Microfluidic devices produced by micromachining with ultra-short laser pulses

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Abstract: *Complete microfluidic systems are being produced by ultra-short laser pulses machining in BK7 optical glass. Small structures have been developed to form various components of a microfluidic circuit, such as microchannels, micro-valves and microreactors. The flow of the reactants is controlled by an external pneumatic system together with microvalves incorporated in the circuits. A program in Labview enables complete control of processes.*

Key-Words: *Femtosecond laser; micromachining; laser machining.*

Introduction: The processing of materials with ultra-short laser pulses (in the order of 10^{-13} to 10^{-14} s) has been developed in the Center of Lasers and Applications both for the understanding of the interaction physics of this type of laser[1] with the matter as for its use in practical applications. Unlike other types of lasers, ultra-short pulses can process structures virtually free of thermal effects. This enables the machining of extremely small structures without burrs, resolidified material or heat affected zone. Using such technique very tiny structures has been produced on several kinds of materials such as glasses, metals and polymers.

The glass processing with this type of laser has been used mainly for the production of components for microfluidic circuits[2]. Micro channels[3], micro reactors, valves and micro pumps are some of the regularly produced components at IPEN. With them, several complete microfluidic circuits were produced, including the injection and control systems. The main circuits already in operation are being used for ELISA assay (Enzyme Linked Immuno Sorbent Assay), for the growth of luminescent nanocrystals and for the control of size and shape of metallic nanoparticles[4].

Experimental: The experiment was conducted with an amplified Ti: Sapphire laser system (Femtopower Compact Pro EC-Phase HP/HR, from Femtolasers) with emission centered at 785 nm, bandwidth of 37 nm, linearly polarized in the horizontal direction (Y-axis) and maximum repetition rate of 4 kHz.

The laser beam is focused on the sample surface and the focal point is swept by a system with translator stages in two dimensions and accuracy of 1 micron. The process parameters were optimized in order to obtain the highest efficiency in the removal of the material, the better finishing of the machined surfaces while maintaining the integrity of the material in the processed region. The process parameters were: Energy per pulse of 100 µJ; pulsewidth of 150 fs, pulse overlap rate N = 4. This overlap of pulses is given by the ratio of the speed of beam displacement, the focal point diameter and the laser repetition rate. Figure 1shows the background of the machined BK7 with these parameters and the 3D image of a machined microchannel.

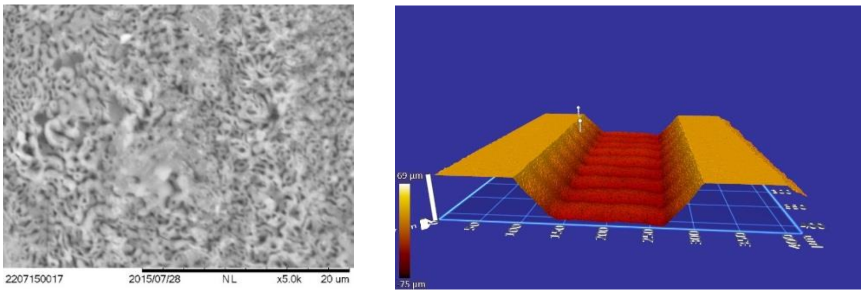

Figure 1 SEM image of channel bottom with optimized parameters (left); 3D microchannel profile (right)

Microchannels can be produced with widths greater than ~ 10 µm and wall slope of ~ 75 °. An arrangement of channels and other structures machined on the surface of a glass plate BK7 form the circuit according to the predetermined drawing. Its closure is made with a thin sheet of PDMS, which is pressed onto the machined set with another glass plate. In the assembly of the circuits, the microchannels are interrupted by a section of approximately 100 µm not machined. At this point, a relief aperture is machined on the surface of the closure plate, and a microchannel connects this aperture with a source of compressed air. When the pressure in the top plate is greater than the supply pressure of the reactant liquid, the flow is stopped, when this pressure is withdrawn, the pressure in the liquid is controlled to enable it to raise the PDMS film and the liquid can flow. Thus, a flow opening or closing microvalve is created at this point. The figure below shows the pressure feed assembly of the microfluidic circuits.

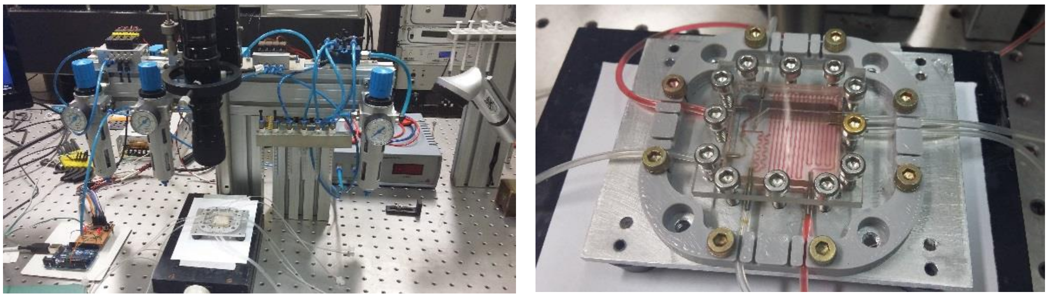

Figure 2 Pneumatic flow control system (left); circuit for growth of luminescent nanocrystals (right)

The control of the pressure on the microvalve is made by means of 3-way pneumatic mini-valves connected to them. The Labview software supplies and determines the operating mode of these mini valves according to the desired process. With this Flow Feed System it was possible to control flow rates up to 0,5 µl /s.

Conclusion: The micro-machining of BK7 optical glass with ultrashort laser pulses has enabled the production of basic components for the production of complex microfluidic circuits. The incorporation of a pneumatic feeding system allowed the control of reagent flows in order to allow controlled reactions to be performed in microreactors. Three circuits are already in operation: one for ELISA assay, another for the growth of luminescent nanocrystals and other for the control of size and shape of metallic nanoparticles.

References and acknowledgements:

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