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Microfluidics Design by using Soft Lithographic Techniques and Their Applications

Sudhanshu Singh, Vandna Singh

Amity University Rajasthan, Jaipur-303002, India
singhs1183@yahoo.com, vandna.rb@gmail.com

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Abstract: The current work described the background of various kinds of lithographic techniques, their properties, advantages, disadvantages, and applications. In this work, we have conducted experimental studies on various kinds of polymers. With the help of these polymers, we have designed micron level channel for the free flow of any kind of liquids, named as micron channel for microfluidics. It may be broadly called as microfluidics design. Also, we have worked for the optimization of the fabricated channel using various polymers. This kind of microfluidics design will be used for various aspects in biomedical engineering applications such as targeted drug delivery, ready to use medical handy kits etc. We are now in the way to design microfluidics channel for a fast and rapid sensor for detection of septic etc.

Keywords: Lithography, microfluidics, polymers.

1. INTRODUCTION

The term 'Lithography' was initially discovered by Senefelder in seventeenth century. In earlier days of this method, a soft and precise part of limestone had been used (therefore named as "lithography": "litho" stone). It was earlier called as Lithology. Currently, it is also called as Photolithography. This word developed from the concept from ancient time, i.e. to write or imprint something knowledgeable and sharable thing on the stone or on any solid materials, to pass some news into the society. It was exactly invented in around 200AD, named as woodblock printing, progress today in 2017, named as Digital UHD printing. Thereafter, it has been progressive changing and getting their applications in various ways. The way of its progression between around 200 and currently 2017, it is shown in the table.1 [1-9].

TABLE1. HIERARCHICAL WAY OF LITHOGRAPHY TECHNIQUES

Time in year (AD)	Lithographic Process Name
1040	Movable type
1440	Printing press
1515	Etching
1642	Mezzotint
1772	Aquatint
1796	**LITHOGRAPHY[5-9]**
1837	Chromolithography
1843	Rotary press
1869	Hectograph
1875	Offset printing
1884	Hot metal typesetting
1886	Mimeograph
1907	Photostat and rectigraph
1911	Screen printing
1923	Spirit duplicator
1925	Dot matrix printing
1938	Xerography
1949	Phototypesetting
1951	INKJET PRINTING[6-15]
1957	Dye sublimation
1969	Laser printing
1972	Thermal printing
1981	3D PRINTING
1986	Solid ink printing
1991	DIGITAL PRINTING[10-18]

The lithography techniques are getting its way in various latest STEM applications such as social and technological applications. Earlier stone and other solid materials were used for the write-up. Now a day, there is various kind of polymeric substrate and micron-substances or materials are being used such as PDMS [13-21]. Lithography generally uses easiest chemical methods to design an image. For example, the '+ve' (positive) part of the image is a water-repellant ("hydrophobic") substance, while a '–ve' (negative) image would be water-attraction ("hydrophilic"). Therefore, as the used substrate plate is kept in contact with a favorable printable ink and water mixtures, the ink will be gone to the +ve image and the water will clean the -ve image. This allows a flat print plate to be used, enabling much longer and more detailed print runs than the older physical methods of printing.

2. MATERIALS USED

A. PDMS

It is the abbreviation of Polydimethylsiloxane. It belongs to a group of the polymeric organosilicon compound. These are

commonly called as Silicones[1-3]. It is the most widely used silicon-based organic polymer and is particularly known for its unusual rheological (or flow) properties. PDMS is optically clear, and, in general, inert, non-toxic, and non-flammable. Sometimes, it is also called Dimethicone and is one of the several types of silicone oil. Its applications range from contact lenses and medical devices to elastomers; it is also present in shampoos, food, caulking, lubricants and heat-resistant tiles. The chemical structure of PDMS has been shown in fig.1.

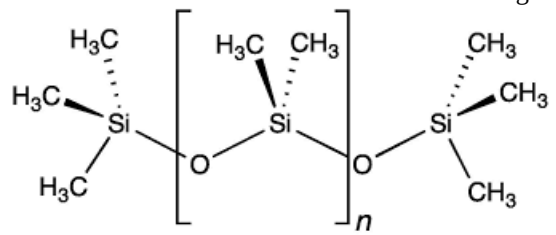

Fig.1 Chemical structure of PDMS

The main reason behind PDMS to be used for biomedical electronics applications are their various properties such as the good chemistry of branching and capping, good mechanical features as viscoelastic, shear modulus and elasticity, chemical compatibility such as polymerization and cross-linking etc. Due to the above-explained properties, we have selected this for our experimental work. Besides our current research work, a lot of prospects or applications of using PDMS are also in the ongoing project such as a surfactant and antifoaming agents, hydraulic fluids, soft lithography, medicines and cosmetics, foods and daily domestic and niche uses.

B. SU-8 photoresist

SU-8 is a commonly used epoxy-based negative photoresist. Negative refers to a photoresist whereby the parts exposed to UV become cross-linked, while the remainder of the film remains soluble and can be washed away during development. As shown in the structural diagram, fig.2, SU-8 derives its name from the presence of 8 epoxy groups. It is these epoxies that cross-link to give the final structure. It is now mainly used in the fabrication of microfluidics (mainly via soft lithography, but also with other imprinting techniques such as nanoimprint lithography [21-25] and Microelectromechanical systems parts.

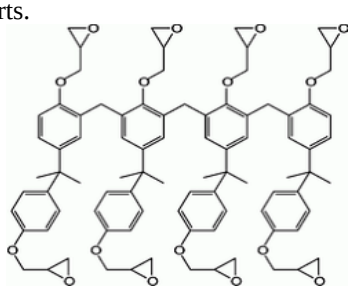

Fig.2 Chemical structure of SU8

It is also one of the most biocompatible materials known[20-27] and is often used in bio-MEMS for life science applications[28-33].

3. METHOD AND EXPERIMENTAL SETUP

The whole lithographic experimental work is basically divided into nine types :

1: Masking (to make a film)
2: Moulding (to design pattern)
3: Exposure (UV light)
4: Baking (chemical treatment)
5: Developing (finalization)
6: Silanization (activation of bond)
7: Coating (film preparation)
8: Curing (for precision)
9: Detaching (separation)

These whole 9-steps may be clubbed into three main categories of the much simplicity for experiments, i.e.

1: Substrate pre-treatment (chemical mixing, exposure etc)
2: Intermediate stages (baking, moulding etc)
3: Final separation (rinse, dry etc)

All the materials have been purchased from Sigma Aldrich and are used as acquired. First of all PDMS solution has been used in solution form. In parallel, some conducting base/substrate has been selected such as ITO or Si Wafer, single or double side coated. In the first layer, SU8 has been uniformly spread over base Si-wafer. Then over the layer of Si-wafer, photoresist is to be fixed. Then the photomask (which design is to get at the final stage such as centrifugal, spherical, cylindrical, rectangular, any random design of channels etc). Then this whole setup has been gone through intermediate stages such as exposing under the influence of UV light but keeping in mind the global safety regulation of UV light as prescribed by UN authority. Then after, baking has been done for the updated makeup samples. In sequence, developing of the channel has been done and observed in the normal ambient environmental conditions. Now as the bars or aligned structured are being formed a visible under the microscope on some 10/100/1000X zooms, developed PDMS has been poured on these structures to get settles in between the vacated spaces. Then after silanization and coating has been performed. Later on Curing and detaching of the base of Si wafer has been done. At the last stage, we have got the structure or channels of PDMS. This whole experimental way is a standard way in the area of microfluidics design, but optimization of primary, secondary, and extraneous variables/parameters has been changed in our experimental work. The whole experimental work may be described as fig.3.

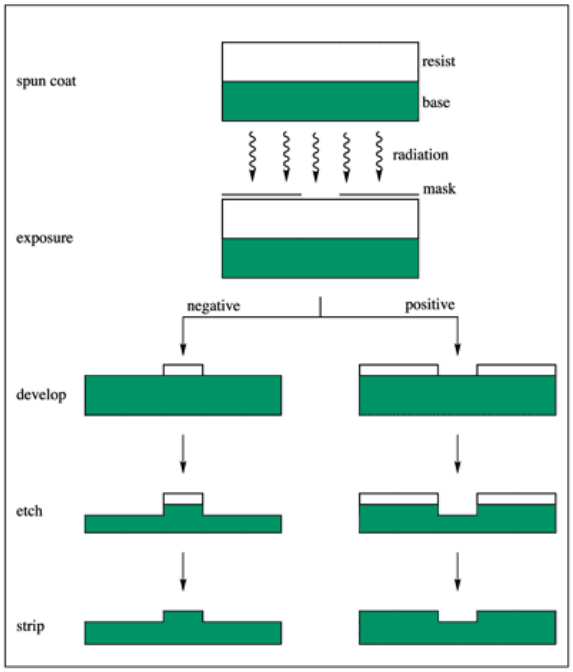

Fig.3 Pictorial representation of microfluidics design

4. RESULTS AND DISCUSSION

The formed microfluidics design has been characterized with the help of LEICA microscope and the confirmation of mobility of microfluidics has been confirmed with the help of electrical circuit and their configurations. Various zooms such as 10/100/1000X on oil and non-oil lenses have been studied. While in the case of electrical characterization, frequency, voltage, current .power, time –rating has been well optimized to get the better results. With the help of Photoresist spinner, we are in the position to fabricate a channel of various micro/nanomaterials of precise and optimized thickness. The micron level channel is showing their dimension in the range of few micron, but due to the some environment affect such as handling of specimens and moving our samples from working bench to the characterization plate form, liquid samples get distorted in few place because of small level of turbulence in channels, rest is precise in the optical imaging. Electrical set up has been well controlled and keep in observe condition to check the fluctuations in the electrical parameters such as voltage, current, and/or frequency. We used PCB based electrical setup to showcase the fast response. Digital multimeter has been used for measurements. With the help of conductivity meter, in each step, we are in the able position to keep a check on conductivity properties of microfluidics samples. These results (micropattern, electrical, optical and instrumentation facilities used)are shown in fig.(4-9).

Fig.4 (a) Photoresist unit (b) Micro Pattern just after curing

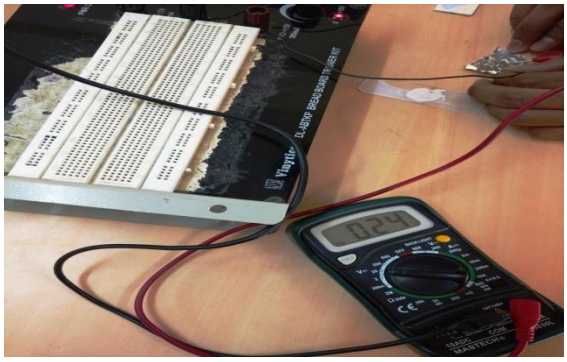

Fig.5 Electrical setup and reading

Fig.6 Electrical conductivity of nano/microfluid

Fig.7 making solution of PDMS/SU8

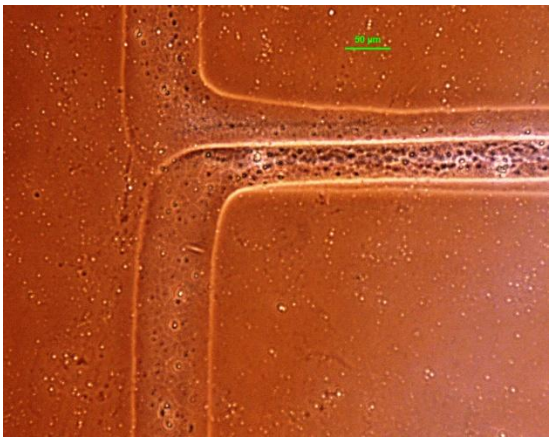

Fig 8. 50-micron channel

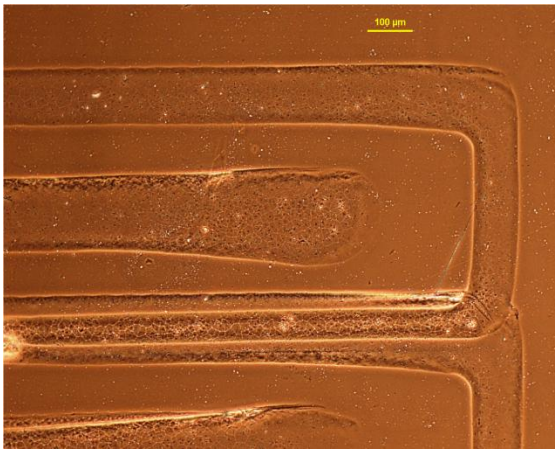

Fig. 9. 100 Micron channel

These kind of results encourage the applications in biomedical and nanoelectronics areas. When we are talking about the novelty of our approach, there are various scientific aspects such as only a few have demonstrated in their work the use of room temperature working experiments. Also, we have collaborated the digital electronics platform, sandwiched with nano and microfluidics, not focusing on the biological aspects.

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