VOL. 11, NO. 12, JUNE 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

UTILIZING RAPID PROTOTYPING 3D PRINTER FOR FABRICATING FLEXOGRAPHIC PDMS PRINTING PLATE

M. I. Maksud, M. N. Nodin, M. S. Yusof and S. Hassan
Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, Malaysia
E-Mail: midris1973@gmail.com

ABSTRACT

Recently printed electronic field is significantly growth. Printed electronic is to develop electrical devices by printing method. Conventional printing method that has been studied for this kind of printed electronic such as flexographic, micro contact printing, screen printing, gravure and ink jet. In flexographic and microcontact printing, a printing plate is used to transfer the designed and desired pattern to substrate through conformed contact. Therefore printing plate is play a big role in this area. Printing plate making by photopolymer which used in flexographic have limitation in achieving a micro-scale of pattern size. However, printing plate of microcontact printing have an advantages in producing micro, even nano-scale size by PDMS (Polydimethylsiloxane). Hence, rapid prototyping 3D printer was used for developing a PDMS micro-scale printing plate which will be used in reel to reel (R2R) flexographic due to high speed, low cost, mass production of this type of printing process. The flexibility of 3D printer in producing any shape of pattern easily, contributed the success of this study. A nickel plating and glass etching master pattern was used in this study too as master pattern mould since 3D printer has been reached the micro size limitation. The finest multiple solid line array with 1mm width and 2mm gap pattern of printing plate was successfully fabricated by 3D printer master mould due to size limitation of the FDM (Fused Deposition Modeling) 3D printer nozzle itself. However, the micro-scale multiple solid line array of 100micron and 25micron successfully made by nikel platting and glass etching master mould respectively. Those types of printing plate producing method is valueable since it is easy, fast and low cost, used for micro-flexographic in printed electronic field or biomedical application.

Keywords: micro-flexographic, printing plate, Polydimethylsiloxane, printed electronic, 3D printer.

INTRODUCTION

Flexographic printing is playing very important role in printed electronic, considered as high throughput methods allowing mass production at higher printing speed (Faddoul *et al*., 2012). Hubler (Hübler *et al*., 2011) had studied to print oscillator circuit which has not only horizontally arranged parts, but inverter stges stacked vertically on top of each other other in four through-connected substrate layers by flexographic printing. Mäkelä (Mäkelä *et al*., 2007) had employed gravure printing process in order to print polyaniline lines on paper substrate. Meanwhile Faddoul (Faddoul *et al.,* 2012) had been optimized a silver paste by flexographic printing on LTCC substrate. A radio frequency tag was contrived by combining two printing techniques, which are rotogravure and inkjet printing. They employed R2R gravure printing process in order to print the coil and capacitor bottom electrodes (Allen *et al*., 2011). Deganello (Deganello *et al*., 2010) was printed conductive tracks within networks of 74.6 µm width and 0.74 µm height by flexographic. Carbon nanotube (CNTs) ink had been printed by micro-flexographic in various substrate such as on silica, polymer, fabric and paper (Maksud *et al*., 2014). He also studied the combination of flexographic printing and microcontact printing (micro-flexographic) technique to achive the finest solid line (instead of dot printing in flexographic) by utilizing the PDMS printing plate which normally used in microcontact printing process.

In flexographic, the photopolymer printing plate is made by standard exposure with mask ablation technique as shown in Figure-1 (Gilbert and Lee, 2008).

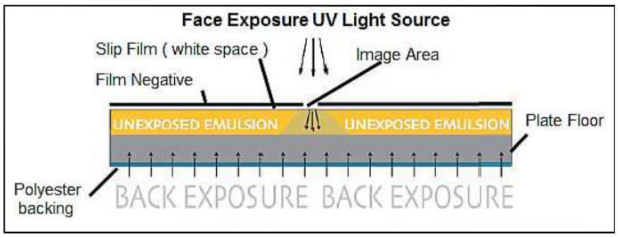


Figure-1. Conventional flexographic printing plate making.

This technique is the most widespread flexographic printing plate making procedures. The others technique is computer-to-plate (CTP) digital imaging process is accomplished without the use of a film negative. Plate manufacturers have accomplished this by adding an integral black carbon masking material to the photopolymer plate material(Gilbert and Lee, 2008) as shown in Figure-2.

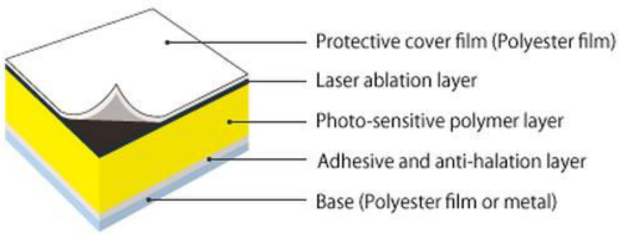


Figure-2. CTP photopolymer.

VOL. 11, NO. 12, JUNE 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

However those printing plate cannot be achieved micro-scale pattern size. Hence, an investigation has been done to use PDMS of microcontact printing process onto flexography printing by replacing the photopolymer printing plate. This has principle to the novel that commercial printing process can be applied to the fabrication of micro-scale electrical devices.

Since introduced 30 years ago, 3D printing technology is set to modernize research and teaching laboratories. Fused Deposition Modeling (FDM) 3D printer was developed by Scott Crump of Stratasys, FDM is one of the most widely used manufacturing technologies for rapid prototyping today. FDM fabricates a 3D model by extruding thermoplastic materials and depositing the semimolten materials onto a stage layer by layer. As shown in the schematic process in Figure-3(Gross *et al.*, 2014).

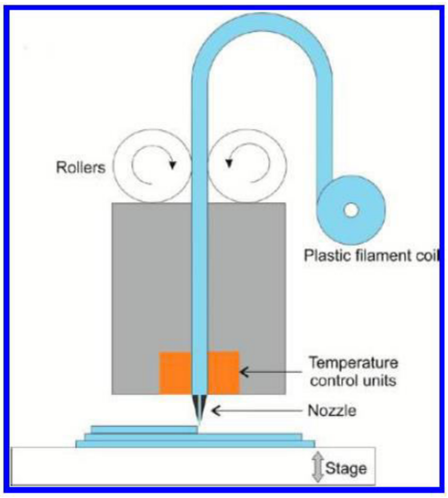


Figure-3. Schematic of an FDM 3D printer. In this method, plastic filament is directed into a heating block where it is heated to a semimolten state. The molten material can be printed onto an adjustable stage to form a layer of the desired object. The stage is adjusted (lowered) and another semimolten layer is printed.

A notable benefit of FDM is that it can produce objects fabricated from multiple material types by printing and subsequently changing the print material, which enables more user control over device fabrication for experimental use. Besides conventional materials such as PC, polystyrene (PS), and ABS (Gross *et al.*, 2014).

Figure-4. 3D printed bionic ear.

The examples of utilizing 3D printer in biomedical research is in hydrogel applications for tissue engineering encompass a vast array of organ and soft tissues. Incorporation of support (silicon), biological (chondrocytes), and electronic (conducting silver nanoparticles) modalities has led to the development of an anatomically correct 3D printed bionic ear capable of detecting electromagnetic frequencies produced from a stereo shown in Figure-4 (Gross *et al.*, 2014).

Microcantact printing is known for patterning micro or nano scale size. These stamping methods involve the direct patterning or the deposition of the ink molecule on the substrate just like flexographic printing.

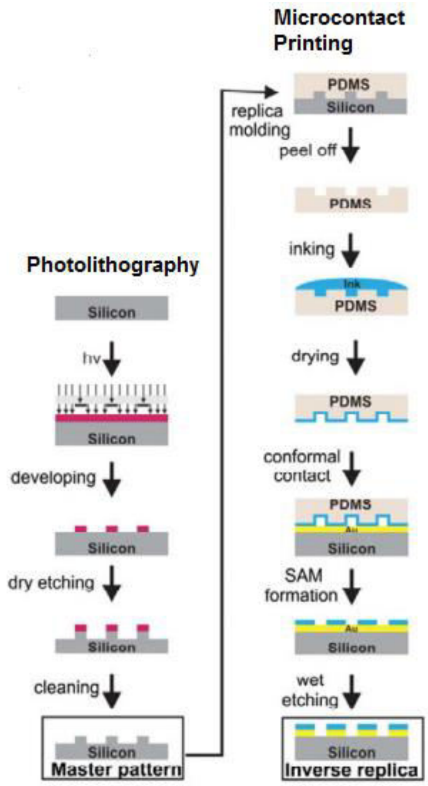


Figure-5. The master pattern in microcontact printing is fabricated by photolithography.

The stamp is fabricated by PDMS through master pattern. The master pattern production and schematic microcontact printing process is shown in Figure-5 (Chen and Chang, 2014).

The combinations of flexographic and microcontact printing method has successfully developed by Maksud. This invention technique as principle low cost and mass production of printed electronic device like a flexible, bended or rolled consumer product like a LCD display, printed RFID antenna and etc. Therefore, it is crucial to study the development of printing plate to counter limitation in fine size of flexographic photopolymer and high cost of photolithography method for master pattern of microcontact printing in the large scale of printing plate in micro-flexgraphic (Maksud *et al.*, 2014).

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EXPERIMENTAL METHOD

The master pattern mould were fabricated directly by 3D printer where the pattern is coarse, around 1mm and above in size. However for the patterns which need finer sizes (below 100µm), only the outer mould was used 3D printer for fabrications, while master patterns were prepared by nickle plating or laser etching process. Multiple fine solid lines pattern was selected in this experimental. Selected material for coarse master patterns and outer casting mould is acrylonitrile butadiene styrene (ABS). The 3D solid modeling SolidWorks was used in designing the pattern. The data was connected from PC direct to 3D printer (Makerbot Replicator 2) as shown in Figure-6. Figure-7 shown the fabrications process of master pattern mould.

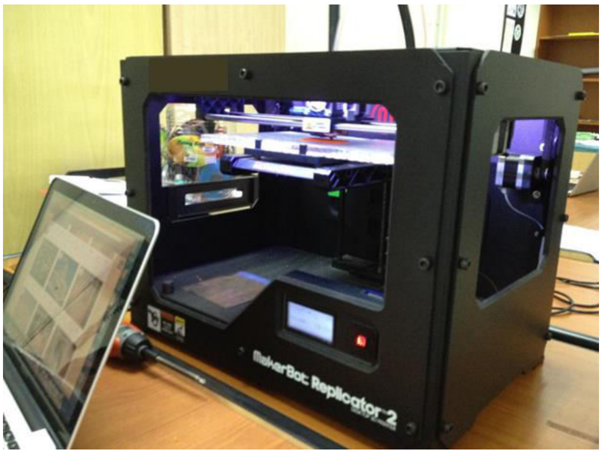


Figure-6. 3D Printer with PC(3D Solid Modeling).

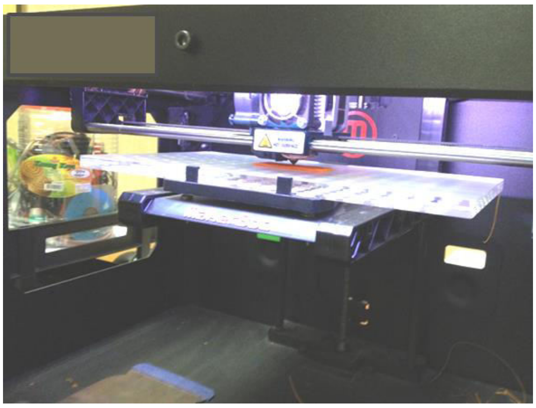


Figure-7. 3D printing making of master pattern.

After the preparation of master pattern and outer mold were ready, the PDMS printing plate making was as below steps:

- Poured the desired amount of PDMS (Sylgards 184-Dow Corning) into polystyrene cup.
- Used a disposable syringe to inject curing agent into the PDMS. The ratio curing agent and PDMS volume is 1/10. Digital weight is used as Figure-8. Figure-9 shown the PDMS Sylgards 184, curing agent, fine master mould, dissicator and vacuum pump.

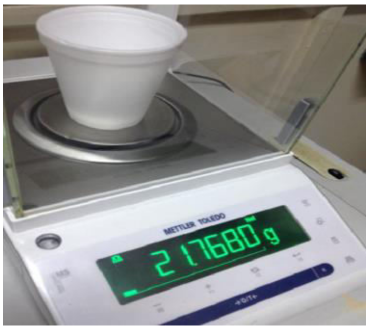


Figure-8. Digital weight for scaling the PDMS and curing agent of 1:10 ratio.

Figure-9. Main apparatus and material for the experiment.

- Stired the solution vigorously for 2 minutes using a disposable stir rod.
- Poured PDMS mixture onto each master pattern mould. Figure-10 is references.
- De-gased the mixture by placing in the dissicator and opening the vacuum valve (vacuum gauge -0.1MPa). Degas until the bubbles remove/disppear from most of the mixture.Figure-11 shown the removal of bubbles.
- Heated in a leveled oven at 70 ^{o}C for 1hour.

Figure-10. Mixture is poured into coarse 3D printed master pattern mould.

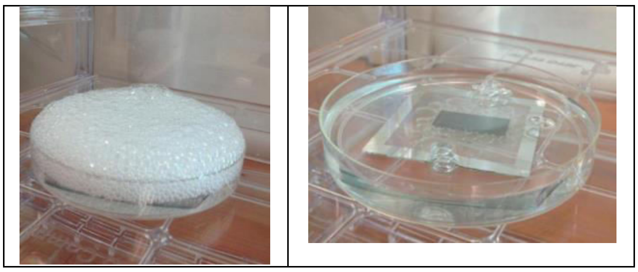


Figure-11. Shown the removal of bubble.

VOL. 11, NO. 12, JUNE 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

- Carefully removed the PDMS from the master. Often this requires peeling 1cm in from all sides of the master before peeled the bulk.
- Cutthe PDMS with a dull razor blade either on the master or after peeling.

The quality of printing plate will be check visually and detailed by microscope. The comparison between the master and the casting PDMS also been analyzed.

RESULT AND DISCUSSION

Both types of experimental 1) PDMS casting by direct 3D printer master pattern mould and 2) using electroplating master plate as a pattern while used 3D printer as outer mould had been successfully casted and the pattern had been transferred to the solid PDMS material.

Figure-12 shown the casted PDMS printing plate with coarse multiple solid lines, after removed from 3D printed mould. The limitation of the convex and concave surface size while designing the multiple solid line array is the size of the 3D printer nozzle. The smaller nozzle can give finer size of the solid line width and gap. Beyond this experimental using MakerBot Replicator 2, 3D printer the finest lines is 1mm width and 1mm gap. Hence, any printing patterns with only required to a coarse dimensional is suggested to use direct 3D printer to fabricate a master pattern mould.

Figure-12. PDMS printing plate with multiple solid lines array casted by 3D printer master mould.

The pattern printing plate which need finer pattern which cannot be done by direcit 3D printer, prepared by master plate. Figure-13 shown result of nickel plating mater plate for solid lines array pattern. Figure-14 shown master pattern template inside the outer 3D printed outer mould with PDMS after curing and removed from the outer mould. Finally the shape was trimmed to square as final printing plate.

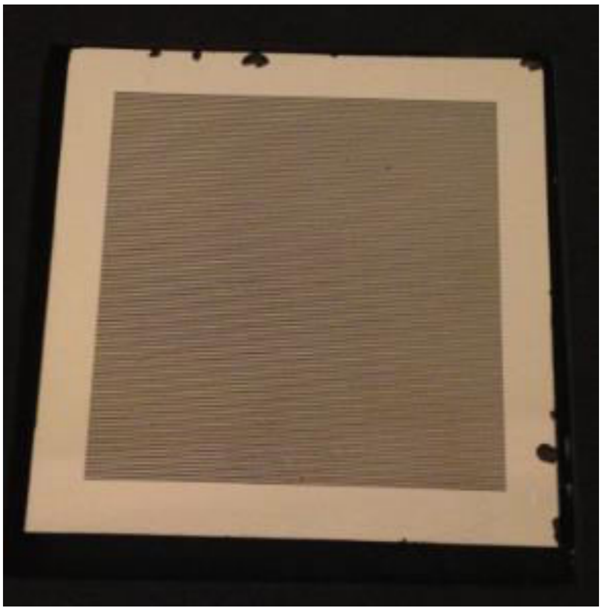
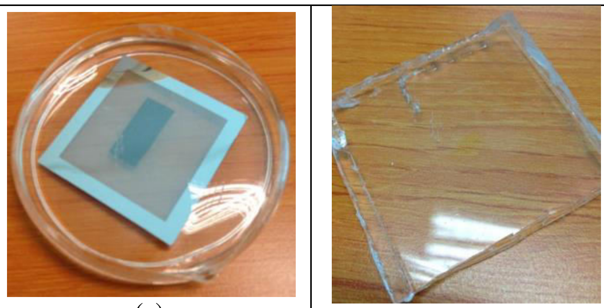


Figure-13. Fine solid lines array pattern by nickel plating.



(a) (b)

Figure-14. (a) Master pattern template and (b) completed PDMS after trimed to square shape.

In Figure-14 experimental, the dimension selected for this master pattern is multiple solid lines (100µm lines width and 100µm line gap. The pattern was successfully transfer to the PDMS material). Here, for the finer dimension (<100µm) master pattern template has to be prepared separately using photolithographic, etching, electroplating and etc. in order to get the fine pattern in the template. This method was an invention of large scale printing plate with low cost but able to achieve very fine scale patterns. This invention especially very useful in micro-flexographic printing process which is the aim is to print very fine solid lines array pattern.

ARPN Journal of Engineering and Applied Sciences

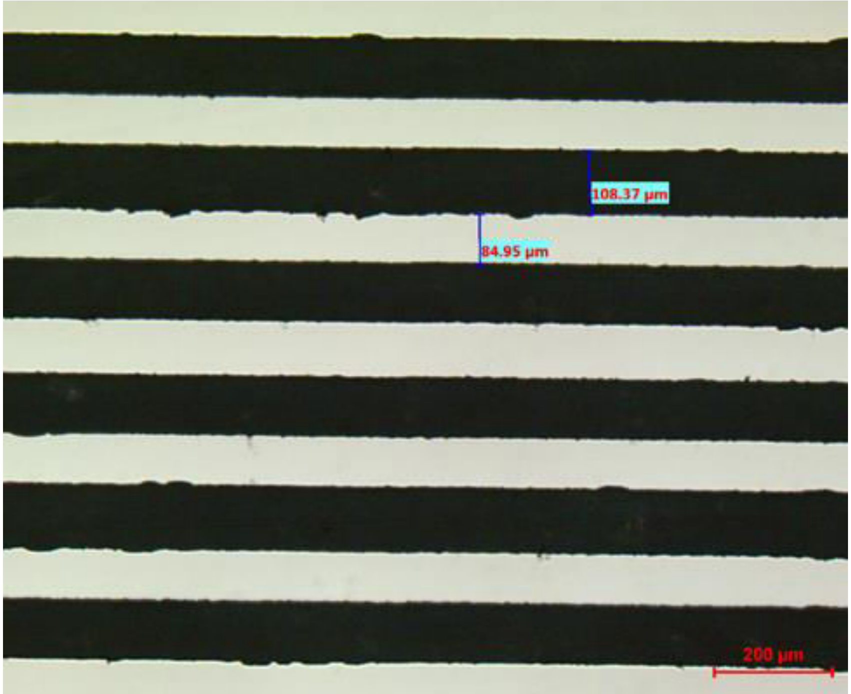


Figure-15. Microscopic view of 100µm solid line array of nickel plating master template.

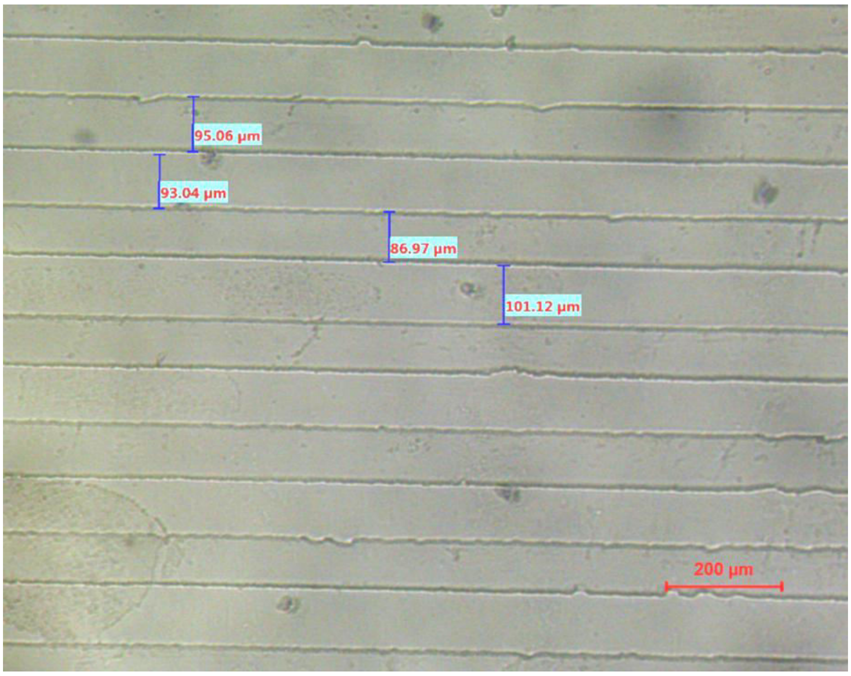


Figure-16. Microscopic view of 100µm width solid line array casted PDMS.

Figure-15 and Figure-16 is comparison of microscope between master pattern template and PDMS printing plates. The uneven boarder lines in the original master pattern template also can be seen in the casted PDMS. The width pattern on the master pattern template is between (85-95) µm, while on the casted PDMS is (87-95) µm, therefore no significant different.

The 25µm solid lines width PDMS printing plate successfully fabricated by glass etching master pattern template as shown in Figure-17. The convex (depth) is around 1µm can be determine from the AFM result data shown in Figure-18. The roughness is 0.16µm. The thickness of the printing plate also important to make sure it easy to install to the printing roller in flexographic. Here, the suggested thickness is around 2mm. This thickness is flexible enough to attach onto printing roller. The printing trial using those fabricated PDMS printing

ARPN Journal of Engineering and Applied Sciences

plate need to be done to confirm the printability and functional of those printing plate.

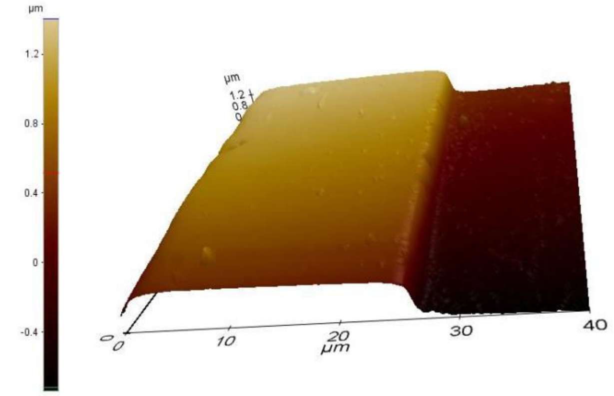


Figure-17. AFM image of 25µm PDMS printing plate.

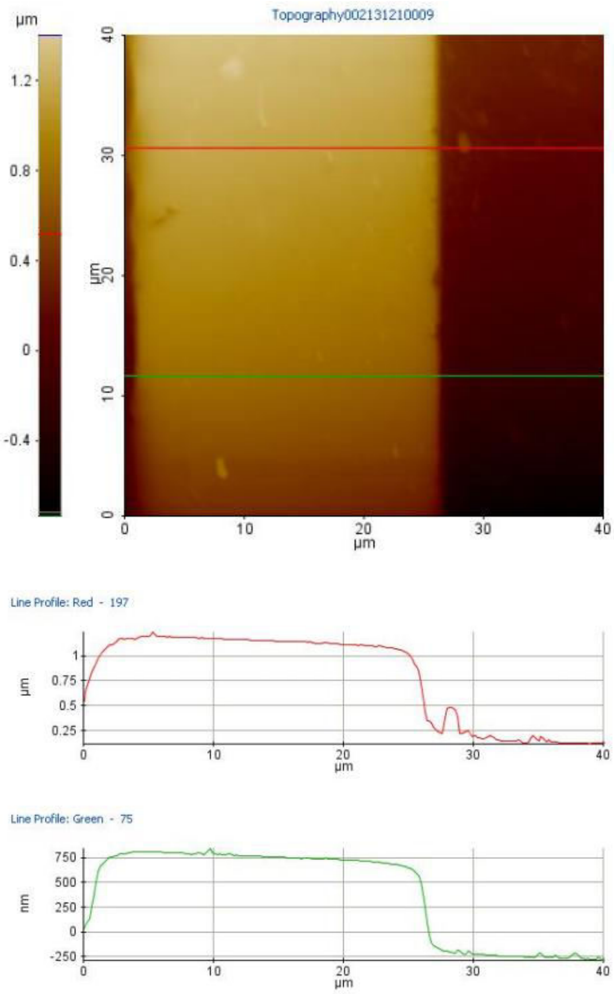


Figure-18. Lateral dimension of PDMS printing plate.

CONCLUSIONS

The study for using 3D printer and master pattern template in PDMS printing plate making for microcontact printing or flexographic or micro-flexographic (combination of microcontact and flexographic) was successfully done. The pattern which is bigger than1mm, can be used of 3D printer directly to make a pattern mould. The finest dimension pattern is directly depend to the size of 3D printer nozzle. The finer the nozzle, the finer dimension pattern can be achieved. However the 25µm fine solid lines printing plate can be achieved but have to use master pattern template fabricated by glass etching process. The finner pattern may achieve by photolithographic process of master pattern.

This study is a step to move forward in order to fabricate micro or nano structure in printed electronic and biomedical application specially by micro-flexographic printing process, which is benefit to large scale of printing plate, roll to roll process, mass production and low in cost capability.

ACKNOWLEDGEMENT

This project was supported by “Fundamental Research Grant Scheme” (FRGS) 1217, MyBrain 15 Scholarship from Ministry of Education Malaysia and ‘Skim Latihan Akademik Bumiputera’ (SLAB).

REFERENCES

Allen, M., Lee, C., Ahn, B., Kololuoma, T., Shin, K. and Ko, S. 2011. R2R gravure and inkjet printed RF resonant tag. Microelectronic Engineering. 88(11), 3293-3299.

Chen, J. K. and Chang, C. J. 2014) Fabrications and applications of stimulus-responsive polymer films and patterns on surfaces: A review. Materials, 7(2), 805–875.

Deganello, D., Cherry, J. a., Gethin, D. T. and Claypole, T. C. 2010. Patterning of micro-scale conductive networks using reel-to-reel flexographic printing. Thin Solid Films, 518(21), 6113–6116.

Faddoul, R., Reverdy-Bruas, N., Blayo, A., Haas, T. and Zeilmann, C. 2012. Optimisation of silver paste for flexography printing on LTCC substrate. Microelectronics Reliability. 52(7), 1483-1491.

Gilbert, B. E. D. and Lee, F. 2008. Flexographic Plate Technology: Conventional Solvent Plates versus Digital Solvent Plates Technology : Conventional Solvent Plates versus Digital Solvent Plates. Journal of Industrial Technology, 24(3).

Gross, B. C., Erkal, J. L., Lockwood, S. Y., Chen, C. and Spence, D. M. 2014. Evaluation of 3D printing and its potential impact on biotechnology and the chemical sciences. Analytical Chemistry. 86(7), 3240-3253.

Hübler, a. C., Schmidt, G. C., Kempa, H., Reuter, K., Hambsch, M. and Bellmann, M. 2011. Three-dimensional integrated circuit using printed electronics. Organic Electronics, 12(3), 419-423.

Mäkelä, T., Haatainen, T., Majander, P. and Ahopelto, J. 2007. Continuous roll to roll nanoimprinting of inherently conducting polyaniline. Microelectronic Engineering, 84(5-8), 877-879.

Maksud, M. I., Yusof, M. S., Embong, Z., Nodin, M. N. and Rejab, N. A. 2014. An Investigation on Printability of Carbon Nanotube (CNTs) Inks by Flexographic onto Various Substrates. International Journal of Materials Science and Engineering. 2(1), 49-55.

Maksud, M. I., Yusof, M. S. and Jamil, M. M. A. 2014. A Study on Printed Multiple Solid Line by Combining Micro- contact and Flexographic Printing Process for Microelectronic and Biomedical Applications. International Journal of Integrated Engineering, 5(3), 36-39.