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Tunable focal photopolymer lenses printed for the first time by laser-induced-forward transfer without a sacrificial layer

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The fabrication of polymeric lens arrays on flexible surfaces for its use in wide-field visual systems is a challenge that is being addressed by using the Laser Induced Forward Transfer (LIFT) technique. The objective is to achieve polymer laser printing by improving both the overall printing quality and the manufacturing time of these lens matrices compared to other techniques. Another challenge when using tunable polymers is the customization of tunable focal lenses dynamically controlling their optical properties. In this work we address both aspects by using a tunable photopolymer thanks to liquid crystal molecules, such as H-PDLC [1].

LIFT printing technique has recently been used to fabricate polymeric lens arrays/matrices [2] in processes that require intermediate steps to achieve lens fabrication, which slows down manufacturing time. Our goal is therefore to achieve one-step, adjustable printing. In this sense, in many cases, the polymer is not capable of absorbing the energy of the laser and, therefore, it cannot be ejected. That is why it is common to use an absorption layer (DRL, or dynamic release layer), exclusively metallic, which absorbs the laser energy and, when ejected, drives the polymer layer [3]. However, this DRL is usually a problem, since it can pollute with small particles of the ejected material on the printed polymeric material, as one can see when printing H-PDLC lenses with a drop diameter of 80 µm and a height of 2.2 µm (Fig. 1.a) by using a titanium layer few nanometers thick.

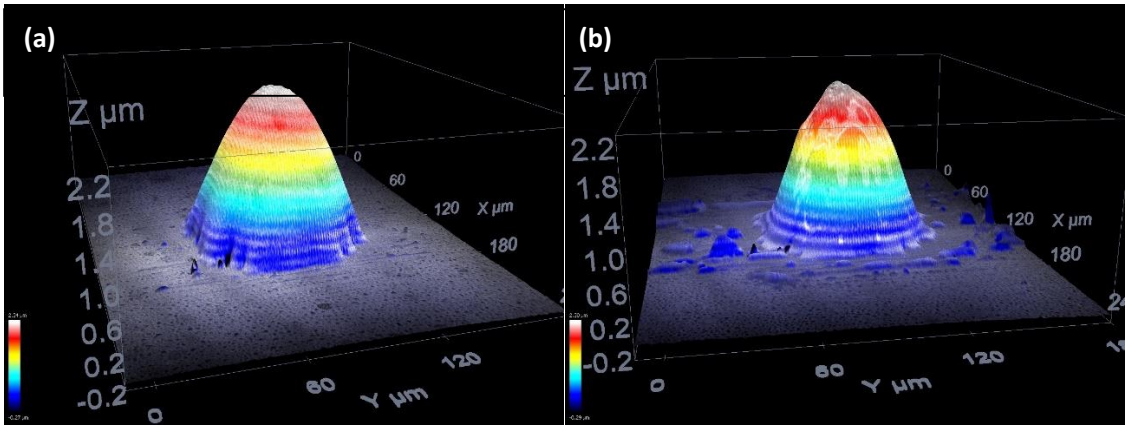

Figure 1: 3D topographic profile of a printed photopolymer drop with a distance (gap) between donor and recipient of 50 µm and a picosecond laser energy of 1.15 mW, before (a) and after (b) the photopolymerization process, taken with a confocal microscope by using a 50x objective.

As one can see in Figure 1.a, the titanium microparticles, originating from the DRL layer, are deposited

on the upper part of the lens, which affects its optical properties. Because titanium is highly absorbent, when illuminating the uncured material with a powerful source of white light to induce its photopolymerization, it increases the temperature producing unwanted material melting, as one can see in the upper part of the lens in Figure 1.b but also partial evaporation of the polymer. This not only worsens the surface quality of the lens, but also affects its optical performance.
In this sense, it is ideal to refrain from the use of such a DRL layer, which is why we have investigated the irradiation parameters (fluence, donor-receptor distance, donor thickness, and pulse duration) and the absorption properties of the polymer, to achieve propelling without the need for a sacrificial coating. For this we used a LIFT system with a laser of 1030 nm, a pulse duration between 250 fs and 10 ps, at max. power of 5W, and a frequency between single pulse and 1 MHz.
In this study, it was possible to print for the first time a low absorbency photopolymer without using an absorbent, sacrificial layer (DRL) (Fig. 2). It was necessary to use pulse durations of femtoseconds to eject the material. In addition, the power window is very small (90mW), as slightly higher power generates a splashing process that stains the surface. Likewise, the range of thicknesses of the polymer layer is very small, since thicknesses greater than 10 µm can no longer be displaced even at high power. In addition, the distance between recipient and donor substrates should also be very small, because in the case of polymers, their high density and viscosity cause a cavitation bubble to form in the ejection process, but not an ink jet. Therefore, for the cavitation bubble to impact the receptor, we need to set the gap between them at 20 and 90 µm. Finally, it has been possible to print lenses on both on glass (Fig. 2a) and ITO slides (Fig. 2b). On glass, the lens is 10 µm in diameter and 400 nm in height, compared to 15 µm and 350 nm achieved on an ITO. This shows that the amount of material ejected is approximately the same in both cases and that only the adhesion of the material to the surface results in a more spherical profile in the case of the ITO sample.

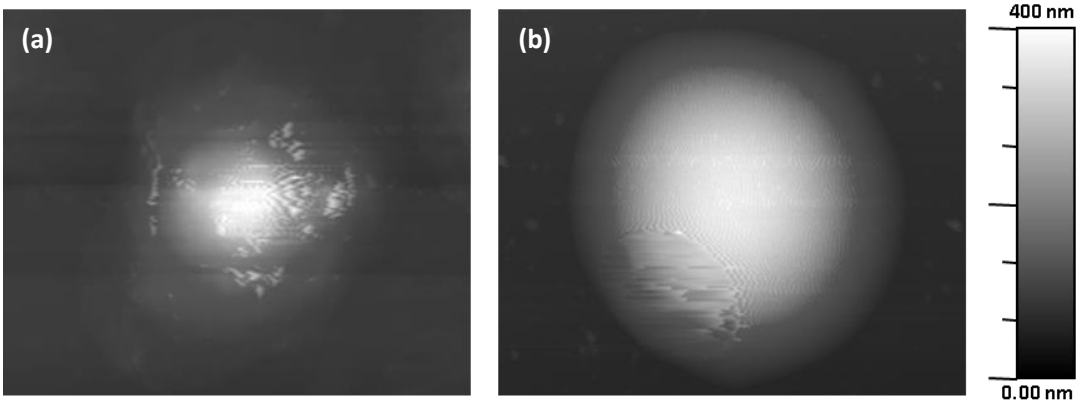

Figure 2: Images of the topographic profile of the polymer droplets deposited on a glass sample holder using a separation gap of 75 µm and power of 90 mW (a) and on a sample holder with ITO with conditions of a Gap 60 µm and power of 90 mW (b) obtained with an atomic force microscope.

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