Laser manufacturing of microsieves for bioengineering applications

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Abstract—Laser drilling is a noncontact technology which allows high flexibility and full automation of the process. The present research aimed at developing laser technology for manufacturing microsieves in thin Ni and Al foils. Involute and square distributions of holes were formed with an overall dimension of 3mm. The distance between adjacent holes was 25μm to 100μm, which meant fabricating up to 10,000 openings per microsieve. Owing to the optimisation of optical system design and laser micromachining system parameters, holes with a desired diameter of around 12μm were fabricated, limited only by the diffraction divergence of a laser beam.

Matrices of microholes (microsieves), fabricated using different materials, such as polymers, silicon and metals, are necessary in many technological applications, among others in microfluidic systems and filtration-separation techniques [1]. Simple processes of fast drilling of thousands of holes per cycle with low processing expenses are desired. The ideal tool in this case is a laser beam with a proper energy density and a high pulse repetition rate, operating without contact with the material in an easy-to-automate and fast process of position control [2].

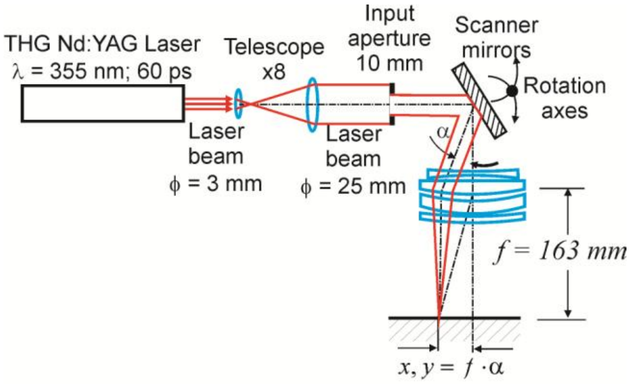


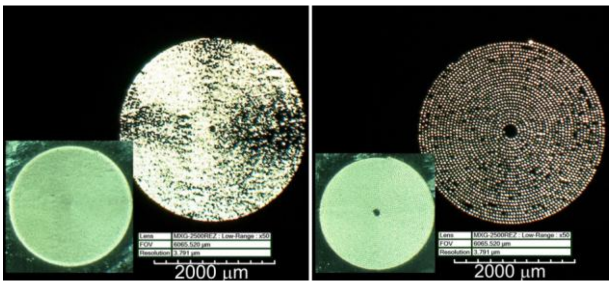
Fig. 1. Scheme of experimental arrangement.

Experiments were performed using picosecond Nd:YAG laser, emitting 60ps pulses with a repetition rate of 1kHz at a wavelength of 355nm (third harmonics), which was coupled to a galvanometric scanner, equipped with F-theta lens with a focal length of 163mm (Fig. 1). Kepler's telescope, expanding the laser beam to 25mm (8×) was inserted at the output of the laser head.

The system was limited by an input scanner aperture with a diameter of 10mm. The diffraction angle of laser beam divergence was around 6×10^{-5} radian, and the expected size of a spot at the focal plane should be around 12μm.

Samples of involute microsieves were perforated in an aluminium foil with a thickness of 7μm, using "on the fly" method [3] with different scanning velocities. Each hole was drilled with a single laser pulse. The diameters of fabricated holes were within the range of 5μm to 12μm. The distance between adjacent holes and variable scanning rate allowed manufacturing of different final microsieve transmission (porosity), which is shown by microscopic images in transmitted light in Fig. 2.

Low resolution images show correctly only the distances between the holes, but overestimate their diameters (Figs. 2-4). Even at a magnification of 350 the diameters are overestimated by 30% (Fig. 5). Valid measurements of diameters are obtained at magnifications at least 1000.



a) b)

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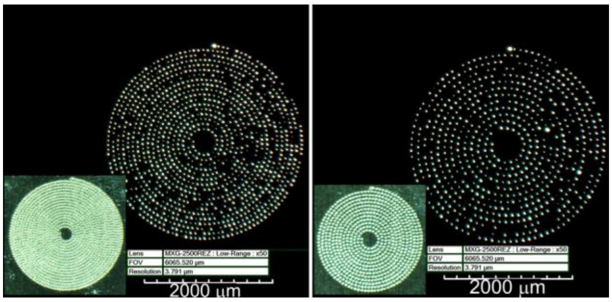

Fig. 2. Illustration of circular microsieves porosity control using a variable distance between adjacent holes in transmitted light: a) mean distance between holes 25µm: b) 50µm; c) 75µm; d) 100µm. Small left insets show microscopic images taken in reflected light.

The square sieves were fabricated using percussion drilling [4] with five laser shots per hole, in aluminium foils with a thickness of 50µm (Fig. 3).

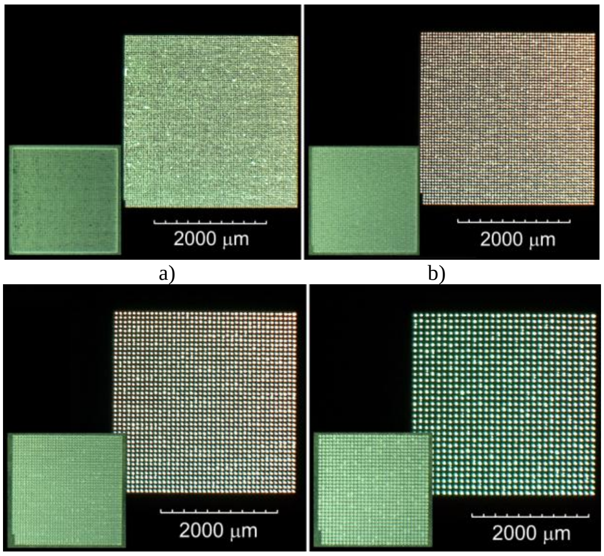

Fig. 3. Illustration of square microsieves porosity control using a variable distance between adjacent holes in transmitted light: a) mean distance between holes 25µm: b) 50µm; c) 75µm; d) 100µm. Small left insets show microscopic images taken in reflected light.

The tests of geometrical dimensions, transmissions and distributions of hole diameters were based on numerical analysis of digital images, performed by a 3D optical microscope KH8700 from Hirox Co Ltd, Japan. Exemplary results are shown in Figs. 4-6.

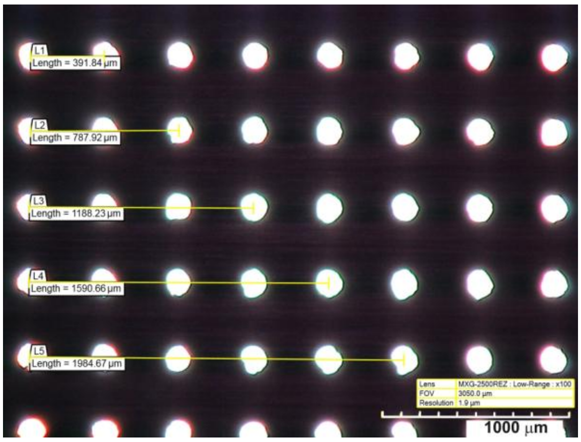

Fig. 4. Exemplary test of hole period repeatability.

A suitable selection of optical arrangements and parameters of picosecond laser system allowed the achievement of near to diffraction-limited dimensions of aluminium and nickel foil perforations. Practically, any of the hole diameters in both kinds of sieves did not exceed 15µm (Fig. 6).

The final transmission of optimised sieves with periods of 100, 75, 50 and 25µm was equal to 1%, 2.5%, 5% and 22%, respectively. Exceptionally short processing times of 1 second for sieves with 900 holes and below 10 seconds for sieves with 10,000 holes were obtained using techniques of "on the fly" laser drilling and percussion laser drilling. Fabricated microsieves will be used in the research on filters and microfluidic devices for bioengineering applications.

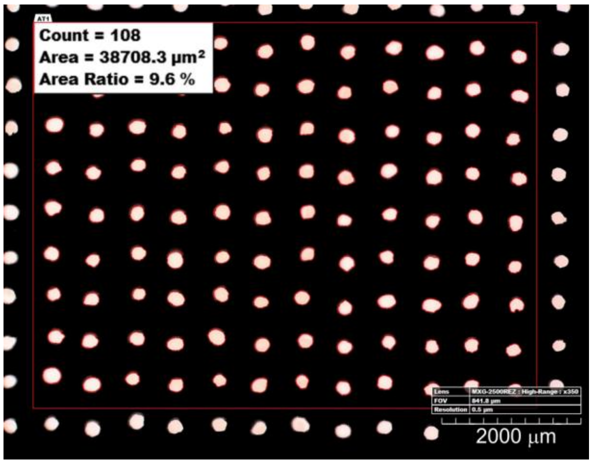

Fig. 5. Exemplary result of test of microsieve porosity. Areas inside red circles were counted.

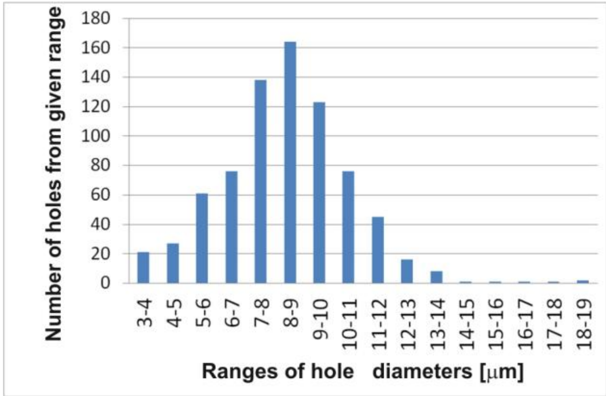

Fig. 6. Exemplary result of hole diameter distribution measurement.

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