Fabrication technique of a 3 dimensional SU8 mold on PMMA substrate

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Abstract: Silicon or glass was a common material for SU8 coating. However, these materials are hard and brittle, make it difficult for drilling and dicing. This paper reported the effect of grayscale and resolution based on the various length of time for Propylene Glycol Methyl Ether Acetate (PGMEA) developing towards SU8-10 coated on polymethylmethacrylate (PMMA). The grayscale results show that the 0\% (solid black) produced the highest percentage on the square structure formed to the SU8-10 film coated on PMMA and the highest resolution had been produced for the 30 minutes of PGMEA developing.

Keywords: PGMEA, PMMA, SU8-10, grayscale, resolution

Classification: Electronic materials, semiconductor materials

References

SU8 was originally developed for the microelectronics industry to provide a high resolution negative imaging resist for use in the fabrication of MEMS devices. Nowadays, the attributes had been extended to microfluidics and MEMS due to high-aspect-ratio resist [1]. It is highly transparent in the ultraviolet region allowing fabrication of relatively thick structures with nearly vertical side walls make it suitable for masking deep RIE etching [2], electroplating molds [3, 4] and microfluidic components [5]. After exposure and developing, its highly cross-linked structure gives it high stability to chemicals and radiation damage [6].

The common microfluidic devices used SU8 coated onto a wafer silicon or a glass slide [7, 8]. However, dicing silicon and glass into individual devices required expensive equipments such as DRIE and diamond-coated cutter. Moreover, the thermal expansion coefficients (TEC) of silicon/glass are ten times smaller than that of SU8. TEC mismatch is the main cause for microcracks on SU8 film [9].

The use of PMMA as a base material in the SU8 fabrication process has been reported in this paper. PMMA also known as Plexiglass, Perspex or Acrylic was chosen for being easy to present grayscales method to characterize the thickness of the negative SU8-10 photoresist coated onto acrylic 1 mm. Moreover, it is known as easy to drill or cut, biocompatible, transparent and cheaper than silicon wafer or glass slides [9].
walls cutting were cleaned with isopropyl alcohol (IPA) and deionized (DI) water. All these were dried in an oven (UNB 200: Memmert GmbH & Co. KG) at 90°C for 30 minutes. These cutting were merged together through the solvent bonding [10] process by using Chloroform. Chloroform is toxic in liquid form but when it contacts with air, it vaporized and free of traces. Chloroform is applied with a brush on the edges of the four side walls and the 4 cm x 4 cm square PMMA that were going to be stick to each other. The application was being performed in a well-ventilated area to prevent the vaporization. The edges will be welded and become as hard as a normal PMMA.

2.2 SU8 coating
A 3 ml of SU8-10 (MicroChem Corp) was dispensed onto the PMMA square box by using a syringe. The liquid will be uniformly distributed in the box mounted with the four side walls produced an average of 1500 µm thickness. The resist was baked in the oven (UNB 200: Memmert GmbH & Co. KG) at 90°C for 10 hours and cool down to room temperature of 25°C. Next, the mounted four sided walls were being dismantled and the 4 cm x 4 cm square PMMA base was soft baked in the oven at 70°C for 30 minutes and cool down to room temperature of 25°C to ensure the whole SU8-10 resist had been hardened onto the PMMA. The other reason for the soft baked is to reduce the excessive edge bead associated with square edges during the coating process. This excessive edge bead prevented the photo mask to properly contact with the majority of the resist surface during exposure, causing resolution lost [9].

![Fig. 1. Close-up at one edge corner of SU8-10 coating before and after soft baked process.](image)

The close-up shot on one edge of the corner for SU8-10 coating is as shown in Fig. 1. The edge before the soft baked process shows the uneven, unsmooth and cracking surfaces while the after baked process shows the complement.

2.3 Fabrication of polydimethylsiloxane (PDMS) relief
The SU8-10 resist that had been developed by the above mentioned process can be used as a mold to fabricate the polydimethylsiloxane (PDMS) relief. Different thickness of SU8-10 resulting from the grayscale value of the
transparency photomask will produce variation to the mold. This also will affect on the different thickness of the PDMS mask produced. The SU8-10 mold was placed in a plastic container onto which PDMS (Dow Corning Sylgard 184) was poured. PDMS was mixed with the catalyst at a rate of PDMS:catalyst=10:1. Then PDMS was defoamed in a vacuum desiccators for 24 hours. After that, PDMS was peeled off from the container.

3 Analysis of results

3.1 The square grayscale structures

A transparency film had been used to produce the positive mask by using color laser jet printer (5550, Hewlett Packard). The result after the UV light exposure (LV204: Mega Electronics Ltd) for 6 minutes and PGMEA developing for 2 hours had been analyzed. The positive mask consists five (5) rows of different gray scales value – fill transparency percentage - ranging from 0% (solid black), 25%, 50%, 75% and 100% (solid white).

![Fabrication process to develop the mold](image)

(a) Exposure to UV light using a transparency mask

![The mold after developing](image)

(b) The mold after developing

Fig. 2. Fabrication process to develop the mold.

Table I. Square structure measurement on the mold produced from the transparency mask.

<table>
<thead>
<tr>
<th>Grayscale Values</th>
<th>Mask Measurement</th>
<th>Mold Measurement</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area ((\mu m^2))</td>
<td>Perimeter ((\mu m))</td>
<td>Area ((\mu m^2))</td>
</tr>
<tr>
<td>0%</td>
<td>27.51 x 10^6</td>
<td>21.17 x 10^4</td>
<td>24.43 x 10^6</td>
</tr>
<tr>
<td>25%</td>
<td>27.51 x 10^6</td>
<td>21.17 x 10^4</td>
<td>20.67 x 10^6</td>
</tr>
<tr>
<td>50%</td>
<td>27.51 x 10^6</td>
<td>21.17 x 10^4</td>
<td>19.53 x 10^6</td>
</tr>
<tr>
<td>75%</td>
<td>27.51 x 10^6</td>
<td>21.17 x 10^4</td>
<td>none</td>
</tr>
<tr>
<td>100%</td>
<td>27.51 x 10^6</td>
<td>21.17 x 10^4</td>
<td>none</td>
</tr>
</tbody>
</table>
of area and perimeter is described as shown in Eq. (1). The formula of area and perimeter as used in Table I were described at Eq. (2) and Eq. (3).

\[
\text{Mold Measurement} \times 100\%
\]

\[
\text{Mask Measurement}
\]

\[
\text{Area} = x \times y
\]

\[
\text{Perimeter} = 2x + 2y
\]

### 3.2 The resolutions

A transparency film had been used to produce the negative mask by using color laser jet printer (CLJ 5550: Hewlett Packard). The result after the UV light exposure of 6 minutes and PGMEA developing for different time frame of hours had been analyzed. The negative mask consists of 6 stripes of the same length (30 mm) but varies in width. Width values were ranging from 5 mm (first stripe), 4 mm (second stripe), 3 mm (third stripe), 2 mm (forth stripe), 1 mm (fifth stripe) and 0.25 mm (sixth stripe).

The results show that the best resolution could be formed at 30 minutes developing in which 4 stripes of a 5 mm, 4 mm, 3 mm and 2 mm had been formed. Whereas for 45 minutes, only 3 stripes had been formed, that is for a 5 mm, 4 mm and 3 mm. The resolution for the 2 mm stripe was poor. Further developing for 60 minutes, peeled of the whole SU8-10 film coated onto PMMA as well as side etching for the mold formed.

### 3.3 The PDMS relief

The mold obtained from SU8-10 film on PMMA by using the grayscale transparency film that had been discussed previously had been used to fabricate the PDMS relief.

The fabrication process began with the printed grayscale image on the transparency film to produce a positive mask. The positive mask was put onto the SU8-10 film coated on the PMMA and brought to the exposure process by using UV light (LV204: Mega Electronics Ltd) with an energy density of 5 mW/cm² for 6 minutes. The procedure to prepare this SU8-10 film coated on the PMMA had been discussed in Section 2.2 and by using the exposure method as being mentioned in Section 3.1. Then this SU8-10 film was developed in the PGMEA developer (MicroChem Corp) for 30 minutes. Then, it was blown dry with nitrogen (N₂) gas.

This SU8-10 film was ready to be used as a mold. It was then being placed in the plastic container and the PDMS (Dow Corning Sylgard 184) was poured. PDMS was mixed with the catalyst at a rate of PDMS:catalyst=10:1.
Then PDMS was defoamed in a vacuum desiccators for 24 hours. After that, PDMS was peeled off from the container.

The SU8-10 mold shows the variation in terms of thickness at both sides of the image. Thus, this results in a 3D PDMS relief. The mold and relief produced a sharp and clear image from the transparency film used.

4 Conclusion

Based on the data and result obtained, SU8-10 gives a promising result to be coat on PMMA. The grayscale effect had shown a good quality on the SU8-10 film. It proved a variation in terms of the perimeter and area formed to produce a 3D mold and mask. SU8-10 film coated on PMMA was flexible thus eliminate the PMMA excessive edge bead at four corners edges. Moreover, the cost for PMMA is much cheaper compare to a silicon wafers or a glass slide. In conclusion, being low cost, easy to machine, transparent and biocompatible, PMMA is a promising base material for SU8-10 process.

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