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Soft lithography Using poly (dimethyl siloxane) with Application in Microfluidics

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Abstract
Soft lithography, which represents a method of rapid prototyping of nano and microfabrication, has gained dominant position in cell biology, microfluidics, lab-on-a-chip and etc. One of the most conventional polymers used in soft lithography is poly (dimethyl siloxane), which is an inexpensive, flexible and chemically inert, biologically accepted polymer to fabricate disposable stamps. Moreover, initial cost of this polymer is relatively low.

Keywords: Soft lithography, PDMS, Microfluidics, Mask bias.

Introduction
Soft lithography employing PDMS provides advantages over photolithography, such as, simplicity in experimental work, possibility of producing certain three-dimensional patterns and structures used in microfluidic devices. Soft lithography also obviates the need of clean room facilities, hence decreases the cost of fabrication, while PDMS as a promising polymer offers favorable optical and mechanical properties. Based on the desired application different methods of Soft lithography are used. However, the process is generally done through a four steps procedure as follow:
1. Pattern design: Mask pattern is based on experimental needs as represented in mask design. Several software programs can be employed to design the desired pattern. The available drawing programs should be vector-based, such as, Adobe Illustrator. AutoCAD is also an advanced drawing program, which provides patterns with more precision.
2. Mask fabrication: Photo masks with chrome- on-glass usually are recognized as binary masks. A binary mask is either mostly transparent or occludes the light. A mask is called a dark field, if it is mostly covered with chrome and merely small openings, whereas it is either called an open or bright field mask if it is covered with only small percentage of chrome [1]. The patterns of up to 20um can be printed on an appropriate type of glass using a conventional printer with 5060 d.p.i. However, for higher resolution up to 1um normally Chrome masks are used. The cost of conventional printing is less expensive than Chrome mask fabrication. Therefore, literature has recommended transparent glass mask rather than Chrome mask for experimental works [2].
3. PDMS stamp fabrication: In order to form a master with pattern structure for PDMS stamp, conventional photolithographic methods are used. In photolithography a substrate- normally silicone wafer- is coated with a light sensitive polymer (photoresist). Then it is heated to remove excessive amount of solvents. To replicate the pattern structures, the coated wafer is exposed to UV light within a certain wavelength, proceeding by a developing procedure, utilizing an appropriate developer solution. Classic photolithography can provide structures with feature sizes down to 1-2um. However, Electron-beam lithography (EBL) can be applied in cases that minimum geometry is 20-30nm. For MEMS and bio-medical application, aspect ratio of 7 or higher at 100um thickness is not
Sylgard184 elastomer kit, which is used to fabricate PDMS stamp, consists of two containers: one is the base polymer and the other one is the curing agent. Normally, to fabricate PDMS stamp the materials are to be mixed in ratio of 10:1. The components are thoroughly mixed for approximately 2 minutes. The container is then placed in a vacuum desiccator for 10-20 minutes so that it is out-gassed and bubble free. PDMS is then poured gradually on the master. The whole assembly is placed in the vacuum oven, set at 70C for one hour to be thermally cured [2, 4, 5].
4. Fabrication of micro and nanostructures using PDMS stamp: Two soft lithographic methods are used to fabricate micro and nano structures on PDMS surface or within microfluidic channels:
(I) Capillary molding: In this method, the patterned PDMS mold is placed on either a polymer or a solution containing a polymer. Within solvent evaporation or heating the polymer above the glass transition temperature negative image of the PDMS stamp in

replicated on the polymer surface. The assembly is then exposed to UV radiation, producing a negative replica. (II) Contact printing: In this method a PDMS stamp is soaked in the molecular ink. The stamp is replicated on the desired substrate to transfer the microfluidic structures [1,3]. Mask bias means the (line-width/ space-width) on the mask is (larger/ smaller) than the desired nominal feature on the wafer processing used positive tone photo-resist.

In this paper, images of a binary mask transfered to a silicon wafer using contact photolithography. Imaged silicon wafer was then used for soft lithography method to form PDMS stamp.

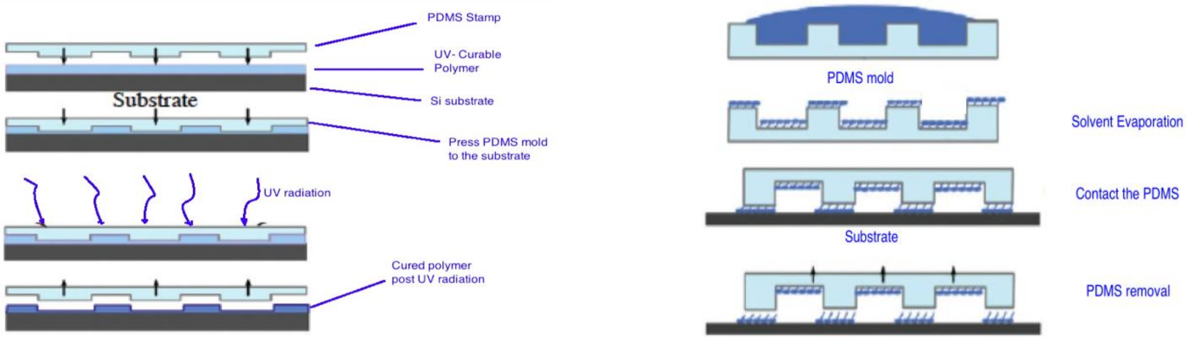

Fig1. Soft lithography- Left: Capillary molding, Right: Contact printing [4]

Experimental

Lithography process carried out employing positive tone photo-resist AZ9200 was spin coated on Si wafer <100> using the standard program as follow: 500 RPM for 15 seconds followed by a 2500 RPM step for 60 seconds. Coated wafer was then baked on a hot plate set at 90 C for 70 seconds. UV exposure was carried out using AUT contact printer for 20 seconds. Development was done in AUT developer for 1-2 minutes. Soft lithography was carried out using PDMS Sylgard 184 elastomer kit. PDMS part 1 and 2 were mixed thoroughly in ratio of 9:1 for 90 seconds. The mixture was out-gassed in a vacuum desiccator for almost 20 minutes. PDMS mixture was poured on imaged wafer placed in a mold. The whole assembly was then placed in a vacuum oven set at 70 C. PDMS replica was pealed off from wafer. Observation and measurement of both wafer and PDMS stamp was carried out using optical microscope.

Result and Discussion

Fig2.(a) represents the ratio of printed image to mask image. According to this diagram images printed employing lithography are larger than actual size on binary mask with coefficient of 1.006. The ratio of images on PDMS stamp to images on silicon wafer are shown in Fig2.(b). As can be seen images on PDMS stamp are smaller than lithographic images with coefficient of 0.93. Results from mask bias and stamp bias represent deviation from actual size of different geometries on both silicon wafer and PDMS stamp.

Lines and spaces on silicon wafer and mask were measured using Optical microscope as can be seen on Fig3.

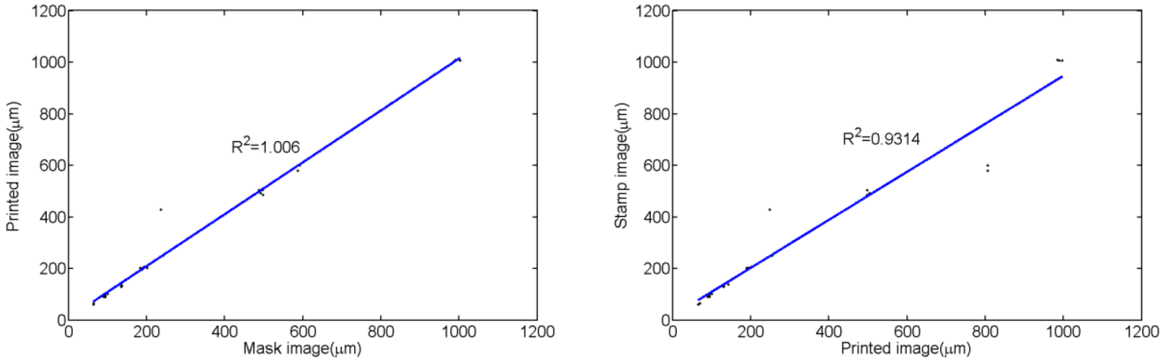

Fig2. Optical Microscope images- Left: image on Chrome mask, Right: image on silicon wafer

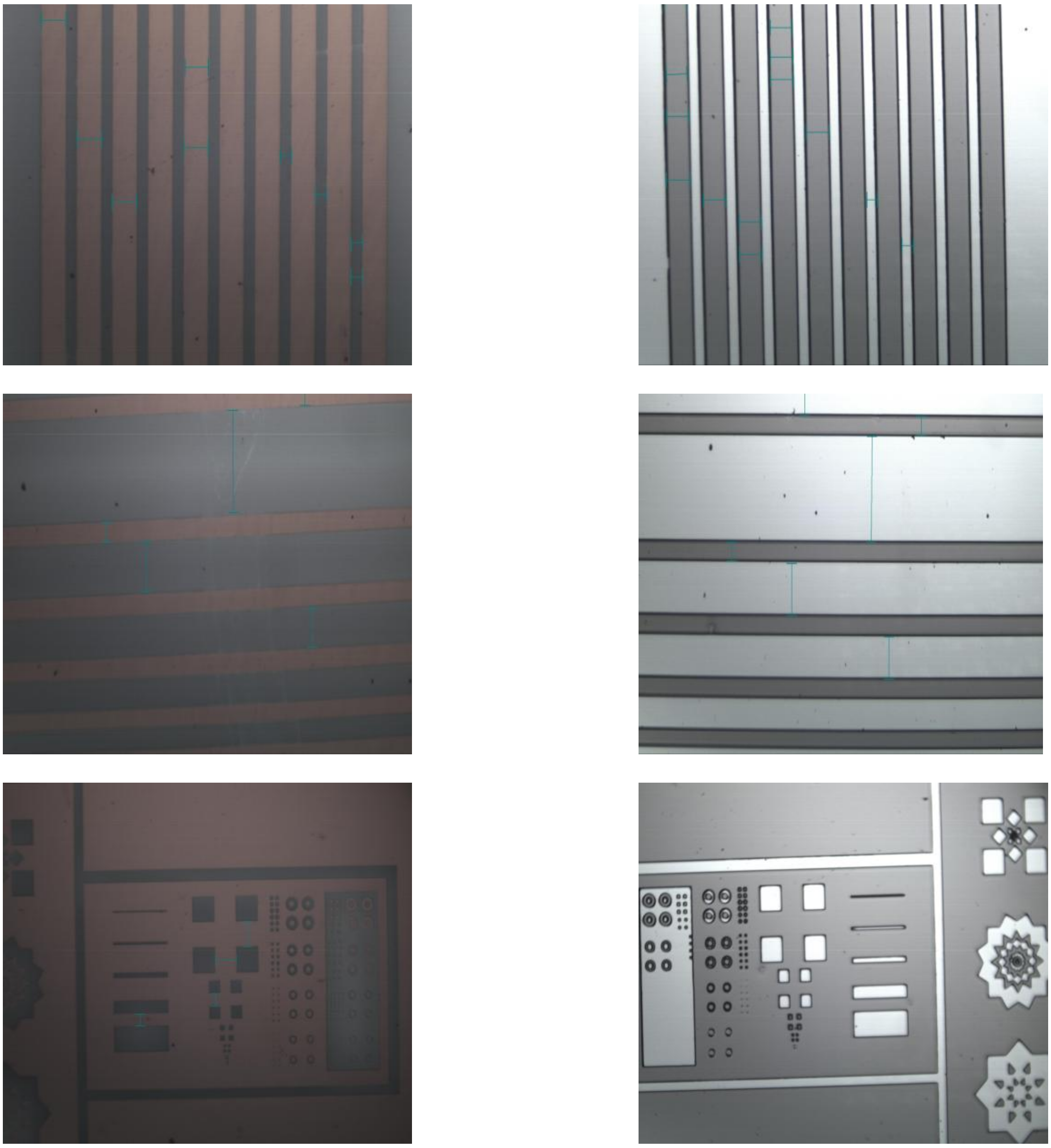

Fig3. Optical Microscope images- Left: image on Chrome mask, Right: image on silicon wafer

Fig4. Imaged PDMS stamp

Conclusions

Soft lithography method employing Poly dimethyl siloxane (PDMS) is considered as a less costly process to prepare a biocompatible substrate with application in lab-on-a-chip, microfluidics and etc. This process obviates the need of clean room facilities and hence decreases net cost of processes.

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Reference

[1] Franssila Sami, Introduction to Microfabrication, Wiley, 2004

[2] Dong qin, younan xia, George M Whitesides, Soft lithography for Micro- and Nanoscale Patterning, Nature publishing group, 2010

[3] J. Cooper McDonald, David C. Duffy, Janelle R. Anderson, Daniel T. Chiu, Hongkai Wu, Olivier J.A. Schueller, George M Whitesides, Fabrication of Microfluidic Systems in poly (dimethylsiloxane), Electrophoresis 2000, 21, 27-40

[4] Pilan Kim, Keon Woo Kwon, Min Cheol Park, Sung Hoon Lee, Sun Min Kim, Kahp Yang Suh, Soft lithography for Microfluidics, Biochip journal, Vol.2, No.1, 1-11, March 2008

[5] David C. Duffy, J. Cooper McDonald, Olivier J.A. Schueller, George M Whitesides, Rapid prototyping of Microfluidic Systems in poly (dimethylsiloxane), Anal. Chem. 1998, 70, 4974-4984