Laser-manufactured microfluidic devices for the study of mechanisms governing transport in porous media

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Microfluidic devices in geological and petroleum engineering research have found use as micromodels to investigate mechanisms governing transport in porous media. These micromodels comprise structures of interconnected pores whose shape and arrangement are designed in such a way to represent simplified versions of internal porous structures of geomaterials, e.g. hydrocarbon-bearing rocks.
Pore network structures can be manufactured on the surface of different materials, such as photoresist, PDMS, PMMA, glass or silicon [1]. These structures can be generated in different ways, but typically via a complex, multi-step process that involves a combination of photolithography and etching, requiring the use of specialised equipment, different masks, chemicals, and a clean room. The structures are enclosed from the top by using a transparent plate (made of either polymer or glass) in order to confine flow of fluids only to the area of pores and microchannels, whilst providing optical access, thereby enabling the direct observation and visualisation of fluids inside the structures. Different bonding methods are used dependent on the materials used, e.g. "thermal fusion" for joining glasses and polymers, whilst "anodic bonding" for joining glass to silicon [2]. All these methods, however, are time consuming and require very clean and flat surfaces.

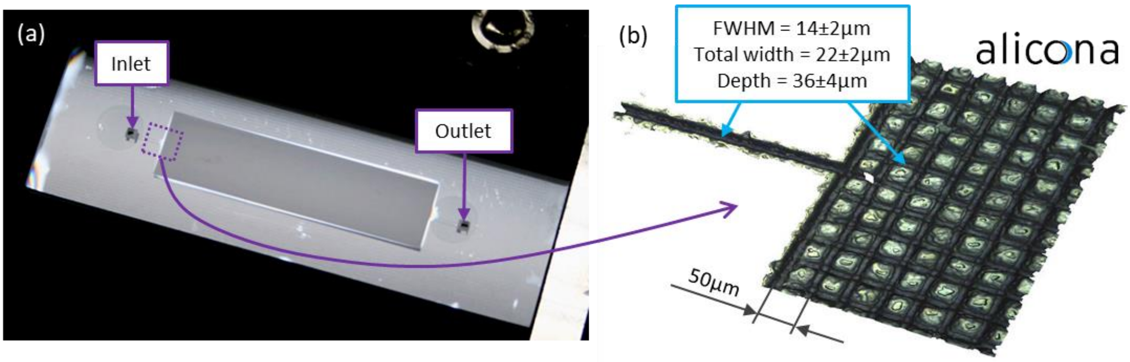

Figure 1: Enclosed microfluidic device manufactured using a picosecond laser: (a) photograph and (b) 3D surface profile of microchannels.

This paper presents a laser-based process that enables rapid manufacturing of enclosed porous structures using borosilicate glass substrates [3]. Glass is a preferred host material over silicon and polymers because it is transparent and exhibits similar chemical reactivity to real geomaterials. The process uses a single picosecond laser (Trumpf TruMicro 5x50) both for the generation of microstructures directly on glass (by laser ablation [4]) and for the enclosing of the microstructures from the top with another glass plate (by laser micro-welding [5]). Figure 1 (a) shows a micro-fluidic device that was fabricated from two 75mm × 25mm × 1.1mm thick glass plates. The device contains a grid of micro-channels spaced by 50µm, as shown in Figure 1 (b). Each channel within the grid is 14±2µm wide (FWHM) and 36±4µm deep. Two ports (inlet and outlet) enable the injection of fluids to the grid. Fluid flow tests performed for the laser-generated microfluidic devices will be presented during this talk.
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