Fabrication of Nanostructures by Laser Optical Focusing

Bao Wang, Dong Feng, Jiadao Wang and Darong Chen

ABSTRACT

Surface structures have a broad application prospects, because the nanostructure or microstructure can improve the tribological properties. Laser processing has been widely used for microstructures due to the excellent controllability and universality and the precision of this method can be significantly increased by optical focusing. However, it is difficult to prepare nanometer scale material as focusing media. Here, a self-assembled monolayer of silica microspheres with diameter of about 900nm was formed on a bearing steel substrate and could be used as the focusing media. Large-area nanoholes were fabricated using overlapping pulses obtained through laser beam scanning. Scanning electron microscope (SEM) and profilometer characterized the shape and dimension of nanopatterns. Finally, the mechanisms of the formation of such structures depending on the number of laser pulses applied were discussed.

INTRODUCTION

Surface textures with the scale range from micrometer to nanometer had drawn much attention due to their broad application prospects, such as reduction of the friction coefficient [1], wetting property modification [2], optical devices [3], etc. Compared with other surface patterning technologies in previous investigations [4-5], laser processing has advantages: (1) high energy density, (2) good controllability and (3) universality. Therefore, it has been widely used in the fabrication of surface textures. To improve the precision, optical near-field nanofabrications through an evanescent near-field optical lithography method [6] or an embedded-amplitude mask [7] are characterized. And, illuminating of microspheres as microlenses [8] realizing high throughput patterning has attracted much attention and has been widely applied in the field of micro or nano fabrication. The surface morphology can be affect by different diameter sphere with different wavelength and different laser fluences [9-10]. Recently, it was reported that the substrate materials with diverse refractive indices played a role on the optical field modulation [11]. For the fabrication on nanostructures by optical focusing, the focusing media with nanometer scale was essential, but it is difficult to fabricated.
In this paper, a monolayer of self-assembled two-dimensional lattice of silica microspheres was prepared as focusing media for laser processing. And dense nanoholes on large area were fabricated on a bearing steel substrate. The created nanofeatures were observed.

FOCUSING MEDIA

The bearing steel plate was selected as substrate for the experiments, the substrate was cut into squares with 1.5×1.5 cm² and then cleaned ultrasonically in acetone, ethanol and deionized water in turn for 20 min, respectively. The solvent of monodispersed silica sphere suspension (2.5 wt. %) with sphere diameter of 900 nm was a 50 vol. % mixture of water and ethanol. The suspension was added to the water surface. The monolayer readily formed at the air-water surface and could be seen by the bright, colorful Bragg reflexes. A substrate was immersed into the suspension and elevated under a shallow angle to form the monolayer. The substrate was dried under an angle of 45°. As a result, a dense silica sphere monolayer was obtained on the bearing steel surface as shown in Figure 1. The monolayer silica spheres obtained by the proposed method could break the limitation of the focusing media. Furthermore, it is simple procedures, operating conveniently and quickly to preformed large-area focusing media.

Figure 1. SEM image of monolayer of silica microspheres with a diameter of 900 nm.

NANOSTRUCTURES

The silica monolayer array was used as focusing media and was irradiated laser pulses of a coherent Ti: sapphire femtosecond laser. The laser operated at 800 nm with a pulse duration of 50 fs and had a Gaussian spatial beam profile. The laser patterned surface was characterized by scanning electron microscopy (SEM) and profilometer for morphological study and for measuring the dimension of the patterns, respectively.
As shown in Figure 2, the results indicated that the dense and regular distributed holes could be easily fabricated. In order to texture large areas, overlapping laser pulses could be applied. This was realized by scanning the laser beam over the monolayer of microspheres on the substrate. Also, it is found that the arrangement of patterns generated on the bearing steel surface reveals that the distance between the patterns is about 900 nm which is equal to the diameter of spheres. Additionally, when the substrate was not plane, this proposed method also achieved the dense and regularly distributed nanoholes, which means that this method should not be affected by curvature radius of the substrate surface.

To detailed analyse the structures of nanoholes, the sectional profiles was shown in Figure 3, the depth of this nanohole is about 110nm, and the diameter was about 400nm. The two important parameters of nanostructures were nanometer scale. The results of measurements indicated that the proposed method could be used to simply and economically fabricate the nanostructures on plate or curving surface.
CONCLUSION

In summary, we have shown that in this paper that the monolayer silica spheres was simply and economically prepared as the focusing media. The application of microsphere lens arrays that are commonly used for laser surface patterning in a single-shot mode can be extended for multi-shot large area processing by rapid scanning a focused laser beam over a self-assembled lens array of silica microspheres on top of a silicon surface. The nanohole pattern has potential applications for the friction reduction, and has a promising application in mechanical engineering.

REFERENCES