Investigation of LIPSS structures fabricated in different surrounding media using focused-ion beam etching

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In this study, we investigate the influence of different media surrounding the laser irradiation spot on the characteristics of the formed laser-induced periodic surface structures (LIPSS). The surrounding media used in the experiments include air, nitrogen, and argon, which mainly affect the chemical composition of the treated surface, while water and polyethylene glycol 300 are used to study the effects of cavitation bubbles that occur in liquids during laser processing. Stainless steel and titanium samples are irradiated with 45 ns and 30 ps polarized laser pulses, emitted by a nanosecond fiber laser (λ = 1060 nm) and a Nd:YAG picosecond laser (λ = 1064 nm), respectively. Variation of the surrounding media [1] and laser processing parameters [2], including pulse fluence, beam scanning velocity, and pulse duration, results in different characteristics of the structures [3] formed in the upper layer of the irradiated material.

In gas atmospheres, when longer nanosecond pulses are used for LIPSS generation, we observe mainly the effect of surface oxidation, while the topographic change (typical for LIPSS at shorter pulses) is almost negligible (Fig. 1a). Interestingly, the oxide layer thickness changes periodically, with a period typical for LIPSS formation. Thus, in this case, LIPSS composes of a thin periodic oxide layer with a thickness of several tens of nanometers. Slight variations in pulse fluence and beam scanning velocity appear to change the characteristics of the oxide layer, which we investigate by cross-cutting (Fig. 1a) and etching (Fig. 1b) the samples with a focused ion beam (FIB). The chemical composition of the upper surface layer is analyzed by energy-dispersive X-ray spectroscopy (EDS) and X-ray photoelectron spectroscopy (XPS).

In liquid environments, we observe the formation of LSFL and HSLF at high pulse overlap, where the liquid viscosity and beam scanning velocity affect the spatial period and repeatability of the fabricated structures. At low pulse overlap, laser-induced cavitation bubbles play a more important role and can lead to formation of curved microgrooves under suitable conditions (Fig. 1c). We assume that the microgrooves in this regime are formed by the modulation of the laser beam intensity at the interface of the generated cavitation bubbles, which act as diffraction objects [4]. When the beam is scanned in altering directions within this regime, meandering structures with ~20 μm radius of curvature are created.

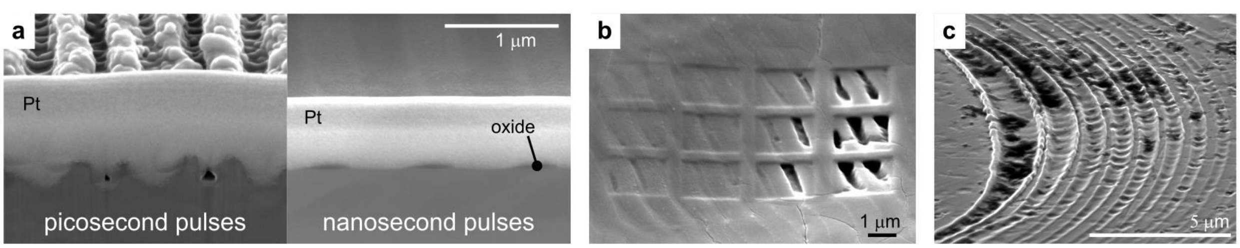

Figure 1. (a) Cross-sections of LIPSS obtained in air atmosphere by picosecond and nanosecond pulse irradiation. (b) Etching the top surface of LIPSS with a FIB. (c) Curved microgrooves obtained by laser irradiation in liquid.

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