Ablation of metal surfaces by low-fluence laser pulses in different gas atmospheres

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Laser ablation leads to topographical and chemical changes in metallic surfaces [1, 2]. When the pulse fluence is lowered below the threshold fluence for laser ablation, part of the laser light is reflected, while the absorbed part is used to heat the surface. This creates an oxide layer several tens or hundreds of nanometers thick, which is visible as a colored metal [3]. In this contribution, we show how this influences the chemical composition of the surface and the corrosion properties of the metal processed with the laser.

When the fluence of the polarized laser pulses is increased slightly above the fluence threshold, laser-induced periodic surface structures (LIPSS) are formed [4, 5]. In this contribution, we further investigate the influence of the ambient atmosphere on the formation of laser-induced periodic surface structures (LIPSS) on the metal surface using 8 ps and 45 ns pulses.

We patterned the surface of AISI 216 stainless steel in air, nitrogen and argon and observed that the properties of the fabricated LIPSS were affected by the change in beam scanning speed and pulse fluence at constant pulse duration. We found that the LIPSS phenomenon strongly depends on the atmosphere surrounding the irradiation point during fabrication. When patterning with picosecond pulses, the dependence was less pronounced and manifested itself mainly in the curvature of the fabricated ribs. The spatial period of the ribs patterned with picosecond pulses was smaller in air than in nitrogen and argon atmospheres. On the other hand, periodic structures with nanosecond pulses were observed only when laser processing was performed in air, suggesting that the structures were related to surface oxidation.

Further analysis using EDS, XPS, AFM and FIB cross-sections revealed that the LIPSS obtained with nanosecond pulses on the samples consisted mainly of periodic parallel ridges of accumulated oxides, while in the case of picosecond pulses, the LIPSS consisted of topographically modulated bulk material with an oxide layer deposited uniformly over the entire surface of the sample. The results indicate that the formation of stainless steel LIPSS is significantly influenced by the surrounding atmosphere and the pulse duration used for laser processing.

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