

# Microfluidics Photomask Design using AutoCAD software for the Application of DNA Extraction in Lab-On-A-Chip Biosensing Devices

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**Abstract**— Photomasks are photographic patterns that are essential stencils used in making microcircuits where it is simulated under ultraviolet light onto a photoresist for pattern transfer in any fabrication process. This study outlines a simple and unelaborated design and specification of microfluidics photomask for the application of DNA extraction in Lab-On-A-Chip (LOC) biosensing devices. There is a set of requirement to be considered to ensure a precise and correct pattern transfer, namely, resolution, dimension, uniformity, and patent alignment. The design is plotted with two inlets and one outlet using AutoCAD software and materialized by inkjet printing. Total surface area of the device is 459 mm<sup>2</sup> in which the width and length is 27 mm and 17 mm respectively. The design was patterned in such particular sizes and dimensions to enhance fluid delivery and biochemical processes involved in DNA extraction while maintaining economical values as a disposable chip for when it is fabricated.

**Keywords**—Microfluidics, Photomask, AutoCAD, DNA extraction, Lab-On-A-Chip

## I. INTRODUCTION

DNA extraction is currently considered a routine procedure in molecular biology or forensic analyses that formed the basis for comprehensive technique in identifying various bacterial and fungi species. DNA extraction routines, however, have long been conventionally undertaken in laboratories. This restriction is critical for current circumstances where DNA detection is much favorable to be done on site as opposed to in laboratories. Current devices have yet provided analytical measurements only for the detection of DNA per se while DNA isolation is still done in laboratories. One way of solving this is by incorporating DNA extraction specified microfluidics structure to such devices. Microfluidics was first applied in microbiology as a tool for analytical analysis used to perform various biological assays as it allows to operate with very small volumes of samples and reagents, which is quite a compelling feature for microanalysis [1–3]. The emerging microfluidics system provides a platform

for the application of DNA extraction on biosensor devices with appropriate microfluidics design and specification.

Photomask design for microfluidic chip is done using AutoCAD, a commercial software application for 2D and 3D computer-aided-design (CAD) and drafting developed by Autodesk [4,5] where the desired geometry was assembled using the three line-based drawing tools, namely, lines, splines and polylines. Microfluidics photomask uses layering techniques to differentiate the transparent and opaque regions of a photomask pattern for correct printing and correct pattern transfer to photoresist layered on the substrate wafer surface in photolithography process [6,7]. For example, region of dark polarity corresponds to a region of the photomask that is opaque to UV light and will not cross-link the underlying polymer if it is a negative photoresist like SU-8. These areas of SU-8 will be removed by the developer in an etching process. Conversely, a light polarity corresponds to areas of the photomask that are transparent to UV light [8]. The SU-8 polymer underneath this region will be cross-linked after UV exposure such that the cross-linked SU-8 features become the raised objects that create microfluidic channels using polydimethylsiloxane (PDMS) as seen in Fig. 1.

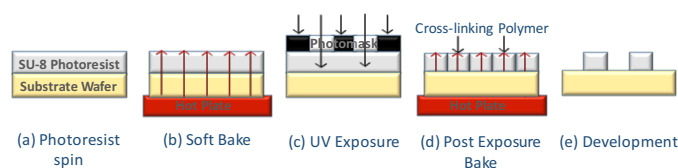


Figure 1: Photolithography process flow

The integration of laboratory function such as microfluidics structure for DNA extraction on a single chip in a biosensor forms a lab-on-a-chip (LOC) device [9], a bioanalytical tool that uses small volume samples for high throughput screening with automation. LOC technology is still novel and is continuously developing.

## II. MATERIALS AND METHODS

### A. Microfluidics Photomask Layout

AutoCAD software is a powerful tool for low cost photomask design. Its user friendly interface as well as ergonomic system allows for easy use and control of design. The microfluidics photomask for DNA extraction is designed using Autodesk AutoCAD 2015 for Mac product version J.51.M.453 and is printed using Canon PIXMA E510 on high-resolution (4800 dpi) transparencies for fast printing and low cost printing expense. The designs and dimensions are as illustrated in Fig. 2 below. Fig. 2(a) and (b) show the mask layout design using AutoCAD and the manufactured transparency photomask. The photomask consists of 10 microfluidic chips that are easily fitted onto a 100 mm (4 inches) diameter silicon wafer. The photomask is inspected using high power optical microscopy (HPM).

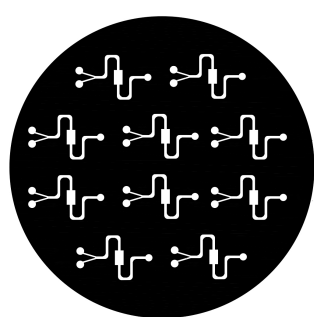


Figure 2(a): Microfluidic photomask design for DNA extraction using AutoCAD

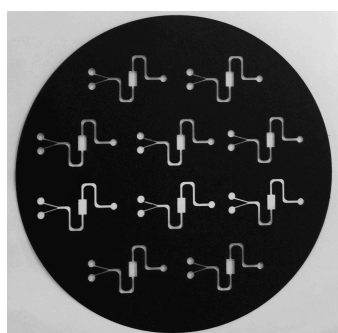


Figure 2(b): Transparent photomask of microfluidic design

### B. Microfluidics Photomask Design and Specification for DNA extraction

Microfluidic photomask was designed with two inlets, a cell capture section, and an outlet at the end as seen in Fig. 3. The design was made in a “two pointed fork” shape for biomaterial sample and chemical reagents inputs that will run together and get mixed; the mixed sample that consists of lysed cells will go through the cell capture section that provides enough space for the accumulation/lysis of cells; the extracted DNA will go through the output, which will be placed on top of a biosensor chip for DNA detection at the end. The dimensions of microfluidics are in milliliters (mm) with a total length and width of 27.0 mm and 17.0 mm, respectively. The inlet is designed with a radius of 1.4 mm, diameter of 2.7 mm, and channel width of 0.56 mm for fluid delivery. The outlet on the other hand is designed with a radius of 1.3 mm, diameter of 2.6 mm, and channel width of 1.0 mm for fluid compliance. The dimensions of cell capture section are 3.0 mm and 5.0 mm in width and length, respectively, with a channel width of 1.0 mm. The inlet and outlet radiuses and diameters are shown in Fig. 4(a) and (b) respectively while Fig. 4(c) shows the dimensions of cell capture section.

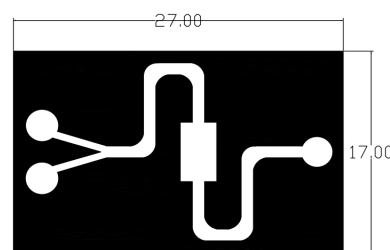


Figure 3: Overall Design and Dimension of Microfluidics Photomask for DNA Extraction

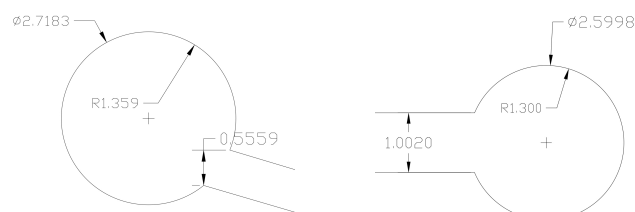


Figure 4(a): Radius, diameter, and channel width of fluid inlet

Figure 4(b): Radius, diameter, and channel width of fluid outlet

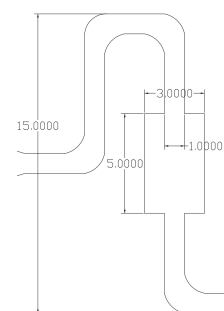


Figure 4(c): Design and dimension of cell capture section for DNA extraction

The sizes of both inlets are the same as seen in Fig. 4(a) and are designed slightly bigger than the outlet due to the bigger size of volume for inputs that are needed for fluid delivery. The sample will pass through the cell capture section which allows the sample to be mixed, lysed and denatured to obtain single stranded DNA. The output volume will be less, therefore, a slightly smaller size for fluid output is necessary. The small size outlet is also crucial for precise alignment with the functionalized biosensor for accurate results. The channel width for the inlets is designed smaller than the outlet in order to increase the capillary effect for fast fluid delivery since the reagents contain enzymes that accelerates chemical reactions.

## III. RESULTS AND DISCUSSION

Microfluidics photomask was examined under high power microscopy (HPM) with an Olympus BX51 microscope upon printed for dimension inspection. Images were taken at several inspection points under 5x magnification as seen in Fig. 5 and

Fig. 6. The results are compared with previous dimensions designed using AutoCAD and tabulated in Table 1.

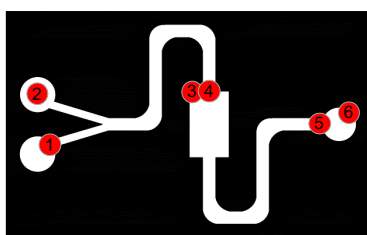


Figure 5: Inspection points for HPM; 1. channel width inlet; 2. inlet radius; 3. cell capture section corner width; 4. cell capture section channel width; 5. channel width outlet; 6. outlet radius

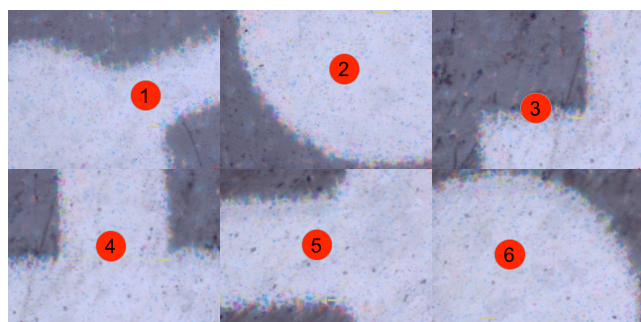


Figure 6: HPM images on different inspection points; 1. channel width inlet; 2. inlet radius; 3. cell capture section corner width; 4. cell capture section channel width; 5. channel width outlet; 6. outlet radius

A close look on the HPM images show formation of uneven, vesicle-like structures around the the edge of inkjet printed microfluidics photomask. This may result from multiple discrete spherical droplets that are “fired” even when a single pixel dot is specified on the transparent paper [10,11]. The quality and high resolution of printed microfluidics photomask can be enhanced by fine-tuning printing and incorporating state-of-the-art technology. Use of inkjet printing technology in the delivery of micro/nano liter volumes of functional biomaterials have been demonstrated in many application including the fabrication of microfluidics channels using an inkjet printer [[4,12–16].

TABLE I. DESIGN DIMENSIONS IN AUTOCAD SOFTWARE AND TRANSPARENT PHOTOMASK

Point of Inspection	AutoCAD (mm)	Transparent Photomask (mm)
1. Channel width inlet	0.56	0.51
2. Inlet radius	1.40	1.38
3. Cell capture section corner width	1.00	0.96
4. Cell capture section channel width	1.00	0.99
5. Channel width outlet;	1.00	0.96
6. Outlet radius	1.30	1.26

Table 1. compares the design dimensions of inlet, outlet and cell capture section of microfluidics photomask between AutoCAD software and printed transparency. The sizes of all point of inspections on transparent photomask are slightly smaller than on AutoCAD software with reduction of 50  $\mu\text{m}$  on channel width inlet, 20  $\mu\text{m}$  on inlet radius, 40  $\mu\text{m}$  on cell capture section corner width, 10  $\mu\text{m}$  on cell capture section channel width, 40  $\mu\text{m}$  on channel width outlet, and 40  $\mu\text{m}$  on outlet radius. The size differences are very small, less than 50  $\mu\text{m}$ , and since the pattern transfer show fine quality as seen in Fig. 2 (b) the differences are negligible.

Fabrication of microfluidics using this photomask design is essential along with the integration of biosensor for the implementation of Lab-On-Chip (LOC) device in the later stages of research. Fig. 7 below illustrates the proposed LOC device after fabrication. This state-of-art device is optimized for in situ DNA detection when the biosensor is hybridized with the target DNA in many nano diagnostic applications such as those in biomedical and agricultural fields.

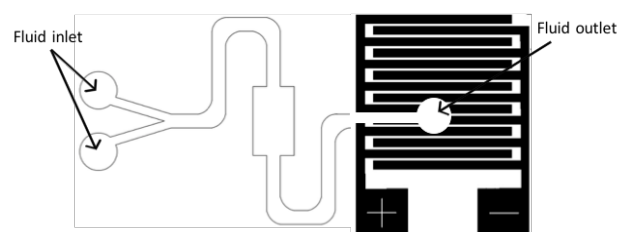


Figure 7: Illustration of Lab-On-A-Chip device

#### IV. CONCLUSIONS

This paper reflects a six-month preliminary study, and offers a simple and inexpensive method of designing microfluidics photomask for DNA extraction using AutoCAD software and inkjet printing. This method is non laborious, quick, and can be done at the comfort of one’s personal computer. The designed photomask will be used for microfluidics fabrication, which will be implemented together with biosensor to form LOC device. HPM observation shows an insignificant difference in size dimensions between transparent photomask and initial design on AutoCAD software, <50  $\mu\text{m}$ . The design can be printed on chrome mask for better resolution and precision down to 1  $\mu\text{m}$ .

#### ACKNOWLEDGMENT

Author Adilah Ayoib gratefully acknowledges the support from Institute of Nano Electronic Engineering (INEE), Universiti Malaysia Perlis (UniMAP), the staff members and colleagues for valuable discussion and helpful comments. This

work is supported by NanoMalaysia Institute for Innovative Technology (NanoMite) Grant (9012 00006) from INEE, UniMAP. The views expressed in this publication are the authors' own interpretation based on the data collected and do not reflect in any way the views of the funding agency.

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