Surface microstructuring by laser-induced backside wet etching

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A new groove-microfabrication technique of silica glass employs deposition of laser energy onto a thin layer at the glass-liquid interface. High-precision surface microfabrication of optically transparent materials, such as silica or (more generally) silicate glass, is crucial to structure the microfluidic channels used in lab-on-a-chip and µ-TAS (micro total analysis systems), as well as for microoptics in photonics research and development. However, glass is a hard and brittle material, and precision surface microfabrication is very difficult. Laser-etching techniques, and in particular laser-induced backside wet etching (LIBWE), are therefore useful alternatives. LIBWE deposits laser energy onto a thin layer at the glass-liquid interface during liquid ablation. Assuming negligible UV absorption, the incident laser beam passes through the glass plate, resulting in the excitation of a dye or organic solution. If the latter—which usually strongly absorbs at the light source’s operating wavelength—becomes ablated by laser irradiation of sufficient fluence, etching on the silica-glass surface layer is achieved.1–4

We used a diode-pumped solid-state (DPSS) UV laser at 266 and 355nm: see Figure 1(a).5,6 As single-mode DPSS lasers possess excellent beam quality, as well as high pulse-repetition rates (5–100kHz), the laser beam (characterized by a small laser-spot size at a high repetition rate) is readily available in ambient-air conditions and can be focused with a simple lens. These lasers can therefore handle surface microfabrication on material substrates reliably, rapidly, easily, and at high throughput. Up to a repetition rate of 100kHz, LIBWE works under optimized laser conditions. Figure 1(b) shows a good response of pressure signals to laser irradiation at 100kHz, achieved in 45.5s.7

Figures 1(c) and 1(d) show that well-defined etching grooves of various cross-sectional shapes (free of debris and microcracks around the channels) were fabricated by UV laser irradiation at 266 and 355nm. Laser irradiation was performed at a repetition rate of 5kHz and a scan speed of 50mm/s: see Figure 1(d). The organic solution used for the laser absorber was pyrene in toluene solvent at a dye concentration of 0.4mol/dm³. The flexibility of the cross-sectional channel shapes is owing to the laser’s direct-writing (patterning) capability.

Application of LIBWE using a variety of conventional laser sources under optimized conditions, based on indirect excitation, has led to the microfabrication of new and advanced optical materials. Excimer laser-mask projection systems,1,3 as well as galvanometer-based point-scanning DPSS lasers,5,6 have been employed. Projection using diffractive gray-tone phase masks, two-beam interference with a relevant phase mask, and demagnifying Schwarzschild objectives have also been effective for surface micro- and nanostructuring. The technical challenges are

Continued on next page
particularly significant on these scales, but recent developments have made the new frontiers both alluring and reachable. These are mature and versatile methods that offer a number of key benefits with respect to other more established microfabrication techniques.

As microstructures can be fabricated through laser-induced patterning methods, flexible rapid manufacturing without the need for photolithography will be developed as an efficient, practical tool because of cost and reliability considerations. The techniques are particularly well suited for rapid prototyping and concept optimization, and during the production-development stage of a functional device to reduce development time. This approach also has the potential to be scaled up for large-area or mass production. It is especially useful for rapid fabrication of small- and medium-sized orders in the early stages of specific applications. The manufacturing systems can be compact. They will fit on an optical bench because of their small footprint, so that they will be suitable for practical use.

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