

Regulation of microbial proliferation via LIPSS prepared by GHz burst mode femtosecond laser

Shota Kawabata^{1,2}, Shigeru Uchiyama¹, Takashi Isoshima¹,
Kazunari Ozasa¹, Kotaro Obata¹, Godai Miyaji², and Koji Sugioka^{1*}

¹ RIKEN Center for Advanced Photonics, 2-1 Hirosawa, Wako, Saitama, 351-0198, Japan

² Tokyo University of Agriculture and Technology, 2-24-16 Nakacho, Koganei, Tokyo, 184-8588, Japan

*Corresponding author email: ksugioka@riken.jp

We have applied GHz burst mode femtosecond (fs) laser, which delivers a series of fs pulse trains at an extremely high repetition rate in the GHz range, for the formation of laser-induced periodic surface structures (LIPSS). We have demonstrated that the GHz burst mode with linear polarization produces lattice-like 2D LIPSS (Fig. 1(A)), distinct from the well-known stripe-like 1D LIPSS formed using the conventional fs laser irradiation scheme (single-pulse mode) [1,2]. More recently, we have further found that the GHz burst mode with circular polarization enables the formation of different types of 2D LIPSS, such as rock surface-like and tetrapod-like microstructures. Such unique surface topographies could be applied to regulate microbial proliferation. Controlling microbial proliferation is important not only for suppressing harmful species but also for promoting beneficial ones. While microbial control is typically implemented based on temperature and/or biochemical conditions, regulation by the surface topography could offer a promising alternative. In this study, we explore the possibility of regulating microbial proliferation using LIPSS with various surface nanostructures formed by different modes and polarizations of fs laser pulses. In the experiment, we developed a new method to evaluate the physical effects of surface topography on microbial growth independent of material properties (Fig. 1(B)). To isolate the effect of titanium (Ti), positive patterns of LIPSS created on Ti were transferred to PDMS using a two-step molding process. The growth rate of *S. aureus* colonies, cultured between agar medium and the nanostructured PDMS, was then observed. *S. aureus* colony size below PDMS with lattice-like 2D LIPSS created by linearly polarized GHz burst mode was significantly smaller compared to the flat surfaces (Fig. 1(C)). We further confirmed that the lattice-like 2D LIPSS inhibit the proliferation of *S. aureus* the most among the LIPSS patterns prepared with different modes and polarizations.

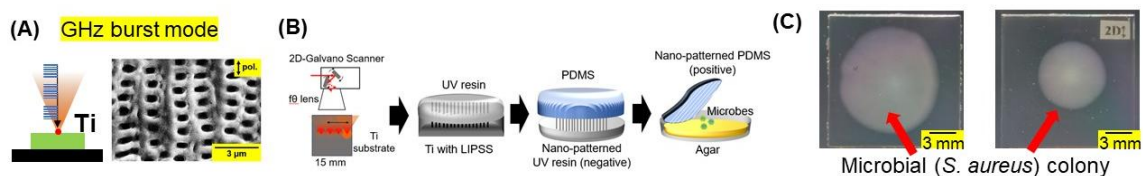


Figure 1 (A) SEM image of lattice-like 2D LIPSS fabricated by linearly polarized GHz burst mode. (B) Schematic diagram of developed new evaluation method to assess the effects of surface topographies on growth rate of microbials. (C) Optical microscopy images captured 56 hours after *S. aureus* spot seeding between agar medium and the PDMS specimens with flat surface (left) and lattice-like 2D LIPSS (right).

References:

- [1] S. Kawabata, S. Bai, K. Obata, G. Miyaji, K. Sugioka, *Int. J. Extreme Manuf.*, 5, 015004 (2023).
- [2] S. Kawabata, S. Bai, K. Obata, K. Ozasa, G. Miyaji, K. Sugioka, *Front. Nanotechnol.*, 5, 1267284 (2023).