

Dimensional accuracy of 3D printing of PEGDA parts using Digital Light Processing technology

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Photopolymerizing 3D printing methods such as Digital Light Processing (DLP) enable high-resolution printing. Poly (ethylene glycol) diacrylate (PEGDA)-based material systems are interesting for biomedical as well as tissue engineering applications. For DLP based 3D printing the material systems need a photoinitiator as well as a light absorber for adequate printing performance. LAP (photoinitiator) and Orange G dye (light absorber) are promising additives to be used for biocompatible, photopolymerizable material compositions to be processed at a wavelength of 405 nm. Here we investigate the dimensional accuracy of DLP printed parts using PEGDA compositions with low concentrations of LAP and Orange G.

I. Introduction

3D printing enables the manufacturing of prosthetics and implants personalised to a patient's anatomy. Among the multitude of 3D printing methods, photopolymerizing techniques such as Stereolithography (SLA) or Digital Light Processing (DLP) offer highest printing accuracy and precision [1]. Moreover, minimal heat input and the possibility to adjust material properties via varying the polymerizing parameters can be beneficial for biomedical as well as pharmaceutical applications. Biocompatible polymers and hydrogels such as Poly(ethylene glycol) (PEG) and PEG diacrylate (PEGDA), Poly-D,L-lactic Acid (PDLA) or Polyurethane (PUR) can be used as matrix polymers for photopolymerizing 3D printing.

In general, for adequate printing performance and accuracy, the presence of a photoinitiator and a light absorber is necessary [2]. The photoinitiator initiates the chemical photopolymerisation process and the light absorber is used to control the penetration depth of the light. Usually, a concentration of a few percent of those additives is needed, but the additives have to match the wavelength of the light source of the 3D printing device (e.g. UV laser or DLP projector). However, the availability of photopolymerizable materials for biomedical and drug-delivery applications is limited [3]. It is notable that cell viability is negatively affected by many photoinitiators. Nevertheless, the photoinitiator Lithium phenyl-2,4,6-trimethyl benzoyl phosphinate (LAP) has gained much attention in the field of biomedical engineering due to its low cytotoxicity and good water solubility [2]. LAP has high absorbance at wavelengths of 365 and 405 nm and is often used in concentrations from 0.1 to 0.5 wt% [4][5][6]. Generally, low concentrations of photoinitiators are favourable in the context of bio- and cytocompatibility [7]. Moreover, Orange G dye has also proven to be an appropriate absorbing agent in the context of biomedical applications. Orange G has an absorbance wavelength of 405 nm and is usually used in concentrations from 0.1 to 0.2 wt% [1][2].

This study focus on DLP 3D printing of different PEGDA-based material compositions using low concentrations of LAP and Orange G. The dimensional accuracy of 3D printed parts is analysed using a benchmark part.

II. Material and methods

For DLP 3D printing investigations, three photocurable compositions of PEGDA and water ($c_1 - c_3$) with varying content of LAP (photoinitiator) and Orange G dye (light absorber) were prepared (c_1 : 0.07/0.07; c_2 : 0.035/0.07; c_3 : 0.035/0.035; designation: "short name of composition: LAP/Orange G concentration in % w/w"). PEGDA of molecular weight of $M_n = 700$ g/mol was used as a matrix polymer. The content of water was 30% w/w for each composition.

Printing investigations were performed using a VIDA DLP 3D printer (envisionTEC GmbH, Gladbeck, Germany). The VIDA printer works at a wavelength of 405 nm, which matches the absorbance wavelengths of LAP and Orange G. A benchmark part ([8], Figure 1) featuring different rectangular, circular, pyramidal and overhanging structures with various complexities was printed to investigate printing accuracy.

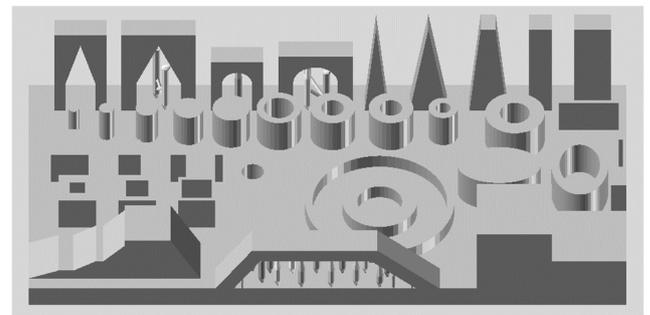


Figure 1: CAD design of the test sample (80 x 40 x 18 mm), overhanging structures are supported.

The layer height was 100 μm (Z-resolution), the XY-resolution of VIDA device was 73 μm . Relatively long

light exposure times per layer of 40 s (t_1) and 20 s (t_2) were chosen because of the low concentrations of LAP and Orange G.

III. Results and discussion

Best printing accuracy was achieved with composition c_1 using $t_1 = 40$ s. All structures of the test sample could be built showing sharp contours (Figure 2 A). When light exposure time per layer is halved ($t_2 = 20$ s), the printing accuracy decreases significantly (Figure 2 B). Here, especially the printing of fine contours is limited but the 3D printing of parts of simple, relatively thick-walled geometry should be possible in acceptable quality. If the LAP concentration is halved, as done for composition c_2 , the printing result is very faulty and of insufficient quality, even when $t_1 = 40$ s is used (Figure 2 C). Possibly, an extension of light exposure time could lead to better results. However, this would result in an excessive time-consuming printing process.

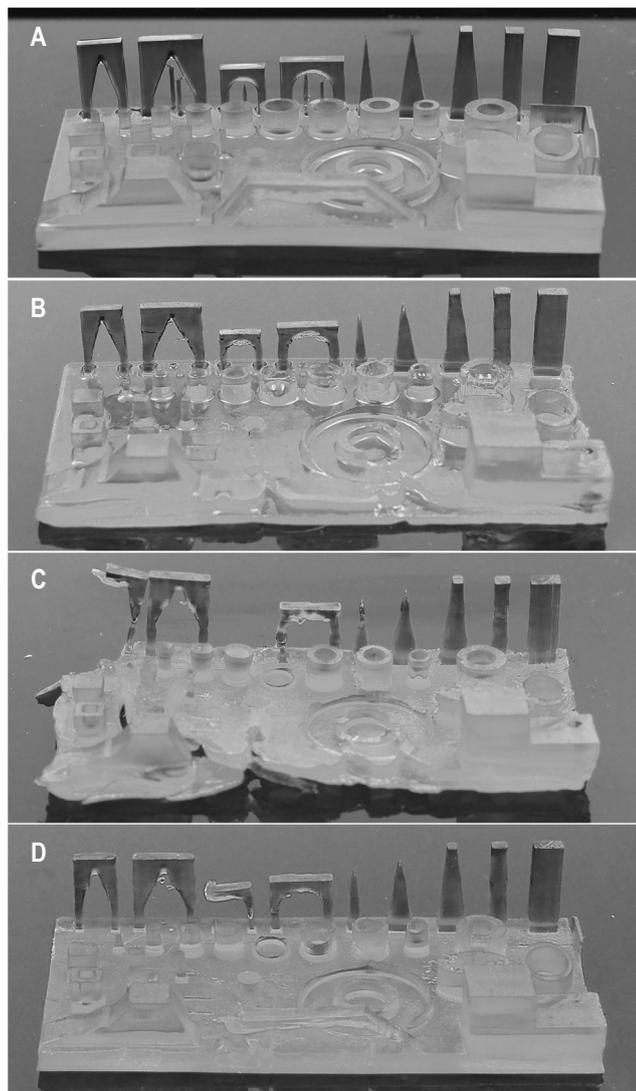


Figure 2: DLP 3D printing of benchmark parts using different compositions of PEGDA and water with varying concentrations of LAP (photoinitiator) and Orange G (light absorbing agent). Two different light exposure times per layer were used ($t_1 = 40$ s and $t_2 = 20$ s); (A) $c_1 - t_1$ (B) $c_1 - t_2$ (C) $c_2 - t_1$ (D) $c_3 - t_1$.

Nevertheless, a printing performance close to the results shown for c_1 can be achieved even with a lower

concentration of LAP as shown for composition c_3 using $t_1 = 40$ s (Figure 2 D). This result demonstrates that it is important to balance the concentration of Orange G and the concentration of LAP.

IV. Conclusions

This short study demonstrates DLP 3D printing of PEGDA based material compositions using LAP as a photoinitiator and Orange G dye as a light absorber. The used material compositions could be promising for biomedical as well as tissue engineering application.

Printing performance and accuracy were investigated. The concentrations of LAP and Orange G and the light exposure time were all varied. It was shown that relatively low concentrations of LAP and Orange G are sufficient due to high absorbance of these agents and lead to the best 3D printing results with regard to the accuracy of the parts. However, a relatively long duration of light exposure per layer is needed for a satisfactory printing performance.

AUTHOR'S STATEMENT

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