Bacterial adhesion on femtosecond laser-induced periodic surface structures

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Motivation

Biofilm formation in industrial or medical settings is usually unwanted and leads to serious health problems and high costs.
Inhibition of initial bacterial adhesion prevents biofilm formation and is, therefore, a major mechanism of antimicrobial action of surfaces.

Surface topography largely influences the interaction between bacteria and surfaces which makes topography an ideal base for antifouling strategies and eco-friendly alternatives to chemical surface modifications.

Objective

Femtosecond laser-processing was used to fabricate sub-micrometric surface structures on silicon and stainless steel for the development of antifouling topographies on technical materials.
Adhesion tests were performed with *Staphylococcus aureus* and *Escherichia coli* as medically relevant test strains.

Laser surface processing

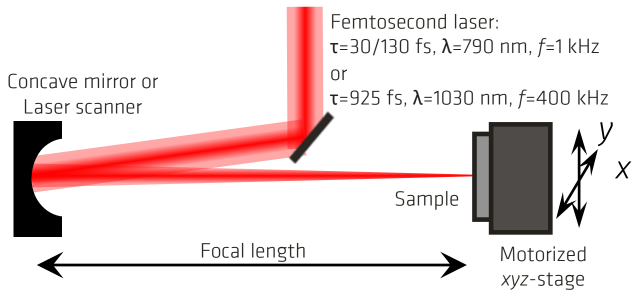

Fig. 1 Schematic of the fs- laser processing setup

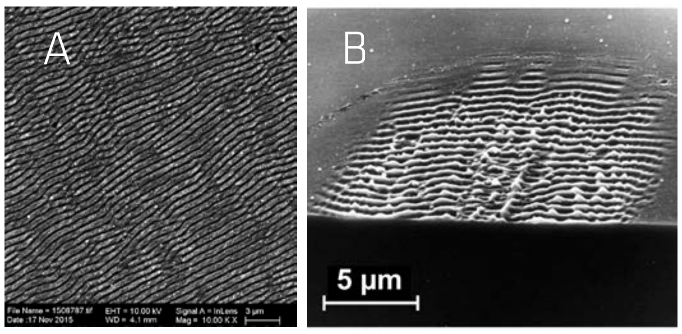

Fig. 2 (A) Top-view SEM of 30-fs-laser-processed V4A stainless steel [1] and (B) Side-view SEM of 130-fs- laser processed LIPSS on crystalline silicon [2].

The laser processing was performed with linearly polarized laser pulses with a pulse duration of 30, 130, or 925 fs, a center wavelength of 790 or 1030 nm and a pulse repetition rate of up to 1 / 400 kHz with a setup shown in Fig. 1.
After femtosecond laser processing, the steel or silicon surfaces are covered by sub-micrometric *laser-induced periodic surface structures* (LIPSS), see the examples of scanning electron micro-graphs (SEM) in Fig. 2.

Structural colors of LIPSS-covered surfaces

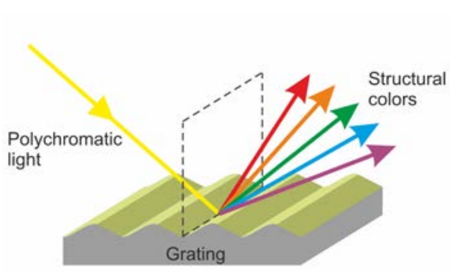

Fig. 3 Principle of ambient light diffraction on a surface grating structure.

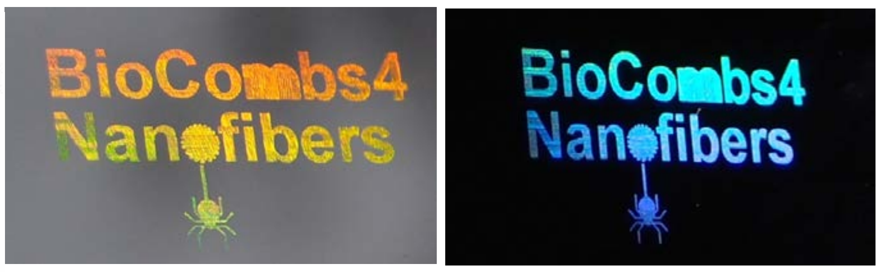

Fig. 4 Photographs of laser-processed *BioCombs-4Nanofibers* project logo with LIPSS as filling pattern at a polished silicon wafer surface. The sample is viewed at different angles under ambient light illumination.

LIPSS represent a quasi-periodic linear surface grating that is capable to diffract light (Fig. 3). Different „structural colors“ can be viewed under varying observation angles.
Figure 4 presents two photographs of a ~20 mm wide laser-processed *BioCombs-4Nanofibers* project logo featuring LIPSS as filling pattern on a polished silicon wafer surface. Choosing the right angle of observation allows to “adjust” the desired color scheme.

Bacterial adhesion on laser-structured stainless steel

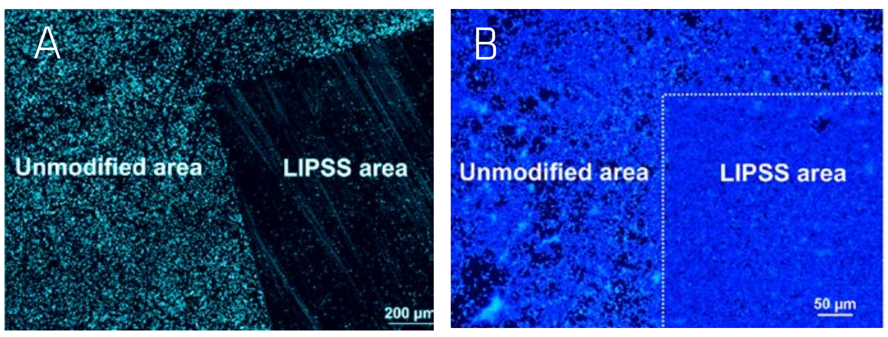

Fig. 5 Fluorescence microscope images of *E. coli* (A) and *S. aureus* (B) on laser-modified (LIPSS) and unmodified stainless steel (V4A) after 3 h (B) or overnight cultivation (A) [1].

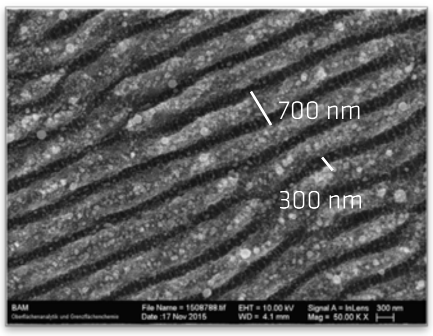

Fig. 6 Top-view SEM of fs-laser-processed stainless steel within the „LIPSS areas“ marked in Figs. 5A, 5B [1].

Adhesion to topographic surfaces with trenches of 300 nm, and thus smaller than the cell body, was significantly reduced for *E. coli* (~1 µm x 2 µm).
S. aureus, however, revealed strong adhesion on laser structured surfaces probably because of its spherical shape (~1 µm diameter) and massive EPS (extracellular polymeric substances) production which masks the micro-topography on the laser modified surface.

Literature
[1] N. Epperlein et al. Appl. Surf. Sci. **2017**, *418*, 420.
[2] J. Bonse et al. Appl. Surf. Sci. **2011**, *257*, 5420.

BioCombs4
Nanofibers

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