

# ULTRA-FINE STRUCTURE GENERATED ON METALLIC THIN FILM USING INTERFERING FEMTOSECOND LASER

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## Introduction

Metamaterials have artificial structures and special natures. They have periodic structures, and based on nano-technology. There are some techniques to fabricate such structure. Among them, femtosecond (fs) laser processing is useful to process materials with wavelength resolution. In addition, periodic structure can be generated in a single process using interfering fs laser beams. We have been investigating the application of this technique since 2002, and quite interesting structures have been generated [1-7].

It had been said that fs laser processing is non-thermal technique. On the other hand, with particular laser and target condition, thermal processes such as melting, inflation, bending and flow become prominent in nano-size region, and nano-sized 3-D and 2-D structures can be generated. In this abstract and the presentation, our recent results are reported.

## Experimental Setup

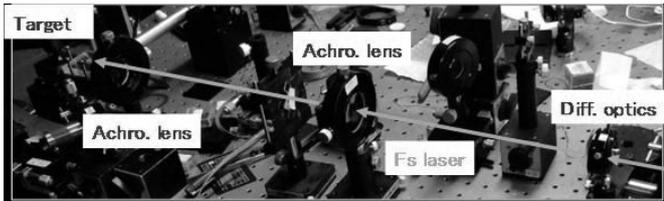


Fig. 1 Experimental setup.

Fig. 1 shows the experimental setup. An ultrashort pulse laser, of which the pulse width was about 130 fs and the center wavelength was about 790 nm, was used. A beam was split by a transmission grating beam splitter, and focused and interfered on a target surface through a demagnification system composed of two convex lenses. A period of interference can be controlled by interference angle which is a function of the grating period and magnification factor. Metallic thin films evaporated on substrates were used as targets. All the processes were done without any evacuation and at room temperature. All the structures shown in this abstract is generated in a single shot of laser irradiation. The resultant structures were observed by SEM.

## Simulation of interference pattern

An interference pattern can be explained by addition of electric fields of interfering beams. The fluence distribution can be explained as follows;

$$\rho(x, y, z) \propto \int \left| \sum_{l=1}^4 E_l(x, y, z, t) \right|^2 dt \quad (1)$$

where  $E_l(x, y, z, t)$  explains fields of the beams, and a target surface is regarded as  $xy$  plane. Fig. 3 (a) is an example of an interference pattern on a  $xy$  plane. Here, interference of four beams with synchronizing phases is assumed. In this case, uniform structures can be generated as shown in Fig. 2 (a). On the other hand, Fig. 2 (b) is simulated with phase shift between the beams. In this case,  $2/3\pi$  shift is added to a beam, and weaker points appear between stronger points. In such case, duplicated structure composed of two different structures is generated. Holographic technique is very powerful to generate a variety of periodic structure.

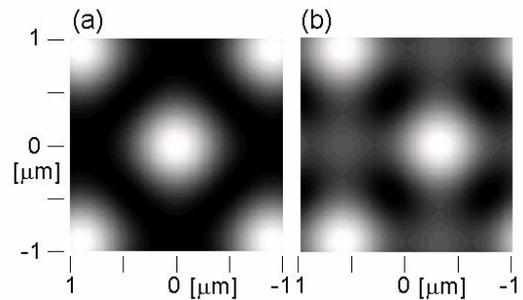


Fig. 2 (a) Simulated interference pattern without shift, (b) with  $2/3\pi$  shift of one beam.

## Experimental Results

Fig. 3 shows a nano-spike in array generated by a single shot of interfering four beams irradiated on a 20 nm thick Au thin film deposited on a silica glass substrate. Each has very spiky top, and the curvature radius is smaller than 20 nm. Such small structure has never been generated by top-down technique. The structure is formed by liquid motion of locally melted Au film, and shrink. The structure freezes according to

temperature fall by thermal radiation and conduction. At lower fluence, totally different structure of nano-waterdrop is generated, as shown in Fig. 4 [1, 2]. This technique can control the liquid motion of nano-sized metal by changing the parameters, and a variety of structure can be generated by a simple and single apparatus set.

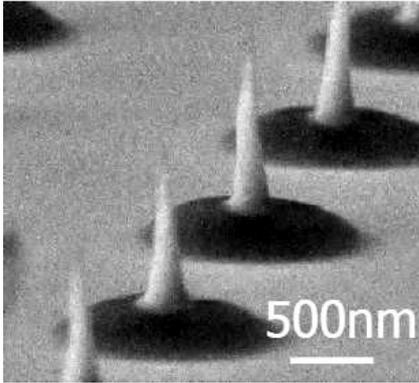


Fig. 3 nano-spike array.

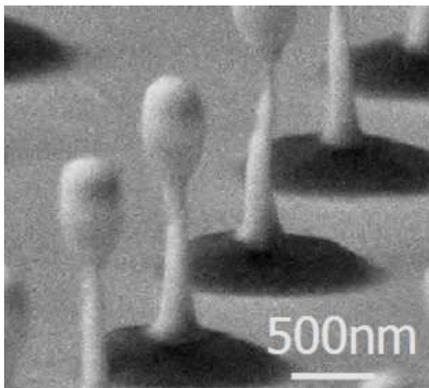


Fig. 4 nano-waterdrop array.

## Conclusion

A variety of nano-textured surface was generated on thin film processed by interfering fs laser beams. These mesoscopic structures are quite useful in nanotechnology, especially plasmonic device, structural colour, surface enhanced field or raman, etc..

## Acknowledgement

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## References

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