting knowledge on the usage of light in furniture designs and for talking with members of lighting companies. This is essential for getting to know the currently available OLED panels, their characteristics and their place on the market. The design office OTT-DESIGN is also studied shortly within the analysis section. Finally all achieved knowledge is summed up in a list of requirements.

Then as many ideas as possible have been generated leading to nine different concepts. For each application (kitchen, office and bathroom), three concepts have been designed. These three rooms are relevant for the design office OTT-DESIGN and the use of OLED panels is possible in these areas. Moreover all lamps have individual characteristics and extra functions resulting in nine different concepts. Finally the first kitchen concept is chosen at the end of a discussion with the owner of the design office Niko Ott. This concept has the highest potential for the design office. Indeed OTT-DESIGN is often working together with kitchen companies and of course lighting companies.

The final lamp consists of three parts: an Upper Lamp, a Side Lamp and two possible add-ons. A flexible OLED panel is integrated in both lamp-parts. The three parts are fixed in the corner between the underside of the wall cupboard and the wall itself. The aim of the lamp is to illuminate the work top from above and the side to minimize the appearing shadows on the work top. Moreover the homogenous and glare free light present the food in its original colour due to the high Colour Rendering Index of OLEDs. The required illuminance of 500lx can be achieved by mounting more OLED lamps next to each other. In this good light condition the user can prepare meals in a suitable environment. All lamps can be easily controlled with a touch sensor or an app. The two add-ons are either a loudspeaker with an USB - and Bluetooth connection or a plug socket with an USB port for charging electrical devices. Furthermore all three parts can be combined in every possible way. The lamp can then get a personal characteristic and kitchen designers and users can choose their own lamp combination.

In the end of the thesis the project and the resulting design have been evaluated. Of course no product is perfect and there are always some achievable improvements. In this case the lamp needs some further developments regarding the add-ons before the final production. Moreover the cost calculation has to be improved. The current price of OLED is used for the calculation but a mass production is soon possible which will decrease the price of the panels. A functional prototype should also be made before the production to see if everything is fitting and working fine. Unfortunately it was not possible to build a prototype within this project due to the high prices of a 3D print and the OLED panels. However, the OLED-Technology will improve within the next years and the OLED panels will get an efficient light source. Thus having knowledge about OLED panels and having OLED lamp designs is a good preparation for the future lighting market.



Zusammenfassung

Das Ziel dieser Bachelorarbeit ist genügend Informationen über Organic Light Emitting Diodes (OLEDs) zu versammeln, um einen möglichen Anwendungsbereich für eine OLED-Leuchte zu finden und um eine Design-Anleitung für das Designen von OLED-Leuchten zu schreiben. Schließlich soll eine Leuchte mit mindestens einem OLED-Modul innerhalb dieses Bachelorprojektes entworfen werden.

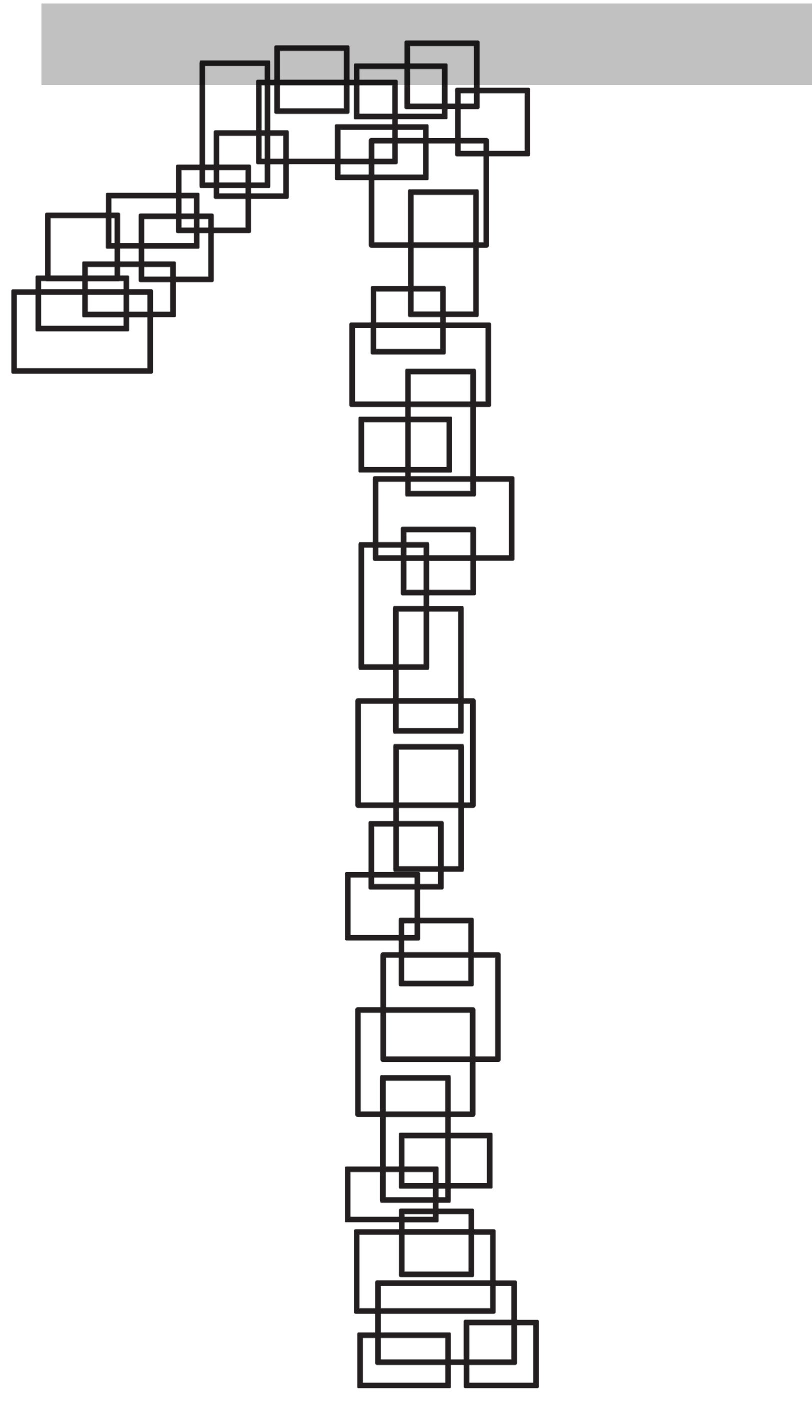
Das Fundament dieser Bachelorarbeit ist eine gründliche Analyse. Zuerst werden die Themen Licht, die Effekte von Licht und die Verwendung von Licht untersucht. Danach wird die OLED-Technologie analysiert, um die Eigenschaften der OLED-Module zu verstehen und sie in einem Leuchten Design verwenden zu können. Die Ergebnisse von beiden Untersuchungen sind relevant, um die Frage für welchen Anwendungsbereich OLED-Leuchten geeignet sind zu beantworten. Darüber hinaus ist der derzeitige Markt mittels Internet, Zeitschriften und Messen untersucht worden. Der Besuch von zwei Messen in Köln und Bad Salzuflen wurde dazu genutzt, den Gebrauch von Licht im Möbeldesign zu analysieren und um mit Mitarbeitern von Leuchtenherstellern zu sprechen. Diese Untersuchung ist relevant, um mehr über die aktuell verfügbaren OLED-Module und ihre Eigenschaften heraus zu finden. Innerhalb der Analyse ist auch das Design Büro OTT-DESIGN kurz beschrieben. Schlussendlich ist das erlangte Wissen in einer Liste mit Ansprüchen an ein Leuchten-Design mit einem OLED-Modul zusammengefasst.

Dann werden so viele Ideen wie möglich kreiert, um neun Konzepte für mögliche Leuchten zu entwerfen. Für die Anwendungsbereich Küche, Büro und Badezimmer wurden jeweils drei Konzepte entwickelt. Alle drei Räume sind relevant für das Design Büro OTT und eine Anwendung von OLED-Leuchten ist in diesen Räumlichkeiten vorstellbar. Darüber hinaus haben alle Konzepte individuelle Eigenschaften und extra Funktionen, sodass neun sehr unterschiedliche Konzepte entstanden sind. Schließlich wird das erste Küchen Konzept in Absprache mit Niko Ott, dem Inhaber des Design-Büros, gewählt. Dieses Konzept beinhaltet das größte Potential für das Design Büro, da OTT-DESIGN viel mit Küchen- und Leuchtenherstellern zusammenarbeiten.

Die entworfene Leuchte besteht aus drei Unterteilen: einer oberen Leuchte, einer seitlichen Leuchte und zwei möglichen Add-Ons. Beide Leuchten beinhalten ein flexibles OLED-Modul als Lichtquelle. Die Leuchte wird in der Ecke zwischen der Unterseite des Küchenoberschrankes und der Wand befestigt. So kann die Leuchte die Arbeitsplatte von oben und der Seite beleuchten, sodass möglichst wenig Schatten entsteht. Dank des hohen Color Rendering Index des homogenen und blendefreien Lichtes erstrahlt das Essen in seiner natürlich Farbe. Die notwendige Beleuchtungsstärke von 500lx kann durch die Montage mehrerer OLED-Leuchten nebeneinander erreicht werden. Die Leuchte bietet optimale Lichtverhältnisse zum Zubereiten von Mahlzeiten. Die Leuchten können mittels eines Touch Sensors oder einer App kontrolliert werden. Die zwei Add-Ons beinhalten entweder einen Lautsprecher mit USB- und Bluetooth-Anschluss oder einer Steckdose und einem USB-Anschluss zum Aufladen technischer Geräte. Darüber hinaus ist es möglich alle drei Unterteile in jeglicher Art zu kombinieren. Dadurch bekommt die Leuchte einen individuellen Charakter und Küchendesigner oder Endverbraucher können ihre eigenen Kombinationen kreieren.

Am Ende der Arbeit werden der Projektverlauf und das Leuchten-Design reflektiert. Natürlich ist kein Produkt perfekt und es gibt immer mögliche Verbesserungen. In diesem Fall benötigen die Add-Ons noch eine weitere Ausarbeitung bevor sie produziert werden können. Außerdem müssen die Kosten nochmals kalkuliert werden. In der Kalkulation in dieser Arbeit wurde der derzeitige Preis von flexiblen OLED-Modulen verwendet. Bald soll aber einer Massenproduktion der flexiblen OLED-Module vorstellbar sein, sodass der Preis der Module drastisch sinken würde. Darüber hinaus sollte auch noch ein funktioneller Prototype gebaut werden, um sicher zu gehen, dass alle Unterteile problemlos ineinander passen und alles funktioniert. Leider war es innerhalb dieses Projektes nicht möglich einen solchen Prototypen anzufertigen, da ein 3D-Druck und die OLED-Module zu hohe Kosten darstellen.

Jedoch wird die OLED-Technologie innerhalb der nächsten Jahre noch weiter verbessert und die OLED-Module werden eine effiziente Lichtquelle. Alles in allem ist eine gute Vorbereitung für den zukünftigen Lichtmarkt, sowohl Wissen über die OLED-Technologie als auch ein Leuchten Design mit OLED-Modulen zu besitzen.



1. Introduction

For the humankind light is essential for surviving but it also helps in having a comfortable and healthy way of living. Sunlight represents the energy input of many significant biological processes (e.g. photosynthesis) which are essential for the earth and the survival of the humans. Moreover most of the people are not just active during daytimes but also have activities during the dark hours of evenings and even nights. Thus the mankind is depending on the usage of artificial light sources.

For thousands of years, humans have been creating light sources starting with fire. It’s only at the end of the 18th century that the industrialization saw the invention of the light bulb which was the first electrical light source. (Fördergemeinschaft Gutes Licht, 2008) Nowadays new technologies for making light are discovered and constantly improve light properties and revolutionize the market. One of these new upcoming light technologies are the Organic Light Emitting Diodes (OLEDs) which have a couple of innovative benefits compared to other light sources.

The organic diodes are made out of organic materials which emit light through a surface. Thus it offers new design options to lamp designers due to the fact that the light source is a surface and not a classic point light. The lighting market slowly discovers this new technology which is mainly used in screens and designers start to design lamps with OLED panels so as the interior designer Niko Ott. He wishes to acquire more knowledge about OLED panels for his own design office OTT-DESIGN and then integrate a OLED lamp in his product catalogue.

The aim of the thesis is to acquire enough knowledge during the analysis for being able to design a proper lamp with OLED panels. Thus a lamp with at least one OLED panel has to be designed. Therefor the topic light and the OLED-technology are analysed for finding a suitable application for an OLED lamp. The specific functions and aims of the lamp are determined during the analysis. Moreover a detailed description of the assignment and a planning for the bachelor project are illustrated in appendix A.1 Assignment Description and A.2 Action Plan.

The thesis is divided into five parts which represent the phases of the design process. The first part explores the topics of light and Organic Light Emitting Diodes. The second part deals with the idea generation and then a couple of inspiration processes and ideas are represented. The thesis continues with a concept section and nine different concepts for lamps are illustrated in this part which leads to the choice of one concept. This selected kitchen lamp is closely examined in the fourth part showing all the details of the designed lamp like the dimensions, materials, user product interaction and visualizations (CAD and prototype) of the lamp. Finally the thesis ends with a conclusion to evaluate the relevance of the designed lamp and the design process. Suggestions for further possible developments on the product are also mentioned in this last part.

2

2. Analysis

The aim of this chapter is to analyse all significant topics for designing an OLED lamp. Therefor this chapter has been divided into five sections. It begins by an analysis of light which includes the characteristics of light and the influences it can have on humans. The second section goes on with an analysis of organic light emitting diodes which includes their structure, workings principle, characteristics, effects on humans as well as a comparison with other light sources and the future of OLEDs. Section three then moves on with an analysis of the market regarding the current usage of OLED and existing OLED providers. The following section then provides information about the company OTT-DESIGN and their already designed lamps. Finally, the last section presents a list of requirements and outlines the main aspects of the analysis.

2.1. Analysis of Light

The first part of the analysis focuses on light and its characteristics as well as on the effect light can have on humans. For designing a good lamp it is necessary to know the characteristics of light and which influence light can have on the human health and on the psyche of human beings. Moreover the usage of light in interior design and the requirements to light in different rooms are examined.

2.1.1. Light

Light can be defined as the visible part of the electromagnetic radiation in the environment. The light spectrum (figure 2.1.) includes wavelengths between 380nm and 780nm which is just a small part of the electromagnetic radiation. To every

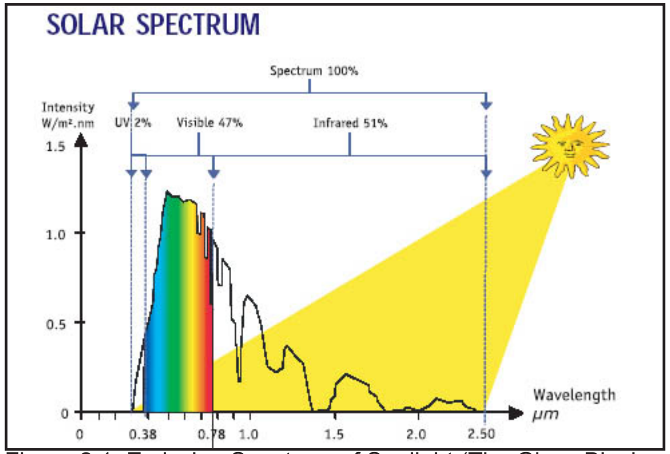


Figure 2.1. Emission Spectrum of Sunlight (The Glass Block, 2011)

wavelength of the light spectrum a colour is connected. Thus a wavelength of 780nm appears red and change colour when the wavelength is decreasing down to 380nm which is violet. Besides the visible radiation, other electromagnetic radiation like Infrared and Ultra Violet exist. (Fördergemeinschaft Gutes Licht, 2008)

Infrared (IR) and Ultra Violet (UV) are also relevant radiations for the earth. Infrared ranges from 780nm to 1mm and is invisible for the human eye. But IR radiation from the sun is vital because the Infrared rays are heating the earth. As soon as IR reaches an object, this one absorbs the radiation and converts it into heat. Moreover the right amount of UV radiation is important for Earth. On the one hand UV is for example essential for humans to create Vitamin D but on the other hand UV radiation can also be dangerous and cause sun burn and skin cancer. It can be concluded that the sun's radiations have different impacts on the health of the Earth's inhabitants and is also heating and lighting the earth. (Fördergemeinschaft Gutes Licht, 2008)

80-90% of our reception of information goes via the eyes. Therefore natural light from the sun and artificial light are significant. But light is also having an impact on the psyche, the circadian rhythm and the orientation of humans. Moreover light can also be seen as a design tool in the architecture, in interior design. Artificial light sources can be used to create extraordinary interior designs or to influence people. (Werth et al., 2013)

People are spending a lot of time inside buildings and artificial light sources are therefore necessary. The humankind already started with making light 300,000 years ago by using fire as a light source. Humans started to use artificial light inside their "homes" for being able to deal with the fact their eyes are not adapted to see in the dark. The area of electrical lighting started when Th. A. Edison reinvented the light bulb of Johann Heinrich Goebel in 1879. Over the past decades the development of electrical lighting has been really skyrocketing and a lot of different modern technologies have been used. Different materials, light sources and environmental aspects are taking part in the improvement of light sources. (Fördergemeinschaft Gutes Licht, 2008)

Different factors can be used to describe the light generated by these light sources in order to compare them. In appendix B.1 few parameters for describing light are presented. Characteristics for describing the power, the intensity per square meter and the colour of light exist. Moreover units which are used for measuring these characteristics are presented which gives an impression of how they are connected with each other.

2.1.2. Effects of Light on the Humans

Health is the general condition of the body and mind and thus not just the absence of diseases. Well-being can be split into physical, mental and social aspects and light can have an effect on all of them. For example light can damage the eyes and the skin and has an influence on sleeping patterns and the circadian system. (Boyce, 2010)

Effects on eye and skin

As a matter of fact, the radiation of light can damage the human eye and skin. Exposures to indoor lightings have a different impact on the human beings than sunlight due to the difference in their emission spectrums. A brief description of the human eye is provided in appendix B.2 for a better understanding of the effects of light on the human eyes and the visual perception of light.

Sunlight is composed of UV and IR radiation which both have negative and positive effects on the human health. The UV radiations can damage the skin. It mostly causes sun burn or skin cancer. Sicknesses like photokeratitis of the cornea and cataract are also caused by UV radiation and they strongly lessen the ability to see. But UV radiation is essential for producing vitamin D. A lack of vitamin D can cause diseases like cancer, multiple sclerosis and diabetes. IR radiation often just causes a raise in temperature on the skin or the tissue of the eyes which is not always harmful. But one of the sicknesses caused by infrared radiation is called chorioretinal injury. It generates a blind spot and no recovery is possible. Appendix B.3 presents a table with all the sicknesses caused by light radiations. (Boyce, 2010)

The human eye is adapted to the sunlight spectrum. Thus the spectrum of artificial light sources can give meaningful information about the impact on the human health. A difference between these two spectrums can cause dry eyes and lead to inflammatory conditions. Eyestrain is also regularly caused by this artificial light. (Majka & Majka, 2012)

A classification system exists in which indoor light sources are compared by using health risk criteria even though they are usually not representing a high risk. However it had been noticed that the action spectrum of photokeratitis is in the blue area of the light radiation. LEDs do have their peak exactly in this blue area. Thus a risk of photokretinitis exists with LEDs. Additionally task lights (halogen or compact fluorescent light sources) are even more dangerous because they tend to have UV radiation. (Boyce, 2010)

Psychological Effects

Next to the physical effects, psychological influence of light can also appear. In contrast to the physical effects the mental ones differ from person to person. How well a person feels under specific light conditions is depending on the individual perceptions and expectations of the visual conditions. Glare and bad visual conditions (too dark or too bright) will of course cause discomfort and bad temper. The mood will be the best when the conditions are equal to the expected lighting conditions and when the people can control the conditions themselves. (Werth et al., 2013)

But a lot of aspects are influencing the subjective impression of the visual conditions of a person. The colour temperature with warm and cold light, the brightness and the possibility to dim the light, the position of the lamps and the uniformity of light are having impacts on the individual perception of light (Küller et al., 2006). A difference between man and women can also be noticed. Women are more sensitive to light conditions and to perceive emotional cues than men (Knez, 2001).

Bad visual conditions can be avoided by creating a diffuse continuous light through the room which does not create a lot of shadows. Next to this general lighting of the room a focused light on workspaces can improve the visual conditions. (Fördergemeinschaft Gutes Licht, 2008)

Considering this knowledge people can also be manipulated with light. Light is creating atmospheres and the attention of people can be influenced. Some examples of moments where people’s attention is influenced by light are at the theatre, when watching movies or even inside shops. (Werth et. al., 2013)

Influence on Work Performance

It can be concluded that if light has psychological effects it also has effects on the work performance of people. Light with an illuminance of around 750lx is causing better working performances than a low illuminance of 300lx. On the opposite, dim light of 150lx is better for team work and creative tasks. (Werth et. al., 2013)

In addition to the illuminance the colour temperature is also playing a significant role. For most of the people a warm white light is the most stimulating when it comes to high working performance. But this influence is again subjective and differs with tasks the person has to fulfil. (Knez, 2001)

Once more the influence on mood shifts varies from the person’s age and gender. Due to the wide variations in results which still exist in light researches further psychological lighting researches have to be performed. (Küller et. al. 2006)

Circadian Rhythm

The internal clock is based on the light of the environment and the whole body system is depending of it. All processes within the body are organized in a 24-hours rhythm. If the light in the environment is changing or would be missing the internal clock would get out of step. This can cause fatigue, mood swings, and damage of the immune system or even depression. Especially old people are sensitive to light and need more light for working and a better sleep quality. (Fördergemeinschaft Gutes Licht, 2014)

Photoreceptors in the eye are connected to internal clock in the brain (the suprachiasmatic nucleus). From this part of the brain the body is controlling all processes which are connected to the sleep-awake rhythm. Melatonin is distributed in the evening for making humans tired and in the morning this distribution is inhibit for making humans awake. The melatonin distribution is connected to the amount of light the human eye perceives. The white cold light during the day with 1000lx is making the human body awake and active. But when the eye perceives less light in the evening hours the melatonin production and distribution starts. But the suppression of the melatonin distribution already starts at an illuminance of 100lx. (Werth et al, 2013)

Thus the illuminance is influencing the circadian rhythm of living beings. People are spending most of the time inside buildings with artificial light and not outside in the sunlight. The difference in illuminance of natural and artificial light is high. The illuminance of artificial light sources inside ranges from 50 to 500 Lux but for the circadian rhythm an illuminance of 1,000 Lux is essential. This darkness can cause depression and sleep disorder. In conclusion light has a massive impact on humans and lamps have to be designed by taking the human wellbeing and health into consideration. (Fördergemeinschaft Gutes Licht, 2008)

Social Behaviour

Furthermore light is influencing the social behaviour of humans. The lighting atmosphere of the room can have impacts on how people are behaving even if it remains subjective. On the one hand a cosy atmosphere with a low illuminance and warm light makes people more open minded. Thus more intimately conversations are coming up. The willingness to cooperate and intimacy are getting higher. On the other hand light conditions can also cause anonymity and the people tend to behave more aggressive. This is mainly due to the lower feeling of responsibility caused by the lighting. (Werth et al., 2013)

2.1.3. Usage of Light in Interiors

Light inside houses is essential for a comfortable and healthy way of living. Like the sun is lighting our earth and nature the artificial light has to light our homes. The lighting system can be split up in room light, zone light and mood light. The function of a room light is to evenly illuminate the entire room and it can be seen as the main lighting of a room. The zone light fulfills the function of lighting special areas like workspaces, kitchen tables or reading areas. Contrary to these functional lights the mood light is supposed to create a cozy and relaxed atmosphere to make the user feel at home. But the usage of light and the functions of light are in every room different. In appendix B.4 a detailed description of the usage of light in the kitchen, the office, the bathroom, the bedroom and the living room is presented. Here just the requirements for

Figure 2.2.Light Usage in kitchens

Figure 2.3. Light Usage in Offices

Figure 2.4. Light Usage in Bathrooms

kitchen, office and bathroom lighting are briefly discussed. (Fördergemeinschaft Gutes Licht, 2009)

Kitchen
Lighting systems of kitchens are separated into four sections: general lighting, workspace lighting, kitchen cupboard lighting and kitchen table lighting. Moreover figure 2.2 indicates the diverse applications of lamps in these four areas. These sections are also supporting the various usages a kitchen has to provide nowadays to the users. Indeed in addition to cooking and baking people are also partying or working inside their kitchens. Thus it can be concluded that every section has its own light requirements. (Fördergemeinschaft Gutes Licht, 2009)

General lighting:
(These requirements are valid for kitchen, office and bathroom)
- Even illumination of entire room
- Illuminance of 150-300 lux
- Color Rendering Index of 80

Workspace lighting:
- Illumination of countertop, stove and sink
- No irritating shadows
- Illuminance of at least 500 lux
- Color Rendering Index of at least 80 or higher

Kitchen table lighting
- Illumination of table/bar as well as the persons around it
- Adjustable height
- Illuminance of 200-300 lux
- Color Rendering Index of 90

(Home) Office
Most of the people are daily working in offices or at least have their own home office for organizing bills and other important papers. In every case visual tasks like reading are performed which require good light conditions. Once again this can be organized in different sections. In working places like offices it is significant to have a general lighting. Then the eyes don’t need to compensate the difference between the bright light of the desk area and the dark background. This adaption process would make the working person faster tired and then/ consequently unmotivated. (Fördergemeinschaft Gutes Licht)
The entire desk is called the workspace because it considered that all the work takes place on it. Thus everything on the desk needs to be well visible. Higher requirements are valid for the visual tasks space which is also positioned on the top

of the desks. This limited area is the mainly used space where people are reading and controlling their computer. Moreover it is also essential that no irritating shadows appear in this area. Hence the placement of the lamp has to be made wisely. Examples of suitable desk lamps are presented in figure 2.3. (Fördergemeinschaft Gutes Licht)

Workspace
- Illumination of 500 lux
- High CRI of 80-100

Visual Tasks Space
- No irritating shadows
- Illumination of 750 lux
- High CRI of 80-100
- Self-control over the lamp

Bathroom
The usage of the bathroom is increasingly changing and the bathroom is longer used than before. Almost everyone starts his day in this room to get ready for the coming day. Then every evening people are spending time in their bathrooms before going to sleep. Nightly visits for going to toilet are also really common. These three different situations request that the light in the bathroom is dimmable so that it is not glaring in the evening and night but remains bright enough in the morning. The bathroom can be organized in two sections: general lighting and mirror lighting. Sometimes even some additional indirect lights can be mounted on the walls or ceiling for making the room looking larger. Figure 2.4 represents a small collection of bathroom lamps. (Fördergemeinschaft Gutes Licht, 2009)

Mirror light
- No irritating shadows should appear on the face
- Illumination of 400-500 Lux
- A CRI of at least 80
- Glare Free
- Natural Color Temperature

2.2. Analysis of OLED

Organic Light Emitting Diodes (OLED) are flat light emitting panels which can be defined as area light sources. These panels are currently used as displays or lighting applications. (OLED.at, 2013) The development of OLEDs started in 1953 with the observation of organic light emitting layers by André Bernanose. Then in 1987 Chin W. Tang and Steve van Slyke developed the first light diode out of organic materials. Chin W. Tang personally discovered the electroluminescence of organic materials at a moderate D.C.-voltage. In 1989 R. Friend, J. Burroughes and D. Bradley of the Cambridge University managed to combine organic and polymer layers so that the polymer layers were emitting light. Since then the OLED technology is constantly improved. (Wagner and Wagner, 2009)

More knowledge about OLED panels is acquired in this section for finding possible application for OLED lamps and for being able to use the panels in lamp designs. Therefore the structure and workings principles as well as all characteristics of OLEDs are examined. OLED is compared to other light sources and possible effects on humans are determined with the knowledge of the previous section about light.

2.2.1. Structure of OLEDs

Basically OLEDs consist out of an organic layer sandwiched between two electrodes. These thin layers are positioned on a substrate like glass or a polymer film. When an electrical current is applied on the electrodes the organic layers are emitting light due to the luminous recombination of electron hole pairs. Hence the light is depending on the organic materials. Figure 2.4 illustrates how the structure of OLEDs can look like and gives an impression of how thick the layers can be. This figure is just an example of a possible structure because many usable materials are existing. (Knoth, 2004)

Substrate
The substrate is the basis of the panels and all layers are placed above it. OLEDs do not need a crystalline underground like LEDs and it is thus possible to produce large panels (OLED.at, 2013). As mentioned before glass is mainly used as the substrate. Glass is fitting well because of its transparency and its low roughness. Indeed a high roughness of the substrate material can cause short circuits. (Birnstock & Haldi, 2009)

Electrodes
The choice of the materials for the electrodes is depending on the required characteristics of the OLED panel. For normal rigid OLED panels a metal like aluminium is used as cathode. But transparent or mirror finished OLEDs require other material properties (transparency or appearance of mirror) which can't be fulfilled by aluminium. These characteristics of OLED panels will be detailed later within this section. (Knoth, 2004) The electrical and electronic properties of the

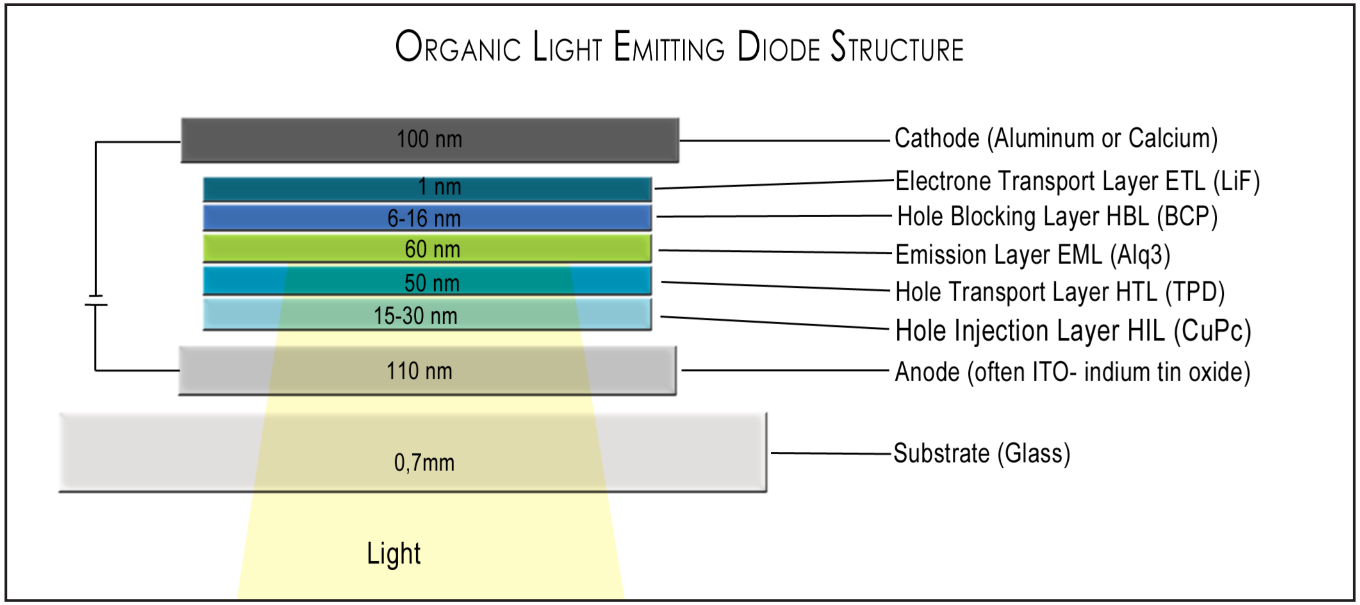


Figure 2.5. Structure of Organig Light Emitting Diode (Narayan et al,,2013 & Spie, 2015)

anode are significant for the injection of positive charge carrier (holes) from the anode into the organic layers. These properties together with the morphology of the material are having a huge influence on the efficiency and life time of the OLED panel. Often an amorphous, transparent and conductive material like Indium-Zinn-Oxyd is used. (Knoth, 2004)

Organic Layers

As demonstrated in figure 2.4 the organic layers is composed of five layers respectively called Electron Injection Layer, Hole Blocking Layers, Emission Layer, Hole Transportation Layer and Hole Injection Layer. Possible materials for all layers are also mentioned inside this graphic. The function of these layers is the optimization of the flow of the electric current so that the light emission is maximized. (LG-Chem, 2013)

As the name Electron Injection Layer implies the function of this layer is to enhance the injection of electrons from the cathode into the emission layer. Then a Hole Blocking Layer is located between the EIL and the EL for improving the luminous efficiency by preventing the leakage of holes towards the cathode. Due to this function the operating voltage can be reduced. The Hole Injection Layer is positioned between the anode and the Hole Transportation layer to lower the energy barrier between them so that the holes can move even at a low voltage towards the EL. (Narayan et al., 2013)

The colour of the light is depending on the organic materials. OLEDs do have a large emission spectrum and can emit almost every colour. For white light three emissions layers are used within the OLED (red, green and blue). Together these three colours generate white light. Moreover the colour is also depending on the radiation angle which can be influenced by the thickness of the not emitting layers. (Osram, a)

Doping and Dopants

Doping makes OLEDs more efficient and today doped semiconductors are common. Doping means that the organic layers are doped with molecules which can receive or deliver electrons. Then the electrons can move within the layers with less energy. Doping enables that almost the whole energy is transformed into light. The electrical load will be reduced due to the lower electricity consumption. This fact will also increase the lifetime of the panels. (Birnstock & Haldi, 2009)

In white emitting OLEDs, red, green and blue dopants are usually integrated in the emitting layer. Therefore the colour and colour rending of an OLED can be optimized with these dopants. Most of the panels are doped with phosphorescent emitters. (Acuity Brands, 2014a)

Different methods of ordering the three emission layers inside the OLED are existing and presented in figure 2.6. One is called blending and the three colours are mixed inside the emission layer. Another possibility is a multilayer distribution where the three emission layers are directly added on top of each other. Three complete OLEDs can also

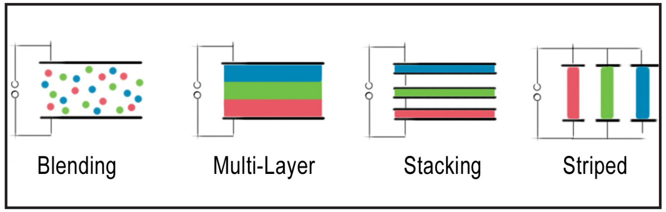


Figure 2.6. Approaches to Generate White Light (Gather, Köhnen & Meerholz, 2011)

be added on top of each other to form a stacked OLED. Finally an OLED can be composed of stripes where the three emission colours are added next to each other. All four opportunities do have their disadvantages and advantages regarding the OLEDs characteristics and production. (Gather, Köhnen & Meerholz, 2011)

Encapsulation
Another essential part is to protect the organic layers against oxygen and humidity. This is done by adding an encapsulation layer on top of the OLED. Therefore a thin layer will be added on top of the cathode surrounding all layers. This encapsulation is still really sensitive and needs to be extra protected for example by another glass layer. (Osram, a)

Diffusor film
Around 85% of the light gets lost inside the substrate and the organic layers. A diffusor film can change the reflection of the light so that more light is leaving the panel. As a consequence the total performance and mix of colours of the OLED panel will improve. (Osram, a)

2.2.2. Workingsprinciple

The emission of light by a physical object is called luminescence. This radiation can be released by the transition of an electron from an excited state back into a normal state. If the emission is generated by electrical current it is called electroluminescence. This is the case in LEDs and OLEDs. (Wikipedia, 2015d)

When a power is applied between the electrodes the charge carriers (electrons and holes) start moving towards respectively the anode and the

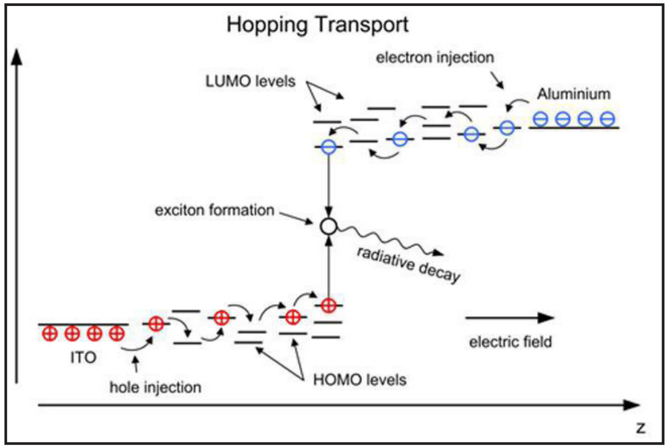


Figure 2.7. Workings Principle (Electroviees)

cathode and are eventually meeting in the emission layer. In other words the charge carriers are injected into their respective layers and then pass the transportation layers until they recombine in the emission layer. (Knoth, 2004) The movement of charge carriers through organic materials is called hopping. The holes are moving from HOMO-level (highest occupied molecular orbital level) on the anodes side and the electrons from the LUMO-level (lowest occupied molecular orbital level) on the cathodes side towards the emission layer (as illustrated in figure 2.5). In this layer they recombine and thereby create an excited state. This state is called exciton and when this latter decays it is emitting light. It is essential that in phosphorescent emitters all excitons can decay by releasing light and is then influencing the choice of the materials. Other emitters like fluorescent emitters also exits but they just have an efficiency of 25% even if they have a longer life time. (Osram, a)

2.2.3. Characteristics of OLED

All characteristics of Organic Light Emitting Diodes are summarized within this section. The section is composed of chemical, ecological, electrical, lighting, mechanical, optical, production and thermal properties.

Chemical properties
The contact with water and moisture should be avoided. Due to water or moisture corrosion of the conductive material can appear. Moreover are OLED panels sensitive to humidity and water. (Philips, 2012)

Ecological properties
The OLED panels offer good ecological attributes in all three phases: manufacturing, usage and disposal. During the manufacturing of OLEDs almost no high temperatures processes are used and the energy consumption and the toxic load remain quite low. Hence the manufacturing of OLED panels is a green process except the purification of the ITO. (Gather, Köhnen & Meerholz, 2011)
8-10% of the electrical power consumption are illumination-related in Europe and the USA (Gather, Köhnen & Meerholz, 2011). OLED panels have the potential for being a high energy efficient light source. Their usage would result in energy savings which have a major impact on the reduction the CO2 emission. (Konica Minolta, 2015a)

Moreover OLED panels do not contain any toxic components like arsenic and mercury. First this makes the OLED panels a save light source for humans because there are no negative effects on the human health due to the materials. Second it makes the disposal of OLED panels beneficial. The panel's materials can be combusted by mainly realising CO2 and H2O. (Gather, Köhnen & Meerholz, 2011)

Electrical properties

Current and Voltage

The current which needs to be applied on an OLED depends on the size of the OLED and the required light output. The required voltage is depending on the organic stack, internal architecture and the aging of the OLED (Philips, 2012).

OLED panels are powered by a low DC current and require a low voltage around 2-7V. Consequently they can't be connected directly to the AC grid and the conversion of the voltage is essential for an OLED lamp. (Gather, Köhnen & Meerholz, 2011) Moreover a constant current is needed for providing a constant luminance and a maximum life time. Due to the degradation process the luminous efficiency of a panel declines and the static resistance increases. Under constant voltage operation the increasing of the resistance leads to a decline in the current which again leads to a greater decline in the luminance then just by the degradation process. This is resulting of the proportional behaviour of the luminance and the current. Thus the current has to be constant so as to make the luminance declining slower which increases the lifetime. (Osram, b)

Efficiency

The efficiency is a determining characteristic of a light source. OLED panels are still in development and the efficiency gets continuously improved. In 2006 an efficiency of 60 lm/W was reached and under laboratory conditions efficiencies of 100lm/W and 120lm/W have already been realised. Unfortunately it is not possible to reach such a high efficiency in mass production yet. (Gather, Köhnen & Meerholz, 2011).

Other electrical properties

Furthermore OLED panels should be connected in

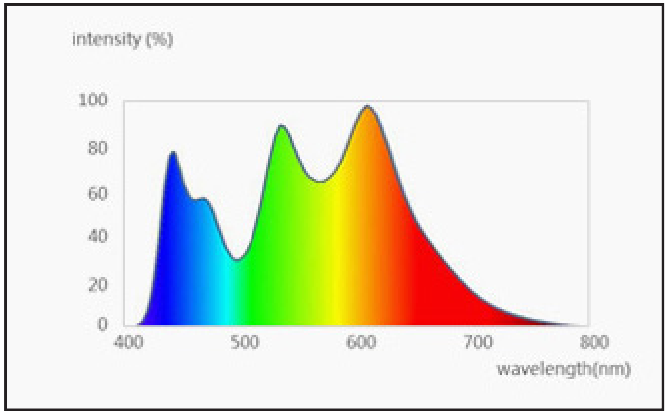


Figure 2.8. Emission Spectrum of an OLED (LG-Chem, 2013)

series and not in parallel. Also is it possible to dim OLED panels. (Osram, b)

Lighting properties

Emission spectrum

The emission spectrum of OLED panels is large. As shown in figure 2.8 the spectrum contains every colour in the range of visible light but no Infrared and Ultra Violet radiation. As mentioned before OLED panels can emit white light by mixing the emission of red, green and blue light. The panels offer a high colour quality directly when they are turned on. (Osram, a)

Moreover the best light sources have a similar emission spectrum than/to sunlight. This light is gentle to the eyes because they are close to the emission spectrum of natural light. Indeed the OLED panels have the closest light's spectrum to sun light (LG-Chem, 2013).

Radiation

The radiation of OLED panels can be described with a lambertian curve. This means that the panel has an even brightness all over the panel independent from the view angle. (Osram, a)

Luminance, Colour Rendering Index, Colour Temperature and other properties

Light has a couple of significant characteristics like the Colour Rendering Index (CRI), the luminance and the Colour Temperature (term definitions are presented in appendix B.1). The luminance of OLED panels is usually around 2 000 cd/m² (Osram, a) and reaches a CRI of around 90 which is satisfying for a good light source (Gather, Köhnen & Meerholz, 2011). The panels are available in colour temperatures of around 3 000 - 4 000 K (Acuity Brands, 2014b). Moreover the light of OLED panels is glare free and has a homogeneous illumination (Gather, Köhnen & Meerholz, 2011).

Mechanical properties

Dimensions

The dimensions of the panels are still varying a lot but remain small for the beginning. All characteristics of the panels are studied in detail during the market analysis. In general the panels are either rectangular, quadratic or round. The thickness of the panels varies between 0, 25-2mm which makes them a thin and light weight light source. The panels can easily be added on


Figure 2.9. Flexible OLED Panel (Osram, 2015d)


Figure 2.10. OLED inside a mirror turned on (Osram, 2015b)


Figure 2.11. OLEDs inside a mirror turned off (Osram, 2015b)


Figure 2.12. Transparent OLED panel (Osram, 2015c)

surfaces or inside lamp designs without increasing their thicknesses. The diameter of the lighting areas of round panels varies between 71-100mm. The lighting areas of rectangular panels vary from 55mmx53mm to 320mm x 110mm and the lighting areas of quadratic panels are between 40mm and 3200mm. More information about the dimension of all panels is provided in appendix B.7.

Hardness

OLED panels are really thin panels with a thickness of just 2mm. Moreover glass is often used as a substrate. Thus mechanical stress like shock, pressure and point loads should be avoided. (Philips, 2012)

Flexibility

One unique characteristics of OLED panels is the ability to bend the panels (see figure 2.9). This flexible panels offer new possibilities for lamp designers. These flexible panels are not free 3D-surfaces but 2.5D structures which means that each point of the OLED can just be bend in one direction. But further research on the panels is still necessary for a mass production. A flexible encapsulation is essential like the thin film encapsulation. Then a bending with a radius of some centimetre would be possible. Regarding the choice of the electrodes a metal cathode is more useful due to the fact that they are better bendable than the ITO-electrode. (Osram, 2015d)

However LG-Chem already published its first flexible OLED panel with a plastic substrate and in July 2015 mass production is supposed to start (OLED.at, 2015).

Life time

OLED panels can currently achieve a lifetime of 30 000 hours at a brightness level of 5000 cd/m² (Gather, Köhnen & Meerholz, 2011). As mentioned before this life time is depending on a lot of factors like the voltage, current, temperature and static resistance of the OLED (Osram, a & b).

Optical properties

Appearance

In addition to the flexibility, OLED panels can also have the unique characteristics of transparency or mirror finished. These unique characteristics offer new freedom for designers.

Mirror finished OLED panels have the ability to fulfil two functions. When they are turned on they illuminate their environment but when they are turned off they act like mirrors. It is even possible to just light up parts of a large mirror with the suitable technology (figure 2.10 and 2.11). In this case the cathode does behave like a mirror and the organic materials and the anode are made out of transparent materials. (Osram, 2015b)

Another possibility is to create transparent OLED panels by using two transparent electrodes. But the current transparent electrodes have a low conductivity compared to the metal electrodes. Consequently it is still a challenge to produce large transparent OLED panels and transmission and conductivity are highly competitive parameters. Moreover a diffusor film can't be used due to the resulting opacity. (Osram, 2015c)

The vision of this technology is that transparent OLED panels can be integrated inside windows. Transparent panels do have a bright side and a less bright side. If a person looks into the panel from the bright side the objects behind the panel are not visible anymore. On the less bright side the objects on the other side are visible and illuminated. Osram already developed its first transparent panel with 116cm² and a transmission of 57%. (Osram, 2015c)

Segmentation
It is possible to organize the panel into sharply separated cells which can be controlled independently. By controlling the segments individually light effects can be created and even 3D is possible. A distance between the different segments of just 10 µm is achievable. Also segments with different colours are in the realms of possibility. (Osram, 2015g)

Production properties
The manufacturing processes of OLED panels are still slow and expensive. Most of the panels are currently made by thermal evaporation of small molecules under high vacuum. Spin coating and printing are low-cost material processing techniques and promise a low cost production but they still need to be developed. (Gather, Köhnen & Meerholz, 2011)

Thermal properties
OLED panels just generate a small amount of heat during operation. This makes OLED panels a suitable light source for applications close to temperature sensitive objects (Konica Minolta, 2015b). The optimal operation temperature of OLEDs ranges between 15-25°C and the storage temperature of OLED panels ranges between 15-40°C (Philips, 2012)

2.2.4. Effects of OLED on humans
All light sources impact the humans and so does OLED. As examined during the light analysis the human eye is adapted to the sun light. Thus a good light source should have a similar spectrum to the sunlight spectrum. The emission spectrum

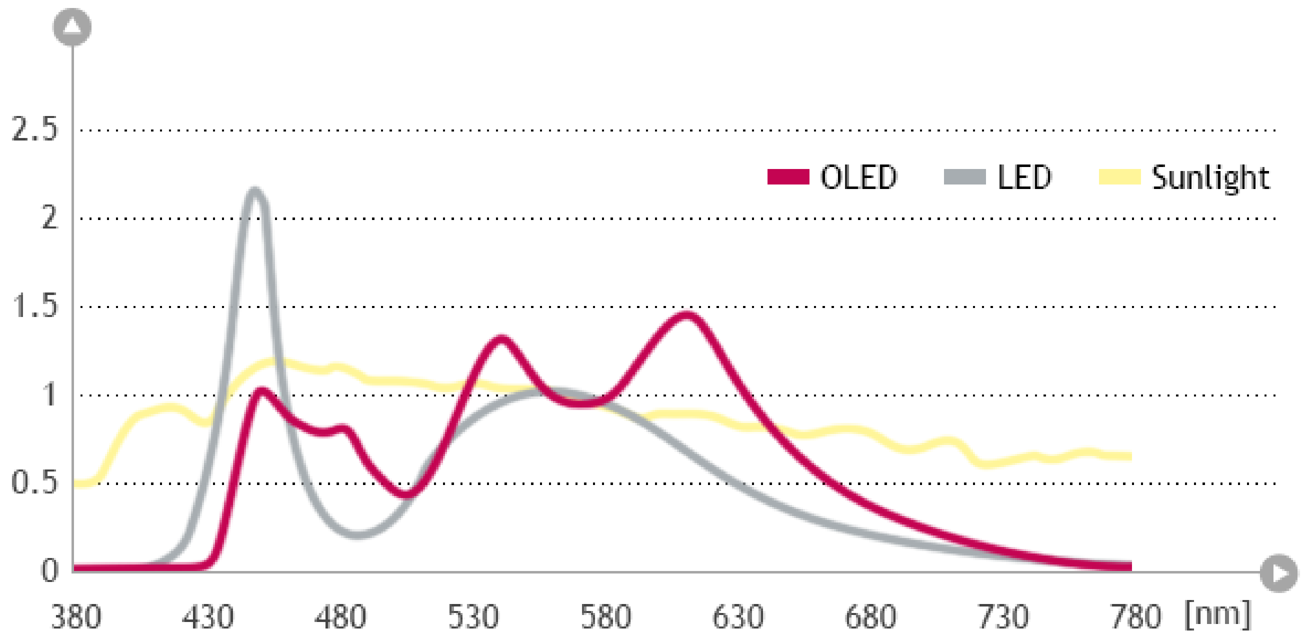


Figure 2.13. Emission Spectrum of OLED, LED and Sunlight (LG-Chem, 2014)

of OLED is actually close to the one of natural light which makes the OLED panels a healthy light source (Majka & Makja, 2014). Moreover the light of an OLED does not contain Infrared and Ultra Violet radiation. These two kinds of radiation are the most harmful for the human eyes and skin as seen in the health effect section of this report. Finally OLED panels do not contain any hazardous material which could harm people in the direct environment of the panel.

2.2.5. Comparison between OLED and other Light Sources
Considering that OLED technology is still in development, OLEDs have a high potential on the lighting market compared to other existing light sources. Table 2.1 presents a summary of the comparison between OLED and LED, incandescent light bulbs, fluorescent lamps, compact fluorescent lamps and halogen lamps. This table and the following conclusion is based on information of the website of the Leo Group Companies (2011).

First of all OLEDs are area light sources and not point light source like the other light sources. Then the efficiency of the OLED is already as high as the one of compact fluorescent lamps and higher than the one of incandescent light bulbs. The efficiency of OLEDs is still about to improve. Moreover the colour temperatures of all light sources range in the area of warm white and natural light. Additionally the Colour Rendering Index of OLED is already quite high with 90 compare to the fluorescent lamps and LED. When it comes to the lifetime OLEDs are of course functioning longer than common light

	OLED	LED	Incandescent Light bulb	Fluorescent lamp	Compact Fluorescent lamp	Halogen
Kind	Area Light Source	Point Light Source	Point Light Source	Between Point and Area Light Source	Between Point and Area Light Source	Point Light Source
Efficiency	~ 60 lm/W	65-160 lm/W	12 lm/W	80 lm/W	60 lm/W	18 lm/W[2]
Colour Temperature	2 700 -4 000K	2 700-10 000K	2 500- 2 700K	2 700- 6 000K	2700-6000K	3 000- 3 200K
Colour Rendering Index	80-90	> 65-95	>90	>80	80-90	>90
Life Time	5 000 -10 000h	50 000h	1 000 - 2 000h	7 000 - 15 000h	7 000 - 10 000	2 000 - 4 000h
Mercury	No	No	No	Yes	Yes	No
UV-Radiation	No	No	Yes	Yes	Yes	Yes
IR-Radiation	No	No	Yes	Yes	Yes	Yes

Table 2.1. Comparison of OLED to other Light Sources (Leo Group of Companies, 2011)

bulbs but the LEDs are still having a way higher lifetime than the OLEDs.

Consequently the life time needs to be improved especially under the consideration that LEDs are 20 cheaper than OLED (OLED-info, 2015). If the OLED wants to become a concurrent of LED the efficiency and life time has to increase and the price needs to be reduced. But the OLED seems to be healthier than LED regarding their emission spectrums. Figure 2.13 shows the emission spectrums of OLED, LED and sunlight. The OLED doesn't have a harmful peak in the blue area and is way closer to the one of sunlight which makes it a healthier light source.

OLED can be seen as a really environmental friendly and healthy light source as described during the characterizations of OLEDs. OLEDs do not contain mercury and do not have any UV and IR radiation in their emission spectrum. Other common light sources do contain these dangerous rays and the hazardous material mercury.

2.2.6. Future

At the moment just small OLED panels are produced for lighting. But high quality lamps, lights for orientation, lighting boards, decoration lights and lighting in the automobile area shall soon become more common. Then after some years the OLED will be integrated in the general lighting. A long term vision would be to have windows or curtains which can light up or OLED panels inside walls of cupboards or glass cabinets. (Wagner & Wagner, 2009)

But first the OLED technology needs further improvement regarding the materials of OLED panels and the manufacturing (Novaled, 2015). These improvements are especially concerning flexible and transparent OLED panels. However the OLED panels are having a high potential of being an efficient and healthy light source. That's why Europe and the USA are supporting researches on the OLED technology so as to be able to integrate this light source on the future lighting market (Wagner & Wagner, 2009). This is mainly due to the fact that OLED panel offer the opportunity to lower the illuminated-related electrical power consumption and they not contain any noxious materials.

The prices for OLED is supposed to decline until 2020 so that the OLED can compete with LED regarding its price, efficiency and life time (OLED. at, 2014). Konica Minolta even thinks that 50% of the fluorescent lamps and 40% of the incandescent light bulbs will be replaced by OLED by 2030. They


Figure 2.14. OLED Lamps

calculated that it would be then possible to save up to 20% of the power consumption (Konica Minolta, 2015a).

2.3. Market Analysis

In this section the market is analysed. First the usage of OLED and then the already existing OLED lamps are described. In the end of the market analysis all existing OLED panels are collected within a table. This is essential for the concept generation for knowing which panels can be integrated inside the lamps.

2.3.1. Current Usage of OLED and usage of light

OLEDs are currently used as displays and for lighting (OLED.at, 2013). The OLED panels are used for lighting in cars and lamps. In appendix B.5 a collage of the current usage of OLED panels is provided. With its unique characteristics of being flexible, transparent and mirror finished they offer new interesting possibilities for designing lamps.

During the trade fairs IMM Cologne in January 2015 and the ZOW in Bad Salzuflen in February 2015 the different usage of light and the existing light sources had been analysed. On the IMM Cologne it was obvious that light can either fulfil functions like illuminating working zones or be used as art. Lamps themselves can be art or they can be used as highlight for supporting the furniture designs. On the ZOW the company Elektra was the only one presenting their OLED panels which underlines that LEDs are mainly used nowadays. Moreover all the lamp designs follow the same functions. They all contain the ability to get dimmed and the function tuneable white. Moreover the company D-Leuchten and L&S already work with apps for controlling their lamps. The apps contain all options: turn on/off, dimmable, tuneable white and sometimes even the ability to change the colour of the light from white to blue, red and other colours.

2.3.2. OLED Lamps

In figure 2.14 a selection of OLED lamps are presented and two more collages are illustrated in appendix B.6. Conspicuous is the simple design of the lamps. The designs often support the exceptional characteristics of the OLED panels like their slimness, transparency or flexibility. Moreover a bride variation of materials is used like metals, wood, glass and plastic. Material and design together give a high quality impression. Some lamps are used as eye catcher, for general lighting and as tasks lights.

2.3.3. Producer of OLED panels

Osram, Philips, LG-Chem, Tridonic, Lumiotec and Kaneka already provide OLED panels for lighting. Every company produces different panels with different properties. The German company Osram offers basic rigid panels like quadratic, rectangular and round panels and even a transparent rectangular panel. They already provide transparent panels as the only company. Next to their basic panels Philips also provides mirror finished and LG-Chem already produce their flexible OLED panel. Basic panels are also provided by Tridonic, Lumiotec and Kaneka. Kaneka does even sell panels in colours as red, amber, blue and green. All panels do have different lighting properties and dimensions. A detailed table of all panels is presented in appendix B.7.

2.4. Analysis OTT-DESIGN

Finally the design office OTT-DESIGN itself is examined. This step is essential for designing a lamp which is extending and matching with the product catalogues of the office. First the company OTT-DESIGN will be described and subsequently some of the lamps designed by OTT-DESIGN will be presented.

2.4.1. OTT-DESIGN

OTT-DESIGN is a design office which is acting in the area of interior and product design. the product design is apparently mainly focused on furnitures and products connected to the interior design. Niko Ott, the founder and owner of the office, and his five employees are running a bright variation of projects for kitchens, bathrooms, living rooms, doctors offices, stores, public buildings and also offices. OTT-DESIGN is not just operating in Germany but is also international and deals with other european countries. A more detailed description of the office and area of operation of OTT-DESIGN is presented in the action plan in Appendix A.2.

Figure 2.15. Lamps designed by OTT DESIGN

2.4.2. Lamps designed by OTT-DESIGN

OTT-DESIGN already developed a couple of lamps for various functions and with different light sources. So far they just worked with LEDs and Halogen bulbs but not with OLED panels. Some ideas of design for OLED lamps already exist but they are not fully developed yet. In the collage of figure 2.15 a collection of the designed lamps are shown.
Moreover the lamps fulfil different functions in diverse areas. For instance some of the lamps are designed for the kitchen. These lamps are integrated into furniture for illuminating the work top or are used for illuminating the whole kitchen.

Other lamps are designed for the bedroom, stores or showrooms. By combining different kinds of light, the user can choose himself which light he wants. Next to the functions the style of the lamps can also be described. Simple and inorganic are the two main words which cross the mind while analysing the lamps of the design office. Metal, black and white are often used and no bright colour or unusual materials are used as eye catchers.

2.5. List of Requirements

General

- The Lamp should support the positive characteristics of OLED
  - No Hazardous materials
- The Lamp should present any of the unique characteristics of OLED
  - Flexible
  - Transparent
  - Thin

Functional

- Lamp contains at least one OLED panel
- Lamp can be turned on/off manual by the user
- Light of the lamp can be dimmed
- Lamp should not get hotter than 40°C
- No short circuit should appear
- OLED panel should be changeable
- Casing should be stable

Usability

- Light should turn on within 1sec
- Light should be dimmable within 1 sec
- Lamp can be cleanable within 30 sec
- Lamp is comprehensible
- User can turn on the light within 10 sec
- User can dim the light within 10 sec
- User can tune the light within 10 sec
- Lamp has to be safe for the user
  - No electric shocks are allowed
  - No sharp edges where the user can hurt himself

2.6. Conclusion

All in all OLED offers some interesting new design solutions for lamp designs. The usage of OLED in lamps is totally different than the one of the current light sources. This is mainly due to the fact that OLED panels are area light sources but also because they have many unique characteristics. These unique characters are:

- Flexible, transparent or mirror finished
- Ultra-thin and light weight
- No glare
- Homogenous light over the surface
- No IR and UV radiation
- High Color Rendering Index
- Eco-friendly
- Closest emission spectrum to one of sunlight

Because of its unique characteristics OLED panels can be used as a lamp in every room. While designing a lamp for bathrooms and kitchens, facts like humidity and splash water have to be taken into account. A good design solution will then even make the usage of OLEDs in bathrooms and kitchen possible. In the end OLEDs allow designers to create new designs and to break away from the known lamp layouts. OLEDs should be used in the modern and future lighting design.

3

3. Idea Generation

The intention of this chapter is to present ideas of a future OLED lamp. These ideas are generated by considering the knowledge of the previous chapter regarding OLED and light. This part starts with presenting three different ways to find inspiration. Mind maps, collages and light structure models are here the chosen tools for getting inspired. Then the idea sketches are illustrated and finally a morphologic schema summarizes all the different solutions. This schema is a tool for creating concepts which is the purpose of the next chapter.

3.1. Brainstorming

A brainstorming over the themes ‘Light’ and ‘Lamps’ was performed as a first step in the idea generation. The results of the brainstorming are two mind maps which are presented in the appendix C1 figure C.1 and C.2.

A brainstorming is particularly useful and enables wide and abstract thought of a topic. No rules about what is allowed to write inside the mind map are existing and as a consequence everything which comes across the mind can be part of the mind map. This can provide a relevant impression on what is connected to the design of a lamp and can give first ideas related to this design.

The mind map ‘Light’ presents everything which is belonging to the topic light. The other mind map ‘Lamp’ shows all the significant aspects for designing a lamp from material, light source, color of the light up to turning on the lamp and the energy supply. This mind map is displaying a couple of solutions which have been used in the morphological schema at the end of this chapter.

3.2. Collages

Additionally to the collages of the analysis chapter two ‘Inspiration’ collages are presented in this section. In the ‘Inspiration’ collages a collection of extraordinary lamps is shown. All the collages have been used for stimulating the creativity during the sketching section.

Bride variations of lamps designed by different designers and companies are collected in the collages in figure 3.1 and figure 3.2. A couple of lamps have been designed by the designer Ingo Maurer. He is a well-known lamp designer and is developing abstract and special lamps. Different materials like broken dishes have been used in his lamps for creating fascinating light effects. These abstract lamps and the more basic lamps are used to discover other lamp models than just the already existing OLED lamps.

Figure 3.1. Inspiration collage

Figure 3.2. Inspiration collage

Figure 3.3. Light Structures

3.3. Light Structures

Various tools can be used for finding inspiration during a design process. Brainstorming and collages are tools where knowledge and pictures

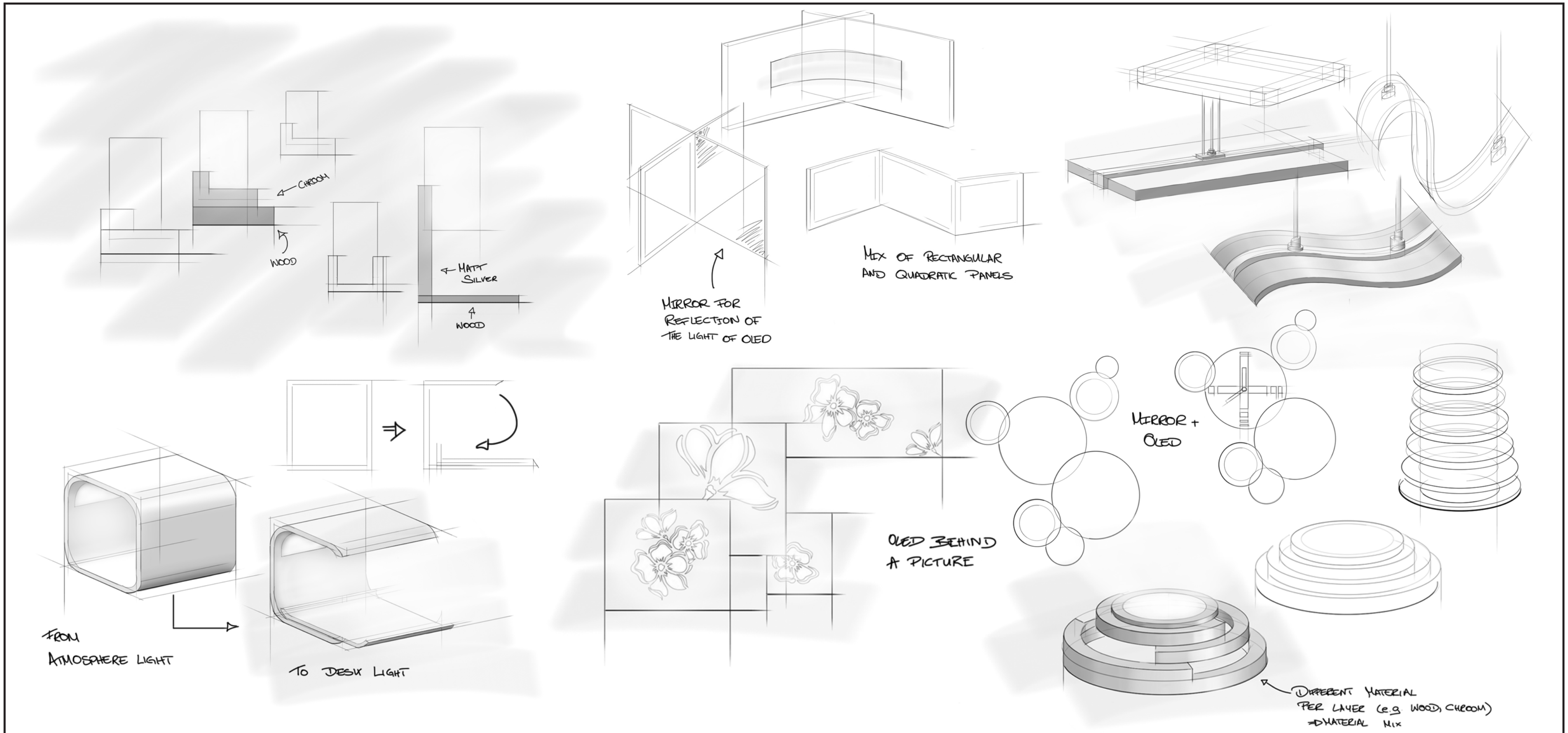


Figure 3.4. Sketches

of existing products are collected. But constructing little models with the one's own hand is a total different tool. Models can either look like real products or can be totally abstract. Both kinds help to get a feeling for forms and dimensions. In this case abstract models have been made which give an impression on different aspects like the shadow-light effect.

A variation of material has been used for the models called 'Light Structures'. Light materials like wood sticks, paper, yarn, tape and little mirrors have been used for creating structures. All the photos of the structures are shown in appendix C2 and figure 3.3 presents a small collection of these photos. Either a lamp or the flash of a camera has been used while taking these pictures for creating shadow-light-effects.

3.4. Sketches

After all the inspirations, sketches of lamps have finally been realized. Figure 3.4 shows selected (not all) sketches and all of them are presented in appendix C.3. Lamps for kitchens, bathrooms and offices have been sketched and dispatched among

10 sketching sheets. The aim was to present a large quantity of ideas and to think about as many solutions as possible. So far only lamps have been sketched but not yet any switch, remote controls or other additional elements a lamp can have. This will be part of the next chapter where different concepts are constructed.

3.5. Morphologic Schema

The last tool which can be used during the generation of ideas is the morphologic schema. In the steps before, a large amount of ideas and solutions has been thought of. A morphologic schema aims at summarizing all ideas and solutions answering the problems the designer has to deal with in a lamp-design. A list of requirements has been developed during the analysis and is of course relevant for the schema. Some other results like the different OLED panels of the OLED analysis are used as well.

The list of requirements shows which problems have to be solved inside a design. These problems are represented in the left column of the morphologic schema. In the other columns, a catalog of possibilities to solve a problem is illustrated. An example of the schema presented in figure 3.5 could be the energy supply. A lamp needs energy for emitting light which means that the energy supply is a requirement. The plug, induction, solar power or a battery are just ideas of power supply for the lamp. As mentioned before this table is essential for the next section. Indeed all the possibilities are used to create different concepts and for each matter a solution has to be found. The lines inside the morphologic schema in appendix C.4 are representing the concepts which are further described in the next chapter. They highlight which solution is chosen for the concepts.

TYPE LAMP	Ceiling Lamp	Desk Lamp	Wall Lamp	Floor Lamp	Integrated into Furniture
OLED PANEL	Quadratic	Rectangular	Circle	Triangle	
DIMENSIONS PANEL	< 50 mm	50 - 100mm	101 - 200mm	201-300mm	>300 mm
THICKNESS PANEL	< 1 mm	1 - 2 mm	2 - 3 mm	> 3 mm	
COLOR TEMPERATURE	Warm White < 3300 K	Natural White 3300 - 5300 K	Day Light White > 5500K	All Three (Tunable)	
COLOR LIGHT	White	Blue	Red	Green	Amber
FEATURES	Mirror Finish	Dimmable	Tunable White	Transparent	Flexible
MATERIAL	Metal	Paper	Wood	Glass	Plastic
WAY OF TURNING ON7OFF	Switch	Remote Control	App	Touch Function	Motion Sensor
ENERGY SUPPLY	Plug	Induction	Battery	Rechargeable Battery	Air Charge

Figure 3.5. Morphologic schema

4

4. Concepts

The purpose of the concept step is to create a variation of concepts by using the ideas generated in the chapter before. Moreover this chapter presents nine concepts of lamps either for kitchens, offices or bathrooms with respectively three concepts for each room. These three rooms are selected because they offer a wide range of possibilities for lamp designs due to the multifunctional lamps located in these rooms. Moreover do just a few OLED lamps for these areas exist yet which offers the possibility to create new lamps with OLED. The requirements the lamps have to fulfil in these areas are identified in the list of requirements which is presented in the analysis section (pages 15-16 and 25). Finally one lamp is chosen to be worked out in detail in the last chapter.

4.1. Concepts Kitchen

In this section of the chapter three designs of kitchen lamps are illustrated and described. As mentioned before the kitchen is a frequently used room. People are not just cooking inside it but also eating, relaxing, working or partying. Thus a set of lamps which fulfil the bride variation of functions are essential. These functions can be concluded out of the plenty ways of using a kitchen. Detailed information about the usage of light in kitchens is provided during the light analysis. The unique characteristics of OLED panels can be used in various ways in the kitchen lighting and is proved by the three concepts. Each of the lamps has their individual function and place inside the kitchen.

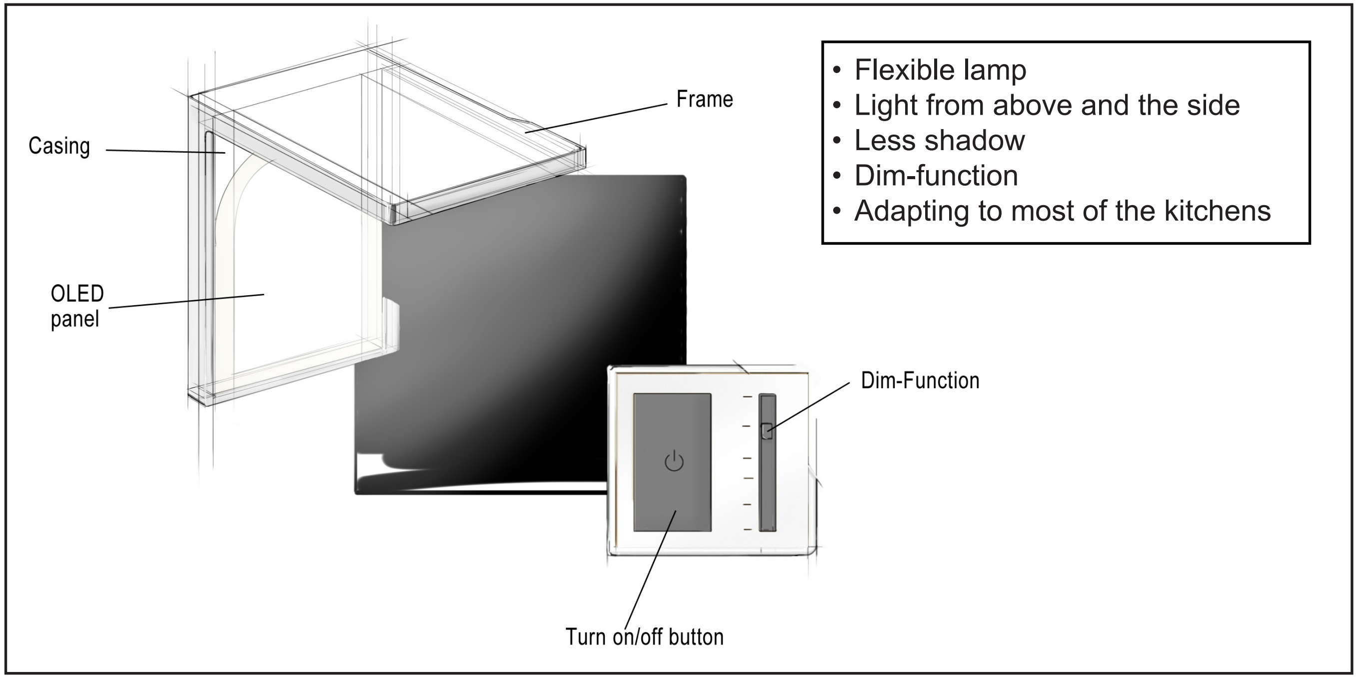


Figure 4.1. Product Presentation - Flexible Corner Light

4.1.1. Flexible Corner Light

The “Flexible Corner Light” illuminates the work top. Therefore the lamp with one flexible OLED panel can be integrated into the kitchens’ furniture. It is basically placed in the corner between the kitchen cupboard and the wall. The lamp illuminates the work top from above and the side. Thus no irritating shadows should appear in the working area. The aim of this lamp is to light the work top in such a way that the user can work under good lighting conditions.

Styling

First of all some form-finding-sketches have been made and are illustrated in appendix D.1. The chosen styling and an adaptable switch are presented in figure 4.1. The lamp is composed of three parts: a flexible OLED panel, a casing and a frame. The casing of the lamp emphasises the flexible shape of the OLED panel. The frame is surrounding the whole lamp and is used as connection between the wall and the casing. The edges of the frame are round off so that the styling of the frame is adapting to the one of the casing.

Functions of the lamp

The work top lighting is not just used for lighting a workspace while cooking but also for creating a calm atmosphere while eating or relaxing inside the kitchen. Hence the dim function is a relevant feature. A switch will be placed close to the lamps. By pressing the large button the light can be turned on or off. The light can be dimmed by the slide switch.

Materials

The idea is to design the lamp and switch in line with the kitchens which is mainly depending on the material choice. The complex shape can be the best produced with plastic. A white plastic for the casing and a grey plastic for the frame have been chosen. Indeed this materials and colours are adapting to most of the existing materials and colours in kitchens.

Workings Principle

An illuminance of 500 lx is required for working areas as examined during the analysis. For achieving this illuminance several lamps needs to be mounted above the work top. The amount of lamps is depending on the size of the work top. The only existing flexible OLED panel of LG-Chem does provide a luminous flux of 75lm. With this value the illuminance on the work top can be calculated.

The frame of the lamps can be attached with screws to the wall and the underside of the kitchen cupboard. Consequently all lamps can be mounted separately. The casing is fixed inside the frame by using a snap connection These interconnections are illustrated in appendix D.2. The size of the lamp logically depends on the chosen OLED panel. The panel of LG-Chem has a size of 211mm x 50mm (appendix B.7) and possible dimensions for the lamp are illustrated in appendix D.3.

Moreover the panel needs to be connected to a power supply due to the fact that it can't be directly connected to the AC grid. The OLED panels can be

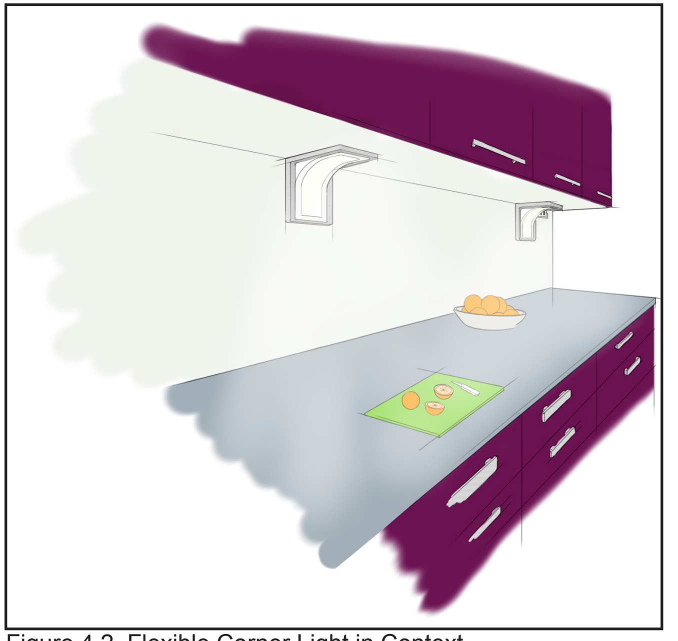


Figure 4.2. Flexible Corner Light in Context

connected in series to a driver. The choice of the driver depends on the electrical level of the panel and the driver. Also the amount of panels per driver is essential for the choice. All cables can be hidden inside and behind the cupboard so that the power supply can be placed on top of the cupboard where it is connected to the electrical grid.

4.1.2. Flexible Ceiling Light

The "Flexible Ceiling Light" is a hanging lamp with flexible OLED panels. The lamp is composed of two wavy-shaped parts which will be placed on top of the kitchen table or bar (figure 4.3). The aim of the lamp is to evenly illuminate the whole table from the top. The flexible OLED panels are creating less shadow because of the bended shape. For larger tables or bars more lamps can be fixed above them or the lamp can be extended as in figure 4.4.

Styling

Sketches of different designs have been made and are presented in appendix D.1. The chosen wavy shape and an example of a possible switch are sketches in figure 4.4. The lamp is having two wavy parts with a total of four integrated OLED panels. Moreover the OLED panels are placed in a thin chrome casing on which an aluminium casing is fixed. The OLED panels are integrated into a thin casing to support their thinness. The casing is a bit larger and also contains two wire connections. The two thin wires connect the lamp to the ceiling and hide the cables. The lamp is creating a contrast between the soft wavy shape and the quadratic forms of the casings.

Functions of the lamp

The lamp aims at evenly illuminating the kitchen table. People are eating at their kitchen table and

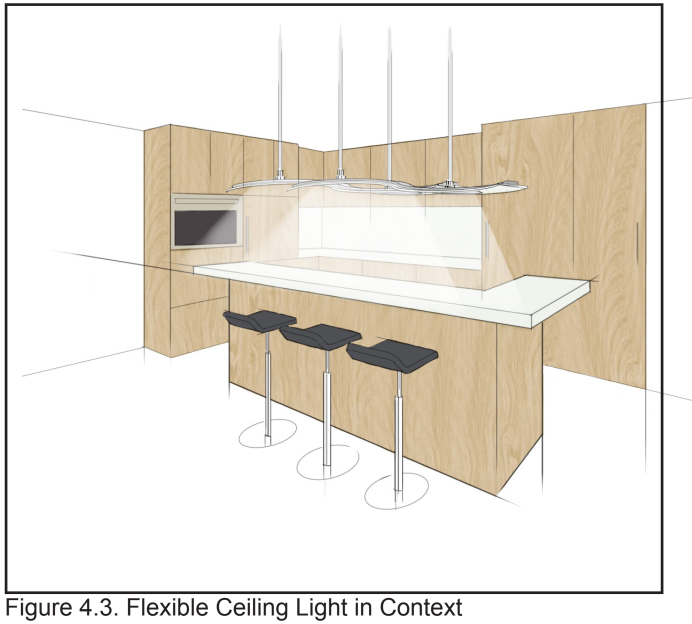


Figure 4.3. Flexible Ceiling Light in Context

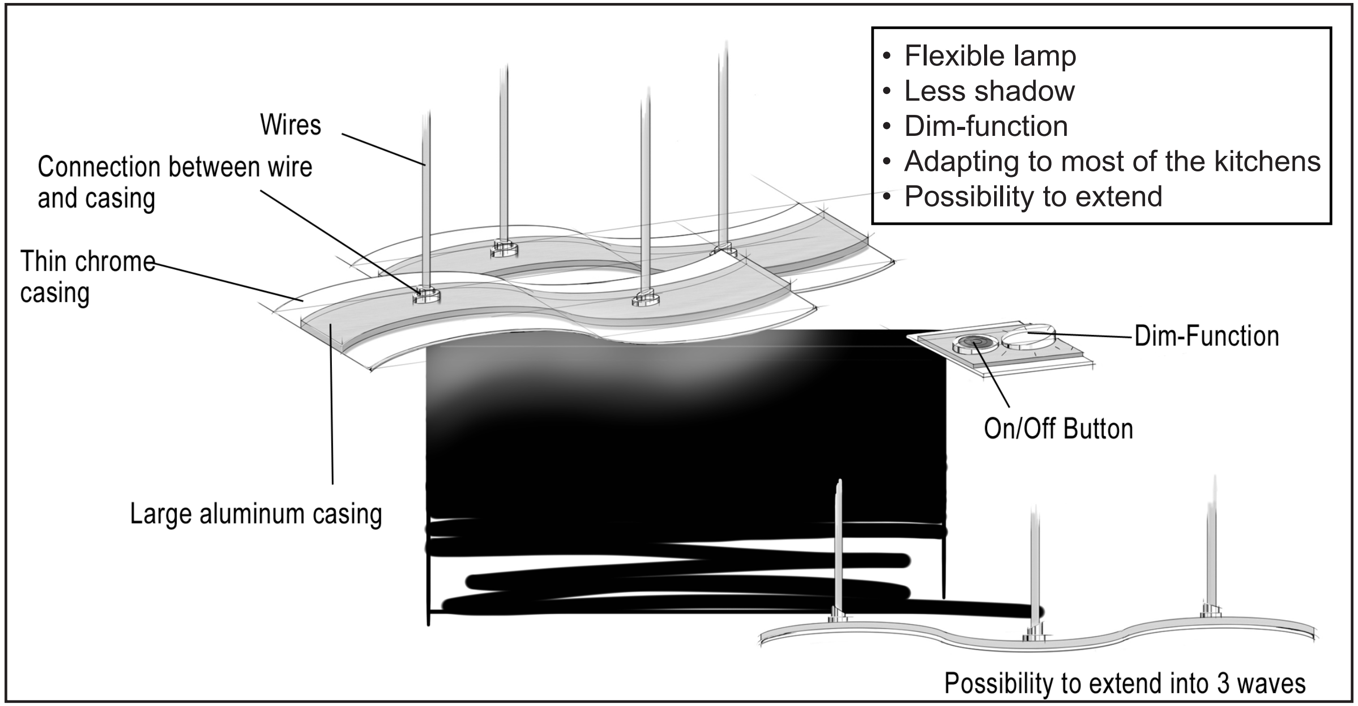


Figure 4.4. Product Presentation - Flexible Ceiling Light

sometimes even invite friends to a dinner party. After they ate they often enjoy a glass of wine or a beer. In this case bright light is not always essential and the lamp should have the possibility to dim it. A switch for the lamp with an on/off button and one rotary knob for the dim function should be places somewhere close to the table.

Materials

A possible choice of material for the thin casing is chrome and a dark grey brushed aluminium for the larger casing. Metals will support the high quality appearance the lamp is supposed to give. A small contrast would be created due to the choice of the light chrome and dark coloured aluminium. Moreover these materials are also adapting quite well in almost every kitchen.

Workings Principle

Four flexible panels with each 211 mm x 50mm and a luminous flux of 75lm will be used. 200-300lx is required for illuminating a kitchen. The distance from the table to the lamp should at least be 60cm. The illuminance can be calculated with the luminous flux and the distance to the table.

The OLED panels are integrated into the chrome casing. This casing then can be attached to the larger casing by a snap connection. Also for this concept the interconnections and the possible dimensions are presented in appendix D.2 and D.3.

Again a power supply for the OLED panels is necessary. It will be hidden inside the aluminium casing. Another point is that the OLED panels have to be connected in series and not parallel. To each driver two panels are connected. Thus the output voltage has to be high enough for running two panels. The cables from the electrical grid to the driver are hidden inside the wires.

4.1.3. Transparent Shelf Light

In this concept a transparent OLED panel is integrated into a glass shelf. This OLED panel is emitting light in two directions: up and down. Thus it has the ability to illuminate the whole kitchen cupboard. An impression of such a shelf light is given in the context drawing in figure 4.6. Light in kitchen cupboards should make the inside of it good visible but also fulfils the role of a mood light. It is also possible to integrate such a panel in every glass cupboard or cabinet. In any case the OLED definitely has to be protected by extra glass layers on top and under the panel.

Shaping

In this concept the shape depends on the transparent OLED panel. The only currently available panel is provided by Osram with a size of 180x65mm (Osram, 2012). The OLED will be surrounded by a metal frame. In addition to these stability reasons, this frame is highlighting the light source. It will make people aware of the panel even though it is turned off. Some form-finding-sketches for the frame are illustrated in appendix D.1. The chosen aluminium frame is sketches in figure 4.5.

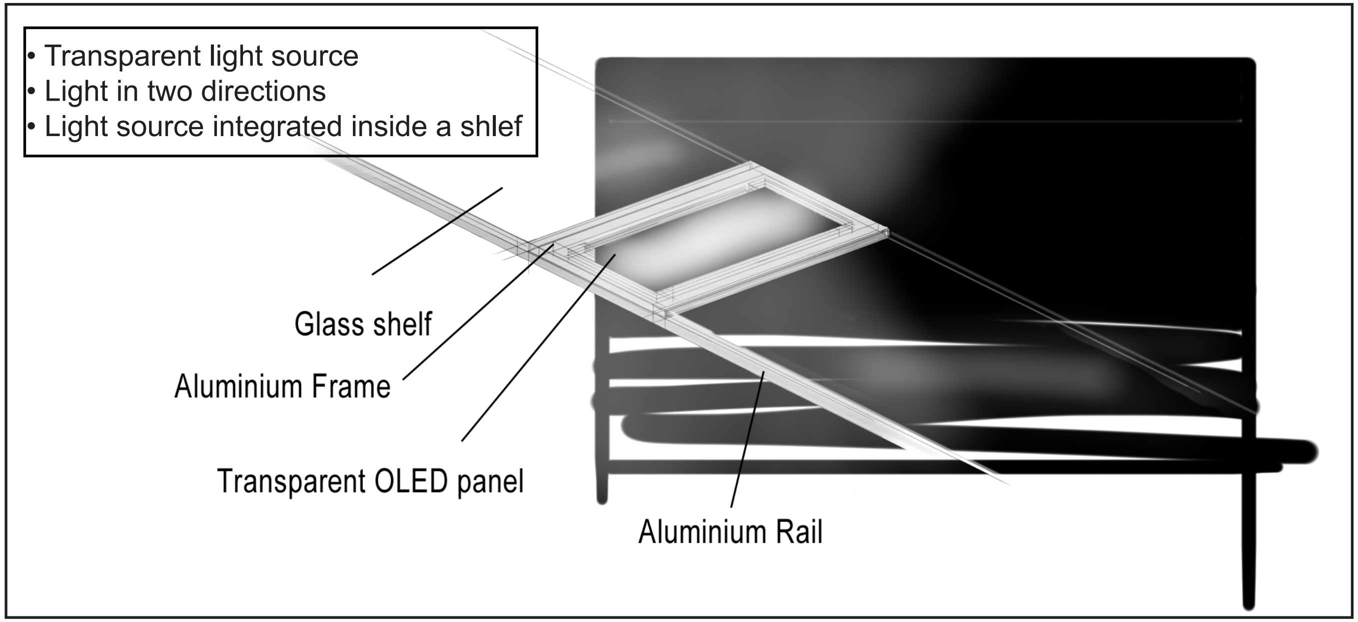


Figure 4.5. Product Presentation - Transparent Shelf Light

Figure 4.6. Transparent Shelf Light in Context

Functions of the lamp

As discussed above the shelf-light illuminates the kitchen cupboard from inside. The light needs to be bright enough for illuminating the inside of the cupboard so that the user can see everything clearly. This is useful when people want to place something inside the cupboard or when they want to take objects out. Moreover this light can also function as a mood light during evenings in the kitchen. Finally it would be plus if the light could be dimmed.

Materials

The frame is out of aluminium. This material is stable enough to hold the glass shelves and the panel and it has a fine-tune appearance. For the protection layers of the OLED glass seems to be the best option because of its transparency. An OLED panel is also really thin with around 2mm and glass shelves are quite thick. The protection layers can then bring the OLED part on the same thickness as the rest of the shelf. The dimensions of the shelf light are illustrated in appendix D.2. figure D.6.

Workings Principle

The shelf will be fixed on both sides as in general kitchen cupboards. It is necessary that the shelves stay adjustable in height. The frame is connecting the two glass shelf-parts and the OLED part with its protection layers.

The energy supply remains at stake. One possibility is to hide the cable in the back wall of the cupboard but it is then difficult to hold the shelves adjustable. Another option could be a bus bar in the side of the cupboard. The power supply were the AC current will be transformed into a DC current will be hidden again on top of the cupboard like in the first kitchen concept.

4.1.4. Smart Lighting in Kitchens

The products in the world are getting smarter every year. Designers are developing products which take over tasks from the humans. Sensors are measuring the whole environment and allow the products to take proper action.

First a lot of products in our environment are working with apps. Almost every one owns a smart phone and has the possibility to control his environment by using apps. It is already possible that lamps can be turned on and off, dimmed and tuned by apps. Like this the user has easy control over the lighting in the kitchen and that even from far away.

Then it is of course possible to make the app even smarter by integrating a “biological light” function. The light is controlled in order to match with the environment and the human circadian rhythm. In the morning and during the day the light should have an activating impact and in the evening the light should get dimmed to make the people relaxed. A light sensor in the kitchen is measuring the current light situation. With a clock in the app it can be calculate how bright the light has to be at any time. There should always be the possibility for the user to change the settings.

Other smart lighting options are a warning light (CO2 amount in the air) or that the light automatically turns on and off. For the warning light a sensor which is measuring the CO2 amount in the air needs to be placed somewhere in the kitchen. If the amount gets to high the light blinks to catch the attention of the persons in the room. Turning on light automatically can be easily realized by locating a motion sensor inside the kitchen. If the sensor measures any motion the lamps turn on. If the sensor doesn’t measure any motion for a while it will turn off again.

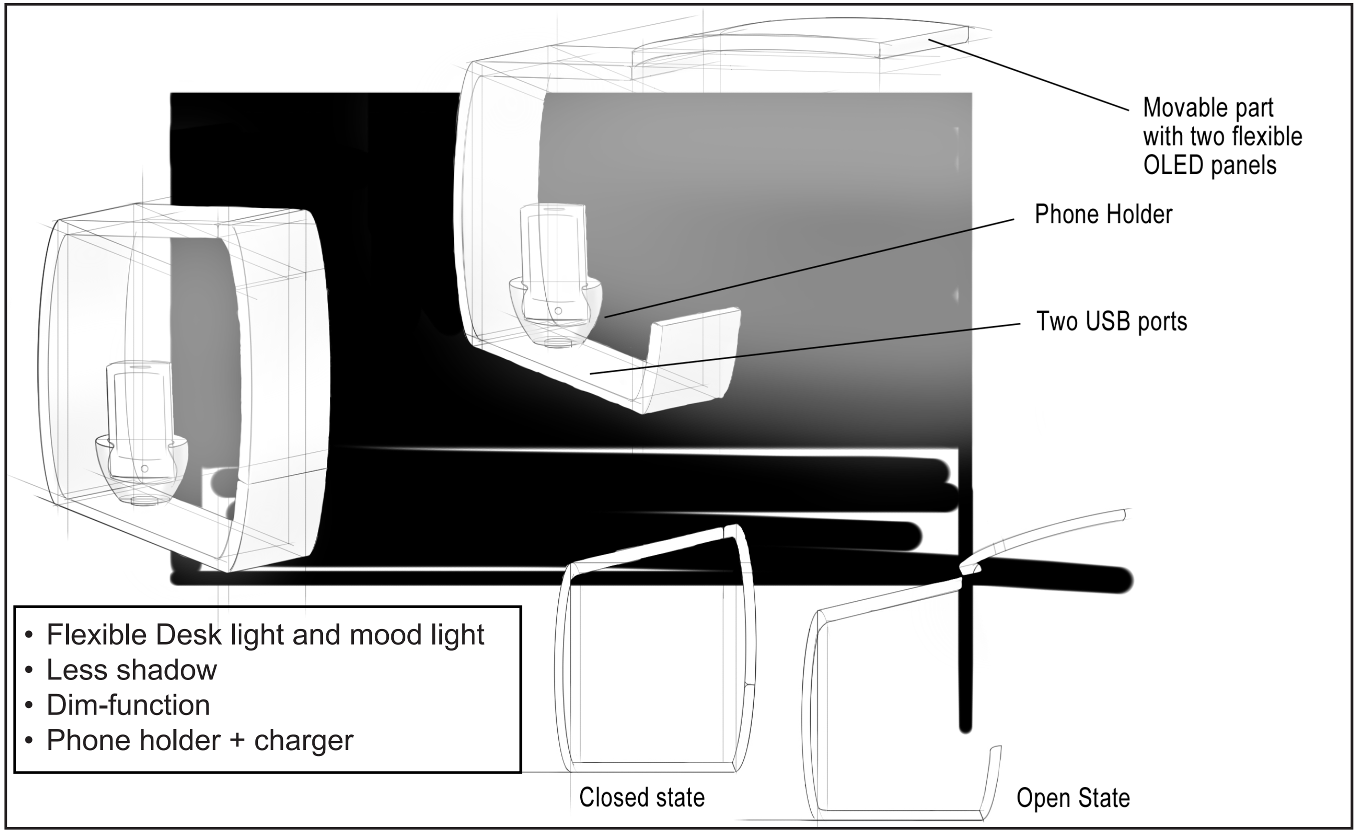


Figure 4.7. Product Presentation - Transparent Shelf Light

4.2. Concepts Office

This part of chapter four presents three different task lamp designs. Good light conditions are significant for a healthy way of working. Moreover people often spend their day working at their office desk. Thus a task lamp has to be designed with attention to the health of the humans. OLED panels are adapted with its healthy emission spectrum and its homogenous and glare-free light. Primarily the lamps just need to fulfil the function of illuminating the direct workspace but it would make a lamp more interesting if it could fulfil additional functions.

The requirements for task lamps are listed in the analysis chapter. Some form-finding sketches are illustrated in appendix D.3.

4.2.1. Flexible Box Light

The “Flexible Box Light” is a desk lamp and a phone charger at the same time. Nowadays almost everyone owns a phone and often these phones are placed on the desk top even while working. Moreover the recent smart phone autonomy often forces people to charge it at work if they don’t want it to run out of battery. Everyone knows the feeling when the phone is suddenly empty. With the new “Flexible Box Light” the phone can be charge and stay accessible while working. The phone can be placed inside a phone holder in the lamp and will be charged with induction.

Moreover the lamp with two flexible OLED panels can be used as a desk light and as a mood light. In the closed state (like in figure 4.8) it is generating an indirect light on the desk. By opening the box (like in figure 4.7) the lamp can function as a desk light. This multifunctional lamp is perfectly fitting into home offices which are

Figure 4.8. Flexible Box Light in Context

located in the living room.

Styling

In the first instance the lamp reminds on a box. The round edges and bended sides of the box are supporting the shape of the flexible panels. These panels are integrated in the right side of the box. They illuminate the desk without creating a lot of shadows due to their form. Moreover the frame is supposed to be relatively thin to support the thin appearance of OLED panels. All in all the styling is simple like the one of an OLED panel.

Functions of the lamp

The lamp is mainly illuminating the direct workspace on the desk. Of course it can also be used as a mood light during the time no one is working but people are around. The light can be turned on and off with a touch function which can also be used for dimming the light. This is necessary for giving the user a maximum control over the light to make him feel comfortable with his own lighting conditions.

The lamp can charge phones with induction. Therefore it contains a phone holder where the smartphone can be placed. This holder can be turned so that the screen of the phone is visible from all view angles. Moreover loudspeakers could be placed inside this lamp so that the users can even listening to music while working.

Materials

The lamp will be out of a high quality plastic. A shiny white plastic is supporting the simple design which is matching in almost every environment.

Workings Principle

Once again the flexible OLED panel of LG-Chem is chosen for this design. The dimensions are represented in appendix D.4 figure D.8. Two panels with a luminous flux of 75lm are integrated into this lamp which means that the lamp has in total 150lm. For the direct workspace an illuminance of 500 to 750lx is required. Again the illuminance can be calculated with the luminous flux and the distance of the panel to the work top.

The two OLED panels are integrated into the casing of the lamp. A hinge on the upper side of the box is used for making the lighting part of the lamp movable. This hinge is engaged in the closed or open state. Moreover all parts for induction are hidden in the underside of the lamp. Also the power supply for the OLED panels needs to be hidden there and the OLED panels will be connected in series. Again the output voltage needs to be higher than the sum of the voltages of the two panels. A cable of the lamp needs to be plugged to the electrical grid.

4.2.2. Flexible Office Light

The “Flexible Office Light” is a desk light which contains two flexible OLED panels. Moreover this desk lamp offers space for pens, paper and other small stuff (see figure 4.9). Although nowadays most of the work is done with computers and laptops, pens and papers for notes are still used. This lamp contains both the possible storage of this office materials and a healthy light source for working. The primary function is of course to illuminate the direct workspace.

Styling

The lamp can be divided into two parts regarding the shape. The lighting-part of the lamp is following the bended form of the flexible OLED panels. On the contrary the pen and paper holder are sharper and quadratic formed. Moreover these holders

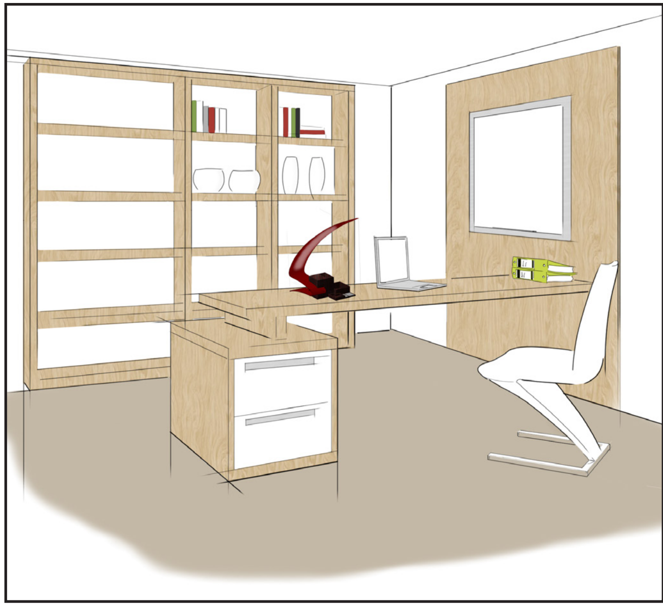


Figure 4.9. Flexible Office Light in Context

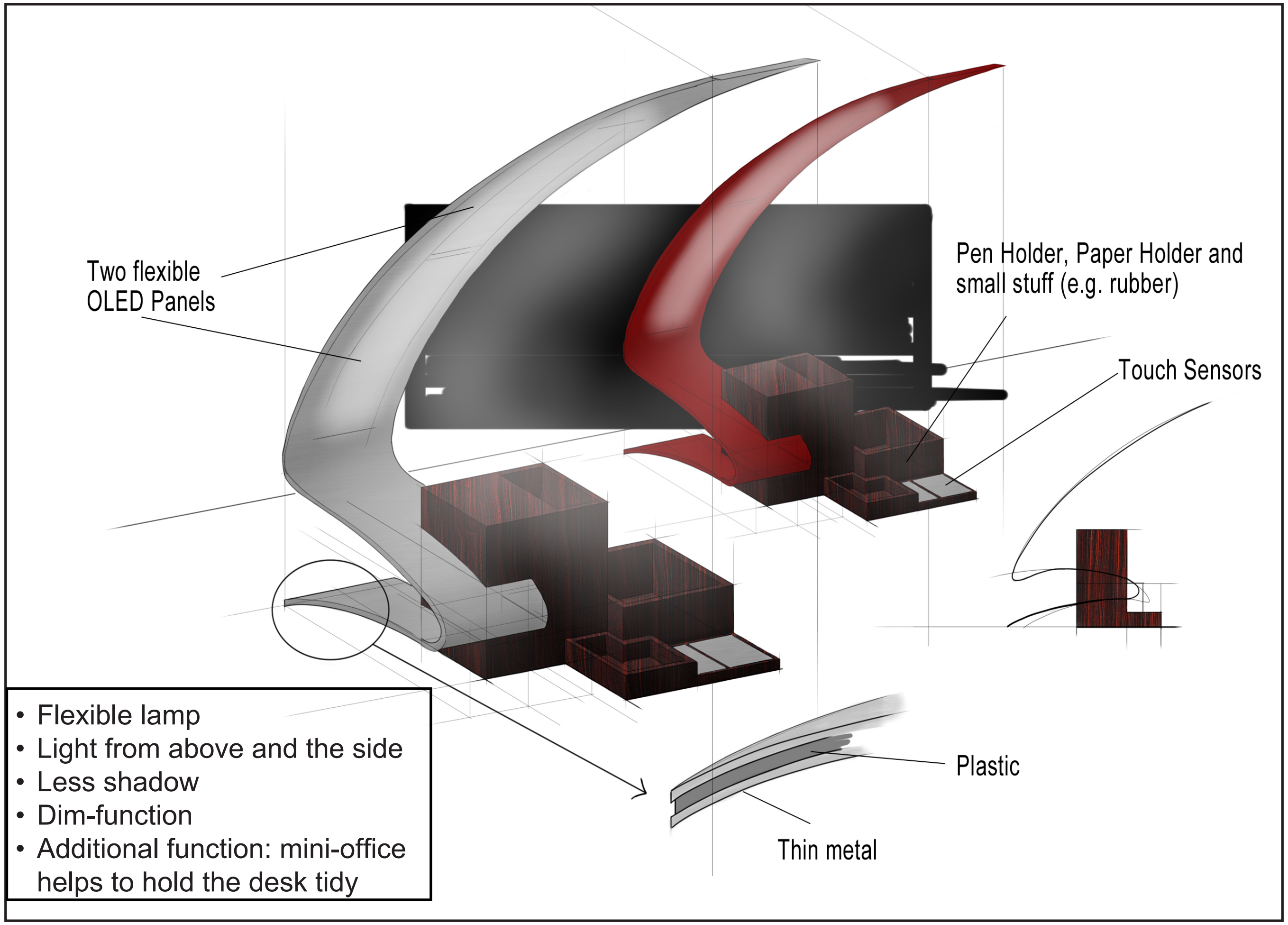


Figure 4.10. Product Presentation - Flexible Office Light

appear quite thick in contrast to the thin casing of the lighting part. This contrast in shapes supports the two different functions the lamp contains. It also makes the lamp an eye catcher on every desk.

Functions of the lamp

Indeed the main function of the lamp is to illuminate the direct working space on top of the desk. But it is improving the mood of the user if this latter can control the light himself. As a result the dim-function would also be integrated in this desk lamp. Other usages in home offices and living rooms are also possible and the ability to dim the light would make the desk lamp at the same time a mood light. The lamp can be turned on and off and dimmed by a touch pad located next to the pen and paper holder.

It is even possible to dim the panels separately for giving the user a maximum control over the light conditions.

Materials

Contrasts can be created not just with shapes but also with materials. The thin lighting part is made out of a metal frame and a thin plastic casing. The two OLED panels are integrated in the inner metal frame. The material of the paper – and penholder is a dark wood which supports the strong block impression of the shaping.

Workings Principle

An illuminance of 750lx is required for the direct workspace on top of desks and 500 lx for the entire workspace. Two flexible OLED panels with 75lm are integrated in the desk lamp which means that the lamp has a total flux of 150lm. Again the illuminance on the work top needs to be calculated. The metal frames in which the OLEDs are integrated are connected via snap connection to the plastic casing. Then the lighting part is pushed into the wood part of the lamp. The dimensions are depending on the length of the panels, the length of pens and the dimensions of small papers. Suitable dimensions are illustrated in appendix D.4 figure D.10.

Once again the lamp needs to be connected to a power supply. The power supply unit can be hidden inside the wooden block and the user can connect the lamp to the electrical grid with a cable. A driver to which two panels can be connected needs to be chosen. The panels need to be connected in series.

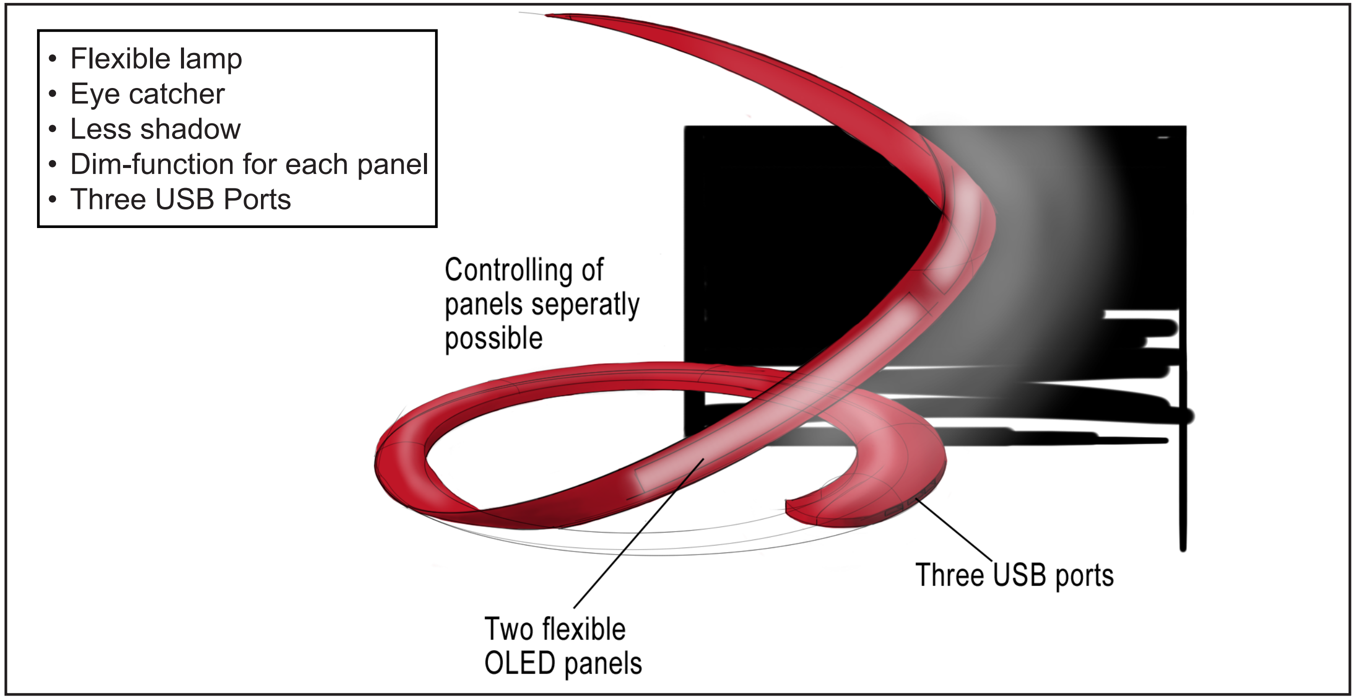


Figure 4.11. Product Presentation - Flexible Spiral Light

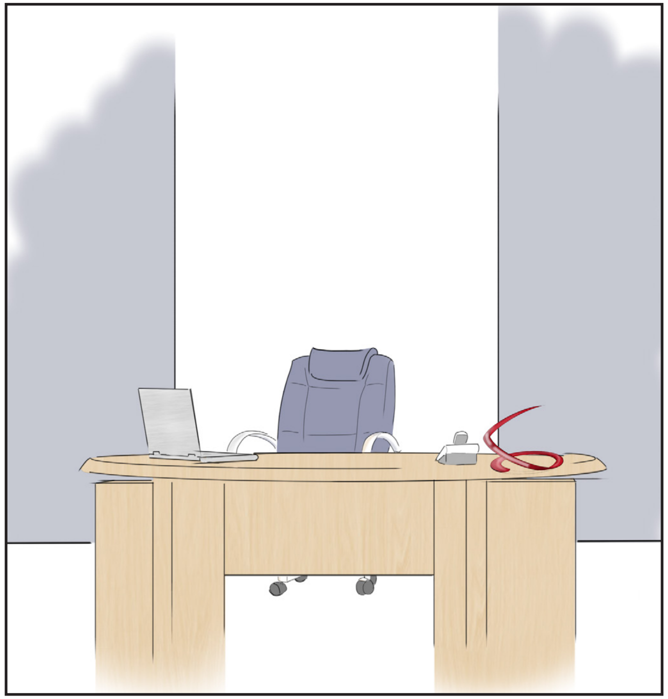


Figure 4.12. Flexible Spiral Light in Context

4.2.3. Flexible Spiral Light

The “Flexible Spiral Light” (figure 4.11) is an office lamp with two flexible OLED panels. The eye catcher of this lamp is its unusual shape which reminds on a snake. An extra light effect can be created by controlling the both panels individually. But this lamp also offers some extra usability with its three USB ports. They are placed in the basis of the lamp and can be used for charging technical devices like phones. As mentioned in the first office concept nowadays almost everyone owns a smartphone and has to deal with low battery issues.

Styling

The shaping of the lamp reminds on a spiral or on a snake. This shape is exceptional and sets itself apart from other desk lamps. The base of the lamp is thicker than the rest for holding the lamp in equilibrium. The upper part with the two panels is relatively thin like the OLED panels themselves. Like this a high quality and fascinating shape is created which is definitely an eye catcher on every desktop.

Functions of the lamp

The OLED panels of the lamp are turned on and off by different touch sensors. One sensor is placed inside the basis with which both panels can be controlled. Two other sensors are located next to the panels so that they can be controlled separately. Once again it is essential to give the user a maximum of control over the lamp by adding the dim-function. In this case the two panels can be individually dimmed which makes this lamp special. The same sensors can be used for dimming the light.

Materials

This complex shape can be made the best out of a high-quality and shiny plastic. A colour like red would even be a greater eye catcher but also simpler colours like white, blue or grey or even other materials like aluminium could be chosen.

Workings Principle

This desk lamp has the same luminous flux of 150lm than the two other concepts. And again the same calculations for the illuminance on the work top are necessary.

The panels are integrated in the casing and the respective power supply unit is hidden inside the lamp's basis. Again it is essential to choose a driver for two panels and to connect the panels in series. Another convert needs to be connected to the USB ports . The whole lamp is connected by a cable to the electrical gird.

4.2.4. Smart Lighting in Offices

As for the kitchen concepts also the office lamps can be designed in a smart way. Indeed an app for the lamps is again possible. With this app the lamps can be even controlled from distance in case the user forgot to turn off its lamp. Also a biological lighting function in the app is conceivable but less useful than for lighting in kitchens and bathrooms. In first instance a desk lamp needs to illuminate the desktop so that the user can work under good conditions. A biological light is then not useful.

But another function like an alarm for meetings or for the finishing time at work could be added to the lamps. The blinking light would make the user who is focused on his work aware of the time and of meetings. Thus the user of the lamp would not miss any meetings anymore. But for this function an app is essential for programming the time for the alarms. The alarm function of the lamp could even be connected to the calendar of the user so that not every alarm needs to be filled in the app individually.

A motion sensor close to the lamp could be used for turning the lamp automatically. Like this the user not even needs to turn its lamp on and off.

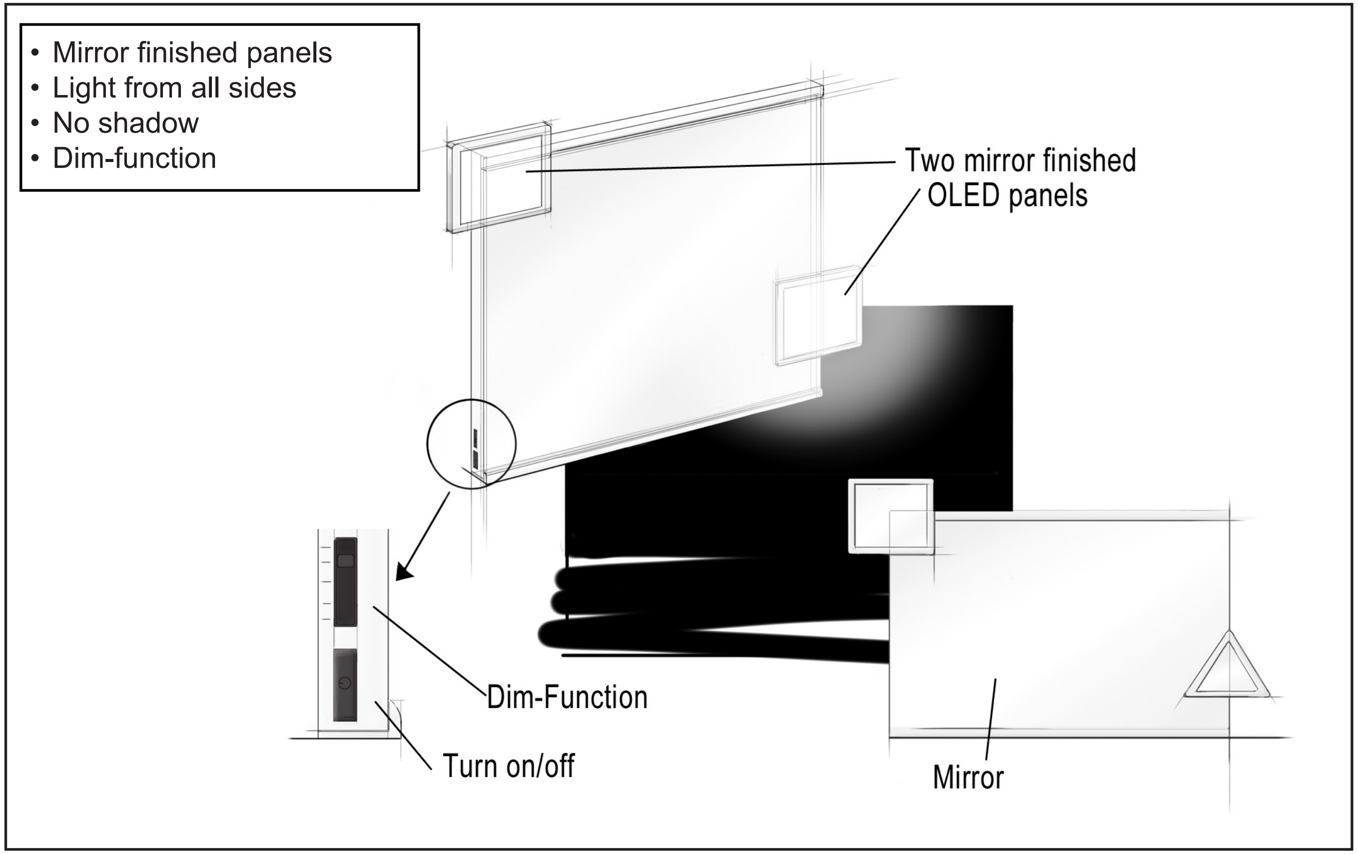


Figure 4.13. Product Presentation - Movable Mirror Light

4.3. Concepts Bathroom

The third part of this chapter deals with the three OLED lamp designs for bathrooms. The light conditions also play an essential role in the bathroom as described during the light analysis. People want to start and finish their days in good lighting conditions. People are especially sensitive to light in the morning. OLED panels can also be used the best in the bathroom because of their unique characteristics (glare free and homogenous). The panels can be used for mirror lighting, indirect lighting or general lighting.

4.3.1. Movable Mirror Light

The "Movable Mirror Light" is the first concept for a bathroom lamp. In this concept the mirror finished panels of Philips are used. The remarkable point of these panels is the fact that they have the appearance of a mirror when they are turned off. In this concept four panels are integrated into a mirror. If the panels are turned off it seems like a large mirror but if they are turned on they function as a

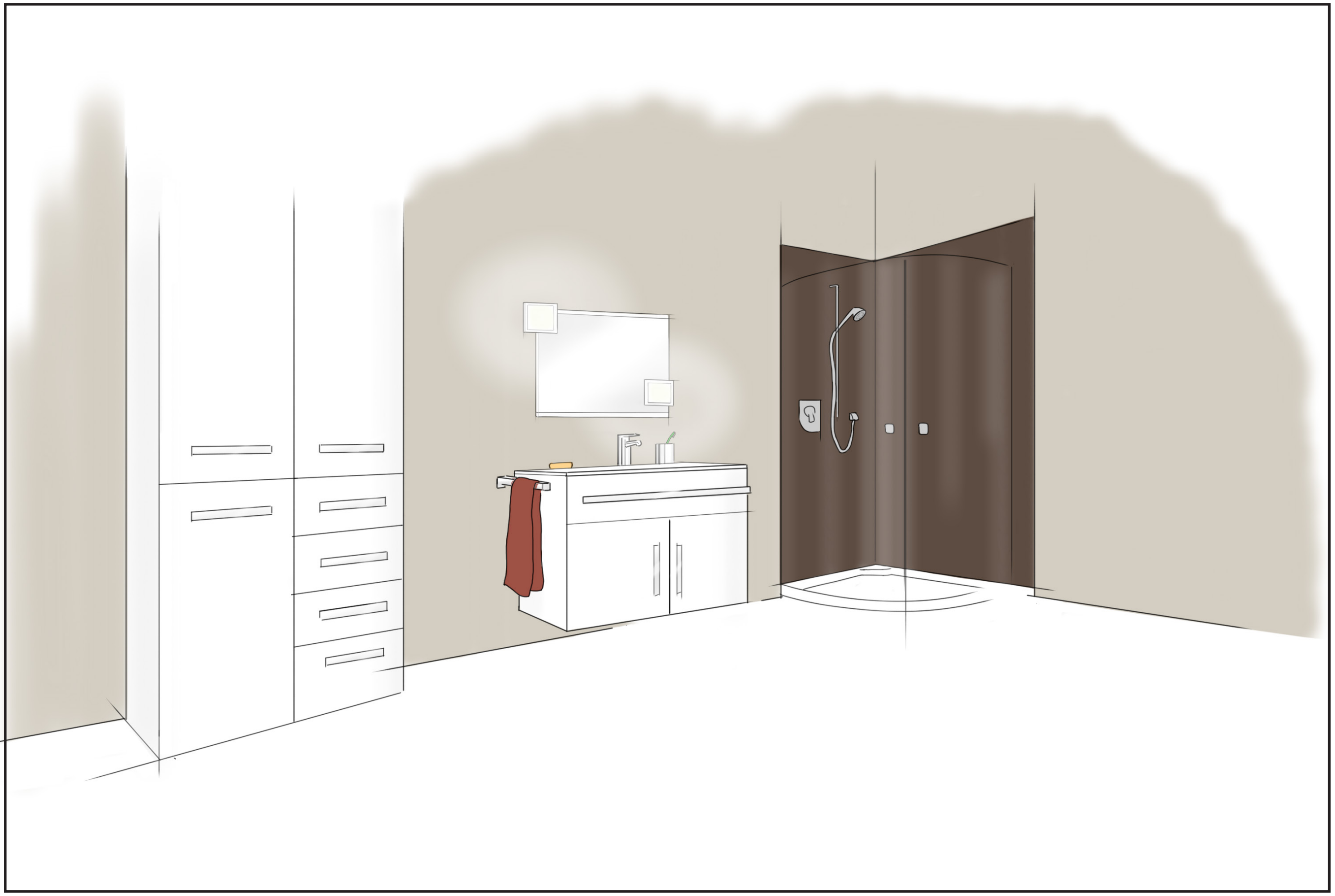


Figure 4.14. Movable Mirror Light in Context

light source. Moreover the two panel areas are also movable and can be controlled separately. A group of two panels is movable so that the user can use it as a mirror and turn on the other panel for having light.

Styling

Some form-finding sketches for the mirror light are presented in appendix D.5 figure D.11. The shaping is simple and adapted to the mirror. The mirror and the panels are surrounded by a frame to separate them from each other. The frames also make the user aware of the multi-functionality of the mirror parts.

Functions of the lamp

The panels can be turned on and off separately. It is even possible to dim the light. In case someone wants to relax in the bath it gives extra functionality to the lamps if it can be used as mood light. With the buttons on the left side of the mirror the panels can be dimed and turned on and off (figure 4.13).

Moreover the panels are placed in the top left corner and the bottom right corner for illuminating the face from all sides. It is essential that the light is not creating any shadows on the face.

Materials

The frames are out of chrome which is fitting well with the other bathroom materials.

Workings Principle

An illuminance of at least 400lx is required for mirror lightings. The chosen mirror finished panel

Figure 4.15. Indirect Bathroom Light in Context

of Philips has an luminous flux of 28,5lm and a size of 74 mm x 74 mm. Four panels are with a total flux of 110lm are illuminating a mirror of 500 x 300mm.

A large frame is holding the panels and mirror together. A hinge behind the panel areas makes it possible to turn them. Finally the whole mirror is connected with screws to the wall above the sink (figure 4.14). Possible dimensions of the mirror lighting are presented in appendix D.6 figure D.14.

The power supply unit is hidden behind the mirror and the panels are connected in series to it. Then the power supply just needs to be connected to the electrical grid. For the choice of the driver it is relevant that the drivers output voltage is higher than 28,8V (4 x 7,V) and that the current is higher than 250mA.

4.3.2. Indirect Bathroom Light

The “Indirect Bathroom Light” is the second concept for a bathroom lamp. By using an indirect lamp small bathrooms can seem larger (figure 4.15). Thus some layers of a transparent material are fixed in front of an OLED. The last layer contains a pattern which is inspired by the nature. This pattern will light up when the OLED panels are turned on and give an extra atmosphere effect.

Styling

The lamp is supposed to remind on a picture. Thus a rectangular shape is chosen and some form finding sketches are shown in appendix D.5 figure D.12. The pattern on the last glass layer is inspired by nature patterns. This is matching quite well with bathrooms where water is the most present element.

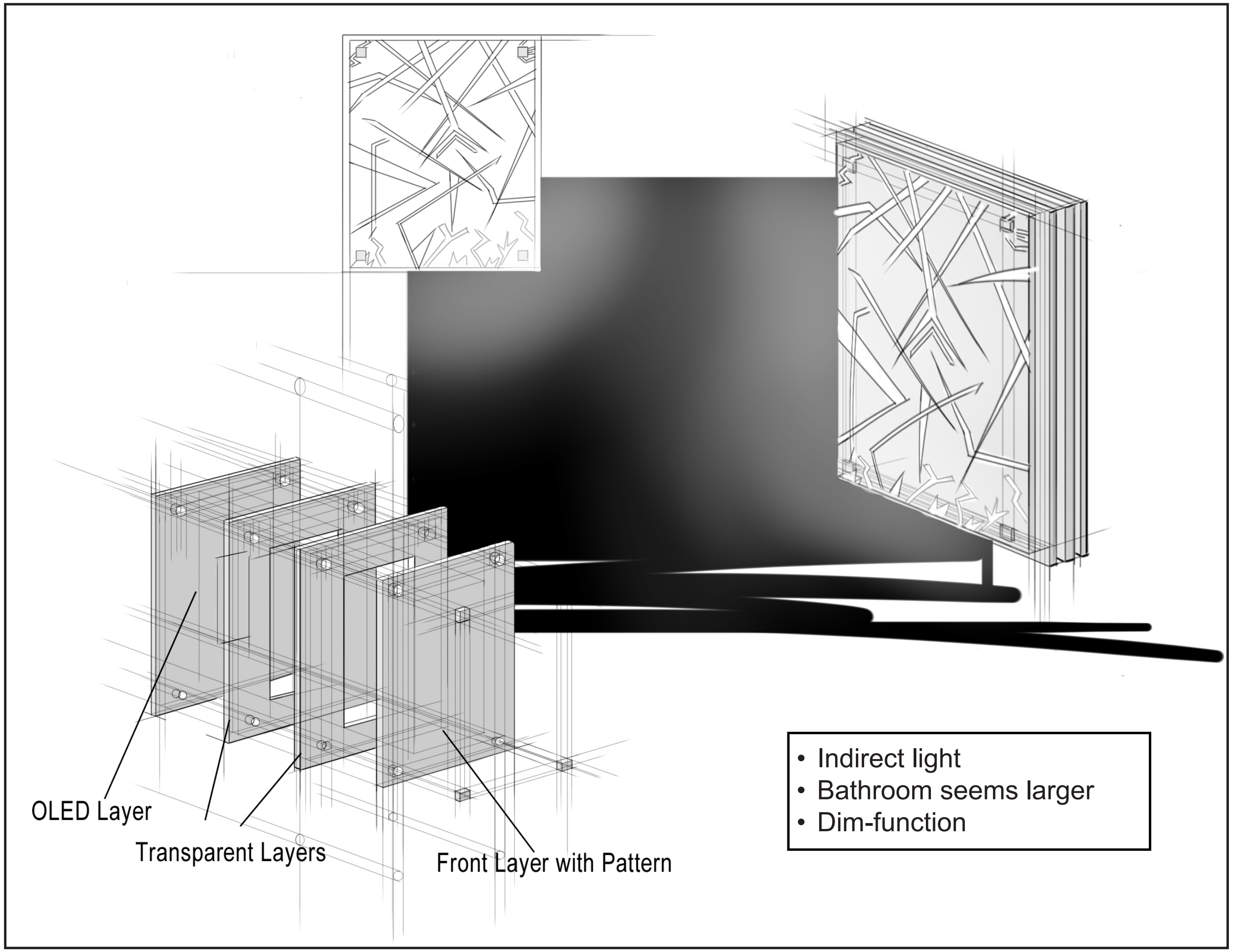


Figure 4.16. Product Presentation - Indirect Bathroom Light in Context

Functions of the lamp

First it remains essential that the panels can be turned on and off as a normal light. An additional functionality of the lamp could be a dim-function even if it is not required for an indirect lamp. A dim-function would give the user a bit more control over his lamp which can improve his mood.

Materials

The choice of the layers material in front of the OLED panels is determining. A transparent material like glass or a transparent plastic is essential. The

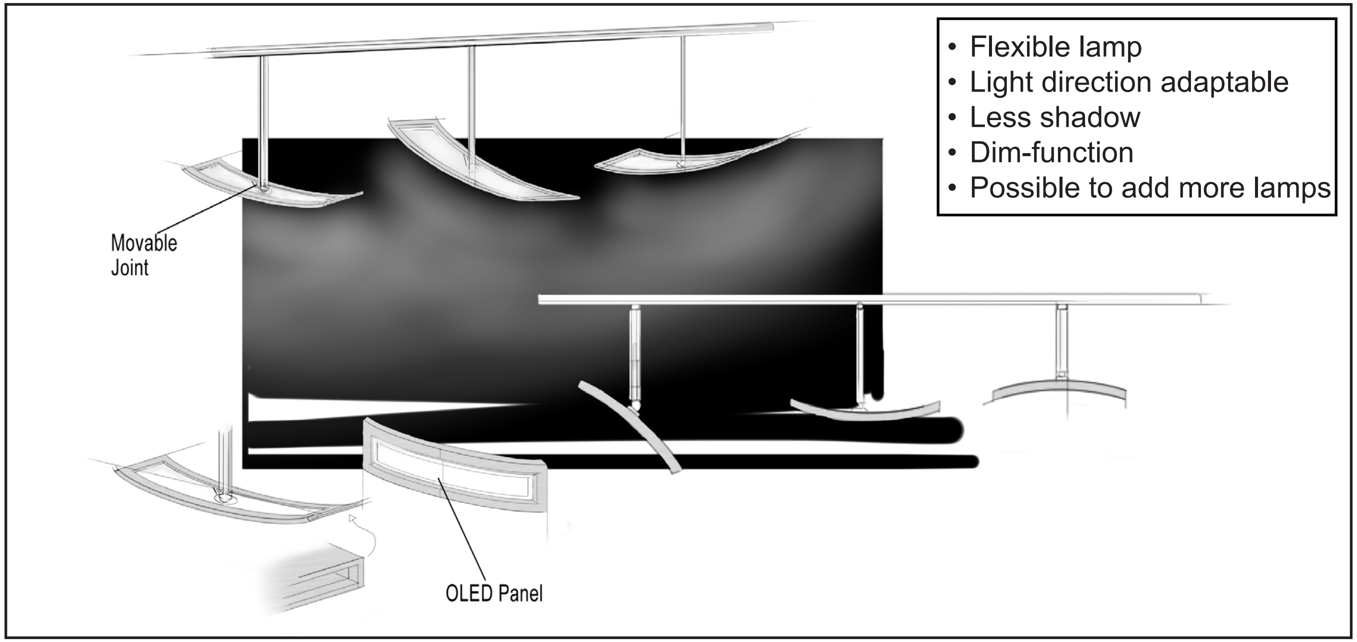


Figure 4.17. Product Presentation - Flexible Bathroom Light

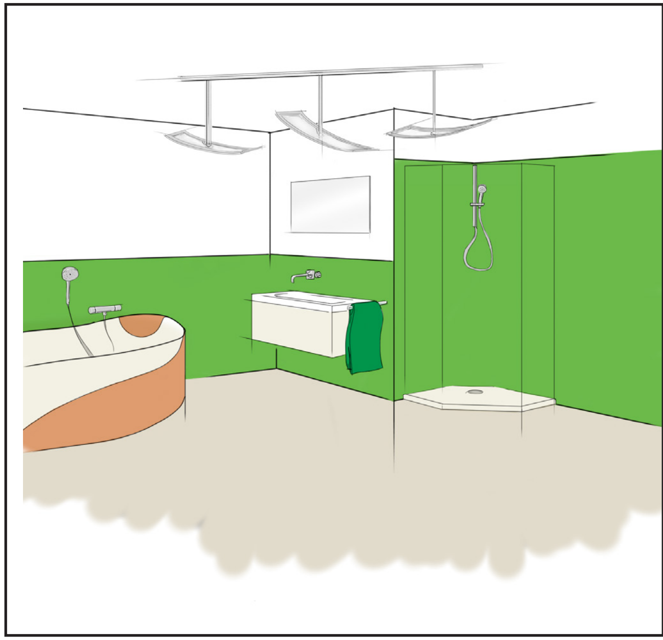


Figure 4.18. Flexible Bathroom Light in Context

best quality choice would be glass and an extra design effect could be created by using coloured glass.

Workings Principle

Indeed there is no required illuminance for this concept because it is a mood light. The lamp is not supposed to illuminate an area where good light conditions are required.

Four bars are used for holding the panels together and to fix them on the wall (figure 4.16). The two layers in the middle have a hole so that the light can pass through them and up to the last layer with the pattern. Another panel is shining in the direction of the wall so that the indirect light effect seems brighter. Either two non-transparent or one transparent panel can be used. The choice depends on the price and brightness of the panels. Indeed the normal rigid panels will be cheaper and should be used in first designs. The power supply of the panels is hidden on the last layer where the OLED panels are fixed. Once again the panels are connected in series to this power supply. Possible dimensions are illustrated in appendix D.6 figure D.16.

4.3.3. Flexible Bathroom Light

The “Flexible Bathroom Light” is a ceiling lamp for bathrooms. A specific amount of OLED lamps is added on a rail which is fixed on the ceiling (figure 4.18). The OLED lamps can be turned in every direction so that the user himself can choose the direction of the light. This is beneficial because every bathroom is organized differently. Then fascinating lamp arrangements can be created individually. The OLED panels are flexible and create extraordinary light conditions with less shadow. Moreover depending on the size of the bathroom more or less lamps can be added to the rail.

Styling

Once again some sketches have been made for finding a suitable shape for the ceiling lamp (appendix D.5 figure D.13). It is chosen to hold the design of the lamp relatively basic. In first instance the design of the lamps follows the bended form of the panels. Some design lines are added and supported with the material choice. The design of the rail is really basic as sketched in figure 4.17. In this design the main attention is focused on the flexible OLED panel like in most of the concepts.

Functions of the lamp
Bright light in bathrooms is essential while people get ready for their day. But dimmed light is also required for example for a relaxed bath. Thus the lamp has to contain a dim-function. A switch which needs to be placed inside the bathroom is used for turning the lamp on and off and for dimming the light. Moreover it is possible to change the direction of the light by turning the lamps. This is fulfilled by adding a ball joints to the lamps. With this joint the lamps can be turned and then locked in the chosen position.

Materials
For this last concept metal has again been chosen. The material needs to be resistant against humidity and therefore not all metals are matching. The different finishing of the metals (matt, shiny and brushed) can make the design of the lamp more interesting.

Workings Principle
As in every room an illuminance of 300lx is required for general lighting. The flexible panel of LG-Chem has a luminous flux of 75lm and each lamp contains four panels. Thus one lamp has a flux of 300lm. But depending on the other lamps in the bathroom more or less lamps can be added.

The OLEDs are integrated in the casing. Moreover they are protected by a transparent film against humidity and water. For the interconnections of the casings snap connections are chosen. The rail is connected with screws to the ceiling of the bathroom. Possible dimensions of the last concept are illustrated in appendix D.6 figure D.15.

The power supply for the lamps is hidden inside the casing of the lamps. The four OLED panels are connected in series to one power supply. Therefore the driver needs a higher output voltage than 34,4V and a larger current than 150mA. The connection of the power supply to the electrical grid is realized via the rail which functions as a bus bar.

4.3.4. Smart Lighting in Bathrooms
The bathroom is a frequently used room and smart lighting can make the life of the users easier. A biological light can regulate the lighting conditions regarding the circadian rhythm of the humans. This means that the light is programmed for being activating in the morning and during the day but dimmed during the evening hours. Especially for bathrooms, it is admirable when the light is dimmed during the night. Everyone hates the bright light on the nightly visit on toilet. Moreover it would be excellent if the light would get slowly lighter in the morning while getting ready for the day. This function would wake the user slowly up without any glaring light. This “biological light” needs a control point which could be an app. This would be the easiest solution because otherwise an additional device would be necessary. An app could be used for programming the biological light to the personal wishes and for having always control over the lighting conditions. An additional light sensor in the bathroom can measure the luminance and adapt the emitted light of the panels to the current lighting conditions.

As mentioned in the two other concept descriptions the light could also turn on and off automatically. Once again a motion sensor could be used for this. On the nightly visit of the bathroom no one needs to press a switch and the user can just enter the bathroom.

4.4. Choice
The last step of the concept generation is to choose one concept which will be worked out in detail in the following phase. This choice has been made by discussing with the company and by evaluating all the concepts with the list of requirements. In first instance it is essential that the concept which has the most potential for the company is chosen. Indeed this is the concept that the design office OTT-DESIGN could sell the best to its clients.

The first kitchen concept the “Flexible Corner Light” has been selected to be worked out in detail within this project. This concept does not just fulfill all requirements but has also the highest potential for the design office. This latter has a couple of clients in the kitchen-lighting area. Ott-Design has already designed a couple of kitchen lamp for different companies.

Moreover no OLED based kitchen lamp already exists. Thus the design can be interesting for the kitchen lighting industry.

5

5. Design Completion

This chapter aims to develop a complete design of the concept chosen in the previous chapter. Therefore this chapter is divided into eleven parts. In the beginning of this chapter a design guide for designing a lamp with OLED panels is presenting the organisation of the sections of this chapter. First a general description of the lamp and its parts is provided. Visualization tools like drawings and renderings are vital elements of this description. Moreover the shaping, the mounting of the lamp, the user product interaction, the OLED panel, the electrical connection and the material choice are respectively discussed in the other parts of the chapter. Finally the last two sections then describe a possible production, give an estimated cost price and end on the discussion of the prototyping of this lamp design.

5.1. Design Guide

The purpose of this section is to provide a design guide for designing a lamp with OLED panels as a light source. This design guide has been built up in small steps from the general design process until a detailed guide for designing with OLED panels. Each design process follows a strict planning but of course different ideas and philosophies exist about the planning of design processes. The steps which are followed within a process are also depending on the aim of the design process. While the general design process and associated steps are discussed in the first two sections, the two last one deal with a description of the usage of OLED in the design process.

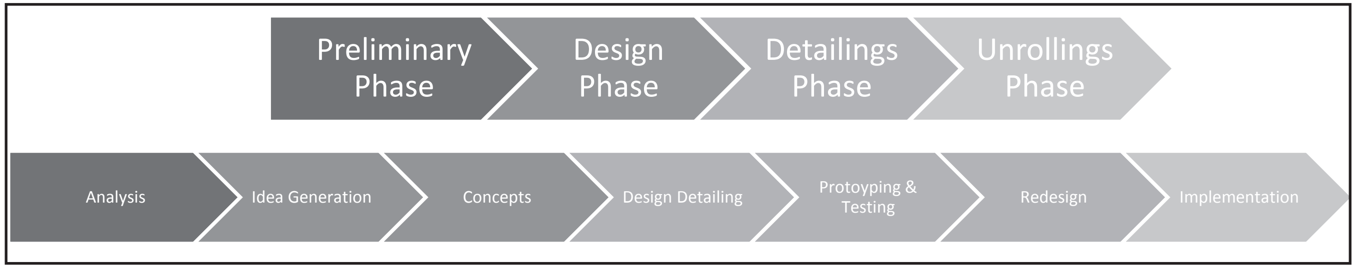


Figure 5.1. The General Design Process

General Design Process

One possibility of a design process and the general steps which are realised within the design process is presented in figure 5.1. In this case the problem is first analysed within the preliminary phase and ideas are then generated for creating different concepts in the design phase. One concept is finally chosen and worked out in detail in the detailing phase. The final design is often tested within usability tests for creating an improved redesign. This redesign can eventually be produced and integrated in the market in the unrolling phase. (Eger, Bonnema, Lutters & van der Voort, 2010)

The Design Detailing Step

Figure E.1 in appendix E.1 illustrates the design detailing step of the detailing phase. The steps in this phase are adapted to this project. The first steps within the design detailing are the styling of the product, the user product interaction and the functionality of the product. Depending on the aim of the design these steps often take place at the same time because they are influencing each other.

Then a material can be chosen which can be used for the products shape. The possible manufacturing can be set up with the results of the earlier steps and an assumed cost calculation can be set-up.

The Final Design Process with OLED panels

Figure E.2 in appendix E.1 shows the final design process with additional steps which have to take place for designing an OLED lamp.

The earlier created concept and the list of requirements of the lamp are used as the input of the final design. The lighting conditions requirements are special requirements linked to the OLED panel and influence the panel choice. At the same time the lamps style, the functionality and the user product interaction are worked out and result in the choice of a suitable OLED panel. After the interconnection and the electrical connection need to be selected because they also influence the material choice, the manufacturing as well as the cost calculation.

Designing with OLED panels

Figure 5.2 presents the steps for designing with OLED panels with more details and can be used as a design guide. The first step is to choose a suitable OLED panel for the lamp design. The properties are depending on the functions (transparent, non-transparent or mirror finished) and the style (rigid

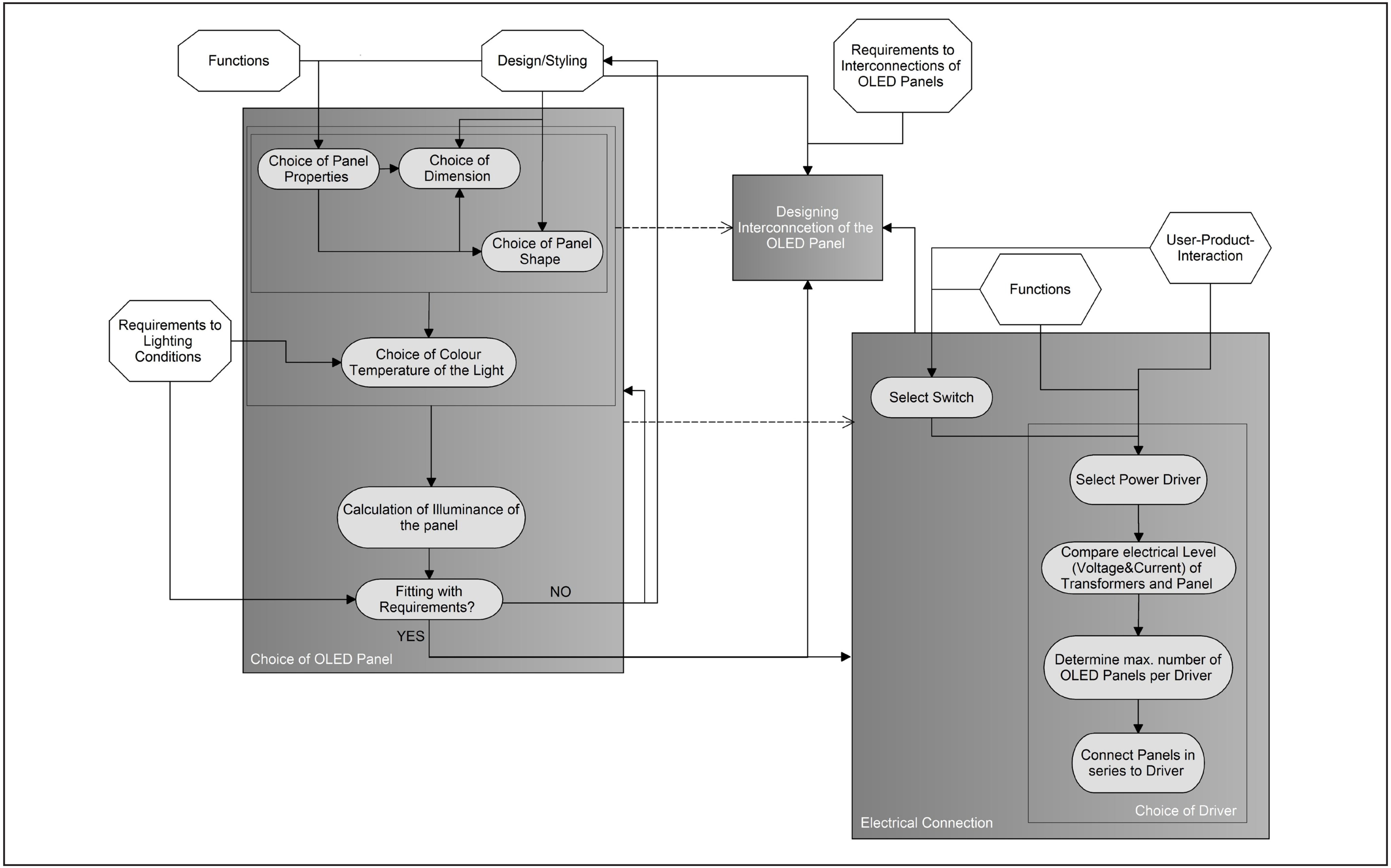


Figure 5.2. OLED Lamp Design Process

or flexible) of the lamp. The designer can chose between four main OLED panels:

- Rigid Panel
- Transparent Panel
- Flexible Panel
- Mirror Finished Panel

After this choice the dimensions and shape which fit with the design can be selected. The panels are also available in different Colour Temperatures so the designer can chose between cold and warm white light. This choice is of course depending on the lighting conditions' requirements.

Then it comes to a vital step for the lighting conditions. The illuminance generated by the selected OLED panel needs to be checked to know if it is fulfilling the expected lighting conditions. The luminous flux can be found in the data sheet of the OLED panels and with this flux the illuminance can be calculated.

First some assumptions have been made. The panel is assumed to be a point light source instead of an area light source for this calculation. Moreover a beam angle of 60° is chosen as sketched in figure 5.3. It is also assumed that 100% of the energy is present inside this angle. Of course these are ideal conditions which are slightly overestimating the real performance of the lamp. But in fact the other lightings of the kitchen are not considered which would also have an impact on the illuminance.

The illuminance on the work top can be calculated with the following formula (Wikipedia, 2015a):

$$E_V = I_V/R^2 \cdot \cos(\varepsilon) \qquad (1)$$

E_V = Illuminance
I_V = Luminous intensity
R = Distance form Light Source to Surface
ε = Angle between the normal of the surface receiving light and the luminous flux

First of all the luminous flux is used for calculating the luminous intensity:

$$I_V = \phi_V/\Omega \qquad (2)$$

ϕ_V = Luminous flux
Ω = Solid Angle

In this case a solid angle of 60° has been chosen which is equal to 0,8418 steradian (Wikipedia, 2015b):

$$\Omega = 2\pi \cdot (1-\cos(Angle/2)) = 2\pi \cdot (1-\cos(60/2)) = 0{,}8418 \text{ Steradian} \qquad (3)$$

Replacing the I_V of the second formula in the first one gives:

$$E_V = I_V/R^2 \cdot \cos(\varepsilon) = (\phi_V/\Omega)/R^2 \cdot \cos(\varepsilon) \qquad (4)$$

Illuminance in point A:

$$E_A = (\phi_V / 0{,}8418\text{steradian})/R^2 \cdot \cos(0) \qquad (5)$$

Illuminance in point D:

$$E_B = ((\phi_V / 0{,}8414\text{steradian})/\sqrt{(R^2+D^2)}^2)\cdot\cos(30) \qquad (6)$$

With:

$$D = \tan(30) \cdot R \qquad (7)$$

Indeed all the steps within the OLED Panel Choice have to take place at the same time because they influence each other. Moreover it is essential that the styling of the lamp is also taking place at the same time. In case the required illuminance is

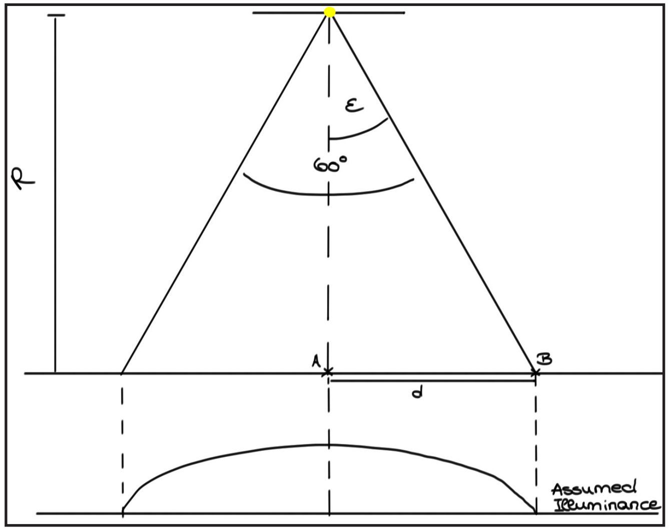


Figure 5.3. Lighting Conditions

not reached the design can be changed and more panels can be integrated inside the lamp.

Once the quantity of panels has been decided, the electrical connection can be designed. The functionality of the lamp and the user product interaction are essential in this design. This input determines how the lamp will be turned on and off and whether it is dimmable or not. A switch needs to be selected first and then the Power Driver of the OLED panels is chosen. For OLED panels the same kind of drivers than for LEDs can be used (Philipps, 2012). First the electrical level (the voltage and the current) of the OLED panel and possible drivers needs to be compared. The maximal number of OLED panels per driver needs to be determined. The sum of the voltage of all OLED panels should be lower than the output voltage of the driver. The current output of the driver should also be higher than the current of one panel. Finally the panels can be connected in series to the driver. (LG-Chem, b)

At last the interconnection of the OLED panel and the lamp needs to be designed. This connection needs to be designed carefully depending on the interconnections requirements of OLED panels(LG-Chem, b):

- Avoid contact to chemicals and water
- No heat applying interconnections
- Avoid mechanical stress as shocks and pressure
- Avoid touching the panels surface with fingers (formation of moisture possible)

5.2. The Design

The final design is a kitchen lamp which illuminates the work top. As examined during the analysis section, good lighting conditions are essential for the work top because people are using their eyes constantly while cooking and preparing meals. The lists of requirements for a kitchen lamp are listed in the analysis chapter.

Moreover it is a challenge to design a uniform lamp which fits into every kitchen. All rooms for kitchens are different because the water and electrical connections are located in different places in every kitchen. Thus kitchen designs need extra attention and are often designed individually. The designer and the technician need to be able to place and fix the lamp in the kitchen and then connect all parts to the electrical connections. The mounting and the electrical connection will be discussed in details in the following sections.

The lamp is illuminating the work top in the kitchen from above and the side. The lamp is placed in the corner between the kitchen cupboard and the wall. The design is composed of three parts and the lamp is separated into an upper lamp, a side lamp and two different add-ons (figure 5.4). Both lamps contain a flexible OLED panel which can be turned on either by touch sensor or by an app. The add-on ‘Sound’ contains a loudspeaker which can be used via an USB-connection or a Bluetooth connection. The add-on ‘Energy’ contains a plug and a USB-port. The parts will either be fixed on the kitchen cupboard (the upper lamp) or on the wall (the side lamp and the add-ons) as illustrated in figure 5.5. The parts on the wall are quite long and almost reach the work top. Each part can be fixed individually which makes all combinations of the three parts possible.

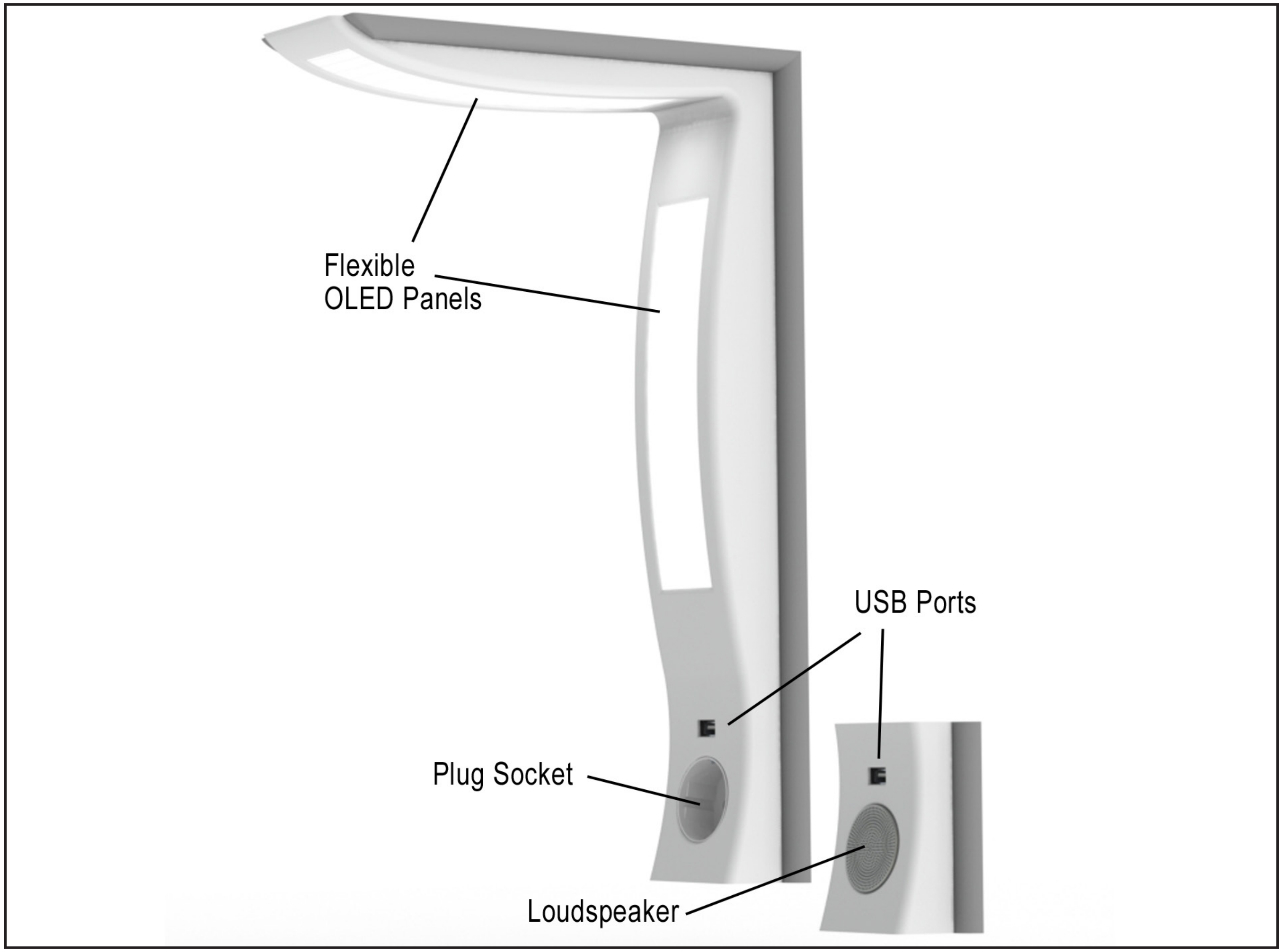


Figure 5.4. The Design

The lamp is divided into three parts which gives the user the opportunity to choose its own lamp combination. Nowadays individuality in products is

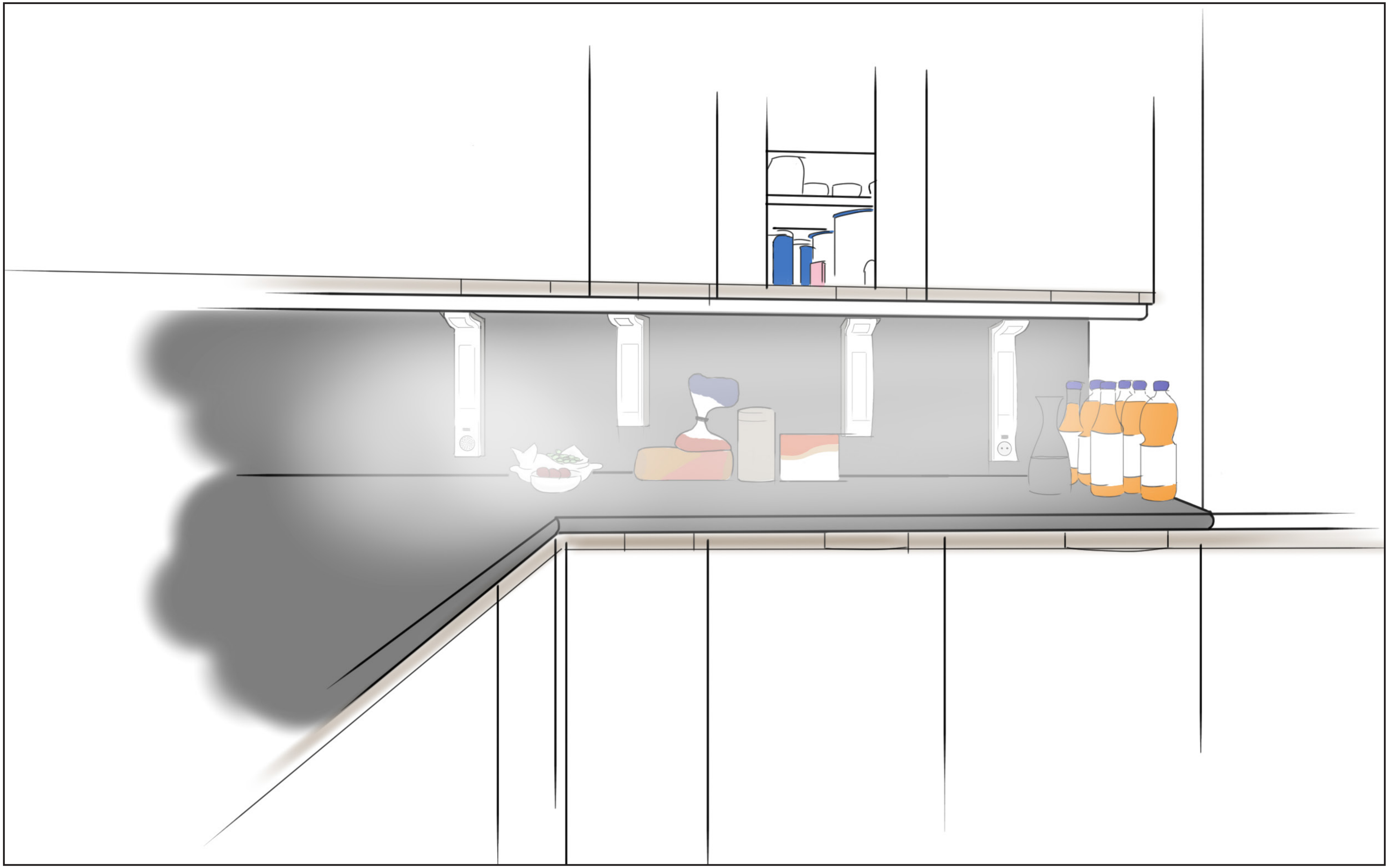


Figure 5.5. Context Drawing

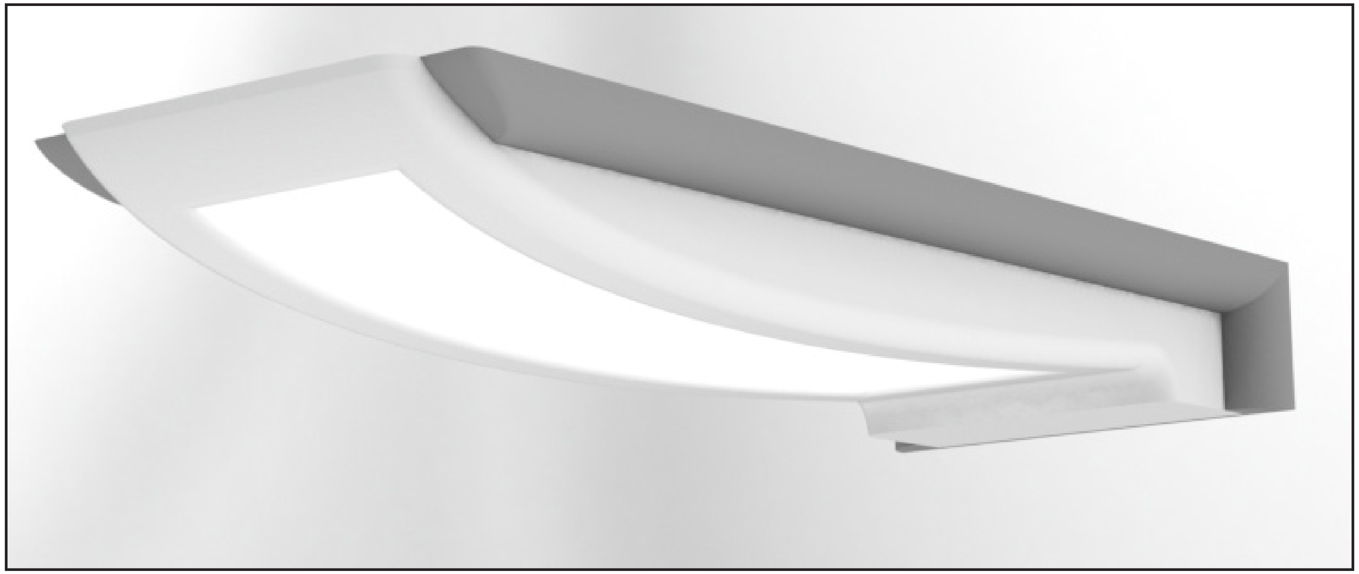


Figure 5.6. The Upper Lamp

essential because most of people want personalise the goods to make it unique. The trend leads to the creation of personal styles by making the customers choosing themselves the product characteristics (e.g. colour, sizes or combinations of parts). Moreover the lamp gives more freedom to kitchen designers who have to integrate the designed lamp in their kitchen design. The four parts and all the possible combinations are discussed in this section.

5.2.1. Upper Lamp

The upper lamp is directly located under the kitchen cupboard and its main function is to illuminate the worktop from above. The centre of the design is the light source: a flexible OLED panel. A rendering of the upper lamp is presented in figure 5.6. Moreover the lamp is composed of a back element, a casing, an OLED panel and a touch sensor. Renderings of all parts are presented in appendix E.2 and technical drawings of the assembly, the back element and the casing are represented in appendix E.3.

Back Element

The back element is mainly used for fixing the entire upper lamp to the cupboard. Therefore the back element contains two holes for screws. Due to its function the back element design is mainly depending on stability. All parts of the lamp (OLED panel, casing and touch sensor) are light weight so that the stress on the back element is reasonable.

Another relevant factor was to not use any ineffectual material in the design. The larger holes in the middle of the element do not affect the stability. This part would not have any impact on the stability and that's why the material must not remain there. The single connection between the two sides is enough for holding the part stable.

Moreover the design of the element was also depending on the production of this part. Most of the edges are round off in order to assure good results of an injection moulding process. The material can then flow better through the mould and the quality and stability of the part will be higher.

A hole is located in the end of the back element and is essential for passing the cables through it. The cable route is described in detail in the mounting section of this chapter.

Casing

The casing includes all technical parts (OLED panel and touch sensor) of the lamp and is attached to the back element by a snap connection. Snap connections are cheap, easy to mount and to take apart which is beneficial for recycling products. Moreover no tools are necessary and the mounting is performed fast. Moreover a snap connection is not visible which supports a high quality appearance. (CES EduPack 2014) The snap connection of the casing and the back element is illustrated in figure 5.7.

The main function of the casing is to hold all parts together and to protect them. Therefore it needs to be stable. The thickness of this part is 2mm which is stable enough because of the low weight of the OLED panel less than 5g (LG-Chem,

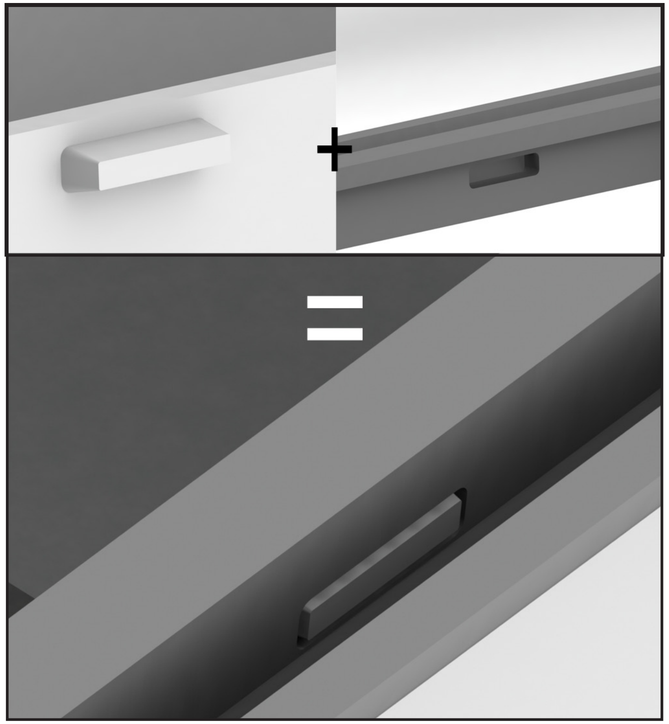


Figure 5.7. Snap Connection

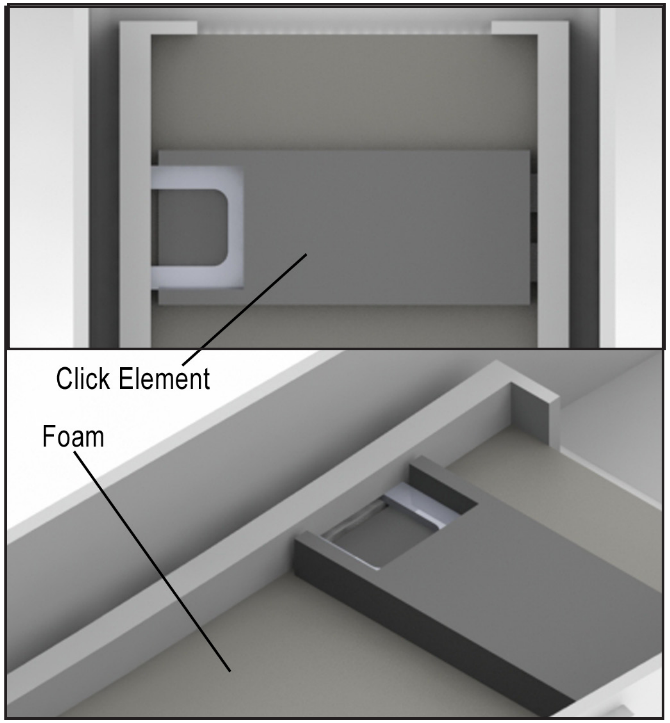


Figure 5.8. Connection

2015). Such a thickness is also matching with the injection moulding and most of the edges are again rounded off for a good quality part.

A transparent protection layer is located in front the OLED. OLED panels are still sensitive to shocks and fingerprints should be also avoided (LG-Chem, b). The protection layer which is fixed with glue inside the casing is protecting the OLED panel. In kitchens, where people are cooking, it can happen that the lamp gets dirty and the user wants to clean it. This layer allows the user to clean the lamp carefully without any damage on the OLED panels.

Then the OLED panel is placed in the respective frame in the casing as illustrated in figure 5.7. It is recommended to use spring or snap contacts for integrating OLED panels in design because the contact with chemicals like glue needs to be avoided (LG-Chem, 2015). Some possible interconnections for the OLED panel are illustrated in a small morphologic schema in appendix E.4. One of the suitable interconnections is illustrated in figure 5.8 and cross section of the integration of the OLED panel in the casing is presented in figure 5.9. A foam layer is placed above the OLED panel. This is beneficial because the foam will protect the OLED panel and isolate it at the same time. In the morphologic schema some different solutions for holding the panel in place can be seen. One is illustrated in figure 5.8. It is a small click element which can easily be placed into the holes in the casing. It is even possible to exchange the OLED panels with this interconnection. Moreover this element does not damage the foam or OLED panel.

Finally a hole is located on the underside of the casing. This hole is used for the cables of the other two parts which also need to be hidden behind the cupboard. It is possible to add a cap in the hole in case just the upper lamp is used.

5.2.2. Side Lamp

The side lamp (figure 5.10) is attached to the wall and thus illuminates the work top from the side. Indeed this is possible because OLED panels are glare free. By lighting the work top from above and the side no irritating shadows will appear on the work top. Two panels obviously emit more light and the illuminance increases.

As in the upper lamp this lamp also contains a flexible OLED panel, a back element, a casing and a touch sensor. Renderings and technical drawings of the parts are provided in appendix E.5 and E.6.

Back Element and Casing

The design requirements for the back element and the casing are exactly the same than for the upper OLED’s. Both parts are connected to each other by a snap connection. The integration of the OLED panel inside the casing is also the same as illustrated in figures 5.7 and 5.8. The only difference between these parts is the shape and their position above the work top. Moreover the side lamp also includes two holes on the top and bottom for the cables of the OLED panel and the possible add-ons.

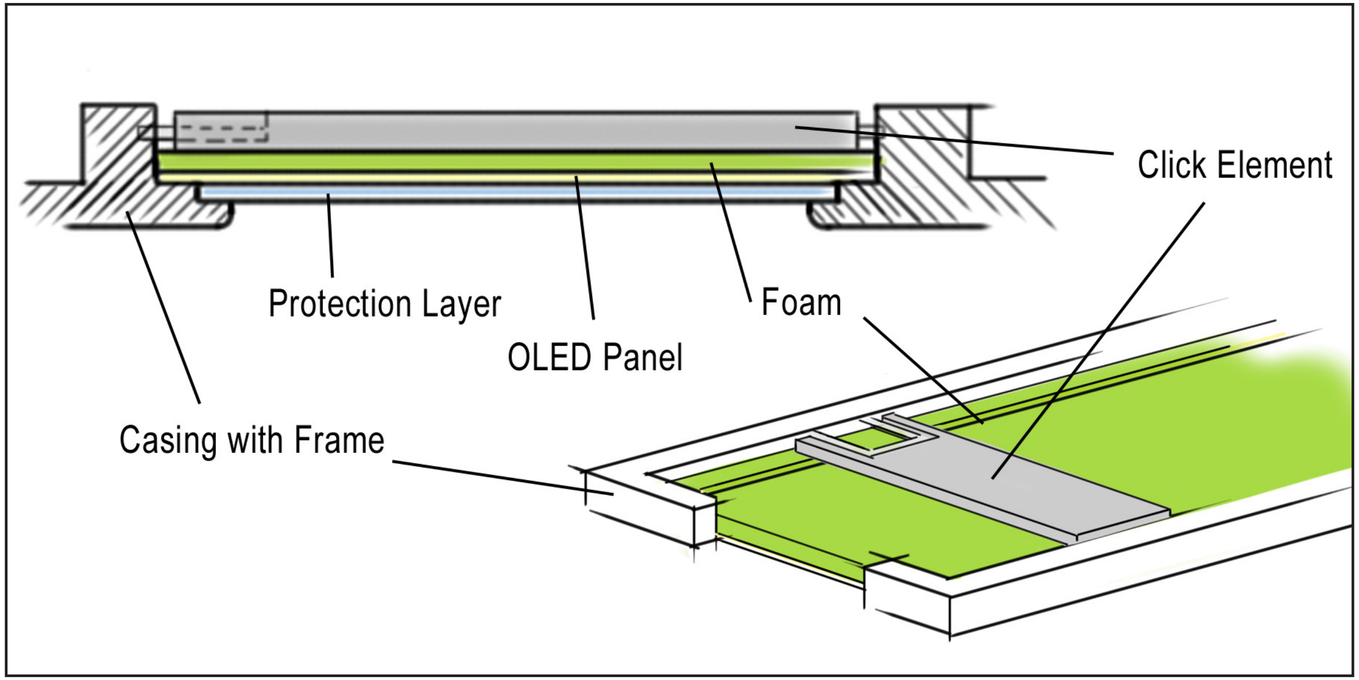


Figure 5.9. Integration of the OLED Panel

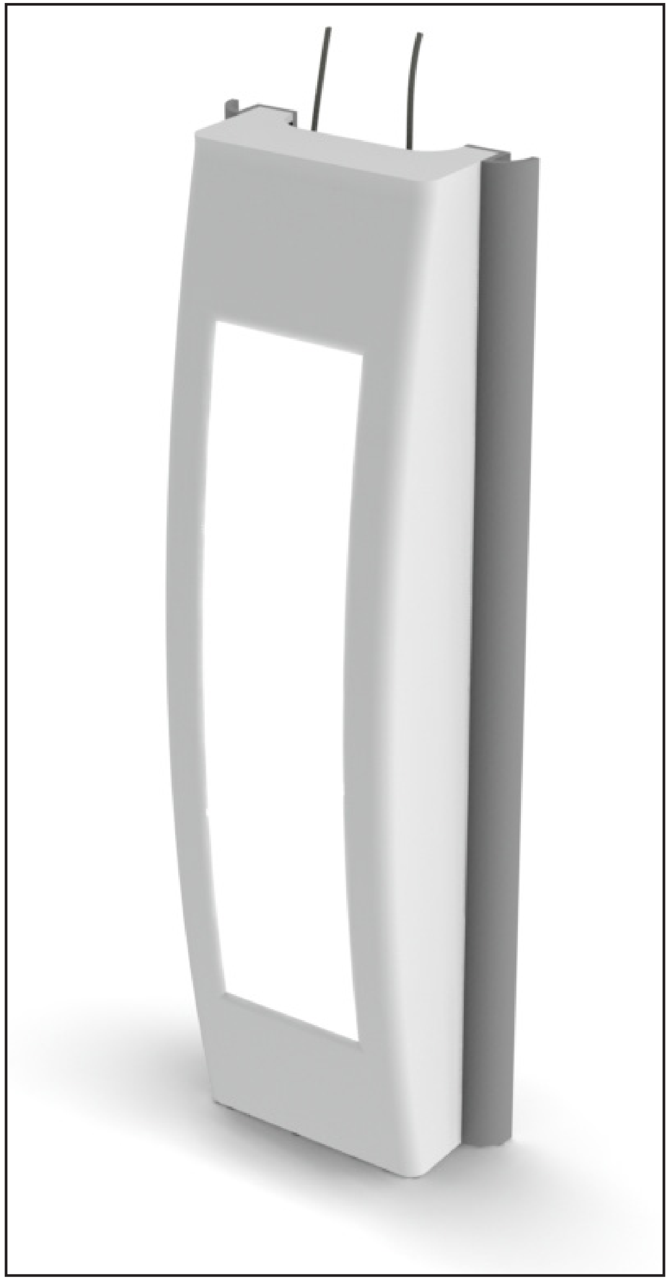


Figure 5.10. Side Lamp

5.2.3. Add-On Sound

In addition to the lamps two add-ons have been designed. Both add-ons offer extra functionalities to the user. One add-on is called 'Sound' is illustrated in figure 5.11. It contains a loudspeaker, an USB connection and a Bluetooth connection. With this add-on it is then possible to listen to music while cooking. The user can connect his phone to the loudspeaker either by the USB connection or via a Bluetooth connection. The user can then connect his phone or other technical devices to the add-on for listening to his music. Renderings of all parts of the add-on are illustrated in Appendix E.7 and a technical drawing in appendix E.8.

Back Element and Casing

Once again the same requirements than the one for the upper and side lamp are valid for the design of the back element and the casing of this add-on. The only differences are the fact that one quadratic hole for the USB port and a round hole for the loudspeaker are present in the casing. Moreover a hole for the cables of the technical parts of the add-on is located on top of the casing.

5.2.4. Add-On Energy

The second add-on (figure 5.12) contains a plug socket and an USB plug. It offers the opportunity to plug kitchen devices to the electrical grid or to charge technical devices via a USB connection. Plug sockets are essential for kitchens and with this


Figure 5.11. Add-On Sound


Figure 5.12. Add-On Energy

add-on the design of the plug socket will match to the lamps.

Back Element and Casing
For both add-ons the same casing and back elements can be used and is then saving money for the production of the add-ons. The mould is the causing high costs and like this no second mould for the second add-on needs to be produced. Moreover the design of these two parts follows the same requirements than the design of the casing and back element of the two lamps. Again the hole is used for the cable route of the cables from the plug socket and the USB-port. But sometimes it is possible to use the wall panelling (around 12mm) for extra space or for the add-on. Sometimes even the connection through the panelling to the electrical grid is possible.

5.2.5. Combination Possibilties
The shape of the lamp allows combining the three parts in almost every way. In total eleven combinations are possible in which every part can be used either alone or together with the other parts:

- Upper Lamp
- Side Lamp
- Add-On Sound
- Add-On Energy
- Upper Lamp + Side Lamp
- Upper Lamp + Add-On Sound
- Upper Lamp + Add-On Energy
- Upper Lamp + Side Lamp + Add-On Sound
- Upper Lamp + Side Lamp + Add-On Energy

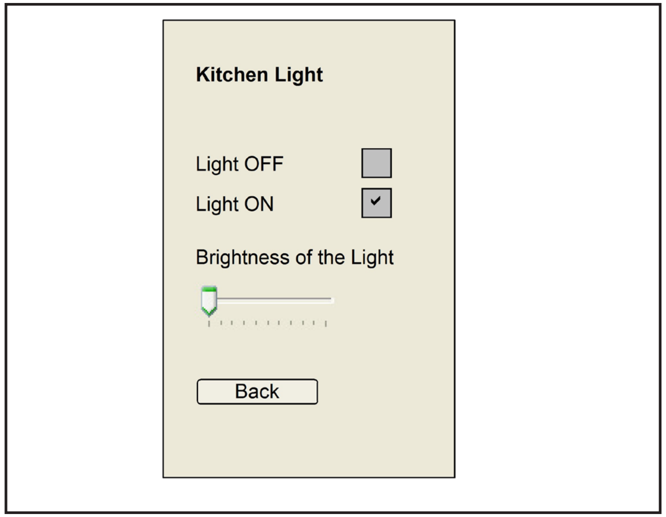


Figure 5.13. App

- Side Lamp + Add-On Loudspeaker
- Side Lamp + Add-On Plug Socket

The renderings of these eleven combinations are presented in appendix E.9 and appendix E.10 shows the context drawings of some combinations. It is also possible to add different combinations into one kitchen design. For example just one of the lamps could be combined with one add-on. The designer and the user have a lot freedom and can create their own lighting system.

5.2.6. Touch Sensor and App
The lamp can be mainly controlled by a touch sensor which is located inside the casing of the lamps. This touch sensor reacts when the person touches it. If the user holds his hand longer close to the touch sensor the light can be dimmed.

There is also the option of using an app for controlling the lamp. With this app the lamps can be simply turned on and off but also dim. The

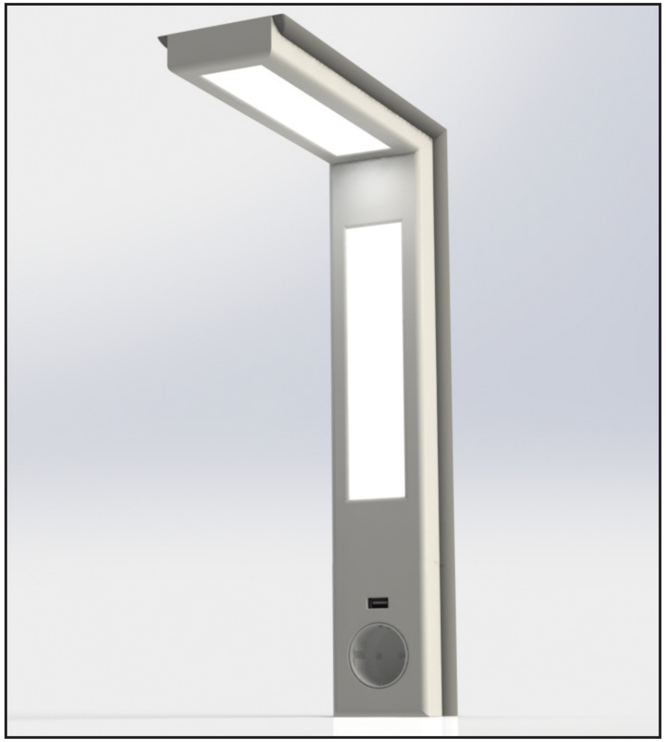


Figure 5.14. Rigid Model

app works as a remote control and can be used on distance. So if the user is sitting comfortable somewhere in the kitchen or outside he can still control the light. The advantage of an app would be to not have another remote control. A couple of devices are already having remote controls and the amount of them gets more and more. Users can mix them up or even lose them. Most of the people do always have their smart phone with them and can use this as the remote control. A simple idea of an app is given in figure 5.13, but in case the company that produces the lamp already has an app it just can be connected to this app. Otherwise the User Interface of the app needs to be designed

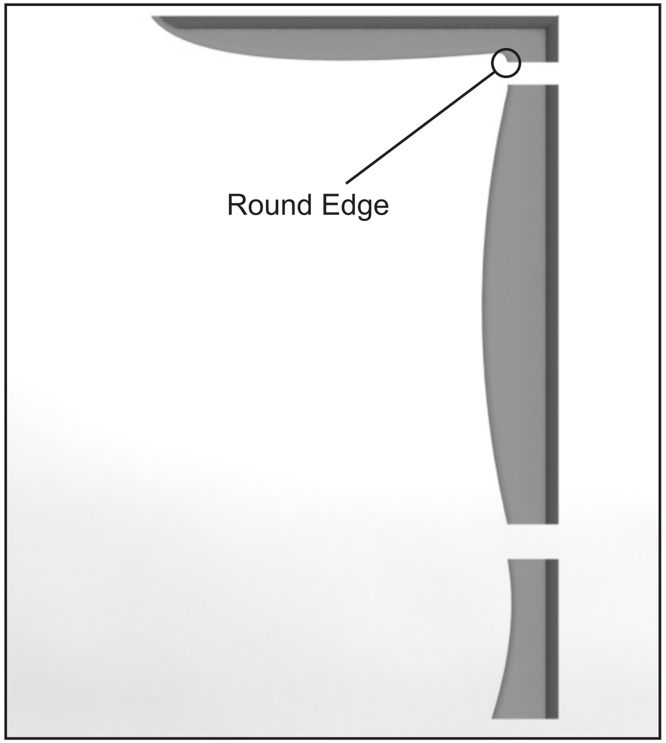


Figure 5.15. Lamp from the side

with more details.

5.2.7. Rigid Model

In addition to the flexible design, a design provided with rigid panels is also available. Instead of two flexible panels this design contains two rectangular rigid panels of LG-Chem with the dimensions of 210x50mm. The design follows the same requirements concerning the geometry and the external and internal connections than the flexible design. The only different is the shape which is not soft and wavy anymore but reminds more like a quadrat. But most of the edges are still round off for creating a softer design. Figure 5.14 presents this rigid model.

5.2.8. Smartness

Smart lamps already exist for various areas (e.g. smart desk lamps) and smart lighting is also fitting in kitchens. As mentioned before the lamp can be controlled by either the touch sensor inside the lamps or by an app. By adding a motion sensor to the lamps or inside the kitchen the lamp could turn on and off automatically. An app would also offer the opportunity to add more smartness to the lamp like a biological light function.

Biological light is adapted to the human circadian rhythm. Humans need brighter light during the day than during the evening hours. By using an app the 'biological light' can be adapted to the preferences of the user. Moreover a light sensor can measure the current lighting conditions in the kitchen for adapting the light to it. With this functionality the lamps always offer perfect lighting conditions by themselves.

A function with which the user always can overrule the current settings remains essential. Thus it is always possible to change the lighting conditions by the touch sensors or by the app manually for at least half an hour

5.3. Styling

As for every design the appearance of the product is at stake. People often decide based on the appearance and styling whether they like a product or not. Moreover the styling of a product can catch people's attention and make them focus on specific parts. Thus styling is an essential design tool.

The styling of the OLED lamp is held simple and the light source is the centre of the design. OLED panels are thin, simple and clean. The simple design of the lamp is reflecting these characteristics of OLED panels. In first instance the shape of the lamp follows the form of the bended OLED panels. A wavy and soft form is created as presented in figure 5.15. Almost all edges of the lamp are Also round off to support the soft and wavy appearance. Just the bottom of the upper and side lamp and the add-on contains sharp edges because of the possible combination with other parts. If the user wants to combine all parts together round edges on the bottom would create irritating lines. Moreover the lamps thickness is kept as thin as possible but due to inner part like the plug, loudspeaker and the USB-port a specific thickness is necessary. In addition, no interconnection of the parts are visible in this styling which creates a simple and high quality appearance matching with the OLED panels.

The difficulty in the design was to find a round and wavy geometry with which it is possible to divide the lamp into three parts which all can be combined with each other. Therefore it is chosen to add a small round edge to the upper lamp. This round edge is located in the end of the lamp where it not visible to the user out of a standing perspective. But this round part makes it possible to add the two other components (side lamp and the add-ons) on it without irritating edges. The casings of the two other parts do have a tangent relationship to the round part of the upper lamp.

Last but not least the colour white is chosen for the casings and grey is chosen for the back elements. These two colours are adapting the best to other kitchen designs. White is additionally matching with the white appearance of the OLED panels. Two different colours for the casing and the back element are chosen to create a more exciting appearance of the product. Moreover it makes the user aware of the fact that the lamp is composed of different elements. A simple interplay of different elements stands for high-quality.

5.4. Mounting

The mounting of lamps which illuminate the work top is different than the mounting of other lamps. These lamps are usually directly placed under the kitchen wall cupboard. In this case the lamp is placed in the corner between the kitchen wall cupboards and the wall. The upper lamp is attached to the wall cupboard and the side lamp and the Add-Ons are attached to the wall. The service technician just needs to fix the back elements with two screws to the wall/cupboard. Then all the elements like the OLED panel just needs to be clicked into the back element. This is an easy and fast mounting process and thus a low-cost mounting.

The cable route is also special for kitchen lamps. The driver is often not placed directly in the lamp casing but is hidden on top of the cupboard. Then the cables from the OLED panels go through a hole in the bottom of the cupboard and behind the back wall of the cupboard up to the top where the driver is placed. There the driver is connected to the electrical grid. Figure 5.16 illustrated this possible cable rout which is not visible for the user.

5.5. User Product Interaction

For almost every product the user product interaction is a challenge. The aim is that the user understands fast how the product works and that he is satisfied with this interaction with the product. In this case the user product interaction concerns the control of the lamp. Figure 5.17 presents a storyboard which

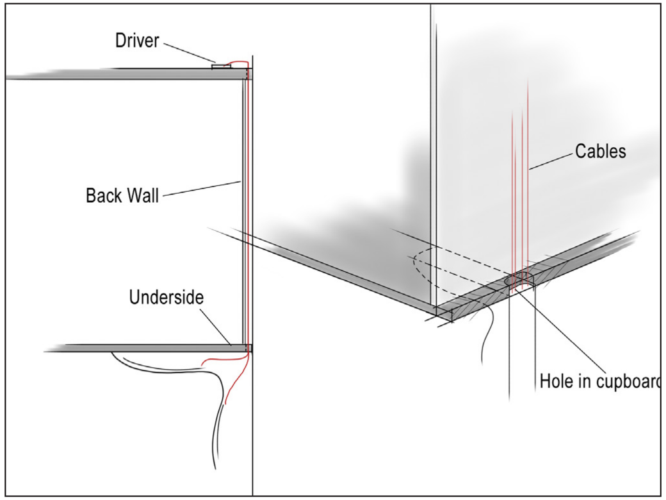


Figure 5.16. Cable Routes of the OLED Panels

illustrates the usage of the lamp. First of all the lamps are turned on by simply touching one of the lamp so that the touch sensor reacts. The touch sensor already reacts when the hand of the user comes close to the lamp. Then the user holds the hand closer to the lamp for a while for dimming the light. The add-on sound can be used for listening to music. A smart phone can be connected via a Bluetooth connection to the add-on. The other add-on energy offers the possibility to plug kitchens devices. After cooking the light can turned off by just touching one of the lamps once.

5.6. The OLED-Panel

Another essential step in the design process is the choice of the OLED panel. The shape of the lamp already requires that the panel is flexible and in fact just LG-Chem is already selling flexible OLED panels. Moreover a flexible panel is chosen because this is one of the characteristics of OLED panels which make it unique. The panel is the centre of the

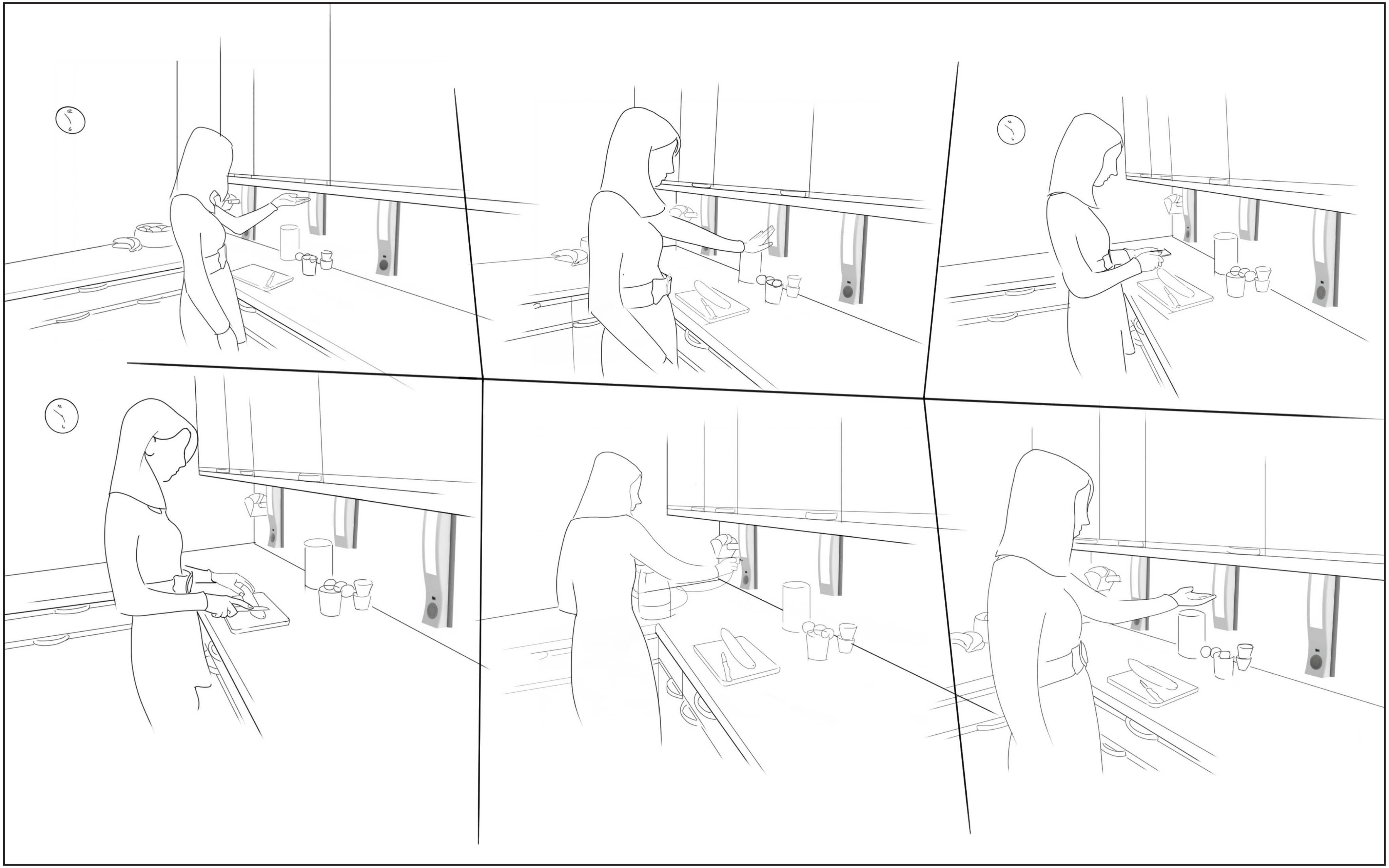


Figure 5.17. Storyboard

design. In fact the new flexible Panel P6BA30C is chosen and in appendix E.10 information from the datasheet of this panel are collected.

This flexible panel is rectangular (211x50mm) and just 0.25 mm thick. The luminance area of the panel is 188.2 x 41.0 mm. Moreover the panel is not just really thin but has also a low weight of < 5g. The colour temperature of this panel is 2700 K which is in the range of warm white. (LG-Chem, 2015) In fact warm white light is required for kitchen lighting and is described in the analysis of the usage of light in interior design. The panel has a colour rendering index of 85 which is perfectly adapted to kitchen lamps. Lamps with a high colour rendering index present the food in its original colour so that the food looks tasty. The operating temperature of the panel is between 0 and 40°C. The electrical characteristics are described in the following section about the electrical connection.

5.7. Electrical Connection

Within this section the electrical components of the lamp and the add-ons are briefly discussed. The right choice of electrical components is essential for an efficient operation of the product.

5.7.1. Electrical components of the lamp

OLED Panel

The most relevant electrical component of the lamp is of course the light source itself. The only company which is already providing flexible OLED panels is LG-Chem. This panel has a size of 211mm x 50mm and a 0.25mm thickness (LG-Chem, 2015). All characteristics of this panel are summarized in the appendix E.10.

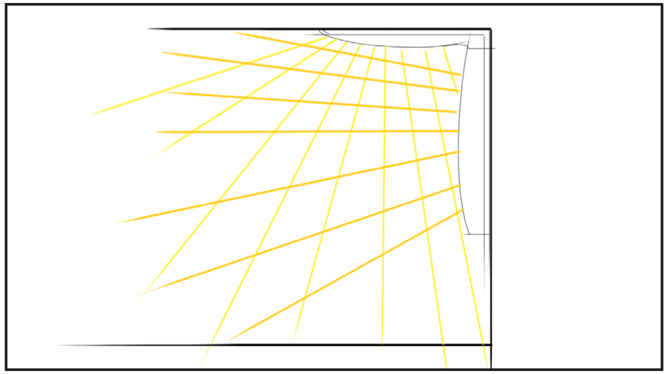


Figure 5.18. Light Distribution

The rectangular flexible panel has a forward voltage of 8.6V and a forward current of 150mA for a average luminance flux of 75lm (LG-Chem, 2015). Moreover OLED panels are Lambertian surface emitters. That means that they appear evenly bright from any view angle. (Osram, a) It is essential to calculate the illuminance of the panels of the lamp. Therefore two calculations should be made for the panel of the upper lamp and the panel of the side lamp. The panels have different positions regarding the worktop (parallel and perpendicular) which cause two different illuminances. The figure 5.18 gives an impression of the light distribution of the OLED panel. The calculation of the illuminance of the panels is shown in appendix E.11.The upper lamp has an illuminance on the work top of around 50lux and the side lamp has an illuminance of around 25lux. For achieving an illuminance of around 500lux more lamps need to be placed next to each other.

Driver/Power supply unit

OLED panels need to be connected to an AC/DC converter. Indeed The electrical grid provides an AC current and OLED panels require an DC

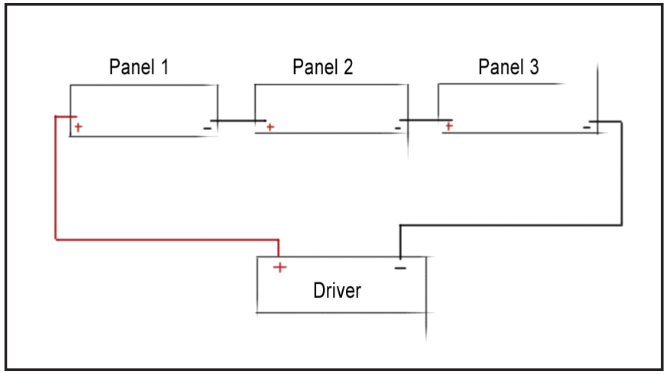


Figure 5.19. Electrical Ciruit (LG-Chem, b)

current. Drivers which are used for inorganic LEDs can also be used for organic LEDs (Philips, 2012). The brightness of the panels is proportional to the current input. Thus the driver's current should be higher than the current of the OLED (>150mA). The output voltage can be used for calculating the amount of panels which can be connected to one driver (voltage of the panels </= voltage of the driver). The panels need to be connected in series as shown in figure 5.19. (LG-Chem, b)
In the design guide of LG-Chem (b) some drivers are listed. In the list are also two dimmable driver from the company HEP. It is either possible to connect a driver and a dimmer to the panels or to use a dimmable driver. Hep provides also dimmable drivers with a high output voltage. A dimmable driver, the LBC20W350 1C UNI has been selected out of all of them. This driver has been chosen because it has one of the highest output voltages and it is dimmable. The voltage needs to be high so that as many panels as possible can be connected to one driver. This driver has an output current of 350mA which is as required above the one of the OLED panel. The output voltage is 55.7 VDC which means that 6

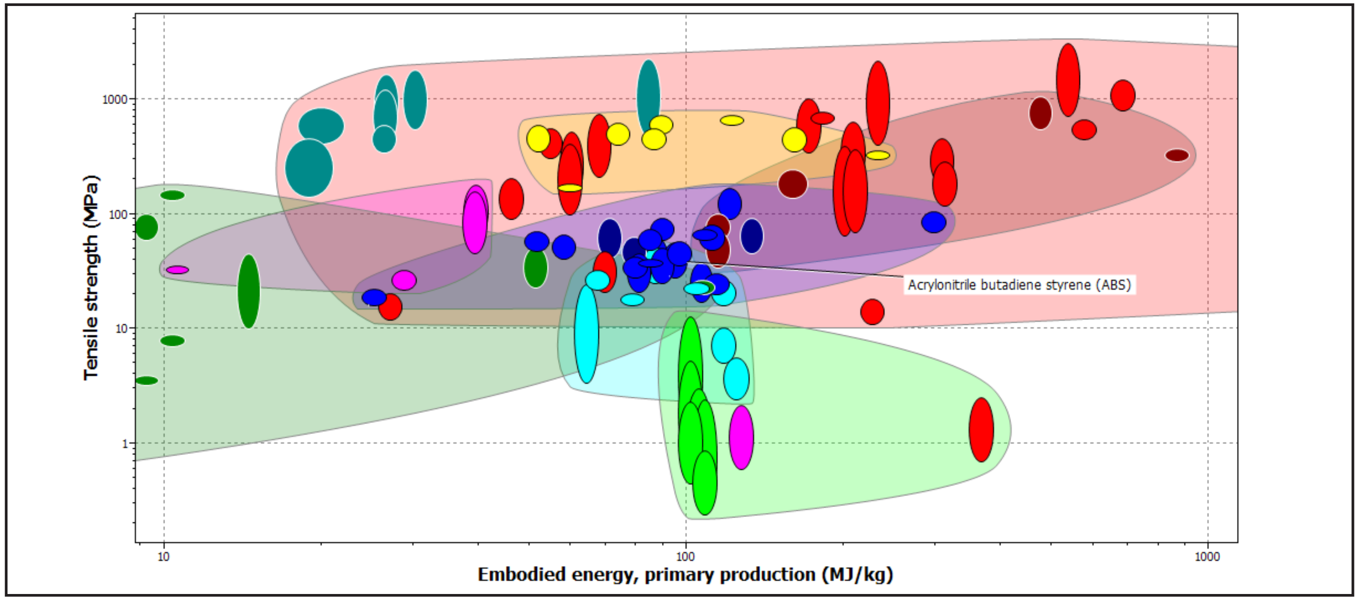


Figure 5.20. Tensile Strength and Embodied Energy of possible Materials

panels (3 lamps) can be connected to the driver. Moreover this driver has a dimmable range of 10 to 100%. Of course a dimmable driver with a higher VDC would be better so that all the lamps can be fixed to one driver. Moreover this is a constant current LED driver. For the brightness of the panels and the lifetime it is essential that they are driven by a constant current as examined during the analysis section (characteristics of OLED panels). (Hepgroup)
Driver Voltage**:** 8.6Vx6 = 51.6V < 55.7VDC

Touch sensor
Both lamps contain a small touch sensor which reacts when the hand of the user comes close to it. If the user holds his hand there for longer the light slowly gets dimmed.

The touch sensors in the lamps need to be connected to the driver either by a cable or by sending a signal to a receiver. The receiver is a technical device which can receive information from the touch sensor or from the app. This communication can take place via Wi-Fi.

5.7.2. Electrical components of the Add-Ons

The add-on energy contains a plug socket and an USB connection. Both components need to be connected to the electrical grid. Moreover the USB port also needs to be connected to an AC/DC converter.

The add-on sound is composed of a speaker, a Bluetooth connection and a USB connection. In this add-on the USB-port is used for connecting every technical device via USB to the speaker. The speaker and the Bluetooth need to be bought at a supplier. Also these components need to be connected with each other and the electrical grid.

Then the electrical components of the add-ons just need to be added in the casing either with screws or snap connections. The geometry of the components often offers either a snap connection or holes for screws but the exact geometry needs to be known for this. Companies often have their own suppliers for these parts and when the geometry is known the connections can be modeled inside the casing.

5.8. Material Choice

Another essential step within the design completion is to choose a suitable material for the designed lamp. This choice is mainly depending on the shape of the product and the requirements the material has to fulfil. The casings and back elements of the lamp have quite complex shape and the easiest way to produce them is by injection moulding which unfortunately limits the material choice already to polymers.

List of requirements to the material:

- Excellent usage for injection moulding
- High-quality appearance
- High Tensile Strength
- Recyclable
- Low embodied energy
- Low CO2 footprint

As injection moulding is the only suitable process to create such a complex shape, the chosen material needs to have excellent characteristics for injection moulding. Moreover the material should have a high quality appearance for being worth the high price. An excellent quality material also matches with the appearance of OLED-panels because OLED is still a high-cost technology.

The chosen material is used for the casing and the back elements of the lamp. Thus the tensile strength needs to be high so that these parts are able to hold the low weight elements inside the lamp like the OLED panel and a touch sensor without the appearance of cracks and breaks.

The OLED technology is known as eco-friendly and it is required that the designed lamp supports this characteristics. An eco-friendly material should be chosen for the designed elements of the lamp to keep this aspect. In a word the material should first be recyclable and then the embodied energy should be low.

A material has been selected with the help of the software CES EduPack 2014. The software offers the possibility to select materials by applying wished requirements and creating lists and graphs. In this case all the polymers which can be used for injection moulding and which are recyclable have first been selected. Then the embodied energy and the tensile strength have been added to a graphic which is illustrated in figure 5.20. The next step showed that the CO2 footprint of ABS is also acceptable. The material ABS has an acceptable tensile strength, embodied energy and CO2 footprint. ABS makes detailed designs possible and is often used for casings. Thus the ABS has a good quality appearance and can also be used for the casings of the lamp. Moreover this material can be coloured which is necessary for this design (white and grey) (CES EduPack 2014).

5.9. Manufacturing and Costs

In this section possible production processes and an assumed cost calculation are presented.

Production and Assemblage

The best process for producing plastic products with a complex shape is injection moulding. Injection moulding can be used the best for small, precise and complex parts. Moreover the surface finish of injection moulding parts is good. (CES EduPack 2014) The material ABS can be used excellent for injection moulding as described in the material choice section. All the other parts like the OLED panels, the plug sockets, the USB-plugs, the loudspeaker and the screws are imported from other companies.

The assemblage of all parts of the lamp is cheap and fast due to the usage of snap connections, screws and spring contacts. The integration of the OLED panels into the lamp takes the most attention because it has to be made really carefully. OLED panels are still really sensitive and shouldn't be manipulated with hands. Thus usage of gloves is highly recommended (LG-Chem, b). The mounting of the lamps to the wall with screws and the connection to the electrical grid will approximately take most of the time.

Cost Calculation

An assumed cost price for the lamp has been estimated. In this simplified calculation the material costs, the production and assembly costs, the import costs of the electrical components and the overhead costs (15%) have been used. This is actually an assumed price and way more factors have to be considered for a real cost calculation.

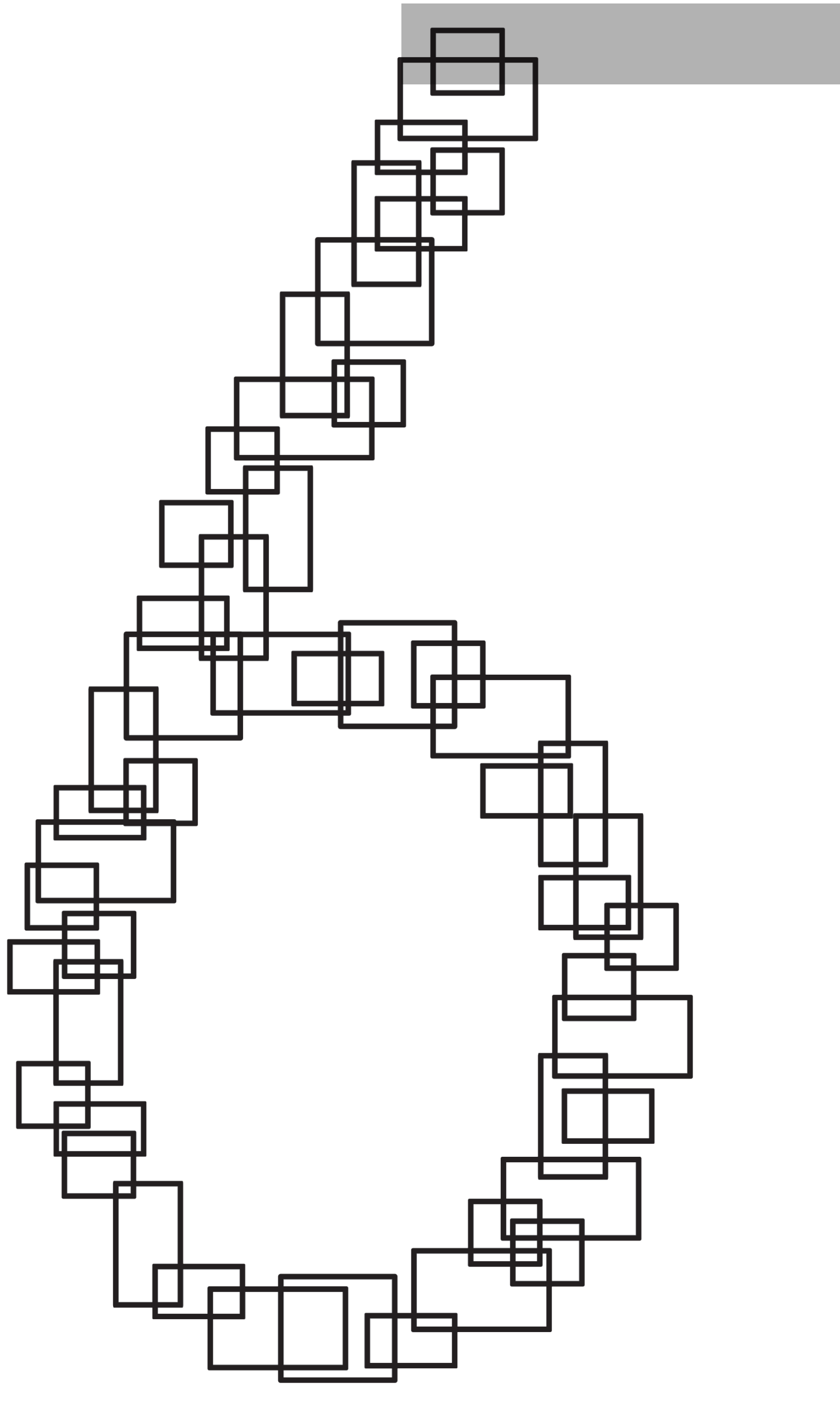
However, the assumed price would be quite large with 300€ for the upper lamp, 300€ for the side lamp, 70€ for the add-on sound and 50€ for the add-on energy. The high price of the lamp is mainly caused by the price of the OLED panel of 250 Dollar. But LG-Chem proposed to start with the mass production of the flexible panels in summer 2015. (OLED.at, 2015) In this case the price would decline and the lamp will be cheaper. The fully calculation is presented in appendix E.11.

5.10. Prototyping

The best impression of a product is given by a prototype. This prototype can be used for testing a product and for seeing whether or not all parts are matching inside the product. It can be distinguished between functional and non-functional prototypes. The functional prototypes focus on the functionality of the product. Often this prototype is used for testing the technic and the functionality of the product. A usability test can be used for testing how well the product and the user product interaction are working.

The non-functional prototypes focus more on the appearance of the product and its dimensions. In fact They are mainly used for getting a better feeling of the size of the product and for getting to know if the user likes the appearance of the product. In this prototype the functions of the product often do not work.

Within this project a non-functional prototype will be made for the exam. Unfortunately it was not possible to build a functional prototype because it would be quite expensive due to the high-cost of the OLED panel and a 3D-print. But the non-functional prototype will be made for giving a better impression of the lamp.



6. Conclusion

The aim of this thesis was to acquire knowledge about the OLED technology and to design a lamp with at least one OLED panel. The thesis has been made for the design office OTT-DESIGN while running a three month internship in the company. A project plan has been set up for planning the entire thesis with its phases. The result of the thesis is a design guide and an OLED lamp design for kitchens. The design process and the design are evaluated in this section. Therefore the questions and the planning which have been set up within the project plan are used.

Evaluation Design Process

In the project plan a specific planning for each week of the internship has been made. The phases are quite similar to the chapters of this thesis. The project started with an analysis and went on with idea generation and concept creation to end on a final design. The project went as far as initially expected and the planning has been followed.

The first step of the thesis was to lead a study about light and the OLED technology. All relevant questions which needed to be answered during this phase have been listed before in the project plan. The topic light has been split up in three parts which are light characteristics, effects of light on the humans and the usage of light in interior design. All three topics have been crucial for designing a lamp with an OLED panel. The characteristics of light represent the basic knowledge of lighting terms which are essential for designing a lamp. Moreover it was compulsory to know how artificial light sources can influence the human beings. A lamp needs to be designed in a healthy way and should not harm the user. This knowledge was used after to examine the effects of OLED panels on the humans. The study of the usage of light in interior design then has been used for setting up requirements for every area where lights can be used. This detailed list of requirements has been a fundamental input for the concept generation and the final design.

Then the OLED technology itself has been analysed. The characteristics of the OLED panels are essential for knowing how to use OLED panels inside designs. Moreover it was useful to study the benefits of OLED panels for highlighting them within the lamp design. In a detailed market analysis a list with all existing OLED panels and their characteristics has been set up as an input for the following steps. All in all the entire analysis phase brought up a lot of useful information for designing a lamp and all questions from the project plan could find an answer. The result of this phase is a detailed list of requirements which is the most essential input for all the following phases. It was also not a problem to find references because the OLED technology is a quite current issue.

Then ideas and concepts have been generated. The concept phase actually took more time than expected because nine concepts have been generated instead of the three initially planned. The generation of a lot of different ideas has succeeded and even thought this phase took longer than expected nine proper and different concepts have been created. In the end one lamp design has been chosen in a discussion with the owner of the design office.

Then the design completion also required a few more days and resulted is a design guide and a kitchen lamp which contains two flexible OLED panels. Concerning the lamp, it can be split into three parts. An upper lamp can be combined with a side lamp and two possible Add-Ons. All parts of the lamp have been worked out in detail following different aspects like the styling, the mounting, the electrical components, the user-product-interaction, the material choice and the production and costs. The calculations of the lighting characteristics have been quite complicated due to the fact that the OLED panel is not a point light source but an area light source. The calculations for area light sources are way more complex and not easy to find. Unfortunately no prototype has been made within the planned time and will be made on later because no mean were existing at the office and because of the too high cost of a 3D-printed prototype. Moreover the OLED panels are quite expensive and no functional prototype could be made. A non-functional prototype in the workspace of the University of Twente will still be made for getting an idea of the size of the lamp. All in all the relevant question of the design are answered within this section. A detailed CAD-model has also been made and renders as well as drawings are used for visualising the design.

The Design

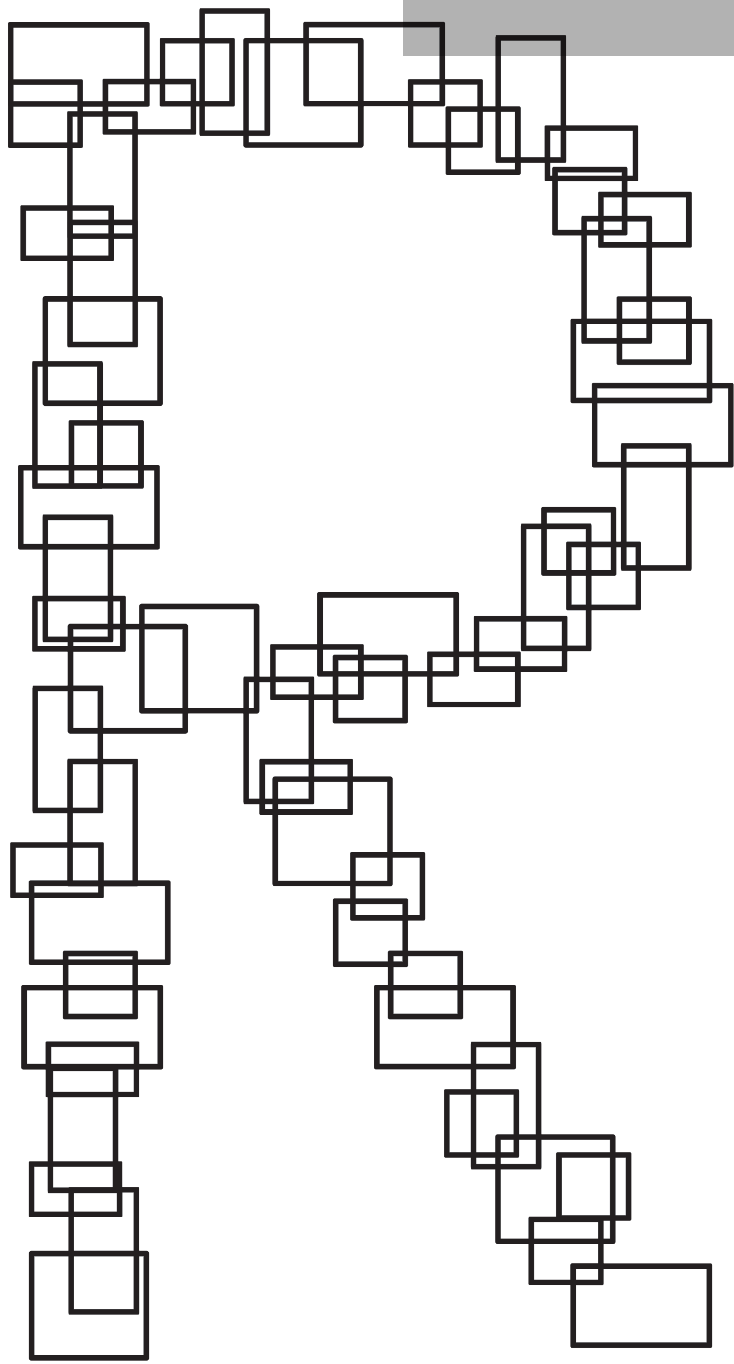
No product is perfect and this lamp is not an exception. Some slight improvements on the lamp can be still done. The lamp design supports the unique characteristics of the flexible OLED panel which are the flexibility, thinness and the eco-friendliness. The panel is the centre of the design and the styling of the product supports the flexible and thin shape of the panel. OLED panels are offering some advantages and are a healthy light source because their light spectrum is one of the closest to the sunlight. Moreover the colour temperature is in the warm white area as required and the colour rendering index is high enough for the kitchens. OLED panels provide a light which allows the colours in their environments to remain quite natural. One panel is fixed above the work top and one on the side of the work top. Thus less irritating shadows are created on the work top. Indeed this is possible because the OLED panels are glare free. The two add-ons sound and energy give extra functionality to the lamp. The fact that the lamp can be combined in every way gives the kitchen designer and the user a lot freedom. Today this freedom is an extra feature which is quite essential. Indeed the today’s users love to create their own products for being different than the others. In fact a unique design with a suitable light source has been created.

Some small parts of the lamp design could be improved or need further development. The SolidWorks model could be worked out more detailed regarding the connection of the technical parts inside the casing of the add-ons. Another component which needs to be further developed is the app which is not designed within this project. The possibility that the company producing the lamp already owns an own app is high and In this case the lamp should be connected to this app. This app could include some smart functions like the biological light as mentioned in the design completion chapter.

The cost price of the lamp will be quite high due to the current price of the panels. The price needs to be as low as possible so that more lamps can be placed inside a kitchen without problems. The price of the panels is actually supposed to decrease soon so that the lamp will become way cheaper.

The high price of the OLED panels is definitely problematic and the illuminance of the lamps is not high enough yet. It is of course possible to mount more lamps next to each other along the work top or to combine this lamp design with another light source like LED or Halogen lamps. Moreover the general lighting in the kitchen and other light sources will increase the illuminance on the work top. But this lamp also functions more as a design lamp and eye catcher and in fact often kitchen lamps do not achieve the required illuminance of 500lx. However, the OLED panels are still undergoing improvements and the efficiency and the luminous flux of the panels will improve over the next few years. All in all the aim of the thesis has been achieved and a lot of information about the OLED technology and the light usage have been collected and successfully used for designing a lamp. A design which definitely can be used in the future has been created. The lamp contains a healthy, efficient and eco-friendly light source which will improve and create a revolution in the future lamp market.

6. Conclusion



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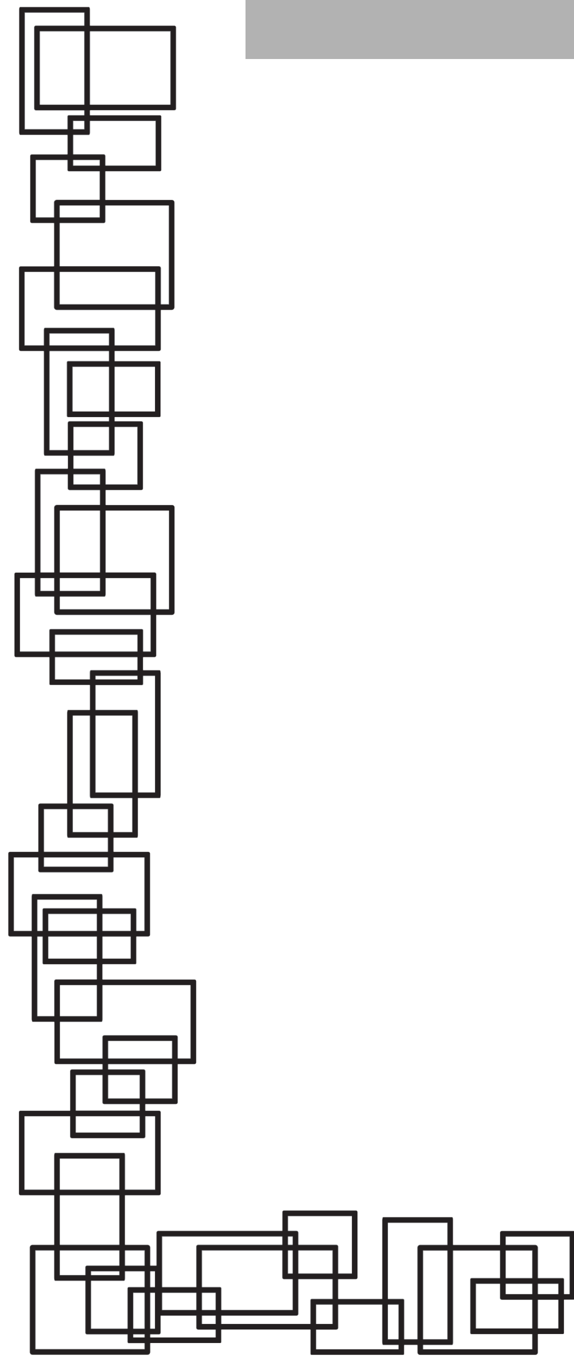

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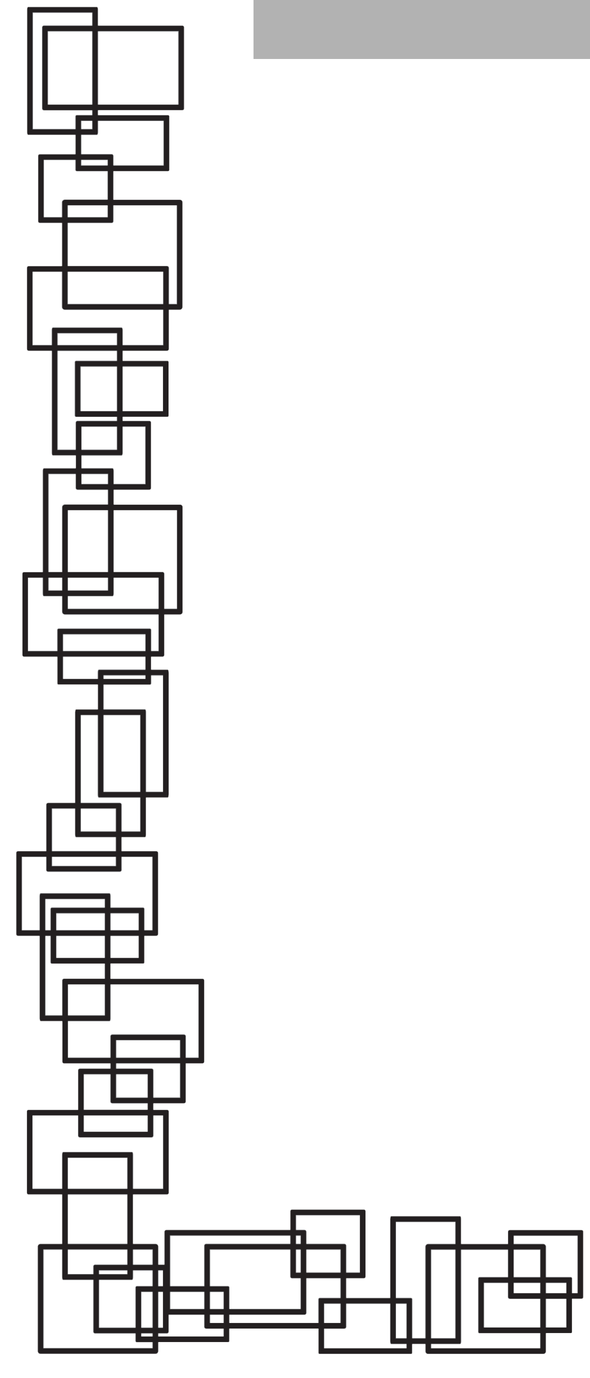

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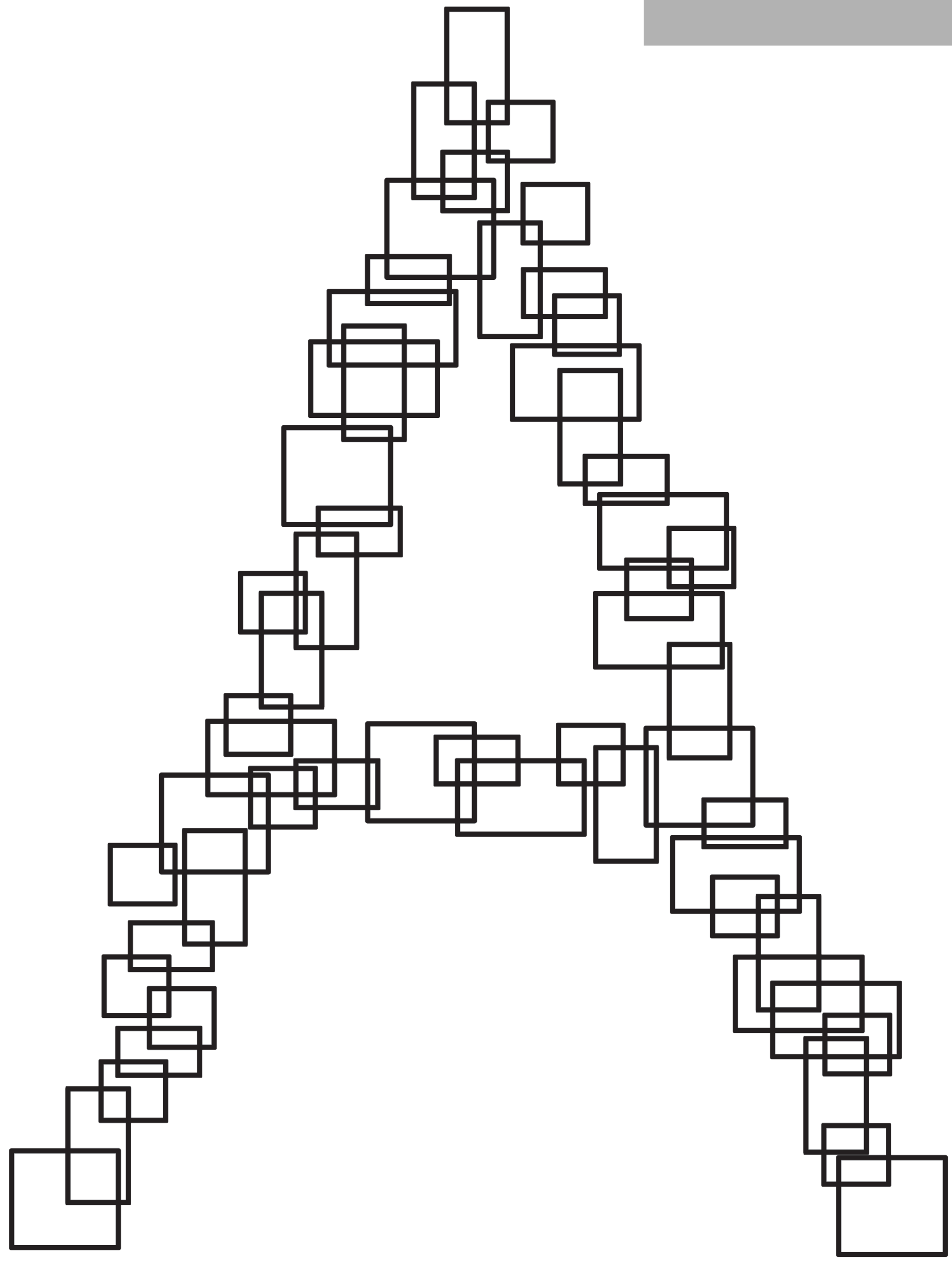


Appendix

A. Introduction

A1. Assignment Description

Based on existing OLED panels a lamp has to be designed for the company OTT Design. The lamp could be placed on furniture or be directly integrated inside it.

OTT DESIGN is a small Design Office located in Herford, Germany. The owner Niko Ott and his employees are running projects in the areas of Interior design, Product design and Visualization. The product design is mainly dealing with kitchens, bathrooms and offices.

Many lamps have already been designed within this design office but only LED technology has been used. All the office will then discover the area of OLED lamps so as to extend their product catalogue.

The aim of the assignments is to get to know the OLED technology, its characteristics and benefits to see where it can be used the bests (e.g. kitchen or bathroom) so as to design an OLED lamp. Round, rectangular, quadratic OLED panels from the leading companies like Phillip, LG-Chem and Osram will be used during the project and in the prototype. The choice of electrical components (like the ELT-adaptation unit) is also at stake because the office is dealing with a new kind of light system. Finally a lamp will be designed and a 3D prototype will be made.

A2. Action Plan

1. Actoranalysis - Company and Stakeholders

The company is OTT-DESIGN a design office located in Herford, Germany. The office was founded in 1986 by Niko Ott in Bad Oyenhausen, Germany (OTT-DESIGN, 2008a). Then in 2005 the whole office moved to Herford. 5 employees are working for OTT DESIGN as interior designers, product designers or working on visualizations. (OTT-DESIGN, 2008b)

The focal point of the company OTT-DESIGN is on interior design as well as on product design. The product design is also one of the main focuses when it comes to interior and especially furniture design area. Since 2008 they have also been working on 3D visualization which became a significant aspect of the design branch. OTT-DESIGN is mainly designing kitchens, bathrooms, stands for fairs, store constructions, offices as a whole or products for these areas.

The design office is working for other large companies. On the one hand OTT-DESIGN is in charge of developing new products while will be produce and sold by their client. This product could be for example a lamp or a whole kitchen. On the other hand OTT-DESIGN is also designing and planning interiors for its clients. Thus the interior of a store or an office could be entirely designed, planned and realized by OTT-DESIGN. (OTT-DESIGN, 2008c)

2. Project Kadar

In interior design light is used for different purposes. First, a light is basically illuminating a place so that people can see in the dark. Thus lighting a working area allows people to work in a comfortable and healthy way whatever the outside light conditions are. But light is also used for decoration and is especially placed in living rooms for creating a cozy atmosphere or in kitchens for adding design highlights. Light can then fulfill different functions and affect several aspects in our environment.

Among other things OTT-DESIGN is also designing lamps for kitchens. However they have been working with only LED lamps so far and OLED technology has been developed and can be used for lamps as well. Thus to extend their product catalogues and to deal with competitors OTT-DESIGN would like to get more knowledge of OLED lamps, how OLED lamps can be used and have a design of an OLED-lamp. Therefor an analysis of the OLED technology and the light generated by OLED has to be performed. Once the characteristics of the OLED are clear it can be decided for which function and area (e.g. kitchen or bathroom) the lamp can be used the best. Finally a lamp will be designed by using all these knowledge.

3. Aim of the assignment

OTT-DESIGN wishes to get more knowledge about OLED and to have designs of a lamp with OLED to extend their product portfolio and to anticipate client needs so as to be competitive. The aim of the assignment is a) to analyze OLED and its characteristics for deciding where the lamp can be used the best and b) to design a lamp with OLED.

This can be realized by analyzing the workings principles of OLED and examining the light created by OLEDs. Moreover the way the lights are currently used, for which functions and for which areas has to be preliminary studied. Indeed it will be essential for deciding where OLED can be used the best. A list of requirements will then be settled permitting the design of this OLED lamp under the optimal conditions. Finally this 3 month assignment will end by making a prototype using a 3D printer.

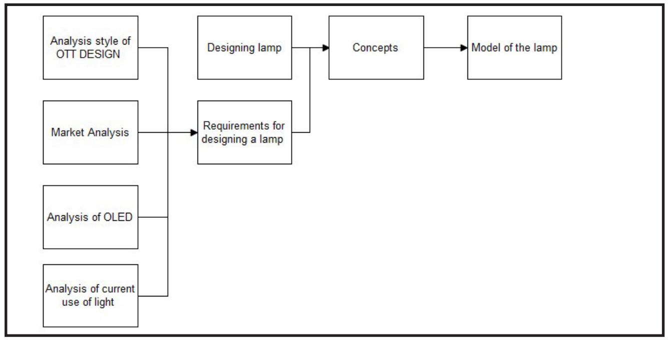


Figure A.1. Research model

4. Term definition

Competitors: Other design offices or companies which are designing lamps.
Additional functions: Other functions a lamp can have except the main
function lighting.
Company: The design office OTT – Design.
Costumer: Companies which are buying the lamp (for example for the kitchen- or bathroom design)
User: Is the person who is using the lamp.

5. Presentation of questions

1. How does an OLED work?
    a. Which parts does an OLED have?
    b. What are the functions of these parts?
    c. What is the workings principle of an OLED?
    d. How does an OLED lamp have to be connected to the electricity?
2. Which characteristics has OLED?
    a. Which forms/shape do OLED panels have?
    b. Which dimensions can OLED panels have?
    c. How bright is the light of an OLED?
    d. Which color can OLED light create?
    e. Which psychological effects does the OLED light have?
    f. What are the costs of OLED panels?
    g. What is the life period of an OLED?
    h. Which voltage is needed for the OLED? (Which transformer is necessary?)
    i. How energy efficient are OLED?
    j. How robust are the OLED panels?
3. Which OLED lamps are already on the market?
    a. For what products are OLED lamps used?
    b. Which functions do these lamps fulfill?
    c. What are the dimensions of these lamps?
4. Which kind of light is used in kitchens, bathroom, living rooms or bedrooms?
    a. Which lamps are used so far in kitchens, bathrooms, living room or bedrooms.
    b. Which main functions does light in these areas need to fulfill?
    c. How is light influencing people in these areas?
    d. How bright has the light to be in the different areas?
    e. Are there any additional functions needed in a lamp?
    f. Which lamps did OTT-DESIGN develop so far?
5. For which area is the OLED light the best?
    a. In which area are the characteristics of an OLED lamp meeting the best the requirements and functions?
    b. Which functions does the lamp need to fulfill in this area?
    c. Who will be the user of the lamp (target group)?
    d. What are the characteristics of the users?
    e. How does the environment of the lamp look like?
    f. Which dimensions can a lamp have in these area?
    g. Does the lamp need any additional functions?
    a. What are the requirements for a lamp?
    a. Which are the limititions of OLED panels?
    b. What are the requirements of the OLED regarding the electricity connection?
    c. What requiremtens does the company have?
    d. What requirements do the customers have?
    e. What requirements do the users have?
    f. Which requirements do insurances have to a lamp?

6. Strategy

1. First how an OLED works has to be analyzed.
   a. For understanding how OLED works it is necessary to know which parts are composing an OLED pannel. This can be done by making researches on internet and at the library or by reading directly the product datasheet of the OLED panels or other documents of the company. If possible an interview with an expert can be done.
   b. The functions of every part have to be clearly identified to understand how the whole panel works. This can be done by making researches on internet and at the library or by reading directly the product datasheet of the OLED panels, an interview with an expert or other documents of the company.
   c. Once all the functions of the parts are clear the whole workings principle of the OLED panels can be studied. The research tool will be once again internet, library and technical datasheet.
   d. Another crucial question is how the OLED will be connected to the electricity and which requirements are induced by it. The research tool will be once again internet, library and technical datasheet.
2. Second it is important to know which characteristics OLED panels have for deciding where the OLED lamps can be used the best.
   a. Therefor a study has to be carried out to determine in which shape OLED panels already exist. This can be done once again by reasearch via internet or library or with documents of the company. An interview with an expert outside or within the design office can also be useful.
   b. In which dimensions OLED panels are available is also playing an important role for the later design. Once again the research tools are reseatch on internet and at the library or with documents of the company. An interview with an expert within the design office can also be useful.
   c. By an internet or library reasearch it can be analysed how bright the light of an OLED panel is and can be. It is significant to know how bright the light of an OLED is so as to be able to chose which function an OLED panel can fulfill. An interview with an expert within the design office can also be useful.
   d. Another characteristic of light is the colour of the light. This can be analyzed as well with an internet reasearch or an reasearch in library. An interview with an expert within the design office can also be useful.
   e. Light can have psychological effects on humans. The psychological effects of the OLED ligth on humans has to be analyzed so as to decide in which area an OLED lamp can be used the best. This can be done with a research on websites or with books out of a library about the effect of different lights on humans.
   f. The price of the OLEDs is also an important factor. The price can also be found out via websites or datasheets from the company.
   g. The life period of the OLED is also a significant point. This can be figured out via websites or datasheets the company.
   h. The voltage and which transformer is necessary can be analyzed via internet or information of the company.
   i. For discovering how efficient an OLED works an analysis via websites over OLEDs or with information of the company can be done.
   j. The last interesting characteristic is how robust an OLED panel is. For example can a OLED panel be bend? As the questions before also this question can be solved by a research on websites with OLED informations or with information from the company or experts.
3. Then it has to be analyzed which OLED lamps are already on the market.
   a. During a research on internet or an observation in shops or on fairs it can be pointed out where OLED lamps are already used.
   b. A research on internet or an observation on existing product can also show which functions these lamps fulfill.
   c. Which dimensions these lamps have can be detailled with a research on internet by analyzing already existing OLED lamps.
4. Moreover the knowledge of what kind of light is used in kitchens, bathroom, living rooms or bedrooms so far seems imperative.
   a. Which lamps (e.g. LED) are used so far in these areas. This question can be the best answered by direct

observations in shops for example but also during an internet research. An interview with an expert within the design office can also be useful.

b. Which functions does light in these areas need to fulfill is a significant question. An internet research or an research in the library can answer this question but also the knowlegde and products of the company so far can be used. An interview with an expert within the design office can also be useful.
c. Next to that it is important to know how light is influencing people in these area. This can be figured out by a research on internet or library. An interview with an expert within the design office can also be useful.
d. How bright has the light to be in the different areas? This question can also be answered by research on internet or on the library. An interview with an expert within the design office can also be useful.
e. Additionally to the main function a lamp can have additional functions. Which additional functions a lamp should have can be analyzed by research on internet e.g. on competitors websites or in library as well as with documentation of the company. He already designed a couple of lamps and knows which other functions a light has to fulfill in the different areas. An interview with an expert within the design office can also be useful.

5. With the documentations of the company and its productportfolio it can be pointed out which products the company designed so far. The last question is in which area the OLED light is fitting the best?
   a. In which area are the characteristics of an OLED lamp meeting the best the requireents and functions? This question can be answered with the results of the second and fourth questions.
   b. Which functions a lamp has to fulfill in these areas is coming out of question four.
   c. Once an area has been chosen the user of this area has to be analyzed either by a research on internet, documentation of the company,or an interview with an expert or observations.
   d. An analysis of the environment can be done by a reseach on internet.
   e. The dimensions the lamps can have are deduced from all the questions above and then can be chosen.
   f. Out of question four it can be concluded whether the lamp needs any additional functions or not.
6. For summarizing the results of all the questions above a list of requirements has to be set up. All the questions can be answered with all own documentations.
   a. Which limititions are there of OLED panels?
   b. What are requiremtens of the OLED to electricity connection?
   c. What requiremtens does the company has?
   d. What requirements do the customers have?
   e. What requirements do the users have?
   f. Which requirements do insurancers have to a lamp?

7. Material

Question	Strategy	Material	Source
1	Analysis topic	Media	Websites about OLED technology
		Literature	Books about OLED technology
	Company	OLED Panels	OLED panels which are at the office
		Documents	Knowledge of company
2	Analysis topic	Media	Websites about OLED technology
		Literature	Books about OLED technology
	Company	OLED Panels	OLED panels which are at the office
		Documents	Knowledge of companys so far
		Interview	With expert in company or outside company
3	Analysis topic	Media	Websites of competitors or about OLED panels
		Literature	About OLED panels and their usage
4	Analysis topic	Media	Websites of competitors or website with user feedback
		Literature	About usage of light in interior design
	Company	Documents	Knowledge of company so far & product portfolio
		Interview	Interview with expert in company
5	Analysis topic	Documentation	Answer of question two and three
		Media	Websites of competitors and user feedback
	Company	Documents	Knowledge of company so far & product portfolio
		Interview	With expert in company
6	Analysis topic	Documentation	Answer question 1-5

Table A.1. Material

8. Planning

ID	Task Name	Start	Finish	Duration	February				March				April				May			
					02.02.- 08.02.	09.02.- 15.02.	16.02.- 22.02.	23.02.- 01.03	02.03.- 08.03.	09.03.- 15.03.	16.03.- 22.03.	23.03.- 29.03.	30.03.- 05.04.	06.04.- 12.04.	13.04.- 19.04.	20.04.- 26.04.	27.04.- 03.05.	04.05- 10.05	11.05.- 17.05	18.05.- 24.05.
1	Writing action plan	02. Feb	06. Feb	1w																
2	Analysis OLED	15. Feb	01. Mar	3w																
3	Analysis Market	15. Feb	01. Mar	3w																
4	Analysis possible areas	15. Feb	01. Mar	3w																
8	List of requirements	23. Feb	01. Mar	2w																
9	Idea generation	02. Mar	15. Mar	2w																
10	Making Concepts	09. Mar	29. Mar	3w																
11	Chosing concept	27. Mar	27. Mar	1d																
12	Working out concept	30. Mar	19. Apr	3w																
13	Prototype	13. Apr	26. Apr	2w																
14	Conclusion and Evaluation	20. Apr	26. Apr	1w																
15	Writing conceptual report	20. Apr	26. Apr	2 w																
16	Extra time	27. Apr	05. May	1 w																
17	Writing final report	11. May	24. May	2w																

Milestone meetings

Figure A.2. Planning

9.Bottleneck

Strategy	Bottleneck	Solution
Analyzing the working principle and characteristics of an OLED, analyzing the lamps used currently in kitchen, living room etc.	Too less information from the company	Discussion with company whether they can give more information or not
Analyzing current OLED products	To less information of products existing on the market	Take more time for a new design
Analysis	Contradictory results during analysis	Use the most logic results in consulting with the company
General problems during the design process		
Design process	To many options during design (during concept phase or conclusion over which are the lamp will be for)	Taking decision together with the company
Final product design	Final product design Failing of the product/design because of emerge problems	Analyzing and if little changes possible changement in prototype

Table A.2. Bottleneck

B. Analysis

B.1. Characteristics of Light

The following description of light characteristics is based on the source Fördergemeinschaft Gutes Licht (2008).

Luminous Flux Φ
The luminous flux is defined as the lighting power of a light source. The unit in which the luminous flux is measured is called Lumen (lm).

Luminous intensity I
The term luminous intensity tends to be used to refer to a part of the luminous flux which radiates towards a particular direction $I = \Phi/m^2$. Candela (cd) is the unit which is used to measure this characteristic of a light source. Moreover the luminous intensity is the power per unit solid angle (Candela = Lumen/ Steradian) (Wikipedia, 2014). The distribution of the luminous intensity can be described with a curved graphic called the luminous distribution curve.

Luminance L
The Luminance is scaled in the unit candela per square meter. This unit shows that the luminance describes the light intensity per square meter. Moreover it describes the amount of light which the eye perceives from a luminous or illuminous area.

Illuminance E
The illuminance can either be measured vertical or horizontal and is generally taken to define the luminous flux of a light source which occur on a particular surface. The unit of the illuminance is called Lux (lx). Lux is equal to Lumen per square meter: $1lx = 1\ lm/m^2 = 1\ (cd*sr)/m^2$. (Wikipedia, 2015a).

Luminous efficiency
The luminous efficiency is generally measured in lumen per watt and refers to the power consumption of a light source: $\eta = \Phi/P$.

Color Rendering Index
The term Color Rendering Index (CRI) Ra is used to determine how well a light source represents the natural color of an object. A CRI of 100 represents all colors in optimal condition. The lower the value the less the light source has the ability to present the natural colors of objects.

Color Temperature
Color Temperature is used for describing the color of a light source and is measured in the unit Kelvin (K). Primarily it can be distinguished between three main groups of color temperatures: warm white (<3,300K), neutral white (3,300K-5,300K) and daylight white (>5,300K). The higher the color temperature the whiter the color of light seems.

B.2. The Eye

Cornea: covers the iris and pupil and refracts light (wikipedia, 2015b)
Lens: refracts light and helps to focuse the light on the retina for a clear image (wikipedia, 2015c)
Retina: beginning of nervous system (consist of nerve endings called rods and cones) (Majka & Majka, 2012)
The Retina is perceiving light stimuli and sends this information to via the visual nerves to the brain where a picture is created out of the light stimulies. (Werth et. al., 2013)
6 million Cones: enable color vision (Majka & Majka, 2012)
120 million Rodes: perception of shape and movement (Majka & Majka, 2012)
Pupil: The eye has to adapt itself to the lighting conditions by changing the diameter of the pupil and the sensibility of the visual nerves. The adaption to bright light is faster than to dark light and the lighter the environment the better are the visual performances. (Werth et al, 2013)

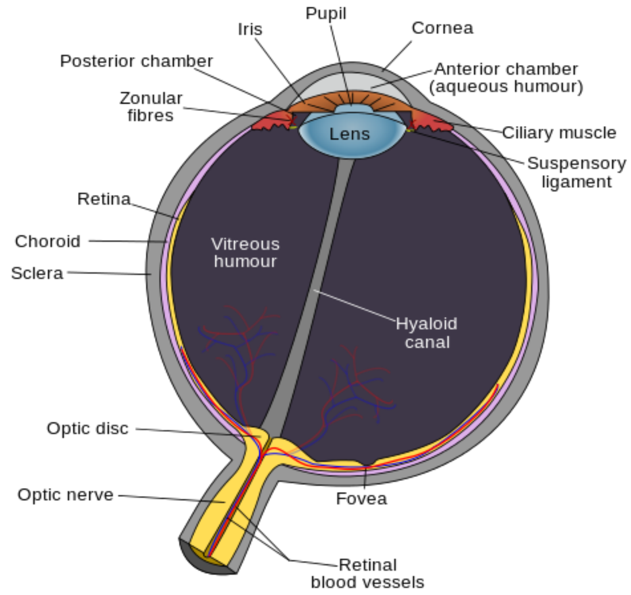


Figure B.1. The human eye (Wikipedia, 2007)

B.3. Influence of Light on Physical Health

The following table is based on Boyce‘s article The Impact of Light in Buildings on Human Health.

	Sickness	Description	Cause by	Symptoms
The eye	Photokeratitis of cornea	- temporary condition with severe pain - typically all symptoms are gone after 48h	UV radiation	- Clouding of cornea - Reddining of eye and Tearing - Photophobia - Twitching of eyelids - Feeling of grit in the eyes
	Cataract	Effect of exposing lens to UV	UV radiaiton	Turbitity that degrades the retinal image through light absorption and scattering
	Chorioretinal injury	- Infrared rays heat the tissue and damage retina - Reovery is limited or doesn‘t exist	400-1400nm (Near Infrared Radiation)	- Presence of Blind Spot - Scotoma in area of absoption
	Photoretinitis	- Photocemical damage of retina - Some recovery possible	Visible wavelengths	
	Raise of Temperature	- Raise of tissue and adjacent areas (10 W/cm^2 necessary)	Infrared <1400nm	Pain
	Eyestrain	- Due to perceptual stress or physical pain (e.g. in muscles)	- Visual task difficulty - Under- or overstimulation - Distraction - Perceptual confusion - Too little or too much light - To High difference between illuminance through the room - Glare, reflection or shadows	
The skin	Erythema	- After exposure to sun - Symptoms depend on dose of sunlight	UV radiation	- Red skin and Peeling of skin - Edema and Blistering - Pain
	Skin Cancer	Frequent and long exposure to sun	UV radiation	
	Skin Aging	Frequent and long exposure to sun		
	Raise of Temperature		Infrared < 1400 nm	Bruns on skin (rarely)

Table B.1. Effects of Light on eyes and skin

B.4. Usage of Light

The right usage of light is essential for a healthy and convenient way of living. Therefore artificial light has to be used for three distinct functions. First the light can be used as a so called room light. This general lighting is supposed to even illuminate the entire room. For this purpose a classic central ceiling lamp can be used the best. In case a room has brighter and darker sections the eyes have to permanently work to compensate this difference. (Fördergemeinschaft Gutes Licht, 2009)

A second kind of light is the zone light. As the name implies this light is utilized for lighting specific zones of room. This regions are zones where more light is wished for fulfilling special tasks. These tasks are often linked to high eye activities. Tasks like reading, working and cooking require bright light. Too less light would have harmful effects on the human health and would also impact the mood. As a zone light almost every kind of lamp can be used. Thus ceiling lamps, lamps integrated into furniture, desk lamps, wall lamps and floor lamps are matching with this task. (Fördergemeinschaft Gutes Licht, 2009)

Last but not least a light can be used as a mood light. Mood lights are usually used for the atmosphere and to make people feel well. Typically this light is used in the evening when people want to relax and are not supposed to fulfill tough tasks with their eyes anymore. Further extraordinary light effects can be used during the dark times. Mood lights are not bright and not functional but appear to have fascinating light- (shadow)-effects. (Fördergemeinschaft Gutes Licht, 2009)

In almost each room of a house all three kinds of light are integrated in various ways. In this section the main used rooms of a house are analyzed. Different requirements are existing for every room because rooms are used for distinct intentions. Therefor the usages of the room are first studied and then the required functions of light are deduced from it.

Kitchen

The kitchen can be seen as one of the most used rooms inside a house. Before kitchens were mainly used for cooking and backing but now this room is also used for other purposes (Fördergemeinschaft Gutes Licht, 2009). On the one hand people are working and reading inside their kitchen which requires bright light conditions. On the other hand people are also spending more time with friends and families inside their kitchens and require mood light. During party is the kitchen a popular place but also often used for long family dinners or talks (Fördergemeinschaft Gutes Licht, 2009). For this usage a mood light would be more suitable.

It is necessary to plan the lighting carefully and to think of which functions each light has to fulfil. Therefore the kitchen can be divided into four main parts: the general lighting, the workspaces lighting, the kitchen table lighting and cupboard lighting.

General lighting

General lighting aims at illuminating the entire kitchen with a diffuse light. For this purpose a ceiling light fixed in the middle of the room is the best choice. This light should have an illuminance of at least 150 lux and should have a CRI (Color Rendering Index) of around 80. (Lichtdesign Galerie, 2015b) The CRI describes how well a light source can highlight the colours of objects (detailed discription appendix B.1). Moreover the light should be dimmable so that the user can adjust the brightness of the background light to the other zone lights (Fördergemeinschaft Gutes Licht, 2009). These general lighting requirements are valid for all the rooms which are analysed during this project.

Workspace

Cooking and backing mainly takes place on the work top and stove while cleaning of the dirty kitchen tools takes place in the sink. For these functions a bride zone light is essential. The illuminance of the light should be at least around 500 Lux or even higher (Fördergemeinschaft Gutes Licht, 2009). Moreover the Colour Rendering Index (CRI) should also be high >80. While cooking the quality of the colour rendering should be of high in order to emphasized how fresh and tasty the food is. Else the colour temperature is mainly based on personal taste even if the colour temperature warm white is often used for this zone. (Lichtdesign Galerie, 2015b)

Thus the location of the lamps is relevant. The light should either shine from the wall or from the top to not create disturbing shadows. (Fördergemeinschaft Gutes Licht, 2009)

Finally the lamps should be dimmable in order to be also usable as a mood light. For instance the focus is not on the work top anymore while eating or partying.

Shelves and cupboards

Lighting inside kitchen cupboards is supposed to make the interior of the cupboard visible. Thus the user can have a better overview about what is inside the shelf and how much free space is left. But these lamps can also be used as mood light because they are creating a special atmosphere and have a noticeable decorative aspect.

Kitchen Table/Bar
The kitchen table requires an illuminance of 200-300 lux and the CRI is again supposed to be high with a value of around 90 (Lichtdesign Galerie, 2015c). The entire table has to be illuminated but also the persons sitting at the table. For this reason the light should be of course glare free. Moreover the lamp should not hide anyone on the opposite side of the table and therefore should be fixed at least 60 cm above the table. A height-adjustable light is preferable in this situation. Finally the lamp should include a dim-function to allow the user to have full control of the light. (Fördergemeinschaft Gutes Licht, 2009)

(Home) Office
In working spaces good light conditions are essential. Indeed eyes are permanently used during work and if the environment conditions are not good enough it will directly impact people. They get tired and unmotivated. The home office is commonly used for checking emails, organizing important papers like bills and letters or even sometimes for working. Indeed it is possible in some jobs to work from home and people are sometimes doing extra hour at home to deal with a stressful deadline. Therefor the same lighting requirements are valid in the home office and in offices at companies. The light has to be bright enough and especially glare free. (Fördergemeinschaft Gutes Licht, 2009) A good lighting system of an office can be divided into three sections: the general lighting, the lighting of the workspace and the lighting of space for visual tasks. Each section has its own requirements concerning light but they are also depending on the age of the user. People around 60 years need twice more light than 20 year old person. (Fördergemeinschaft Gutes Licht)

Workspace
The entire desk is used as a workspace and needs to be evenly illuminated. Everything on the desk has to be very visible so that the people can work comfortably. Therefor an illuminance of at least 500 lux is required. (Fördergemeinschaft Gutes Licht) Additionally a high Colour Rendering Index of 80-100 is also recommended. (Fördergemeinschaft Gutes Licht, 2009)

Visual Tasks Space
The visual tasks space is a small area on top of the desk where most of the working activity takes place. Here visual tasks like reading or using the computer are taking place. This space obviously requires a higher illuminance than all the other section with at least 750 lux. Moreover the light has to be glare free for not disturbing anyone working inside the office. (Fördergemeinschaft Gutes Licht) Again the Colour Rendering Index should be high to present everything in the original colours. The colour temperature is depending on what the user prefers. Once again warm white is often used for desks lights. It is also desirable to not have disturbing shadows in the visual task area and for this purpose lamps should be placed on the left side for right-handed users and on the right side for left-handed users. (Fördergemeinschaft Gutes Licht, 2009)

The best desk light is actually one which can be controlled by the user himself. It is more motivating and pleasant for the user if this latter can personally adjust his lamp and lighting conditions to fulfil his wishes. (Fördergemeinschaft Gutes Licht)

Bathroom
The bathroom is the room where the day starts but also where many people are relaxing. Taking a bath in the end of a hard day or just taking care of one’s own body with make up or lotions are some examples. Thus the lighting conditions are also relevant to study for the bathroom. In general the bathroom needs a general lighting and a separate lighting for the mirror. An indirect light on the ceiling or on walls can also be used to make small bathrooms appear larger. (Fördergemeinschaft Gutes Licht, 2009)

The light needs to be energizing in the morning and restful in the evenings. Therefore all the lights in the bathroom should be dimmable. For instance no one wants bright light during a night visit to toilet. (Fördergemeinschaft Gutes Licht, 2009)

Moreover another essential requirement for the bathroom is safety. In the bathroom water is constantly used and a lamp has to be resistant against splashed water. Every puddle of water has to be visible. (Lichtdesign Galerie, 2015a)

Mirror light
The main purpose of a mirror light is to present all the body of the person in front of the mirror in a good light. Therefore the light has to be even and no shadows should appear. Accordingly the best is to fix the lamps on the right and left side of the mirror. An additional lamp can be fixed above the mirror. A glare free light with natural colour temperature (often warm white) should be selected. (Fördergemeinschaft Gutes Licht, 2009)

Everyone wants to see himself in real colour and it is crucial while applying make-up. Due to this reason the Colour Rendering Index should be high with at least 80. The illuminance of the light should be between 400-500 lux since the eye is making a lot of effort again. (Lichtdesign Galerie, 2015a)

Living Room

The living room can be regarded as the most multifunctional room which also requires a multifaceted lighting. By and large people are reading, eating, working, talking, watching TV, gaming, partying and playing inside their living rooms. All these different activities require a flexible control of each lamp made by placing the switch close to the zone or by using a remote control. Ideas of lamps suitable for the living room are collected in figure B.2.

Moreover the living room should also offer a cosy atmosphere for properly welcoming guests. As in the other rooms a general lighting is essential. In addition to the general lighting the reading areas, the TV/Computer areas and sometimes also dining tables are sections of the living room. For the dining table the same requirements than for the kitchen table are valid. (Fördergemeinschaft Gutes Licht, 2009)

Figure B.2. Usage of Light in LivingRooms

Zone lights (Reading area, TV/Computer area)

The possible zone lights in the living room are ceiling-, wall – and floor lamps. It can be concluded out of the office requirements for reading areas that an illuminance of 500-750 lux is required for this zone. Moreover a high CRI of 100 is desirable to make reading and watching TV a pleasant. As regards the reading activity, the lamp should be placed behind or on the side of the reader. The same should be applied with the TV (lamps either behind or on the side of the TV) to avoid reflections of the light on the screen. (Fördergemeinschaft Gutes Licht, 2009)

Bed Room

The bedroom is probably the most personal room. This room is mainly used for having a rest but also activities like choosing the daily outfits. Basically the bedroom can be divided into a general lighting, a bed lighting and cupboard lighting section. Figure B.3 illustrates lamps of these sections. The user needs to have control over the lights when he is entering the room and from the bed for comfort reasons and a safe feeling. (Fördergemeinschaft Gutes Licht, 2009)

Bed lighting

A light next to the bed is used in various ways. It is lighting the room when the person wakes up and while activities like reading a book or working on the laptop inside the bed. The light needs to be focused on the bedside of the user and should be controllable by this latter. It is also desirable that the lamp can be dimmed. As the light it is used for reading the same requirements than for an office light can be applied. (Fördergemeinschaft Gutes Licht, 2009)

Cupboard Lighting

This light is supposed to make the interior of cupboard visible and to give an overview about what is inside the cupboard. The lighting can be positioned in front of the cupboard. However it is often directly integrated into the cupboard. A high CRI is essential to show the clothes in their natural colour allowing the user to choose the right one. A mirror is often mounted on the cupboard where the user can see how his chosen outfit looks like. For this function a shadow free warm white light is suitable as it was the case for the bathroom mirror. (Fördergemeinschaft Gutes Licht, 2009)

Figure B.3. Usage of Light in Bedrooms

B.5. Current usage of OLED

Figure B.4. Current Usage of OLED

B.6. OLED-Lamps

Figure B.5. OLED Lamps Collage

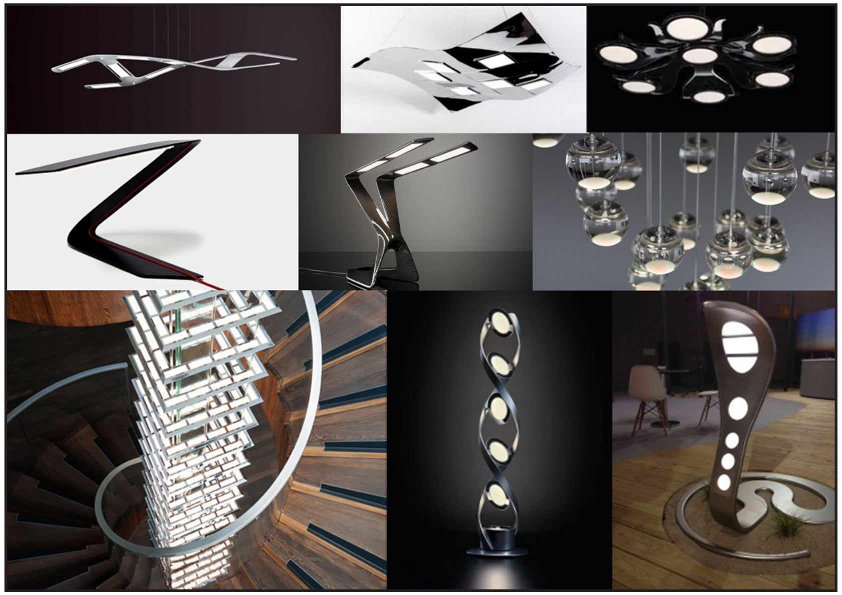


Figure B.6. OLED Lamps Collage

B.7. Producer of OLED Panels

Company	Osram						Philips		
Name	Orbeos SDW-058*[1]	Orbeos RDW-046*[2]	Orbeos CDW-030*[3]	Orbeos SDW-058+*[4]	Orbeos RTW-078*[5]	Orbeos Air*[6]	Lumiblade GL46*[7]	Lumiblade GL26*[7]	Lumiblade GL55*[7]
Shape	Qudratic	Rect-angular	Round	Quadratic	Rect-angular	Rect-angular	Round	Rect-angular	Rect-angular
Size	118,75 x 118,75 mm	125 x 47,5mm	90 x 85mm				85 mm	74 x 74 mm	130.2 x 47.8 mm
Lighting area	105 x 105 mm	112,8 x 34,9 mm	76,8 mm		180 x 65 mm		71 mm	60.5 x 61.4 mm	116.7 x 35.2 mm
Thickness	2,2 mm	2,2 mm	2,2 mm				1,94 mm	1,8 mm	1,94 mm
Forward Voltage	6.0 V	6.0 V	6.0 V				7.1 V	7.2 V	7.2 V
Power Consumption	1.7 W	0.6 W	0.7 W						
Luminous Flux	68lm	24lm	28lm				48.0 lm	27.5 lm	55.0 lm
Luminance	2,000 cd/m²	2,000 cd/m²	2,000 cd/m²	3,000 cd/m²			3,800 cd/m²	2,000 cd/m²	4,200 cd/m²
Luminous Efficacy	40 lm/W	40 lm/W	40 lm/W	65 lm/W	20 lm/W				
Color Temperature	3,400 K	3,400 K	3,400 K				3,200 K	2,900 K	3,200 K
Color Rendering Index	80	80	80				89	87	86
Operational Lifetime L70	10,000 h	10,000 h	10,000 h	15,000 h			10,000h	10,000 h	10,000 h
Current	285 mA	103 mA	115 mA				350 mA	270 mA	390 mA
Operatin Temperature	25°C	25°C	25°C						
Color of Light	White	White	White				White	White	White
Notes					57% Transmission	Same than RDW-046	Matted finished	Mirror finished	Matted finished

*1 - (Osram, e)
*2 - (Osram, d)
*3 - (Osram, c)
*4 - (Osram, 2015e)
*5 - (Osram, 2015f)
*6 - (Osram, 2015a)
*7 - (Philips, 2012)

Company	Philips						Philips		
Name	Lumiblade GL30*[7]	Lumiblade GL8*[7]	Lumiblade GL350*[7]	OLED Panel Brite FL300 ww N*[8]	OLED Panel Brite FL300 ww N w/o Rset*[8]	OLED Panel Brite FL300 ww A0*[8]	OLED Panel Brite FL300 ww B1 PCAL*[8]	OLED Panel Brite FL300 FL300 wm N*[9]	OLED Panel Brite FL300 wm A0*[9]
Shape	Triangle	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
Size	115.4 mm each side	54.7 x 49.4 mm		120,5 x 120,5 mm	120,5 x 120,5 mm	127 x 127 mm	127 x 127 mm	120.5 x 120.5 mm	127 x 127 mm
Lighting area	94.6 mm each side	40 x 40 mm	103.8 x 103.8 mm	102.4 x 102.4 mm	102.4 x 102.4 mm	102.4 x 102.4 mm	102 x	102.4 x 102.4 mm	102.4 x 102.4 mm
Thickness	1,8 mm	1,8 mm		1.4 mm	1.4 mm	2.1 mm	3.0 mm	1.8 mm	2.0 mm
Forward Voltage	7.3 V	7.0 V	14.3 V	20 V				20 V	
Power Consumption				7.4 W				7.4 W	
Luminous Flux	36.0 lm	8.0 lm	120 lm	300 lm				190 lm	
Luminance	2450 cd/m²	1500 cd/m²	4000 cd/m²	8,300 cd/m²				3,800 cd/m²	
Luminous Efficacy				40-50 lm/W				26-30 lm/W	
Color Temperature	3,200 K	2,950 K	3,250 K	3,000 K				2,500 K, 4,000K	
Color Rendering Index	86	89	>90	80					
Operational Lifetime L70	9,000h	10,000h		10,000h				10,000 h	
Current	350 mA	75 mA	500 mA	368 mA				368 mA	
Operatin Temperature									
Color of Light	White	White	White	White				White	
Notes	Mirror finished	Mirror finished							

*8 - (Philips, 2014a)
*9 - (Philips, 2014b)

Company	Philips			LG-Chem*11				
Name	OLED Panel Brite FL300 ww A0*9	OLED Panel Brite FL300 L N w/o Rset*10	OLED Panel Brite FL300 L AO*10	N6SB40	N6SB30	N6SA40	N6SA35	N6SA30
Shape	Quadratic	Rect-angular	Rect-angular	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
Size	127 x 127 mm	62.7 x 240.6 mm	67 x 245 mm	55x53mm		100x100mm		
Lighting area	102 x 102 mm	46 x 222 mm	46 x 220 mm	46x46mm		90x90mm		
Thickness	2.9 mm	1.1 mm	2.1 mm	1,97mm		0,88mm		
Forward Voltage	20 V	20 V		6.0V	8.5V	6.0V	6.0V	8.5V
Power Consumption	7.4 W	7.4 W						
Luminous Flux	300 lm	300 lm		20lm		75lm		
Luminance	8,300 cd/m²	8,300 cd/m²						
Luminous Efficacy	40-50 lm/W	40-50 lm/W		55 lm/W	60 lm/W	55 lm/W	55 lm/W	60 lm/W
Color Temperature	3,000 K	3,000 K		4000K	3000K	4000K	3500K	3000K
Color Rendering Index	80	80		90		90		
Operational Lifetime L70	10,000h	10,000h		30 000h	40 000h	30 000h	30 000h	40 000h
Current	368 mA	368 mA		60 mA	40 mA	230 mA	230 mA	150 mA
Operatin Temperature								
Color of Light	White	White		White	White	White	White	White
Notes								

*9 - (Philips, 2014b)
*10 - (Philips, 2014c)
*11 - (LG-Chem, a)

Company	LG-Chem*11							
Name	N6SC40	N6SC30	N6BA40	N6BA40	N6OA40	N6OA30	F6BA40	F6BA30
Shape	Quadratic	Quadratic	Rect-angular	Rect-angular	Circle	Circle	Rect-angular	Rect-angular
Size	140x140mm		200x50mm		Diameter: 110mm		210x50mm	
Lighting area	127x127mm		188x41mm		Diameter: 97,4mm		188x44mm	
Thickness	0,88mm		0,88mm		0,88mm		0,25mm	
Forward Voltage	6V	8.5V	6V	8.5V	6V	8.5V	6V	8.5V
Power Consumption								
Luminous Flux	150lm		75lm		75lm		75lm	
Luminance								
Luminous Efficacy	50 lm/W	60 lm/W	55 lm/W	60 lm/W	55 lm/W	60 lm/W	55 lm/W	60 lm/W
Color Temperature	4 000 K	3 000 K	4 000K	3 000K	4 000K	3 000K	4 000K	3 000K
Color Rendering Index	90							
Operational Lifetime L70	30 000h	40 000h	30 000h	40 000h	30 000h	40 000h	30 000h	40 000h
Current	480 mA	300 mA	230 mA	150 mA	230 mA	150 mA	230 mA	150 mA
Operatin Temperature								
Color of Light	White	White	White	White	White	White	White	White
Notes							Flexible	Flexible

*11 - (LG-Chem, a)

Company	LG-Chem*[11]						Tridonic		
Name	N6BB40	N6BB30	N6SD30	N6SD40	N6BC30	N6BC40	Lureon REP 10-40DC/ DL 2*[12]	Lureon REP 20w5-40 DL/ DC*[12]	Lureon PURE 10-40 DC/DL*[14]
Shape	Rect-angular	Rect-angular	Quadratic	Quadratic	Rect-angular	Rect-angular	Quadratic	Rectangular	Quadratic
Size	320x110mm		320x320mm		213x113mm		99x99mm	200x50mm	100x100mm
Lighting area	300x90mm		300x300mm		200x100mm		89x89mm	190x40mm	100x100mm
Thickness	0.88mm		0.88mm		0.88mm		3mm	3mm	6.5mm
Forward Voltage	6V	8.5 V	8.5 V	6V	8.5 V	6V	5.9V	5.8V	5.9V
Power Consumption							1.4W	1.35W	1.33W
Luminous Flux	250 lm		800lm		185lm		70lm		65lm
Luminance									
Luminous Efficacy	55 lm/W	60 lm/W	60 lm/W	55 lm/W	60 lm/W	55 lm/W	> 50 lm/W		50 lm/W
Color Temperature	4 000 K	3 000 K	3 000 K	4 000 K	3 000 K	4 000 K	4 000K		4 000K
Color Rendering Index	90						>90		>90
Operational Lifetime L70	30 000h	40 000h	30 000h	40 000h	30 000h	40 000h	230 mA		230 mA
Current	800 mA	500 mA	1600 mA	2500mA	370mA	570mA	0 - 40°C		0 - 40°C
Operatin Temperature									
Color of Light	White	White	White	White	White	White	White	White	White
Notes									

*11 - (LG-Chem, a)
*12 - (Tridonic, 2015a)
*13 - (Tridonic, 2015e)
*14 - (Tridonic, 2015f)

Company	Tridonic			Kaneka*[18,19]									
Name	Lureon REM 10-30 DL*[15]	Lureon REM 15-30DL*[16]	Lureon REM 29w9-30DL*[17]	White		Blue		Green		Red		Amber	
Shape	Quadratic	Quadratic	Rect-angular	Quadratic		Quadratic		Quadratic		Quadratic		Quadratic	
Size													
Lighting area	75.8x 75,8mm	123x 123mm	262x 74.8mm	50x50 mm	80x80 mm	50x50 mm	80x80 mm	50x50 mm	80x80 mm	50x50 mm	80x80 mm	50x50 mm	80x80 mm
Thickness	2.3 mm	2.5 mm	2.5 mm	0.96mm									
Forward Voltage	8 V			7V	6.2V	6V	6.2V	5.8V	5.5V	5.4V	4.6V	**6V**	**8.8V**
Power Consumption	1.4 W	3.6 W	4.6W	1.8W	4W	1.5W	4W	1.5W	3.5W	1.4W	2.9W	1.5W	3.7W
Luminous Flux	57 lm	138 lm	172lm	11lm	34lm	14lm	35lm	18lm	66lm	6.6lm	27lm	**8.1lm**	**31lm**
Luminance				15000 cd/m²		2000 cd/m²	18000 cd/m²	3200 cd/m²	3700 cd/m²	1000 cd/m²	900 cd/m²	1100 cd/m²	1700 cd/m²
Luminous Efficacy	~40 lm/W			6.3 lm/W	9.1 lm/W	9.3 lm/W	8.8 lm/W	12 lm/W	18 lm/W	4.6 lm/W	9.1 lm/W	**5.4 lm/W**	**8.3 lm/W**
Color Temperature	2 800 K			3 000K									
Color Rendering Index	80			67									
Operational Lifetime L70				10 000h		1000h	5000h	20 000h		4500h	11 000h	**20 000h**	
Current	170 mA	450 mA	580 mA										
Operatin Temperature													
Color of Light	White	White	White	White		Blue		Green		Red		**Amber**	
Notes													

*15 - (Tridonic, 2015b) *17 - (Tridonic, 2015d) *19 - (Kaneka, 2013b)
*16 - (Tridonic, 2015c) *18 - (Kaneka, 2013a)

Table B.2. OLED Panels

C. Idea Generation

C.1. Mind Maps

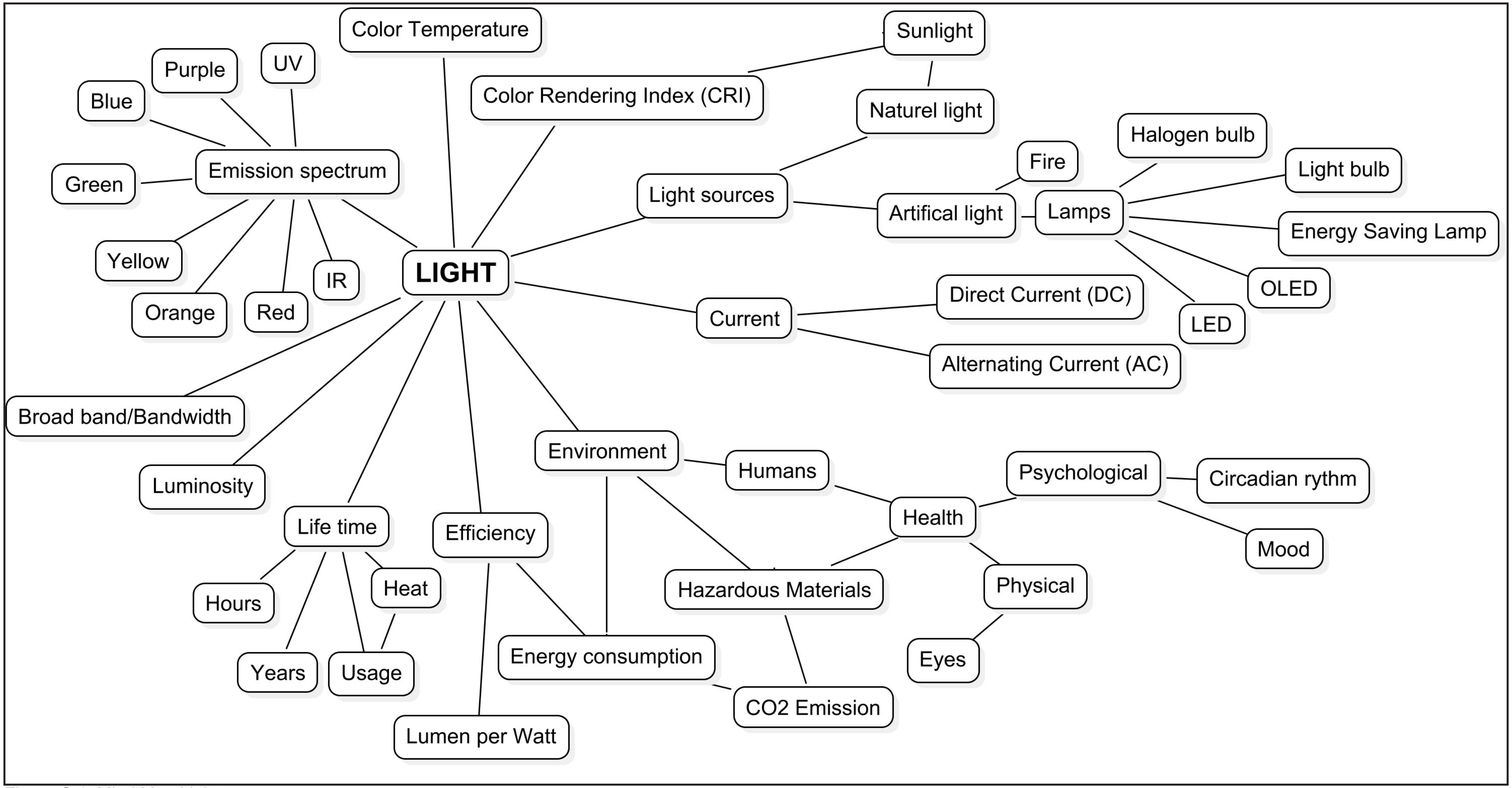


Figure C.1. Mind Map Light

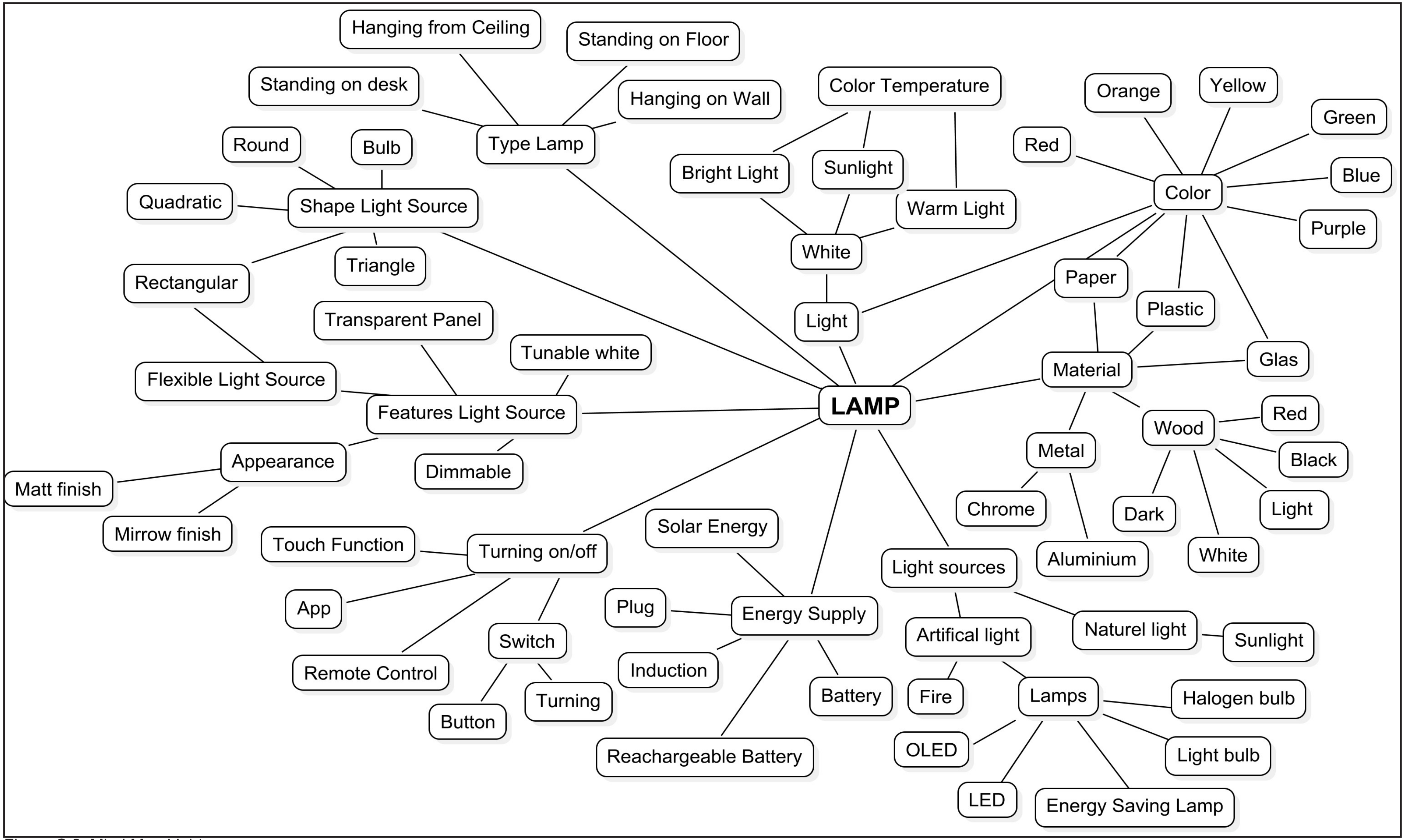


Figure C.2. Mind Map Light

C.2. Light Structures

Figure C.3. Light Structures 1

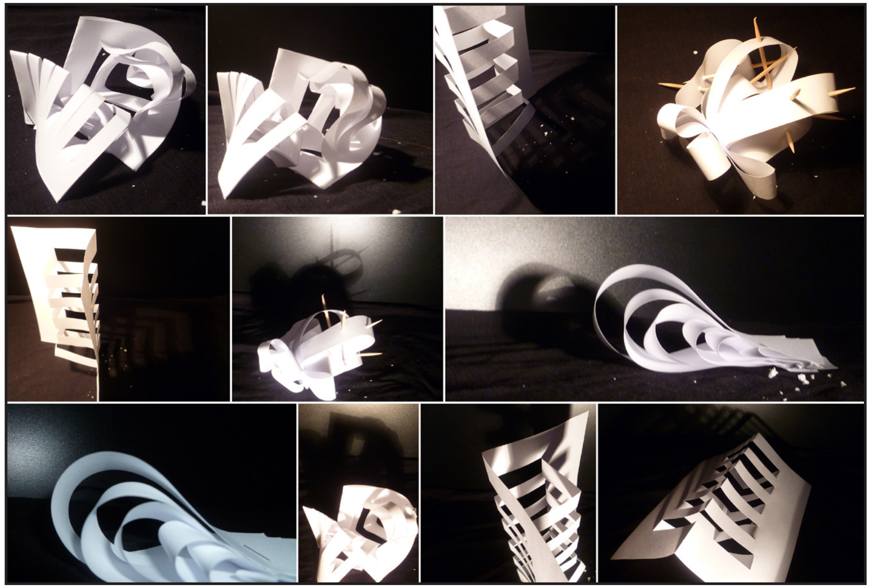


Figure C.5. Light Structures 3

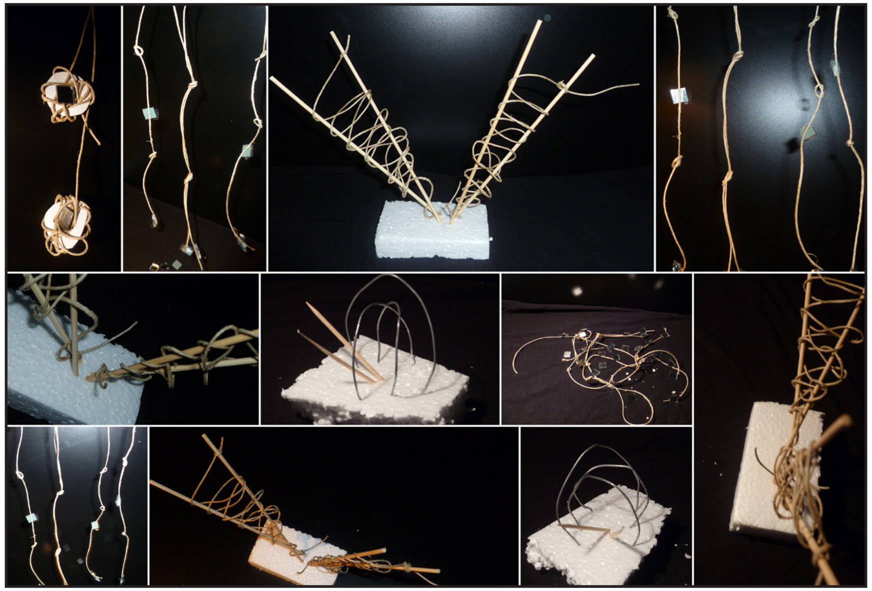


Figure C.4. Light Structures 2

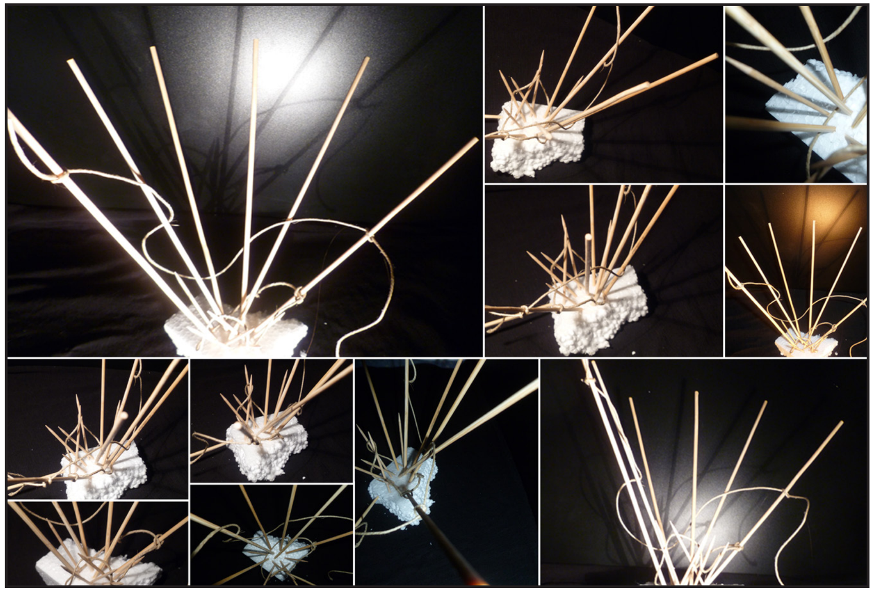


Figure C.6. Light Structures 4

C.3. Sketches

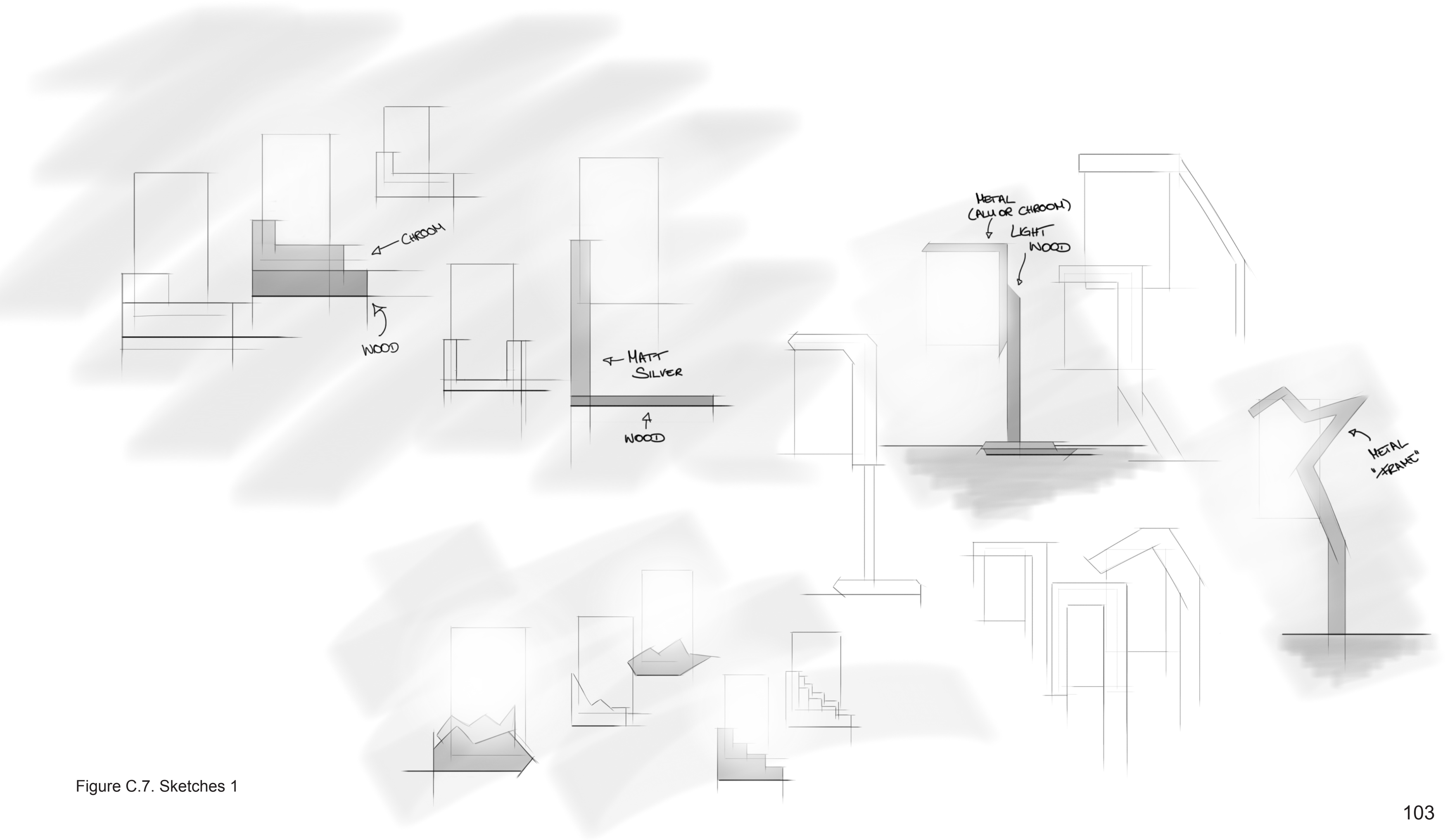


Figure C.7. Sketches 1

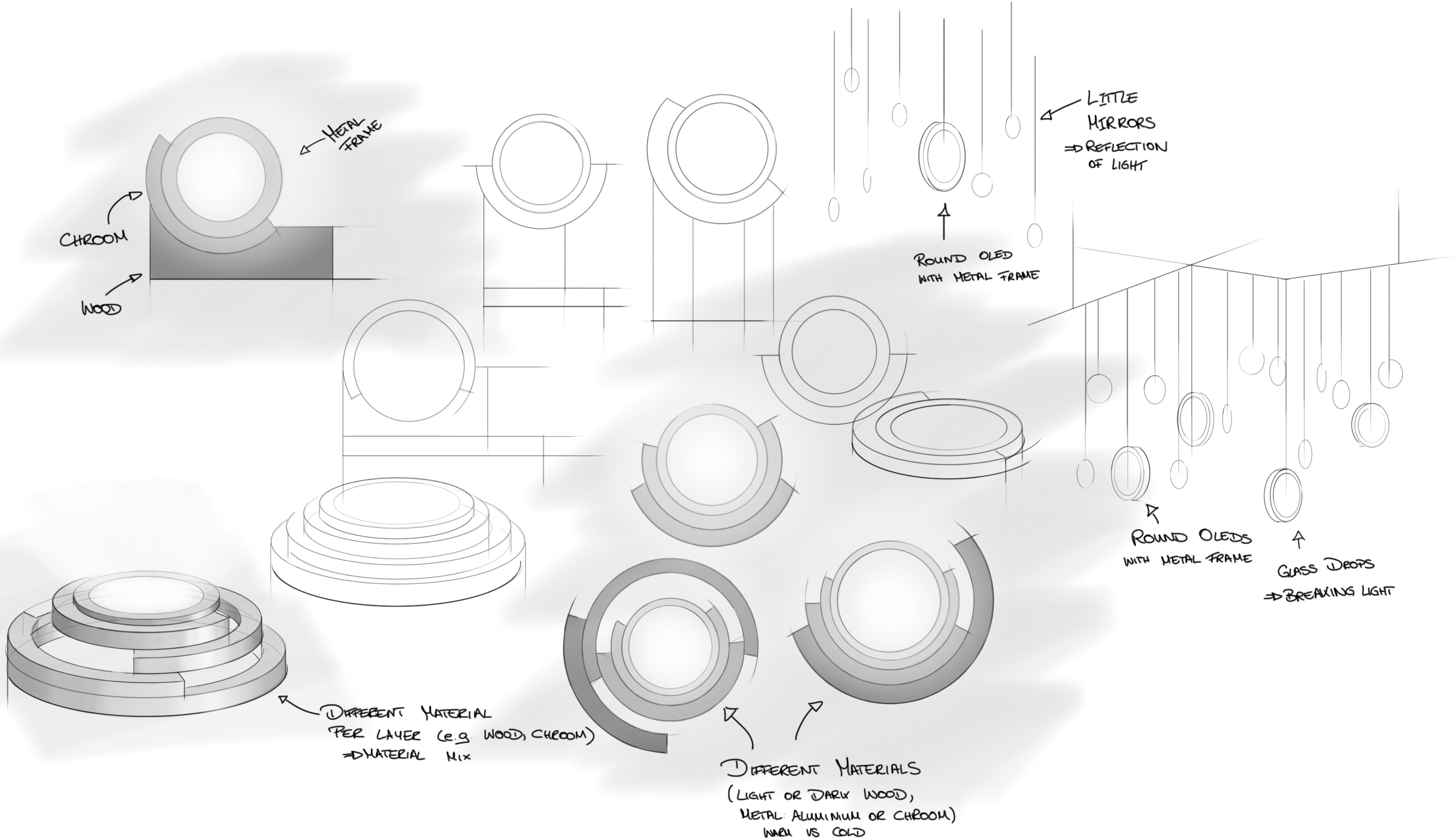


Figure C.8. Sketches 2

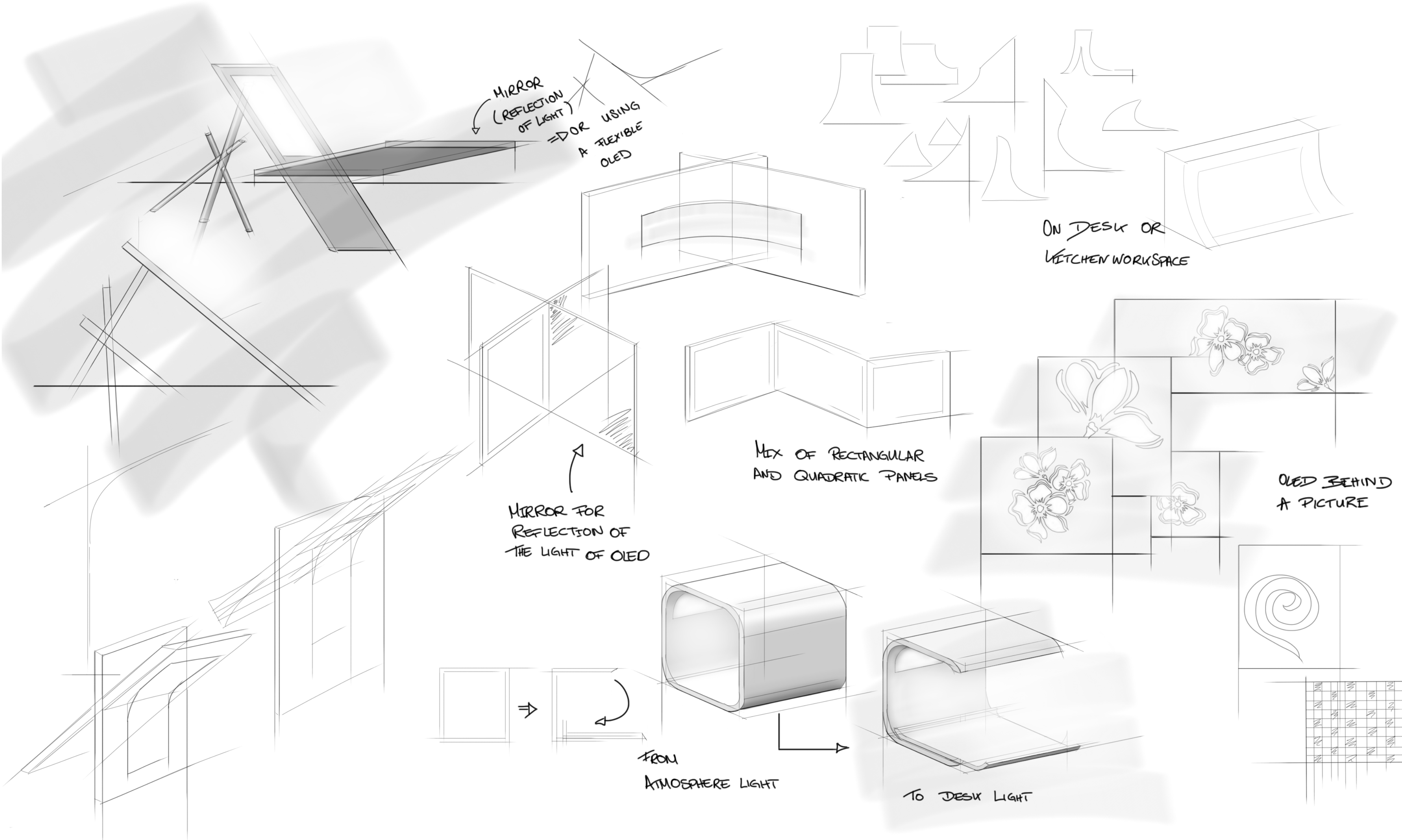


Figure C.9. Sketches 3

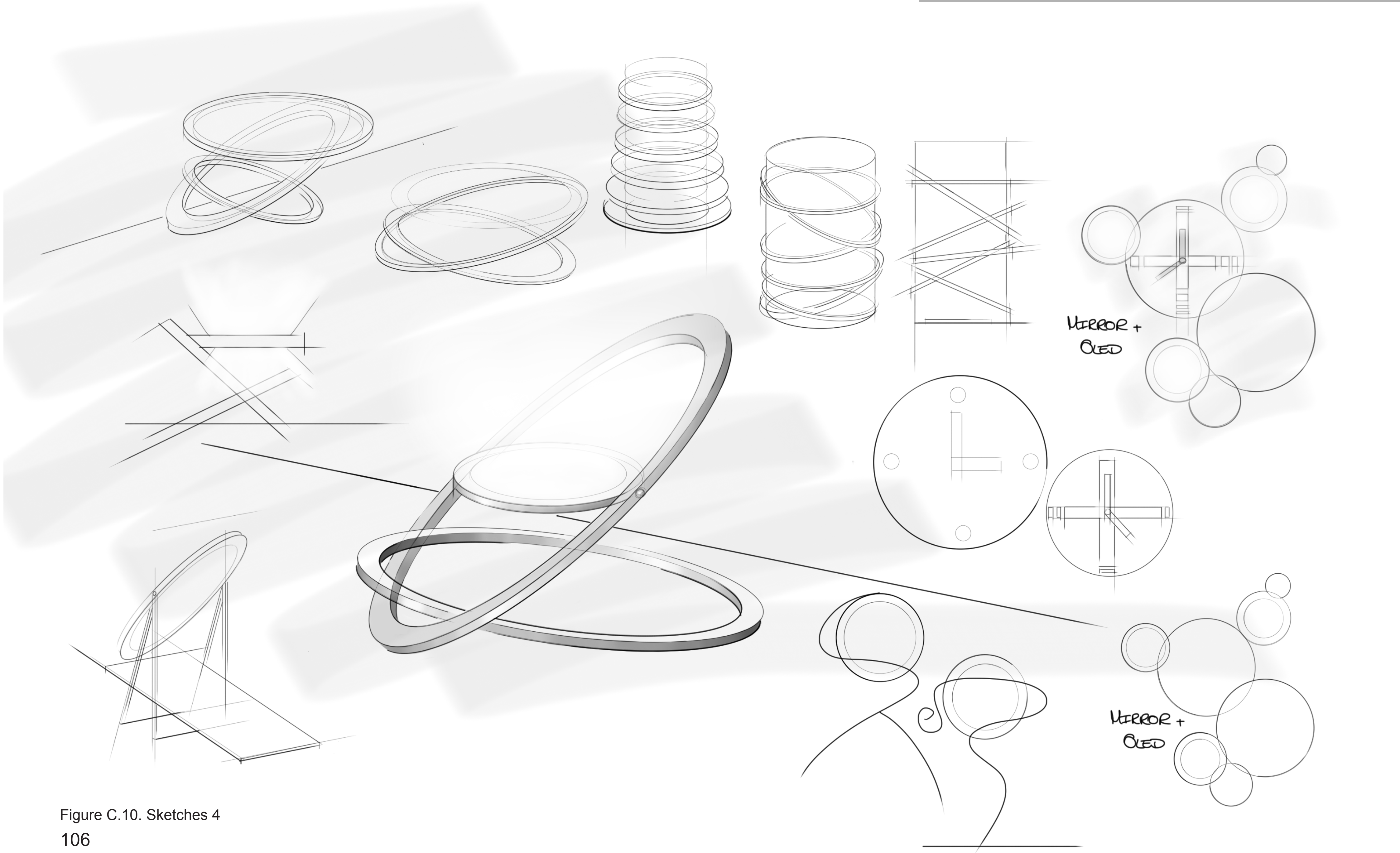


Figure C.10. Sketches 4

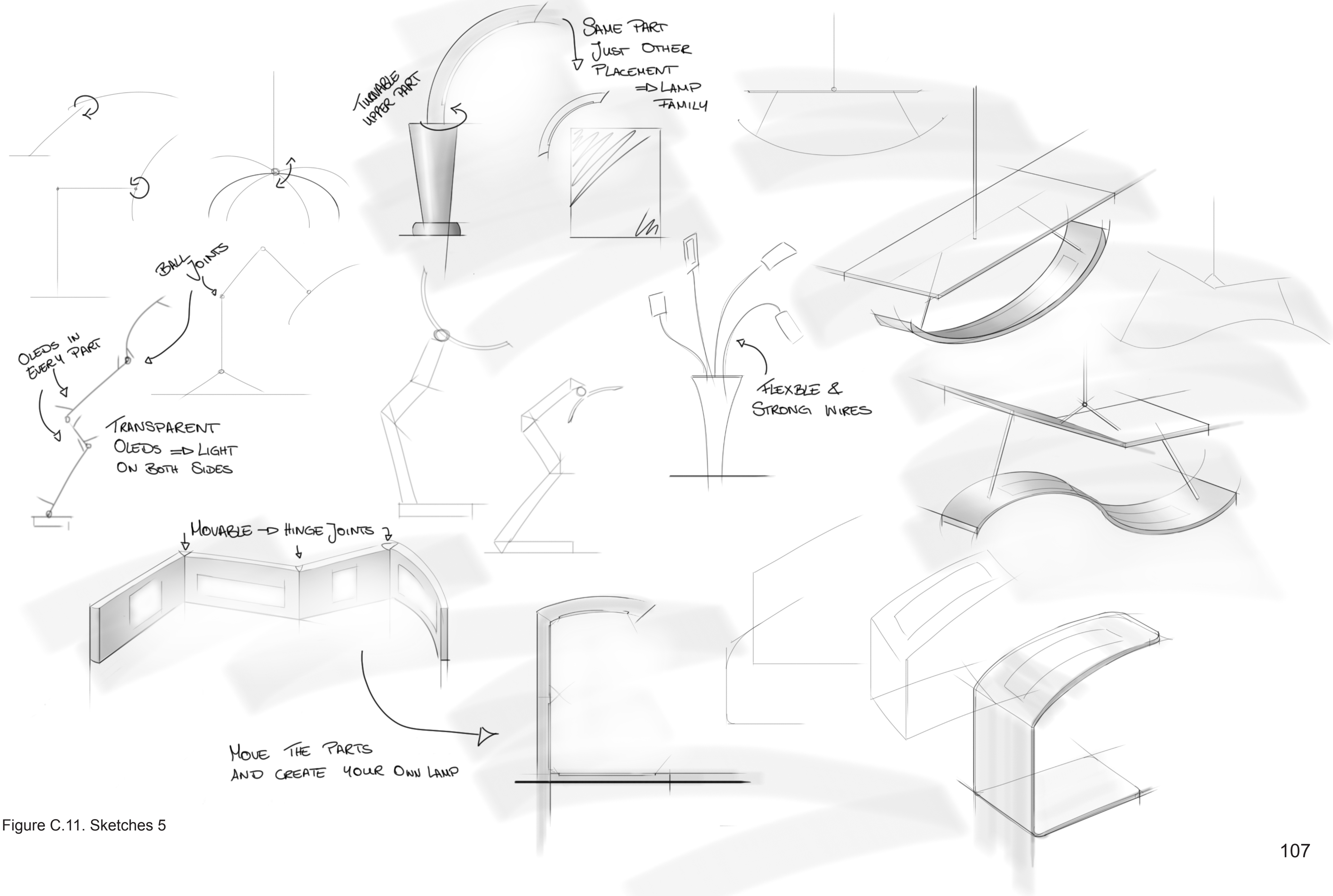


Figure C.11. Sketches 5

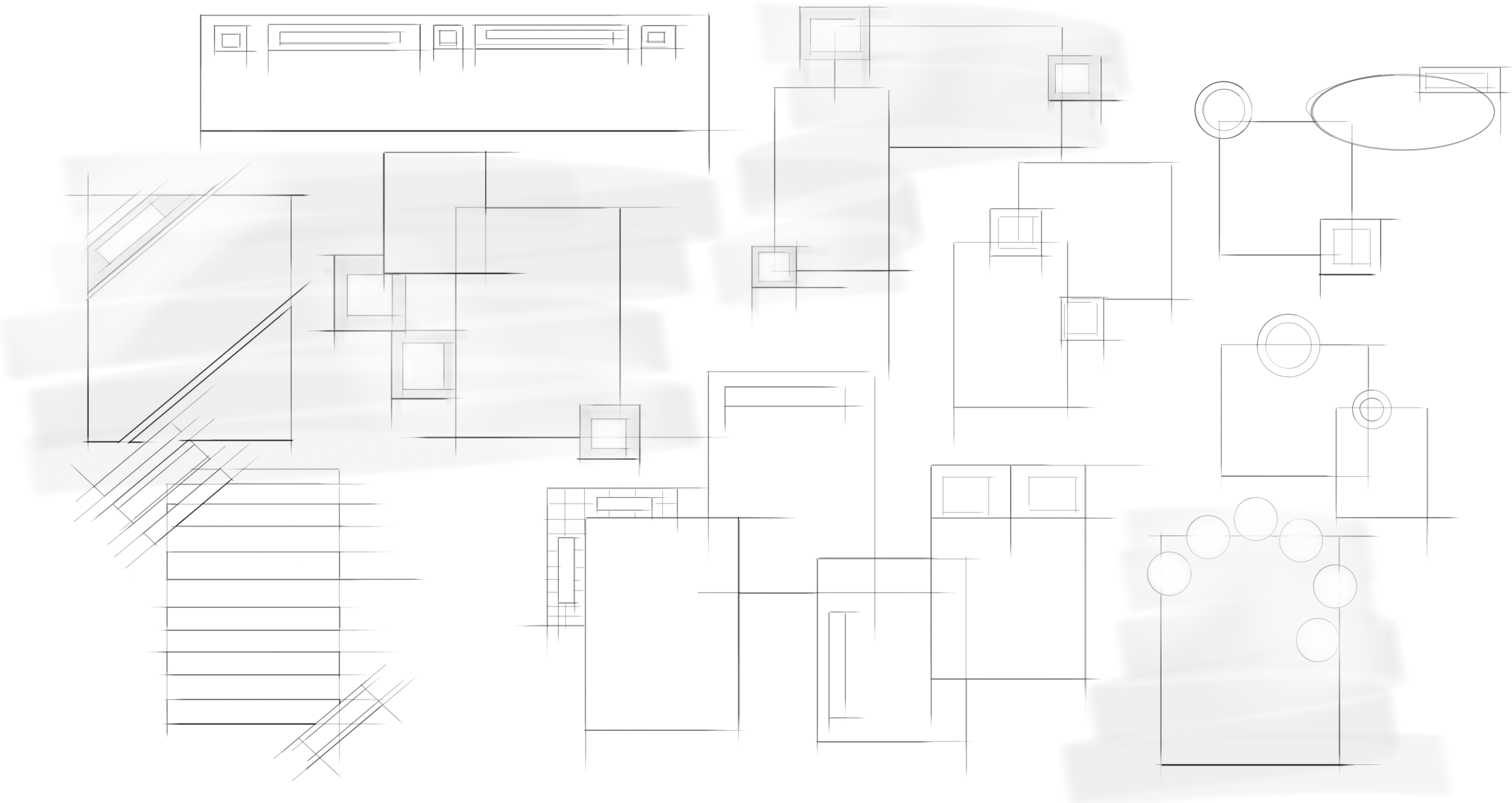


Figure C.12. Sketches 6

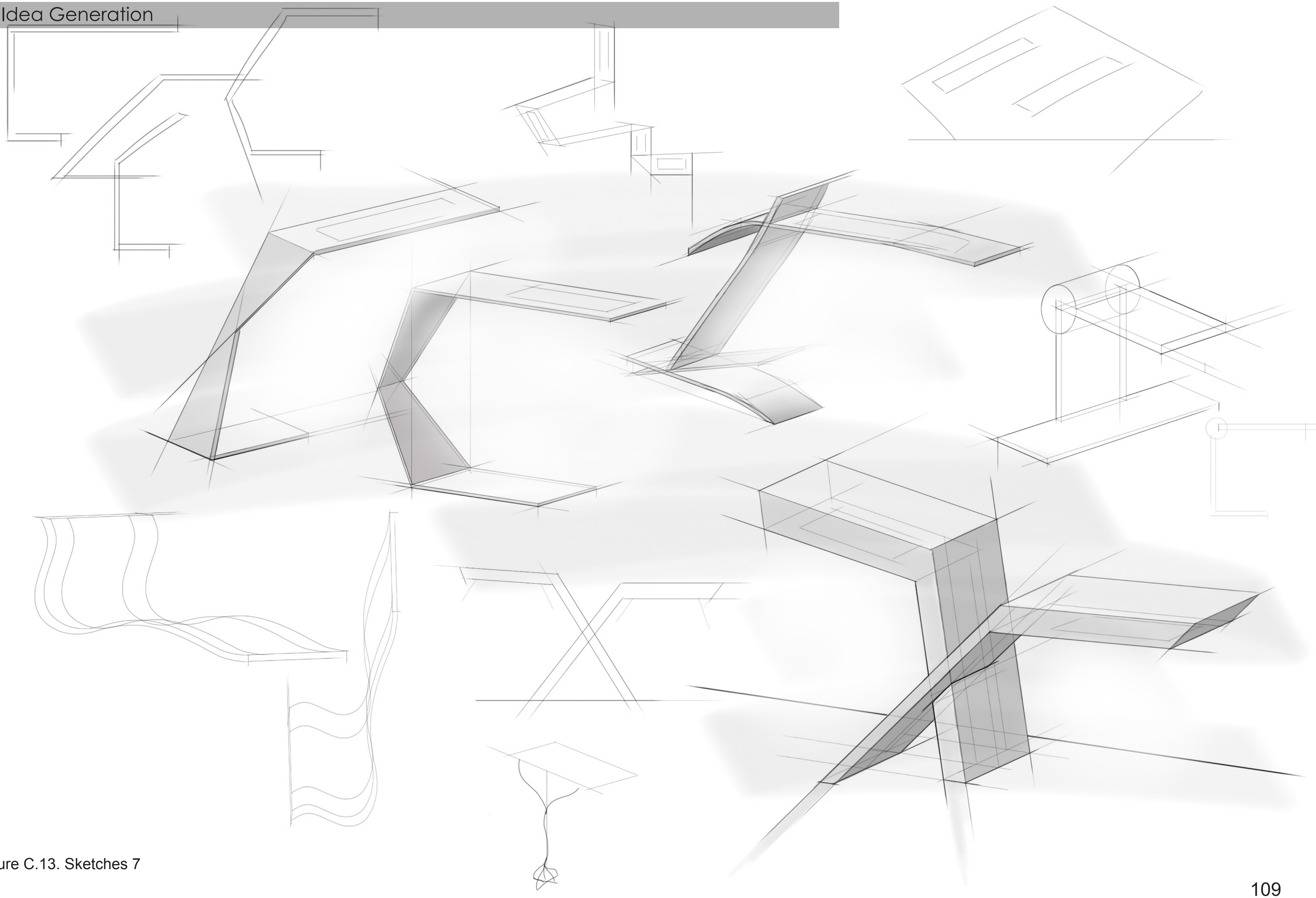


Figure C.13. Sketches 7

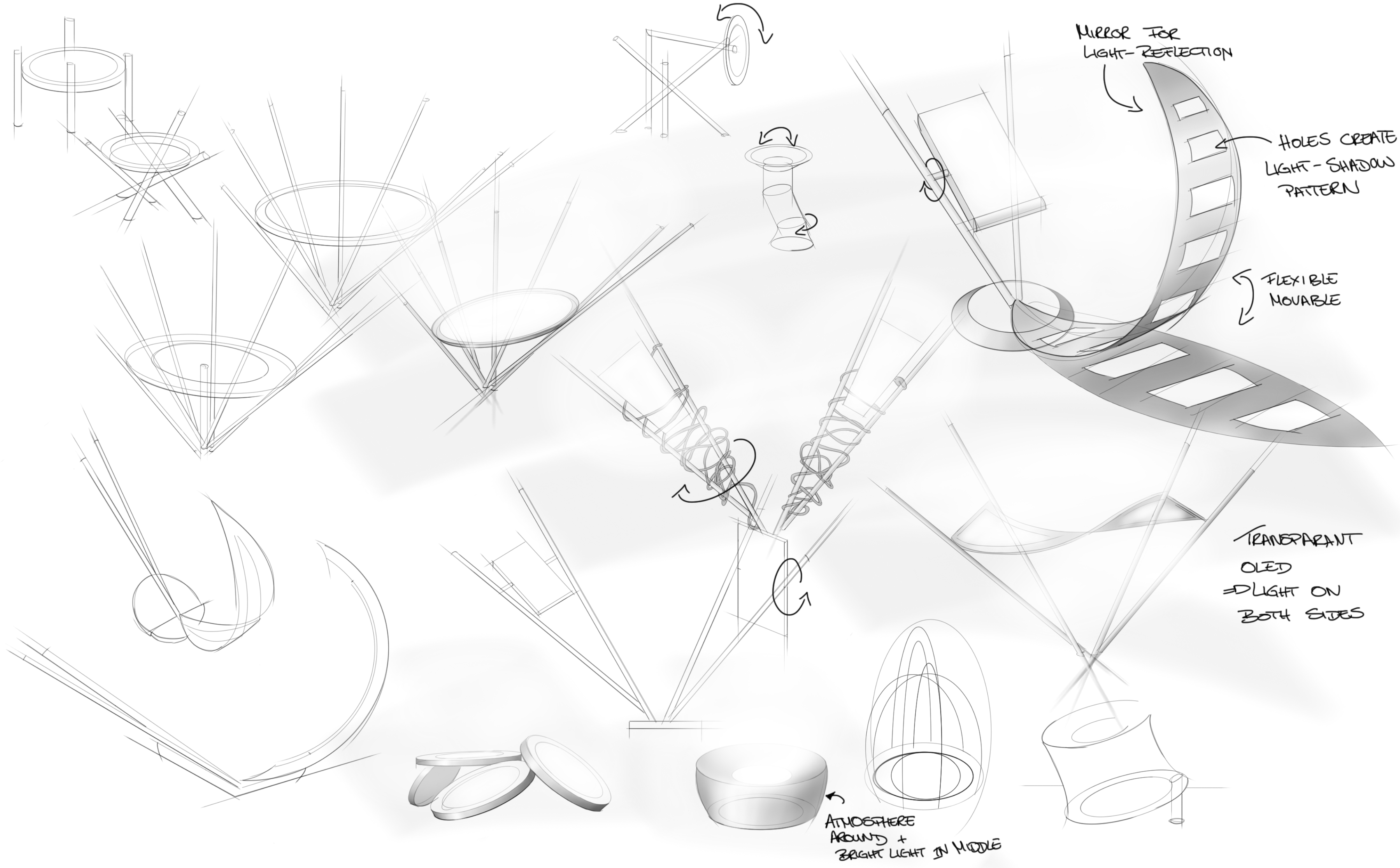


Figure C.14. Sketches 8

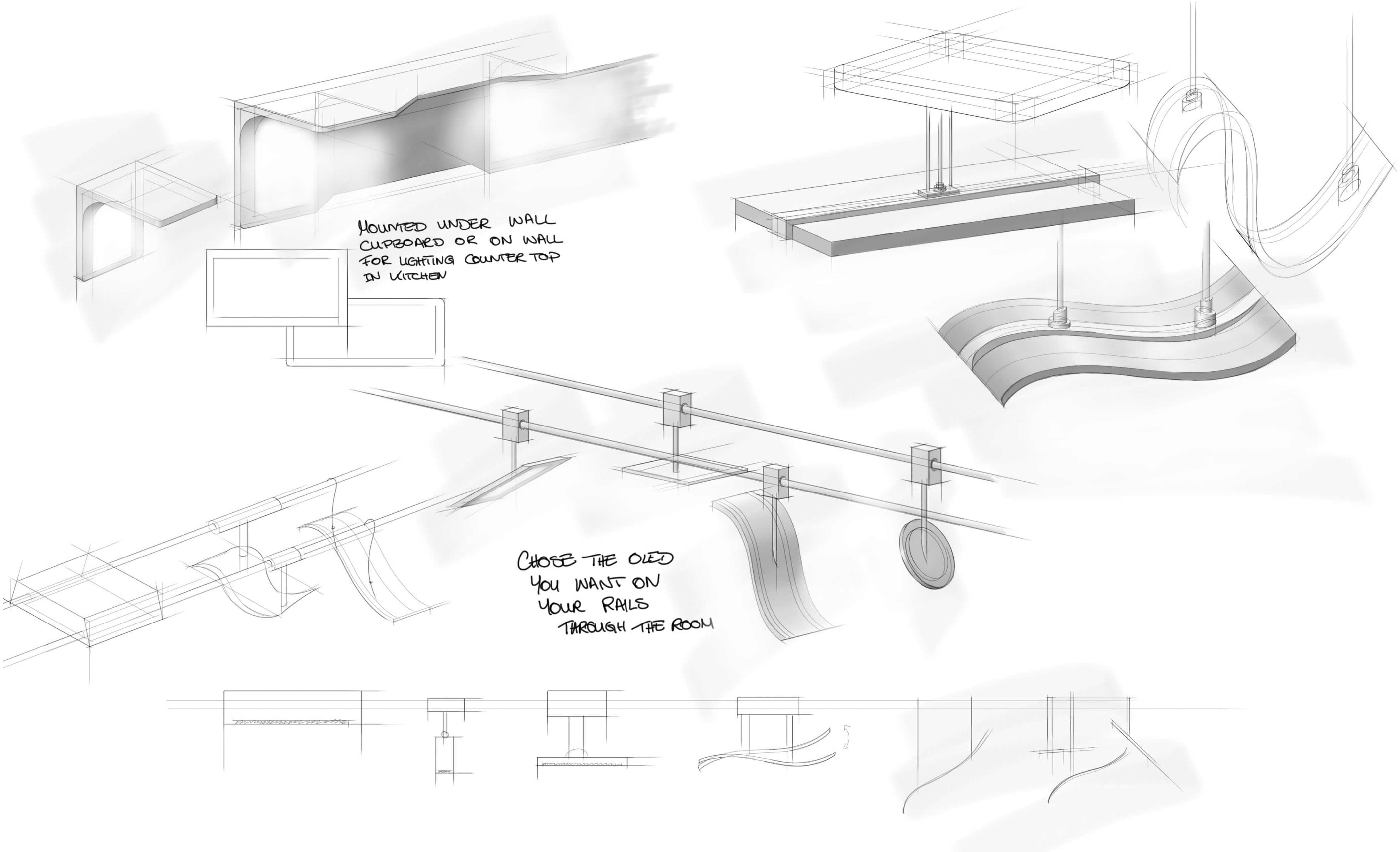


Figure C.15. Sketches 9

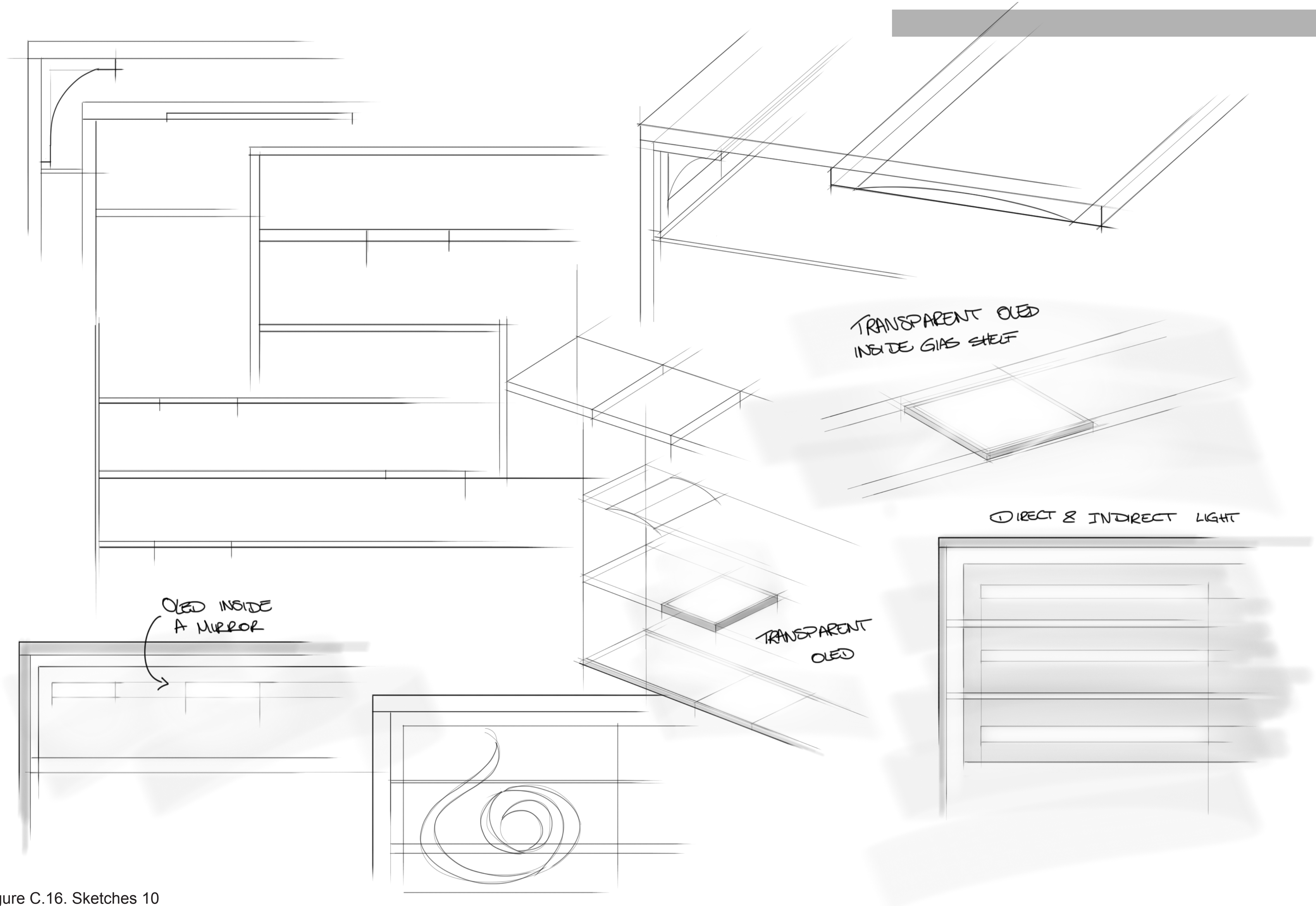


Figure C.16. Sketches 10

C.4. Morphologic schema

TYPE LAMP	Ceiling Lamp	Desk Lamp	Wall Lamp	Floor Lamp	Integrated into Furniture
OLED PANEL	Quadratic	Rectangular	Circle	Triangle	
DIMENSIONS PANEL	< 50 mm	50 - 100mm	101 - 200mm	201-300mm	>300 mm
THICKNESS PANEL	< 1 mm	1 - 2 mm	2 - 3 mm	> 3 mm	
COLOR TEMPERATURE	Warm White < 3300 K	Natural White 3300 - 5300 K	Day Light White > 5500K	All three (Tunable white)	
COLOR LIGHT	White	Blue	Red	Green	Amber
FEATURES	Mirror Finish	Dimmable	Tunable White	Transparent	Flexible
MATERIAL	Metal	Paper	Wood	Glass	Plastic
WAY OF TURNING ON7OFF	Switch	Remote Control	App	Touch Function	Motion Sensor
ENERGY SUPPLY	Plug	Induction	Battery	Rechargeable Battery	Air Charge

- Flexible Corner Light
- Flexible Ceiling Light
- Transparent Shelf Light

Figure C.17. Morphologic schema: Kitchen Concepts

TYPE LAMP	Ceiling Lamp	Desk Lamp	Wall Lamp	Floor Lamp	Integrated into Furniture
OLED PANEL	Quadratic	Rectangular	Circle	Triangle	
DIMENSIONS PANEL	< 50 mm	50 - 100mm	101 - 200mm	201-300mm	>300 mm
THICKNESS PANEL	< 1 mm	1 - 2 mm	2 - 3 mm	> 3 mm	
COLOR TEMPERATURE	Warm White < 3300 K	Natural White 3300 - 5300 K	Day Light White > 5500K	All three (Tunable white)	
COLOR LIGHT	White	Blue	Red	Green	Amber
FEATURES	Mirror Finish	Dimmable	Tunable White	Transparent	Flexible
MATERIAL	Metal	Paper	Wood	Glass	Plastic
WAY OF TURNING ON7OFF	Switch	Remote Control	App	Touch Function	Motion Sensor
ENERGY SUPPLY	Plug	Induction	Battery	Rechargeable Battery	Air Charge

- Flexible Box Light
- Flexible Office Light
- Flexible Sprial Light

Figure C.18. Morphologic schema: Office Concepts

TYPE LAMP	Ceiling Lamp	Desk Lamp	Wall Lamp	Floor Lamp	Integrated into Furniture
OLED PANEL	Quadratic	Rectangular	Circle	Triangle	
DIMENSIONS PANEL	< 50 mm	50 - 100mm	101 - 200mm	201-300mm	>300 mm
THICKNESS PANEL	< 1 mm	1 - 2 mm	2 - 3 mm	> 3 mm	
COLOR TEMPERATURE	Warm White < 3300 K	Natural White 3300 - 5300 K	Day Light White > 5500K	All three (Tunable white)	
COLOR LIGHT	White	Blue	Red	Green	Amber
FEATURES	Mirror Finish	Dimmable	Tunable White	Transparent	Flexible
MATERIAL	Metal	Paper	Wood	Glass	Plastic
WAY OF TURNING ON7OFF	Switch	Remote Control	App	Touch Function	Motion Sensor
ENERGY SUPPLY	Plug	Induction	Battery	Rechargeable Battery	Air Charge

- Mirror Light
- Indirect Bathroom Light
- Bathroom Ceiling Light

Figure C.19. Morphologic schema: Bathroom Concepts

D. Concepts

D.1. Sketches Kitchen Concepts

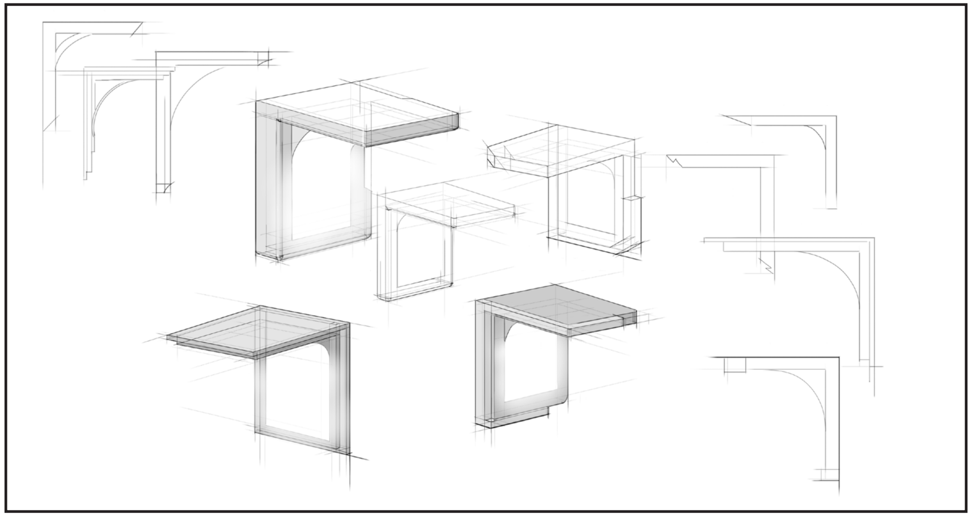


Figure D.1. Sketches Flexible Corner Light

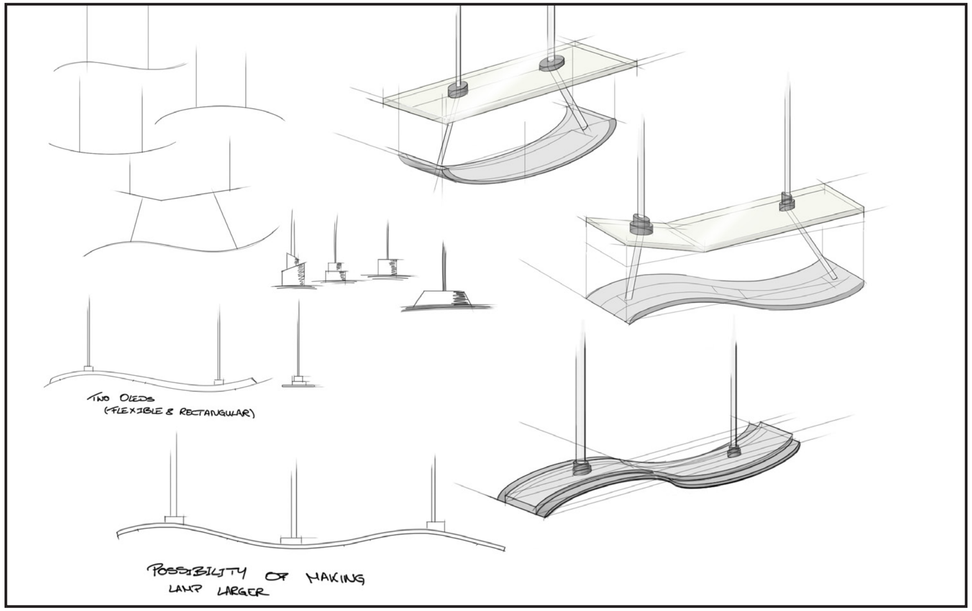


Figure D.2. Sketches Flexible Ceiling Light

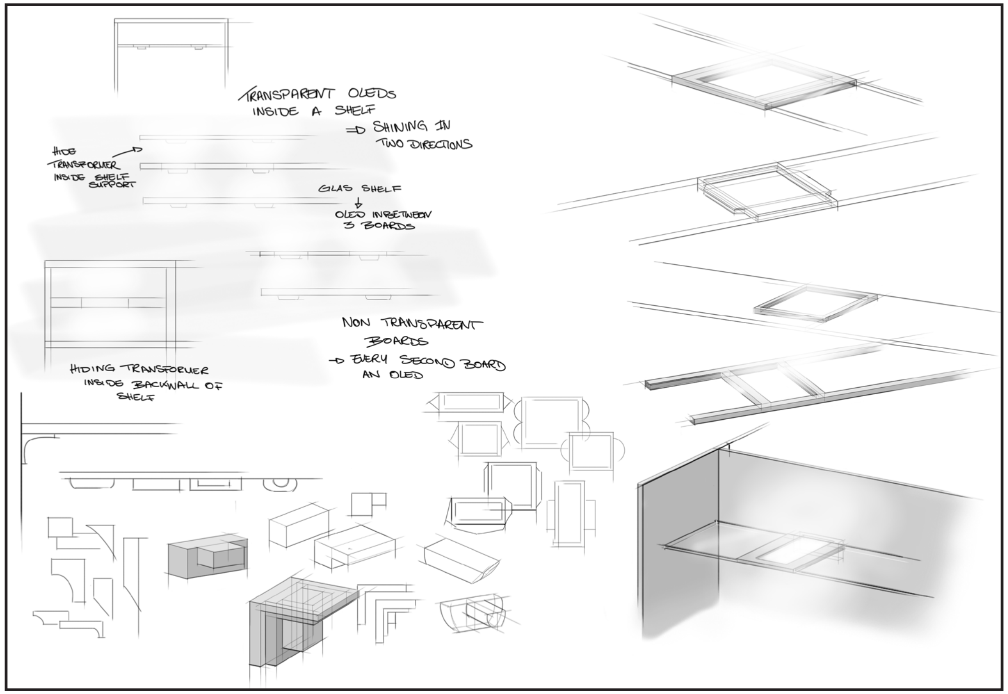


Figure D.3. Sketches Transparent Shelf Light

D.2. Dimensions of the Kitchen Concepts

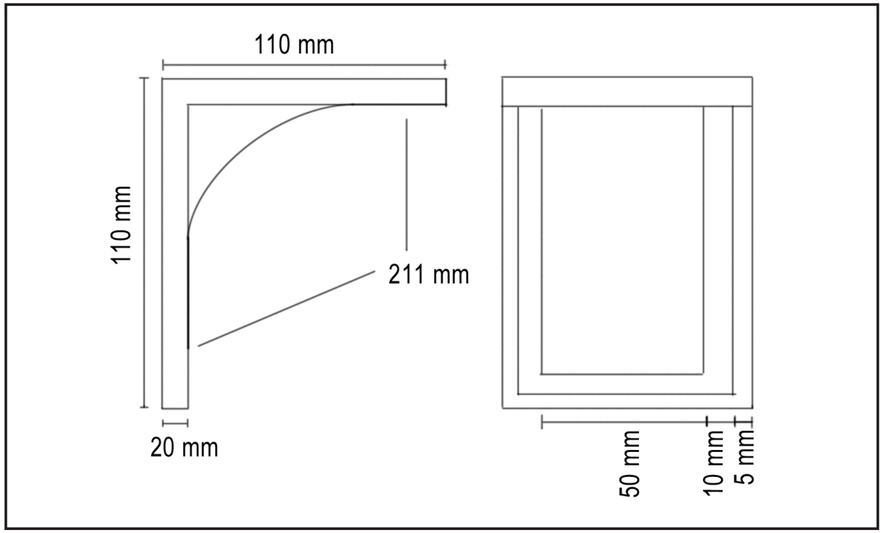


Figure D.4. Dimensions Flexible Corner Light

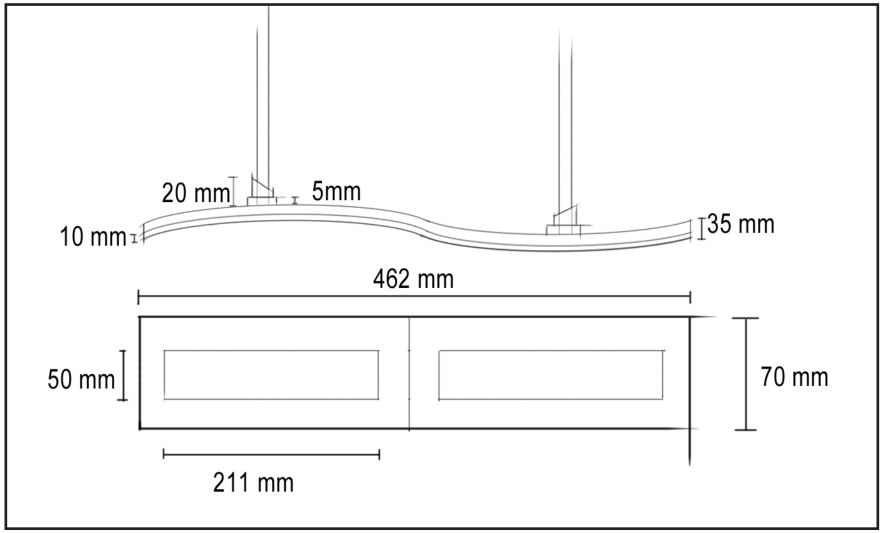


Figure D.5. Dimensions Flexible Ceiling Light

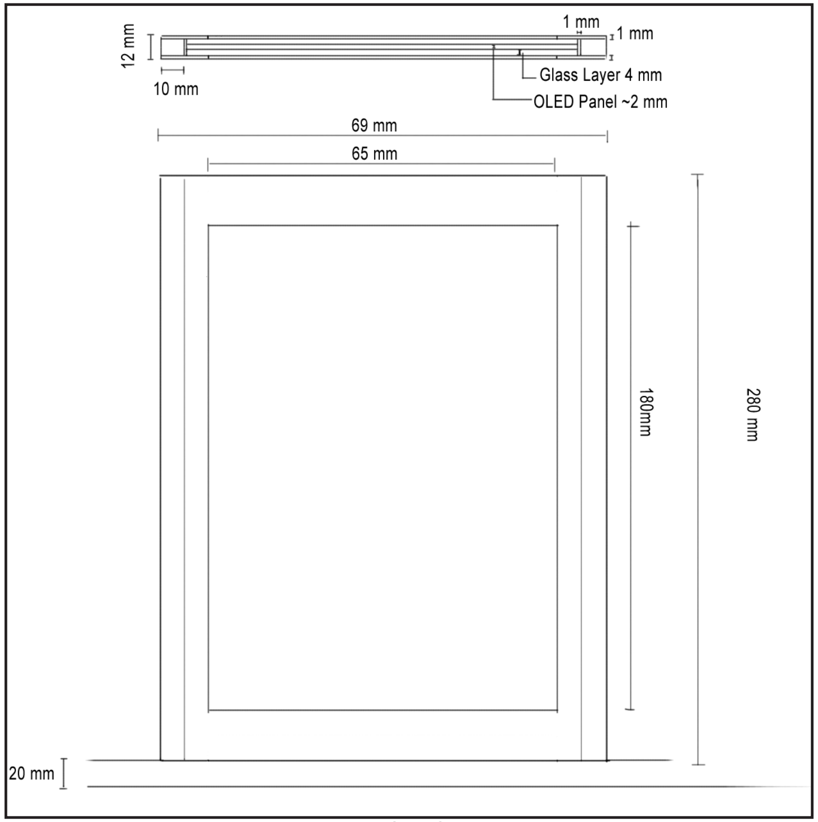


Figure D.6. Dimension Transparent Shelf Light

D.3. Sketches Office Concepts

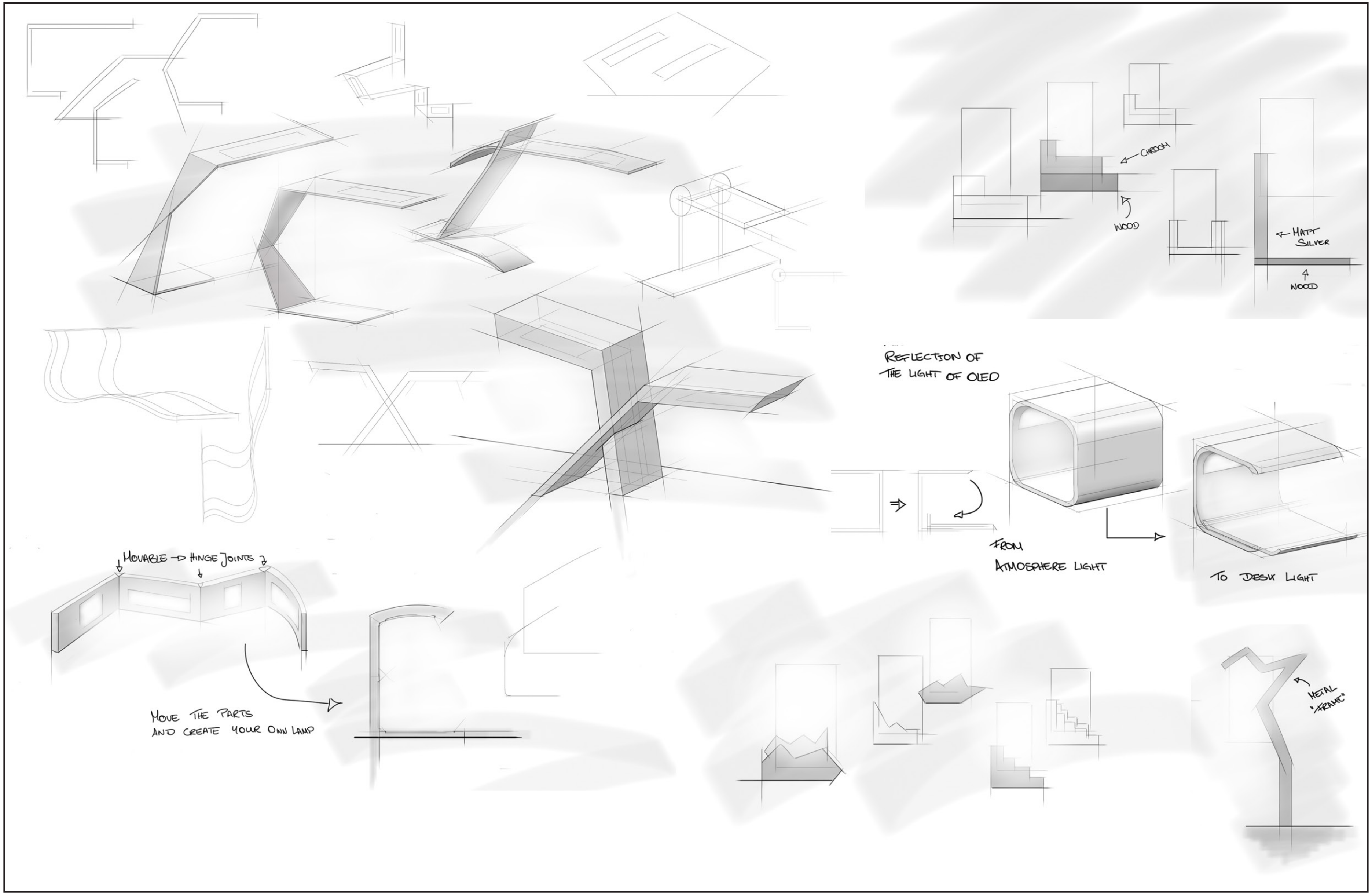


Figure D.7. Sketches Office Lamps

D.4. Dimensions of the Office Concepts

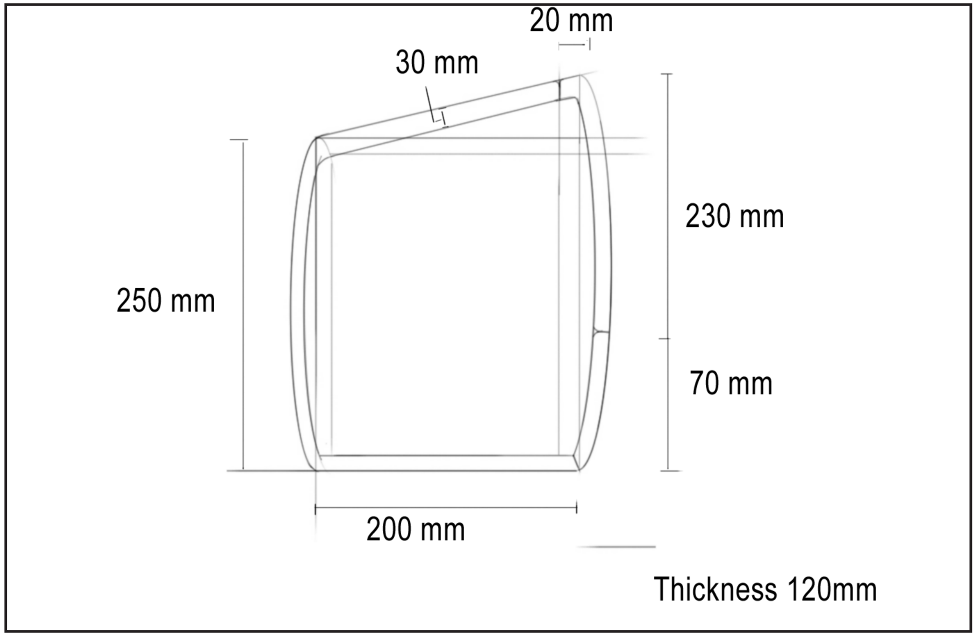


Figure D.8. Dimensions Flexible Box Light

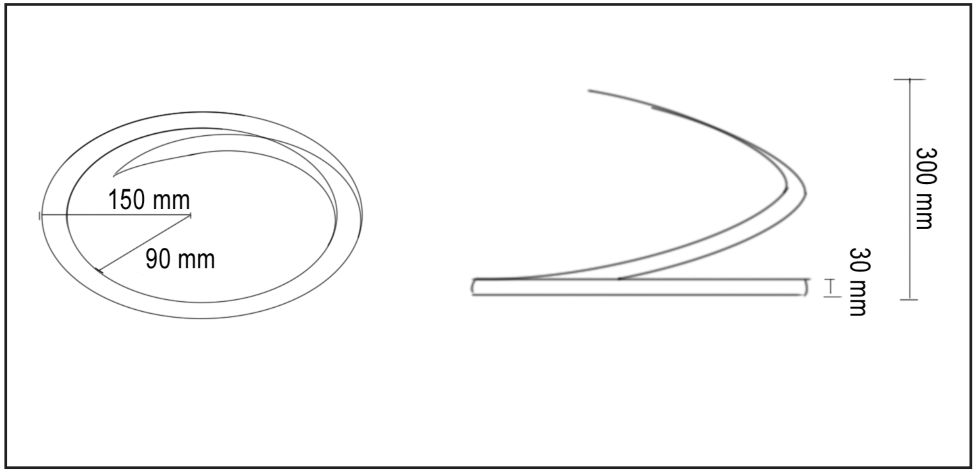


Figure D.9. Dimensions Flexible Spiral Light

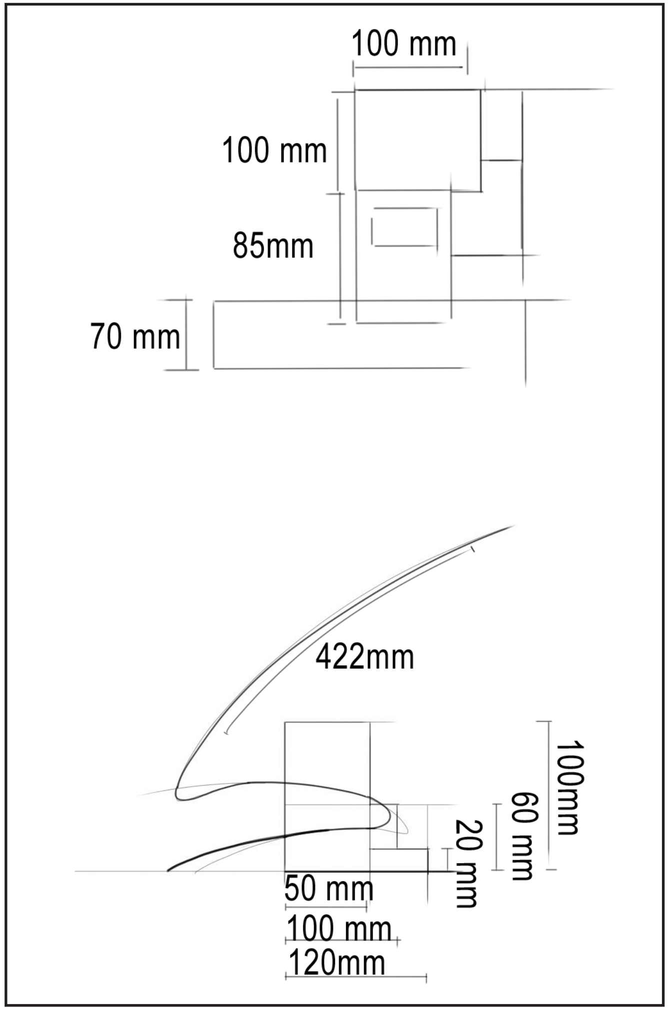


Figure D.10. Dimension Flexible Office Light

D.5. Sketches Bathroom Concepts

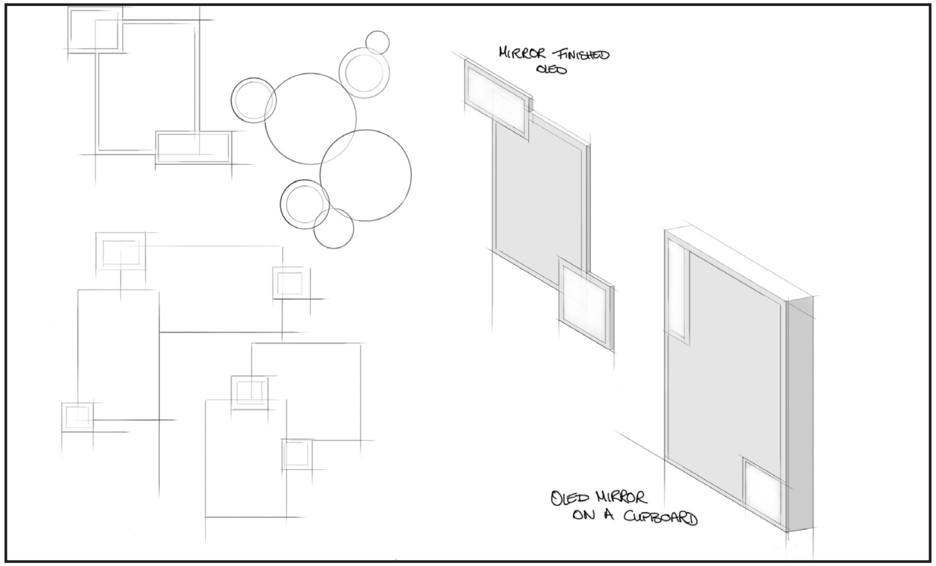


Figure D.11. Sketches Movable Mirror Light

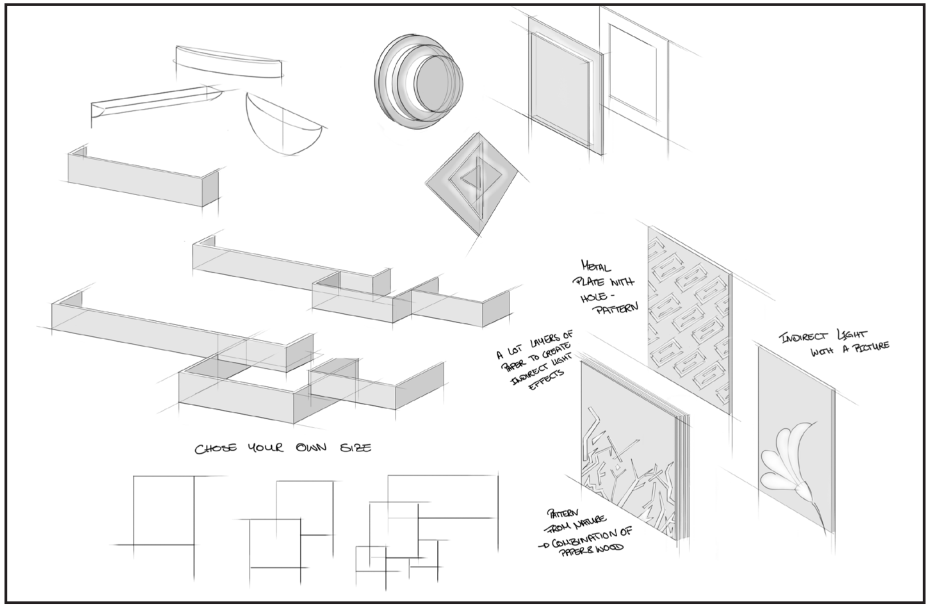


Figure D.12. Sketches Indirect Bathroom Light

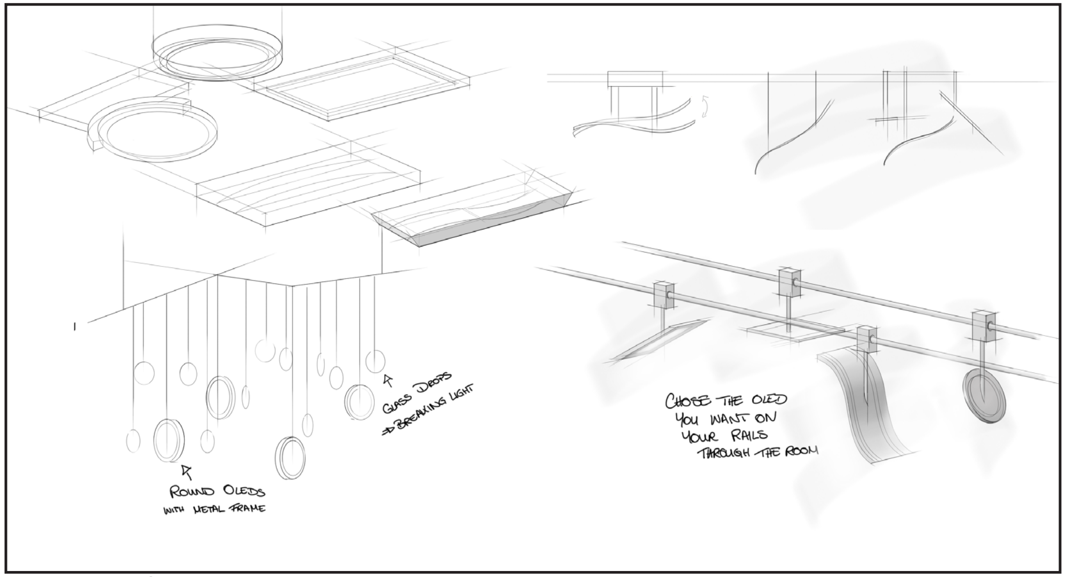


Figure D.13. Sketches Flexible Bathroom Light

D.6. Dimensions of the Bathroom concepts

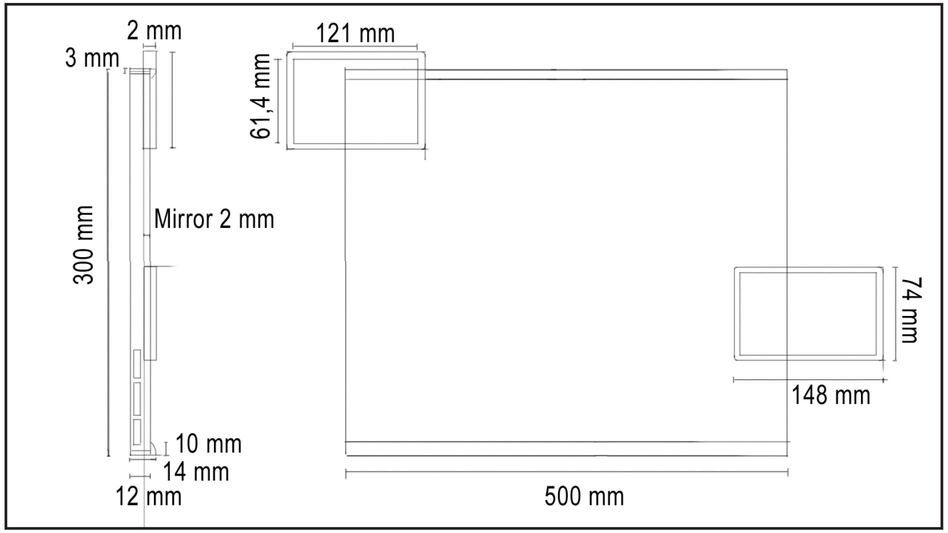


Figure D.14. Dimensions Movable Mirror Light

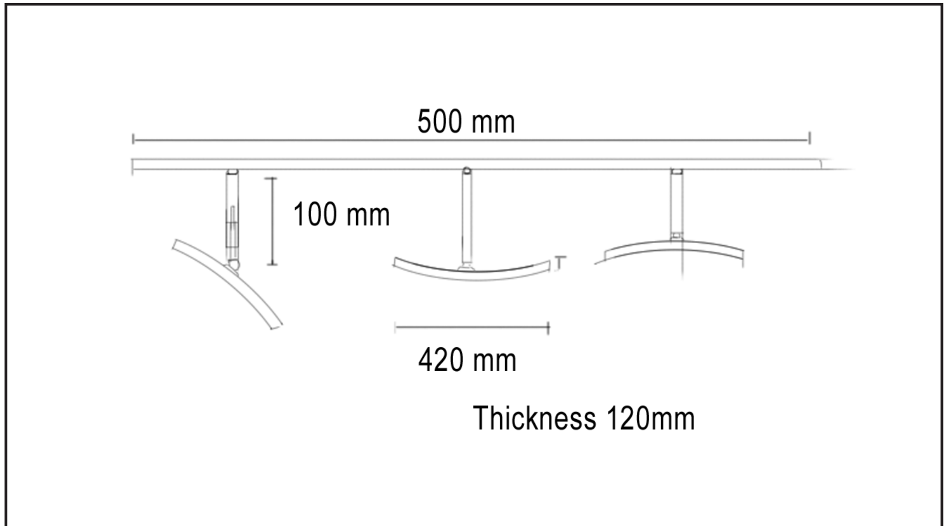


Figure D.15. Dimensions Flexible Bathroom Light

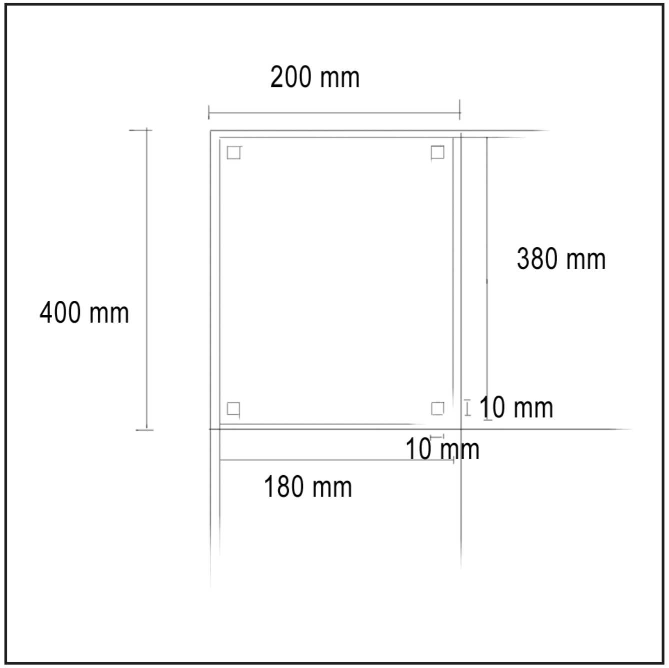


Figure D.16. Dimension Indrect Bathroom Light

E. Design Completion

E.1. Design Guide Graphics

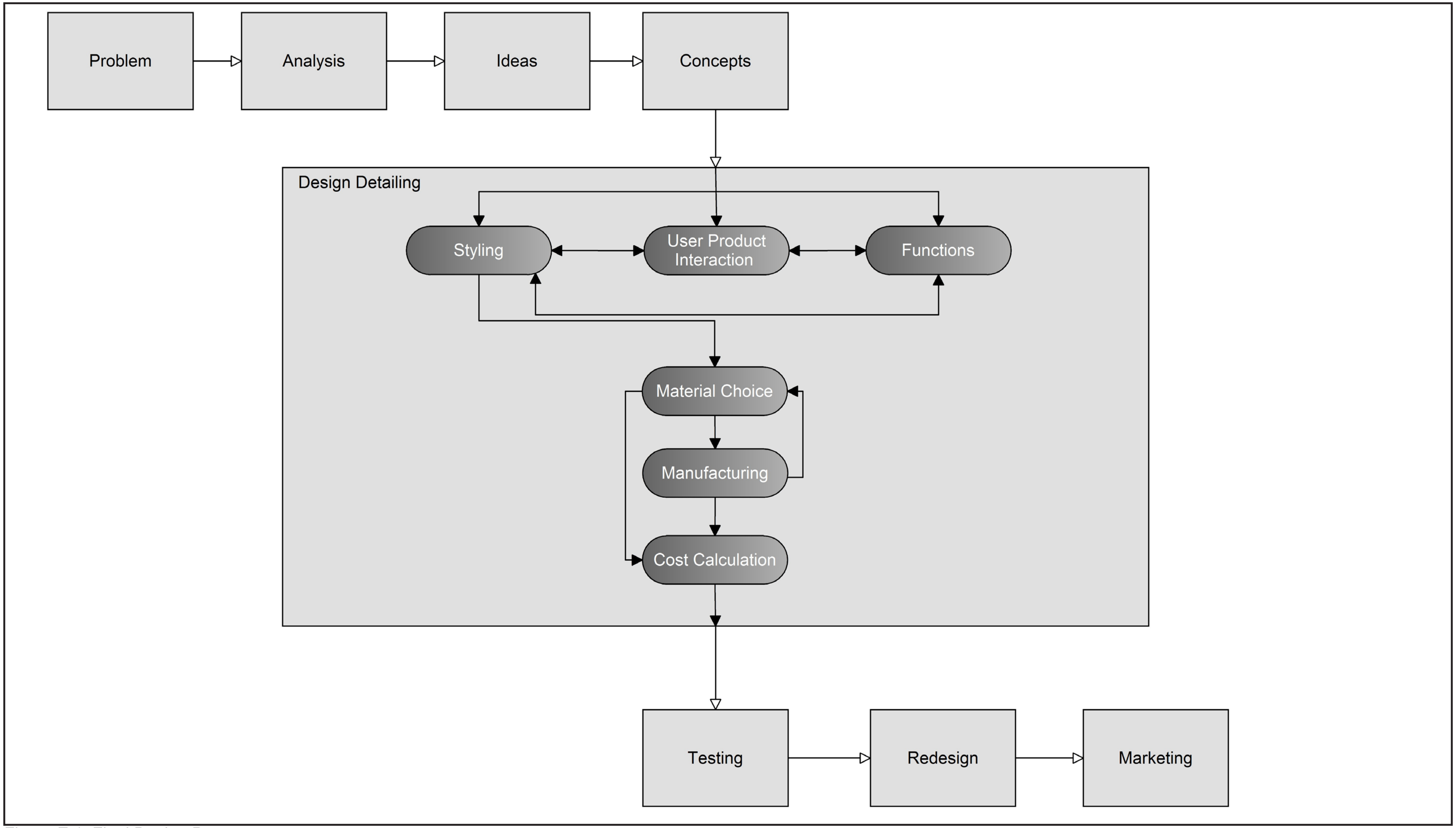


Figure E.1. Final Design Process

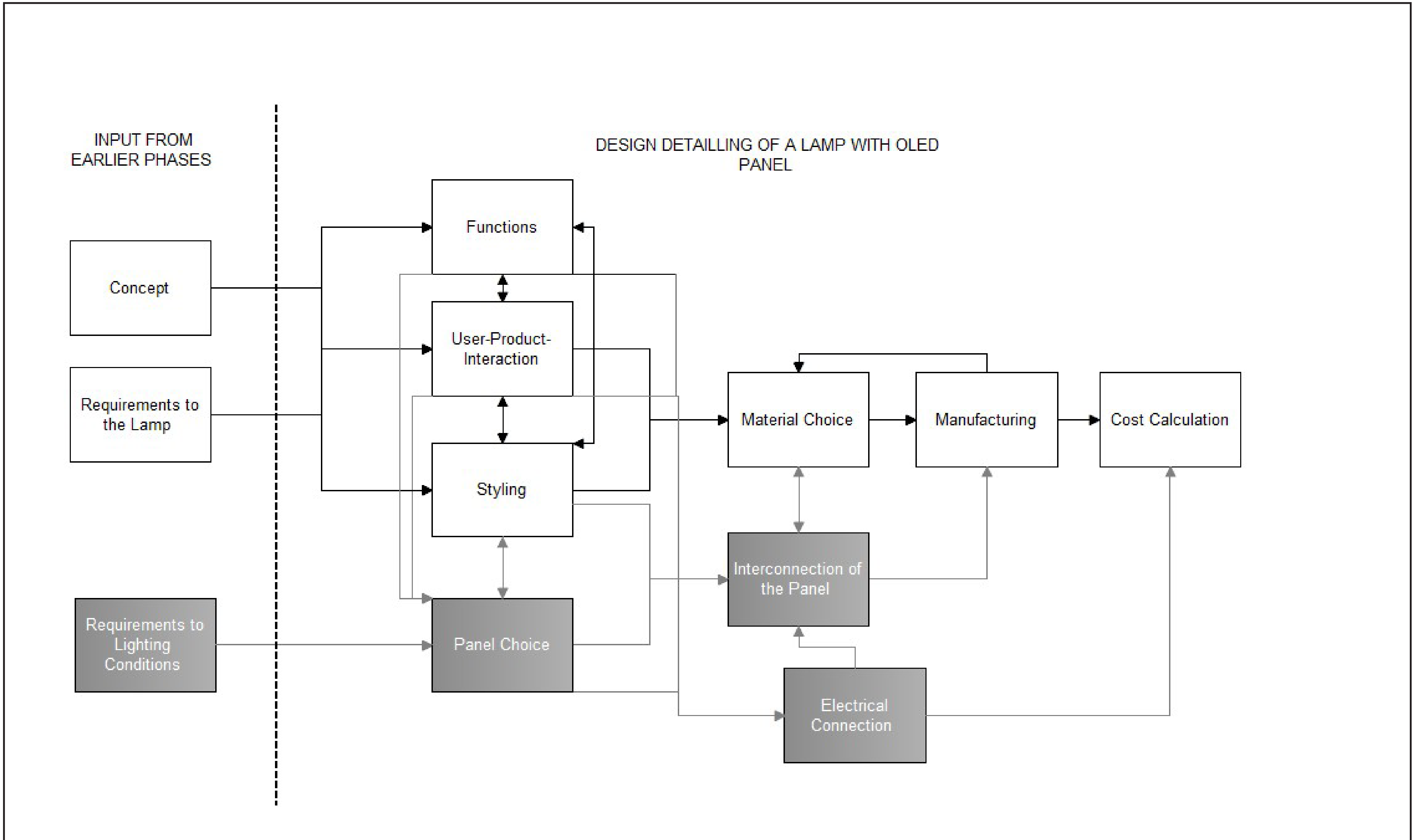


Figure E.2. Final Design Process plus OLED

E.2. The Parts of the Upper Lamp

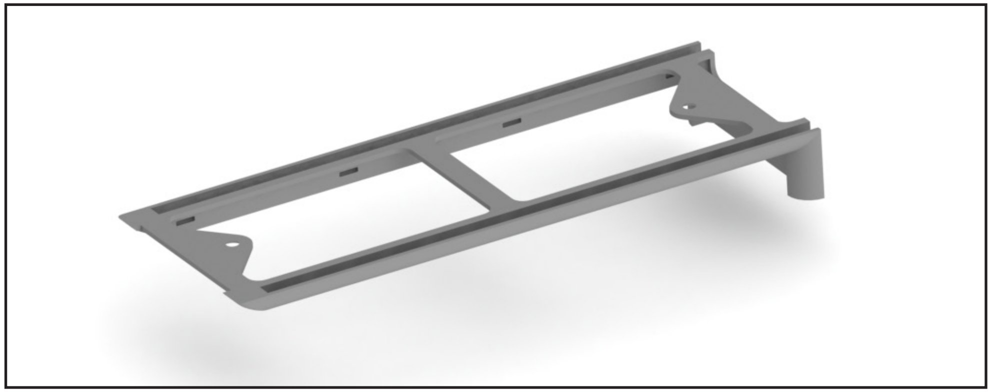


Figure E.3. Back Element of the Upper Lamp

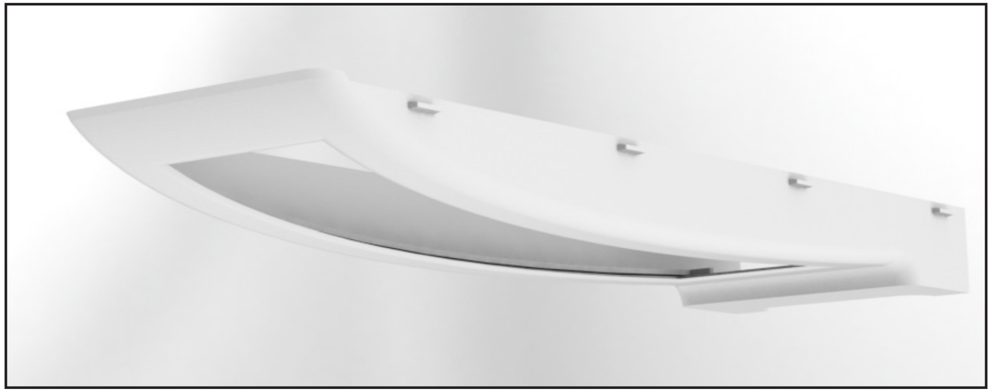


Figure E.4. Casing of the Upper Lamp

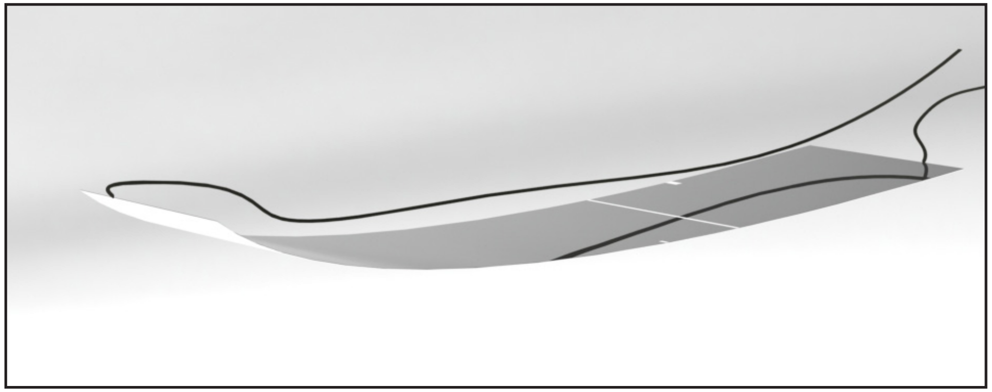


Figure E.5. OLED Panel of the Upper Lamp

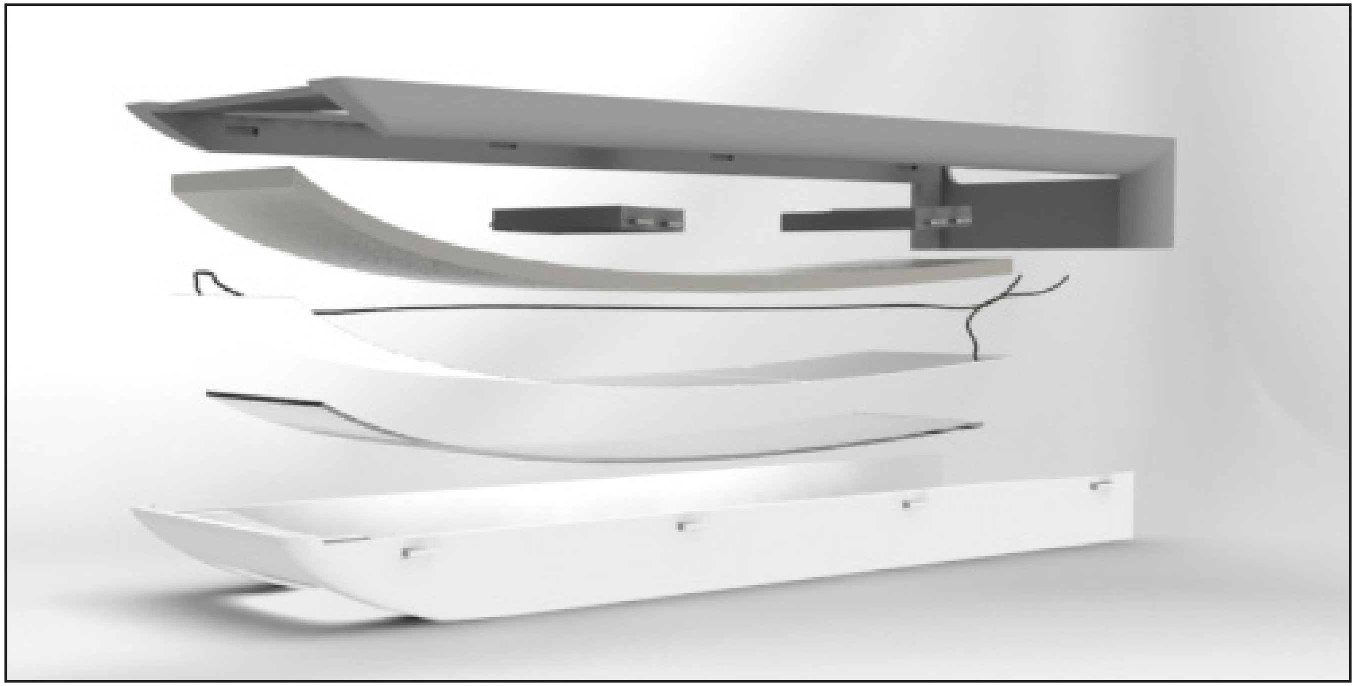


Figure E.6. Exploded View of the Upper Lamp

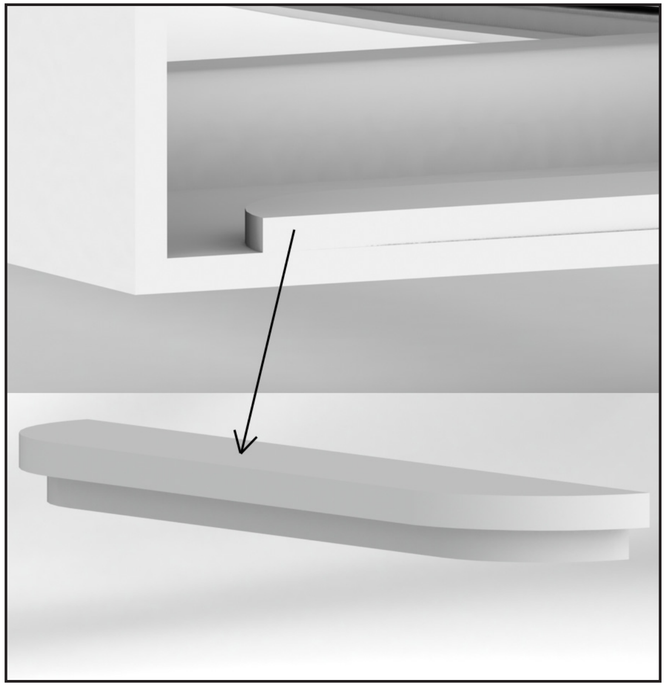
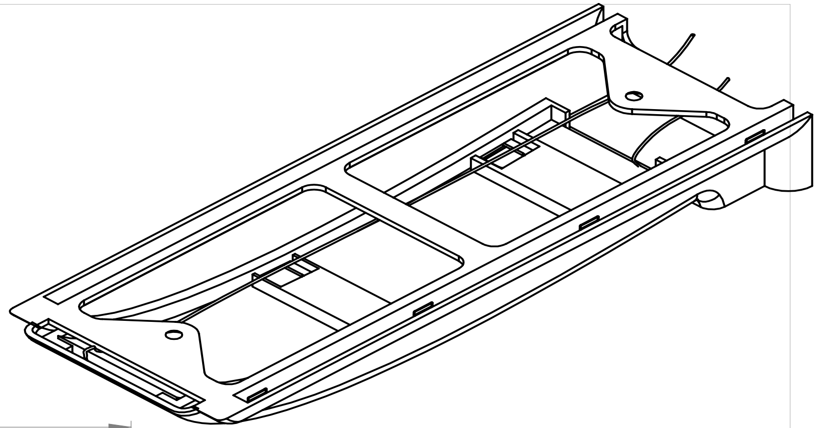
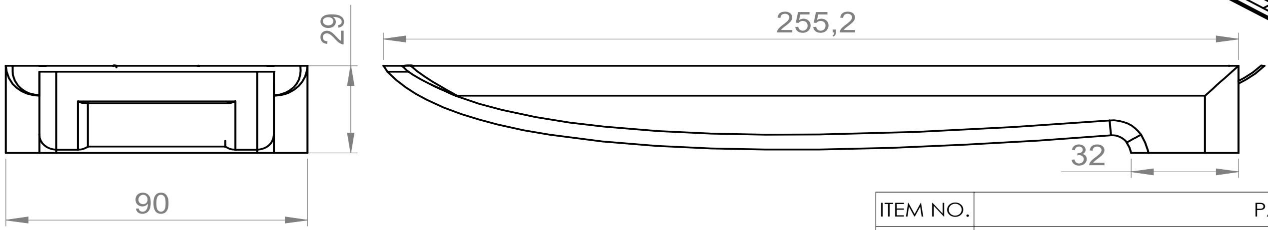


Figure E.7. Possible Cap

E.3. Technical Drawings of the Upper Lamp





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
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2	Casing_UpperLamp^UpperLamp_Final		1
3	UpperOLED^UpperLamp_Final		1
4	ProtectionLayer^UpperLamp_Final		1
5	Foam^UpperLamp_Final		1
6	ClickConntect^UpperLamp_Final		2

PROJECTION METHOD	UNLESS STATED OTHERWISE: TOLERANCES ± 0,5 MM	DRAWN	C. Spreen	DATE	10.06.2015
		CHECKED	--	SCALE	1:2
UNIVERSITEIT TWENTE.	MATERIAL --	TITLE Upper Lamp		REV. 01	
	SURFACE FINISH --	DRAWING NO. 01		A4	
		FILE / PART NAME UpperLamp_Final			
FACULTY OF ENGINEERING	DIMENSIONS IN MILLIMETERS			SHEET 1 OF 1	

Figure E.10. Technical Drawing of the Upper Lamp

E.4. Morphologic Schema: Interconnection of the OLED Panel

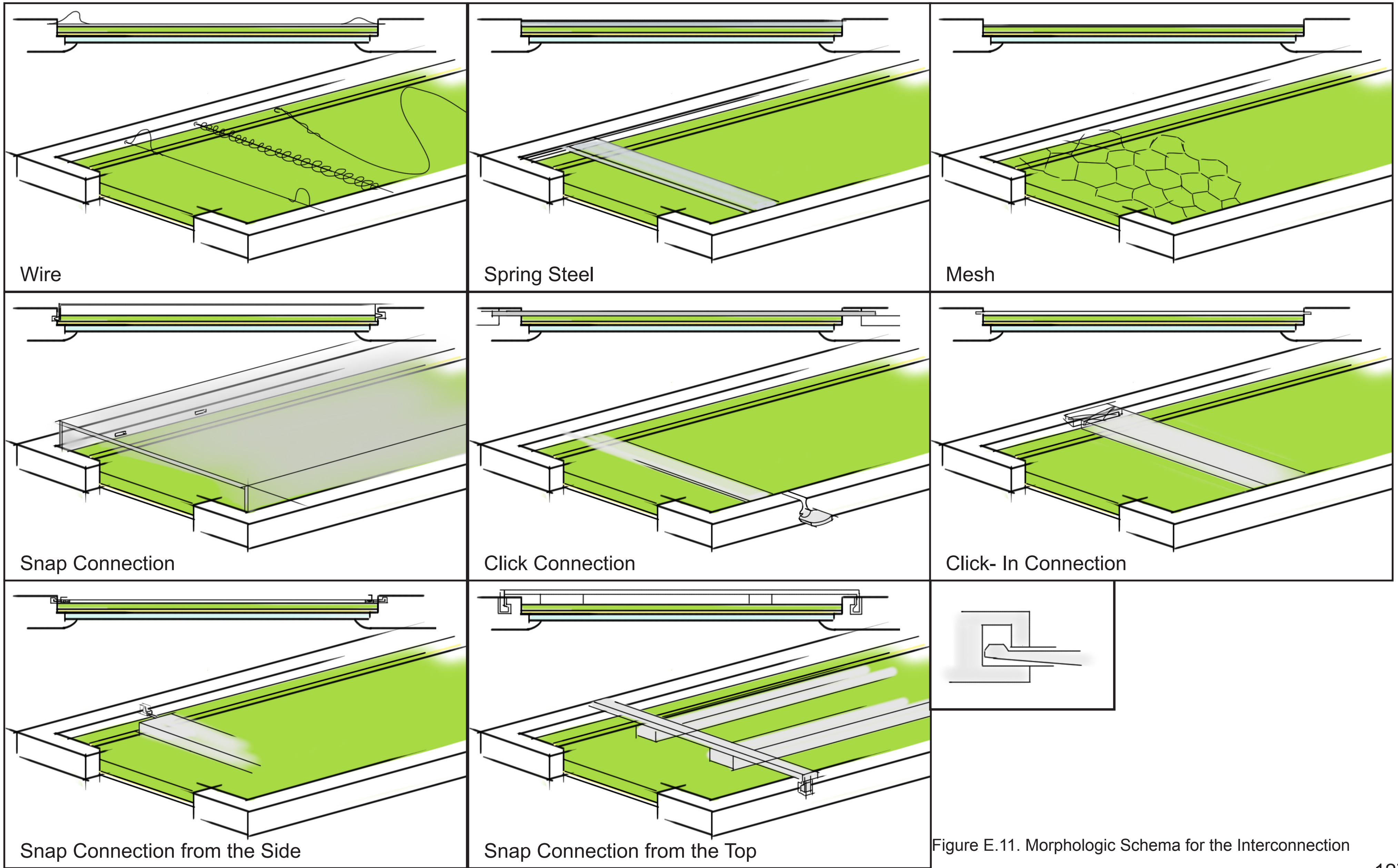


Figure E.11. Morphologic Schema for the Interconnection

E.5. The Parts of the Side Lamp

Figure E.12. Back Element of the Side Lamp

Figure E.13. Casing of the Side Lamp

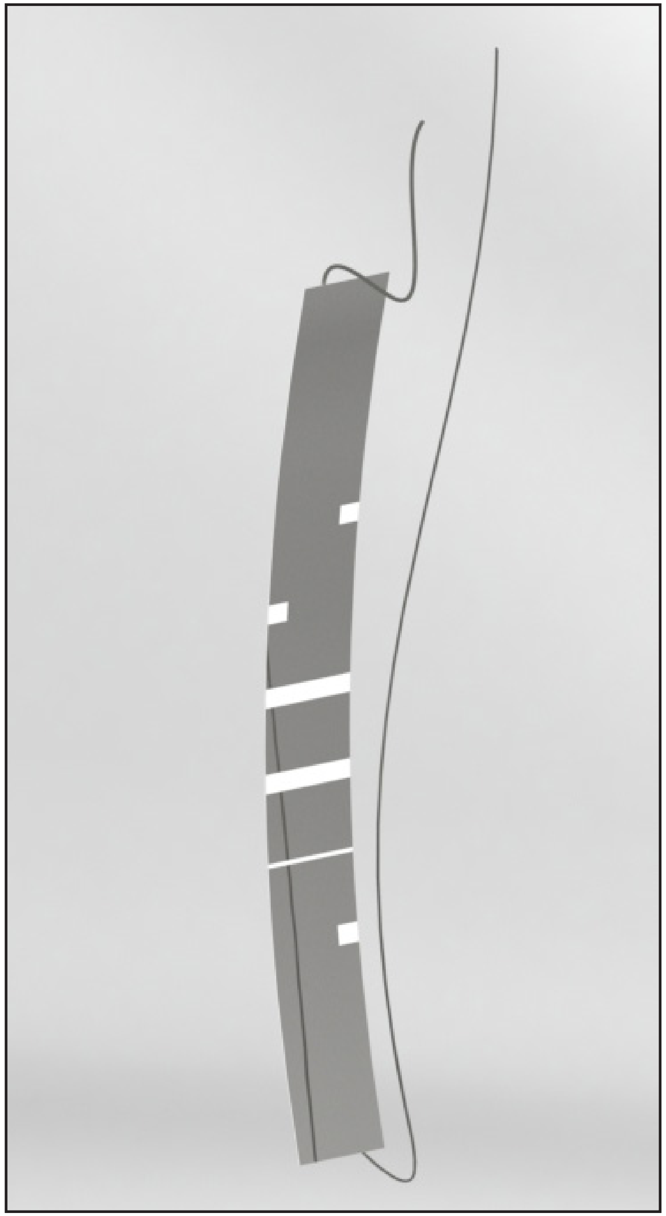


Figure E.14. OLED Panel of the Side Lamp

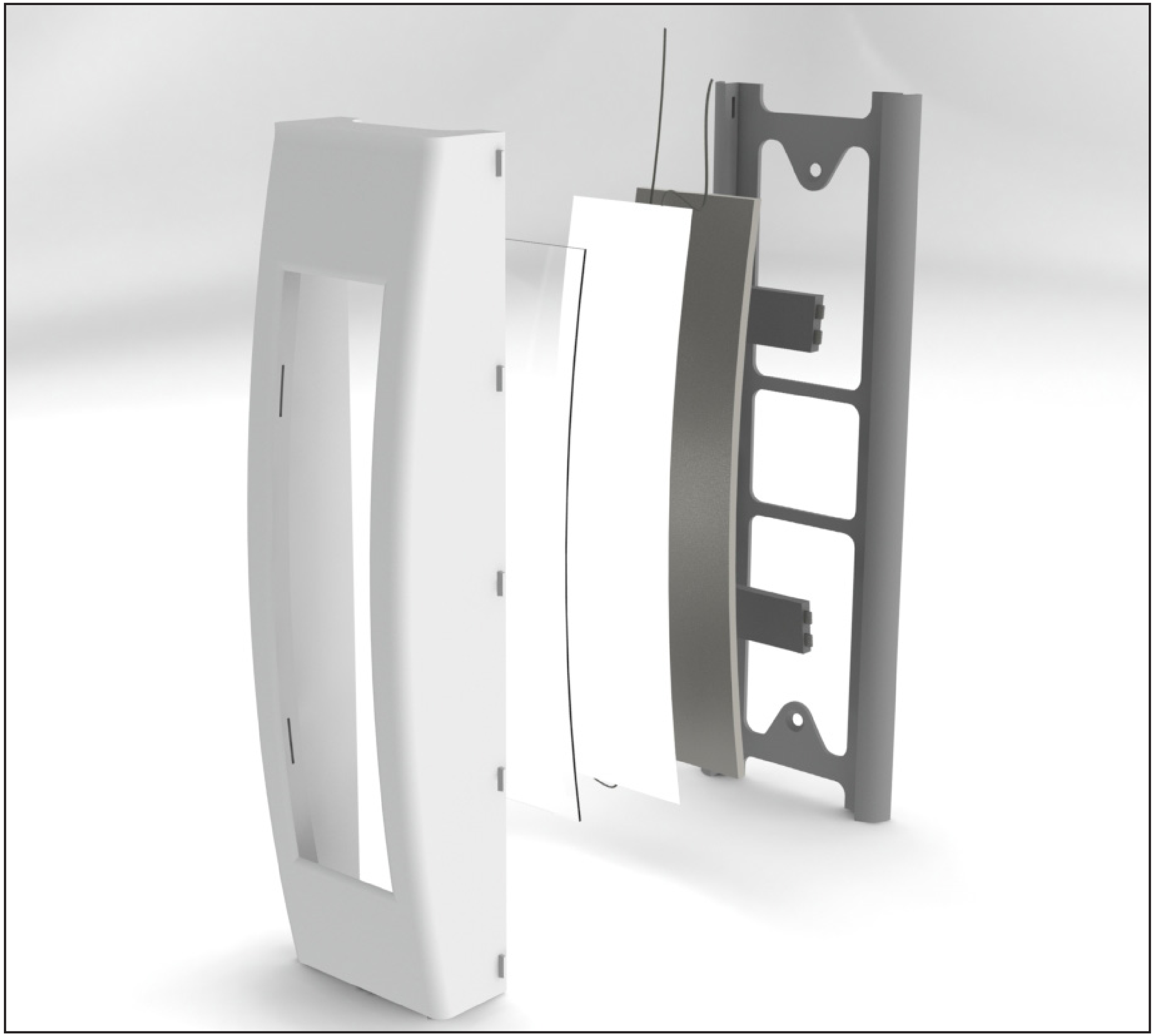
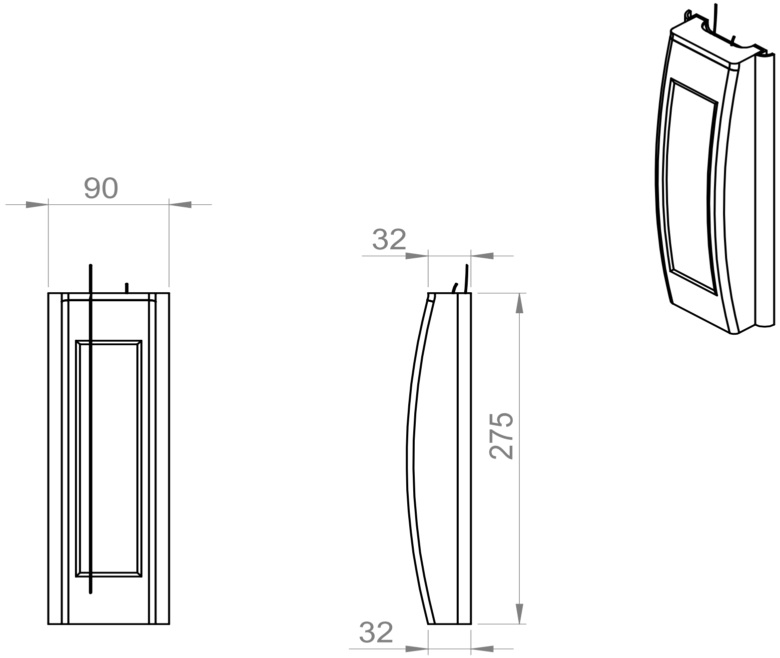


Figure E.15. Exploded View of the Side Lamp

E.6. Technical Drawings of Side Lamp



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
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2	Casing_LateralLamp^LateralLamp_Final		1
3	ProtectionLayer^LateralLamp_Final		1
4	SideOLED^LateralLamp_Final		1
5	Foam^LateralLamp_Final		1
6	Click Connection		2

PROJECTION METHOD

UNLESS STATED OTHERWISE: TOLERANCES ± 0,5 MM

DRAWN	C. Spreen	DATE	10.06.2015
CHECKED	--	SCALE	1:5

UNIVERSITEIT TWENTE.

FACULTY OF ENGINEERING

MATERIAL
--
--

SURFACE FINISH
--

TITLE
Side Lamp

DRAWING NO.
02

FILE / PART NAME
LateralLamp_Final

REV.
01

A4

DIMENSIONS IN MILLIMETERS

SHEET 1 OF 1

Figure E.18. Technical Drawing of the Side Lamp

E.7. Parts of the Add-Ons

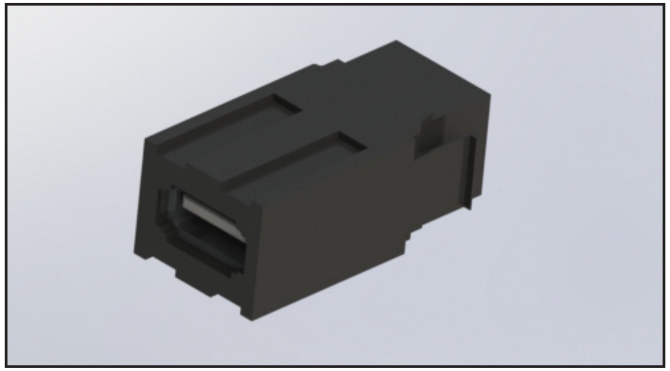


Figure E.21. Example of a USB-port

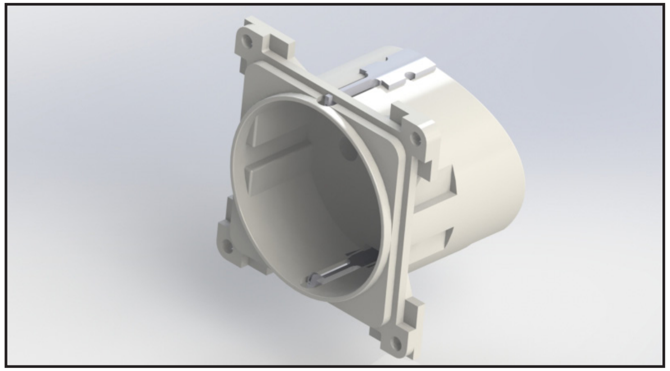


Figure E.22. Example of a USB-port

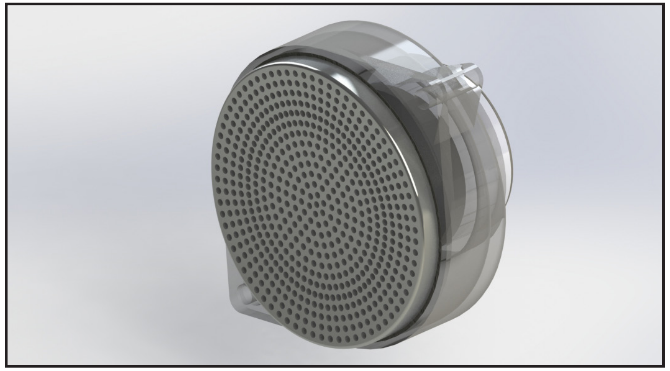


Figure E.23. Example of a USB-port

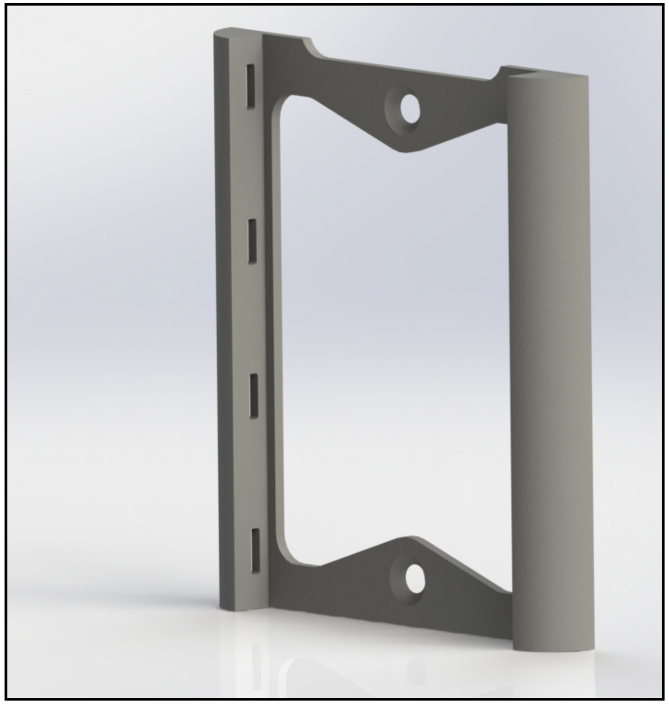


Figure E.19. Back Element of the Add-Ons

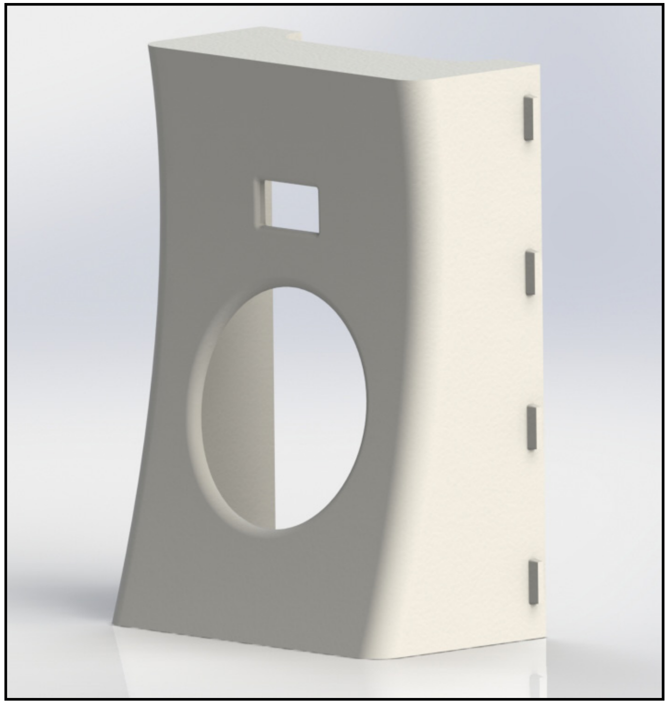


Figure E.20. Casing of the Add-Ons

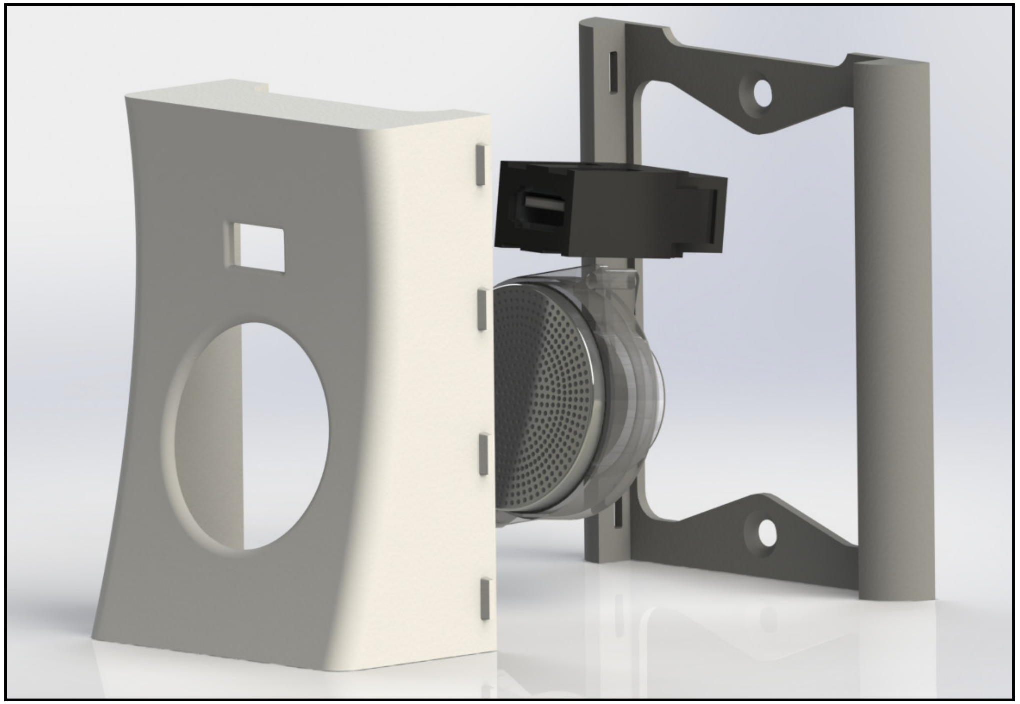


Figure E.24. Exploded View of the Add-On Sound

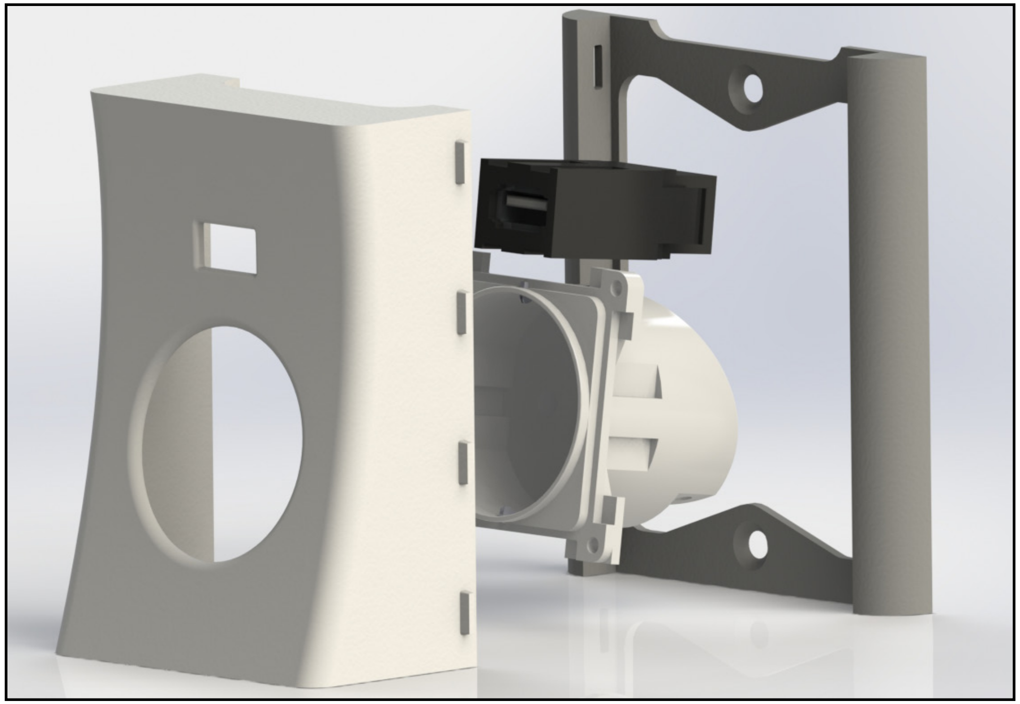
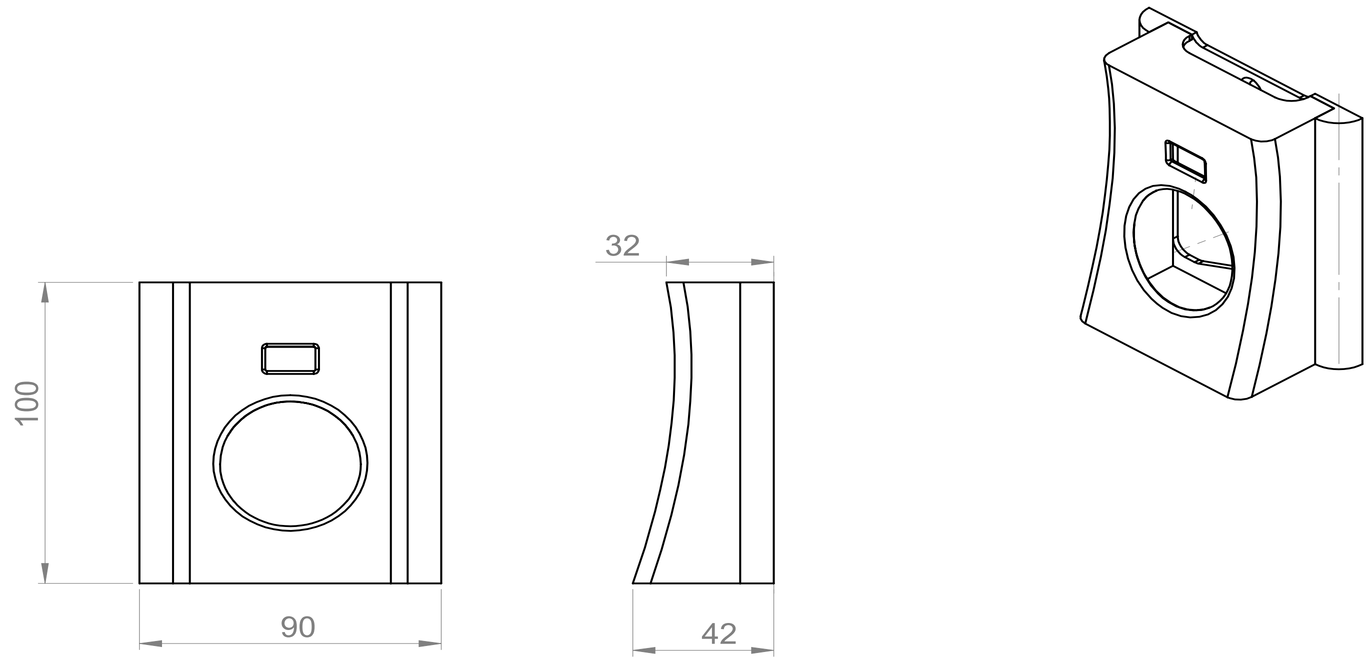


Figure E.25. Exploded View of the Add-On Energy

E.8. Technical Drawings of the Add-Ons



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
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PROJECTION METHOD	UNLESS STATED OTHERWISE: TOLERANCES ± 0,5 MM	DRAWN	C. Spreen	DATE	10.06.2015
		CHECKED	--	SCALE	1:2

UNIVERSITEIT TWENTE.	MATERIAL -- --	TITLE Add-On	REV. 01
	SURFACE FINISH --	DRAWING NO. 03 FILE / PART NAME AddOn_Final	A4
FACULTY OF ENGINEERING	DIMENSIONS IN MILLIMETERS	SHEET 1 OF 1	

Figure E.26. Technical Drawing of the Back Element of the Add-Ons

E.9. The different Combination Possibilites

Figure E.29. Upper Lamp + Add-On Sound

Figure E.30. Upper Lamp + Add-On Energy

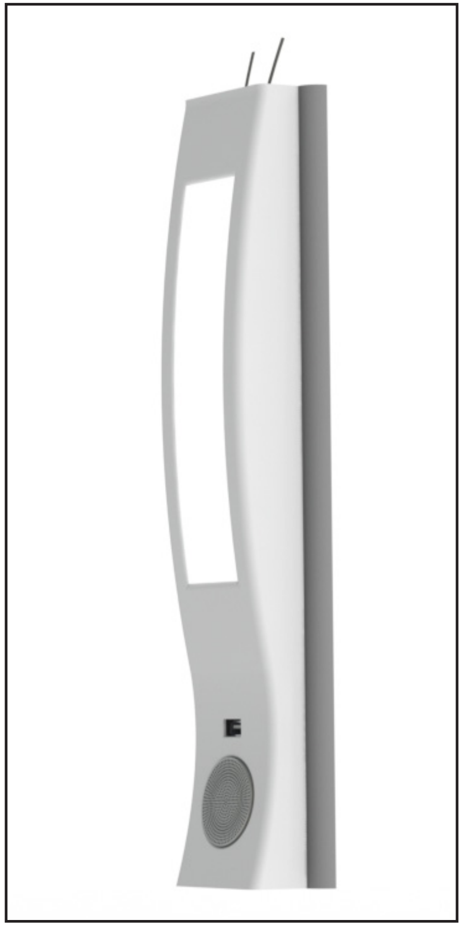


Figure E.31. Side Lamp + Add-On Sound

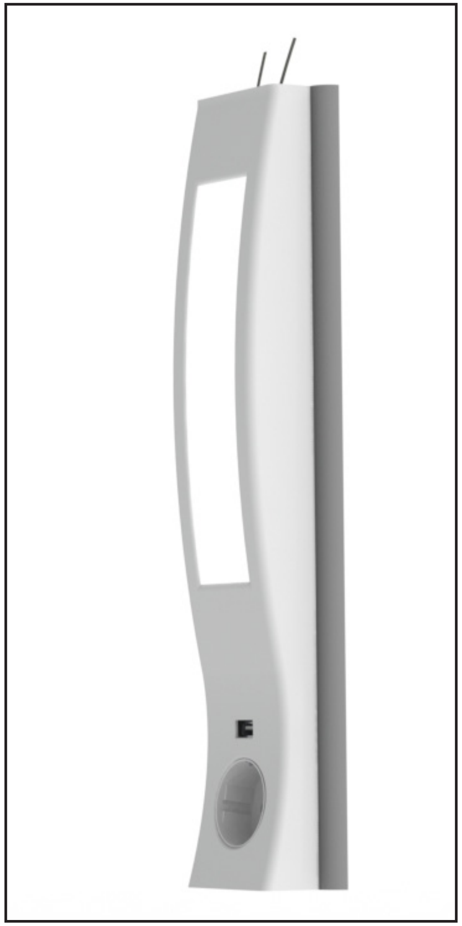


Figure E.32. Side Lamp + Add-On Energy

E.10. Data of the OLED Panel

Bendable Bar Type OLED Panel (P6BA30C)

1. Ordering Information

Model	Description	Efficacy	CCT	Product Code
P6BA30C	With F-PCB	60lm/W	3000K	

2. General Conditions

Parameter	Temperature	Humidity	Remark
Storage condition	0°C~40°C	< 70% RH	
Transport condition	-20°C~60°C	< 85% RH	Not over 170hrs
Operating condition	0°C~40°C	< 70% RH	

3. Maximum Ratings

Parameter	Sym	Unit	Max.	Condition
DC Forward Voltage	V_F	V	10.0	T_A=25°C
DC Forward Current	I_F	mA	250	T_A=25°C

Disclaimer: Device reliability may be affected if product is operated beyond the given conditions for an extended period of time

4. Electrical & Optical Characteristics

Operation @75lm

Parameter		unit	Min.	Typ.	Max.
Electrical data	Forward voltage*	V	8.2	8.6	9.0
	DC forward current (Current density)	mA (mA/cm^2)		150 ($1.94mA/cm^2$)	
	Power consumption	W	1.23	1.29	1.35
Optical data	CCT (integrated)	K	2500	2700	2900
	CRI	Ra	85		
	Duv		-0.005		0.005
	Spatial uniformity**	%	80		
	Efficacy	lm/W	53	60	67
	Flux	lm	65	75	85
Lifetime***	LT70, @$1.94mA/cm^2$	Hrs.			

*Voltage is measured after stabilization. Panel under test is regarded as stable if the voltage do not change during1min interval measurement or total turn on time is over 5min.

** Luminous uniformity calculation formula: U = [1-(Lmax-Lmin)/(Lmax+Lmin)] x100%

*** Operating Lifetime is from the beginning of operation until brightness reaches 70%of the initial luminance.
(Assumed Operating Condition: 25 ℃ at typical brightness level)

LG Chem
IT&E Materials Company

5. Mechanical Dimensions

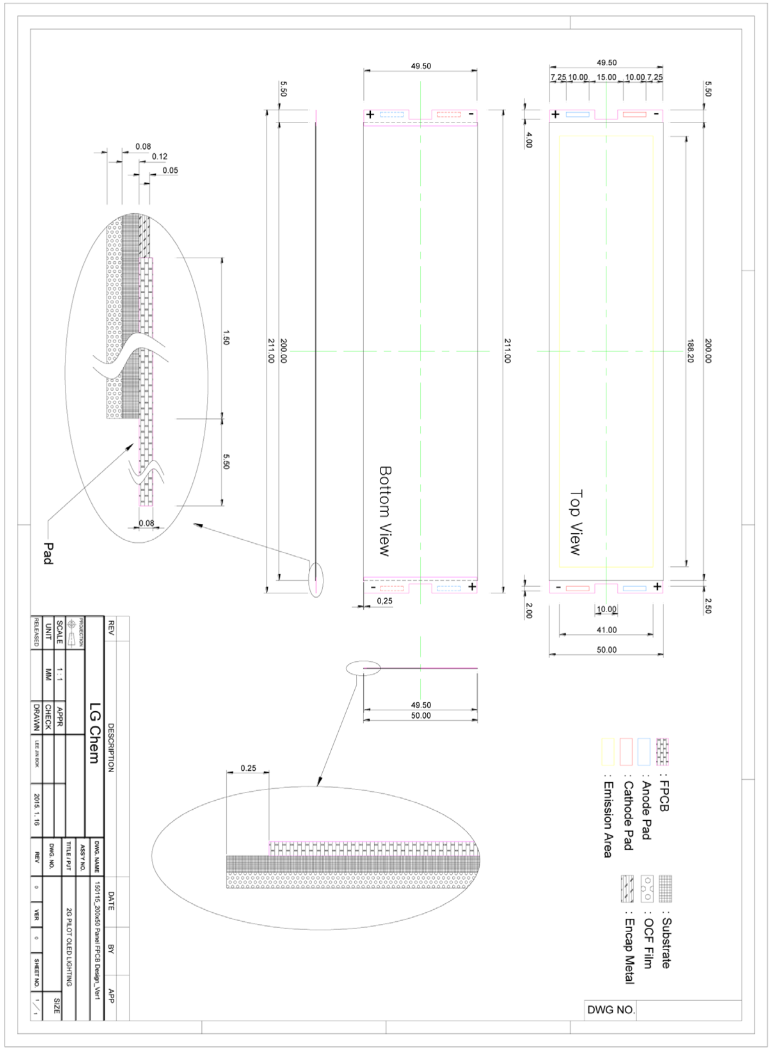
	Parameter	Sym	Unit	F-PCB Panel
Outer	Length	L	mm	211±0.3
	Width	W	mm	50±0.3
	Thickness*	T	mm	0.25±0.05
	Shape			Rectangle
	Weight		g	<5
	Bending Radius		mm	30
Inner	Encapsulation area		mm^2	200x50
	Luminance area		mm^2	188.2×41.0

* Thickness with out-coupling film

LG Chem
IT&E Materials Company

Figure E.33. Data Sheet OLED Panel (LG-Chem, 2015)

6. Drawings



LG Chem
IT&E Materials Company

Figure E.34. Data Sheet OLED Panel (LG-Chem, 2015)

HEP ower for light **LBC20Wxxx-1C UNI**

120-277VAC

Constant Current Dimmable LED Driver

Approval Marks

Australia Certificate No. : TUV017156E

Certified

EN 61347-1:2008+A1
EN 61347-2-13:2006
EN 62384:2006+A1

Electronic

Parameter		Conditions	Min	Nom	Max	Unit
I/P Voltage Range			108	120-277	304	Vac
Input Frequency			47	50-60	63	Hz
Input Power		High Power LED	-	-	25	W
Input Current		@120Vac	-	-	250	mA
Sink Current			-	-	1	mA
Output Voltage Range	LBC20W350-1C UNI		-	36-55.7	-	Vdc
	LBC20W450-1C UNI		-	28-44	-	Vdc
	LBC20W500-1C UNI		-	26-40	-	Vdc
	LBC20W550-1C UNI		-	24-36	-	Vdc
	LBC20W600-1C UNI		-	21-30	-	Vdc
	LBC20W700-1C UNI		-	18-28	-	Vdc
Output Current Range	LBC20W350-1C UNI		332	350	368	mA
	LBC20W450-1C UNI		427	450	472	mA
	LBC20W500-1C UNI		475	500	525	mA
	LBC20W550-1C UNI		522	550	572	mA
	LBC20W600-1C UNI		570	600	630	mA
	LBC20W700-1C UNI		665	700	735	mA
Rated Output Power	LBC20W350-1C UNI		-	12.6-19.5	-	W
	LBC20W450-1C UNI		-	12.6-19.8	-	W
	LBC20W500-1C UNI		-	13-20	-	W
	LBC20W550-1C UNI		-	13.2-19.8	-	W
	LBC20W600-1C UNI		-	12.6-18	-	W
	LBC20W700-1C UNI		-	12.6-19.6	-	W
THD			-	-	20	%
Efficiency		Full Load	80	-	-	%
Standby Power			-	-	1	W
Rise Time			-	-	500	ms
Start-up Delay			-	-	500	ms
Ripple Current		Peak to Peak @ Full Load	-	40	-	%
Output Current Overshoot			-	-	20	%
Power Factor		Full Load	0.90	-	-	-
Protection		Over-voltage Protection		Auto recovery		
		Open-circuit Protection		Max output voltage at no load		
		Short-circuit Protection		Auto recovery		
RoHS Standard				Compliant		
Case Temperature(Tc)			-	-	+85	℃
External Operating Temperature			-20	-	+50	℃
Operating Humidity Range			10	-	95	%
Storage Temp. Range			-40	-	+85	℃
Lifetime		at Max Case hot spot Temperature	-	50,000	-	hrs
Dimming Type				1-10V Dimming		
Dimming Range			10	-	100	%
Case Dimensions		Built-in Type	94	44	30	mm

LP-13-02/ 15-02

Figure E.35. Data SheetDriver (Hepgroup)

HEP ower for light **LBC20Wxxx-1C UNI**

120-277VAC

Constant Current Dimmable LED Driver

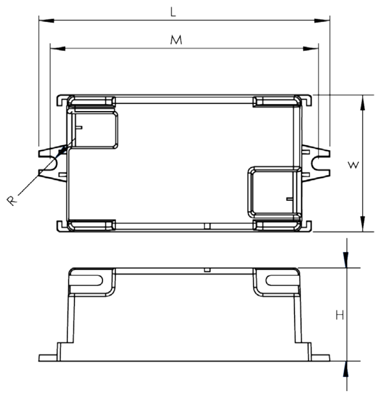
Approval Marks

Australia Certificate No. : TUV017156E

Certified

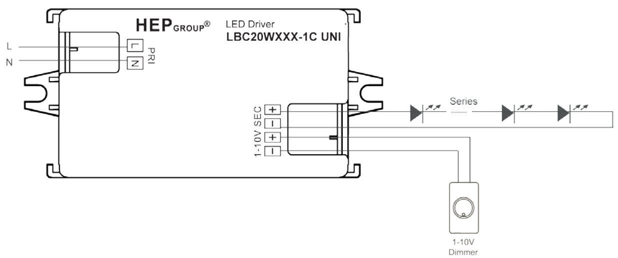
EN 61347-1:2008+A1
EN 61347-2-13:2006
EN 62384:2006+A1

Physical
Parameter



L : 94 mm H : 30 mm
M : 86.7 mm R : 2.1 mm
W: 44 mm
Tolerance : ≥0 ~ 100 ≥ +/-0.5mm
100 ≥ +/-1 mm
Terminal Block : PRI : Push Button - AWG#18-16
SEC : Push Button - AWG#22-20
Housing Material : Polycarbonate
Soldering : Lead-Free, Comply With RoHS
Label : Surface Print

Wiring



E.11. Calcuation of the Illuminance

The steps of the design guide are used for calculating the illuminance. In this case the illuminance of the light on the work top is relevant. Therefore distance between a kitchen cupboard and the work top is assumed to be 0,45m. Moreover it is assumed that the beam angle is 60° and that the light source is a point light source as descripted in the design guide.

So first of all the luminous intensity is calculated with equation 2:

$I_v = \phi_v/\Omega = 75lm/(0,8418\ steradian) = 89,1cd$

Then the illuminance of the upper lamp in point A (figure E.36) can be calculated by using the fifth equation:

$E(A) = (89,1\ cd)/0,42^2 * \cos(0) = 505lx$

The distance from point A to point B can be calculated with equation 6:

$D= \tan(30)*R=\tan(30)*0,42m=0,24m$

By knowing this distance the illuminance on the edge of the light can be calculated with equation six:

$E(B)=89,1cd/\sqrt{((0,42m)^2+(0,24m)^2)}^2 *\cos(30)=330lx$

This means that the illuminance directly under the light source is the highest and then slowly declines to the sides.

The illuminance of the side lamp will be way lower because the light source is parallel to the work top. In figure E. 37 the situation is sketched. The luminous intensity is the same for this panel. As the position of the point light the middle of the panel is chosen. Therefore the distance on the outer edge of the light on the work top is calculated.

$E(c)=89,1cd/\sqrt{((0,53m)^2+(0,306m)^2)}^2 * \cos(30)$
$=206lx$

The middle of the panel has been chosen as the reference but the lowest point of the panel will illuminate the work top with a greater illuminance and upper points with even less.

All in all it can be concluded from this calculation that the illuminance on the work top is high enough. By positioning the lamps next to each other with a distance of around 20cm the required illuminance of 500lx is reached in almost every point.

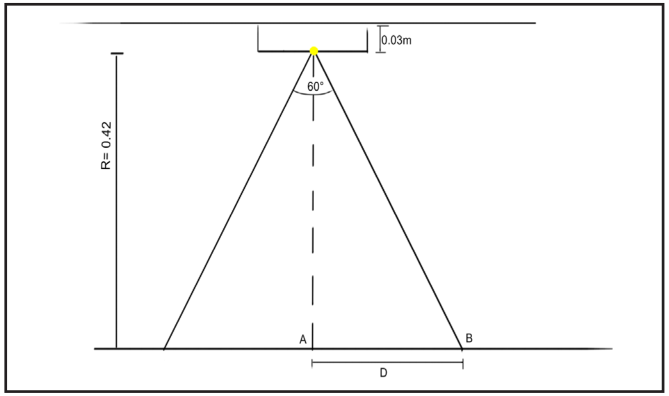


Figure E.36. Illuminance Upper Lamp

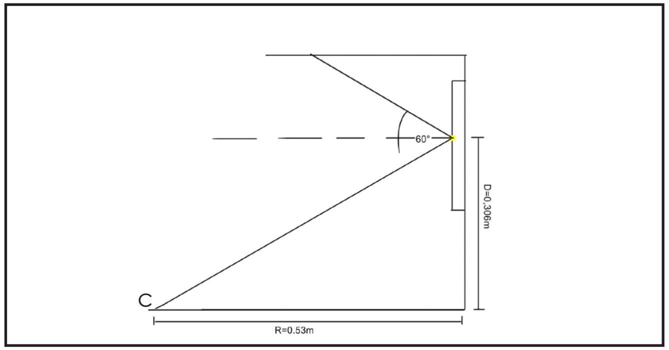


Figure E.37. Illuminance Side Lamp

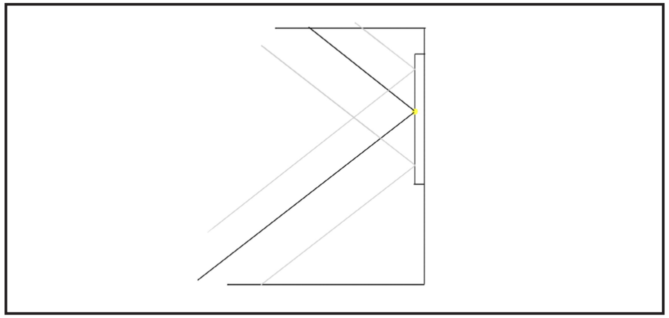


Figure E.38. Reference Point on Side Lamp

E.12. Cost Calculation

Material Costs

	Upper Lamp	Lateral Lamp	Add On
Material Price*	2,06 €	2,06 €	2,06 €
Weight Back Element in kg	0,03473	0,04021	0,01259
Weight Casing in kg	0,05655	0,08746	0,03057
Price Per Part	0,19 €	0,26 €	0,09 €

* CES EduPack2014

Table E.1. Material Costs

Production Costs

	Upper Lamp	Lateral Lamp	Add On
Mould	10.000	10.000	10.000
Assemblage+ Workning Hours	10	10	10
	30	30	30

Table E.2. Proudction and Assemblage Costs

Import Costs

	Upper Lamp	Lateral Lamp	Add On Sound	Add On Energy
OLED Panels*	230	230	0	0
Loudspeaker	0	0	12	0
USB Plug	0	0	6	6
Bluetooth	0	0	15	0
Plug Socket	0	0	0	8
Import Costs	230	230	33	14

*(OLED.at, 2015)

Table E.3. Import Costs

Total Costs per Part

	Upper Lamp	Lateral Lamp	Add-On Sound	Add-On Energy
Material Costs	0,19 €	0,26 €	0,09 €	0,09 €
Production Costs	30,00 €	30,00 €	30,00 €	30,00 €
Import Costs	230,00 €	230,00 €	33,00 €	14,00 €
Overhead (15%)	39,03 €	39,04 €	9,46 €	6,61 €
Total	299,22 €	299,30 €	72,55 €	50,70 €

Table E.4. Total Costs