Tailoring surface topographies on solids with Mid-IR femtosecond laser pulses

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Irradiation of solids with ultrashort pulses using laser sources in the mid-infrared (mid-IR) spectral region is a yet predominantly unexplored field that opens broad possibilities for efficient and precise surface texturing for a wide range of applications. In the present work, we investigate both experimentally and theoretically the impact of laser sources on the generation of surface modification related effects and on the subsequent surface patterning of metallic and semiconducting materials. Through a parametric study we correlate the mid-IR pulsed laser parameters with the onset of material damage and the formation of a variety of periodic surface structures at a laser wavelength of $\lambda_L = 3200$ nm and a pulse duration of $\tau_p = 45$ fs. Results for nickel and silicon indicate that the produced topographies comprise both high and low spatial frequency induced periodic structures, similar to those observed at lower wavelengths, while groove formation is absent (Fig. 1a,b). The investigation of the damage thresholds suggests the incorporation of nonlinear effects generated from three-photon-assisted excitation (for silicon) (Fig. 1c) and the consideration of the role of the non-thermal excited electron population (for nickel) at very short pulse durations (Fig. 1d). The results demonstrate the potential of surface structuring with mid-IR pulses, which can constitute a systematic novel engineering approach with strong fields at long-wavelength spectral regions that can be used for advanced industrial laser applications [1].

Fig. 1 Map of morphologies for Silicon (a) and Nickel (b). Periodicity of LIPSS for 22 pulses for Silicon (c) and Nickel (d).

References
[1] Maragkaki S., Tsibidis GD, Haizer L., Pápa Z., Flender R., Kiss B., Márton Z., Stratakis E., ‘Tailoring surface topographies on solids with Mid-IR femtosecond laser pulses’, Applied Surface Science 612, 155879 (2023).