DESIGN OF MASTER MASK FILM, FABRICATION OF PDMS MOLD AND FABRICATE UV LED CURING UNIT TO TEST IMPRINT CAPABILITY OF ROLL-TO-PLATE NANOIMPRINT LITHOGRAPHY SYSTEM

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JUNE 2017

This dissertation is submitted to

Universiti Sains Malaysia

As partial fulfillment of the requirement to graduate with honors degree in BACHELOR OF ENGINEERING (MANUFACTURING ENGINEERING WITH MANAGEMENT)

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Declaration

I, Mohamad Hazwan Bin Mohd Ghazali, hereby declare that I am the sole author of this thesis and that neither any part of this thesis nor the whole of this thesis has been submitted to any other University or institution for any level of education.

I certify that, to the best of my knowledge, my thesis does not involves anyone's copyright including the figures, tables, techniques and ideas used in this thesis and if it does exist, it has been cited properly.

Signature of author,

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Date : 3 June 2017

Acknowledgement

On June 6, 2017, I have finally completed my final year project entitled "Fabrication of PDMS mold and modifications of roll to plate NIL machine". The project along with this thesis is made possible because of the encouragement and help from many individuals. I would like to extend my sincere appreciation to all of them.

First and foremost, I want to express my gratitude and gratefulness to the GOD Almighty because of my good mental and physical health during the period of this project. Because of this, I was able to finish my project and thesis according to the schedule provided.

I would like to show my special gratitude and thanks to my supervisor, Dr. Khairudin Mohamed for imparting his knowledge and expertise in this area. Apart from that, his constant advice and correction on both project and thesis means a lot to me. It is thanks to him that I have better understanding about NIL generally and this project specifically.

Besides, I want to thank my project partner, Mr. Lee Lai Seng who is currently doing Masters regarding this project. Thanks to his knowledge, guidance and hardwork that I was able to conduct this project and complete my thesis without any significant problem. In other words, this thesis could not become reality without him.

I take this opportunity to show my appreciations to my colleagues in the Nano Functional Materials (NFM) lab especially Mr. Khi Khim Beh due to his help while conducting the experiment and also his permission to use the plate to plate NIL machine. I also want to highlight another individual named Johnson who aided me on this project.

My thanks and appreciations also go to Mr. Halim who taught me about machining skills and it is thanks to him that I was able to fabricate some components for the modification of roll to plate NIL machine. Finally, I want to express my gratitude to those who directly and indirectly help me completing this project and thesis.

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List of Abbreviations

MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
BJT	Bipolar Junction Transistor
NIL	Nanoimprint Lithography
LADI	Laser Assisted Direct Imprint
PDMS	Polydimethylsiloxane
UV LED	Ultra Violet Light Emitting Diode
R-LTIL	Roll-typed Liquid Transfer Imprints Lithography
RIE	Reactive Ion Etching
T-NIL	Thermal Nanoimprint Lithography
SFIL	Step – and – Flash Lithography
RNIL	Roller Nanoimprint Lithography
PC	Polycarbonate
Tg	Glass Transition Temperature
AI	Adobe Illustrator
CAD	Computer Aided Design
OPC	Optical Proximity Correction
CMM	Coordinate Measuring Machine

Abstract (BM)

Teknik litografi optikal yang digunakan pada masa kini masih tidak dapat memenuhi permintaan industri yang semakin meningkat terutamanya daripada industri bio-perubatan dan elektronik. Bukan sahaja mempunyai produktiviti yang rendah, ia juga sukar untuk dilakukan, di samping hasil produk tidak setepat yang dijangka. Disebabkan masalah-masalah ini, banyak alternatif lain sedang dirangka dan dikaji. Antaranya ialah litografi nanotekap (NIL).

NIL adalah alternative yang lebih baik kerana ia lebih ringkas, murah dan mempunyai produktiviti yang lebih tinggi. NIL gulung ke bongkah rata adalah salah satu daripada NIL teknik dan akan difokuskan dalam projek ini. Objektif utama kajian ini adalah untuk mengubahsuai mesin NIL gulung ke bongkah rata yang masih lagi dalam proses pembinaan supaya ia menjadi satu mesin lengkap yang mampu menghasilkan acuan bersaiz besar dan juga boleh menjalankan proses gulung ke bongkah rata NIL.

Projek ini boleh dibahagikan kepada dua bahagian; pengubahsuaian mesin gulung ke bongkah rata NIL dan proses NIL. Pengubahsuaian ini melibatkan pemasangan elemen pemanasan, stesen rawatan UV, mekanisme doctor bilah, stesen acuan tanpa garisan pertemuan, pemasangan motor dan komponen-komponen yang lain. Disebabkan mesin ini masih belum sempurna, proses NIL dilakukan menggunakan mesin bongkah rata ke bongkah rata NIL untuk menguji konsepnya.

Walaupun mesin yang digunakan berbeza, konsep NIL masil lagi sama. Pertama sekali, corak yang direka mestilah ditukarkan daripada ‘master mask film’ ke gelas mikroskop secara serta merta, dibantu oleh radiasi UV. Kemudian, corak ini akan dipindahkan daripada gelas mikroskop ke acuan PDMS sebelum ditekapkan ke wafer menggunakan mesin bongkah rata ke bongkah rata NIL. Pada mulanya, corak yang direka berjaya ditekapkan ke wafer tetapi ianya kurang tepat kerana sebahagian corak tidak dapat dilihat. Dalam eksperimen kedua, struktur corak baharu berjaya ditekapkan dengan keputusan yang lebih baik disertakan sekali dengan dimensinya.

Abstract (BI)

Current optical lithography method still cannot cope with the increasing demands from the industry especially electronics and biomedical industry. Not just it is low throughput; it is also difficult to conduct, not to mention the end product of this method is not as accurately as anticipated. Due to these limitations, lots of other alternatives are being developed and one of it is nanoimprint lithography (NIL).

NIL is a better alternative to the conventional lithography method as it is simpler, cheaper and has higher throughput. Roll to plate NIL is one of the many NIL techniques and it will be focused in this project. The main objectives of this study is to modify the roll to plate NIL machine which is still under development so that it can be a complete machine capable of both large area mold making and roll to plate NIL process.

This project can be divided into two parts; modifications of the roll to plate NIL machine and NIL process. Modifications include installation of heating element, UV curing station, doctor blade mechanism, seamless mold station, motors and other supporting components. Because the roll to plate NIL machine is still not fully complete, NIL process was done using plate to plate NIL machine to test its concept.

Although the machine used is different, the concept of NIL is still the same. First of all, the designed patterns are directly transferred from master mask film to microscope glass, aided by UV rays. Then, the patterns are replicated to PDMS mold before being imprinted to silicon substrate using plate to plate NIL machine. At first, the designed patterns were successfully imprinted on the silicon substrate but it was less accurate as some patterns cannot be seen. In the second experiment, the new structures has been successfully imprinted with better results along with its dimensions.

Chapter 1: Introduction

Sometime people must be wondering how electronic device such as metal–oxide–semiconductor field-effect transistor (MOSFET) are fabricated, with nanometer scale patterns imprinted on it. Before going any further, MOSFET is a smaller type of transistor that is widely used in microprocessor and memory chips. Compared to bipolar junction transistor (BJT) or in other words, regular transistor, MOSFET consume less power and it is relatively cheaper. Figure 1.1 below shows one of the MOSFET available in the market at a price of as low as RM4. The information of circuit design which is represented by nano-scale patterns will be transferred to the device's wafer and this is made possible with the application of optical lithography, which is the current industrial technology.

Optical lithography is a process applied in microfabrication which uses light to pattern parts of a thin film or the bulk of a substrate [11]. In layman's term, it is a technique of samples or design patterning. However, apart from being high cost and difficult to operate [12], optical lithography always associated with light diffraction. This phenomenon occurs when light passes through obstacle, in this case a mask (refer figure 1.4), and bend which will results in lower accuracy of pattern transfer. This is where NIL was introduced.

NIL is a simpler, low-cost, and high-throughput alternative to micro- and nanofabrication as well as offering fabrication of sub-10 nm feature size. Basically, most of the nano-scale design can be patterned by using this technique. In the NIL process, a prefabricated mold containing an inverse of the desired patterns is pressed onto a resist-coated substrate to replicate the patterns via mechanical deformation. Mold is a material containing design or pattern while substrate is a solid material or medium in which other material (mold) is applied to it. Basically, mold and substrate are one of the most vital components in NIL process. From figure 1.2 below, it can be observed that the examples of pattern or design used in NIL ranging from 10 μm to 1μm. This design can be either a simple design or a complicated one such as map and circuit design.

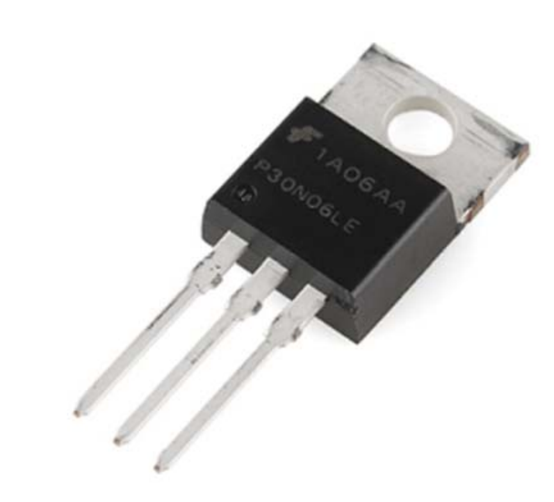


Figure 1.1: MOSFET sold in the market [26]

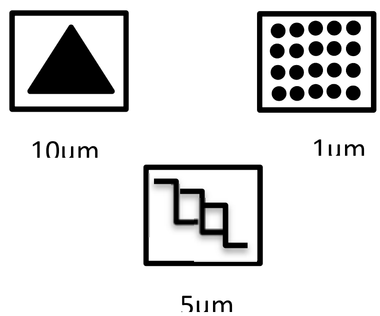


Figure 1.2: Examples of patterns used in NIL ranging from 10µm to 1µm

As time passes by, several techniques have been developed to further improve the NIL process and fulfill the increasing demand in this field. Reverse NIL, roller NIL (RNIL), laser assisted direct imprint (LADI), chemical nanoimprint, electrical-field assisted NIL are some of the NIL techniques [21] developed for the sole purpose of improving the quality of the pattern and increasing the throughput. Each of these techniques has their own advantages and limitations. Focusing on RNIL, it is a technique of imprinting pattern onto substrate by using roller which creates force during the imprinting process. It is still considered as a new area and needs further researches and explorations so that all the limitations can be countered.

There are myriads of materials that can be utilized to make mold in the NIL process which includes polydimethylsiloxane (PDMS) which is an organic polymer, glass, diamond and quartz. Hard mold (glass, quartz, diamond, etc.) and soft mold (PDMS) have different optical, chemical and mechanical properties and it is important to choose the mold material wisely. For example, although hard mold has better wear characteristic, it possesses greater risk of breaking during demolding process. Figure 1.3 below shows the PDMS and quartz mold which has different characteristics.

Figure 1.3: (left) Demolding process of PDMS mold [27] and (right) quartz mold [28]

This project will focus on RNIL generally, and roll to plate NIL specifically, which is one of the three imprint contact types. The other two are roll to roll NIL and plate to plate NIL. In this project, quartz roller will be used to transfer micro-patterns to the heated PDMS mold. Firstly, PDMS was chosen as mold material and coated to the entire quartz roller by using a dispenser. Then, some heating rods will be used to dry the PDMS material. After that, master mask film is wrapped around the quartz roller to imprint the micro patterns that have been created before to the PDMS mold. Finally, six ultra violet light emitting diodes (UV LED) will be applied to the roll to plate machine to cure the PDMS mold, making it hard. Silicon is chosen as a substrate material. In this project, roller imprint tool is already being fabricated. However, certain additions and modifications are still needed to make it a complete roll to plate NIL machine.

One of the problems that might be encountered is how to efficiently cover the entire roller with PDMS and fully wrap the master mask film around the roller. Wrong wrapping of the master mask film can lead to seams and overlapping pattern imprinted on the roller.

1.1 Problem Statement

Large area mold making technique and continuous large area transfer of micro and nano pattern structure onto the substrate is still a challenge and so far NIL clearly stands out as a promising technology to achieve this goal. Roll to plate NIL, which is one of the NIL techniques, requires the perfect wrapping of the PDMS mold around the substrate to ensure that all substrate area is covered for the uniformity reason. Then, the imprint capability of this system can be characterized.

Typical area of mold produced is 4 inch and to produce mold larger than 4 inch will be a challenge in this project. The micro pattern structures produced also might not be as desired in terms of shape and dimensions in the PDMS mold. This problem arises because of the proximity effect of the designed pattern and printing capability when obtaining the master mask film. Proximity effect will be further explained in the chapter 3 (methodology) section.

1.2 Scope of Work

This project will cover NIL technique which is used to fabricate and transfer micro and nano pattern structures. The other approach which is roll-typed liquid transfer imprint lithography (R-LTIL) will not be investigated in this research. Rather than making emulsion mask, master mask film will be straight away used in the large area PDMS mold making process, which will also be covered in this research. Apart from that, only roll to plate NIL will be used for this research instead of roll to roll NIL and plate to plate NIL.

1.3 Objective / Goal

Because NIL still needs further researches and improvements, hopefully this project can be useful so that it can be applied in the industry in the future. This project aims to proof the roll to plate NIL concept through the newly developed machine, as well as fabricating large area mold by using the same machine which has not been done by anyone so far. Some objectives have to be fulfilled so that the goal can be achieved;

i) Modification of roll to plate NIL machine

ii) Large area mold making process using soft lithography

ii) NIL process

iii) Minimizing seam during master mask film wrapping

1.4 Project Background

The study of NIL is so important that some of the companies invest lots of money in the NIL research so that it can further fulfill the demands generated from the recent developments in the semiconductor and electronics industries. This is due to the fact that it is a simple, low-cost, and high-throughput process for replicating micro and nano scale patterns. As mentioned before, this project will focus on evaluating imprint capability of large area roll to plate NIL system.

Compared with the flat NIL, it has the advantage of better uniformity, less force and the ability to repeat a mask continuously on a large substrate. In this project, rather than creating emulsion mask from master mask film (both emulsion mask and master mask film can be observed in figure 1.4), the film will be wrapped around quartz roller of the roll to plate machine which can then be applied to imprint micro and nano scale patterns for various practical applications. Figure 1.5 shows roll to plate NIL machine which is still under development. This machine will be used to imprint the nanoscale patterns onto silicon substrate. PDMS material of course will be coated on the quartz roller first. This can increase the productivity of the nano and micro scale structure as well as reducing the cost of the imprinting process.

Figure 1.4: (Left) emulsion mask and (right) master mask film [29]

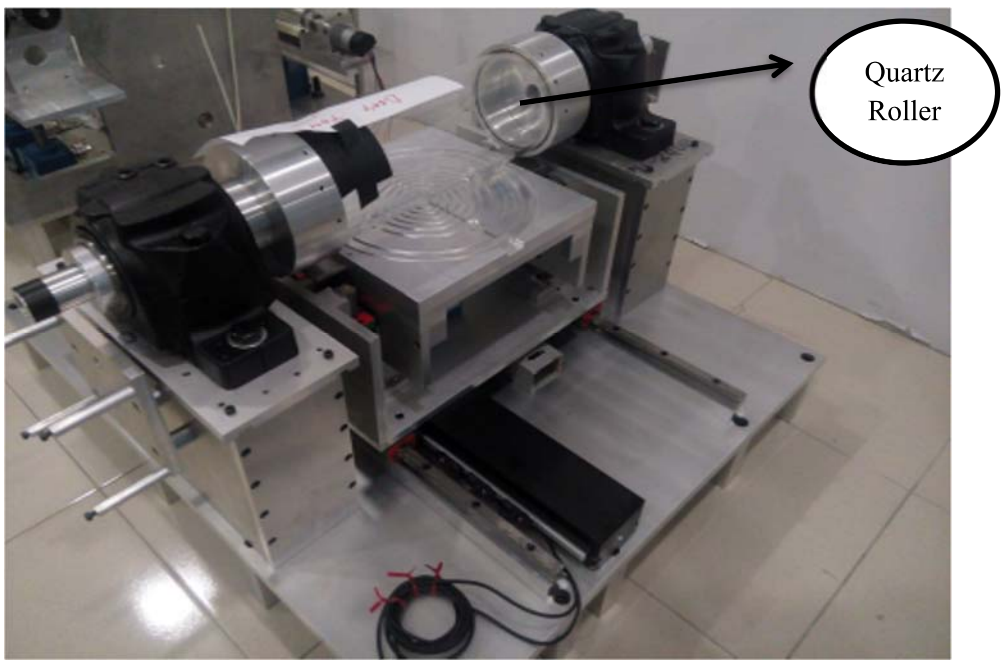


Figure 1.5: Roll to plate machine before modifications

For roll to plate NIL, the actual contact area during imprinting is only a line along the roller in contact with the substrate rather than the entire stamp area such as in plate to plate NIL. In plate to plate NIL, the entire resist is imprinted simultaneously and the pressure is applied until the resist is cooled down. By having smaller contact area, this will reduces the required imprinting force in the NIL process. Apart from that, due to the line contact, the roller-based NIL process has the advantage of reduced issues regarding trapped air bubbles, thickness variation, and dust pollutants, which also greatly improve its replication uniformity [6].

Rather than using hot embossing process, UV LED curing system will be used in this project. The basic process flow of hot embossing process can be observed in figure 1.6 below. In hot embossing process, the substrate must be made of thermoplastic material such as polycarbonate and polypropylene. If otherwise, it needs to be coated with hot embossing material such as polymer by using spin coater [22]. If UV is applied, instead of manipulating the phase change via resist temperature, UV exposure causes resist hardening due to cross-linkage in the polymer. The unaffected area of the resist will remains soft and will be eliminated in the next step of process. This type of curing system is chosen for the roll to plate NIL because it can be conducted at room temperature without the need to raise the imprinting temperature.

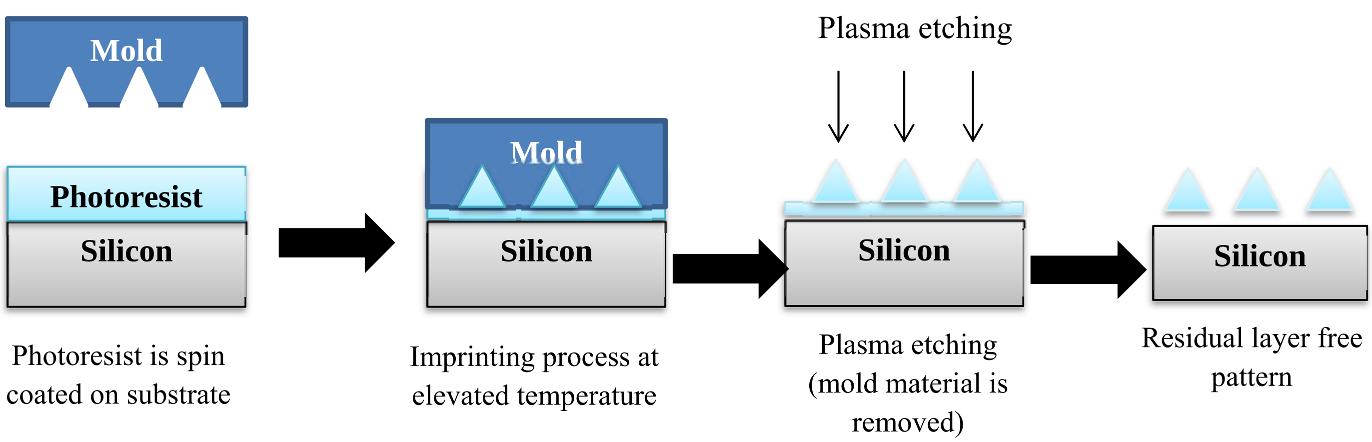


Figure 1.6: Process flow of hot embossing process

Basically, chapter one aims to provide the general idea about what this project is all about to the readers. Roll to plate NIL is just one of the many lithography alternatives generally, and one of the NIL techniques specifically. In the next section which is the literature review, the researches about NIL and mold making that have been conducted by researchers all around the world will be discussed.

Chapter 2.0: Literature Review

NIL is a manufacturing process where micro and nano pattern structures are fabricated. Discovered in 1995 by Stephen Chou and his teams [2], according to their research, this high-throughput and low cost fabrication process has been successfully used to fabricate devices such as quantum wire, ring transistors and nanoscale photodetectors [2]. As mentioned before, the purpose of NIL is basically to counter the disadvantages of current optical lithography technique. NIL consists of two important steps mainly known as imprint and pattern transfer step (figure 2.1). According to Stephen Chou and his teams, what makes NIL special and different from any other conventional techniques is that it is not limited by the effects of wave diffraction and interference in a resist.

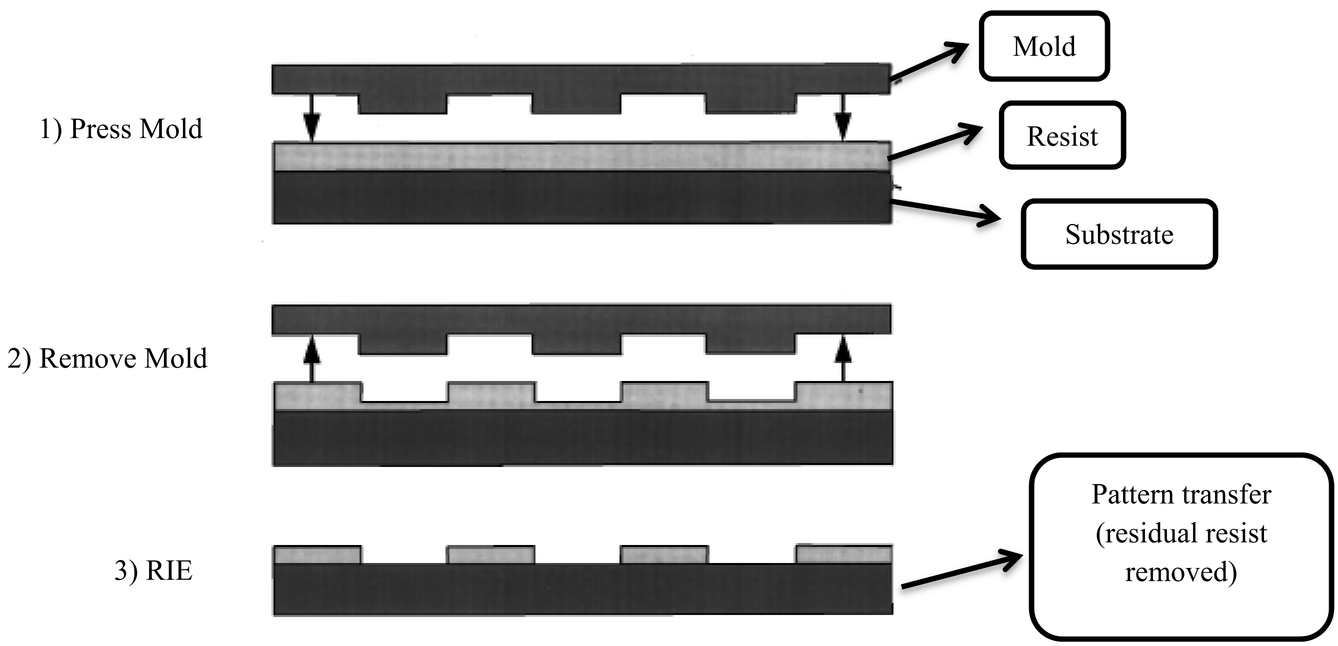


Figure 2.1: NIL process (imprint + pattern transfer) [2]

Back in 2010, due to the continuous research in NIL, several NIL techniques have been developed which include Thermal NIL (T-NIL) and Step – and – Flash Lithography (SFIL) [17]. T- NIL consists of heating, stamp pressing, cooling and removing process. Both heating and cooling processes involve glass transition temperature (Tg) of the polymer used. In contrast to the T-NIL, no heating element involved in the SFIL technique. SFIL technique is pretty much the same as the technique used in this project because both techniques apply the concept of UV radiation through the mold. The process diagram for both T-NIL and SFIL can be observed in the figure 2.2 below.

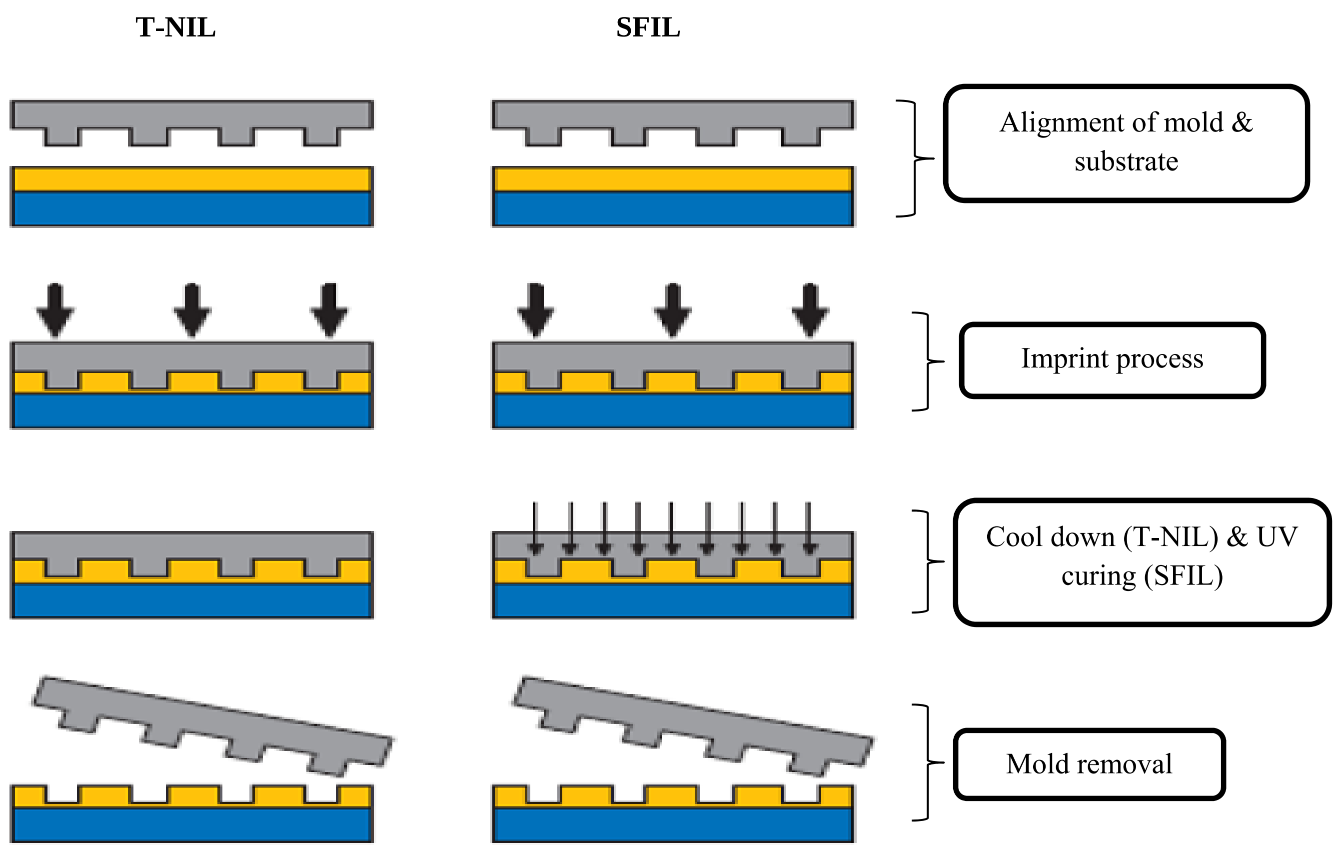
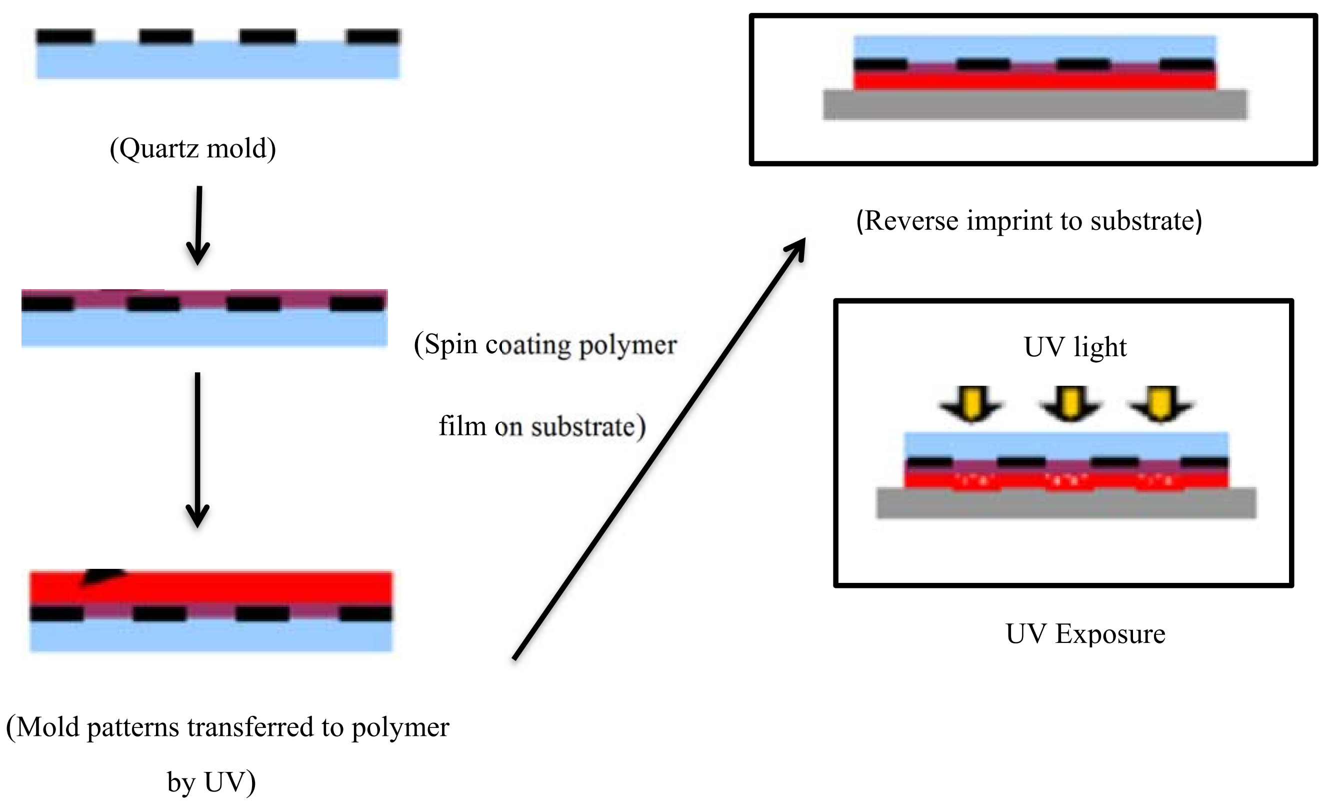


Figure 2.2: T NIL and SFIL techniques [17]

Both of these techniques however have limitations. For T-NIL, high viscosity of the thermoplastic might cause longer time when filling the mold [23]. High viscosity can be defined as substance with high resistance to movement. The problem worsens when the mold has different size of patterns because high viscosity can provide non uniform stress distribution that will lead to deformation [23]. Heating and cooling elements that associated with T-NIL is no doubt will prolong the imprinting cycle time. Although UV NIL overcomes most of the limitations of T-NIL, it still has difficulty to control the volume of imprint material due to the rate of evaporation.

In addition to that, one interesting technique has been explained by Hongbo Lan and Yucheng Ding [21] which is reverse NIL. In this technique, instead of transferring the micro patterns from substrate to mold, the patterns are formed on the mold before transferring to the latter. The mold used in this technique is quartz metal. By spin coating, the mold patterns are formed in polymer film first and because this polymer film has better adhesion to substrate, it can be detached from the mold, allowing the successful transfer of micro patterns. For further information, refer figure 2.3 below.



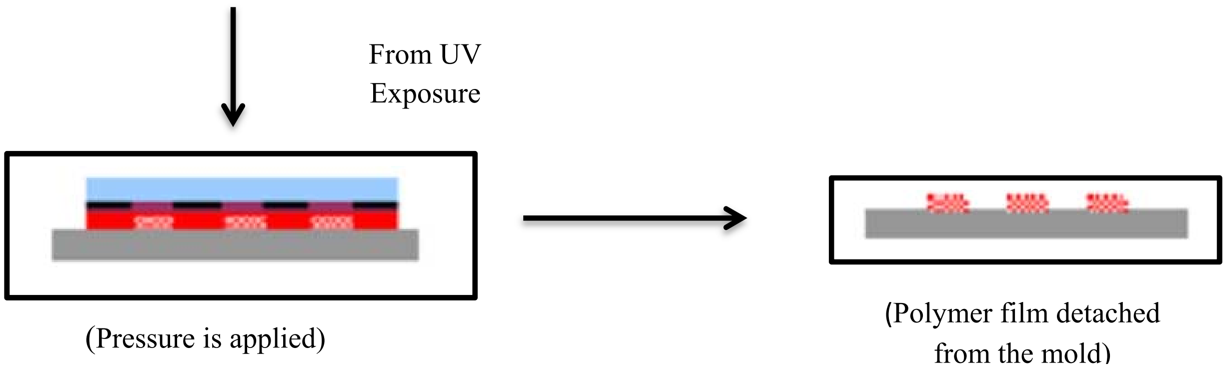


Figure 2.3: Reverse NIL technique [21]

Focusing on RNIL, there are three imprint contact types in NIL which are plate to plate NIL, roll to plate NIL and roll to roll NIL. In plate to plate NIL, a flat rigid mold is used to transfer patterns onto a flat rigid substrate. This technique has the largest contact area compared with the other two techniques. In roll to plate NIL, a roller is used to imprint patterns onto a flat rigid substrate whereas in roll to roll NIL, a roller is used to transfer pattern onto another roller substrate. Both of these techniques have a contact area of only a line along the roller that is in contact with the substrate [6]. The contact areas can be graphically represented in the figure 2.4 below.

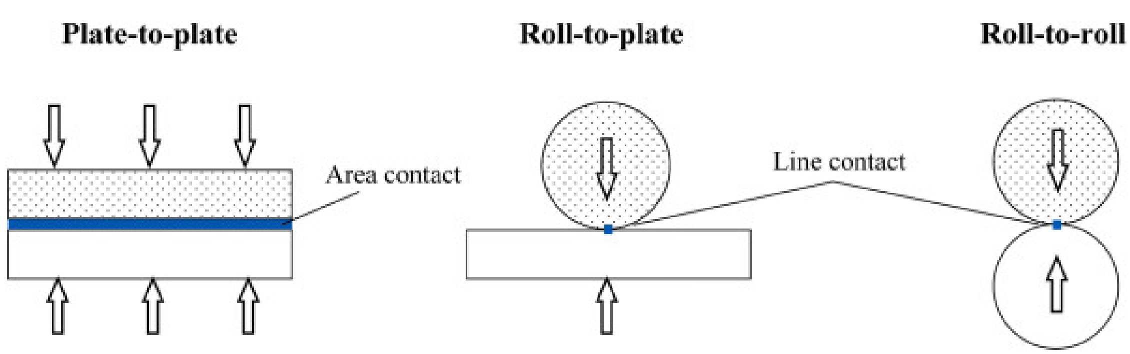


Figure 2.4: Contact area of plate to plate, roll to plate and roll to roll NIL [6]

For plate to plate NIL, due to its larger contact area, there is always a risk of imperfect imprint of micro patterns. This might be because of the plates involved are not parallel to each other and the sample is not flat. This will create uneven imprint force which eventually will increase the chance of breaking the mold [20]. The visuals of these limitations can be seen in the figure 2.5

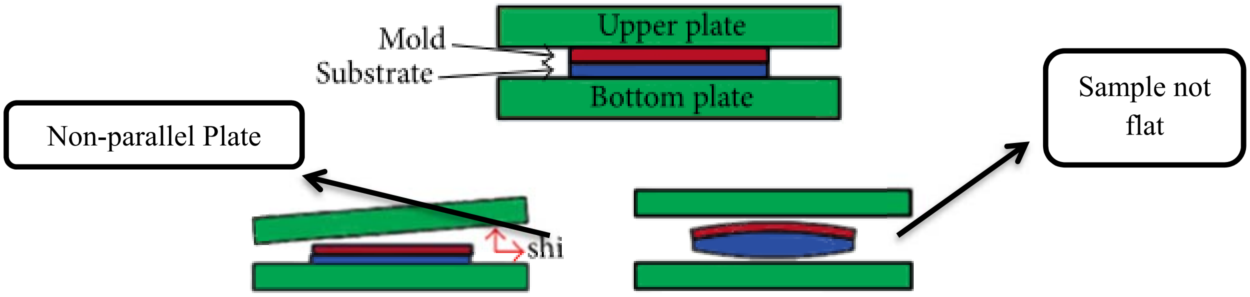


Figure 2.5: Limitations of plate to plate NIL [20]

Apart from RNIL, another technique to fabricate nanoscale and microscale structures is by applying R-LTIL as proposed by Lee Jaejong and his research team in 2014. This technique also consists of two major steps. The first step includes resist coating and detaching while the second step involves the transfer of resist to flat surface with the help of UV curing [1]. According to Lee Jaejong and his research team, this approach can counter the problem of residual layer thickness as well as minimizing the nanoimprint proximity effect. From the two major steps, this technique can be broken down into five steps which can be further observed in figure 2.6 below.

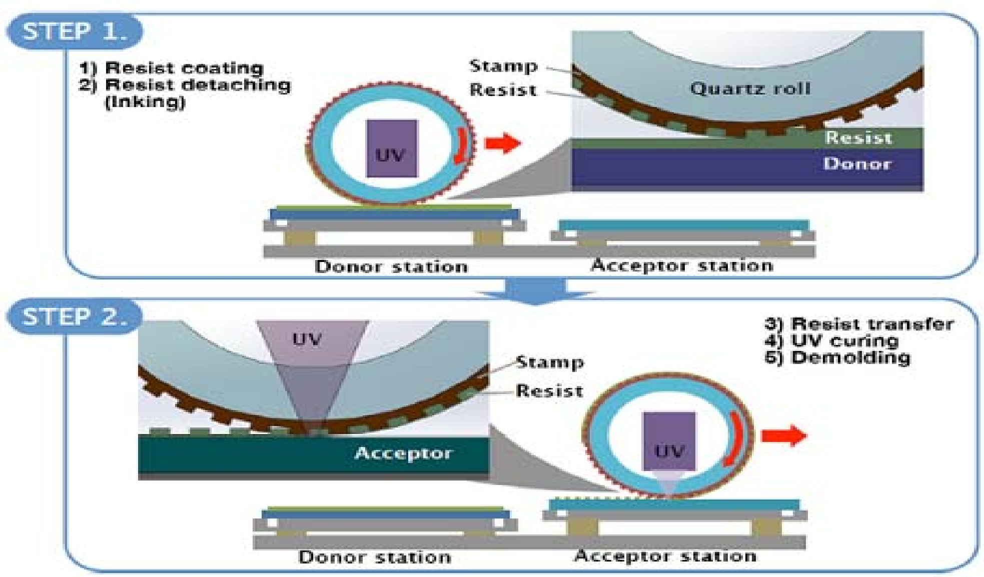


Figure 2.6: R-LTIL technique that consists of five steps[1]

It should be noted that they managed to successfully replicate the patterns to 6 inch wafer. In their findings, the velocity of the roll stamp when transferring the patterns was the critical parameter in their experiment. This is due to the fact that excessively fast speed might prevents curing while excessively slow speed causes the resist to be cured before any contact is made between substrate and roller.

Both of the aforementioned techniques require the making of PDMS mold as the mold material. Due to the material's unique properties concerning its flexibility, high UV transparency and easy handling, PDMS mold has been widely used to fabricate micro-electro-mechanical devices. Aside from being cheap, by using spincoat process, it can be coated uniformly on the substrate and its thickness also can be controlled.

Recently, soft molds including PDMS are widely used to replace hard molds such as glass, quartz and silicon molds. One of the reasons hard mold is replaced because there will be a problem in the patterning process. Air bubble formed between mold and resist-coated substrate might lead to defects in the patterns and this defect will worsen when the mold is repeatedly used. Another reason why hard mold are not favored is because it possesses a greater risk of breaking both mold and substrate during demolding process [20]. PDMS will be used as a mold in this project and thus it will be focused more compared to hard mold.

In biomedical field, there is a high demand for reliable and precise surface patterning technique of PDMS for different microfluidic and bioengineering applications because it is impossible to achieve that using conventional lithography technique. Thus, Weiqiang Chen and his team came out with a wafer-scale PDMS surface micromachining technique to fulfill this demand [18]. This technique still makes use of the conventional lithography method but in addition to that,

oxygen plasma is applied to the PDMS. This method is also compatible with existing silicon based surface. The detailed process of this technique can be seen in figure 2.7.

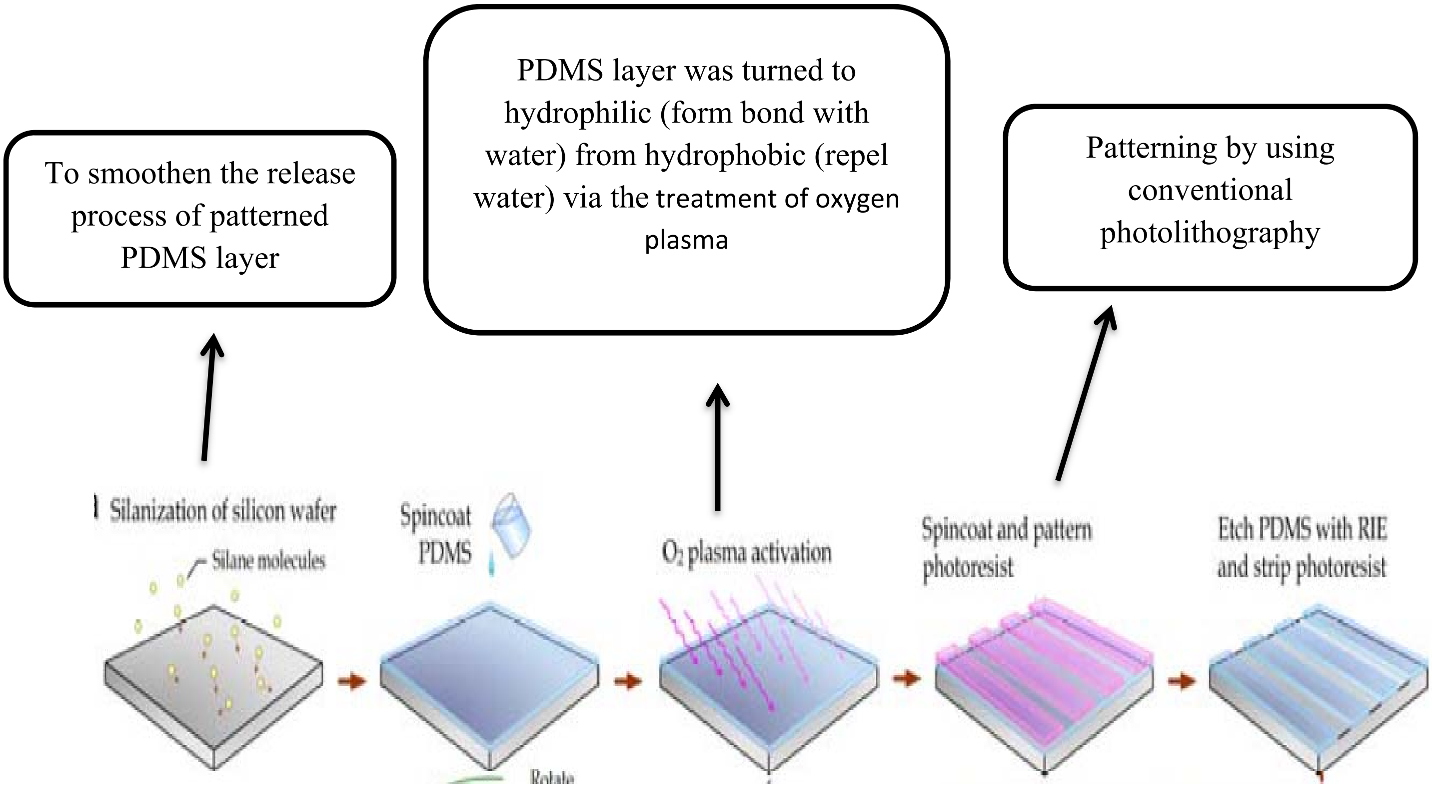


Figure 2.7: Wafer-scale PDMS surface micromachining technique [18]

To date, one of the works involving the large area substrate is performed by JaeJong Lee and his teams. They proposed a system of transferring nano scale patterns to 6 inch silicon substrate [1]. As mentioned earlier, the detailed process of this technique can be seen in figure 12. Besides that, pattern transfer to the large substrate has been proposed by Hyungjun Lim and his teams [19]. Based on their research, nano patterns can be transferred to large substrate role (250 mm diameter and 366 mm width) via roll to roll NIL that makes use of smaller hollow master roll (200 x 200 mm) and larger substrate roll. The basic concept of this process is just like SFIL and can be further seen in figure 2.8.

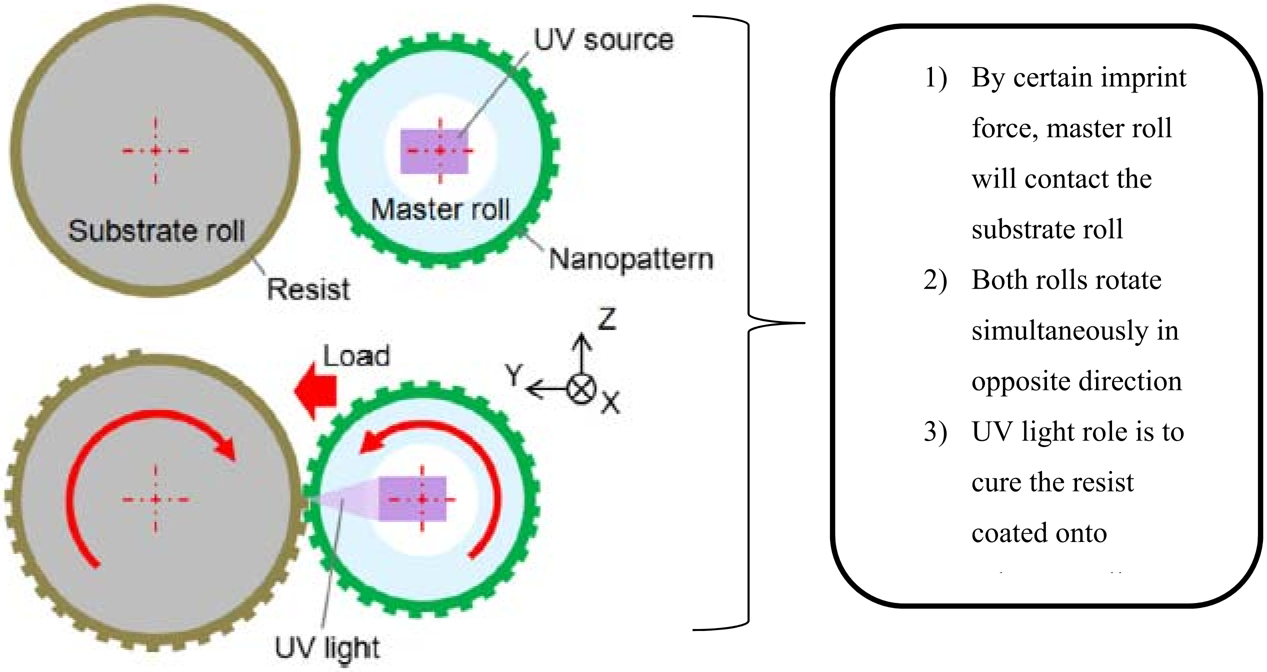


Figure 2.8: Pattern transfer from master roll to substrate roll[19]

The master roll has been attached with nanopatterned PDMS sheet while the substrate roll was attached with resist-coated polycarbonate (PC) film. PC film is attached because it is hard to coat the large substrate roll with NIL resist. In order to reduce the seams which appeared at the beginning and end of the process in their experiment, make sure that the UV light is as narrow and sharp as possible because according to their finding, 2mm band of UV light is considered too big.

Another research has been done by Se Hyun Ahn and L. Jay Guo. They managed to successfully demonstrated 4 inch wide imprinting of structures by using their newly developed apparatus capable of both roll to roll NIL and roll to plate NIL [16]. In other word, a two – in – one process involving successful large area PDMS mold making and nano scale pattern transfer capability still has not been demonstrated yet. Their machine applies the concept of dual imprint rollers which are supported by two rollers so that constant pressure can be maintained during curing process. To further understand this application, refer figure 2.9 and 2.10. For roll to roll NIL, the substrate used is master mask film whereas for roll to plate NIL, the substrate used is glass substrate.

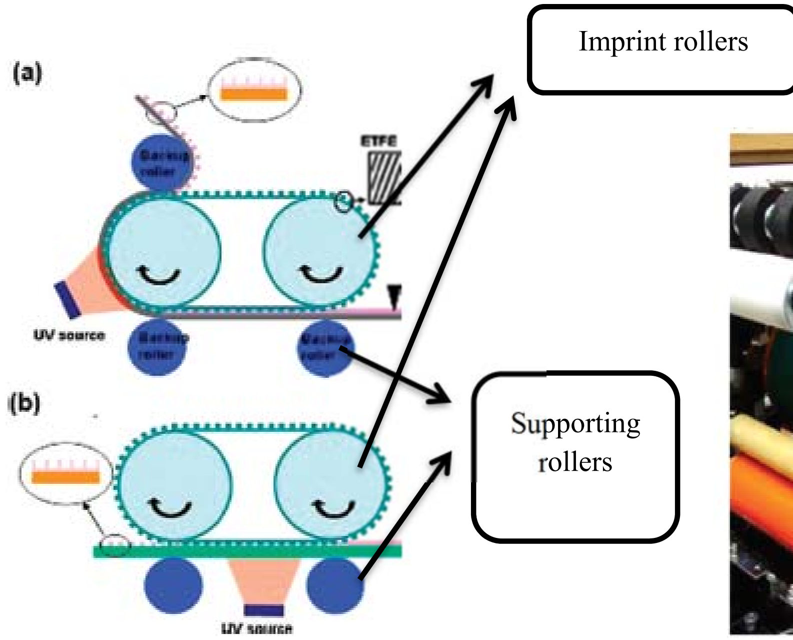


Figure 2.9: Roll to roll NIL (a) & roll to plate NIL (b) [16]

Figure 2.10: Two-in-one roll to plate and roll to roll NIL machine [16]

Hua Tan and his teams also developed a two – in – one concept machine which is composed of cylinder and flat mold [25]. They can either roll a cylinder mold on a flat substrate just like the roll to plate NIL or apply roller on top of a flat mold which in turn is located on top of a substrate. The design of this machine can be observed in figure 2.11.

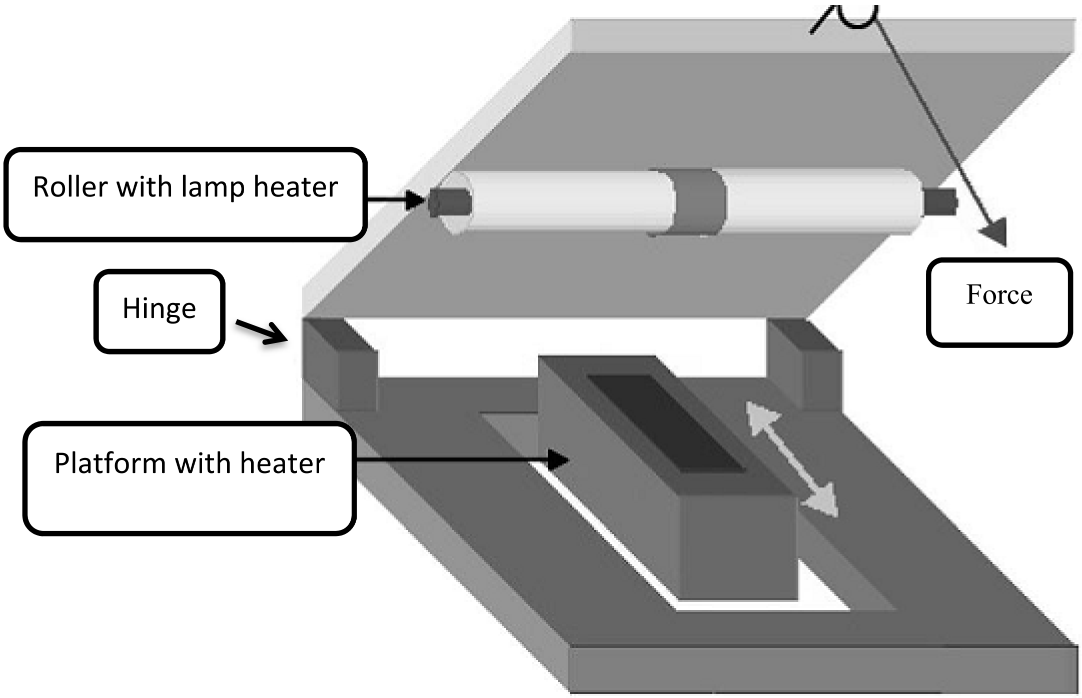


Figure 2.11: Design of machine capable of applying both cylinder and flat mold [25]

Unlike this project which makes use of UV, their research applies the concept of T-NIL which involves the glass transition temperature. Three critical parameters have been addressed in their findings which are temperature, pressure and speed of the moving roller. When the speed of the roller is too fast, there is insufficient time for the resist to change its shape and this situation is also the same for low pressure [25].

Chapter 2 concludes some of the researches conducted all over the world regarding NIL and mold making. There are still much more to discover in NIL area as well as mold making technique. In the next chapter which is Chapter 3: Research Methodology, all the methods while conducting this project will be discussed and new components that will be equipped to this machine are going to be introduced.

Chapter 3: Research Methodology

Research methodology is the techniques or methods applied in order to achieve the objectives mentioned before. It can be divided into the modifications of the roll to plate NIL machine and NIL process. Generally, modifications of the roll to plate machine are needed because the large area mold will be made on the machine itself aside from the NIL process. Apart from that, several equipment or components also need to be equipped to the machine and thus modifications of the machine are vital. The details of each step for both sections are as follow:

3.1) Modifications of the roll to plate machine

First of all, the roll to plate NIL machine needs to be modified so that it can serves as 'all in one' machine. This means that the machine can make PDMS mold as well as imprinting the patterns designed onto the silicon substrate by using the same machine. The modifications involve the installation of heating rods, UV LEDs, cable chain, pulley, linear guide rail, motors, seamless mold station, and doctor blade.

3.1.1 Installation of heating rods

Heating rods will act as heat supplier for the heating stage of this NIL process. The heating stage aims to dry the PDMS material so that it does not drip from the quartz roller. Four heating rods as being shown in figure 3.1 will be utilized for this purpose and it is obtained from an oven. The process for obtaining the heating rods and how to equip it can be observed in figure 3.2 and figure 3.3 respectively.

Figure 3.1: One of the four heating rods used in this machine for the heating purpose

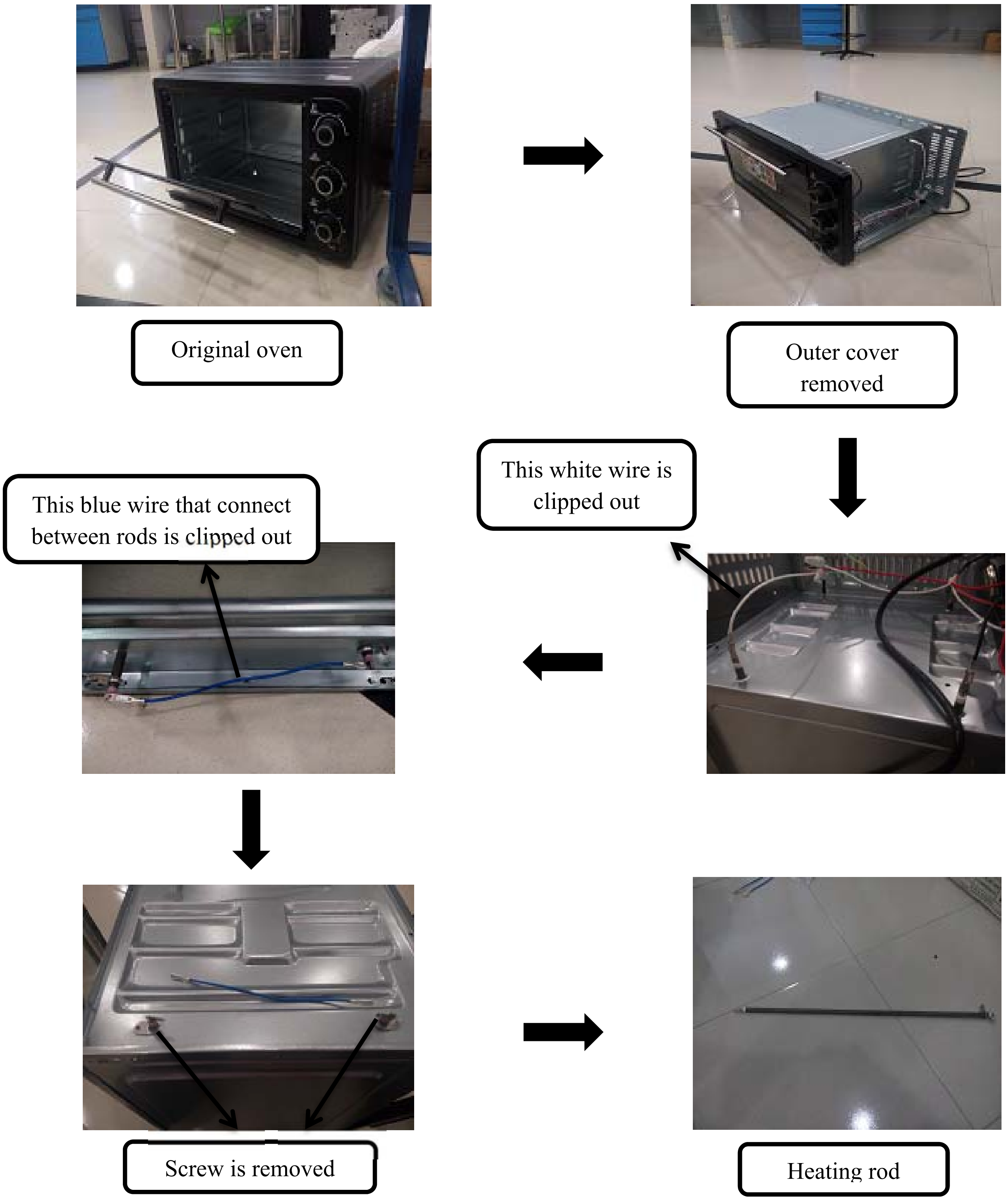


Figure 3.2: Process flow of obtaining heating rods from an oven

In addition to that, heater cover is needed to prevent the heat dissipated from heating rods into the atmosphere. This box-like cover is made from 1mm thick mild steel and will be located at the top of the roll to plate NIL machine**.** First of all, the mild steel was cut into desired dimensions using shearing machine (refer APPENDIX I). After that, a few holes are drilled to hold all the heating rods and then welded into box like shape by using gas arc welding. Figure 3.4 shows the process flow of how to fabricate the heater cover starting from the raw material until the final product. Mild steel is preferable compared to aluminium because it is much easier to weld and all types of welding can be used to weld it. Two aluminium plates were fabricated to act as a holder for all the heating rods and L brackets are used to hold the cover and plates together. The length of the heater cover is 44cm with its width and height being 11cm and 6cm respectively.

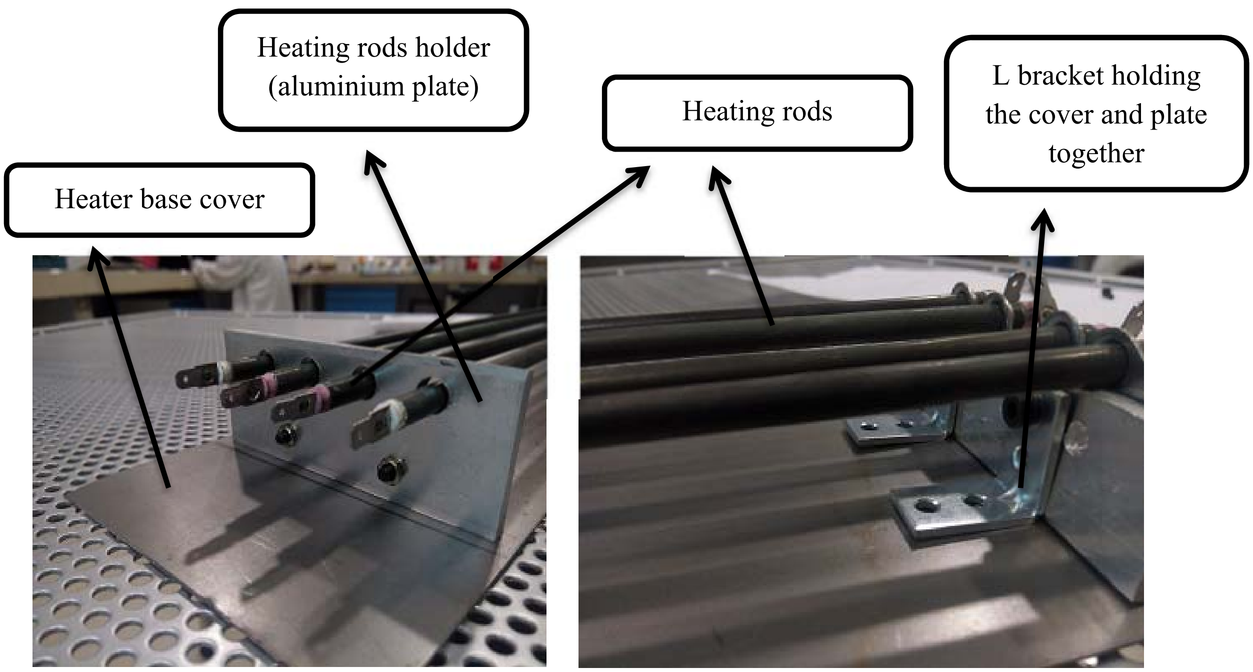


Figure 3.3: Installation of heating rods to the heater cover by using two aluminium plates and four L bracket

a) Raw material (mild steel)

b) Mild steel cut into desired shape and drilled

c) Gas arc welding (intersection of plates welded)

d) Heater cover after being sprayed

Figure 3.4: Process flow of fabricating heater cover

3.1.2 Installation of cable chain

Cable chain which is bought from vendor is equipped to the roll to plate NIL machine in order to move the horizontal support plate along with the silicon substrate to its desired position and return it to its original position**.** Cable chain tighten blocks made from aluminium are fabricated so that the cable chain can be fixed to the horizontal support plate. Two screws are used to fix the other end of cable chain to the base of the roll to plate NIL machine. Figure 3.5 below shows the cable chain used in this machine along with two cable chain tighten blocks. In figure 3.6, it can be seen that the cable chain is fixed to the base of the machine by using two screws and the cable chain tighten blocks are used to fix the cable chain to the horizontal support plate.

Figure 3.5: Cable chain used in this machine and two cable chain tighten blocks used to fix this component to other parts of the machine

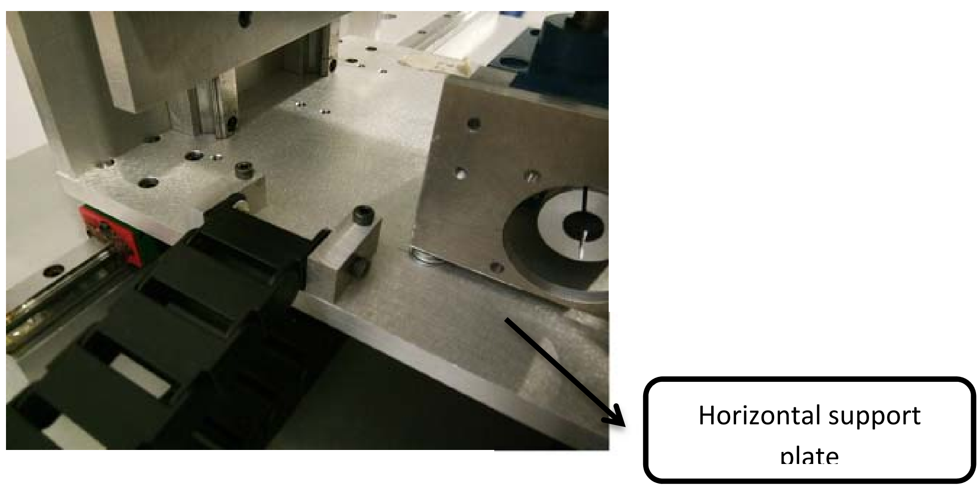


Figure 3.6: (top) Two screw used to fix the cable chain to the base plate of roll to plate NIL machine and (below) cable chain tighten blocks used to fix cable chain to the horizontal support plate

3.1.3 Installation of doctor blade mechanism

In PDMS coating stage, doctor blade will be used to remove excess PDMS on quartz roller, thus making sure that uniform coating of PDMS material can be achieved. Thus, the roll to plate NIL machine needs some additional components so that this blade can be equipped to the machine. First of all, doctor blade is a type of blade mainly used for uniformity purpose and it usually available in a roll form which can be clearly seen in figure 3.7 below. It can be cut off just by using scissor. However, doctor blade holder is needed to make use of this blade.

Figure 3.7: Doctor blade in a roll form with 0.15mm thickness

This holder is made up of top and bottom doctor blade holder. This identical aluminium plates will hold the doctor blade together by clasping it before being inserted into doctor blade brackets. Doctor blade holder can move back and forth along these brackets and after there is desired contact between doctor blade and coating on quartz roller, doctor blade tighten screw blocks are used to fix the position of the doctor blade holder. Doctor blade brackets are screwed to one aluminium plate with dimension of 352mm in length and 50mm in height.

Figure 3.8 shows two differential micro screw heads that are used to move the doctor blade along with its holder to the desired position by just rotating the adjuster. Figure 3.9 shows some of the components that are used in order to apply doctor blade in this project such as doctor blade top and bottom holder, doctor blade brackets and doctor blade tighten screw blocks. Finally figure 3.10 shows the combination of all these components including doctor blade before being equipped to the roll to plate NIL machine. After some discussions have been made, it is decided that the doctor blade contact angle is 30 degree.

Since the contact angle between doctor blade and quartz roller needed is 30 degree, the position of the doctor blade have to be adjusted. This contact angle is obtained manually by determining the reference line based on the center of the quartz roller and then using protractor to measure the 30 degree angle as shown in figure 3.11. After obtaining this angle, doctor blade holder will be screwed to the adjuster plates. L brackets are used a connector where they are screwed to seamless mold station brackets and aluminium base plate.

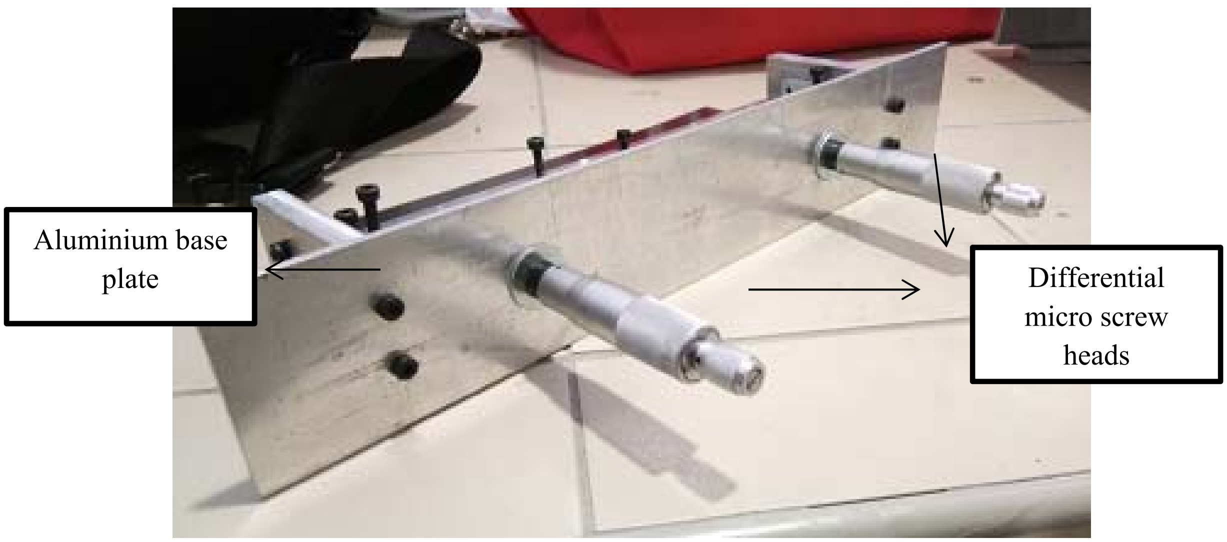


Figure 3.8: Differential micro screw heads used to move the doctor blade by rotating the adjuster