

# RAPID PROTOTYPING AND NON-PLANAR PATTERNING USING PHOTODEFINABLE PDMS

Preetha Jothimuthu, Ali Asgar S. Bhagat, and Ian Papautsky

Department of Electrical and Computer Engineering,  
University of Cincinnati, Cincinnati, USA

## ABSTRACT

In this work, the new photodefinable PDMS (*photoPDMS*) material was applied to simplify otherwise complex microfabrication procedures such as fabrication of multi-layered microfluidic devices and patterning free-standing thin films for shadow masking on planar and non-planar surfaces. This new *photoPDMS* material offers numerous significant advantages over traditional PDMS fabrication techniques including (i) direct patterning eliminating the need for a master template; (ii) ability to process under ambient light eliminating the need for sensitive lighting; and finally (iii) all advantages of PDMS including low cost and simple fabrication enabling rapid prototyping.

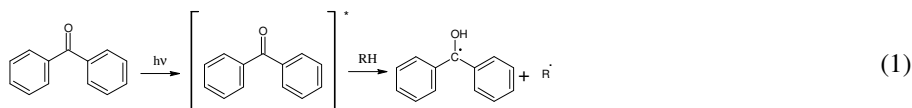
**KEYWORDS:** *PhotoPDMS*, rapid prototyping, benzophenone, FTIR.

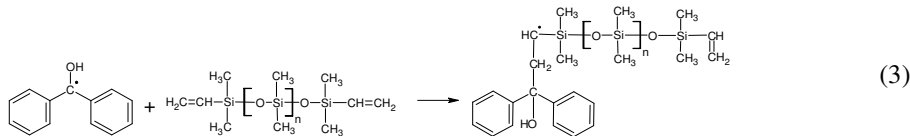
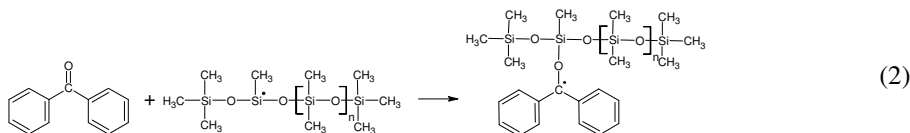
## INTRODUCTION

Patterning of PDMS using photoinitiators has also been successfully demonstrated by other investigators [1,2]. Lotters *et al.* [1] using 2,2-dimethoxy-2-phenyl acetophenone (DMPAP) photoinitiator to directly pattern PDMS. This material acted as a negative photoresist. Tsougeni *et al.* [2] demonstrated photopatterning of several types of siloxane copolymers with vinyl-methyl siloxane groups as polymerizable units with different photoinitiators. However, sensitivity to O<sub>2</sub> as well as ambient light has limited the use of these materials for rapid prototyping of lab-on-a-chip (LOC) devices. Recently we introduced the concept of direct patterning of polydimethylsiloxane (PDMS) thin films by the addition of benzophenone photoinitiator [3]. The *photoPDMS* is *positive* acting and is *not sensitive to ambient light*, which makes chip design and fabrication easier.

## METHODS

The proposed chemistry is presented in the following equations. When benzophenone is irradiated with UV light, free radicals are generated (Eq. 1). These free radicals reacts with the crosslinker and the base monomer of PDMS forming short complexes as shown in (Eqs. 2-3). Thus, benzophenone interferes with the conventional crosslinking and forms a weakly crosslinked region.





The *PhotoPDMS* mixture was prepared by dissolving benzophenone in xylene and then mixed with PDMS base and curing agent. The mixture was then spin coated on a 300 $\mu\text{m}$  thick glass wafer and selectively exposed to UV radiation at <365nm with an exposure energy of 12mW/cm<sup>2</sup> for 10min. This was followed by a soft bake step in a conventional oven at 120°C to crosslink the unexposed regions and then developed in toluene for 3-5s. Thus the *photoPDMS* mixture acts as a positive photoresist with the unexposed regions getting cured while the exposed regions wash-off from the substrate. The process is schematically shown in Figure 1. Figure 1d shows the schematic of a double-layer microchannel which can be fabricated by patterning the second layer on the existing first intermediate PDMS layer.

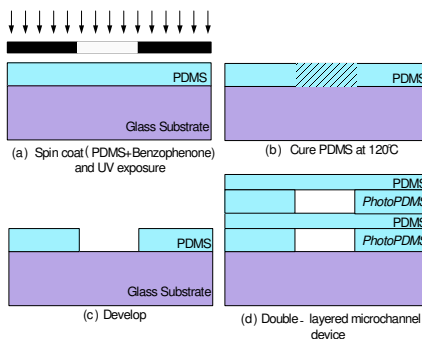


Figure 1. Schematic diagram illustrating the fabrication sequence of *photoPDMS*.

## RESULTS AND DISCUSSION

FTIR analysis was performed to confirm the cross-linking behavior of *photoPDMS* (Figure 2). From the analysis, it was observed that the carbonyl C=O group of the benzophenone at 1664 cm<sup>-1</sup> decreases in intensity. Similarly, the C=C of the vinyl group of the base and the Si-H group of the crosslinker also decreases at 1600 cm<sup>-1</sup> and 2169 cm<sup>-1</sup> respectively. This confirms the reaction of benzophenone with the base monomer and the crosslinker.

To demonstrate application to LOC, multilayered microchannels

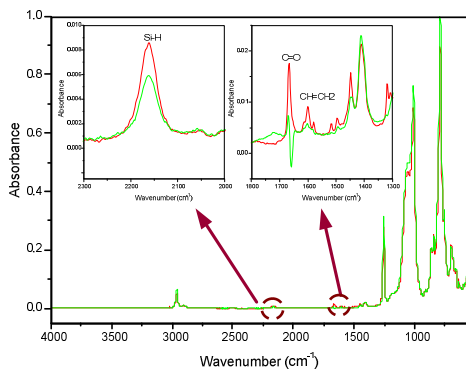


Figure 2. FTIR spectrum of the *photoPDMS* mixture showing the reaction between benzophenone, PDMS monomer and cross-linker taken before (red) and after (green) UV exposure.

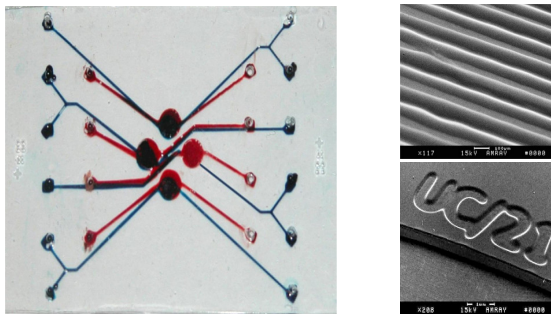


Figure 3. (left) Photograph of a double-layered microfluidic device fabricated using *photoPDMS*. (right) SEMs showing line features of 100  $\mu\text{m}$  width and other patterns fabricated using *photoPDMS*.

were fabricated using this direct photopatterning technique. Figure 3(left) shows a double-layer microchip. The two patterned layers were bonded using corona discharge with an intermediate layer of PDMS to seal the microchannels. Two different colored dyes were used to visualize the channels on each layer, and shows excellent channel definition. Figure 3(right) shows SEMs of *photoPDMS* patterns 50 $\mu\text{m}$  to 500 $\mu\text{m}$  in dimension.

To further demonstrate the versatility of *photoPDMS*, free-standing patterned thin films were fabricated consisting of square patterns ranging from 500 $\mu\text{m}$  to 2mm in size. These films were then used as shadow masks for patterning of 200nm-thick gold regions on planar and non-planar surfaces (Figure 4). The flexibility offered by these films will enable their use as low-cost shadow masks for patterning of biological samples such as cells and proteins on a wide range of substrates.

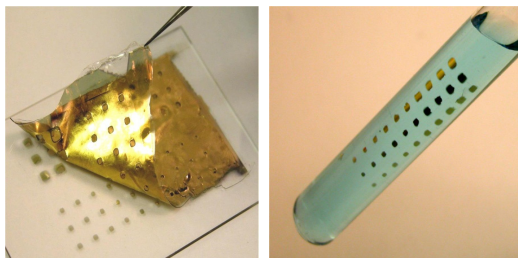


Figure 4. *PhotoPDMS* thin film used as a shadow mask for patterning on (top) planar, and (bottom) non-planar surfaces.

## CONCLUSIONS

In conclusion, a new and simple approach enabling direct patterning of PDMS polymer for fabrication of microfluidic devices and patterning thin films was successfully demonstrated. The *photoPDMS* is robust and can be processed under normal ambient light. We expect it will enable rapid prototyping of low-cost, disposable LOCs without clean room facilities, envisaging its numerous applications in microfluidics and LOC fields.

## REFERENCES

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