High Resolution Single-Pulse Multiphoton Polymerisation using a Digital Multimirror Device

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There is considerable interest in the use of digital multimirror devices (DMDs) for laser-based machining, and recent work has demonstrated step-and-repeat ablation patterning with ~400nm writing resolution [1], with proposed applications in photonics and the medical sciences. DMD-based laser-machining can be a high resolution (sub-micron), rapid (1cm by 1cm per hour is predicted) and flexible technique that is proposed to offer an alternative approach to existing focussed ion beam and lithography-based fabrication, which while offering higher resolution are considerably slower .

Here, we demonstrate the capability for rapid DMD-based multiphoton polymerisation (MPP). As MPP is a nonlinear threshold process, the polymerised region is generally some fraction of the size of the focussed spot, hence enabling sub-100nm writing resolution [2]. However, a significant disadvantage of this approach is the time required, due to the small interaction volume. Through use of a DMD to spatially shape the intensity profile of the incident laser pulse, we have been able to demonstrate a significant increase in speed, at the price of only a small loss in writing resolution. DMD-based MPP generally has the advantage over liquid-crystal spatial-light-modulator based approaches, such as [3], in both cost and switching speed.

Here, we show improvements over results recently demonstrated by Li et. al. [4] (which show fabrication times on the order of seconds to minutes) and present results obtained via single ultrashort laser pulses. The laser system used for this work produces 1mJ, 150fs pulses, of wavelength 800nm and at a repetition rate of 1kHz. The incident pulses are spatially shaped by the DMD (which effectively acts as a binary intensity mask with a resolution of 608 by 684) and imaged by a 50x objective to a region approximately 30 by 30μm inside the polymer. The photopolymer used here is an organic-inorganic hybrid material containing silicon and zirconium alkoxides [5].

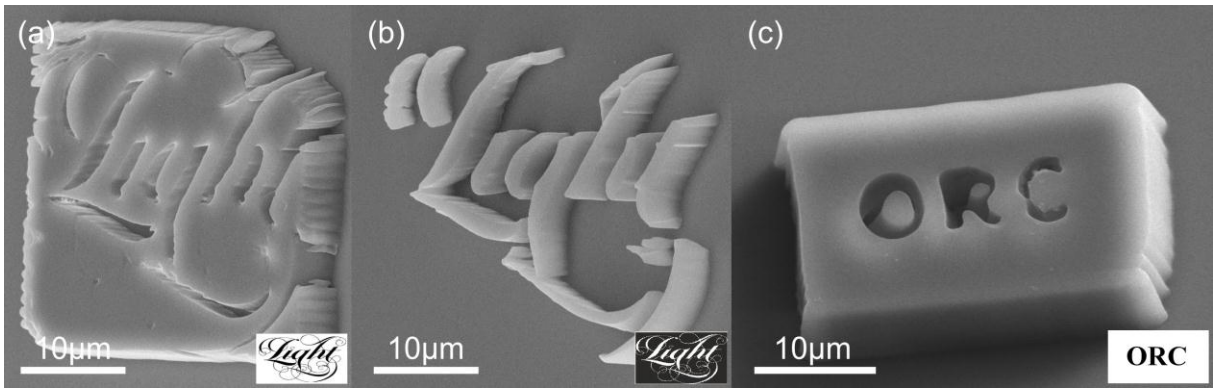

Fig. 1 SEM images showing a-b) ten pulse fabrication and c) single pulse fabrication of glass micro-structures.

Figure 1 shows SEM images of structures that have been fabricated using a-b) ten laser pulses and c) just a single laser pulse. All structures have a height of ~5μm, corresponding to the thickness of the resist. In each case, the inset shows the binary mirror that was displayed on the DMD. We will discuss the limits of this approach and present our latest work on contiguous patterning of ~1mm sized regions (where individual patterns have been stitched together).

References

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