Simultaneous patterning and deposition of thin films via femtosecond laser-induced transfer using a digital micromirror device for spatial pulse shaping

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The laser-induced forward transfer (LIFT) of thin films is a versatile technique to deposit materials on a size scale that can span nanometres to millimetres. During LIFT, the energy of a laser pulse is absorbed in a small volume of a thin film to be transferred (*donor*) or in an auxiliary layer (*dynamic release layer*) causing an explosive expansion which is used to propel a portion of the donor away from the transparent *carrier* substrate and transfer it as a deposit onto a *receiver* substrate as shown in Fig. 1(a). Ultrashort laser pulses, as used here, can limit laser damage that is usually present using longer pulses, e.g. nanosecond pulses, to remaining areas of the donor.

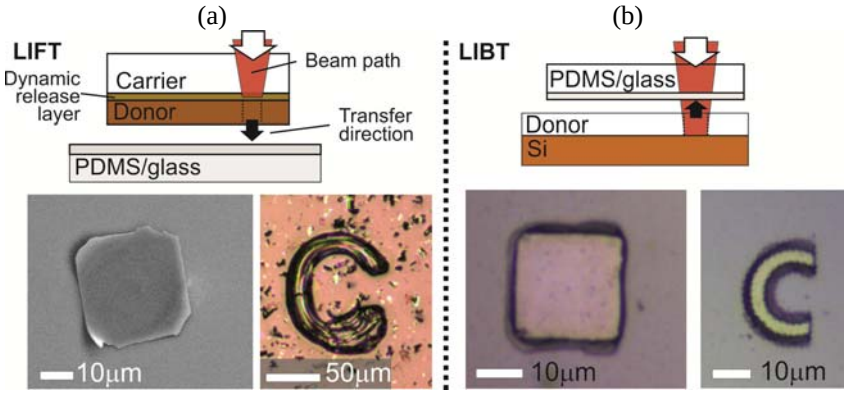

Fig. 1 Experimental schematic (top) and microscope images (bottom) of resulting polymer deposits on receiver substrates for (a) LIFT and (b) LIBT configurations.

Recently, the use of a spatial light modulator (digital micromirror device, or DMD) acting as an object mask to dynamically modify the intensity spatial profile of the laser pulses used for LIFT has shown that shaped deposits of materials such as pastes and solid films can be successfully printed and this further increases the versatility and speed of laser-induced transfer for direct-write applications [1,2].

In this work, DMD-based LIFT was complemented by laser-induced backward transfer (LIBT) [3] of solid polymer donors. In LIBT, the transparent receiver is situated in the beam path to allow for the donor-side illumination of the donor-carrier sandwich as depicted in Fig. 1(b). For transparent donors as used here, the laser energy is absorbed in a small volume at the carrier surface and causes a transfer in the opposite direction to that of the incident laser pulse.

In this parametric study, the reproducibility, resolution and positioning accuracy of LIFT and LIBT of polymers and inorganic semiconductors were compared. Furthermore, the creation of debris and the expected superficial damage to the deposit was investigated. For all these experiments, pulses with 150fs duration, 800nm central wavelength and maximum pulse energy of 1mJ were used, which were homogenised, directed onto a DMD acting as a dynamic object mask, and imaged at the donor-carrier interface. The receivers were polymer-coated glass substrates and were in contact with the donors, which consisted of ~1µm thick films of silicon, bismuth telluride, poly (methyl methacrylate) and cured S1800 resists coated onto glass for LIFT, and coated onto silicon for LIBT. As shown in Fig. 1(a) and Fig. 1(b), we have successfully transferred intact deposits from the polymer donors in particular, which showed good adhesion to the receiver.

In summary, we have demonstrated DMD-assisted LIBT as an addition to DMD-assisted LIFT permitting the intact transfer of transparent polymeric donor films onto polymer-coated substrates. LIBT is presented here for the first time with deposits in an intact state and from a solid donor, using a dynamic object mask in the form of a DMD. It is believed that the LIBT of such polymers can be used complementarily to LIFT, in areas of additive manufacturing which may include the fabrication of optical structures such as waveguides.

References

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