

Measuring and Fabricating of Micro-Lens on Photosensitive Glass with UV Nanosecond Laser Pulse

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KEYWORDS: Photosensitive glass, Nanosecond pulse laser, Micro-Lens, Surface measurement

Abstract: The photosensitive glass has been widely used in optical field, for example machining micro-lens and directly fabricating circuit board, by its own advantages. In this paper an UV nanosecond pulse laser micro-machining system was designed because the FOTURAN photosensitive glass is sensitive to ultraviolet light. To get the appropriate machining parameters a large number of experiments were done and the results were analyzed. As an example, a bowl-shaped mould was fabricated with the diameter $664.58\mu\text{m}$ and the depth $135.41\mu\text{m}$ at the edge approximately by SEM imaging. So the convex lens can be molten with certain material. For characterizing the structure a measuring probe system was designed. The system was consisted of a three dimension moving table and a sensing probe based on tunneling effect. The measuring range of the system is 25mm by 25mm by 5mm at XYZ direction and resolution is 0.1nm. With the measuring system the bowl-shaped structure was measured and the results were analyzed.

Manuscript received: January XX, 2011 / Accepted: January XX, 2011

1. Introduction

The microlens is an important optical component in micro-nano system. The FOTURAN photosensitive glass is different from common optical glass with the doping of Ag^+ and Ce^{3+} . So they show not only the normal property but also some characteristics of metal. The photosensitive glass has been widely used in optical field, for example machining microlens and directly fabricating circuit board, by its own advantages¹⁻⁴.

The advantages of short pulse lasers, for example nanosecond lasers, are very promising for their future applications in precise material processing. As a result of wide applications in the optical material, there are considerable interests in the micromachining on photosensitive glass surface by nanosecond pulse laser⁵⁻⁷.

2. Experiment and results

2.1 Experimental setup

Experimental system included three parts, nanosecond laser micromachining system for the exposure, a programmable oven for the heat treatment, and the acid solution for the etching.

The nanosecond laser micromachining system consists of UV-laser and 3D programmable moving table. The laser is 355nm at wavelength, 100kHz at repetition frequency, 40ns at pulsewidth and

3W at average output power. The moving table is 200mm by 200mm by 100mm at XYZ direction and $1\mu\text{m}$ at resolution. To achieve the precise figuring it is necessary to investigate the interaction between pulse laser and material processed.

The programmable oven can heat the sample from room temperature up to 600 degree centigrade. It can flexibly adjust the slope of heating by changing its program.

The concentration of the acid solution is generally 10%. The etching time is very important to forming structure.

Fig.1 shows the micromachining system with nanosecond pulse laser.

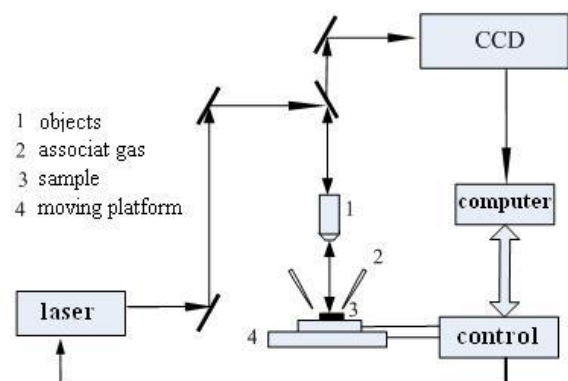


Fig.1 micromachining system schematic drawing

2.2 results and analysis

In the experiments, applied the nanosecond pulse laser micromachining system the samples were irradiated according to the pre-programmed moving track for planned structure. Exposed samples are heated up to 600°C, and then they were processed in the hydrofluoric acid at 4% concentration. Because the parts of exposure are faster etched than other parts, the desired structures were obtained. In our experiments it is found that would get a better effect to re-heat after eroded by acid. So the process of micromachining FOTURAN photosensitive glass is determined on irradiating, heating, eroding and re-heating. In the paper all of experiments were done according to the process above. The FOTURAN photosensitive glass samples are made by Mgt Mikroglas Technik AG, which have the properties of Li-Al-silicate.

The first experiment is to fabricate a deeper hole on the glass. A program is designed for controlling the fabricating trace while the laser irradiated. The designed diameter is 62.5μm and moving speed of the table is 3.75mm per minutes. The pulse energy of laser is 0.1mJ and the numbers of pulse is 100. Then heating the glass fabricated at certain rate up to 600°C, a circular structure of 74.7μm diameter is imaged by microscope. Fig. 2 is the image of the sample. The difference of diameters, designed 62.5μm and fabricated 74.7μm, is caused by the diameter of laser beam. Fig. 3 shows the sample topography with AFM instrument. The depth of the structure is over 5μm.

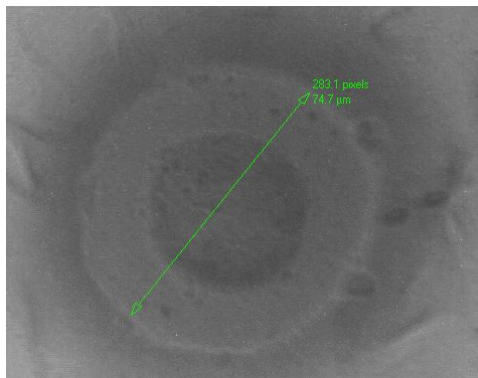


Fig. 2 Image of machining sample before eroded

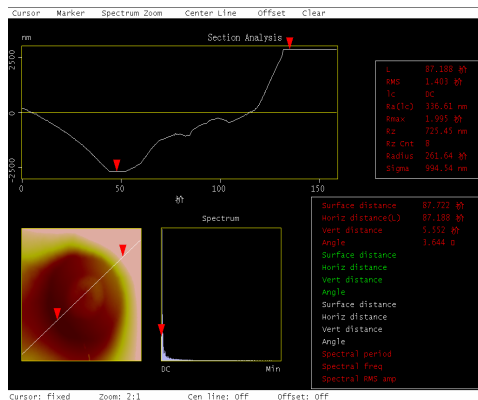


Fig. 3 AFM image of the sample before eroded

Eroding the sample fabricated with the hydrofluoric acid at 4% concentration, a deeper structure obtained with the depth up to 150μm. Fig. 4 shows the structure by SEM imaging. In the image no identifiable ejection is found. And the edge of the deep hole is clearer. This shows that good structure can be achieved with the process

while the correct parameters were selected.

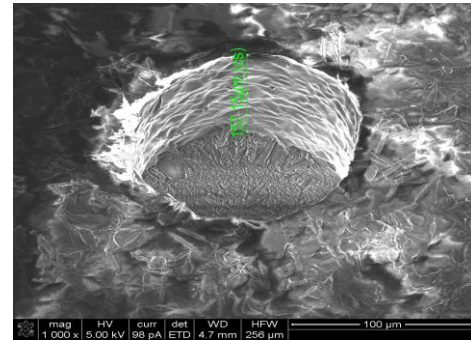


Fig. 4 SEM imaging after eroded

The second experiment is to fabricate a bowl-shape structure on the glass. The structure aimed to mold the micro-lens with relational device. So the topography of the bottom of the sample fabricated is important to mold. It is determined by laser parameters, heating and eroding process. The laser parameters include pulse energy and numbers of pulse, etc. In our experiments the parameters were studied and tested in detail for many times. In final the better parameters were found and applied to fabricate the structure. Fig. 5 and fig. 6 show the bowl-shape structure fabricated at certain parameters. The moving speed of table is 6mm per minutes. The pulse energy of laser changes linearly from 0.1mJ for center to 0.045mJ for edge. Fig. 7 shows the curve of pulse energy of laser changing relative to the position of sample fabricated.

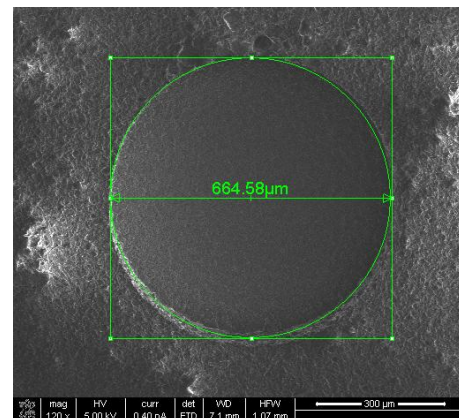


Fig. 5 top view of sample fabricated with SEM imaging

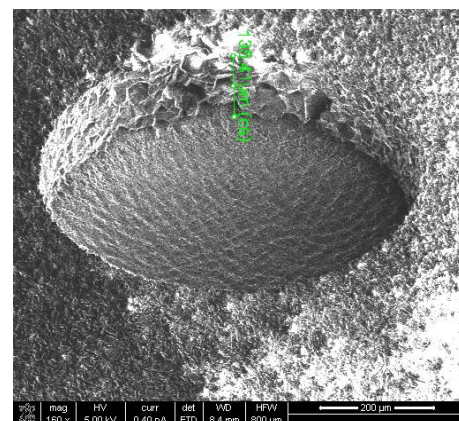


Fig. 6 side view of sample fabricated with SEM imaging

Fig. 5 shows the diameter of the structure is about 664μm. Fig. 6 shows the depth of the structure at the edge is about 134μm. In the

images no identifiable ejection is found. And the edge of the structure is clearer.

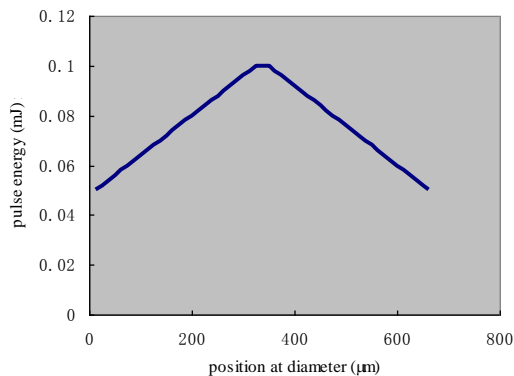


Fig. 7 curve of pulse energy relative to position at diameter orientation

3. Conclusions

Accurately adjusted the laser parameters, moving speed of table, the heating temperature and rate, the concentration of hydrofluoric acid and the etching time, the design structure on the surface of FOTURAN photosensitive glass can be formed. Applied such technics the mold to make micro-lens can be fabricated. And then the bulk products of micro-lens can be fabricated with the micro-mold in later studying.

ACKNOWLEDGEMENT

The research supported by National Natural Science Foundation of China (60723004, 61072013).

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