Light-based 3D printing of functional polydimethylsiloxane-based microfluidic chips

Gustavo A. Gonzalez,[1,2,3] Annalisa Chiappone,[1] Kurt Dietliker,[4] Pirri C. Fabrizio,[1,2] Ignazio Roppolo[1]

[1]Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, Turin; [2]Center for Sustainable Futures @Polito, Istituto Italiano di Tecnologia, Torino; [3]Italian Association for Industrial Research (AIRI), Rome, Italy; [4]Department of Chemistry and Applied Biosciences, ETH Zurich, Switzerland

Abstract

The objective of the work is to fabricate and functionalize 3D printed PDMS-based microfluidic chips through digital light processing DLP-3D printing.

Introduction

Recently, polymeric 3D printing has emerged as a valid alternative for the fast fabrication of complex-shaped microfluidic chips at low costs and with good accuracy that can be used in different fields of biomedical application.[1] Among the 3D printing technologies for polymers, vat polymerization 3D printing techniques such as Digital Light Processing (DLP) or Stereolithography (SL) are among the most versatile since it is possible to operate with the raw materials of the liquid printable polymers for the development of tailor-made structures.[2] This work reports the preparation and printability of a novel resin based on Polydimethylsiloxane (PDMS) to fabricate custom-made 3D printed microfluidic chips with excellent optical features, high chemical stability, and good mechanical properties. Besides, the superficial properties of the 3D printed chips can be easily and selectively modified via UV-induced graft polymerization methods by exploiting the surface unreacted functional groups.

Materials and Methods

The materials for the resin's preparation are PDMS-based oligomer TEGORad 2800 (from Evonik), a silicone-soluble phosphine oxide photoinitiator, disperse red 1 methacrylate dye (from Merck), methyl methacrylate as a reactive diluent. The resin was processed using a commercial DLP-3D printer (Asiga, Australia) with a light source emitting at 405 nm. The grafting solution was composed of acrylic acid in acetonitrile (100 mg/ml) and 2 wt. % (concerning the acrylic acid content) of the BAPO photoinitiator.

Results

After a thorough resin preparation, complex-shaped and precise 3D printed chips from a PDMS-based resin were obtained using a DLP-3D printer. Figure 1.a shows a trapezoidal chip in which inside it hosts a 3-dimensional channel with a square section of 1x1 mm^2. Moreover, facile and selective surface functionalization of the microchannels was achieved during the UV-post-curing step via UV-induced grafting polymerization methods by exploiting the unreacted functional groups after the printing step. As shown in Figure 1b, the properties of the channels were selectively modified after 5 min of UV irradiation using the acrylic-based grafting solution by observing the hydrophobic meniscus on the unfunctionalized part of the channel and the hydrophilic meniscus on the treated side.

Discussion and Conclusions

Complex-shaped PDMS-based 3D printed parts were obtained through digital light processing DLP-3D printing techniques. These devices presented the sought characteristics such as flexibility, stretchability, and high optical transparency, fundamental properties for producing microfluidic chips that can be potentially used in the biomedical field. Besides, the surface prop-

Correspondence: Gustavo A. Gonzalez, Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, Turin, Italy.
E-mail: gustavo.gonzalez@polito.it

Key words: 3D printing; microfluidic; functionalization; photopolymerization; silicone.

Acknowledgments: The present work was developed in the framework of DEFLeCT project funded by Regione Piemonte POR-FESR 2014-2020.

Disclosures: The authors declare no conflict of interest.

Conference presentation: This paper was presented at the Third Centro 3R Annual Meeting - L'era delle 3R: modelli *in silico, in vitro* e *in vivo* per promuovere la ricerca traslazionale - 30 September - 1 October 2021, Evento online organizzato dal Politecnico di Torino.

Received for publication: 9 July 2021.
Accepted for publication: 7 September 2021.

Biomedical Science and Engineering 2021; 4(s1):171
doi:10.4081/bse.2021.171

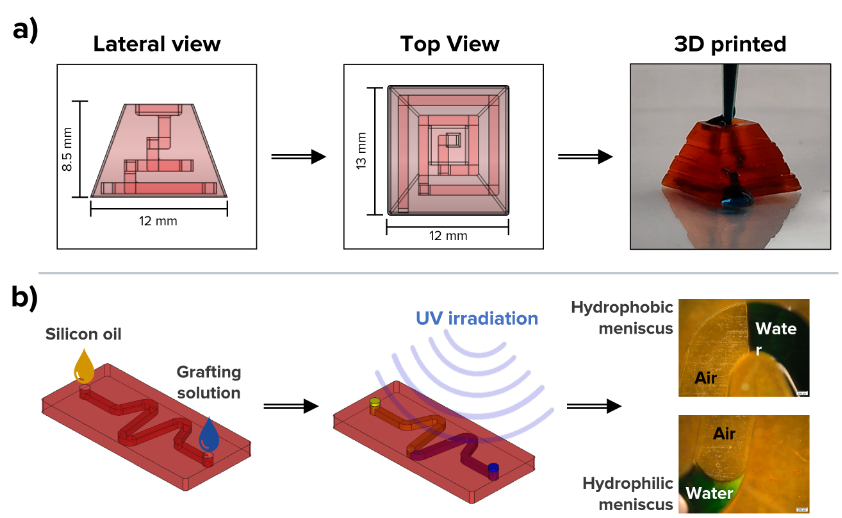

Figure 1. a) CAD design illustration and photographs of the trapezoidal 3D printed microfluidic chip with a 1x1 mm2 channel square section; b) Sketch of surface modification for S-shaped microfluidic. The image shows the selective functionalization of the channel with the formation of a hydrophobic and hydrophilic meniscus inside the same channel.

erties of 3D printed PDMS-based devices were easily and selectively modified during the required UV post-curing procedure through UV-induced grafting polymerization by taking advantage of the unreacted acrylic double bond remaining after the 3D printing step.

References

1. Bishop GW. **3D Printed Microfluidic Devices.** In Microfluidics for Biologists: Fundamentals and Applications. Chandra DK, Ajeet K (Eds), Springer; 2016.
2. Gross BC, Erkal JL, Lockwood SY, et al. Evaluation of 3D printing and its potential impact on biotechnology and the chemical sciences. Anal Chem 2014;86:3240-53.