**Femtosecond Laser Induced Periodic Surface Nanostructuring of Platinum Thin Films**

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## Abstract

The ability to fabricate structures on the nanoscale with high precision and in a wide variety of materials is a crucial issue for the development of the nanoscience and nanotechnology. High resolution lithographic techniques such as electron-beam lithography or EUV lithography, although very accurate and reproducible, usually suffer from low throughput and high operation costs. In this context, laser micro- and nanostructuring techniques are getting increased interest for this purpose. In the last years, femtosecond laser surface nanostructuring has emerged as a novel and versatile technology for producing a wide variety of nanostructured materials for applications such as photonics, plasmonics, optoelectronics, biochemical sensing, micro/nanofluidics, optofluidics, biomedicine, and other areas. Among the entire femtosecond laser induced surface structuring techniques, Laser Induced Periodic Surface Structures (LIPSS) stands out as one of the most actively studied approaches [1]. Although these structures have been observed in a wide range of materials including semiconductors, dielectrics and metals [2-4], these last are of particular interest due to their applications in photonics and sensing. Intense research work has been performed to study the formation of LIPSS on bulk metals [4-6]. However, the optimal conditions for a controllable nanostructuring of metallic thin films using femtosecond laser ablation technique are still unexplored. In this work we present a systematic study of the formation of LIPSS on the surface of Pt thin films as a function of the laser irradiation parameters.

Pt films with a thickness of 200 nm were deposited by DC-magnetron Sputtering onto Si (100) substrates with a 1.2 μm thermally grown $SiO_2$ layer and 5 nm of Cr buffer layer. A Ti:Sapphire laser system consisting of a mode-locked oscillator and a regenerative amplifier was used to generate 100 fs pulses at a central wavelength of 800 nm with a 1 kHz repetition rate. The 12 mm-diameter laser beam was focused on the sample using a 10x microscope objective with a NA of 0.3.

A study of the processing parameters on the formation of surface nanostructures was performed by processing a map of irradiated areas, as detailed in Table 1. The laser beam linearly scanned the target area (0.5 x 0.25 $mm^2$) at a constant speed for different horizontal displacements (Δx). Laser fluence was varied by adjusting the defocusing distance *Z*, i.e., the distance between the Pt surface and the laser focal plane. A variation of the scanning speed results in a modification of the number of overlapped pulses. For a 1 Khz repetition rate, scanning speeds (v) from 0.1 to 1.0 $mm\cdot s^{-1}$ correspond to a number of 10 to 100 overlapped pulses. Light polarization was adjusted using a zero-order half-wave plate.

Scanning Electron Microscopy was used to analyze the influence of the irradiation conditions on the generated nanostructures. FE-SEM micrographs revealed that both Low-Spatial Frequency LIPSS (LSPL) with a period of about 600 nm and High-Spatial Frequency LIPSS (HSFL) with a period around 200 nm can be generated in Pt thin films for specific irradiation conditions (see Figure 1). HSFL appear for high scan speeds (Figure 1.a, 1.d, 1.g) while LSFL are predominant for low scan speeds (Figure 1.c, 1.f, 1.i); for intermediate speeds, both types of structures coexist (Figure 1.b, 1.e, 1.h). Additionally, periodic structures are better defined as laser fluence decreases, as can be deduced from Figures 1.b and 1.e. Therefore, in order to obtain large areas well covered with HSFL, a compromise between laser fluence and scan speed must be achieved. For this particular case, a defocusing distance of 120 μm and a scan speed of 0.3 $mm\cdot s^{-1}$ with a line separation of 10 μm seems to be the optima processing conditions. Micrographs also revealed the influence of the beam polarization on the orientation of the generated nanostructures: HSFL appear oriented along the polarization direction of the beam, while LSFL are perpendicular to the polarization vector.

It can be concluded that both 600 nm LSFL and 200 nm HSFL periodic relieves with controlled orientation can be precisely generated by femtosecond lasers on Pt thin films by properly selecting the irradiation parameters: laser fluence, polarization and scan speed. These nanostructured films are of particular interest for applications requiring an increased active surface, such as miniaturized sensors and surface assisted laser desorption/ionization.

## References


[1] Vorobyev, A.Y., Guo, C., Laser & Photon Rev (2012) 1-23.

[2] Tomita T., Kinoshita K., Murai T., Fukumori Y., Matsuo S., Hashimoto S., Journal of Laser Micro Nanoengineering Vol. 2, No. 2, (2007) 141-145.

[3] J. Bonse, J. Krüger, S. Höhm, A. Rosenfeld, J. Laser Appl., Vol. 24, No. 4, (2012) 042006.

[4] Hwang T.Y., Guo C., J. Appl. Phys. 108 (2010) 073523

[5] Djouder M., Itina T.E., Deghiche D., Lamrous O., Applied Surface Science 258 (2012) 2580–2583

[6] Bizi-Bandoki P., Benayoun S., Valette S., Beaugiraud B., Audouard E., Applied Surface Science 257 (2011) 5213–5218


## Figures

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|---|---|
| Scanning Speed | 0.1, 0.15, 0.3, 0.6, 1.0 mm·s$^{-1}$ |
| Pulse Energy | 0.7 μJ |
| Polarization | Linear ↕↔ ↗ |
| Defocusing Distance (Δf) | (-120, +120) μm |
| Horizontal Displacement (Δx) | 10, 15, 20 μm |

**Table 1.** Laser irradiation parameters used for Pt nanostructuring.

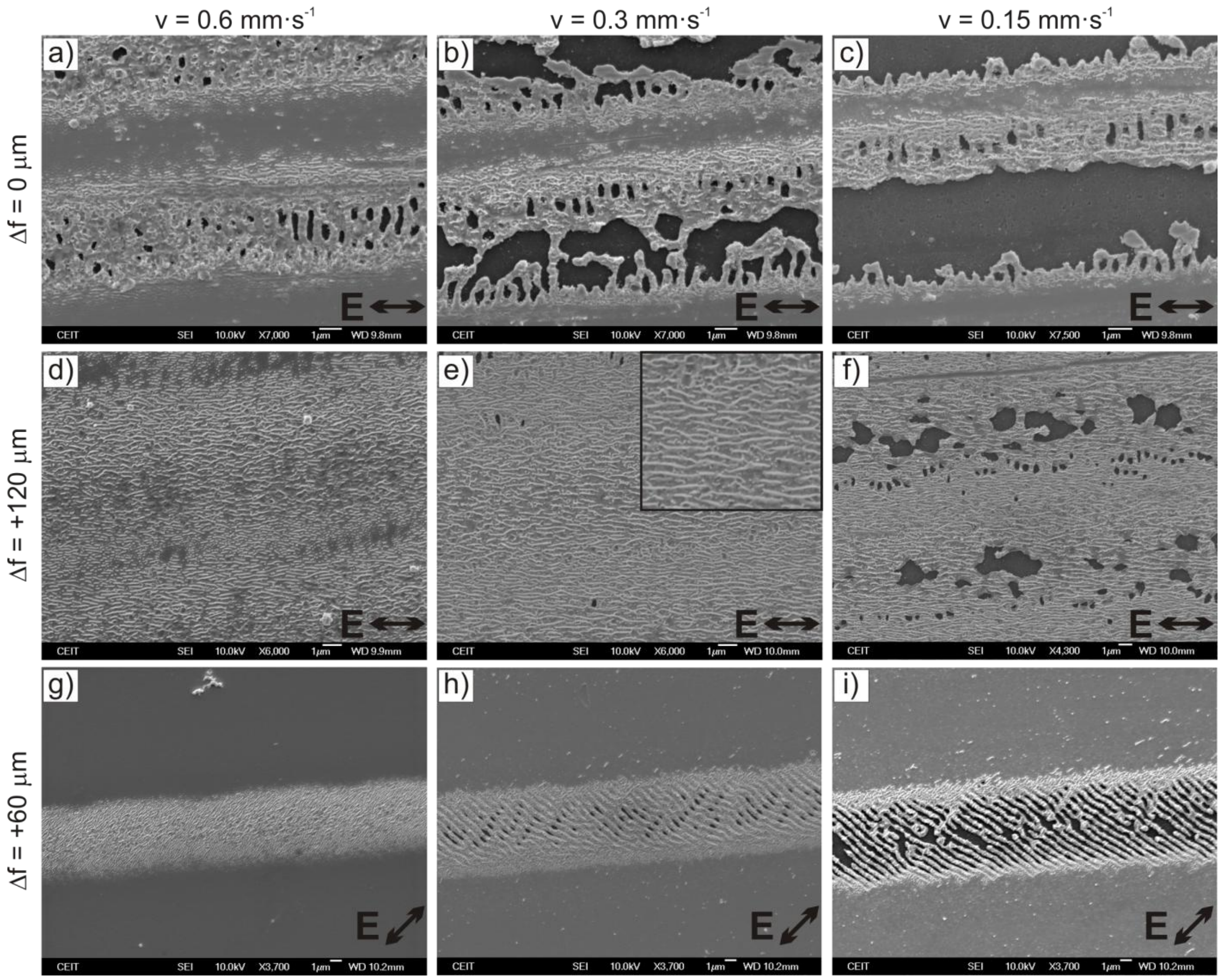


**Figure 1.** FE-SEM micrographs of the resulting LIPSS on Pt films for different irradiation conditions and horizontal displacement of 10 μm.