이광자 중합을 이용한 마이크로 구조물 성형에서의 복셀 특성 분석

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Voxel Characterization for Microstructure Fabrication using Two-Photon Photopolymerization (TPP)

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ABSTRACT

Two-Photon Photopolymerization (TPP) is a microfabrication technique used to create 3D microstructures. In this technique, near-infrared (NIR) ultra-short pulsed laser is used to solidify the photoresist at laser focal spot. Two-photon absorption is a non-linear process that results in high resolution and quality of microstructure. The building block of any microstructure is known as voxel that needs to be identified to do the efficient and high quality microfabrication. In this work, voxel are cured for certain parameters of laser i.e., laser power and exposure time. Minimum available dimensions can be used to make microstructures with finer detailed features.

Key Words : Two-Photon Photopolymerization (TPP), Microfabrication, Voxel

1. Introduction

With the current advancements in the field of nanotechnology, the need is increasing to replicate the large scale objects, structures and machines at micro level. A number of techniques are available for microfabrication which includes bulk micromachining[1], surface micromachining[1] and stereolithography[2]. These techniques have various limitations in one or another way. So, here comes a very promising method for 3D microfabrication named as Two-Photon Photopolymerization (TPP)[3]. With TPP, microstructures are manufactured by solidification of photoresist with near-infrared ultra-short pulsed laser beam. Maruo et al. used TPP to make microstructure for the very first time [4]. Commonly used photoresists include SU-8 (MicroChem) and NOA 89 (Norland Products).

In the case of microfabrication, minimum feature size, also known as voxel, is very important as it defines the resolution of the technique. For a certain optical setup, voxel sizes are generally dependent upon the laser power and exposure time.

2. Experimentation

2.1 Experimental Setup

Figure 1 shows the basic experimental setup used for microstructure fabrication using TPP. In this setup, the parameters of available femtosecond laser are: wavelength = 800 nm, pulse width = 100 fs, repetition rate = 80 MHz, laser power = 400 mW power. ND filter is used to attenuate the laser power. Next is the beam shutter which is used to control the laser exposure time. Laser passes through ND filter and beam shutter and then it reflects to go through beam expander. It is used to expand the laser beam to overfill the back aperture of objective lens. After this, laser passes through various optical components including 100X, 1.4 NA objective lens, to focus it at the sample stage. XYZ motorized stage is also

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installed to move the sample in three axes. Lamp is also available to illuminate the sample and a CCD camera is there to monitor the happenings at sample stage.

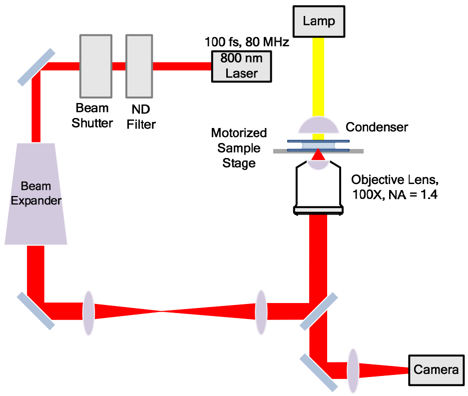

Fig. 1. Experimental Setup.

2.2 Experimental Procedure

First of all, a hair-cross is marked on the coverslip using simple paper cutter. A tape chamber is placed on cover-slip keeping the hair-cross nearly in the center of the tape-defined region. Now, it is placed on sample stage. The center of hair-cross can be easily located in this region. So, this utility can be used to locate the made structure even after the removal of coverslip from the sample stage. The laser is turned on now and minimum focal spot is focused on top surface of coverslip using motorized sample stage, as shown in fig. 2.

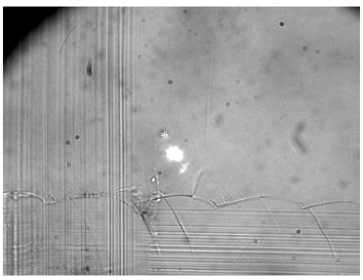

Fig. 2. Laser spot along-with hair-cross.

Laser is turned off now and a drop of photoresist, NOA 89, is dropped in the tape-bounded region. Tilt stage is moved to move the laser spot in a certain region. Certain laser exposure time values are used to solidify the voxel. After completing all the experiments, cover-slip is washed with a few drops of acetone to remove the excessive liquid photoresist. Now, it is again placed on sample stage and solidified voxels are monitored.

3. Results

Voxel characterization is done for a number of values for laser power and exposure time. Five sets of laser power are shown for cured voxels in fig. 3.

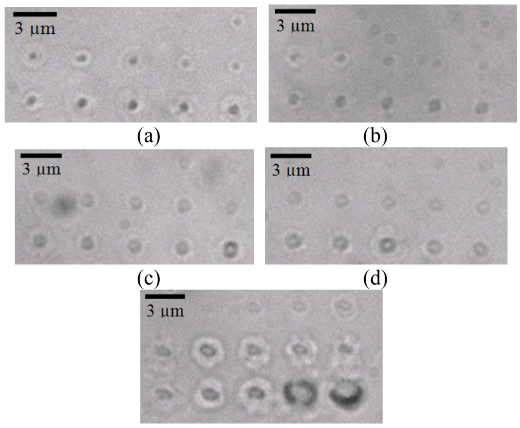

Fig. 3. Optical microscope images of cured voxels. (a) to (e) corresponds to the laser power values as 14 mW, 22 mW, 34 mW, 47 mW and 66 mW, respectively. For each part of fig. 3, laser is exposed for the time = 10, 20, 30… 150 ms. Top left corner: shortest exposure time; Bottom right corner: longest exposure time

These results indicate that when the power is increasing, voxel size is increasing and same is true in the case of exposure time. As the laser power is increasing, it is becoming possible to cure the voxel at even shorter exposure times. For 14 mW to 66 mW, minimum exposure time for voxel curing is decreasing from 50 ms to 30 ms.

For the sake of comparison, a variable, laser dosage, is defined by multiplying laser power and exposure time. In all the voxel curing experimentation, the minimum laser dosage that resulted in a cured voxel was 0.7 mJ with 14 mW laser power and 50 ms exposure time. So, the minimum size of voxel can be made using these parameters. And this voxel size can be used to manufacture very small sized structures.

4. Conclusion

Voxel characterization is an important matter to be discussed for the sake of finer microfabrication. A method was shown for voxel curing at certain location for the ease of re-locating it. It was also determined that when power and exposure time is increased, it causes to increase the cured voxel size. Minimum laser dosage was also found to get a cured voxel.

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References

1. Lopez D, Pardo F, Bolle C, Decca R S and Bishop D, "MEMS Technology for the Advancement of Science," *J. Low Temp. Phys.*, Vol.135, pp. 51-62, 2004
2. Deitz D, "Stereolithography automates prototyping," *Mech. Eng.*, Vol.112, pp. 34-39, 1990
3. Denk W, Strickler J H and Webb W W, "Two-photon laser scanning fluorescence microscopy," *Science*, Vol.248, pp. 73-76, 1990
4. Maruo S, Nakamura O and Kawata S, "Three-dimensional microfabrication with two-photon-absorbed photo-polymerization," *Opt. Lett.*, Vol.22, No.2, pp. 132-134, 1997