Design and Fabrication of a Projectionlithography machine for the application of microfluidic pattern using commercially available UV LED

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Declaration

I declare that the work in this dissertation was carried out in accordance with the requirement of the university's regulations and code of practice for the undergraduate programmed in Bachelor of Engineering (Manufacturing Engineering with Management) and that it has to be submitted only to the university and not to other institutions. Except where indicated by specific reference in the text, thus the work is my own risk. The project was done in collaboration with or with the assistance of others is indicated as such. I have identified all the materials in this dissertations which is not is not my own work through referencing and acknowledgement where I have quoted from the work of other. I have included the source in the reference/bibliography. Any views expressed in the dissertation are those of the author.

Signed:…………………. Date:……………

Acknowledgement

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List of Abbreviations

1. UVLED- Ultraviolet Light Emitting Diode
2. µm- Micrometer
3. W-Watt
4. PDMS- Poly-dimethyl Siloxane
5. MEMS-Micro-electro-mechanical system
6. MTO- Make to order
7. CMOS- Complementary metal–oxide–semiconductor
8. MOSFET- Metal-oxide-semiconductor field-effect transistor
9. SEM- Scanning Electron Microscopy
10. IC- Integrated Circuit
11. LCD- Liquid Crystal Display
12. DLP- Digital light processing
13. BOM- Bil of Material
14. FWHM-Field width at half maximum
15. DSLR- Digital single-lens reflex
16. RM- Ringgit Malaysia
17. CAD- Computer Aided Design
18. Kg- Kilogram
19. 2D- 2 Dimensional
20. IPA- Isopropyl alcohol

Abstract

In the present work, a 12μm PDMS microfluidic channel are developed using an in-house designed projection lithography machine system. A master pattern was first produce by patterning on microscope slide which is spin coated with SU-8 2002 negative photoresist and exposing it with the in-house projection lithography machine. Using commercially available low power ultraviolet light emitting diode (UVLED) as a medium to expose the photoresist at different height with quartz glass and soda lime glass. A flexible replication of the master mold was produced using heat cured poly-dimethyl-siloxane (PDMS) via cast molding process which can be used repeatedly to fabricate more PDMS microfluidic channel. The scanning electron microscopy measurement of the fabricated microfluidic pattern on the PDMS showed promising result with a good pattern quality and resolution using the commercially available low power UVLED. This work has demonstrated that the projetion lithography machine system using commercially available low power UVLED is a promising technique and tool for fabricating microfluidic structure on flexible substrate for future application

Abstrak

Mutakhir ini, saluran mikrofluidik PDMS berukuran 12µm telah dihasilkan menggunakan sistem mesin litografi projeksi yang dihasilkan menggunakan UVLED. Corak induk telah dihasilkan terlebih dahulu menggunakan slaid mikroskop yang telah disaluti dengan SU-8 2002 photoresist negetif dan telah mendedahkannya kepada UV menggunakan mesin litografi projeksi yang telah dihasilakn. Menggunakan UVLED yang terdapat di pasaran sebagai medium untuk mendedahkan photoresist pada ketinggian yang berbeza menggunakan kaca quartz dan kaca soda lime, sebuah replika fleksibel acuan induk telah dihasilakn menggunakan polimer dimetil-silikon (PDSM) yang dihasilakn melalui pencetakan cast yang boleh digunakan berulang kali untuk menghasilkan lebih banyak saluran mikrofluid PDMS. Pengukuran melalui mikroskopi elektron pengimbasan telah dibuat keatas corak mikrofluidik tersebut dan ia menunjukkan hasil yang sangat berkualiti serta resolusi corak yang baik menggunakan UVLED yang terdapat dipasaran komersial. Kerja-kerja ini telah meunjukkan bahawa sistem mesin lithografi projeksi menggunakan UVLED berkuasa rendah yang boleh didapati secara komersial adalah teknik dan alat yang berpotensi untuk menghasilkan struktur mikrofluidik pada substrat yang fleksibel untuk aplikasi di masa hadapan.

CHAPTER 1

1.1 Background of Study

In most recent years, manufacturing industries have been a key area in development of science and technology especially in Malaysia where manufacturing is a key element that pushes the country's economy. A manufacturing is defined as the making of goods by hand or by machine that upon completion the business sells to a customer. Items used in manufacture may be raw materials or component parts of a larger product. The manufacturing usually happens on a large-scale production line of machinery, software's and skilled labour.

Many companies especially in this region are based on the Make to order (MTO) which is common in electric and electronic industries namely semiconductor fabrication. Semiconductor industries rises after the birth of transistor which is used in almost every electronic devices. Following numerous research and innovations, an integrated circuit which was invented in 1959 led to the rise of semiconductor industry as IC progresses toward high performance and multiple functions, its field of application is expanding broadly.

The increasing demand for a lower cost, high resolution micro and nano fabrication technique to fabricate various types of 2D and 3D micro and nanostructured microfluidic featured in various flexible electronic and micro-electro-mechanical (MEMS), biochips and optical device has led to numerous research and development of new lithography technique. [17]

Microfluidic deals with a technology and system that are used for processing or manipulating of small amount of fluids, using channels with dimensions of ten to several hundred micrometre. It offers fundamentally new capabilities in control of concentration of molecules in space and time [15][16]. Today, many types of different microfluidic device are known and used in microfluidic applications. Together with the new method of fabrications, microfluidic enables new insight into certain fundamental difference between physical properties of fluid moving in large channel to those travelling through micrometre scale channels

To enable the fabrication of microfluidic device, the layout of the components is patterned on a photomask (reticle) by a computer and exposed on wafer substrate. The manufacturing processes on a microfluidic consist of cleaning, oxidation, deposition, photoresist patterning, inspection, moulding, ion implementation and packaging.

Among these process involved in microfluidic fabrication, a widely researched area is during the pattern transfer. Pattern transfer is commonly known as lithography process where the pattern information is recorded on a layer of photoresist which is applied on the top of the wafer substrate thus the photoresist changes its physical properties when exposed to light (often ultraviolet) or another source of illumination.

There are several types of lithography technique used today. An example of a lithography technique is projection lithography which has become the advantageous fabrication technique in the manufacturing process of electronic device namely printed circuit board due to its increasingly improvement on resolution that enables small features to be patterned on substrate surface. This technology has been the dominant patterning process for semiconductor fabrication for over 40 years. The patterning process evolved initially from methods used in the printing industry, but as integrated circuits became more complex, and as device geometries shrank, sophisticated new imaging methods evolved. Today's lithography systems represent the highest resolution, most accurate optical imaging systems ever produced. This remarkable evolutionary process continues to this day, inspired by "Moore's Law"[2]. The evolutionary development of lithography systems over the last 40 years is reviewed along with a brief discussion of options for the future.

Projectionlithography is basically a photographic process by which a light sensitive polymer, called photoresist is exposed and developed to form a three-dimensional image on a substrate. It is known as a process of geometrical shapes and pattern transfer to a film or substrate which allows us to make up the complex structure that completes a circuit and fulfilling technological purpose.

In general, the ideal photoresist image has the exact shape of the design or intended pattern in the plane of the substrate with vertical walls through different thickness of the photoresist. Thus, the final photoresist pattern is binary: part of the substrate are covered with photoresist while other parts are uncovered. This binary pattern is needed for the pattern transfer since the part of the substrate covered with the resist will be protected from process of other pattern transfer mechanism.

There are many applications regarding modern lithography process such as MIMOS, CMOS, MOSFET as well as microfluidic lab-on-chip device. Focusing on microfluidic, it deals with the fluids manipulation that are geometrically constrained to a millimetre scale. It is a field at the interception of engineering, physics, chemistry, nanotechnology and biotechnology with practical applications in their system design in which low fluids volume are processed to achieve multiplexing, automation and high-throughput screening. The microfluidic biochip (lab-on-a-chip) is a miniaturized device produced by the microfabrication technique, has been developed rapidly since its advent in the 1990 [18]. Microfluidic biochip has been widely used in various applications especially in bio application, portability and automation. Miniaturized devices with high portability have great potential care application above laboratory setting, such as disease diagnosis [20], food safety inspection [21] and environmental analysis [22]. Various material including silicon [6], glass, polymer, methyl methacrylate and paper has been used for microfluidic platform fabrication. Various modern instruments has been developed for biological assays and environment monitoring. However, many instruments are expensive, which dependent their use in resource setting.

Recent development of projection lithography process observed the tendency to adapt high power UV light bulb due to the advantage of better light dispersion and high chance of successful pattern transfer. However, most of the projection lithography machine that uses high power UV light bulb requires higher operating cost as well as high maintenance cost. In addition to that, the problem of heat dissipation may also occur due to the UV light bulb high intensity and power. Nevertheless, the patterning capability of the in-house developed prototype projection lithography system using low power UVLED in fabrication of microfluidic channel are demonstrated and evaluated in the present work.

1.2 Problem Statement

Defining a pattern into the wafer requires a high precision machine that possess a high aspect ratio. This is necessary in order to enable the exact pattern to be transferred onto the wafer. The resolution can be influenced by many factors including the type of photoresist, the type of optical light source used as well as the predefined patterns dimension itself. Apart from high resolution, it is the machine itself such as the machine structure and mobility.

The optical light source used in current machine is high power florescent light bulb which requires an additional controller machine as well as additional step down power supply to control the current flow. Moreover, using a florescent light bulb as the light source requires a more sealed panel due to some leak in light internally and externally. This leaking may cause problems which includes pre-exposed coated emulsion glass.Besides, replacing the florescent light bulb requires high maintenance cost and time due to the price and availability. For instant at an exposed environment in a low temperature in the laboratory will increase the percentage of light output compared to high temperature[7]. This leads to high operating cost to keep the laboratory at a constant low temperature.

Replacing the florescent light bulb with UVLED light could be a possible solution. The advantages of replacing the florescent light bulb to UVLED light is that it can enable a better percentage reduction in cost due to less energy consumption and less heat dissipation. Moreover, the construction of metal box to prevent UV exposure to the user is also a possible solution. Using a low cost step down power device such as the buck booster eliminate the use of expensive step down power supply currently used by the mask aligner.

Additionally, the current projection lithography machine is lacking of mobility. To move the machine, it requires at least two to three person due to its heavy weight. Overcoming this problems is simply fabricate a new machine panel that are sealed tightly, adding wheels for mobility.

1.3 Objective

1. To design a projection lithography machine that provides a better mobility, frame and rigidity for the lithography process.
2. To fabricate a projection lithography machine with minimal cost as possible using readily available equipment and spare parts.
3. To test the projection lithography machine using substrate to verify using SEM testing machine that it can achieve a good pattern resolution using UVLED.

1.4 Scope of Work

The project aims to develop a projection lithography machine fabricated at the Mechanical School of Engineering with minimal cost materials and while achieving a good pattern resolution. The targeted budget for this fabrication is RM2000 and completed within the twenty six weeks of two semester. There are several task that needs during a period of 26 weeks that is to be done for the success of this project such as:

1. Gathering information through literature review
2. Providing detailed design of three types of prototype
3. Obtaining the materials and spare parts needed
4. Fabrication and assembly process
5. Testing and verification process

1.5 Thesis Component

In this thesis, the fabrication, design and testing of projection lithography machine are describes. To explore the possible replacement for an affordable built machine for the purpose of fabricating microfluidic channel, readily available materials and equipment are used in this fabrication process. Generally there are five chapter in this thesis whereby each chapter are specified to each individual component of the project

A general introduction is presented in Chapter 1, providing the aim and general background of the work and the structure of thesis including the problem statement, objective of the work to highlight the essentials and benefits of the work and also the scope of the work being done.

In chapter 2, a literature review have been done to investigate about the previous work that have been done related to projectionlithography machine fabrication. A general overview of microfluidic fabrication via projection lithography have been discussed in this chapter. Moreover, other important component related to this project which includes the types of light source are also discussed. A review is also done on the use of soda lime glass and quartz glass as an optical element for the fabrication of the machine.

In chapter 3, brainstorming ideas on current available material and machine were done based on specifications and cost. The development of conceptual design of the projection lithography machine are discussed base on selective features. Moreover, the fabrication process and substrate preparation are demonstrated.

In Chapter 4, the results and discussion are presented based on the testing and verification done using SEM, portable camera and original image pattern. The optimal setup of the machine is also discussed chapter.

In Chapter 5, states the general conclusion of the work done. It also highlights the future work that can be done for improvement.

CHAPTER 2

2.1 Literature Review

This chapter will cover a literature review on several aspect of this project. This reviews includes the role of lithography in semiconductor fabrication, the effect of negative and positive photoresist towards the aspect ratio of the transferred pattern, a simple fabrication technique of projection lithography using display projector, the advantages of using ultraviolet light emitting diode (UVLED) as a source of light compared to florescent light , the effect of different ultraviolet LED exposure towards the curing process of photoresist and a brief summary of the literature review.

2.1.1 Role of lithography in Semiconductor fabrication

Semiconductor wafer are widely used in producing integrated circuit (IC) containing millions of small scale component such as resistors, capacitors and transistors. These device act as a multifunction IC which are used in many application such as oscillator, computer memory and micro/nano-processor. In order to create these devices, numerous procedure is involved as shown in figure 2.1. An important procedure that needs to take place is lithography. It is a process of geometrical shapes and pattern transfer to a film or substrate which allows us to make up the complex structure that completes a circuit and fulfilling technological purpose.

Transferring such complex geometrical shape and patterns requires a patternedemulsion mask using this process. Those materials are generally chrome coated emulsion glass lithographic templates design to optically the patterns to wafers or other substrate. Basically, the patterns were created in a drawing using software such as Adobe Photoshop. These patterns are transferred to the chrome coated emulsion glass using lithography tools and machine. The figure 2.1 below shows the steps involved in making the multifunction IC.The patterned chrome coated emulsion glass created can be used multiple times.

Many studies have been done to enable a good pattern transfer to the emulsion mask including creating sophisticated machine such as electron beam lithography, ion beam lithography and x-ray lithography. Meanwhile, conventional optical lithography is being widely used due to its low cost and low maintainability.

Ultimately, sophisticated lithography technique available today enables the formation of micro/nanometer-sized structures which have a role in the nano- and bio-electronic device development such as line and space pattern for the device element as well as microfluidic channel using PDMS. Though, these sophisticated method carries several disadvantages including time-consuming, complicated steps involved as well as high operation cost.

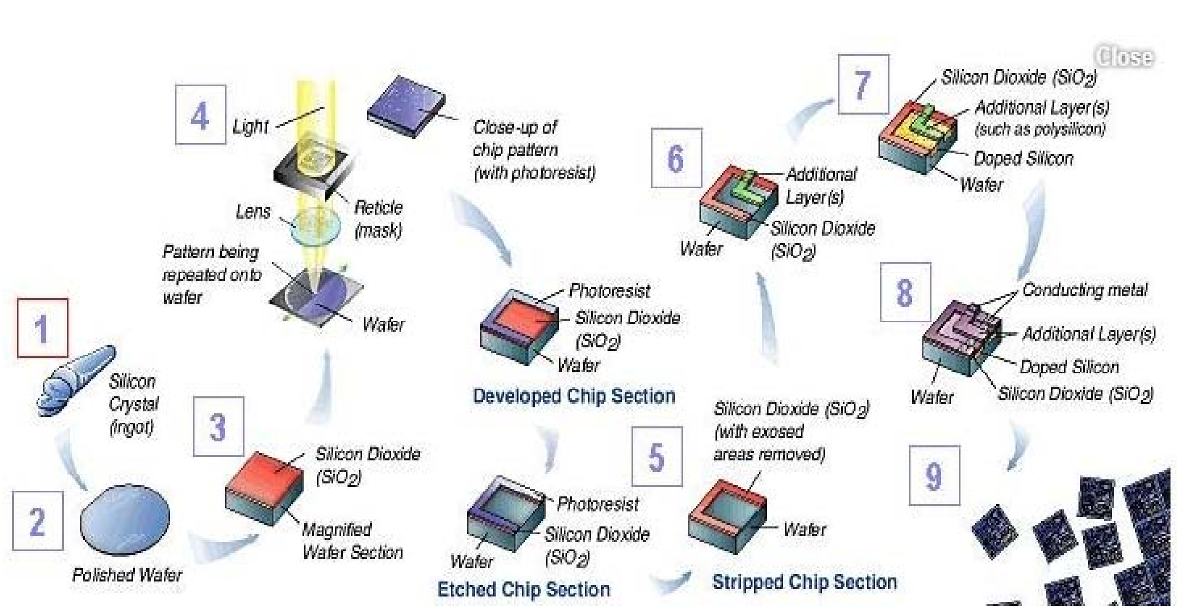

Figure 2.1: Process of semiconductor fabrication.

2.2 The effect of negative and positive photoresist towards the aspect ratio of the transferred pattern

Recently, a new method was develop to form the line and space pattern at a nanometer-scale using negative photoresist that is defined using conventional optical lithographyand metal deposition as well as lift-off technique which aims to achieve a high aspect ratio [1] . This experiment demonstrated the use of these technique in order to obtain a nanometer-scale gap of 20nm without using sophisticated lithography tool.

It is important to note that several factors should be considered in achieving a good pattern namely a high aspect ratio, a high resolution image and a well define image. Photoresist plays an important factor in determining an aspect ratio [1]. Using a positive photoresist (Az 4300) in optical lithography will result in a 20nm gap line and space when a pattern is transferred. However, the drawback of using positive photoresist resulted in a low aspect ratio thus making it unsuitable for Al metal deposition and lift-off process [1].

Therefore, experiments was done using a negative photoresist (PMER) is observed using photolithography method as shown in figure 2.2 and an increase in aspect ratio is expected to be achieved. It was done by using a p-type (100) silicon wafers as well as a 2µm photomask with 12µm negative photoresist (PMER,Tokyo Ohka Kogyo Co.) in the conventional optical lithography and Al deposition/lift-off process..

The mask aligner with an i-line wavelength at a power of 12mW us used and the exposed patterns were developed using PMER P7G (PMER,Tokyo Ohka Kogyo Co.) developer. This resulted in a desired high aspect ratio in nano-scale fabrication of patterns. The figure 2.3 below shows the comparison of the effect of different photoresist used in the pattern transfer phase. Based on the studies, it is identified that the photoresist that will be used for this research will be a negative photoresist available such as the SU- 8 2002 to obtained the desired aspect ratio.

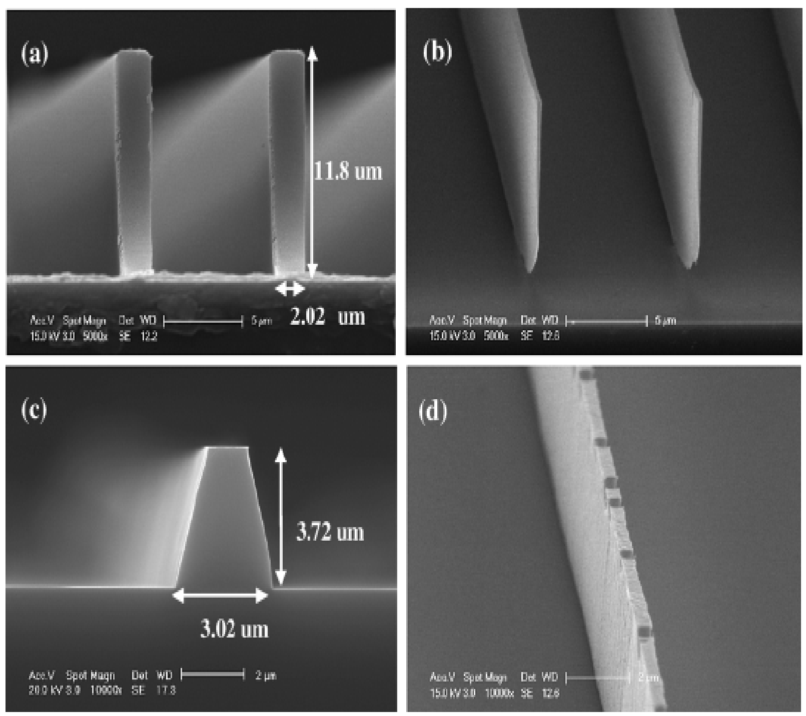

Figure 2.2: SEM images of patterned structure of PMER and Az4330. (a) The aspect ratio of PMER was 5.84. (b) Tilted image of PMER after ashing. (c) The aspect ratio of Az 4330 was 1.23. (d) Tilted image of Az 4330 after ashing.

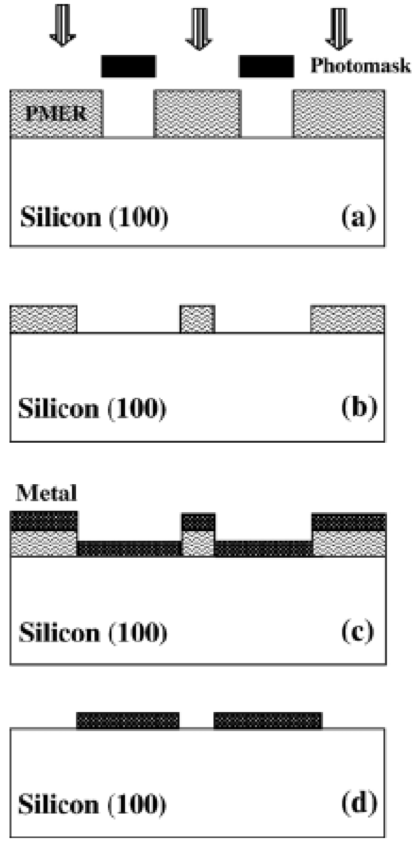

Figure 2.3: (a) PMER is exposed to UV with the predefined photomask. (b) The PMER is developed an etched. (c) Metal is deposited via metal deposition. (d) PMER is removed.

2.3 Simple fabrication technique of projection lithography using display projector

2.3.1.1 Liquid crystal display projector

In addition to high aspect ratio, operating cost and maintainability is crucial in lithography process. In order to sustain the machine, it must be occasionally maintained. Studies have been done to achieve these objective using a simple optical system machine. This type of machine uses projection lens that can be commonly found in a liquid crystal display (LCD) system panel projector. The light source for an LCD projector is a standard white lamp. An LCD projector allows the source light to pass through the three coloured liquid crystal display light panels. The panels in turn allow some colours to pass through and block some colours to form the images on the screen.

2.3.1.2 Photolithography technique using liquid crystal display (LCD) projector

A simple liquid crystal display (LCD) system panel (projector Mitsubishi Electric, LVP-HC5000) is used to see if liquid crystal display can produce a high aspect ratio while maintaining a low production cost in pattern transfer[2].

Modification on the LCD projector were done using macro-lens (Sigma, EX DG MACRO), projection lens as well as fabrication of a new exposure system [2]. By adding a larger projection lens the formation of notches and opaque black matrix parts is avoided [2]. Moreover, the new developed exposure system using a high pressure mercury with a power of 160W was done to control light projection of the LCDs. Thus, patterns are able to be transferred onto the wafer. The fabricated machine and the lens used are shown in figure 2.4.

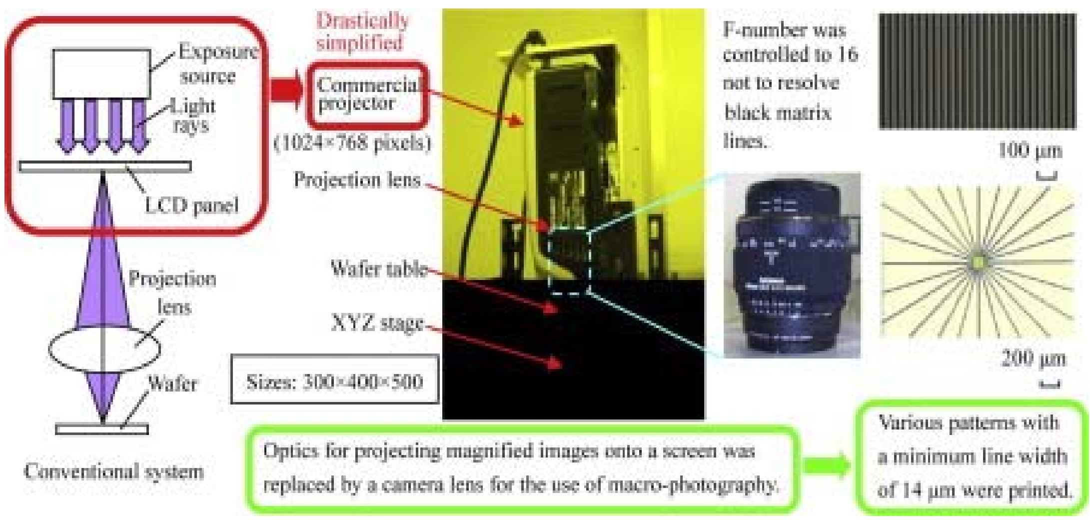

Figure 2.4: Fabricated projection lithography using LCD projector.

In addition, oblique and curved patterns are also smoothly printed using the LCD lithography. Pixel is also an important factor to obtain a clear image, the wider the pattern compared to the pixel pitch, the better the image produced [2]. Therefore, neighbored pixels of a two pixel line patters are assigned in different transmittances. Despite several concerns in using this methods, past research have been successfully developed a multilayer resist process using visible light from the LCD lithography. This method have been used in patterning the surface of silicon, glass, metal etc successfully and it is applicable in prototyping application of MEMS, microfluidic, patterning of sensor and electrode structure due to its high utilization of projected area [4].Moreover, due to cost concerns for the fabrication of this machine regarding the exposure system as well as the motorized lens used. There are other alternative that can be used to substitute those components.

2.3.1.3 Advantage and disadvantage of using LCD projector as a mechanism for pattern transfer

There are several advantages of using an LCD projector. Higher lumen output can be delivered by an LCD projector at a lower cost compared to a digital light processing (DLP) projector. It can also provide greater brightness with lower energy consumption. Unlike DLP projectors, LCD projectors do not suffer from rainbow effects and dithering. Another salient feature of LCD projectors is their image sharpness and providing greater zoom magnification.

Although there are a lot of advantage of using LCD projector lens as stated above. There is also several disadvantages that should be highlighted. Firstly, LCDs can only control the visible light with a wavelength between 420mm and 750mm which is too high for the photoresist to cure [2]. In addition to having a low efficiency in utilizing these lights which are due to the refractive index mismatch between the LED chip and the surrounding environment and it restricts the light escape cone to only 24%. As a result, only a little of the generated light can escape the LED, while the biggest portion is kept in the substrate by total internal reflection which is reabsorbed in the end [5]. Black matrix parts is also a concern, as it is always opaque for exposure light rays in LCDs. Secondly, using the LCD projector lithography may also concerns over achieving a good aspect ratio. While negative photoresist is expensive compared to positive photoresist, it may not be considered in SME industries as cost is a limitation for them. Lastly, in achieving a nano-scale pattern structure, a long curing time is needed as stated before, if it is to be used in the industries, it may not be relevant enough as it takes a longer time just to complete the pattern and geometrical transfer.

2.4 The advantage of using ultraviolet light emitting diode (UVLED) as a source of light compared to florescent light

In terms of intensity, the fluorescent light emits less light intensity compared to other light source such as LED. It is to the fact that fluorescent light are sensitive towards temperature changes. For instant at a low temperature in the laboratory will reduce the percentage of light output compared to the optimal percentage of light output at room temperature [7]. The figure 2.5below shows changes in light output against temperature.

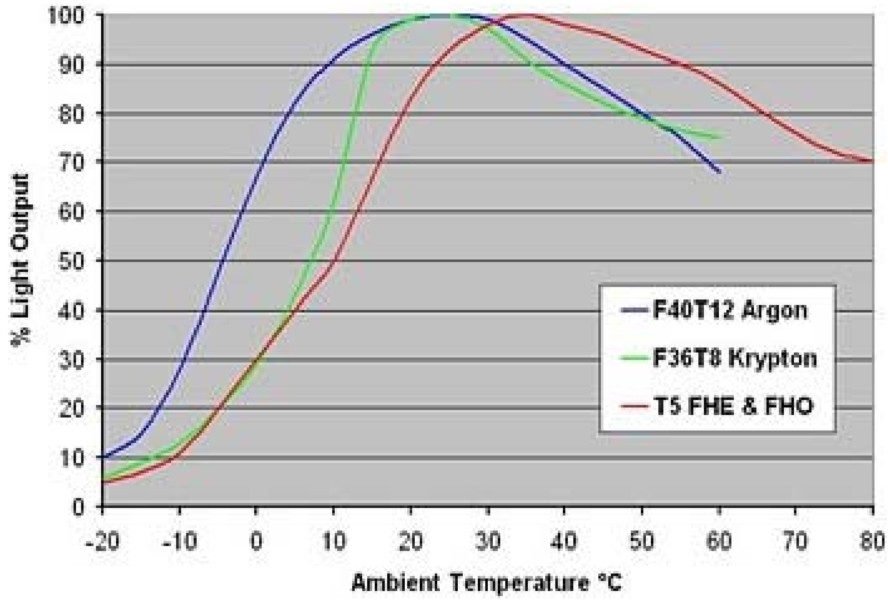

Figure 2.5: Percentage of light output at different temperature.

In term of cost for efficiency and lifetime usage, light emitting diode are better than fluorescent. Even though the efficiency of the light source can be directly seen on the label from the manufacturer, in reality those claims may not be true. On average if the real lifetime of the LED bulb is 4000 hours, the LED and fluorescent solutions seem to be equivalent, but the plot in figure 2.6 does not take into account the maintenance cost [8].

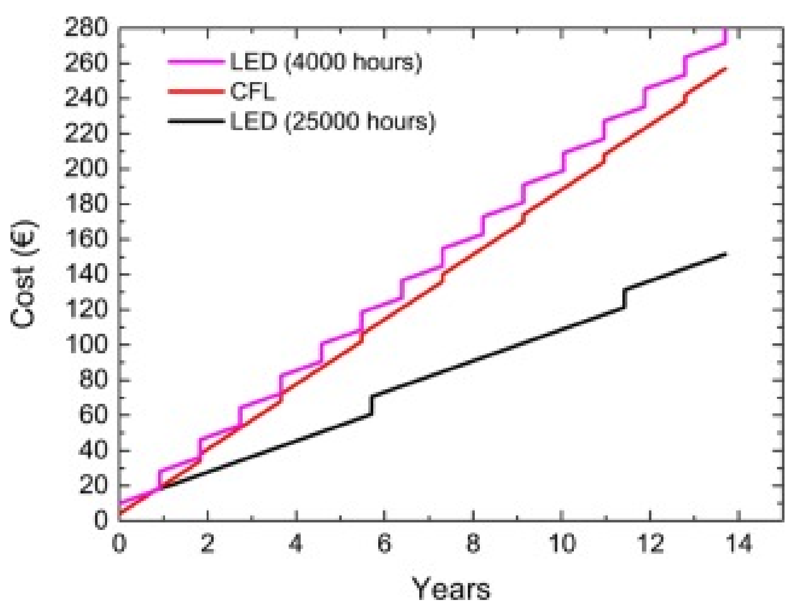

Figure 2.6: Total cost over a few years for a commercial or industrial lighting system used 12h per day [8].

In analysing the figure 2.6 above, it can be seen that the yearly cost of the LEDs (25000 hours) are much lower compared to the fluorescent lights. With a highest total difference of €120 in year 14.LEDs are the best solutions under the condition that their lifetimes is reasonably high. It thus appears clearly that the lifetime or replacement time of the bulbs is a key issue. Overall, the LED solution is evidently economically relevant, despite the larger price of the individual bulb. As one can see, from the previous analysis, the lifetime issue is the key to this matter. The lifetime of a LED bulb will thus usually be linked to the care (and cost) that the manufacturer has put in the packaging and in the electronic drivers [8].

Replacing the fluorescent with UVLED light could be a possible solution. The advantages of replacing the fluorescent light to UVLED light is that it can enable a better percentage of light output and eliminating the use of emulsion mask for the pattern definition. Hence, it can directly save operating cost for material and energy consumption due to its long lifetime and usage. Moreover, these devices offer spatial-temporal control of the emission pattern, and also spectrally selective excitation because the emission bandwidth is typically narrow (~15nm full-width at half maximum (FWHM) [2]. In maintaining a low cost fabrication process of sensor or transferring of pattern, UVLED is able to transfer the pattern directly toward the negative or positive photoresist compared to a normal LED. Though there are several criteria to consider regarding UVLED's. To cure the photoresist, a high power and high intensity (365nm) UVLED is needed.

2.5 Effect of different Ultraviolet LED exposure towards the curing process of photoresist.

The SU-8 2002 is the type of polymer photoresist which contains a crosslinking bond between them. These bonds can be strengthen or weaken depending of the type of photoresist used. To enable this phenomena, curing process is perform. This process can be done using many method which includes exposure to ultraviolet LED which enables polymerization of the photoresist upon exposed [26]. Though generally the exposure from ultraviolet can influence the curing process of the photosensitive polymer, there are certain targeted frequency or wavelength range that can enable the process. Such a wavelength range of ultraviolet include ultraviolet-A, ultraviolet-B and ultraviolet-C [14]. Additionally, these wavelength may also influence the curing time as well as the aspect ratio of the pattern.

2.6 Summary

Based on the literature reviews, it is seen that the use of UVLED are not yet fully utilize to its potential to replace UV light bulb as a mean of exposure medium. Despite the use of projector as a top choice for the main component in projection lithography, it may have several weakness that can be improved with experimenting with different types of glasses including soda lime and quartz glass. It is agreed that an alternative way to reduce cost is eliminating the use of emulsion mask and projecting the image straight onto the substrate via maskless technique. Selecting the type of photoresist and the right frequency or wavelength of UV LED is also a factor to obtain a good aspect ratio. Thus a projection lithography machine using commercially available UVLED is heavily studied and developed which could lead to cost effective small-scale manufacturing [3].

CHAPTER 3

3.1 Development of conceptual idea for the fabrication of projection lithography machine and its fabrication process

This chapter will describe the initial process of generating conceptual ideas, producing the CAD drawing and models and finally fabrication of the machine itself. Moreover, this chapter also demonstrated the process of substrate preparation for the testing and configuration purpose of the machine for the projection process.

3.1.1 Generating conceptual ideas

In order to check the applicability of the newly developed projection lithography machine, several concepts have been developed. The initial steps was to brainstorm the problems that were faced. A mind map method is used in this process as shown below. The main problems for fabricating the machine is the cost and availability of the materials especially the type of glass used,Ultraviolet light sourcesand the required configuration for the machine. In solve the first problem, several consideration have been analyzed including the use of soda lime glass and quartz glass. To obtain the soda lime glass, liquid crystal display (LCD) projector lens were used. This concepts became one of candidate to tackle this problem.

The idea of using an LCD lens was that it can produce images as sharp as the DSLR lens. It can also enable the control of lights such as the red, green and blue. Due to its abundant spare parts, LCD projector are easily obtained at a cheap price. Furthermore, the lens of the LCD projector enables the image projected to become enlarged. By inverting the lens, this enables the images to be shrink at a certain aspect ratio which are dependent of the focal length, and refractive index of the lens itself.

Moreover, an LCD projector lens contains a built in magnification which also enables easy adjustments for the image. The disadvantages of using an LCD projector lens is that there is a potential of having an image distortion as well as the presence of ultraviolet filtration system. The figure 3.1 below shows the LCD projector lens disassembled from mainframe.

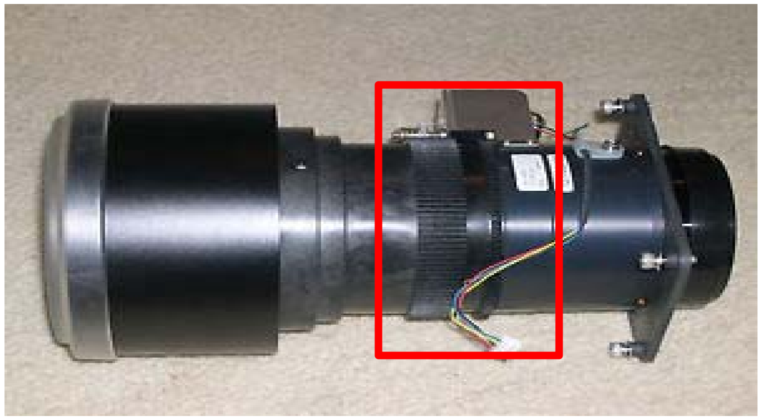

Figure 3.1: Panasonic LCD projector lens.

In figure 3.1, the smaller image lens size of the right side can be used to project the small image towards the photoresist while the larger lens on the left side can be used to capture the images to be projected. Notice on the square area, this enables adjustment of the image size by adjusting the aperture of the light passing through

The second type was using fused quartz glass shown in figure 3.2, this type of glass exhibits a good thermal and transparency properties compared to soda lime glass present in LCD projector lens due to the quarts which have an amorphous (non-crystalline) form fused with silica. The fused quartz glass are shown below alongside its reflectiveness properties. The glass properties are desired in the semiconductor fabrication and laboratory equipment. It can transmit ultraviolet radiation better than other glass including soda lime itself. Due to this properties, a high resolution pattern using direct UV exposure is possible [10].

Figure 3.2 Quartz glass from LCD projector.

Based on figure 3.3, it is shown that fused quartz have the ability in terms of reflectance to transmit UV to the photoresist, this enables several advantages over soda lime glass which include the elimination of master photomask which can indirectly save cost and processing time. Although the advantages seems promising, the fused quartz are not as abundantly available as the soda lime glass present in LCD projector lens. It is also a much more expensive glass to obtain and the glass itself does not have the ability to control the focal length which is present in the LCD projector lens.The two glasses are compared in the table 3.1.

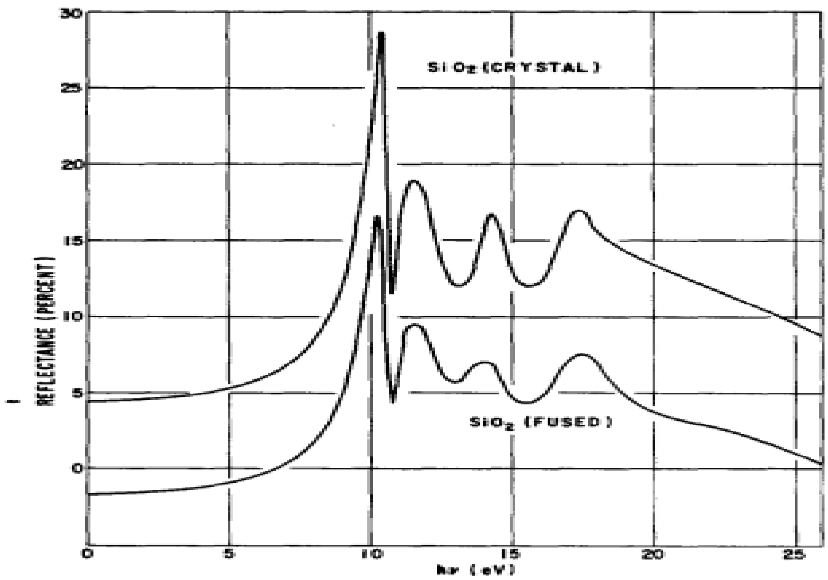

Figure 3.3 : Spectral dependence of the reflectance of crystalline and fused quartz [11].

Table 3.1: Advantage and disadvantage of the glasses.

Soda Lime Glass LCD	Quartz Glass LCD
Built in adjustable focal length	Nona-adjustable focal length
Abundant	Limited availability
Highest Sharp and less distort image	Low thermal coefficient
Built in aperture control	No built in aperture control
High thermal coefficient	Low reflective properties
Inexpensive	Expensive

High reflective properties	Good resolution

The ultraviolet light is an important element in the fabrication process of semiconductor. It enables curing of photoresist which it plays with the bonding present inside the photoresist. Ultraviolet have many different types such as UVA, UVB and UVC [12]. The suitable ultraviolet that can cure the photoresist were the UVA which have a wavelength of 365nm [13]. The A-type ultraviolet are abundant in some LED in the market. Moreover, to enable a good and maintained intensity of the UV light, a power input of more than 5W is needed which in this case a 10W UVA LED is used. The UVA LED are shown below which was recycled from previous project.

3.2 Selected key features

Key features of the mask aligner includes cost savings, lightweight, space savings and alignment accuracy sufficient for most typical microfluidic applications. A comparison of some of these key features between the fabricated mask aligner and a typical commercial system is given in the table. Relative to the commercial system MM605 simple mask fabrication machine from Nanometric Technology Inc. Our system is an order magnitude cheaper, weighs (40kg) less, and occupies (2x) less space and consumes less power.Moreover, it has an adjustable frame with a negligible annual maintenance cost. The comparison of the custom built and commercial projection lithography is tabulated in table 3.2. Finally, even though the resolution and the aspect ratio of the fabricated mask aligner is not as high as the available commercial system, it is sufficient for most of the MEMS and microfluidic application.

Table 3.2: Comparison between current machines with the fabricated machine

Features	**Custom built**	**commercial**
Cost, RM	902	50,000
Weight, Kg	20.7	80
Light source power, W	10W UVLED	15W Fluorescent lamp
Area, cm2	1920	3721

The detailed breakdown of the main component which include the mainframe and electronic component is provided in table 3.9. The major cost comes from the electronic component due to us having to order it from overseas as the parts are hard to obtain locally with the desired specifications. Other important component are the extruded aluminum bar which is among the most costly parts for this project. The entire unit of the mainframe were mounted together using L-bracket, 8mm threaded holes with screws and nuts.

3.3 CONCEPTUAL DESIGN

To see the difference in the concept shown in this section, the original machine is presented with all the specification of the dimensions and material used. These concept are design using SolidWorks 2014.

To construct the prototype, several steps must be taken. The dimension of the whole machine is measured using measuring tape and a Vernier caliper. There are three sections to be measure which are top, middle and bottom section. The top section requires the additional measurement of emulsion mask stand using the Vernier caliper. The middle section required the measurement of the distance from lens to the light source. The bottom layer requires measurement of the light source box and cover. Measurements must include height, width, length and thickness. The screw are standard 4mm with nuts for the mainframe. The electronic circuit board are observe and replicated into the circuit design. Below shows the SolidWorks modelling of the original design.

3.3.1 Original design

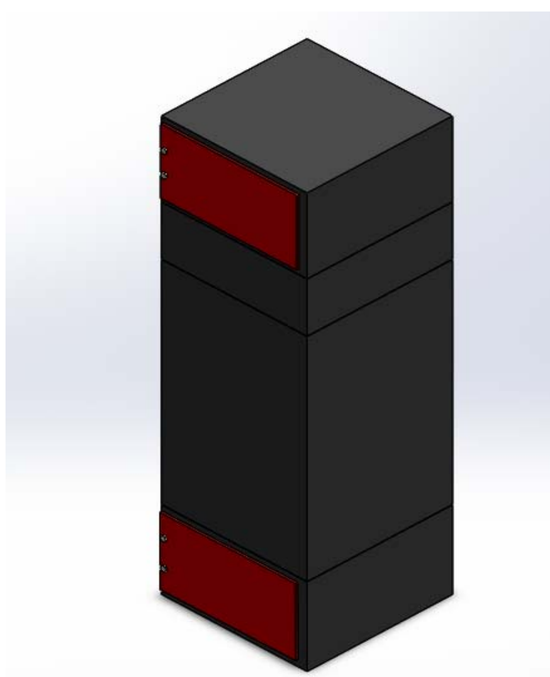

Figure 3.4: Full assembly of the original photolithography machine

The original design of the photolithography machine in figure 3.4 uses different approach. This type of photolithography machine uses 15W florescent lamp that expose that coated silver emulsion glass. Moreover, this machine uses a specifically modified lens as its optical system. The dimension and specification of the machine can be seen in table 3.3. Although this machine is able to provide an aspect ratio of 1:5 and up to 30 µm, due to its size, weight and operation cost there is a need to fabricate a machine that can overcome this problem. The full CAD drawing along with its dimension are shown in appendix C.

Table 3.3: Specification of the original photolithography design

Measurements	**Description**
Height	1872mm
Width	610mm
Length	610mm
Weight	80kg
Light source	Fluorescent white light
Size of mask available	3inch and 4 inch
Advantages	Able to use two type of mask Clear and sharp image Up to 30 micron
Disadvantages	Expensive to operate Heavy Require emulsion mask No mobility

3.3.2 Prototype 1

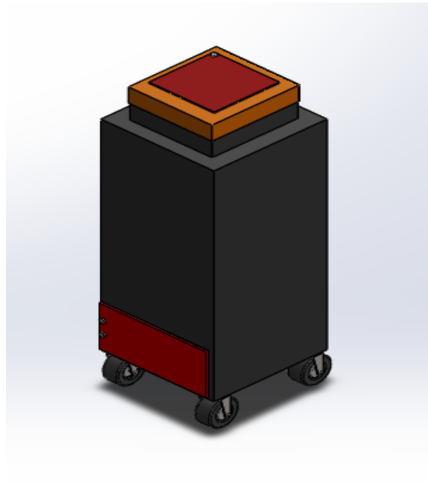

Figure 3.5: Full assembly of prototype 1

The prototype 1 in figure 3.5 is the first prototype idea created. This prototype have a frame construction similar to the original photolithography machine. Several changes have been made which includes adding wheels, reducing the height and weight and adding a small box on top as a place to insert the coated substrate. This prototype does not use florescent lamp as its main source instead it uses a 5 W UVLED. Moreover, the optical lens used were the LCD projector lens obtained from Panasonic projector. A general specification of the machine is tabulated in table 3.4 as well as its CAD drawing in appendix D.

Table 3.4: Specification of the prototype 1 design

Measurements	**Description**
Height	1,144mm
Width	450mm
Length	424.76mm
Weight	22.31kg
Light source	Ultraviolet LED
Size of mask available	4 inch
Advantages	Small Size, Doesn’t require emulsion mask, adjustable optical focal length, portable
Disadvantages	Only for 4 inch

Prototype 2

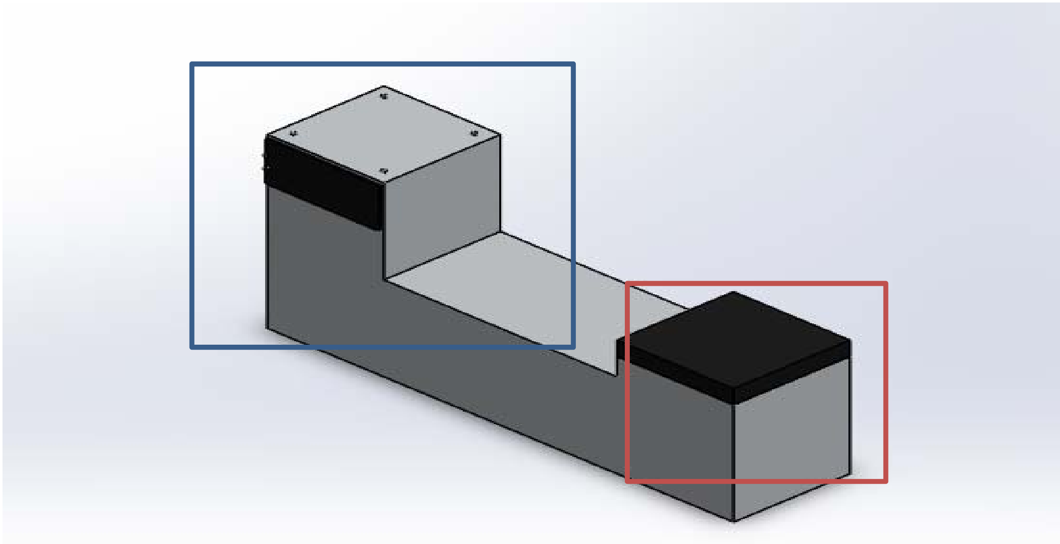

Figure 3.6: Full assembly of prototype 2

The prototype 2 shown in figure 3.6 is the full assembly of prototype 2 which the structure is entirely different from the original photolithography machine. The concept for this comes from binocular prism. Whereby internal reflection is used to project the image to the coated substrate. The parts in the blue box is where the coated substrate is placed while the red box refers to the place where the 5 W UVLED is placed. Along the prototype is where the prism are positioned. This prototype does not have wheels like the rest of the prototype. The general specification and CAD drawing are shown in table 3.5 and appendix E

Table 3.5: Specification of the prototype 2 design

Measurement	Description
Height	500 mm
Width	480 mm
Length	400 mm
Weight	17.2 kg
Light source	UV LED
Size mask available	4 inch
Advantage	Less Space used, direct projection
Disadvantage	Only for 4 inch wafer size, no wheel

3.3.3 Prototype 3

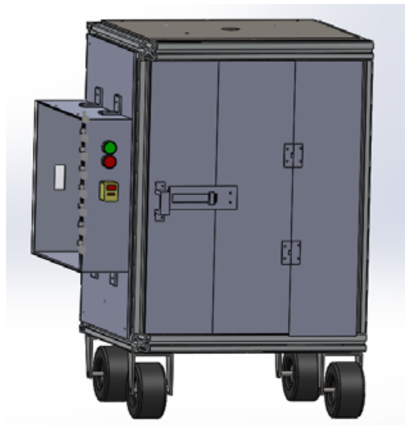

Figure 3.7: 2D drawing of prototype 3

The prototype\3 shown in figure 3.7 is the prototype selected for this project. This prototype is a modification and improvement of prototype 1. Some modification includes adding electronic box for the control of shutter, redesigning the door panel and removing the top box. Moreover, the adjustment system is also included to enable height adjustment. Additional advantage of this machine is that is can be converted into a mask aligner machine. Therefore it is both a projection lithography machine and a mask aligner machine. The general specification and CAD drawing are shown in table 3.6 and appendix F.

Table 3.6: Specification of the prototype 3 design

Measurements	**Description**
Height	569.30mm
Width	480mm
Length	400mm
Weight	20.7kg
Light source	Ultraviolet LED
Size of mask available	4 inch
Advantages	No emulsion mask, can be converted into mask aligner
Disadvantages	Only for 4 inch wafer

Table 3.7: Comparison of the three prototype

Prototype 3 is the selected prototype among the other two due to is convertibility to mask aligner. Moreover, the prototype 3 have an automatic shutter system which is easy for new operators to operate the machine.

PROTOTY DESCRIPTION	PPROTOTYPE 1	PROTOTYPE 2	PROTOTYPE 3
MainFrame	Aluminium and Mild steel plate	Aluminium and Mild steel plate	Aluminium and Mild steel plate
WEIGHT	22.31kg	17.2kg	20.7kg
MOBILITY	Use Wheel	No Wheel	Use Wheel
DIMENSION	1144mm X 450mm X 424.76mm	500mm X 480mm X 400mm	569.3mm X 480mm X 400mm
TYPE OF OPTIC	Soda lime LCD Lens	Soda lime LCD lens and Mirror	Quartz LCD lens
LIGHTING SYSTEM	UV LED	White LED	UV LED
ASPECT RATIO	1:10	1:10	1:10 or 1:1 (mask aligner)
Advantage	Small Size, Lightweight, Doesn't require emulsion mask, adjustable optical focal length, portable	Small Size, Doesn't require emulsion mask,	Small Size, Lightweight, Doesn't require emulsion mask, can be converted into mask aligner
Disadvantage	Only for 4 inch wafer	Heavy , Only for 4 inch wafer	Only for 4 inch Wafer, adjustable height