# A New Patterning Technique on UV Sensitive Transparent Film with Chip Embedded Photomask

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**Abstract**

A new pattering technique on a UV sensitive transparent film that can have important implications for sensor and transparent device applications is proposed. One of the patterning methods on UV sensitive transparent substrates involves UV front-side exposure with an extra photomask, an approach commonly employed in conventional lithographic processes. However, the use of an extra photomask requires an expensive and complicated lithographic process. Thus, this approach is not appropriate for commercial implementation to consumable low-cost device applications. In this paper, a new method involving back-side exposure is demonstrated with a chip embedded photomask. This approach inherently provides a self-alignment process. A SU-8 layer with thicknesses of 30µm and 100µm, respectively, and with designed pattern sizes in a range of 200µm to 700µm was used as a chip embedded photomask to transfer patterns on the front-side of a Polydiacetylene (PDA)-Polyvinyl alcohol (PVA) film substrate with UV light. The UV light was then exposed from the back-side of the chip. A Pyrex glass wafer of 800µm thickness was employed as a substrate, permitting back-side exposure. The designed SU-8 patterns on the Pyrex glass do not allow transmission of the UV light to the PDA-PVA film on the top region of the SU-8 patterns.

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**Keywords:** UV sensitive polymers, Polydiacetylene, Pattern Generation, SU-8 Embedded Mask

## 1. Introduction

Patterning techniques of polymer films are becoming increasingly important in parallel with increasing demand for polymer based biosensors, chromatic devices for polymer displays, optical switches, etc. Most of the proposed methods introduce different chemical processes for the synthesis of the materials, preparation of the composites, and activation of the functional patterns to obtain the final product. Regardless of the chemical synthesis method, most polymer and polymer composite films are characterized by using UV irradiation and heat treatment. As recently reported by Kim's group, the film is generally exposed by a fixed wavelength of UV light through an external photomask in order to form image patterns that may also be fluorescent [1].

After formation of the patterns, the chip is ready for the end-point application, which may be an optical switch, a biosensor array, or a temperature or chemical sensor. At this stage, the chip should be maintained under specific conditions to minimize damage from illumination and temperature until it reaches to the end-user.

It is necessary to provide multiple options for UV irradiation conditions such as time and intensity depending on the end-point application and to protect the patterned chips from denaturalizing ambient effects. However, with the current chip structures, a costly mask aligner and extra photomask are required for this purpose. In this paper, with the aid of MEMS technology, we propose a new chip embedded photomask structure that will allow the user to pattern self-aligned images on the polymer film with a simple UV lamp. A SU-8 layer with thicknesses of 30μm and 100μm, respectively, was patterned. The size ranged from 200μm to 700μm on a Pyrex glass wafer of 800μm. After the formation of a polymer film on the SU-8 patterns, UV light was exposed from the back side of the Pyrex glass to transfer the shape of the SU-8 patterns onto the polymer film. A self-aligned device structure with a back-side exposure process is also common in thin film transistor fabrication technology [2]. However, our approach is the first report to generate color patterns on polymer or polymer composite films using the selective UV transmission property of a SU-8 layer. The SU-8 layer not only functions as an embedded photomask but also isolates the adjacent patterns with its good thermal and electrical isolation properties.

## 2. Materials and Fabrication of the device

Polydiacetylene (PDA) is one of the most attractive color-generating materials. Blue color transition is achieved by UV irradiation of diacetylene molecules at 254nm wavelength. They also show dramatic blue to red color transitions by external stimuli such as temperature [3], pH [4], and mechanical stresses through changes in the effective conjugation length of the PDA backbone [5], [6], [7]. In this research, we used PCDA-EDEA, an amine-terminated diacetylene monomer, with polyvinyl alcohol (PVA) to obtain a solid film of polymer composition. The amine-terminated diacetylene monomer PCDA-EDEA was prepared as described in the literature [8] and polyvinyl alcohol ($M_w$=89,000-98,000) was purchased from Aldrich. In order to obtain the composite solution, the diacetylene vesicle solution was mixed with an aqueous 10 % PVA solution in a volume ratio of 1:1. [1]

Before back side exposure the sample consists of a transparent Pyrex glass wafer, a patterned SU-8 layer, and a polymer film layer dispensed on a SU-8 layer, as shown in Figure 1. Apart from its simplicity, the structure of the device permits the involvement of other fabrication steps depending on the required application.

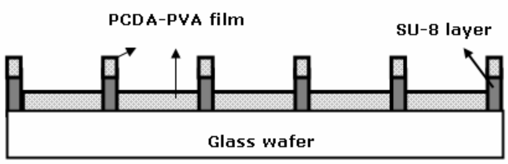



Figure 1. Structure of the chip embedded SU-8 photomask

The process details to prepare the sample are as follows: 4 inch Pyrex glass wafers of 800μm thickness were cleaned with $H_2SO_4$:$H_2O_2$ (1:1) solution for 10 minutes and singed at 200°C for 10 minutes in order to prepare the surface prior to SU-8 coating. SU-8 (MicroChem) layers of 30μ and 100μm thickness were then coated on the surface and patterned with the conditions listed in Table 1. The adhesion of the PDA+PVA composite film on the glass substrate is not sufficient, and therefore oxygen plasma treatment is necessary before dispensing the polymer solution onto the substrate. 150Watt-50sccm-5minute $O_2$ plasma treatment was applied on the SU-8 patterned glass. This also increases the surface energy, which provides better uniformity for the polymer film layer during injection of the liquid polymer solution on the substrate.

| **SU-8** | SU-8 10 | SU-8 2100 |
|---|---|---|
| **Thickness** | 30μ | 100μ |
| **Spin Coating** | 500rpm 10sec<br>1000rpm 30sec | 500rpm 10sec<br>3000rpm 30sec |
| **Soft Bake** | 65˚C 3min<br>95˚C 8min | 65˚C 5min<br>95˚C 60min |
| **Expose** | 300mJ/cm$^2$ | 600mJ/cm$^2$ |
| **PEB** | 65˚C 1min<br>95˚C 4min | 65˚C 2min<br>95˚C 12min |

Table1. SU-8 patterning conditions for 30μm and 100μm

5ml PCDA-PVA solution was dispensed on the surface using a spoid and the film layer was cured at room temperature for 36 hours. After curing, a solid film was formed on the surface, as shown in Figure 4a.

The conventional exposure process for an external photomask and an embedded SU-8 mask are compared in Figure 2. The UV exposure was accomplished with 6-Watt 254nm UV light through the backside of the Pyrex glass wafer for 10 minutes (Vilber Lourmat UV Darkroom). With an up-side-down approach, the polymer film was exposed to UV through the patterns of the SU-8 layer, which serve as a barrier to UV.

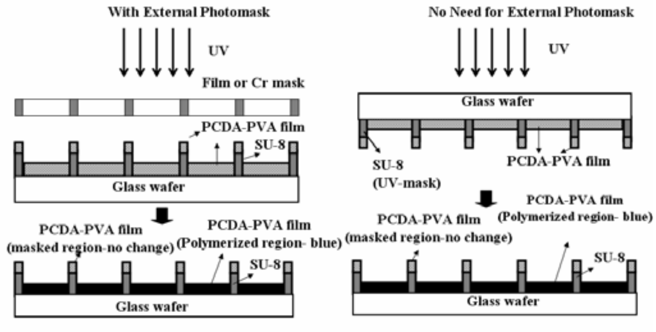



Figure 2. Comparison of the composite-polymer patterning methods with external and chip embedded SU-8 mask

## 3. Measurements and Results

SU-8 is a well-known negative photoresist that is usually exposed around 350-400nm (I-line) UV. While it was optimized for the wavelength of this range, it is virtually transparent above 400nm. This property guarantees the transmission of UV to deep inside the layer, thus resulting in very thick structures. However, the wavelength that we are interested in is 254nm, which is needed to polymerize diacetylene monomers to polydiacetylene molecules. There are very few applications that use SU-8 resist below 350nm, because of its very actinic absorption at this range [9]. This absorption property is the main reason that SU-8 behaves as a very good mask layer to UV. It can play the role of an external photomask to simplify the patterning of an underlying layer.

Figure 3 shows the transmittance of Pyrex, a glass slide, and 100µm SU-8 film. Transmittance measurement of SU-8 was done without a substrate, i.e. with bare SU-8, for convenience. It is clear from the figure that SU-8 transmittance decreases to negligible values for wavelengths less than 350nm. At 254nm, it reaches zero and thus becomes a good UV barrier layer.

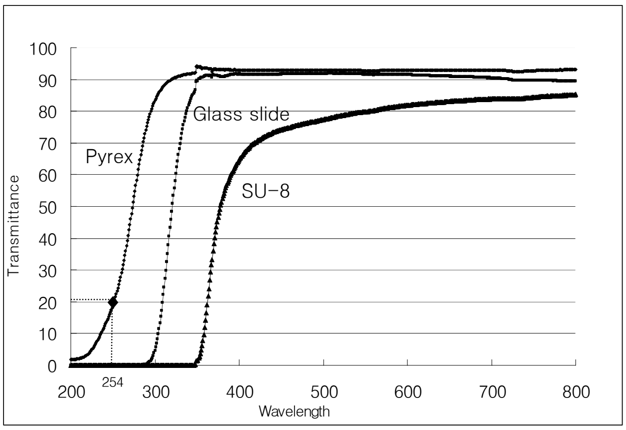
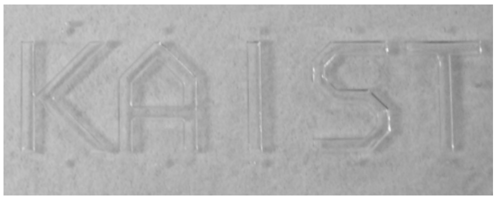


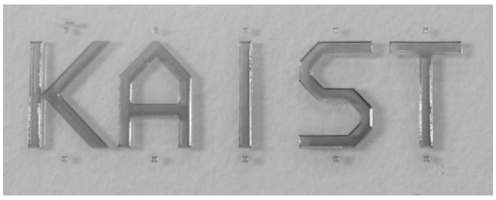

Figure 3. Transmittance (%) values for Pyrex, glass slide, and SU-8 (100µm)

The substrate on which SU-8 is patterned is also important. Figure 3 compares two substrates with different materials, Pyrex and microscope slide glass. UV is irradiated from the back-side, and therefore the substrate should permit the transmission of 254nm UV. In the figure, transmittance of Pyrex is 22.4% while the glass slide shows no indication of transmission. It usually takes not more than 1 minute to polymerize PDA+PVA solution or film using UV (1mWcm$^{-2}$) light [1]. However, in the case of the backside exposure, 10 minutes was required to polymerize the whole film because of the relatively low transmittance of the Pyrex substrate.

Figure 4 shows the PCDA+PVA film on SU-8 of 100µm before and after UV treatment with 254nm wavelength. The pattern size for the letters and the square patterns at the top and bottom are 700µm and 300µm, respectively. It is clear from the figure that the image patterns were selectively formed on the polymer film according to the shape of the SU-8 patterns while the film layer on the SU-8 does not change color. It is worth noting that this backside exposure provides self-aligned patterns, which imply a high packing density.



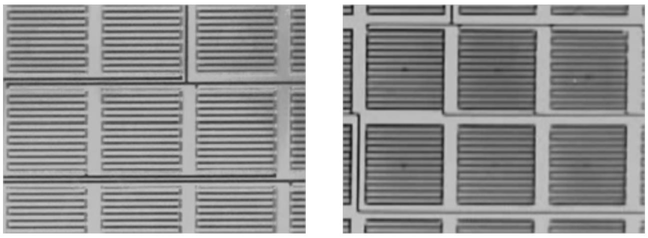

a) Before UV expose




b) After UV expose

Figure 4. PCDA+PVA composite film layer on SU-8

30µm SU-8 layer was also used to demonstrate the masking effect, but this time with additional Ti-Au (10nm-200nm) micro-heater arrays, which were fabricated on Pyrex glass before SU-8 patterning, as shown in Figure 5a. Although the micro-heater layer is not transparent to UV light, partial exposure between the micro-heater wires is sufficient to form desired patterns on the polymer film layer. This structure shows that it is possible to modify the structure depending on the end-point application.



a) b)

Figure 5. 30μm SU-8 and micro-heater structure a) before and b) after 254nm UV irradiation for 10 minutes

## 4. Conclusions

A new pattern generation technique on UV sensitive film was introduced with a device embedded photomask layer by making use of the advantages of low UV transmission of SU-8 below 350nm wavelength. Polymers that are sensitive to UV below 350nm wavelength can easily be patterned using the same method. The generated pattern size and shape depend on the SU-8 patterns as well as the thickness of the SU-8 layer. The substrate transmission should also be considered since most of the transparent materials do not show good transmission below 300nm wavelength.

The key advantage of the proposed approach is the provision of a cheaper and easier patterning process that does not require an aligner or external photomask for end-users. Moreover, the SU-8 layer between the cells of the array functions as a very good thermal and electrical insulator, and is thus attractive for micro-array sensor applications.

## Acknowledgements

This research was partially supported by the Center for Ultra-microchemical Process Systems sponsored by KOSEF. It was also partially supported by an internal fund from KAIST.

## References

[1] J.-M. Kim, Y.-B. Lee, S. K. Chae, and D. J. Ahn, “Patterned Color and Fluorescent Images with Polydiacetylene Supramolecules Embedded in Poly(vinyl alcohol) Films”, Advanced Functional Materials, 16, 2103, (2006)

[2] R. T. Fulks, J. Ho and J. B. Boyce, “A New Laser-Processed Polysilicon TFT Architecture“, IEEE Electron Device Letters, 22, 86-88, ( 2001)

[3] Ahn, D.J., Chae, E.H., Lee, G.S., Shim, H.Y., Chang, T.E., Ahn, K.D., Kim, J.M., “Colorimetric Reversibility of Polydiacetylene Supramolecules Having Enhanced Hydrogen-bonding under Thermal and pH Stimuli”, J. Am. Chem. Soc. 125, 8976-8977, (2003)

[4] Ahn, D.J., Chae, E.H., Lee, G.S., Shim, H.Y., Chang, T.E., Ahn, K.D., Kim, J.M., “Colorimetric Reversibility of Polydiacetylene Supramolecules Having Enhanced Hydrogen-bonding under Thermal and pH Stimuli”, J. Am. Chem. Soc. 125, 8976-8977, (2003)

[5] Alekseev, A.S., Viitala, T., Domnin, I.N., Koshkina, I.M., Nikitenko, A.A., Peltonen, J., “Polymerization of Modified Diacetylenes in Langmuir Films”, Langmuir 16, 3337-3344, (2000)

[6] Huo, Q., Russel, K.C., Leblanc, R.M., “Chromatic Studies of a Polymerizable Diacetylene Hydrogen Bonding Self-assembly: a “Selffolding” Process to Explain the Chromatic Changes of Polydiacetylenes. Langmuir 15, 3972-3980, (1999)

[7] Yang, Y., Lu, Y., Lu, M., Huang, J., Haddad, R., Xomeritakis, G., Liu, N., Malanoski, A.P., Sturmayr, D., Fan, H., Sasaki, D.Y., Assink, R.A., Shelnutt, J.A., Swol, F.v., Lopez, G.P., Burns, A.R., Brinker, C.J., “Functional Nanocomposites Prepared by Self-assembly and Polymerization of Diacetylene Surfactants and Silicic Acid”, J. Am. Chem. Soc. 125, 1269-1277, (2003)

[8] Kim, J.M., Ji, E.K., Woo, S.M., Lee, H., Ahn, D.J., “Immobilized Polydiacetylene Vesicles on Solid Substrates for Use as Chemosensors”, Adv. Mater. 15 (13), 1118-1121, (2003)

[9] C Fu, C Hung, H Huang, “A Novel and Simple Fabrication Method of Embedded SU-8 Micro-channels by Direct UV Lithography“, Journal of Physics: Conference Series, 34, 330-335, 2006