Optical inspection of microchannels formed by femtosecond laser on glass

Victor P. Bessmeltsev, Evgeny D. Bulushev, Alexander V. Dostovalov
Institute of Automation and Electrometry SB RAS, Novosibirsk, Russia
e.d.bulushev@gmail.com

Abstract—The aim of the research was to provide precise inspection of surface of optically transparent materials micromachined by a femtosecond laser. We found that despite the fact that pulse durations are in a femtosecond range in case of non optimal processing modes cleavages may be formed at the border of heat affected zone, and profiles of micro channel are not uniform. For measurement of micro channels the optical inspection technique based on fluorescent confocal laser scanning microscopy and data analysis algorithms was developed.

Keywords—confocal microscopy, fluorescence microscopy, femtosecond laser micromachining, image processing

Femtosecond laser micromachining is a promising technique for modifying optically transparent dielectrics with minimal thermal effect on surrounding substance. To fabricate micro structures based on CAD-model on the surface of glass (e.g. micro channels) with the required characteristics, minimal cleavages and cracks it is necessary to determine the optimal machining mode. For this purpose series of test (10-30) objects are usually formed with different machining modes, qualitative characteristics are measured and a statistical model is constructed (e.g. [1]). In our case roughness of boarders and deviations of depth and width from the desired values were chosen as the qualitative characteristics of micro channels. Ten test objects (example on Fig. 1) were formed by femtosecond laser at different machining modes; it was shown that average roughness of boarders achieves 1-2 μm, width and depth vary correspondingly in ranges of 5-7 μm and 0.5-3 μm. Such high value of roughness is caused undesired cleavages of material.

![Fig. 1. Test object (100×100 μm) and it’s magnification (Leica DMIRB 40x)](image)

The purpose of this work was to develop a method for fast (1-5 min.) inspection of micro channels formed on surface of optically transparent material by femtosecond laser pulses in volume up to 10×10×0.1 mm³. For precise measurement of profiles of such objects we proposed to use methods of confocal laser scanning microscopy. However, when measuring in reflection mode, the interference of scanning laser beam on a rough surface causes errors in measured data, and greatly reduces accuracy.

To improve the accuracy of measuring of high local slopes and to remove interference effects we pre-covered the surface with a thin layer of fluorophore (< 1 μm). The emission of solution of fluorescein in alcohol (5 mg/ml) is registered in spectral range of 490-700 nm, excitation wavelength is 488 nm. An algorithm for reconstructing of 3D surface from optical sections with subpixel accuracy was developed, based on center mass algorithm; depth is calculated using samples of axial response curve that have signal higher than 20% of maximum intensity of curve. Fig. 2 depicts the reconstructed surface and two profiles, shifted by 0.5 μm in the direction of channel. Profiles indicate that cleavages were formed and profile is not uniform. For extraction of qualitative characteristics of micro channels from reconstructed surface the algorithm based on [2] was developed.

![Fig. 2. Reconstructed surface and it’s profiles](image)

REFERENCES
