A novel and simple fabrication method of embedded SU-8 micro channels by direct UV lithography

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Abstract. In this paper, we present a novel and simple method to fabricate embedded micro channels. The method based on different light absorption properties of the SU-8 thick photoresist under different incident UV wavelengths. The channel structures are defined by the ordinary I-line, while the cover layer is patterned by the deep UV. Because the deep UV is obtained directly on the same aligner with a set of filter mirrors, the embedded channel can be easily produced without other rare facilities. Besides, the thickness of the top layer and the exposure dose of the deep UV has been measured by an ingeniously designed experiment. The specific thickness of the top layer of the embedded micro channel can then be secured by the specific deep-UV exposure dose. Furthermore, many meaningful mechanical structures have been realized by this method, the material property of the top layer are also measured.

1. Introduction

SU-8 can be employed to produce very thick micro structures easily and has been profoundly applied to fabricate micro fluidic devices where relative thick structures are needed. Embedded micro channel is one of the most important building blocks among various micro fluidic structures. The essence to fabricate an embedded micro channel is how to create a cover layer on the channel structure. Several methods have been reported including: (1) utilizing photo-insensitive materials to fill channel spaces [1], (2) employing metal mask to protect from secondary exposure [1], (3) laminating dry film on the exposed SU-8 structures [2], (4) using proton beams [3] and (5) applying anti-reflective layer [4], etc. All these methods are not easy enough for either employing more than two materials with complicated process steps or treating with rare facility such as proton beam. In this paper, we are going to present a novel and extraordinarily simple way to produce SU-8 embedded micro channels only by direct UV lithography.

SU-8 is optimized for near UV (350-400 nm) exposure. I-line (~365 nm) tools are usually recommended [5] because SU-8 is virtually transparent above 400 nm. The high transparency guarantees bottom of the resist can be exposed by the incident light. This makes SU-8 to be an excellent thick photo resist.
However, for the wavelength below than 250 nm, SU-8 demonstrates extremely large actinic absorption as shown in Fig. 1 [6], which means most energy of the light will be absorbed by the top portion of the photo resist; the bottom portion of the SU-8 will not have enough light energy to be curried as shown in Figure 2, and therefore will be etched by the following developing step.

![Figure 1](image1.png)

**Figure 1.** Optical absorption of resists used for micro machining: Curve A: SU-8; Curve B: dry film Riston® T-168; Curve C: positive diazo resist. [6].

![Figure 2](image2.png)

**Figure 2.** With near UV (~365nm), SU-8 can be exposed thoroughly, while with deep UV (~254 nm), top portion of the SU-8 will absorb most of incident energy.

### 2. Concepts and fabrication process

The phenomenon mentioned above can be consequently adapted to fabricate the embedded micro channels as shown in the figure 3. For example, the SU-8 is spun on with a speed of 500 rpm for 10 sec and 1300 rpm for 30 sec to obtain a resist layer with a thickness about 120 um. After soft bake at temperature 95 °C, it is exposed by I-line with 500 mJ/ cm² at first through the first mask which defines the patterns of the channel structures. Later on, it is exposed on the same aligner with deep UV through the second mask which defines inlets and outlets of the fluidic system. The deep UV with a characteristic wavelength near 250 nm can be obtained easily with a set of filter mirrors on the aligner. Figure 4 shows an example of the fabricated micro fluidic structures. Figure 5 shows the fabricated device connected with fluidic tubes.
Figure 3. Schematic process steps to fabricate the embedded micro channels: (a) SU-8 spun-on; (b) Expose with I-line; (c) Expose with deep UV (~250 nm); (d) After development.

Figure 4. Example of the fabricated micro fluidic element.

Figure 5. The fabricated device connected with fluidic tubes.
3. Top layer thickness and the deep UV exposure dose

For many applications, to get a specific thickness of the top layer is unavoidable. However, it is difficult to obtain the relationship between the thickness of the top layer and the deep UV exposure dose with a straightforward way as shown in the figure 6(a). Because most of the light energy is absorbed by the top portion of the photo resist; the bottom portion of the SU-8 does not have enough light energy to be curried and therefore will be etched by the following developing step. It is not very easy to estimate the thickness of the floated top layer.

In order to solve the problem, we designed a clever experiment as shown in the figure 6(b). The standard mask used in our lab is made of a 500 um thick soda lime glass with a 100 nm thick Cr pattern. In the case of ordinary exposure, the incident UV light goes through the glass at fist and then illuminates on the resist as shown in the figure 6(a). The exposure condition on the photoresist is almost identical, when we adapt the mask as the substrate and expose the resist from the back side as shown in the figure 6(b). In this case, the cured SU-8 will be left on the substrate after development and its thickness can then be easily measured by an alpha-step.

Figure 9 shows the measured result of the obtained layer thickness in a function of deep UV exposure dose. The specific thickness of the top layer of the embedded micro channel can then be secured by the specific deep-UV exposure dose.

4. Other mechanical structures and applications

Various meaningful SU-8 mechanical structures, for example cantilever beams and bridges, have been realized by the purposed method as shown in the Figure 7. These structures have been further employed to analyze accurate the material properties of the fabricated SU-8 thin films as shown in the Figure 8. Further more, we have successfully adapted this method to produce the nozzle/fluidic channel systems of the ink jet printer heads as shown in the figure 9.
Figure 6. The measured results of the layer thickness in a function of deep UV exposure dose.

Figure 7. Mechanical structures fabricated by the purposed method.

Figure 8. Frequency response of the fabricated SU-8 cantilever beam excited by a PZT transducer for the extraction of the material properties of the deep UV exposed SU-8.
5. Conclusion

In this paper, we presented a novel and very simple method to fabricate embedded micro channels. The method based on the different light absorption properties of the SU-8 thick photoresist under different incident UV wavelengths. The channel structures were defined by the ordinary I-line, while the cover layer was patterned by the deep UV. Because the deep UV was obtained directly on the same aligner with a set of filter mirrors, the embedded channel can be easily produced. Besides, the relationship between the thickness of the top layer and the exposure dose of the deep UV was measured by the ingeniously designed experiment. In addition, various meaning mechanical structures were realized. The material property of the top layer was measured by the BHE method and compared with the result obtained from the indenter. Further more, we have successfully adapted this method to produce the nozzle/fluidic channel systems of the ink jet printer heads.

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Figure 9. The nozzle and fluidic channel systems of the ink jet printer head fabricated by the purposed method.