NON-ABSORBING, CLEAR, FLEXIBLE, AND CASTABLE POLYURETHANE FOR FABRICATION OF MICROFLUIDIC DEVICES

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ABSTRACT

Polydimethylsiloxane (PDMS) has many desirable attributes for the development of microfluidic systems, including simple fabrication processes, biocompatibility, optical transparency and flexibility. However, the partitioning of small hydrophobic molecules into the bulk of PDMS is in part behind the slow industrial acceptance of PDMS microfluidic devices. Here we describe a castable polyurethane that is similar to PDMS in terms of optical transparency and flexibility but that does not absorb small hydrophobic molecules. In addition, polyurethane is compatible for cell culture, and device microfabrication can be achieved via replication molding and corona bonding.

KEYWORDS: Polydimethylsiloxane, Polyurethane, Small Hydrophobic Molecules, Microfluidics, Absorption, Cell Culture, Organs-on-Chips

INTRODUCTION

Strong absorption of small hydrophobic molecules such as drugs, fluorescent dyes, or cell signaling molecules in PDMS microfluidic devices can result in reduction of effective drug concentration, time-dependent changes in compound concentrations, cross-contamination, lower detection sensitivity, and higher background fluorescence. Partitioning of molecules into the bulk is in part behind the slow industrial acceptance of PDMS microfluidic devices. While there are clear and flexible materials such as perfluoropolyethers that make inroads into the fabrication of microfluidic devices, they still suffer from absorption of small hydrophobic molecules [1].

Polyurethanes are a very broad class of polymers that have been used with success in many applications including the medical industry. A subclass of these polymers that do not absorb small hydrophobic molecules, but that are optically clear, flexible, and that can be processed by replica molding in a basic laboratory setting would be particularly appealing for both rapid prototyping and manufacturing of microfluidic devices for cell-based drug and toxin testing applications. Recently, thin polyurethane films have been integrated into PDMS or rigid polymer devices [2,3]; however, to our knowledge, clear and flexible polyurethane microfluidic devices fabricated by replica molding have not been demonstrated. Here we describe performance of a castable polyurethane that is similar to PDMS in terms of optical transparency and flexibility, but that does not absorb small hydrophobic molecules. The material allows for cell culture and device microfabrication by replication molding and corona bonding.

EXPERIMENTAL

The polyurethane used in this work is a commercially available (GSP 1552-2, GS Polymers, Inc.) two-part system that has a 15-minute gel time and cures overnight at room temperature or in two hours at 80 °C. The hardness of the polymer is 60 Shore A. To show fundamental differences in small molecule absorption, 10-mm diameter discs with a 4-mm thickness were punched from fully cured polyurethane and PDMS blanks and immersed in separate glass containers with Nile red, rhodamine B, and FITC solutions for 48 hours. The discs were then spray-rinsed with DI water, air-dried, and imaged from the top side (data not shown). Finally, a ~2 mm-thick slice was sectioned from each disc as depicted in Fig. 1a and imaged from a cut side.

RESULTS AND DISCUSSION

The fluorescent dye absorption profiles of polyurethane and PDMS are shown in Fig. 1b-d. It can be seen that the hydrophobic dye, Nile red, absorbs virtually into the entire bulk of the PDMS disc while the bulk of the polyurethane disc is not effected (Fig. 1b). Rhodamine B partitions significantly into the bulk of PDMS but not into polyurethane (Fig. 1c). FITC does not partition into either elastomer (Fig. 1d). Figure 2 shows side-by-side optically clear and flexible polyurethane and PDMS microfludic devices. Each device consists of a patterned elastomer layer corona-bonded to a glass cover slip. The PDMS device was cast directly from a silanized silicon wafer with SU-8 resist features. Because of a stronger adhesion of polyurethane to silanized silicon masters, the polyurethane device was cast from a silicone mold replicated from the original silicon master. The insert in Figure 2 is a photograph of microchannels of the corona-bonded polyurethane device filled with food-colored aqueous solutions illustrating the feasibility of molding and bonding. To demonstrate suitability of the polyurethane material for fabricating microfluidic cell culture devices, human umbilical vein endothelial (HUVE) cells were cultured on a fibronectin-coated polyurethane polymer surface and the cells attached and spread normally as they do on conventional cell culture substrates (Fig. 3).

CONCLUSION

We have identified a castable polyurethane that is similar to PDMS in terms of optical transparency and flexibility but that does not absorb small hydrophobic molecules. We have shown that the material allows for cell culture and device microfabrication by replication molding and corona bonding. Polyurethane microdevices can find broad applicability in assays that involve cells and/or small hydrophobic molecules, and thus should be valuable for drug screening, toxin testing, fluorescence microscopy and cell signaling studies.

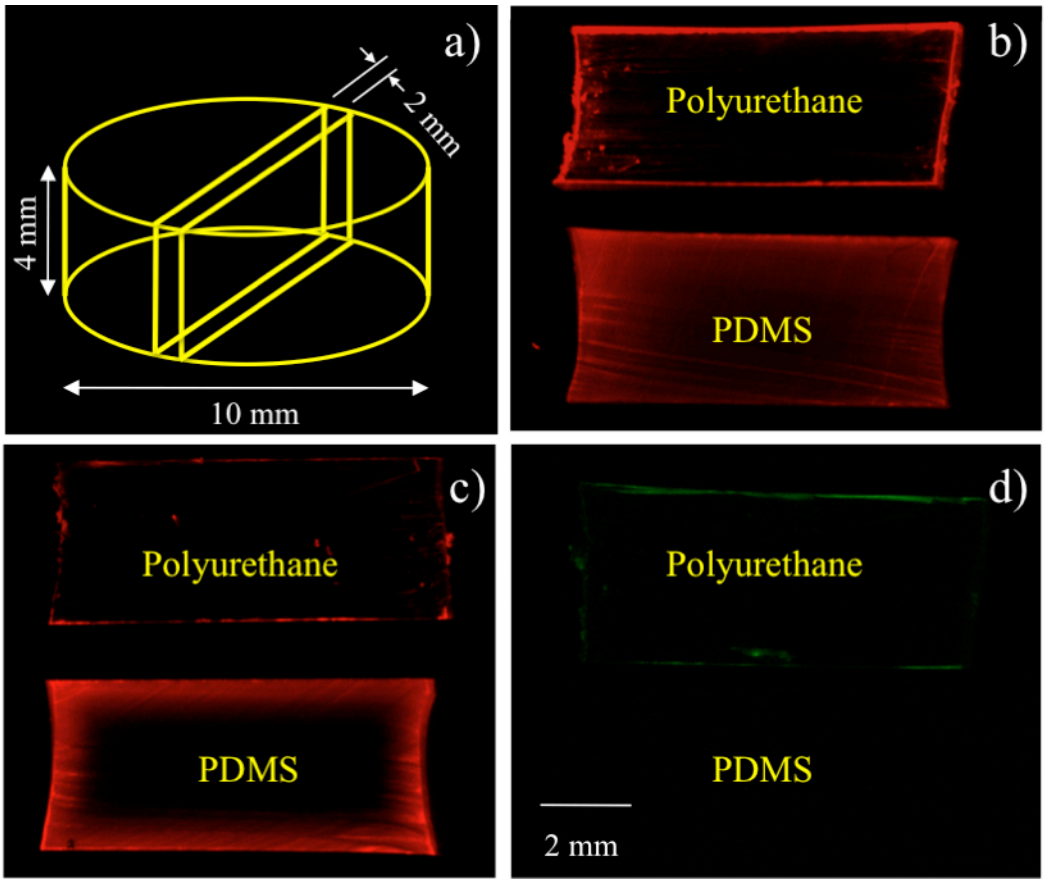

Figure 1: Absorption of dyes into polyurethane and PDMS. Discs were immersed in dye solutions for 48 hours, rinsed with water, and air-dried. A 2-mm thick slice was sectioned from each disc (a). The discs were laid flat and imaged from a cut side. Results show absorption from solutions of Nile red (b), rhodamine B (c), and FITC (d).

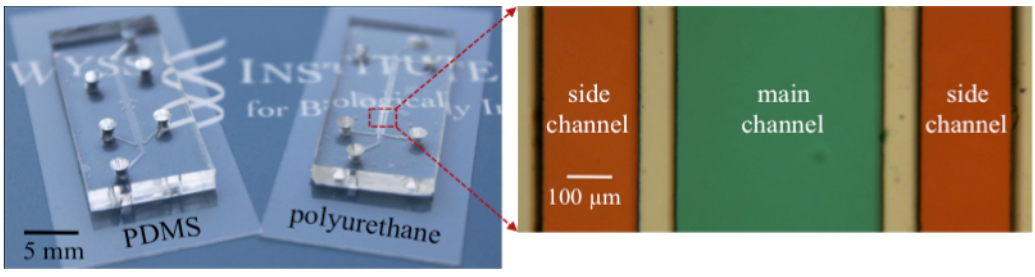

Figure 2: A photograph of optically clear and flexible 3-channel microfluidic devices fabricated from PDMS and polyurethane. The devices were corona-bonded to 22 x 50-mm microscope coverslips. The insert on the right is a photograph of microchannels of the bonded polyurethane device filled with food-colored aqueous solutions. The main channel is 400 µm wide and the side channels are 200 µm wide. All channels are 70 µm deep.

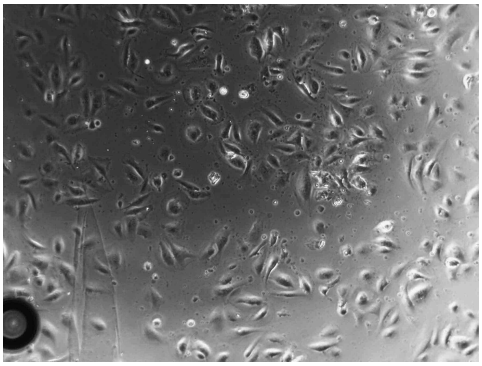

Figure 3: HUVECs cultured on fibronectin-coated polyurethane discs inserted into a 48-well tissue culture plate. Image was taken 3 hours after seeding.

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