A Study of Nano Structure by Roll to Roll Imprint Lithography

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Abstract—Imprint lithography process is a unique printing technique that create graphic, electronic and biomedical printed on substrates. PET plastics are an example of materials that can be used as printing substrate in producing nano-scale electronic and medical devices. Here, it is proposed that extending imprint lithography technique into the multiple nano-structure printing fine solid lines onto substrate. Imprint lithography is a low cost printing technique commonly used in manufacturing and printing industry. This study exhibit successful fine solid lines imprinting below 1 micrometer in line width, gap and height on polyethylene-terephthalate (PET) substrate. This paper illustrates the use of imprint lithography method in producing multiple nano-solid lines printing capability as application of printing electronic, graphic and bio-medical.

Keywords-Imprinting Lithography, Nano-scale printing, Roll to Roll, Solid lines

I. INTRODUCTION

Recently, researchers have shown that imprint lithography process play an important roles in producing the micro to nano-scale fine solid line. This printing technique has been considered as a low cost method for fabricating micro to nano-scale images like silicon ICs. Ultraviolet imprint lithography is the best imprint option for meeting the requirement of future generation of silicon based circuitry [1].

The applications of nanotechnology are still at the concept level which requires more research before they can be produced as a product. Nanotechnology does not have solid commercial prospect, media speculation and most recent advances are closer to nanoscience. Nanotechnology is an international phenomenon which many companies involve in active development in this area. The produce products hope can be as multinational as in the pharmaceutical market [2].

There are two basic steps for imprint lithography as shown in Fig. 1. Firstly, a mold with micro or nano-structures on its surface is pressed into a thin resist cast on a substrate, follow by removing the mold. Secondly, the pattern is transferred by etching process like reactive ion etching (RIE). RIE is used to remove the residual resist in the compress area. During imprint process, the resist is heated to a temperature above its glass transition temperature [3].

In previous research on imprint lithography technique that had been discuss by Morse showed the potential to place it as a future contender on the semiconductor industry manufacturing roadmap and as a viable patterning tool for high-rate production platforms liked roll-to-roll processing. Fig. 2 shows the structure of Ultra-violet roll to roll nanoimprint lithography (UV R2RNIL) process. Value chain for R2R NIL are including application design, process modeling, creation of master and working stamps, NIL processes on a moving web and process monitoring [4].
From previous research in fine solid lines printing done by Yusof stated that by using roll to roll flexography printing machine which was web press industrial method, he managed to print out 50µm width and 50µm gap [5]. This was one of the examples of low cost printing technique that used photopolymer as a mold to transfer the ink from plate roller to subtract.

Step and flash imprint lithography (SFIL) is one of the imprint lithography process in producing nano printing products. It has a potential to become high throughput in producing high aspect ratio and high resolution patterns. At room temperature and 15 psi pressure, SFIL can produces lines image on substrate which features smaller than 60 nm in size [6]. SFIL is using low viscosity material and photopolymerization chemistry to achieve the throughput require for micro and nano-electronic industry [7].

II. EXPERIMENTAL METHOD

The printing process will start with the preparation of printing plate or stamp plate. A pattern of multiple solid line was designed on the stamp plate. The plate was made from silicon wafer and final stamp pattern was array of micrometer lines 1 µm width and 1 µm gap respectively shown in Fig. 3. Then, the stamp plate was attached at upper plate roller or pattern master rotating drum.

In roll to roll (R2R) imprint lithography process, the design from printing plate was transferred to the substrate form using a upper cylinder also known as pattern master rotating drum liked showing in Fig. 4. Polyethylene-terephthalate (PET) plastic was used in this study as a substrate where the lines will be imprinted directly onto the plastic. PET was chose due to low cost, available in rolls, recyclable and suitable for food industry.

In this study a customized roll to roll imprint lithography machine was prepared in laboratory scale as shown in Fig. 5. In this customize design apparatus, basic components of imprint lithography processes like bottom cylinder and upper cylinder for heating process and pressure was replicated. Two rollers were used to place the PET plastic substrate. PET could be softened before pressing by heating the bottom roller. The upper roller will heat the printing plate while printing process was running in a certain temperature.

The printing capability was checked visually by adjusting processes parameters like printing speed, roller temperature and load. The parameter need to be taken care during running the experiment due to the aim of this project is very critical. In parameter setting approach, the speed was set at 8.29 m/hr, the upper roller and bottom roller temperature were set at 120ºC and 70ºC respectively. The load was 130 lbs. All the parameters mention was set to get a good result for printing trial. The result will show the direction of this study in meeting the objective.

III. RESULT AND ANALYSIS

Several printing trials had been done to find the best printed images which can be selected as preliminary result. Before running experimental, the silicon wafer image as a imprint lithography substrate was analysis by using Atomic Force Microscopy (AFM) to find the lines width, gap and height. The result from the AFM analysis was shown in Fig. 6. The lines width and gaps was 1 µm. The height of substrate patterns was approximately 520 nm. The lines height was a critical issue that must be concern expecially in the bio-medical area.

The printing trial had been done successfully on PET plastic substrate liked showing in Fig. 7. The result from Scanning Electron Microscope (SEM) measurement was shown in Fig. 8. The printed image showed that the roll to roll imprint lithography machine had been achieved the printed lines width at 1 µm and the lines gap at 1 µm. Furthermore, the imprint lithography technique could be used to print the fine lines below 1 µm for the nano-structure printing.
The AFM measurement method was used to analyze the features like height, width, and gap of the printed lines as shown in Fig. 9. The result showed that the R2R imprint lithography method had successfully achieved 500 nm height for the fine lines printed. The height value decreased from the previous silicon wafer fine lines which is 520 nm but the value was still in control for the nano application. The result shows that this printing technique could be applied for the nano-structure printing in electronic and bio-medical industry.
During the experimental process, there were four major concern involved in this study. The concern are printing speed, upper roller temperature, bottom roller temperature and load. Those four items were manipulated to achieve a good printing image result. The critical element in printing was to be careful control on the apply force between bottom and upper roller [8]. Therefore, it also needs to be investigated further in order to get better result in the future.

### IV. DISCUSSION AND CONCLUSION

The imprint lithography printing technique will assist toward printed micro to nano scale of RFID (Radio Frequency Identification) antenna and Organic Field Effect Transistor (OFET) which will be used in many sectors for example in electronic devices, biomedical application, security and etc. The interest of RFID technology met the emerging demands in the automation process [9]. These RFID components demonstrated by this technology in relation to other existing identification systems as shown in Fig. 10.

![RFID tags component](image)

Another application in printing electronic was OFET liked showing in Fig. 11. It gave consistency and homogeneous ink layers in printing process. Hence, this study will put a step forward looking the roll to roll printing process which was vital prior to print any functional materials on thin film or other substrates layered. Organic transistors were still in development process stage and their performance cannot be competed with traditional semi-conductor transistors. The wettability and incompatibilities has to be overcome where a smooth and homogeneous interface is crucial for the OFET performance [10].

![OFET design structure](image)

In aspect of biomedical application, cell culturing could be printed in low cost with higher throughput. This printing method could avoid the use of batteries and wires connection which decreased the overall size of the biomedical device. It also could control the force or pressure between upper and bottom roller during printing process.

Within this study of roll to roll imprint lithography process and it’s discussion, it has proven to be successful method in producing fine solid lines with 1μm width, 1μm gap and 500μm height onto PET plastic substrate. The technique of employing Silicon wafer as master mold is a step to move forward in order to achieve nano-structure printing in electronic and bio-medical with simple, rapid, low cost method, less waste and roll-to-roll capability. The imprint lithography concept can also be applied in money printing process for security features.

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### REFERENCES


