Acousto-optofluidics for rapid laser-generation of periodic surface nanostructures

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Abstract

Laser-induced periodic surface structures (LIPSS) offer remarkable opportunities for nano-optics and nanophotonics[1]. LIPSS are simple to prepare, indeed, they spontaneously form upon the irradiation of metals, semiconductors, or dielectrics with focused ultra-short laser pulses. Moreover, the selection of the laser parameters (e.g., flunce or polarization) allows nanostructuring a target surface with tailored optical properties. Nonetheless, synthesizing LIPSS over large areas is a slow process because of the inherent serial nature of any laser direct-write systems.

A method to solve this problem is exlpoiting light interference patterns that, irradiating a region rather then a point, enable large-scale processing of materials at sub-wavelength resolution. However, traditional tools for generating interference patterns lack tunability or operate at extremely low speed (temporal scale 10 ms) that impedes inter-pulse pattern selection at repetition rates of common lasers.

To overcome the above limitations, we present a method for the high-throughput generation of LIPSS in semiconductors and metals. Precisely, large-area (~cm^2) nanopatterning is achieved with a novel light shaping tool that exploits the interaction between acoustic and light waves in a liquid to generate and select laser interference patterns at exceptional speed (temporal scale <1 µs)[1,2]. Successful preparation of LIPSS and their on-the-flay (while scanning the sample surface) arrangement into user-selectable patterns is demonstrated by controlling amplitude, frequency, or phase of the acoustic waves (Fig. 1a). This strategy allowed stitching, on the same substrate, LIPSS-pixels with various structural colorations (Fig. 1b).

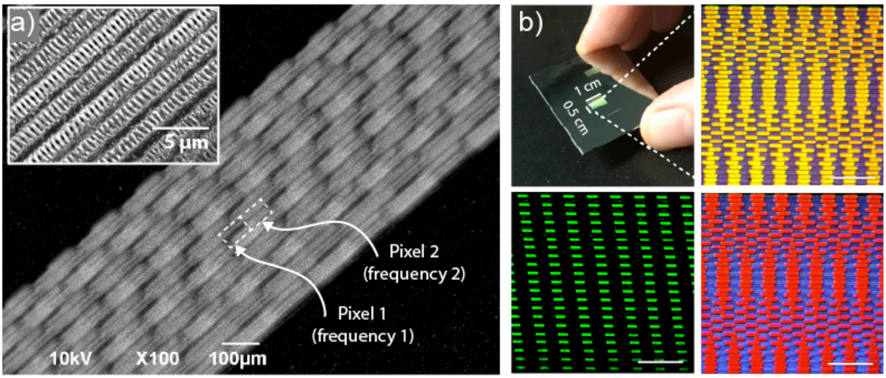

Figure 1: a) Scanning electron micrograph of a LIPSS pattern with two pixels obtained by snake scanning a palladium substrate with a femtosoecod laser while the acoustic frequency swaps between 1.2 and 1.8 MHz. The inset shows LIPSS in the irradiated regions. b) Large area structural colors for different modulation rates of the acoustic frequency. Various structural colors appear by illuminating the pattern with white light at various angles of incidence. Scale bar 500 µm.

References

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