All-in-One Chip Fabrication by 3D Femtosecond Laser Microprocessing for Biophotonics

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Nowadays, a microchip, so called, a lab-on-a-chip device, is getting common tools for chemical analysis, medical inspection, genomic and proteomic science, and drug-discovery research, etc. Simple devices have been already realized, and then development of "all-in-one" microchips in which the microfluidics, micromechanics and microdetector systems are integrated in a single chip is inevitable for the next generation. However, the integration of such microcomponents using today's technology, based on semiconductor processing including photolithography, alignment, assembly, and packing processes, faces great challenges because of the huge amount of the labor spent on the manufacturing. Therefore, it is preferable to develop a new technique by which the integration of the microcomponents can be completed in a single procedure. Femtoseond (fs) laser micromachining becomes a good choice for three-dimensional (3D) integration due to its ability of forming internal structures in transparent materials. In recent years, we demonstrated a rapid prototyping of 3D hollow microstructures buried in glasses by fs laser micromachining [1-8]. The glass used in this work is a commercially available photosensitive glass "Foturan" from Schott Glass Corporation. The fabrication procedure of 3D hollow microstructures consists of the following four steps; (1) 3D fs laser direct writing to induce photochemical reaction at the focal points, (2) thermal treatment to develop the modified regions, (3) wet chemical etching in a HF acid solution to selectively remove the modified regions, and (4) additional thermal treatment to smooth the etched surfaces. Currently, all of microfluidic components, micromechanical components, microoptical components, micro-optical fibers and microlaser systems can be easily fabricated in the glass by the present technique and these structures have been successfully integrated into a single glass chip to construct some functional devices. The biggest advantage of this technique is that any microcomponents can be fabricated in the glass by the single same procedure resulting in easy 3D integration of each microcomponents without any alignment, assembly, stacking and bonding processes

[1] M. Masuda, K. Sugioka, Y. Cheng, N. Aoki, M. Kawachi, K. Shihoyama, K. Toyoda, H. Helvajian, and K. Midorikawa, "3-D microstructuring inside photosensitive glass by femtosecond laser excitation", Appl. Phys. A**76**, 875-1530 (2003)
[2] Y. Cheng, K. Sugioka, K. Midorikawa, M. Masuda, K. Toyoda, M. Kawachi, and K. Shihoyama, "Control of the cross-sectional shape of a hollow microchannel embedded in photostructurable glass by use of a femtosecond laser", Opt. Lett. **28**, 55-57 (2003)
[3] Y. Cheng, K. Sugioka, K. Midorikawa, M. Masuda, K. Toyoda, M. Kawachi, and K. Shihoyama, "Three-dimensional micro-optical components embedded in photosensitive glass by a femtosecond laser", Opt. Lett. **28**, 1144-1146 (2003)
[4] K. Sugioka, M. Masuda, T. Hongo, Y. Cheng, K. Shihoyama, and K. Midorikawa, "Three-dimensional microfluidic structure embedded in photostructurable glass by femtosecond laser for lab-on-chip application", Appl. Phys. A**79**, 8515-817 (2004)
[5] Y. Cheng, K. Sugioka, and K. Midorikawa, "Microfluidic laser embedded in glass by three-dimensional femtosecond laser microprocessing", Opt. Lett. **29**, 2007-2007 (2004)
[6] T. Hongo, K. Sugioka, H. Niino, Y. Cheng, M. Masuda, J. Miyamoto, H. Takai, and K. Midorikawa, "Investigation of modification mechanism of photosensitive glass by femtosecond laser", J. Appl. Phys. **97**, 063517 (2005)
[7] K. Sugioka, T. Hongo, H. Takai, and Katsumi Midorikawa, "Selective metallization of internal walls of hollow structures inside glass using femtosecond laser", Appl. Phys. Lett. (in press).
[8] K. Sugioka, Y. Cheng, and K. Midorikawa, "Three-dimensional micromachining of glass using femtosecond laser for lab-on-a-chip device manufacture", Appl. Phys. A (in press).