LASER SURFACE-TREATED GLASS WITH WICKING CAPABILITY FOR MICROFLUIDICS

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ABSTRACT

This work presents a novel platform for microfluidics which features laser-defined wicking traces that impart rapid passive transport capabilities onto glass substrates. The platform consists of micro channels created by locally fracturing the surface of glass via laser etching. Channels with dimensions 500 µm × 10 mm were fabricated and shown to exhibit wicking and mixing capabilities. SEM and optical microscope images revealed the micro-cracks responsible for the wicking action. The wicking speed of an aqueous solution was found to depend on laser machining parameters (power and speed); with optimized parameters, a maximum wicking speed of 32 mm/s was observed.

KEYWORDS: glass, laser machining, hygroscopic, wicking, microfluidics

INTRODUCTION

Glass has been extensively used in the fabrication of microfluidic and other biomedical lab-on-a-chip devices [1], [2]. This has been due to its optical transparency, rigidity, bio-compatibility, and ease of surface modification/functionalization. Recent research, however, has been focused on lower-cost, flexible substrates such as paper [3], whose remarkable inherent wicking property has allowed the realization of a variety of analytical microsystem [4]–[6]. Wicking, in particular, offers the advantage of passive liquid transport [7], [8] without the need for a micropump, thus significantly reducing the system complexity and cost. Imparting such capability (i.e., wicking) to glass would allow for a unique platform that combines the reliability and established surface chemistry of glass with the passive fluidic transport property of paper.

As a first step towards this goal, we have developed a laser surface-treated method to fabricate wicking glass. The technique consists of creating micro channels by fracturing the surface of the glass via laser etching. The process imparts high energy bursts onto the glass surface, causing thermal shock at the lasing locations. This results in localized cracking of the glass and generation of micro-crevices/cracks that produce capillary action to enable wicking, as illustrated in Figure 1.

EXPERIMENTAL

The fabrication process of the wicking glass platform is straightforward and economical, Figure 2. First, a microfluidic design is created in vector graphics software and loaded onto a commercial CO_2 laser engraver system (PLS6MW, Universal Laser Systems, Inc., Scottsdale, AZ). The system then inscribes the pattern on a standard soda lime glass slide (GOLD SEAL® Micro Slide), producing cracked glass

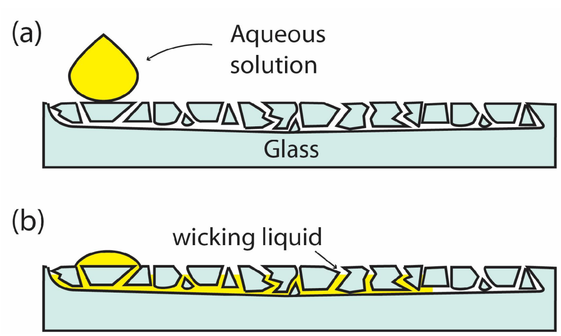

Figure 1: Cross-sectional schematic of the laser-machined wicking glass structure showing its wicking mechanism. (a) An aqueous solution

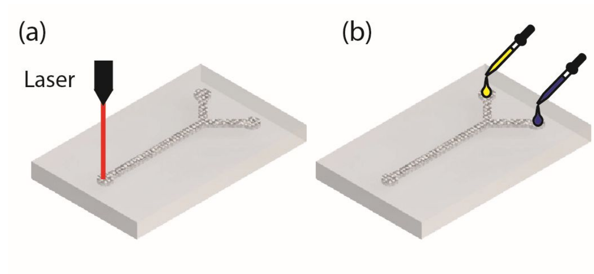

Figure 2: Fabrication process of the wicking glass. (a) Create design in CAD software and laser-ablate design onto a glass slide. (b) Deposit liquid(s) on surface.

microchannels on the surface. The channel geometries and resolution are limited only by the spot size of the laser.

The wicking capability of the glass platform was evaluated in terms of the maximum wicking speed of an aqueous solution in a channel. To achieve this, channels with dimensions 500 µm wide × 10 mm long were created on a glass slide using a commercial laser engraving system set to various laser power (15−75 W) and speed (0.8−4 mm/ms) settings. The time required for a 1 µL droplet of dyed water to propagate the length of the channel was then measured using a stopwatch.

RESULTS AND DISCUSSION

Figure 3 shows photographs of a wicking glass Y-junction channel created by laser machining. The macroscopic photograph in Figure 3a shows the clear definition of the laser-ablated areas. Figure 3b is a magnified view of the wicking region; the photograph reveals a multitude of thin (~ 10 µm) sub-surface, micro-crevices branching off the larger cracks. The crevices are sufficiently small to provide strong capillary force-driven flow. Figure 3c shows two liquid dyes wicking through the glass and mixing at the Y-junction; the broken glass structure of the device splits the two dyes into many interlacing streams for increased diffusion and mixing.

Figure 4a further elucidates the architecture of the wicking glass with an SEM image of the glass surface. A notable feature evident in this image is the straight boundary along the length of the channel (top edge), allowing accurate liquid guiding; here, the cracked morphology is constrained to only the regions exposed to laser, without causing propagating fractures outside of this domain. Figure 4b is a magnified view of the surface and confirms the existence of micro-crevices as small as 2 µm wide.

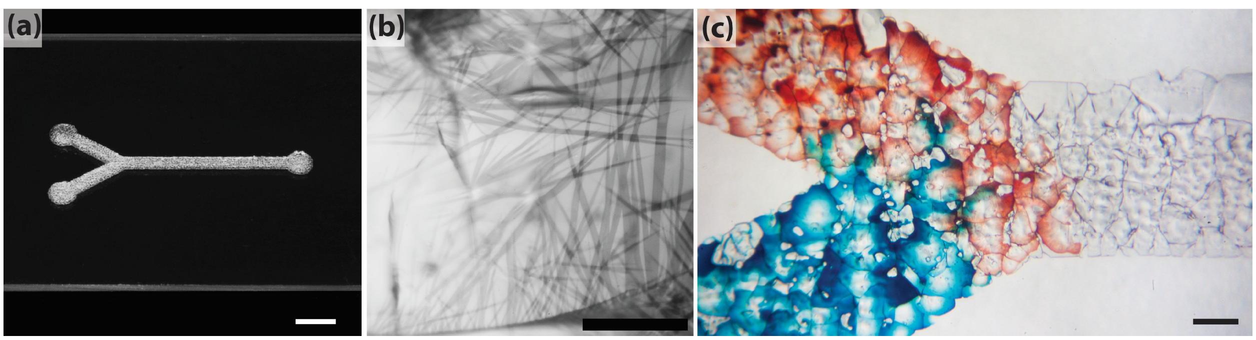

Figure 3: (a) Photograph of a laser-defined Y-junction microchannel on a glass slide [Scale bar: 3 mm]. (b) Magnified view showing the glass micro-cracks/capillaries branching off major fractures [Scale bar: 50 µm]. (c) Photo-microscopy of two colored dyes being wicked and mixed in the Y-junction device [Scale bar: 1 mm]

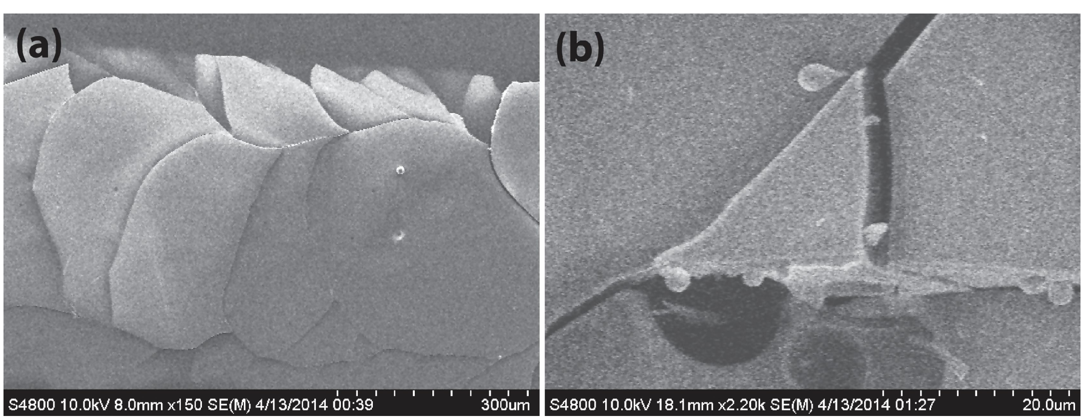

Figure 4: (a) SEM of glass morphology created by laser ablation. (b) Magnified view of the fracture details. The cracks promote capillary flow for wicking action.

The results of the wicking velocity characterization experiments are plotted in Figure 5, as a function of two laser system parameters: power and processing (raster) speed. The data show that high laser power (e.g., > 30 W) generally leads to higher velocities, whereas lower power results in reduced wicking velocities that are inversely proportional to the laser processing speed. By adjusting these parameters, we were able to attain various water wicking velocities from negligible up to 32 mm/s. This value is significantly faster than the typical wicking speed of water in filter paper (about 2 mm/s) [9], which is known to be a very absorbent fiber network. Our wicking glass, therefore, extends the functionality of glass to enable rapid passive transport of aqueous solutions at tunable speeds for lab-on-a-chip applications.

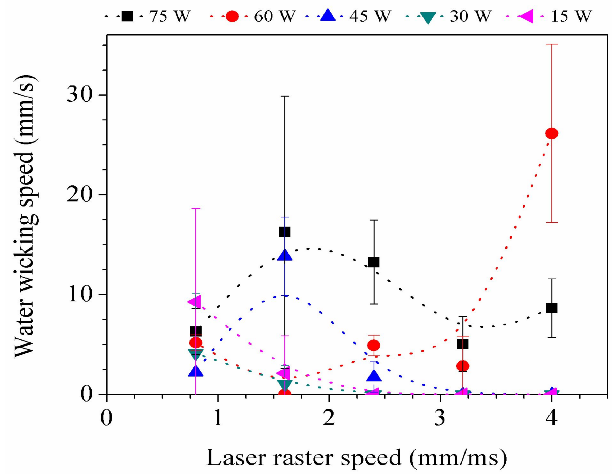

Figure 5: Wicking speed (mm/s) of water as a function of laser power and speed settings. High power settings result in faster wicking. The maximum speed among all samples tested was 32 mm/s.

CONCLUSION

We developed a method for creating glass microfluidics with rapid wicking behavior using surface laser machining. Laser pulses create localized fractures on a glass substrate, resulting in a network of micro-cracks in the form of a pre-designed pattern. The cracks produce a wicking action in the traces comprising the pattern, allowing aqueous solutions to travel at various velocities of up to 32 mm/s. Hence, the wicking glass platform is a hybrid-function structure which combines the passive transport properties of paper with the established chemical/fabrication advantages.

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