2.5D femtosecond laser microstructuring of biomimetic surface patterns

Jaka Mur[1], Matevž Marš[1], Jaka Petelin[1], Vid Agrež[1], Rok Petkovšek[1,*]

[1] University of Ljubljana, Faculty of Mechanical Engineering, Aškerčeva 6, 1000 Ljubljana, Slovenia
*Corresponding author email: rok.petkovsek@fs.uni-lj.si

Surface structuring aimed at improving surface properties has become a widely adopted method, targeting surface improvements in aero- and hydrodynamics as well as heat transfer. As the need for highly efficient manufacturing manifested, patterns took inspiration from nature [1]. Femtosecond laser processing is a mature technology but remains limited in throughput and scalability due to high precision required and relatively low efficiency.
Here we present a novel concept for 2.5D surface structuring that simultaneously improves processing throughput and precision compared to traditional laser surface structuring approaches [2]. We define a 2.5D surface as any surface that can be described by a matrix of heights. Processing of such patterns is enabled by leveraging the pulse-on-demand capabilities of the latest femtosecond laser sources [3]. Our concept employs a grayscale image input to define the desired depth distribution on the material. It utilizes the PoD mode at 30 MHz to modulate the laser repetition rate with high resolution, in turn enabling precise fabrication of the target structure both in the scanning direction and depth definition. Our goal is to improve thermal transfer properties of surfaces and their interaction with coolants and lubricants.

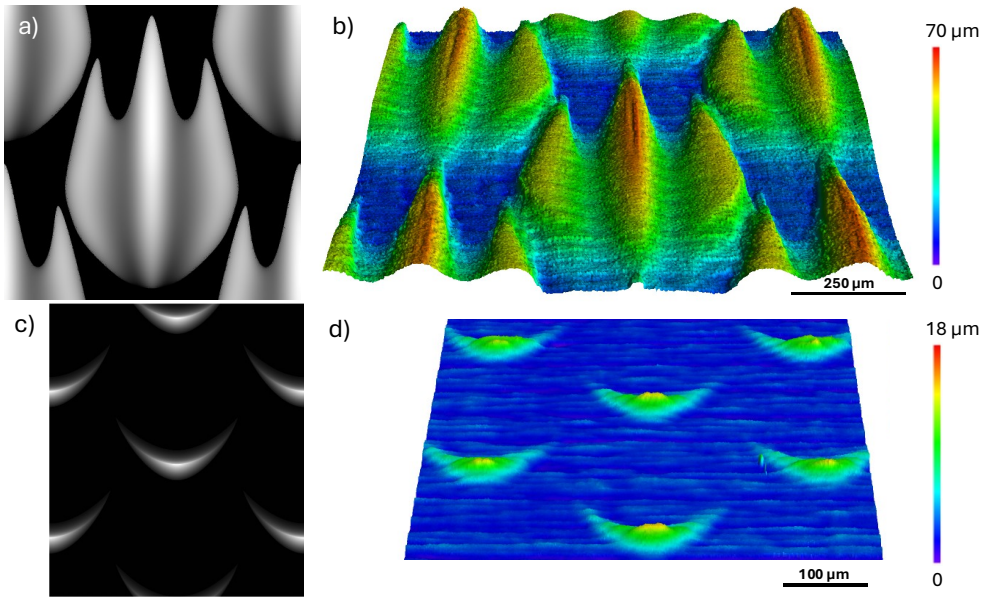

Figure: a) Input image for a 2D periodic shark-skin inspired pattern. b) Topography measurement of the pattern in copper substrate. c) Input image for a high-fidelity fish-scale pattern. d) Topography measurement of pattern in copper demonstrating high precision of processing.

References:

[1] H.N. Kim, S.W. Jeong, B.G. Baik, H. Jang, H.E. Jeong, S.J. Lee, Applied Surface Science, 628, 157365 (2023).
[2] J. Petelin, J.J. Kočica, J. Mur, R. Petkovšek, Surfaces and Interfaces, 61, 106099 (2025).
[3] L. Černe, J. Petelin, R. Petkovšek, Optics Express, 28, 7875–7888 (2020).