Design of OLED Capsule and Automated Blade Coater

Internship Report

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UNIVERSITY OF TWENTE.

Centro de Tecnologia da Informação Renato Archer

Preface

For this internship project I would like to thank all the co-workers at Centro de Tecnologia da Informacao Renato Archer (CTI) - DMI department for their help and expertise. Especially to Viviane Nogueira for being a good mentor and guiding me during the internship.

Abstract

OLED technology is a promising technology for luminance and display technology. Therefore a lot of research is done at CTI in Campinas Brazil. During the internship two assignments were conducted by the student.

OLEDs are very sensitive to water (vapor). That is why they are produced and tested in gloveboxes filled with argon gas. However testing the devices in the glovebox is very unpractical. Therefore it was required to design a small device which can maintain the protective argon atmosphere but allows for testing outside the glovebox. A set of requirements for this OLED Capsule are proposed and four different concepts are developed. The best concept is chosen and is further developed into the final design.

CTI does research on a new production method for making OLEDs called blade coating. For this purpose it was required to design a device called an Automated Blade Coater to conduct this blade coating technique. The problems with the current Manual Blade Coater are identified and a set of requirements for the Automated Blade Coater are proposed. Based on the requirements three different concepts are developed. The best concept is chosen and is being further developed into a final design. The dynamical behavior of the device is modeled in a Simulink model.

Content

1. Introduction

This internship report is written as a result of the internship of Sjoerd de Bekker at Centro de Tecnologia da Informação – Renato Archer (CTI) in Campinas, Brazil. This report describes the assignments conducted by the student in chronological order.

First an introduction is given explaining OLED technology and its applications. Then the assignments are described. There were two assignments completed by the student. One smaller assignment concerning the design of an OLED encapsulation and one larger assignment regarding the design of an Automated Blade Coater. The report is divided in Part 1 which concerns the first assignment and Part 2 which concerns the second assignment. After this a conclusion and a reflection is drawn.

1.1 CTI

CTI is located in Campinas in the state of São Paulo, Brazil. It has about 300 researchers working in 10 different laboratories.

CTI is a unit of the Ministry of Science and Technology and conducts research and development in areas such as micro- and nano-electronics, systems, software and IT applications etc. One major department of CTI is the DMI department; here research is conducted in the field of micro-electronics for display technology. One major research topic for this department is OLED technology.

1.2 OLED

An OLED (Organic Light Emitting Diode or Organic LED) is a chemical-electrical device build up from multiple layers. The main difference between a regular LED and an OLED is that several of the layers in the structure (see 1.2.1) are made from organic compounds like cellulose, tannin, cutin, proteins, carbohydrates etc.[1] OLED technology is often used in display technology and in luminance technology.

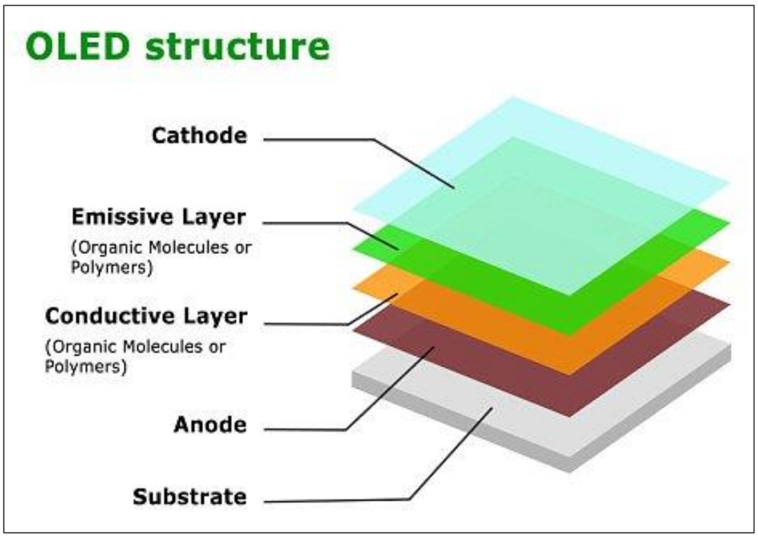


Figure 1; OLED structure
Electronicsmagazine 2010

[1] http://en.wikipedia.org/wiki/OLED#Structure

1.2.1 Structure

The basic structure of a typical OLED can be seen in Figure 1. The structure is build up from the bottom up starting with a glass or plastic substrate. The first layer is the anode, for this usually indium tin oxide (ITO) is used. This material is transparent and has a high conductivity. On top of this anode the conductive layer is placed, this layer is often composed out of organic materials. On top of this layer the emissive layer is placed. This layer produces the light when a current is applied on the device. The final layer is the cathode, for this layer often various types of metal are used.

A positive voltage is applied on the cathode in comparison with the anode. This causes electrons to flow from the conductive layer to the emissive layer resulting in light emission.[2]

1.2.2 Benefits and drawbacks

When compared to LCD and LED display technology OLED has certain benefits and drawbacks, the most important ones are described below.[3]

Benefits

- Because there is no need for backlight displays with OLED technology can be made much thinner than LCD and LED displays.
- Because the light emitting layers are so thin and because OLED can be made on a plastic substrate, the OLED can be made flexible.
- With use of the right chemical composition of the layers, the entire display can be made transparent which is useful for heads-up displays.
- OLED's are easier to produce and can be made to much larger sizes
- Because there is no need for backlight OLED displays consumes less energy.
- OLED displays are in general brighter.

Drawbacks

- OLED's are highly sensitive to water. This is because the organic layers can decompose when it gets in contact with water.
- The lifetime of an OLED display is often shorter than that of LCD and LED.
- Although easier to produce, the current manufacturing methods are expensive.

[2] http://en.wikipedia.org/wiki/OLED#Working_principle
[3] http://electronics.howstuffworks.com/oled5.htm

1.2.3 Applications

Based on the benefits and drawbacks in the previous paragraph several examples of applications are given.

One application of OLED technology is lighting technology; with OLED technology very thin illuminating devices can be created which can (theoretically) be transparent and flexible. For example it would be possible to make glass roof panels with a transparent layer of OLED such that during the day you receive light through your widows and at night you can turn your window into a lighting device. See Figure 2.

Another application is display technology. Currently displays with OLED technology already exist and compete closely (if not better) with other display technologies. But with OLED technology the display thickness can be reduced greatly compared to the others because there is no need for backlight. Also it would (theoretically) be possible to create flexible and transparent displays. See Figure 3.

Figure 2; Luminance application of OLED
V. Nogueira 2011

Figure 3; Display application of OLED
LG 2013

Part 1; OLED Capsule

2.1 Introduction

The organic emissive layer is very sensitive for water even the slightest amount of watervapor in the air can damage the OLED in a relatively short time. That is why OLED devices must be kept under protective atmosphere at all times. CTI uses gloveboxes (see Figure 4) to create a protected atmosphere to work in. These gloveboxes are filled with argon, this noble gas will not react to any of the sensitive components. This also means that the OLED devices cannot be taken outside the glovebox without any form of protection.[4] A typical OLED as created at CTI can be seen in Figure 5.

2.2 Problem definition

Because the OLED cannot be taken outside the glovebox without any protection, the testing of the luminance etc. must also take place inside the glovebox. The optical measurements cannot be done through the glass of the glovebox because regular glass (as installed in the gloveboxes) blocks the Ultra-Violet part of the emitted spectrum. In this way the emitted light is altered before it can be measured, this is undesirable. The fact that the measurements therefore have to be conducted inside the glovebox causes practical difficulties, the researchers find it hard to handle the OLED and the measurement equipment inside the glovebox.

Figure 4; Gloveboxes at CTI
V. Nogueira 2014

[4] Unmodified small-molecule organic light-emitting diodes by blade coating, by Yu-Fan Chang et al. in Organic Electronics 13 (2012) 2149–2155.

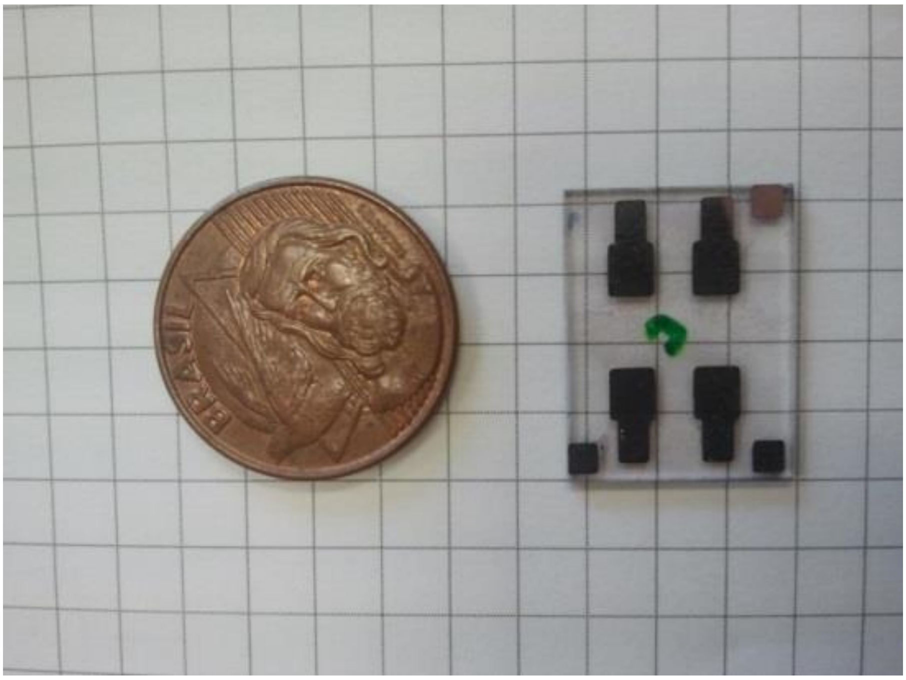


Figure 5; Example of OLED device as created at CTI. There are 4 OLED's on the glass substrate, 5 cent coin for scale.

2.3 Analysis

It would be more convenient to have a device which could maintain the protective atmosphere outside the glovebox and still would offer the ability to conduct the optical measurements of the OLED inside without interference. This device should be an enclosure which must fit through the sluice of the glovebox so that the OLED can be taken outside the glovebox. In this device inside the glovebox the OLED is inserted, then the OLED inside the protective atmosphere can be taken outside the glovebox.

Based on preceding analysis the following set of requirements is set up:

1. Maintain a protective atmosphere, sealed connection.
2. Device must fit through sluice of the glovebox. D_{sluice}=⌀130mm, L=200mm
3. Placing the OLED in and out the device should be relatively easy, one person should be able to place and seal the device inside the glovebox within one minute.
4. Make electrical connection to the outside of the device such that the OLED can be powered.
5. The optical measurements must find no interference of the device. For example if the sample is placed behind glass, the glass will block some part of the emitted spectrum.
6. Different sizes of OLED's must fit inside the enclosure..

2.4 Concepts

Different concepts have been developed. The concepts show different ways to maintain a protective atmosphere to protect the OLED. Different ways of connecting the two parts have been used as well as different shapes for the enclosure. The way the concepts work will be explained for each concept. The material is not yet specified in the concepts, this will follow in 2.5.

For the way the OLED is placed in the enclosure an insert is used which can be inserted in the enclosure. This system will be explained in 2.5.

Concept A

The first concept can be seen in Figure 6. It consists of two cylindrical parts. These two parts can be joined by a threaded connection; the top part can be screwed into the bottom part. The two parts can be attached to each other by hand which is convenient. Although fitting a rubber o-ring in this design for the sealing is more difficult.

In order to do the optical measurements a viewport is created on the top-end of one of the parts. When closed the dimensions are approximately: D = 120 mm, h = 100 mm.

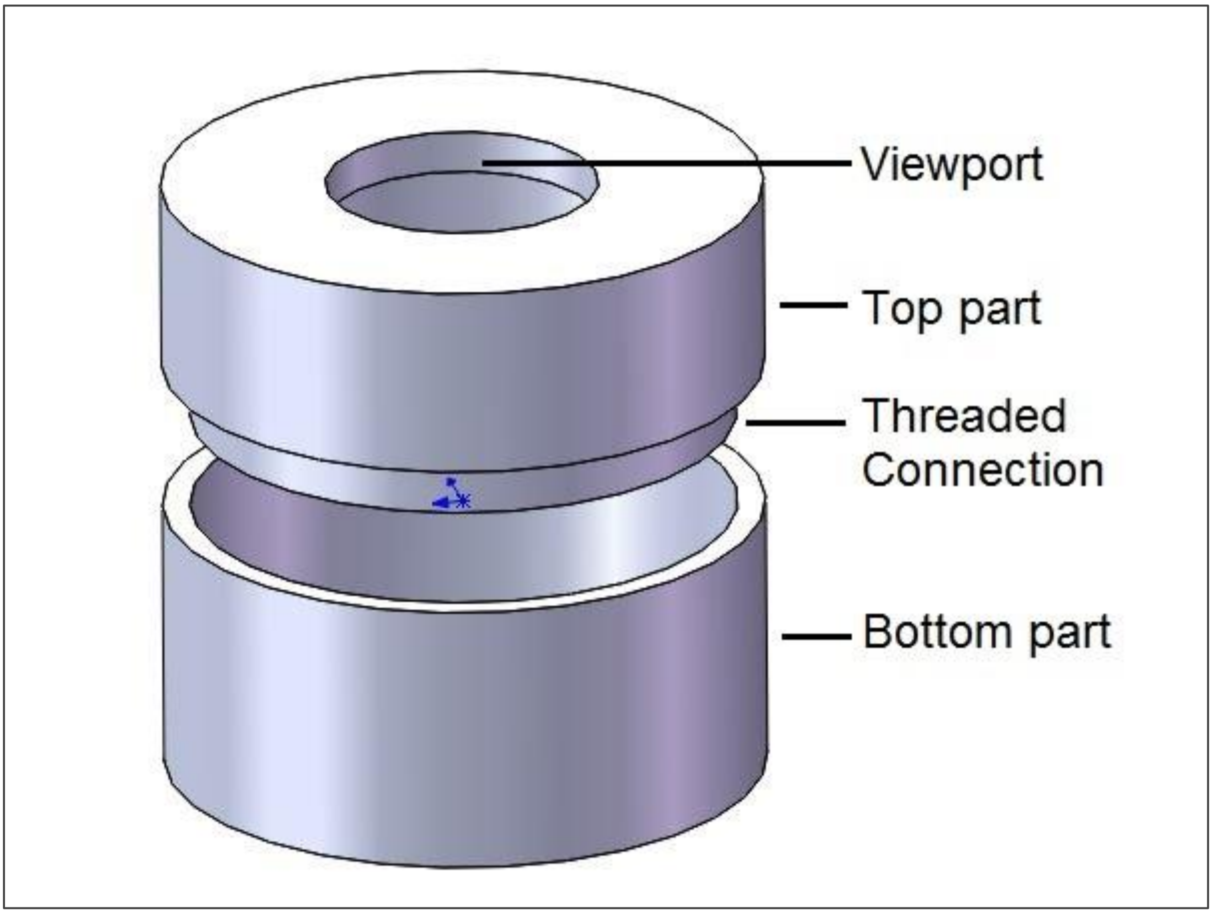


Figure 6; Concept A

Concept B

This concept B can be seen in Figure 7. It is also a cylindrical design but it uses a flange connection to connect the two cylindrical parts. To secure the two parts bolts can be used. An o-ring can be placed in the flange in order to ensure a sealed connection. Although using bolts would make a secure sealing, it will result in many small parts which takes more time to close.

A viewport is placed on one of the parts in order to do the optical measurements. When closed the dimensions are approximately D = 120 mm, h = 100 mm.

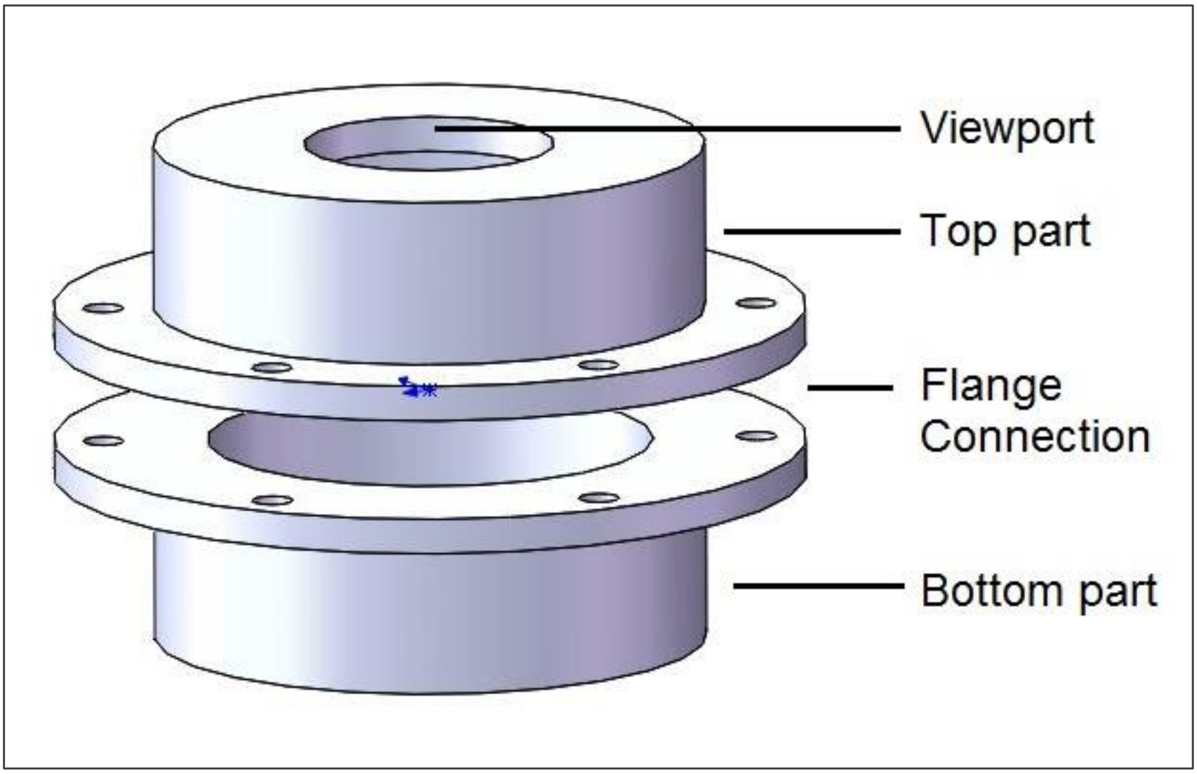


Figure 7; Concept B

Concept C

This concept consists of a rectangular box with a lid. The lid can be secured by some brackets as shown in figure x. The brackets are secured to the box by a bolted connection. Another solution would be to apply a hinge or something similar. To make a sealed connection a rubber seal can be put on the edge of the box. The fact that the design is rectangular makes it more difficult to seal the connection.

A viewport is placed on the lid in order to do the optical measurements. When closed the dimensions are approximately L = 100 mm, W = 100 mm, H = 100 mm.

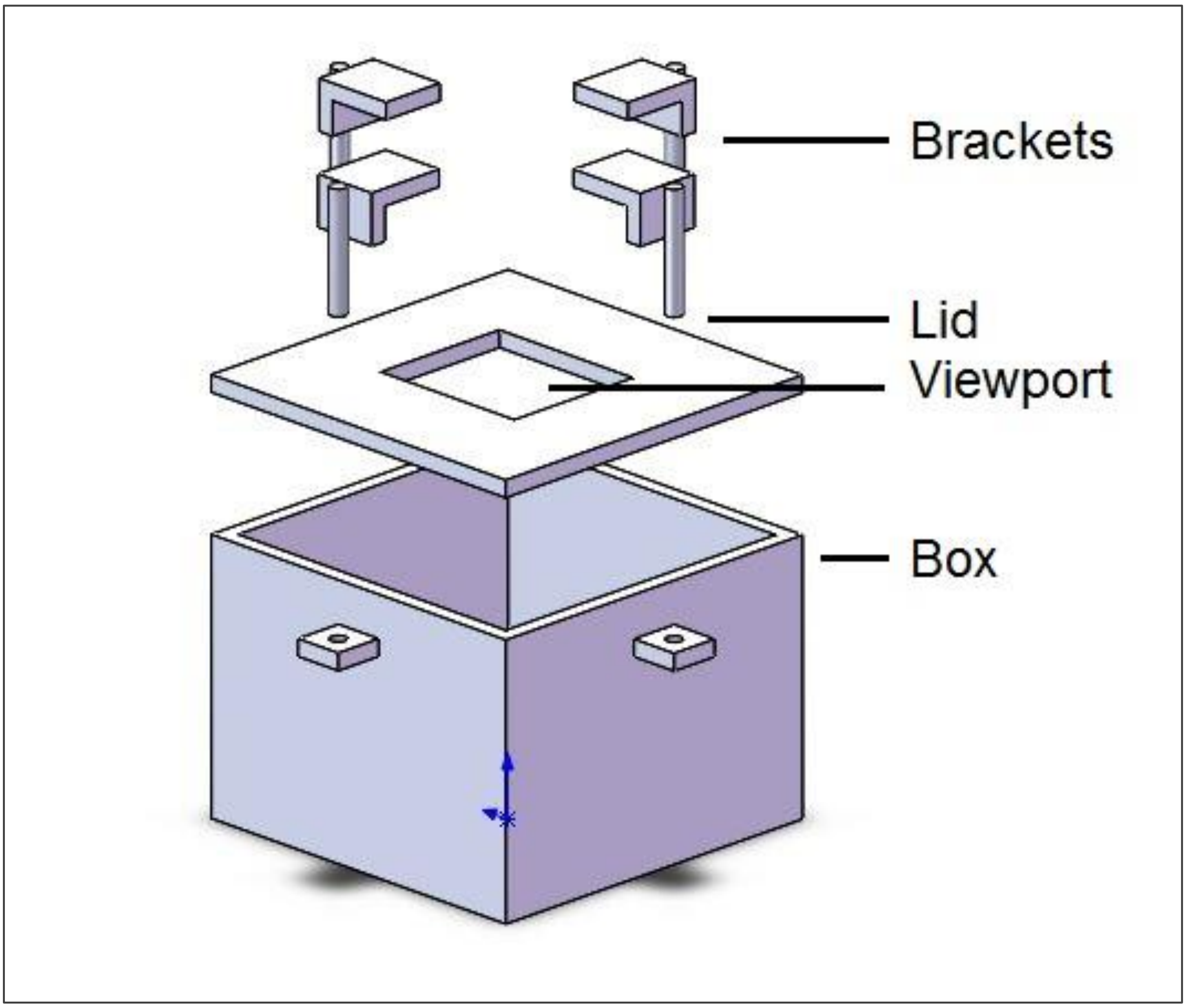


Figure 8; Concept C

Concept D
This concept consists of a rectangular box divided in two parts and is shown in Figure 9. The two parts can be connected by four bolted connections, one at every side. On the edge of the box a rubber seal can be put on the edge to make a sealed connection. Also for this design the fact that it is rectangular makes it more difficult to seal the connection.

A viewport is placed on the lid in order to be able to do the optical measurements. When closed the dimensions are approximately L = 100 mm, W = 100 mm, H = 100 mm.

2.4.1 Concept choice
In consultation with CTI the first concept is chosen, concept A. This concept is chosen because it is the cheapest, most easy to build and most easy to handle. The cylindrical design will most likely ensure a better sealing than the rectangular design because a rectangular design is more likely to leak at the corners. Since there are no corners on a cylindrical design these designs have better sealing.

The internal thread, as shown in concept A, is much more convenient than the design with a flange because fewer parts are required (no bolts or screws). Since requirement number 3 prescribes that the device should be 'easy' to open, the internal thread of concept A is the most promising. Concept A proved to be the most promising design and is therefore chosen to be the final design to be worked out further.

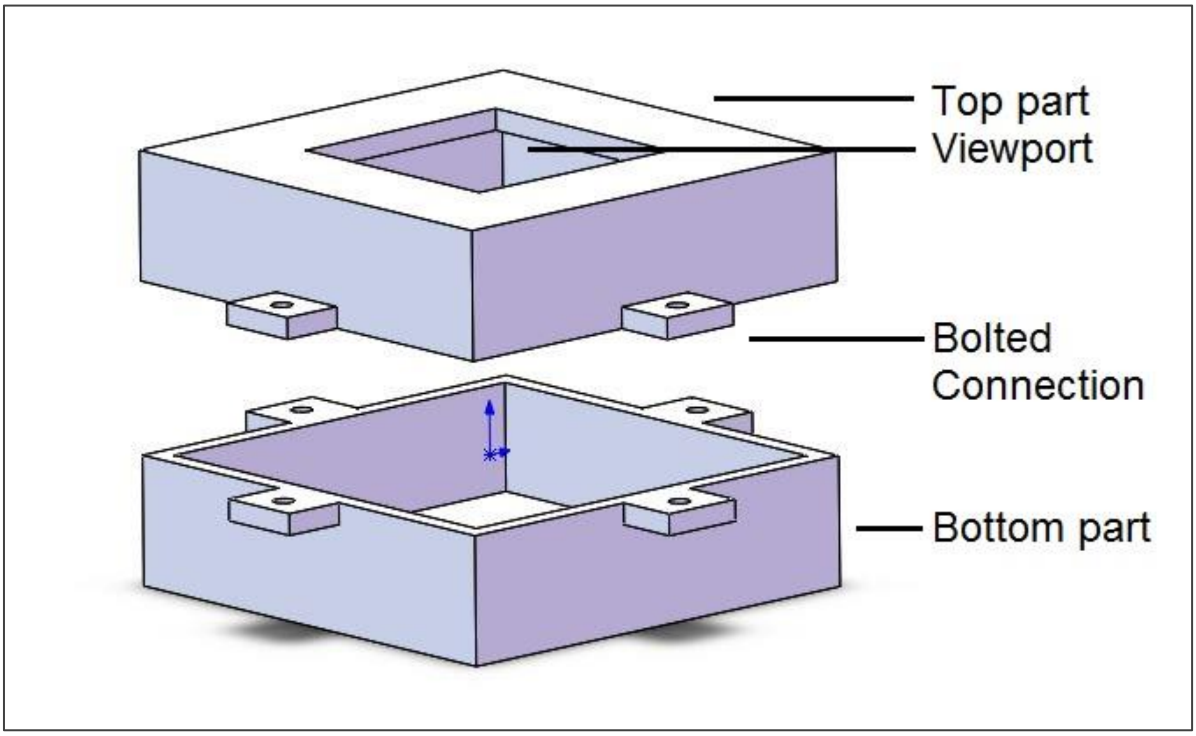


Figure 9; Concept D

2.5 Final design

The final design is based on the concept chosen in 2.4, it consists of two nylon parts which can be joined by a thread connection. At this connection a rubber o-ring seal prevents any leakage. For the material nylon has been chosen because of its ability to be turned and milled, and because of its low density which makes the encapsulation rather low weight. Also using nylon instead of, for example, brass makes it cheaper.

The final design is shown in Figure 10 and Figure 11. Figure 11 shows an exploded view of all components. All the different components will be explained in the following.

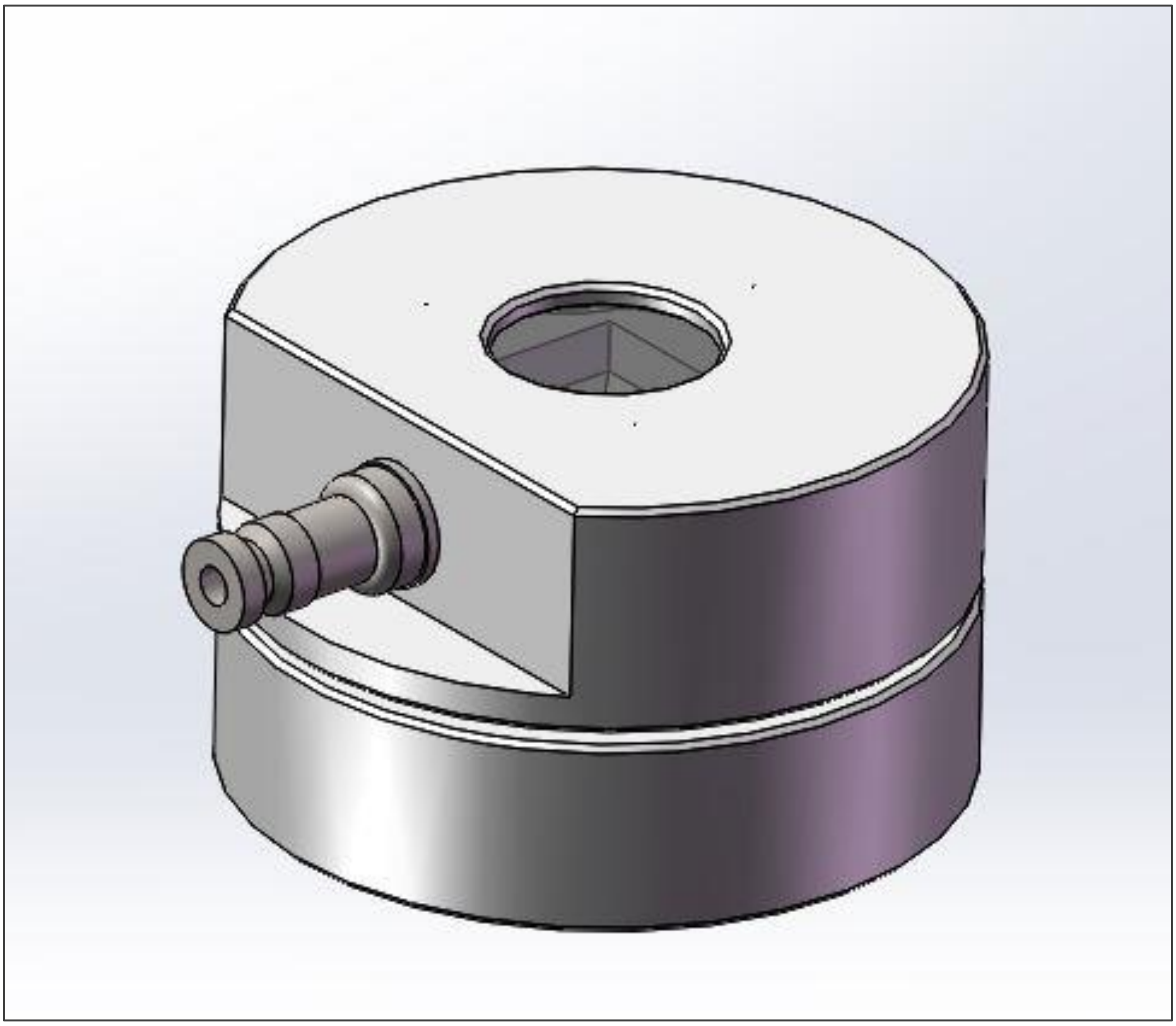


Figure 10; Final design

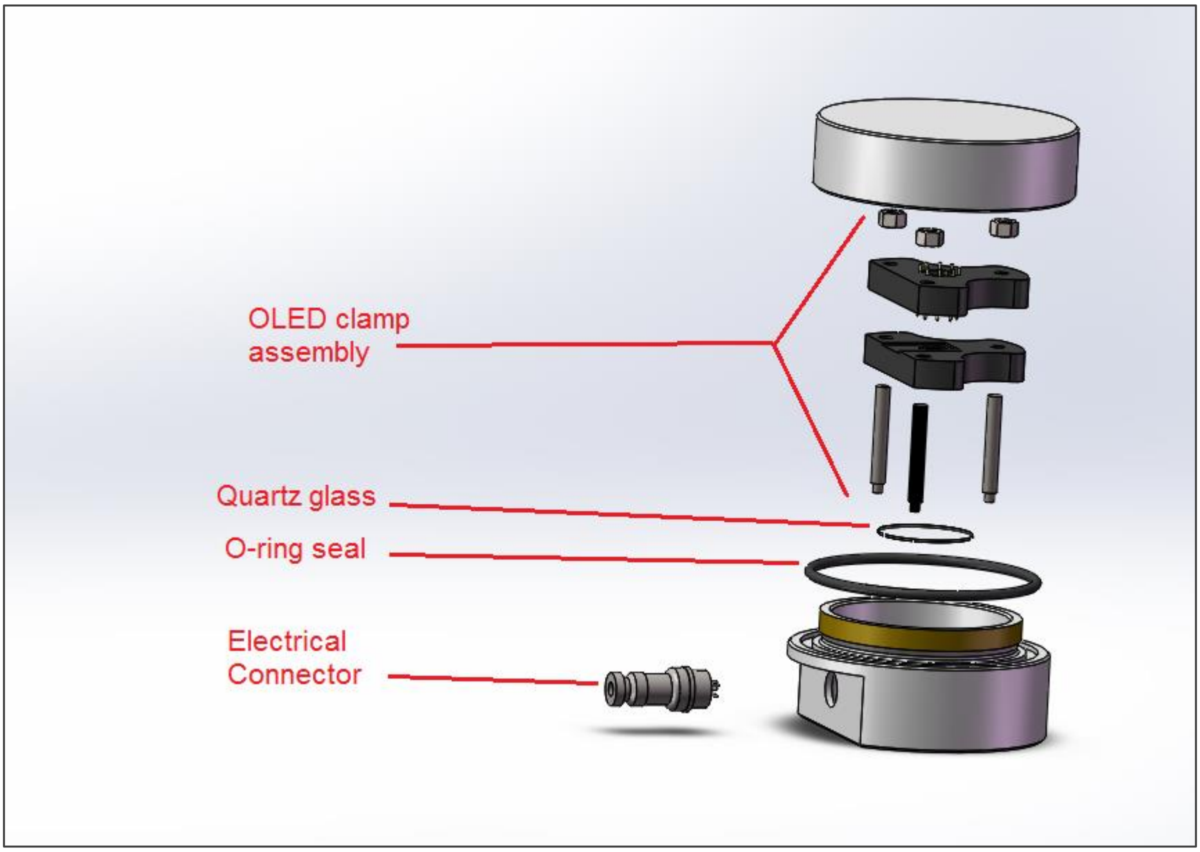


Figure 11; Final design exploded view

The basic idea of Concept A in 2.4 of using a threaded connection can be seen in Figure 11. The two parts are connected by an ISO M85x2 thread. Between the two parts the rubber o-ring is clamped (D = 95 mm and cross-section d = 4 mm). The diameter of the device is 110 mm and the height (when closed) is 68 mm.

The viewport is located at the bottom of the bottom part as can be seen in Figure 10. On the inside of this circular hole a disk of quartz glass is glued to the bottom part. This glue keeps the glass plate in place and seals this connection. Through this viewport all optical measurements can be done. Use was made of quartz glass instead of regular glass because regular glass is not transparent for the ultra-violet light, as explained in 2.2. This means that regular glass will block a certain range of the spectrum emitted by the OLED.

The OLED clamp assembly holds the OLED (one as in Figure 5) in place and conducts the power to the anode and cathode of the OLED. The OLED is clamped between the two plastic (non-conductive) blocks and these are placed on the steel rods which are tightened by nuts if necessary. In the top connector block springs are placed. These springs have a conductive gold coating and maintain pressure on the anodes and cathodes of the OLED.

CTI used similar devices in the past to apply power to an OLED, see Figure 12 and Figure 13. This design had to be changed in order to make it suitable for application in the design of the enclosure, see Figure 14. These connector blocks were manufactured by use of the 3D printers present at CTI. The connector blocks as designed for this application will also be manufactured in the same way.

The OLED clamp assembly functions as an insertable part. One major advantage of using such an insert to clamp to OLED is that it can easily be replaced for other inserts to suit OLED's of different sizes or with different geometry. Because of this the enclosure can be used for many different kinds of OLED's. Different connector blocks can be printed relatively easy and quick.

For the technical drawings of this design see Appendix A.

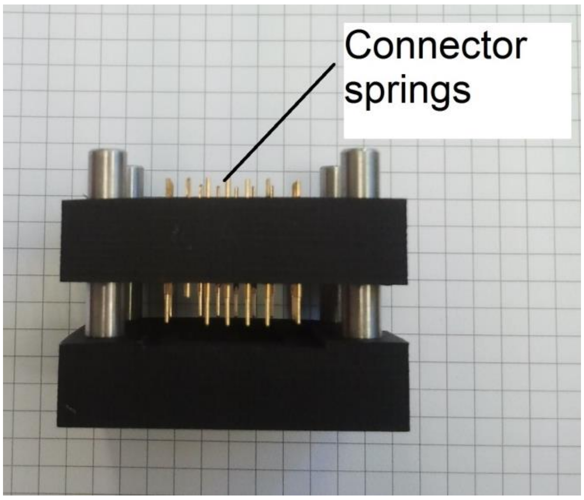


Figure 12; Connector block assembled

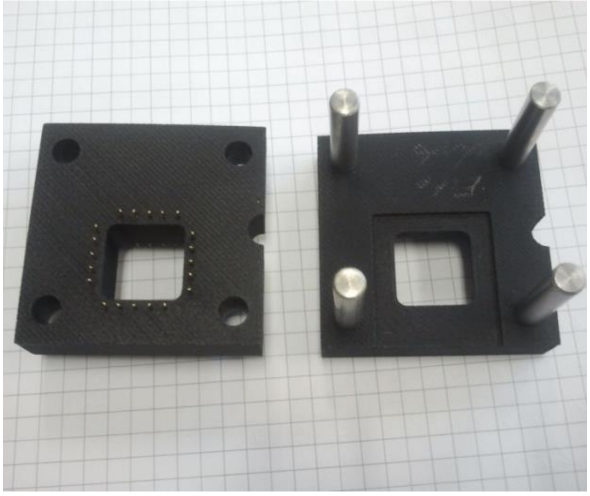


Figure 13; Connector block unassembled

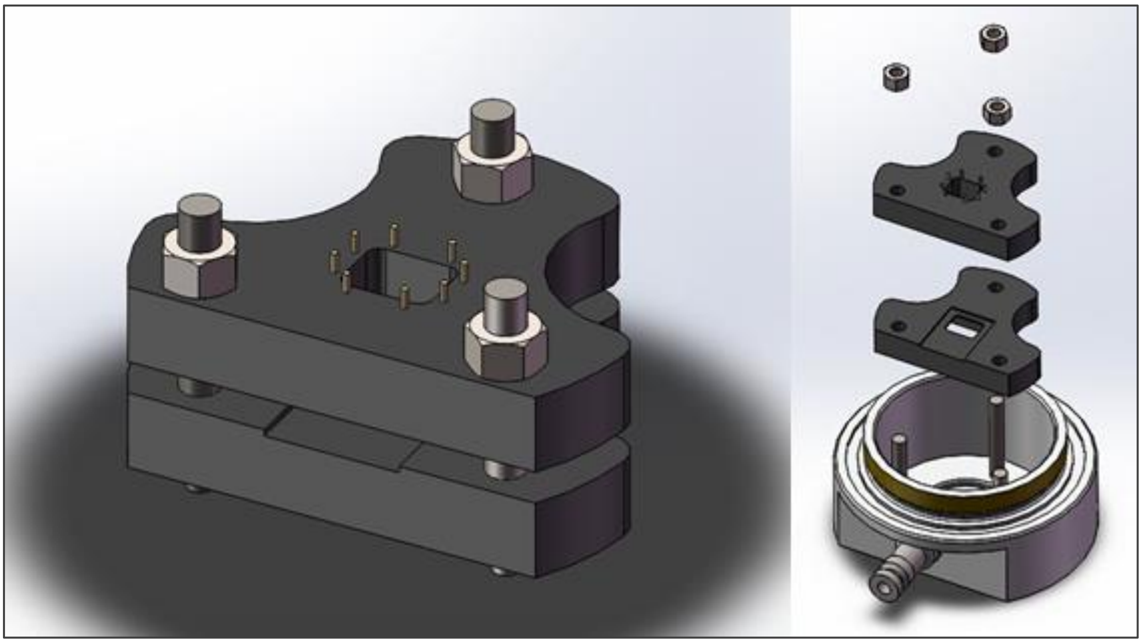


Figure 14; New connector block design

2.6 Conclusion of assignment

In consolation with CTI all requirements were set up. Different concepts have been developed which comply with the requirements. All of these concepts have been considered and one has been chosen which is the cheapest, most easy to build and most easy to handle. This concept has been further developed and the final design is proposed in 2.5. This design makes use of an insertable connector block in which the OLED is clamped. These connector blocks can easily be replaced by other ones in order to clamp and connect other sizes and/or types of OLED.

Unfortunately the product could not be produced during the time of the internship. Therefore it was not possible to test the functionality of the device. This means that requirement 1 and 3 from 2.2 could not be checked. But nevertheless it can be concluded that a design has been proposed which meets the requirements as described in 2.3 and therefore the assignment is completed.

Part 2; Automated Blade Coater

3.1 Introduction

The different layers in OLED devices are currently being produced by use of vacuum deposition. For this method the substrate is placed in a vacuum chamber. In the vacuum chamber an amount of species is injected into the vacuum. This causes the species to deposit on the substrate resulting in a layer with a certain thickness and a pretty high rate of uniformity. The layer is dried and the process is repeated for the other layers. This method is very expensive and not suited for a continuous production process because the substrate has to be placed in and out the vacuum multiple times. Also the production of large OLED devices would be very costly because large vacuum chambers are very expensive.

One aspect of the research by CTI on OLED technology is the production of OLED devices using alternative production techniques. It would be ideal for future production processes if the production technique required for OLED devices could be made roll-to-roll, see Figure 15. This means that the production process is continuous, like the roll-press of a newspaper. This is not the case with vacuum deposition.

A possible way to achieve this is to apply the different layers of the OLED by use of blade-coating (also known as knife coating or doctor blading). This is a technique often used for coating large areas on rigid or flexible substrates. A solution containing the useful material is placed on the substrate in front of the blade. Then by a displacement of the blade relative to the substrate, the solution is coated over the substrate. See Figure 16 and Figure 17. This solution must be dried so that only the functional material in the solution is left; this is done by a thermal treatment using a hot plate under the sample and hot air blowing over the sample. Several scientific papers show that the required accuracy and uniformity can be obtained by this method and that OLED devices can be made using this technique.[5]

Currently the scientific progress is at this very point. It is shown that OLED devices can be made using this technique but further research is required to implement it in roll-to-roll production techniques.

[5] *Unmodified small-molecule organic light-emitting diodes by blade coating, 2012*. By Yu-Fan Chang et al. *Continuous blade coating for multi-layer large-area organic light emitting diode and solar cell, 2011.* By Chun-Yu Chen et al.

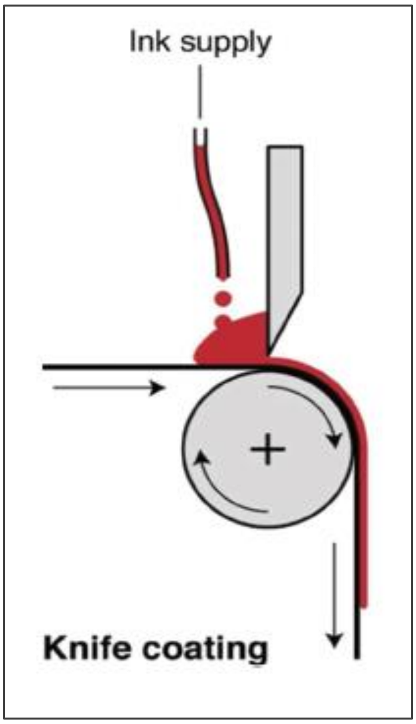


Figure 15; Example of roll-to-roll
Roar R. Søndergaard 2012

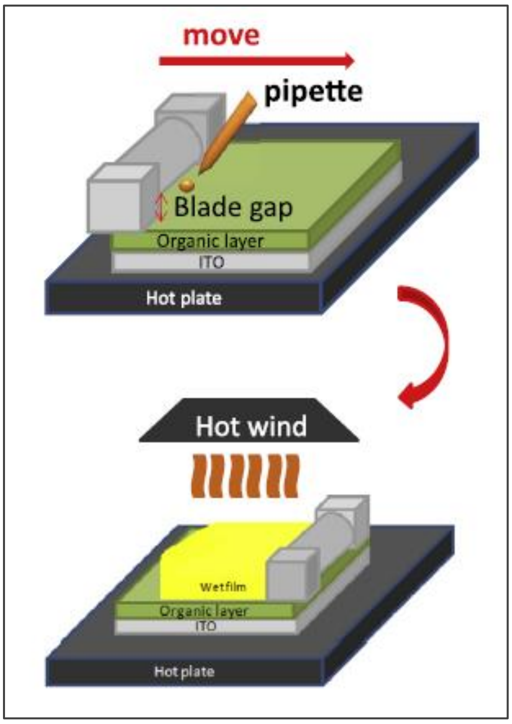


Figure 16; Blade coating principle
Chun-Yu Chen 2011

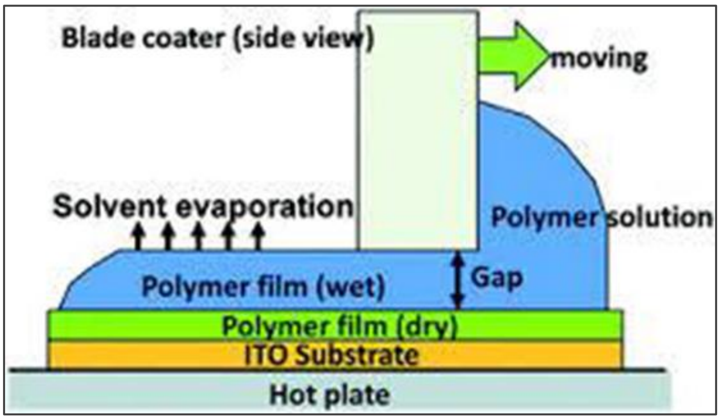


Figure 17; Blade coating principle
Shin-Rong Tseng 2011

3.2 Problem definition

Besides the vacuum deposition technique the blade coating technique is currently also used at CTI for making OLED's. Use is made of a manual blade coating device as shown in Figure 18. With use of a pipette the solution is placed in front of the blade. Then the Manual Blade Coater is moved by hand on the handgrips with a steady velocity. In this way the substrate can be coated layer by layer. The gap height between the substrate and the blade can be adjusted by the two micrometers on the device.

To deposit a layer the gap height and the blade velocity are of importance. Although the gap height can be adjusted very accurately with this device, the speed at which the Manual Blade Coater is moved is not. When the device is moved by hand it cannot be assured that the velocity is constant and that the drag speed is exactly the same for every operation. This results in variations in the layers and thus in the OLED's. For research purposes this is highly undesirable.

3.3 Analysis

If the blade movement would be done automatically then the blade speed will be the same for every operation. This would make the results much more reliable.

The device has to produce a translative motion. It is not required to integrate the actual doctor blade in the design. Commercially available applicators can easily be bought and implemented in the design, see Figure 19. These highly accurate applicators are to be pushed forward by the automated blade coater but must not be rigidly attached. In this way the applicator will follow the contour of the plate over which it travels and the accuracy of the layer thickness will be high.

The Automatic Blade Coater must meet the following requirements.

1. The whole system must fit inside the large glove-box antechamber.
2. Dimensions: minimum and maximum 300±50 x 200±50 mm (LxW), H<200 mm.
3. The surface on where the substrate will be placed must be: easy to clean, smooth, stiff, replaceable and must be able to be replaced by a heated table.
4. Heated table will get up to 150^{o}C; the structure must be able to resist this.
5. Blade speed up to 1m/s.
6. At full speed the maximum deviation in velocity (due to lack of stiffness) must be within ±10%.
7. Blade speed must be adjustable.
8. Device must be capable to coat a substrate with dimensions up to 100x100 mm.

Only the mechanical part of the product is to be designed. The electrical part is not part of the assignment and shall be designed by someone else at CTI.

Figure 18; Manual blade coater

Figure 19; Commercial available device for blade coating
Zehntner 1014

3.4 Concepts

Different concepts have been developed. The concepts show different ways to move the blade over the substrate. For each of these concepts the driving mechanism (belt, actuator, ball screw, toothed rack etc.) has not been specified yet because this can be chosen separately from the design. The way the concepts work will be explained for each concept.

Concept A

In concept A in Figure 20 the blade is rigidly attached. The substrate plate moves over a guidance underneath the blade. Because the guidance has to be located under the substrate plate, the guidance could get contaminated if the solution is spilled over the substrate plate. This is a disadvantage of the concept. Also for the substrate plate a heated plate will be used. This is a heavy component to move.

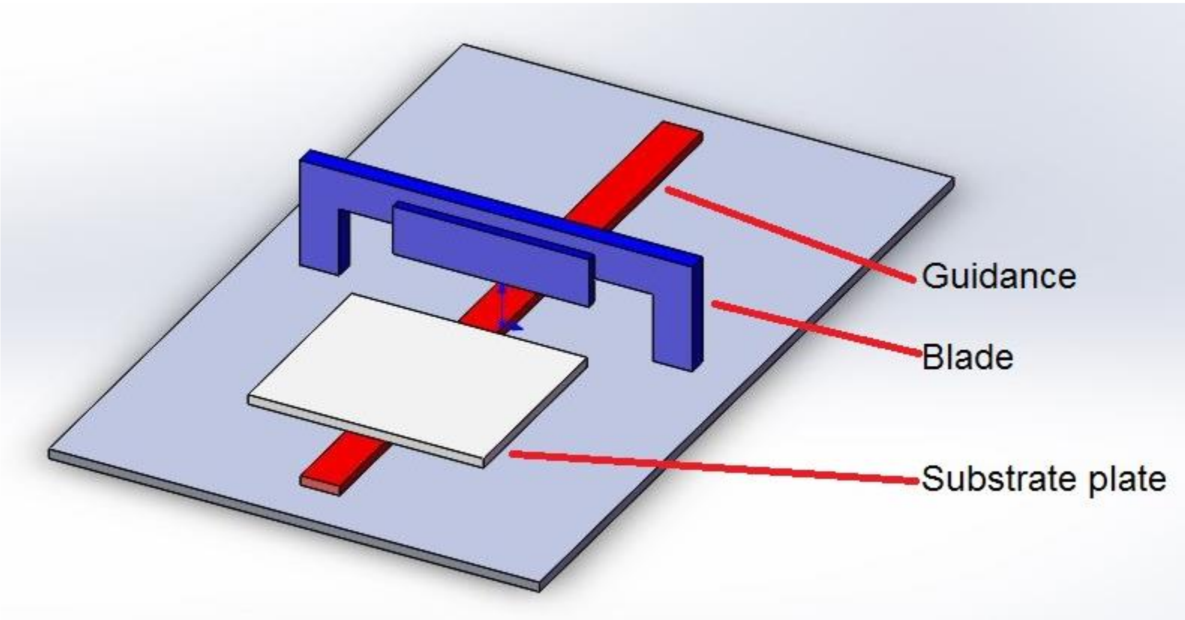


Figure 20; Concept A

Concept B

In concept B in Figure 21 the substrate plate is rigidly attached and the blade moves by a guidance over the substrate plate. There are two guidances at each side of the substrate plate. These can also be located underneath the substrate plate to reduce the size.

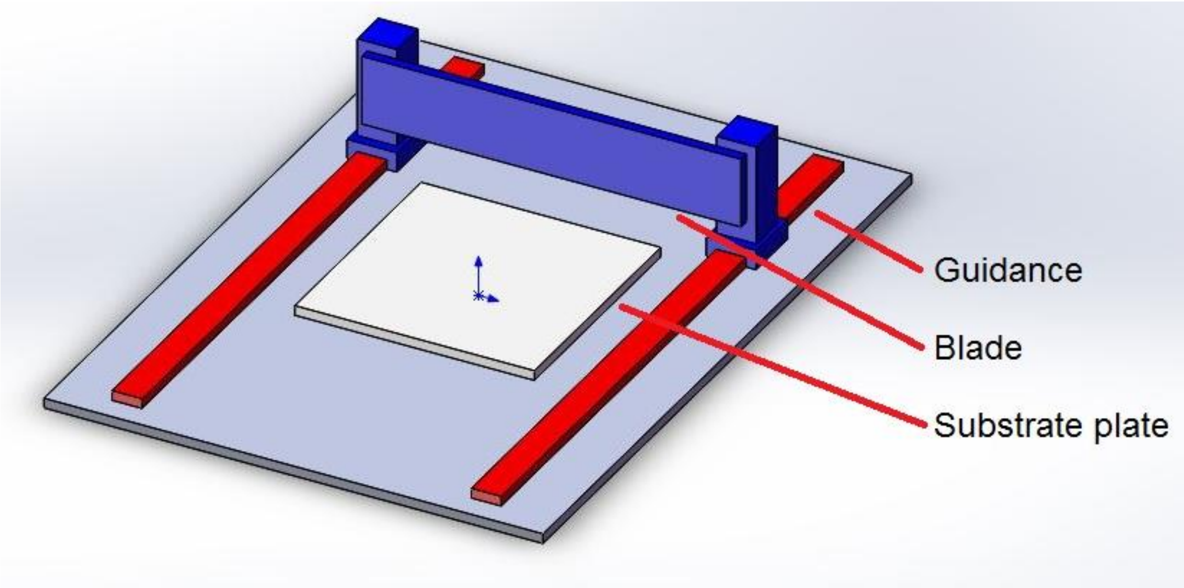


Figure 21; Concept B

Concept C

Concept C is similar to concept B only with one guidance besides the substrate plate, see Figure 22. The blade moves over the guidance. However this design is less accurate.

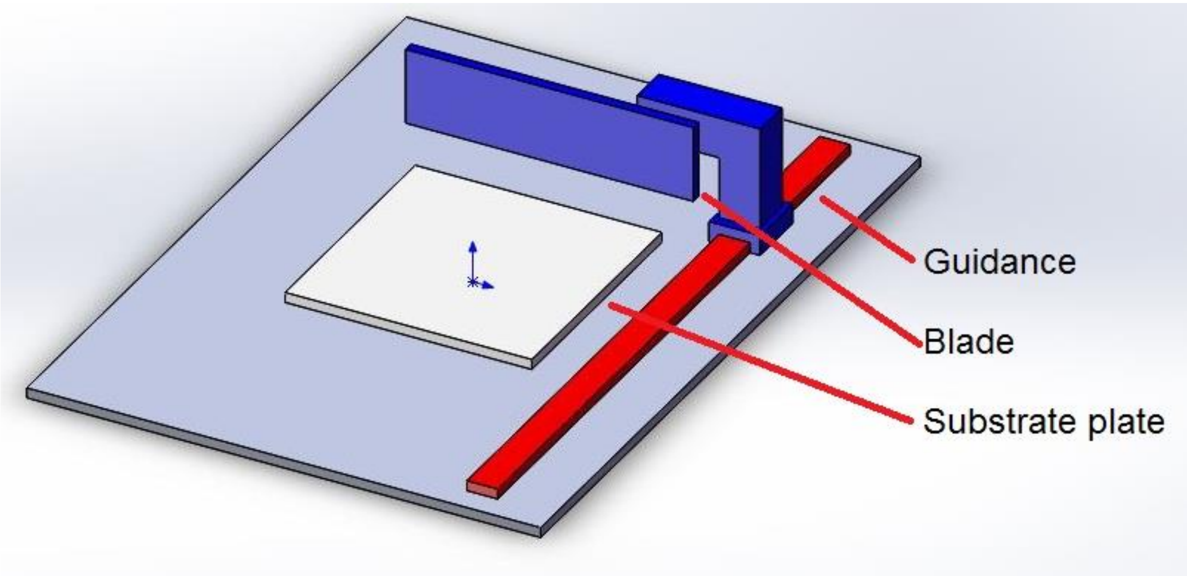


Figure 22; Concept C

3.4.1 Concept choice

In consulation with CTI concept B has been chosen. This concept is chosen because this concept does not have any of the disadvantages of the other concepts. Also with concept B the guidances can be located underneath the substrate plate which makes the design more compact. For the driving mechanism the choice is made to use a belt. This is the cheapest solution which provides enough accuracy.

Concept A is the most promising design and is therefore chosen to be the final design to be worked out further.

3.5 Final design

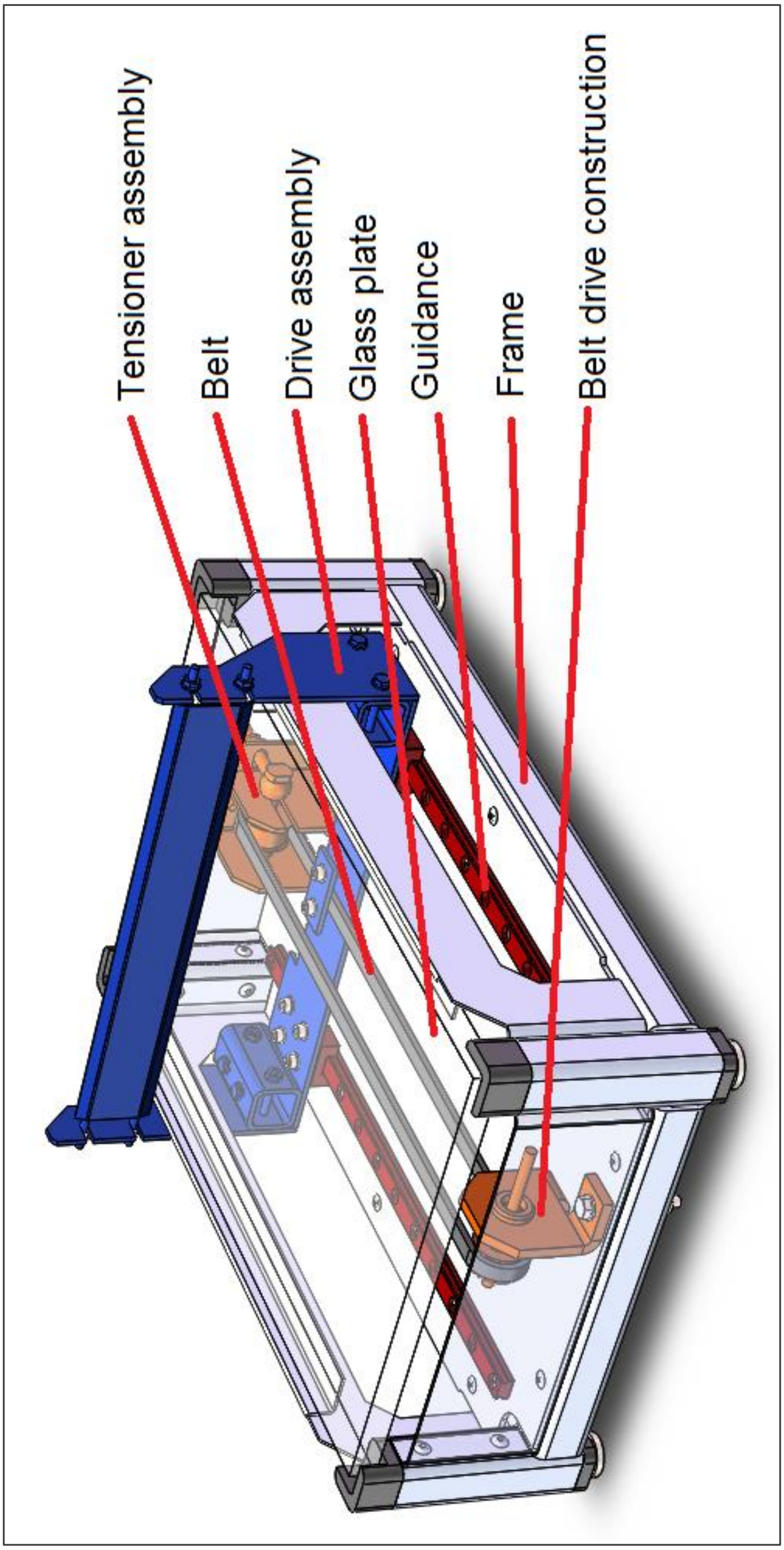


Figure 23; Final design isometric view

3.5.1 How it works

The final design is based on concept B and is shown in Figure 23 and Figure 24. It consists of an aluminum frame where two guidances and a belt construction are attached. The belt drive construction drives the drive assembly forwards and backwards. This drive assembly then moves over the glass plate on top where the sample is created. (See Figure 23 for all the components). The glass plate can be replaced for a heated plate as prescribed in the requirements. During the design phase of the Automated Blade Coater no data was available about the heated plate which was to be used. Therefore in the design just a glass plate is shown. The outer dimensions of the device are 300x200x140 (LxWxH in mm).

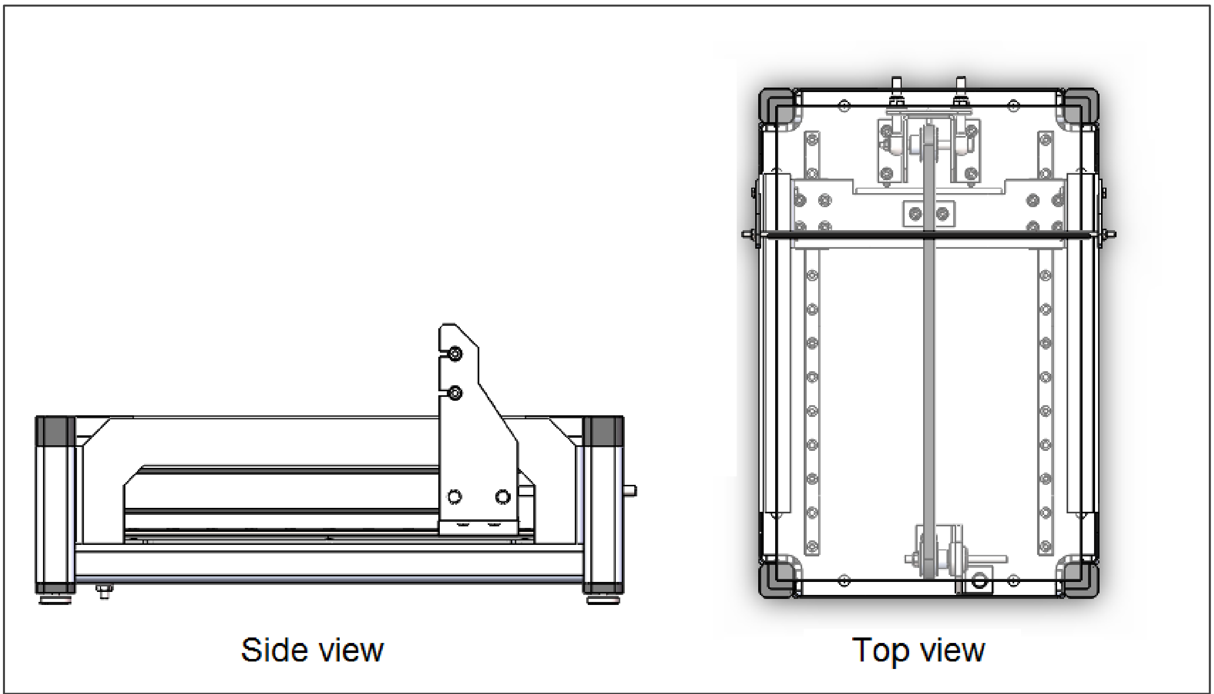


Figure 24; Final design side- and top view

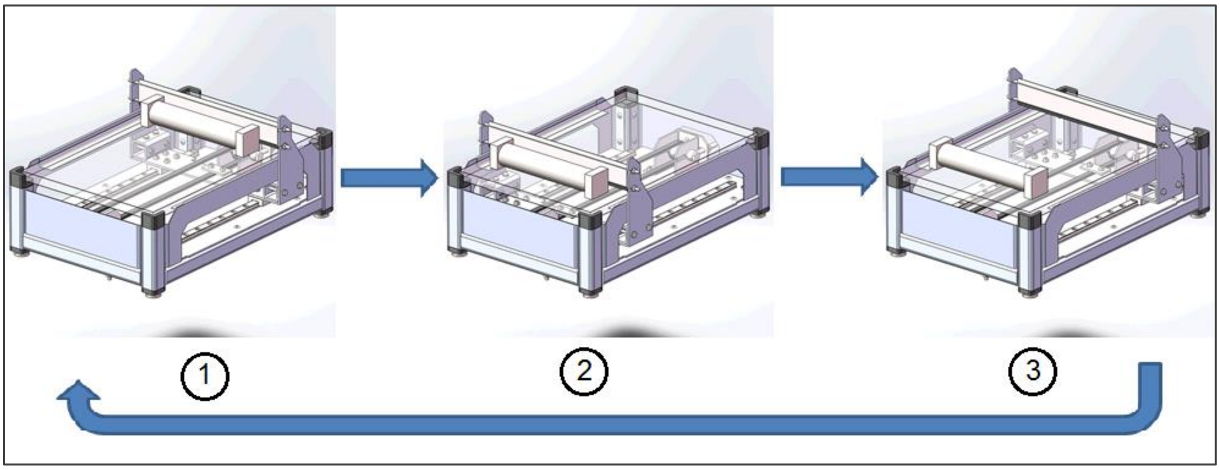


Figure 25; Blade coating cycle

The drive assembly moves forward and pushes an applicator as in Figure 19 with it. The drive assembly accelerates until the desired speed is achieved and then moves with constant speed before it decelerates again at the end of the glass plate. Then the same motion is repeated in the other direction. Figure 25 shows the cycle of the device.

Note that the applicator stays behind at the end of the stroke. The applicator has to be placed in front of the drive assembly by hand after every stroke. There are multiple reasons why the applicator is not attached to the drive assembly.

- If the (glass or heated) plate is not completely straight or flat then the applicator will correct for this when it moves over the plate. Attaching it rigidly to the drive assembly makes in move in a straight line while the plate might not be perfectly straight.
- When the drive assembly moves back again (from situation 2 to 3 in Figure 25) and the applicator would be attached to the drive assembly, the applicator will get in contact with the layer again and this will damage the layer.
- Deposition of different layer thicknesses may be required when making an OLED, therefore different applicators are required. They cannot be changed quickly when they are attached to the drive assembly.

3.5.2 Belt drive/tensioner

The belt is driven by the belt drive construction, see Figure 23 and Figure 26. On this shaft the electro motor will be attached to apply torque to the system. The shaft is placed in a bearing which is placed in the bearing holder and the support. The wheel is rigidly connected to the shaft. All connections are made by interference fits to simplify the assembly; everything can just be pressed into each other. Except for the connection of the wheel and the shaft, this wheel is just clamped to the shaft with the nut and washer.

The other wheel is placed in an assembly which can tighten the belt in order to get the required pre-tension on the belt, see Figure 27 and Table 1. The tightening can be done by adjusting the nut on the set screw. At this assembly the wheel is not rigidly connected to the shaft but there is a needle bearing in between the shaft and the wheel. The needle bearing is clamped between an edge on the shaft and the bushing which is tightened with a bolt and washer on the end of the axle.

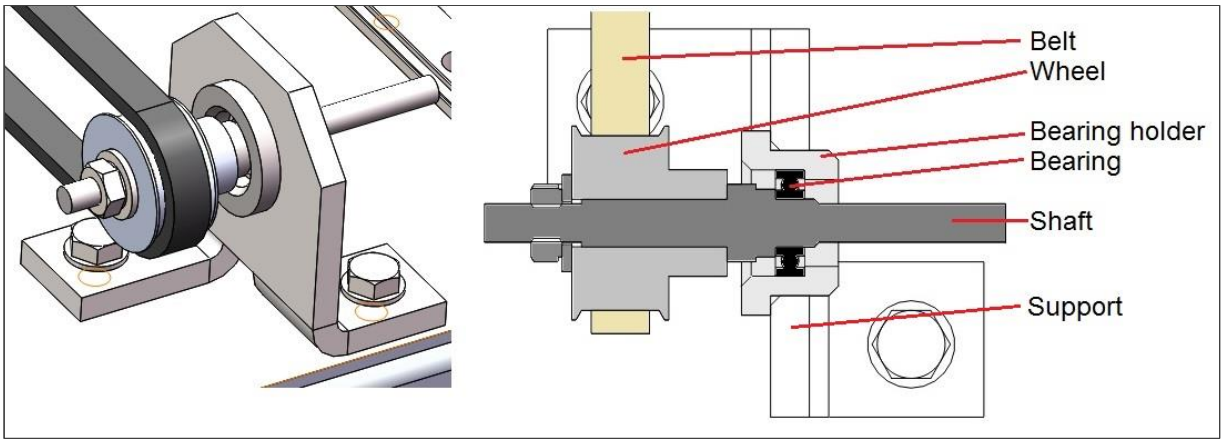


Figure 26; Belt drive construction, isometric left, cross-section right

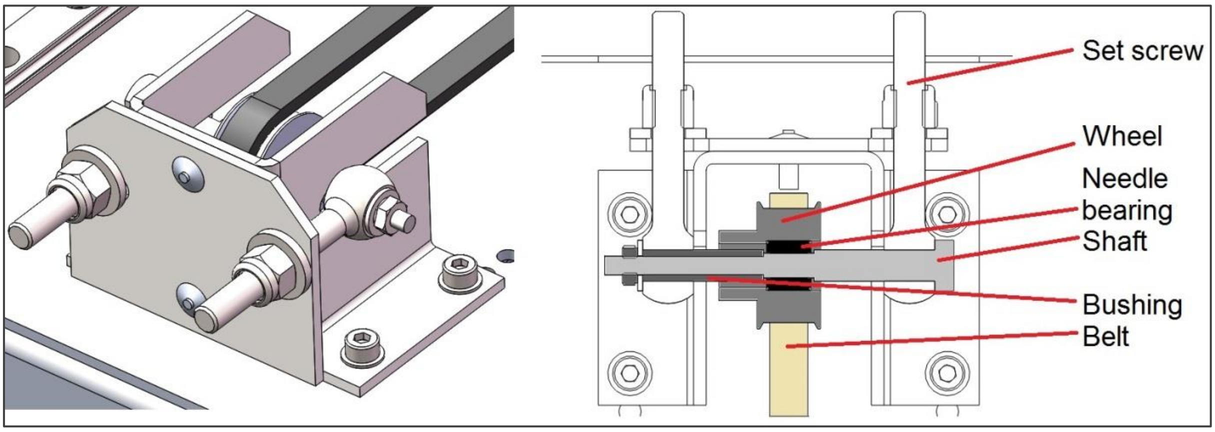


Figure 27; Belt tensioner assembly, isometric left, cross-section right

Part	Description	Remark
Belt	SIT HTD Belt HTD 0525 3 M006	Elasticity = $2*10^9$ N/m
Guidance	NSK-PU09UR	
Bearing	SKF 618-5	
Needle bearing	ISO 3245, D = 7mm, d = 4 mm, W = 7mm	
Wheel	Sprocket 20, D = 18 mm, tooth pitch = 2.5 mm	

Table 1; Parts

3.6 Performance

In order to see whether the dynamic specifications can be achieved a Simulink model of the system was made. As described in 3.3, the final product must be able to achieve a speed of up to 1m/s and cover a distance of 100mm with this constant speed while keeping the variation of the speed within 10%.

The final design makes use of a DC-electro motor that moves the drive assembly by a belt. The construction can be modeled as a 2 degree of freedom model. There is some elasticity between the drive assembly and the driven gear wheel because of the belt. Therefore this belt can be modeled as a spring between the rigid mass of the drive assembly, and the wheel of the DC-motor. The rigid mass has some friction in the guidance and in the upper part where the layer is deposited; these sources of friction are with respect to the static world.

See Figure 28 for the real model, the ideal physical model and the simplified physical model. For the simplified physical model the equivalent mass and equivalent stiffness are used.[6]

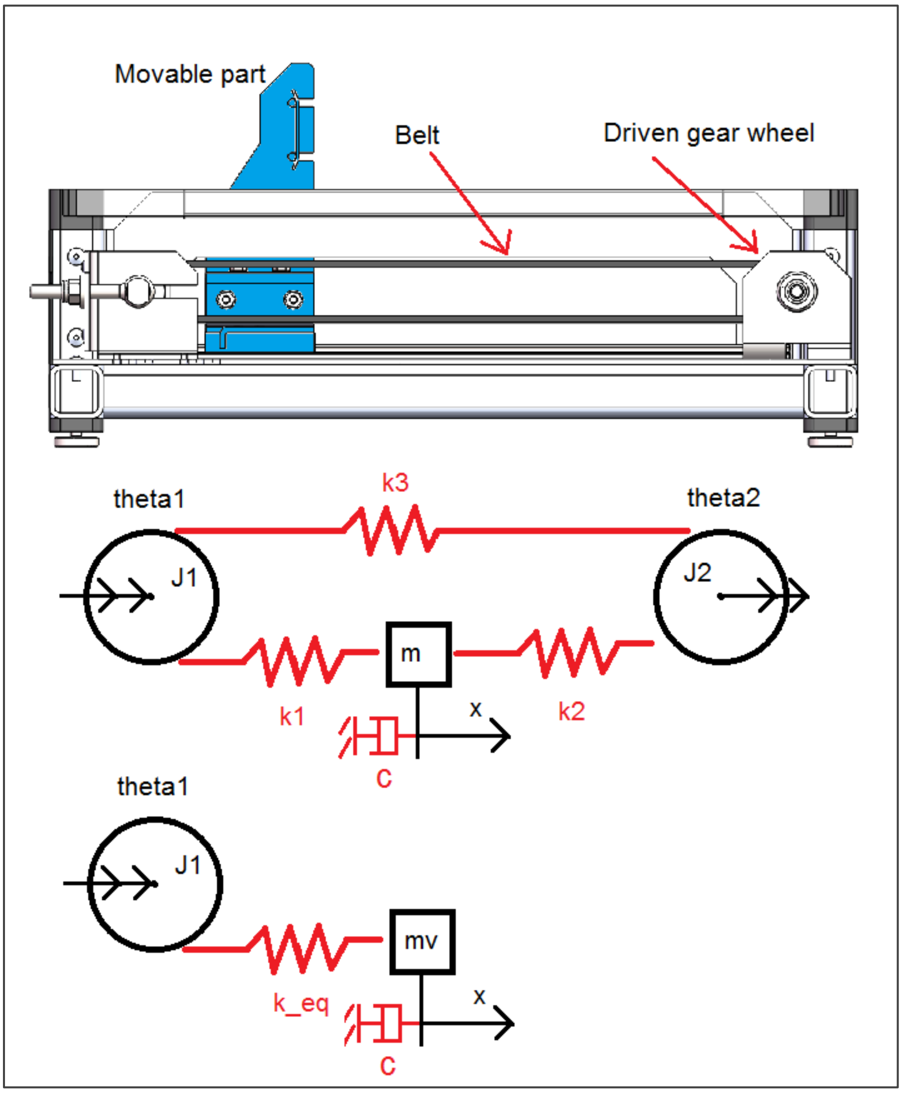


Figure 28; Real model, IPM, simplified IPM

[6] For how to calculate these see; '*System and Control Engineering 1*' by dr.ir. R.G.K.M. Aarts 2010 page 7 & 18.

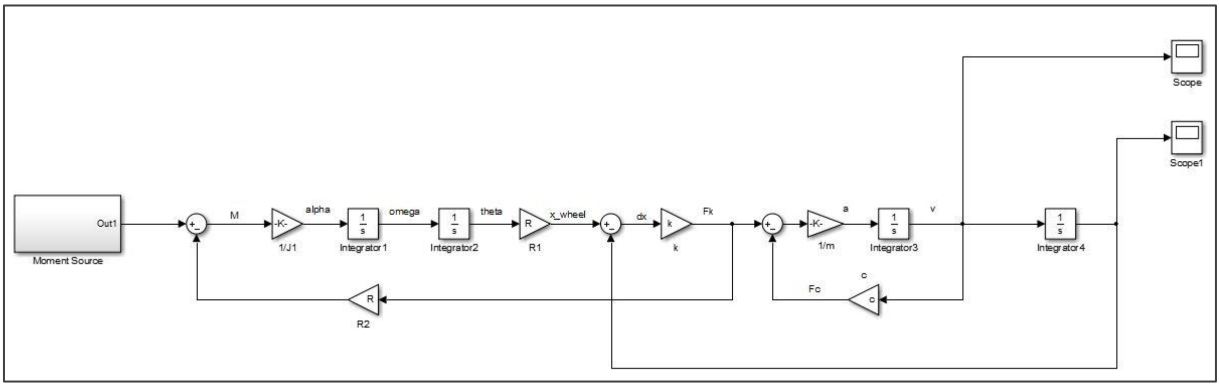


Figure 29; Simulink model of the mechanical system

The Simulink model is based on the simplified physical model and can be found in Figure 29. Before the dynamics of the system is analyzed first the required torque of the DC-electro motor is calculated.

3.6.1 Torque calculation

The total stroke of the Automated Blade Coater is 165 mm, therefore the machine must be able to cover a distance of 100mm (minimum substrate size) at constant speed of 1m/s while having enough room to accelerate and decelerate within this stroke, see Figure 30. A good estimation of these distances and required acceleration can be computed by assuming a rigid body translation. These accelerations will serve as input in the Simulink model in the form of required moment from the DC-electro motor.

If it is assumed that the distance to accelerate is equal to the distance to decelerate, this distance can be computer in the following way.

$$L_{accel.} = \frac{total\ stroke - stroke\ at\ constant\ v.}{2} = \frac{L_0 - L_1}{2}$$

And if a constant acceleration is assumed the required time (t_a) to get to the required speed (v_1) can be computed in the following way. Note that the initial displacement and velocity are zero.

$$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$$
$$x(t) = 0 + 0 + \frac{1}{2} a t^2$$
$$v_1 = v_0 + a t_a = a t_a$$
$$L_{accel.} = \frac{1}{2} a t_a^2 = \frac{1}{2} v_1 t_a$$
$$t_a = \frac{2L_{accel.}}{v_1} = \frac{L_0 - L_1}{v_1}$$

From the velocity equation the acceleration can now be computed.

$$v_1 = at_a$$
$$a = \frac{v_1}{t_a} = \frac{v_1^2}{L_0 - L_1}$$

And from here it is easy to calculate the required moment (or torque) with use of the radius of the wheel that drives the belt (r_{wheel}). Note that the equivalent mass is used in the calculation below.

$$F = m_{eq} a_1$$
$$M = Fr_{wheel} = \frac{m_{eq}\, v_1^2\, r_{wheel}}{L_0 - L_1}$$

Dimension check; $M = \frac{m_{eq}\, v_1^2\, r_{wheel}}{L_0 - L_1} = [kg]\left[\frac{m^2}{s^2}\right][m]\left[\frac{1}{m}\right] = [kg]\left[\frac{m}{s^2}\right][m] = [N][m]$

For the system with the current parameters a required torque of 0.11 Nm at 18 RPM would at least be needed to obtain the required velocity within the stroke of the device.

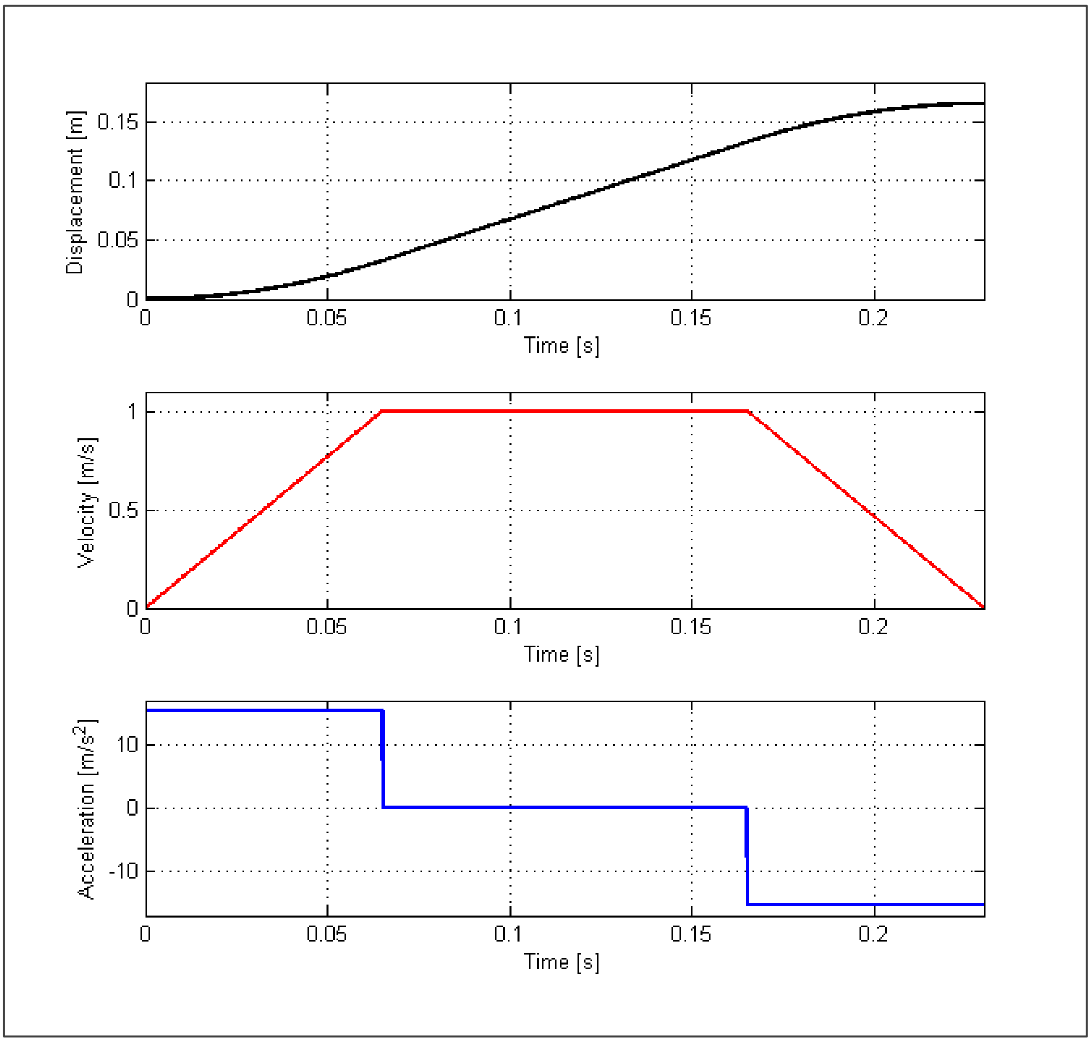


Figure 30; Displacement, velocity and acceleration curves

3.6.2 Simulation of physical behavior

The parameters computed in the previous section are used in the Simulink model of Figure 29. The solution for the velocity is expected to be similar to the second plot in Figure 30 but with some harmonic oscillations in it because the Simulink model contains 2 DOF's (degrees of freedom). Since the electrical part is not considered in this analysis the moment source is considered as an ideal source, this means it will give the 'perfect' step function for input as shown in Figure 31. This is the input function for the worst case scenario, meaning with the highest required velocity (1 m/s).

The velocity response of the system on this input function is shown in Figure 32. The oscillatory behavior can clearly be seen. In the figure it can be seen that the deviation caused by the oscillation is still within 10% of the required value. Hence the chosen parts (see Table 1) should provide sufficient accuracy for the final product. The product could be optimized even further but this is not the goal of the assignment. A device must be designed which meets all the requirements at the lowest costs, implementing other, less common, parts might reduce the performance within the criteria but it will not decrease costs because the device is currently designed with parts which are more easy to come by.

The displacement curve is shown in Figure 33, it can be seen that the end value is exactly the total stroke of the device as expected.

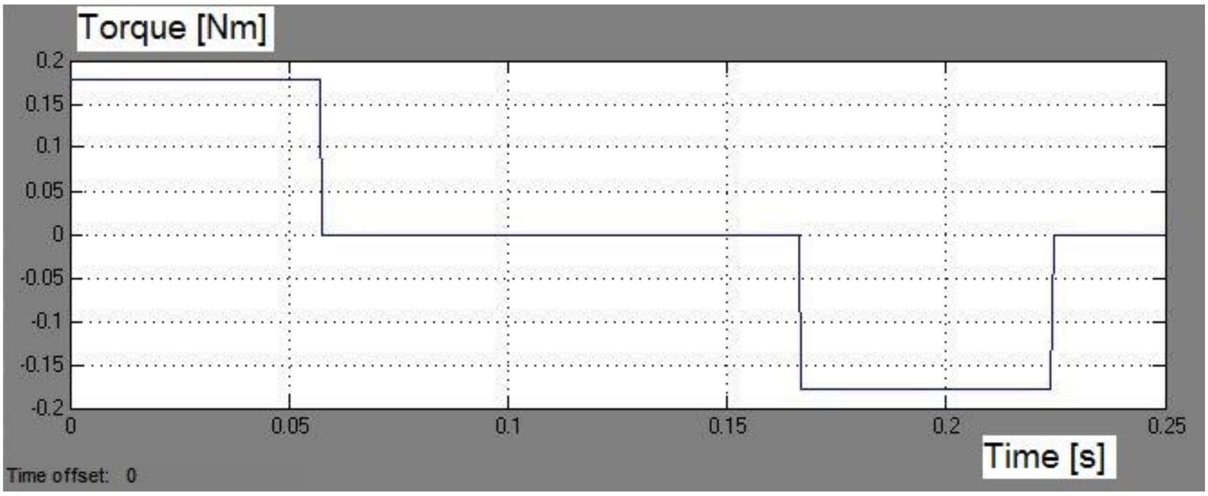


Figure 31; Torque input signal

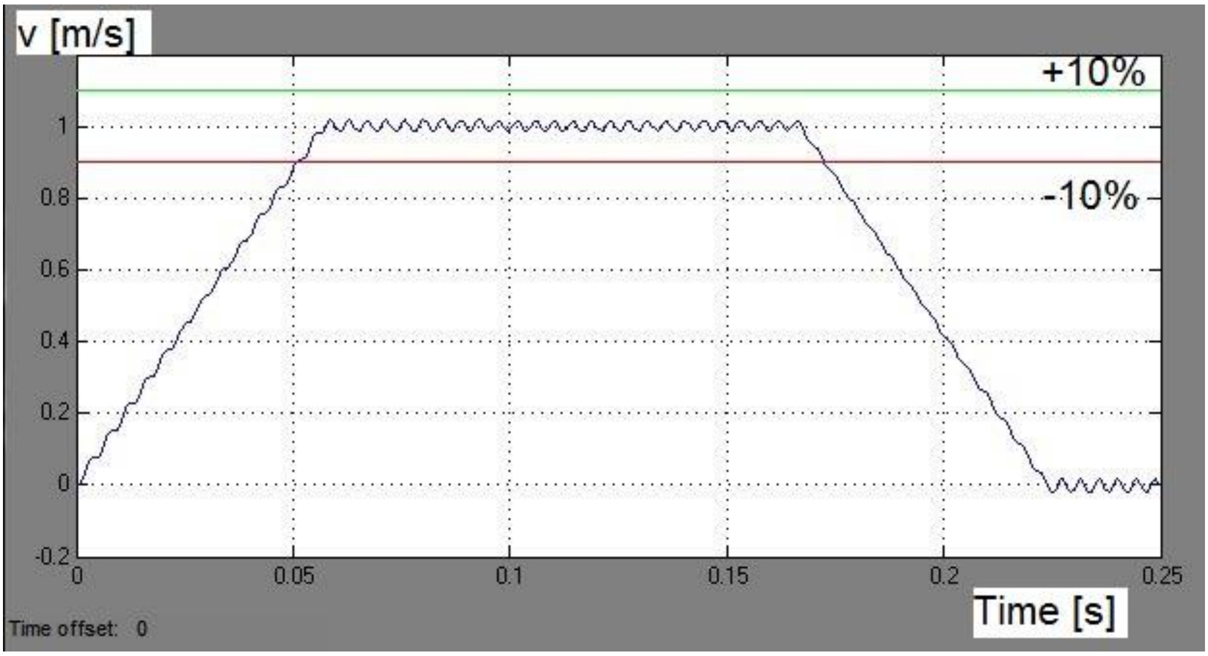


Figure 32; Velocity response without damping

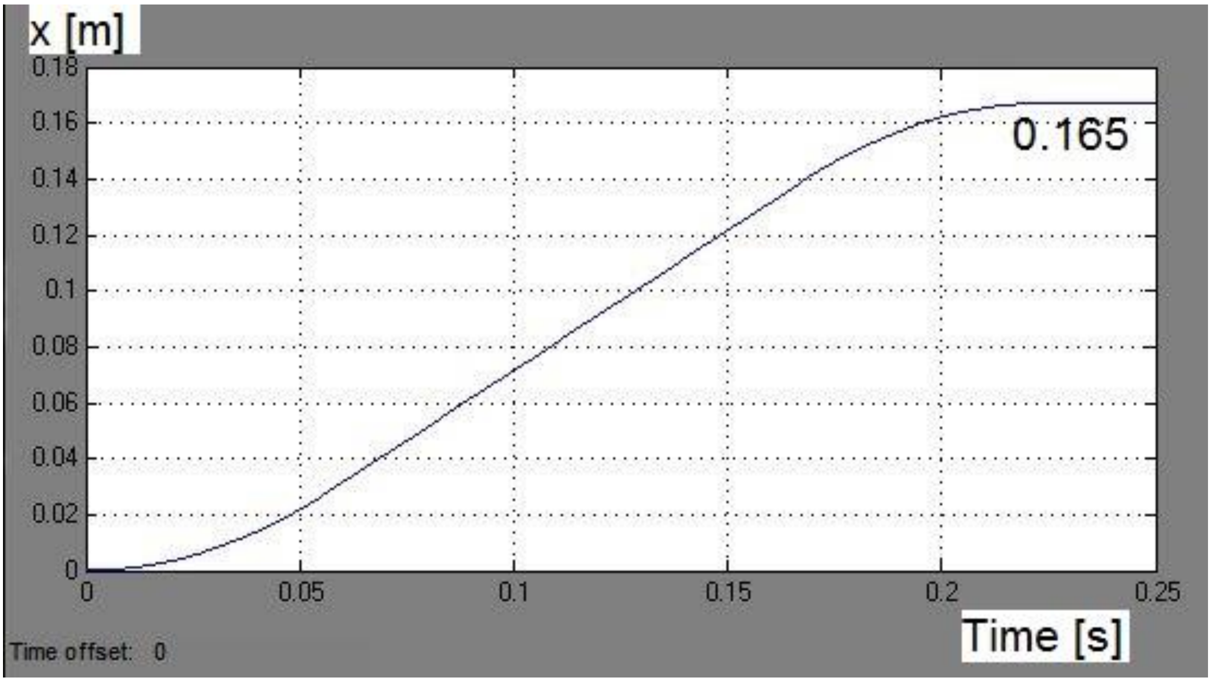


Figure 33; Displacement curve

This analysis is done based on the assumption that there is no friction (c=0), however in reality there will always be friction somewhere in the guidance and in the blade coating area. The exact value of this friction parameter is difficult to obtain theoretically, the most reliable values can be obtained when the device is actually built and the friction is then measured. Once this friction parameter is known the required torque can easily be adjusted to still meet the requirements (assuming that the friction will be small). The result of the velocity profile for different values of friction coefficient is shown in Figure 34 and Figure 35.

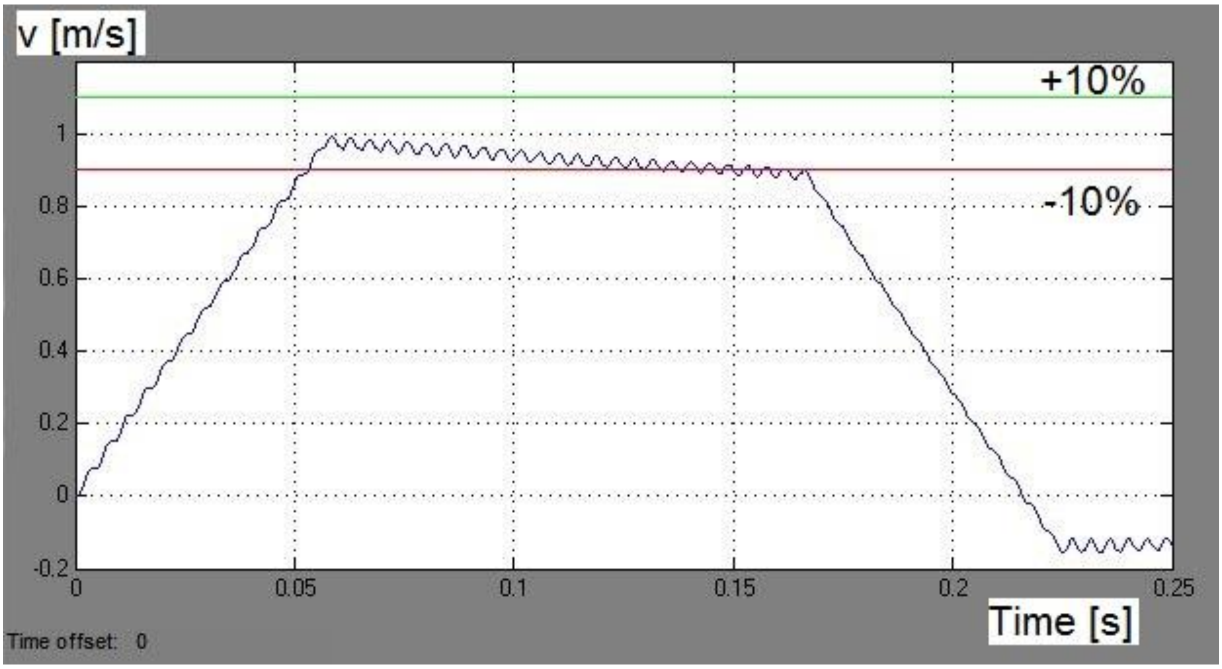


Figure 34; Velocity response with c=0.5

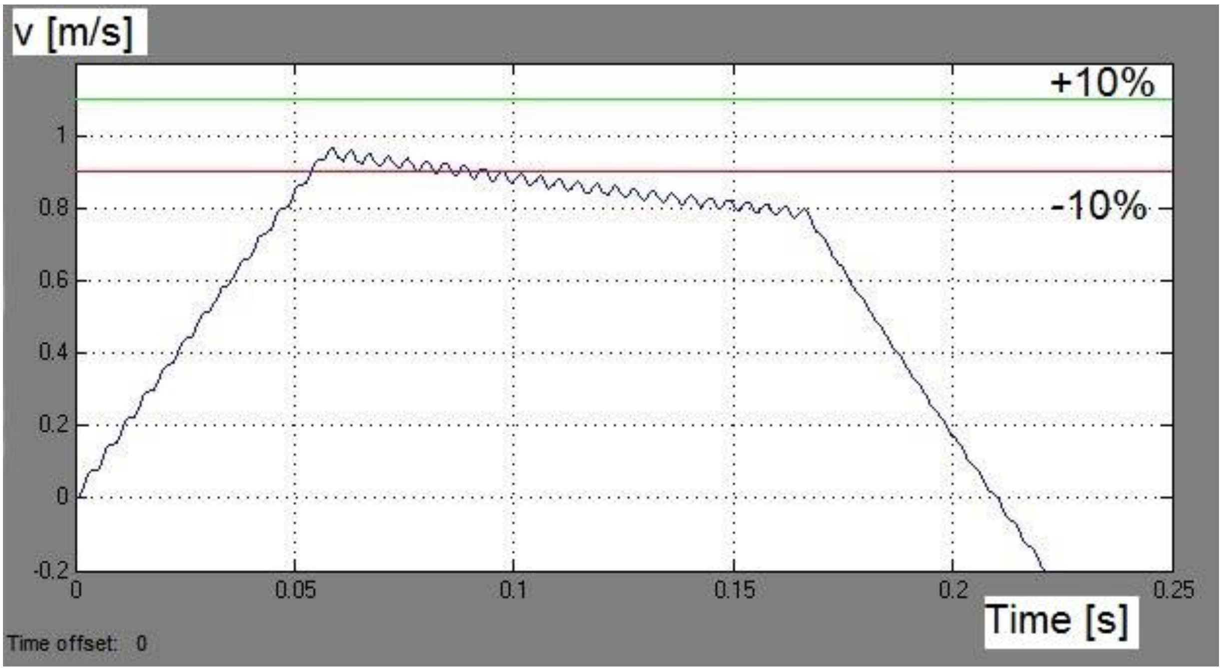


Figure 35; Velocity response with c=1.0

It can be seen that the velocity decreases when it should remain steady, this was to be expected since the torque reduces to zero in this area, see Figure 31. Therefore the small friction reduces the velocity. This can easily be helped by adjusting the torque curve of Figure 31. Another result of the damping is that the oscillation as a result of the accelerations reduces over time, they damp out (this can better be seen in a zoomed image). This would only work beneficial to the design because the deviation by the oscillation will decrease.

With this design all requirements have been met. The electrical system for the device is still to be designed but this should pose no problem. A DC-electro motor is to be implemented as well as its power supply and sensors to limit the stroke of the device (optical sensors for example).

3.7 Conclusion of assignment

The problems occurring with the Manual Blade Coater have been investigated. The solution was to design an Automated Blade Coater. The requirements of this device have been set up in consolation with CTI. Different concepts have been developed and concept B has chosen to be the best option. This concept has been further developed and the final design is proposed in 3.5. The design uses a belt mechanism to move the blade over the stationary table where the substrate is located. The dynamic behavior of the system has been modeled.

It can be concluded that a design is proposed that complies with all the requirements. The electrical part of the device, like the electromotor, power supply, control panel and engine controller still need to be designed. However this will not be a problem for an experienced electrical engineer.

During the internship the production of the Automated Blade Coater could not be completed. Because of this it was not possible to conduct tests in order to see if the calculations were correct. Nor was it possible to measure the amount of friction in the device. However a design has been proposed which meets the requirements as proposed in 3.3 and therefore it can be concluded that the assignment is completed.

4. Conclusion

The internship at CTI has been completed within the designated time and the proposed assignments have been successfully completed. For the OLED capsule a complete design has been made including all necessary technical drawings for production purposes. Currently at the time of writing this device is being constructed at the workshop of CTI. Unfortunately the duration of the internship was slightly too short to see the final product and to conduct tests with it. For the Automated Blade Coater a design have been proposed which meets all requirements, the mechanical part of the design has been analysed and proven to be good for the application.

5. Reflection

During the internship at CTI I have learned a lot about working in a research institute like CTI. At the company I was expected to work a lot on my own. From this I learned to work more independently. Before the start of the internship I did not know a lot about OLED technology. It was required for me to gain knowledge about this technology in a short amount of time. I learned to adapt to situations like this.

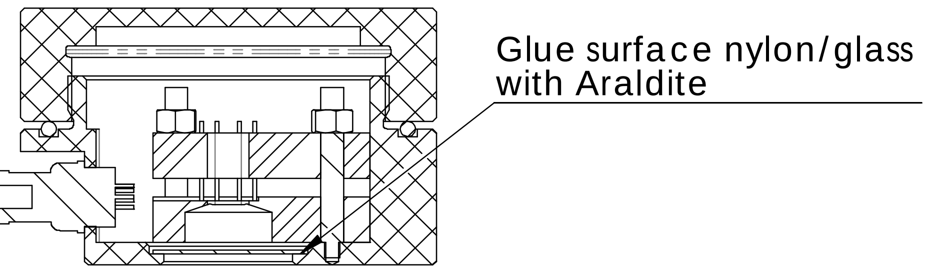
6. Epilogue

Much has been learned by the student from the time here in Brazil, as well in working experience in a research company such as CTI as in cultural knowledge by travelling to and through Brazil. I would like to thank all the co-workers at CTI for all their help during the internship

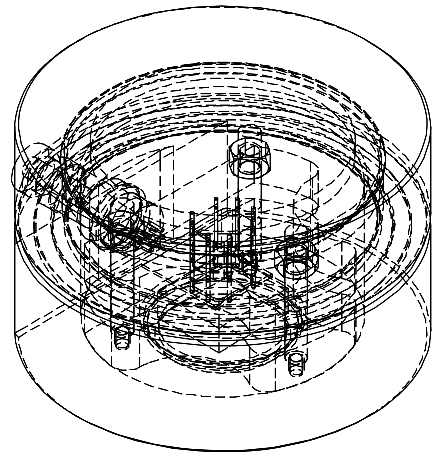
Muito obrigado Brasil, ver você na proxima vez.

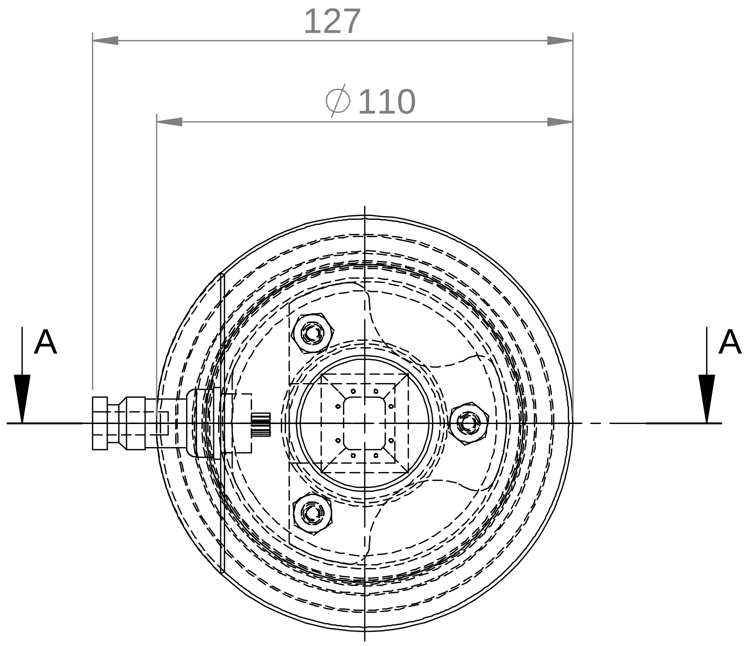
Sjoerd de Bekker 2015

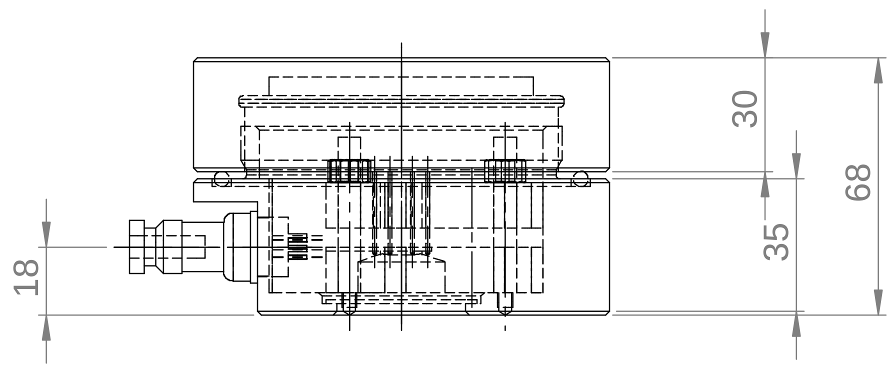
7. Appendix A

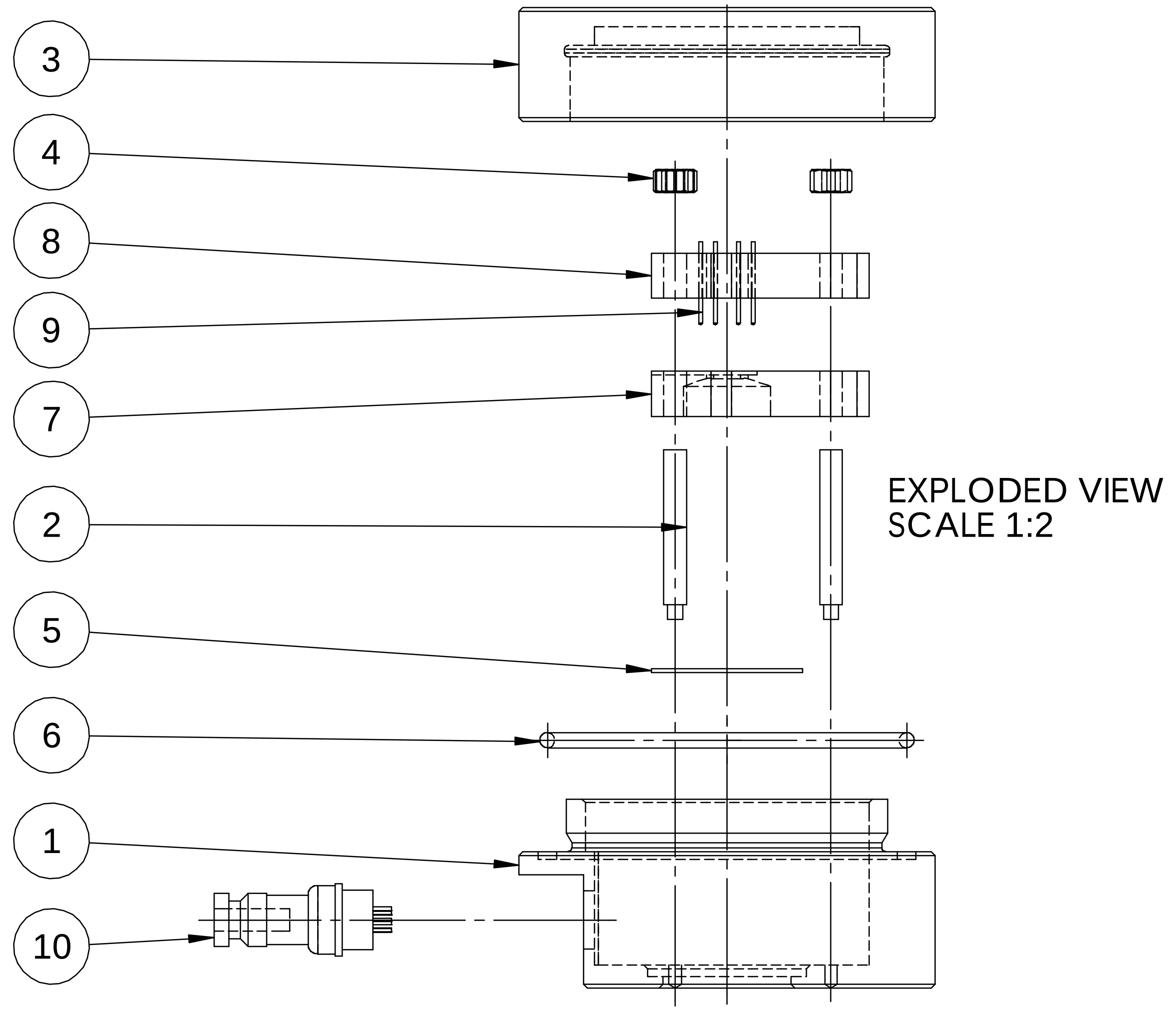


SECTION A-A









EXPLODED VIEW
SCALE 1:2

ITEM NO.	PART NUMBER	DESCRIPTION	Simplified/QTY.
1	Capsule Base 2	Capsule Base	1
2	Insert2 rod	Insert Rod	3
3	Capsule Top 2	Capsule Top	1
4	Hexagon Nut ISO - 4034 - M6 - N		3
5	Quartz Glass Plate		1
6	Rubber Seal		1
7	Insert3 part1		1
8	Insert3 part2		1
9	Insert2 connector		8
10	Connector2		1

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION

	NAME	SIGNATURE	DATE
DRAWN	S. de Bekker		26-11-2014
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

TITLE:

Capsule Assembly

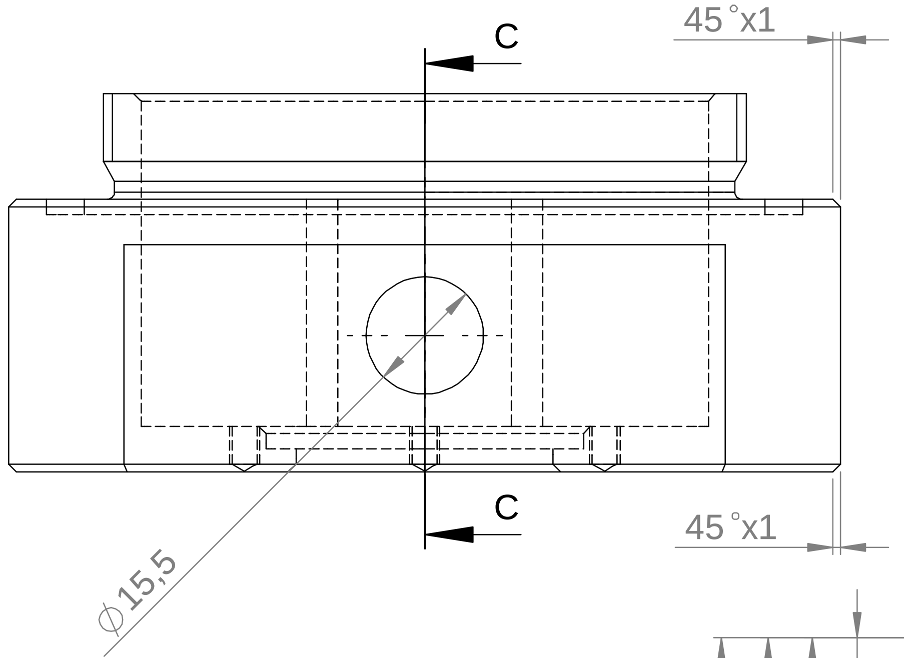
DWG NO.

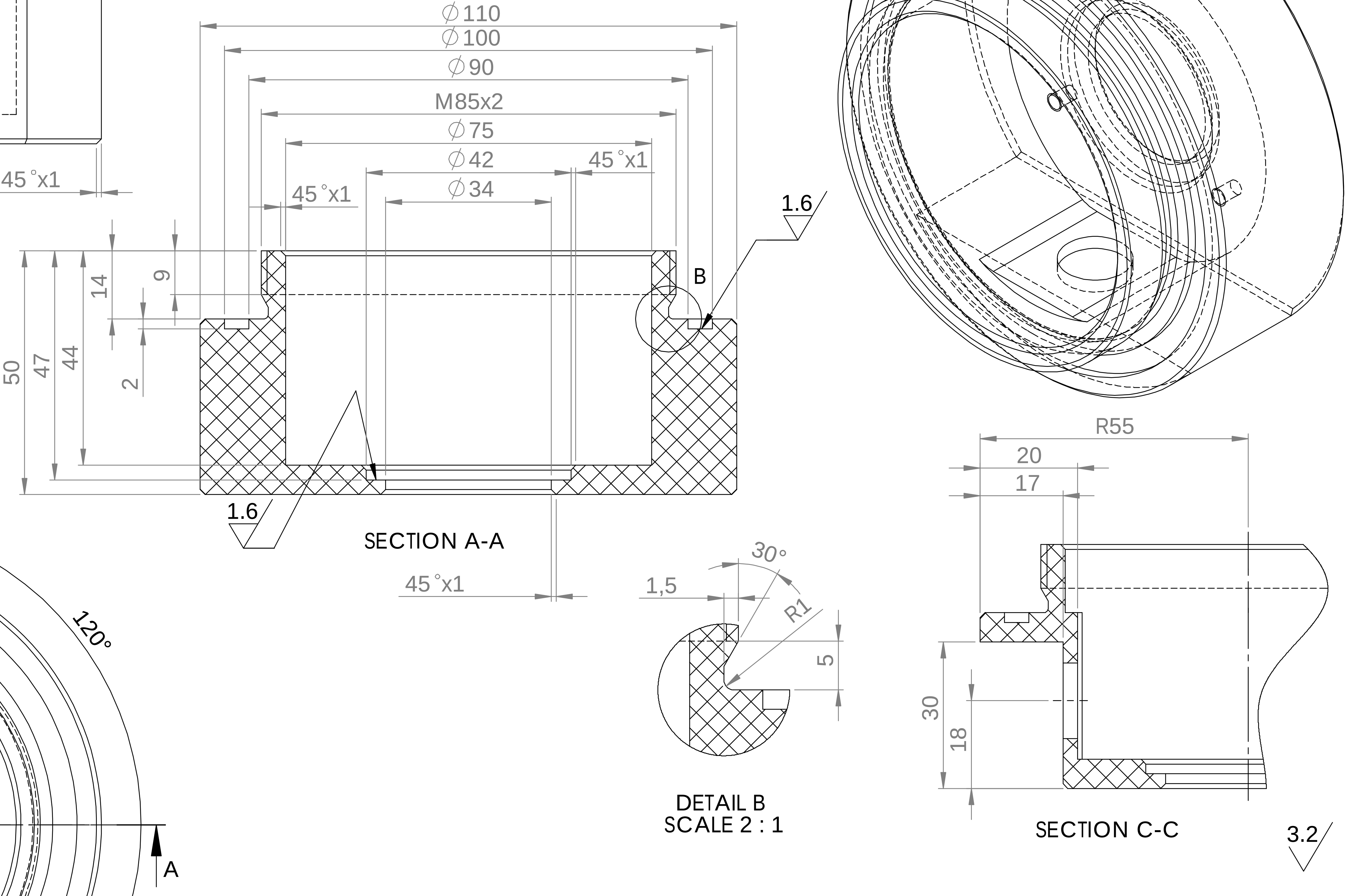
Capsule Assembly v2.1

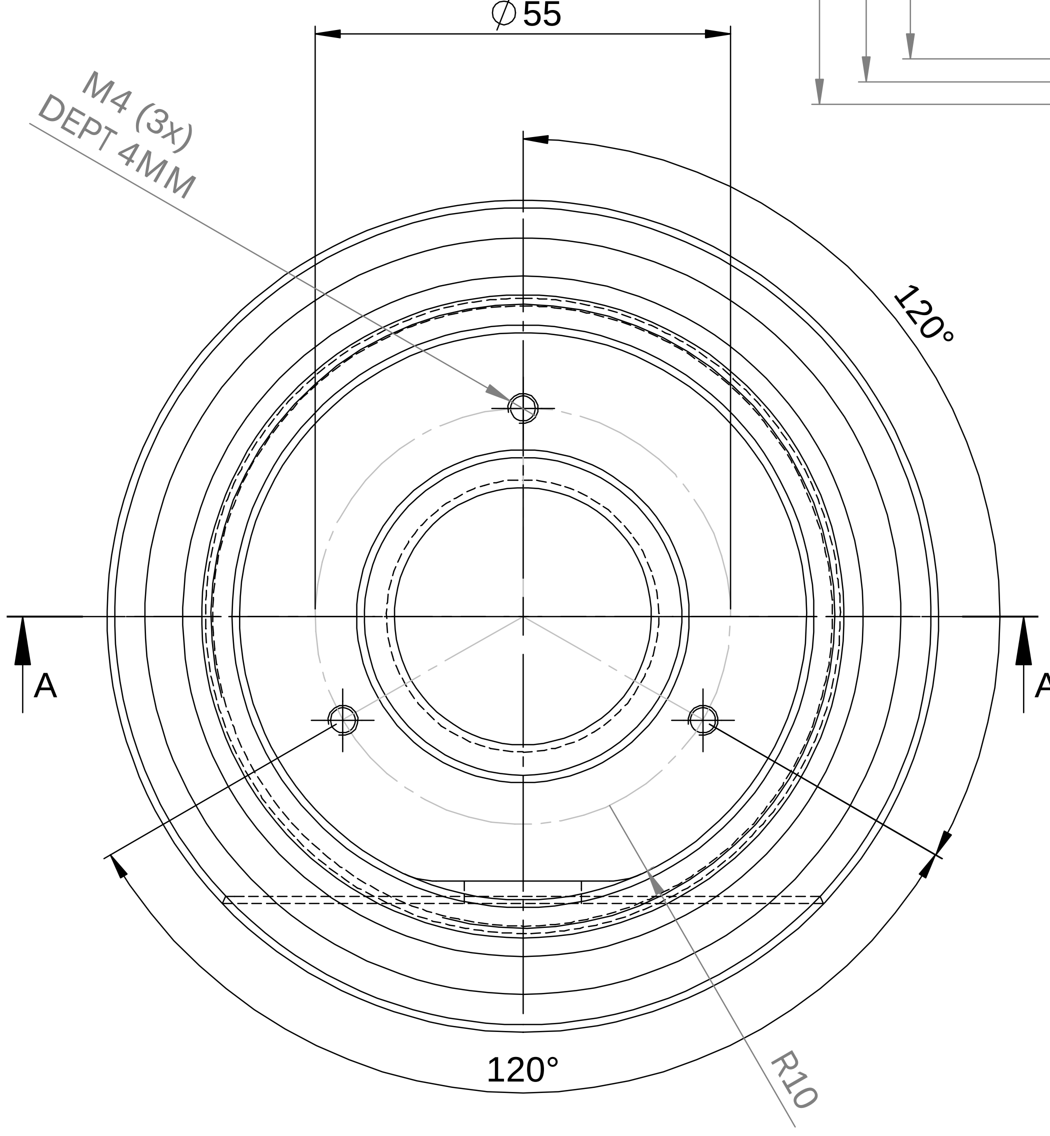
A3

SCALE:1:2

SHEET 1 OF 1







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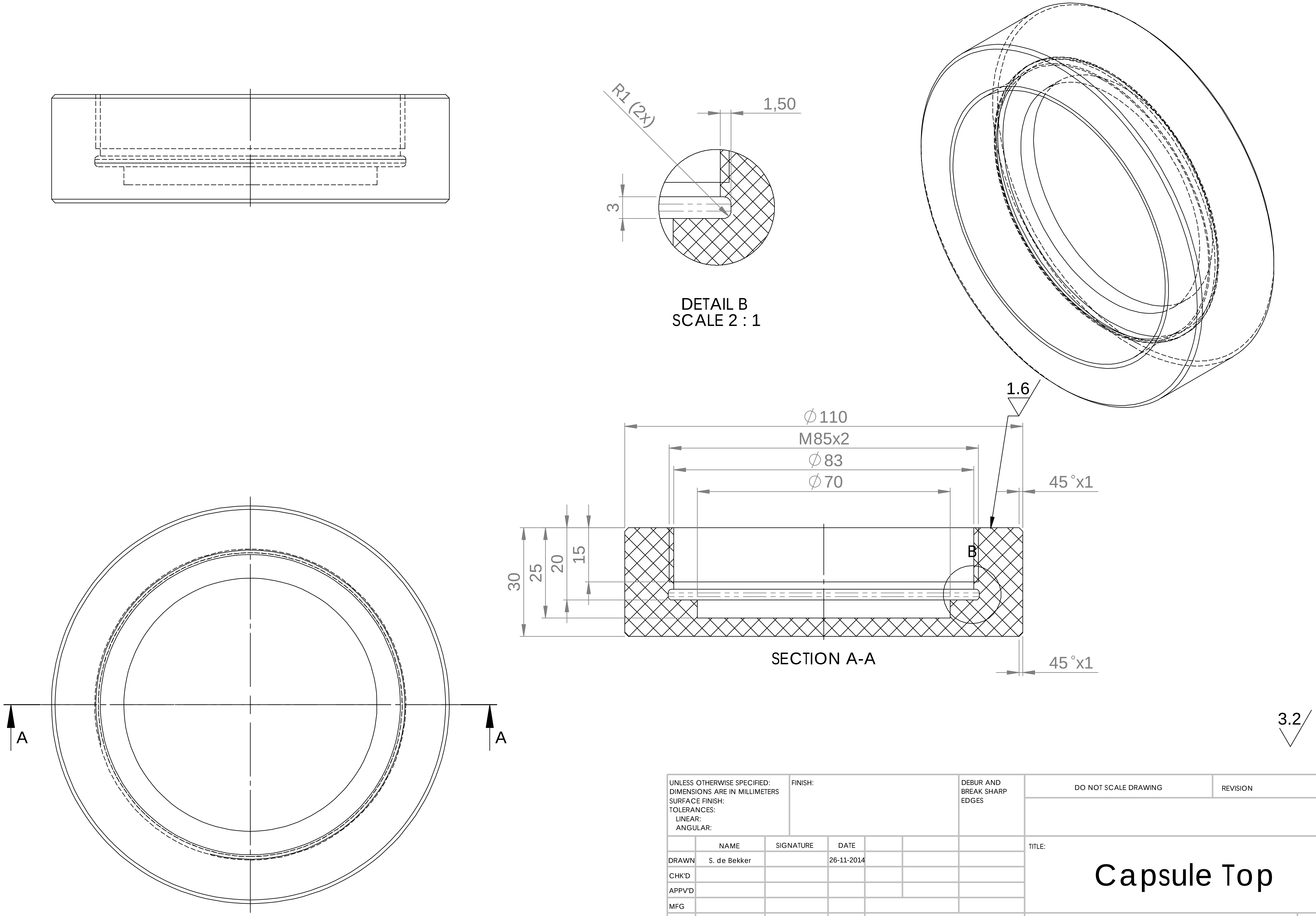
CHK'D							
APPV'D							
MFG							
Q.A			MATERIAL: Nylon		DWG NO. Capsule Base 2		A3
			WEIGHT:		SCALE:1:1	SHEET 1 OF 1	



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CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: Nylon	DWG NO. Capsule Top 2	A3
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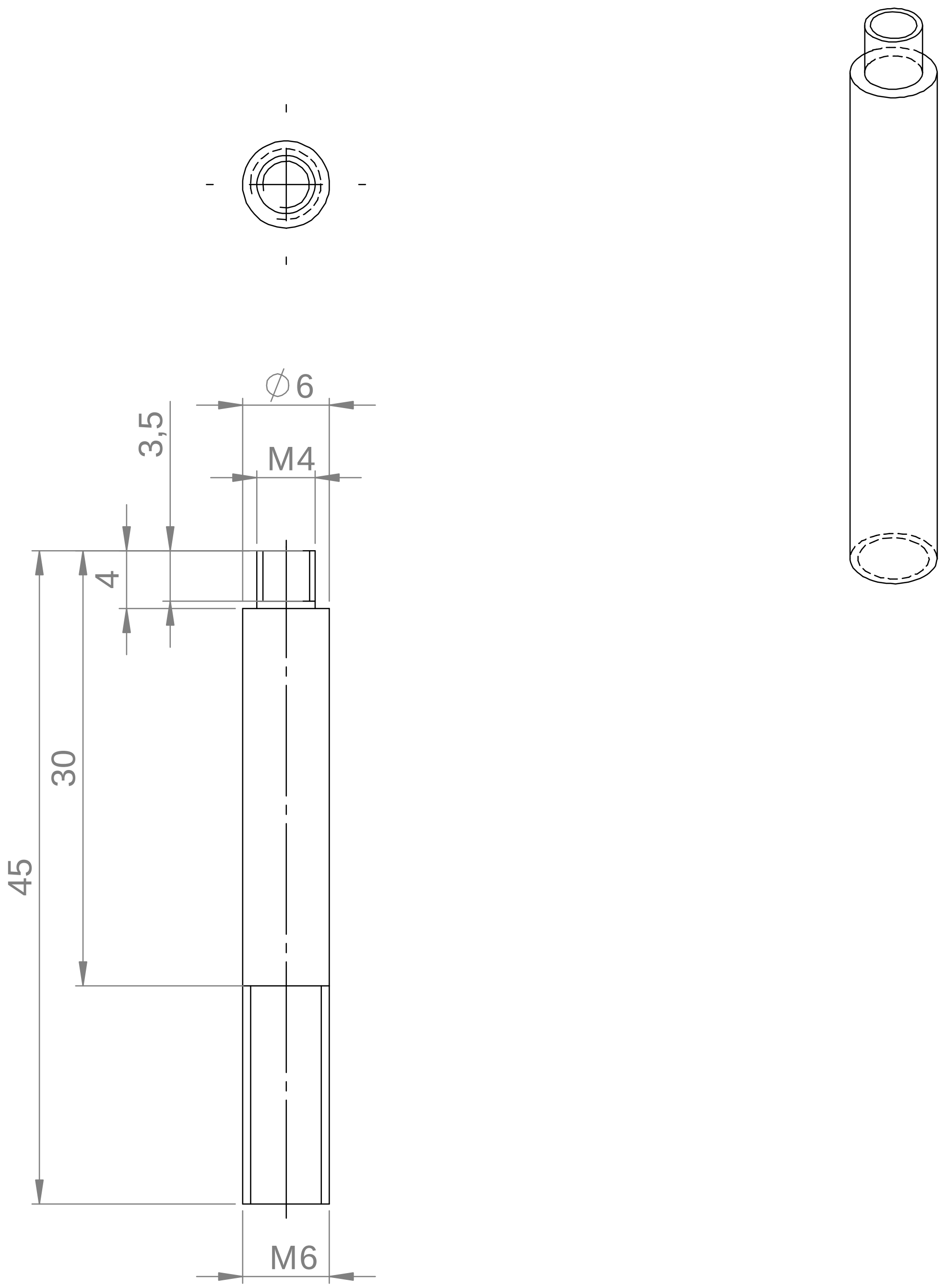

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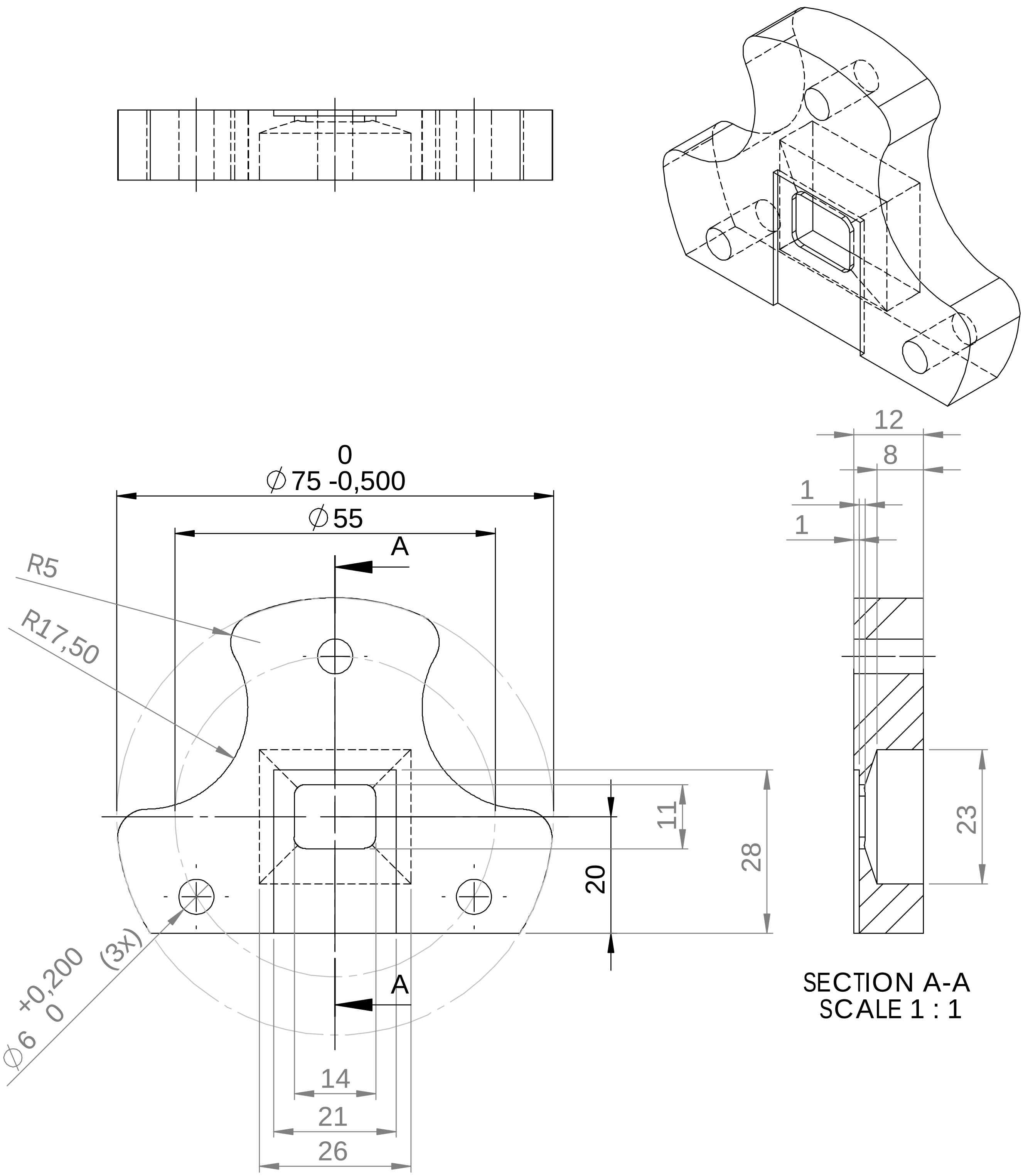
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: Stainless Steel Bar	DWG NO. Insert2 rod	A4
				WEIGHT:	SCALE:2:1	SHEET 1 OF 1



Product to be manufactured by 3D printing
Material: Any non conductive polymer

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	NAME	SIGNATURE	DATE			TITLE:
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL:		DWG NO. Insert3 part1
						A4
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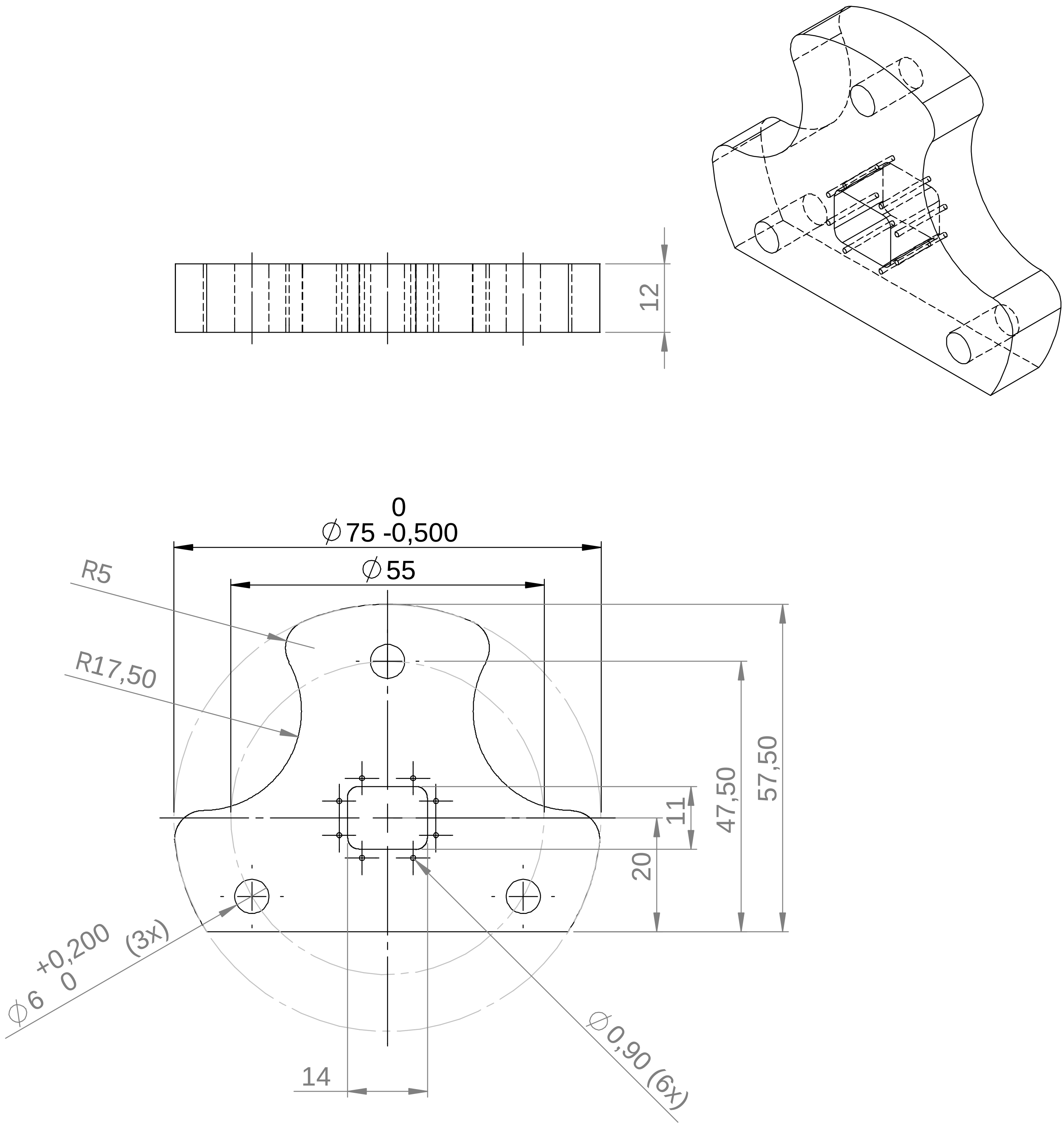
						SHEET 1 OF 1



Product to be manufactured by 3D printing
Material: Any non conductive polymer

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	NAME	SIGNATURE	DATE		TITLE:	
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL:	DWG NO. Insert3 part2	A4
				WEIGHT:	SCALE:1:2	SHEET 1 OF 1