BiBurst mode with GHz fs-pulse burst in MHz burst for efficient surface microfabrication of silicon

RIKEN Center for Advanced Photonics [1], ○Francesc Caballero-Lucas[1], Kotaro Obata[1], Koji Sugioka[1]

E-mail: francesc.caballerolucas@riken.jp

Ultrashort pulsed lasers are becoming used in a wider range of applications thanks to their extremely short pulse durations, which greatly confine the resulting processing within the irradiated zone. This makes possible handling a broad extent of materials with little heat diffusion, ensuring a precise material ablation. However, ultrashort pulsed lasers encounter some challenges at high-speed material removal. In this situation, the use of higher power lasers for increasing ablation rates leads to detrimental effects due to heat accumulation. Recently, GHz burst mode laser ablation has been proposed to overcome this limitation by applying ablation cooling [1]. GHz bursts of ultrafast laser pulses contribute to material ablation before the residual heat induced by previous pulses diffuses away from the processed zone to suppress the thermal effect. In addition, reduction of the pulse energy needed for material ablation is also observed. Owing to that, increased ablation efficiencies have been reported [2]. Following this approach, we study the influence of different configurations of the burst mode on the ablation efficiency and surface microfabrication quality. For that, MHz burst pulses (2-5 pulses) each of which contains sub-pulses (2-25 pulses) at an ultrafast repetition rate of 5 GHz (BiBurst mode) were sent onto a crystalline silicon sample. Results shown in Figure 1 give evidence of the diverse outcomes in ablation among the different configurations for the burst mode in contrast to conventional single pulse laser ablation. Specifically, the GHz burst mode (Fig. 1b) resulted in deeper craters with larger ablated volumes compared to irradiation with a single pulse (Fig.1a), which is further enhanced by the BiBurst mode (Figs. c, d), even though the total accumulated energy was kept the same. Consequently, ablation efficiency was increased from a maximum of 7 $\mu m^3/\mu J$ for the single pulse ablation to 17 $\mu m^3/\mu J$ for the BiBurst mode (2 bursts with 25 intrapulses).

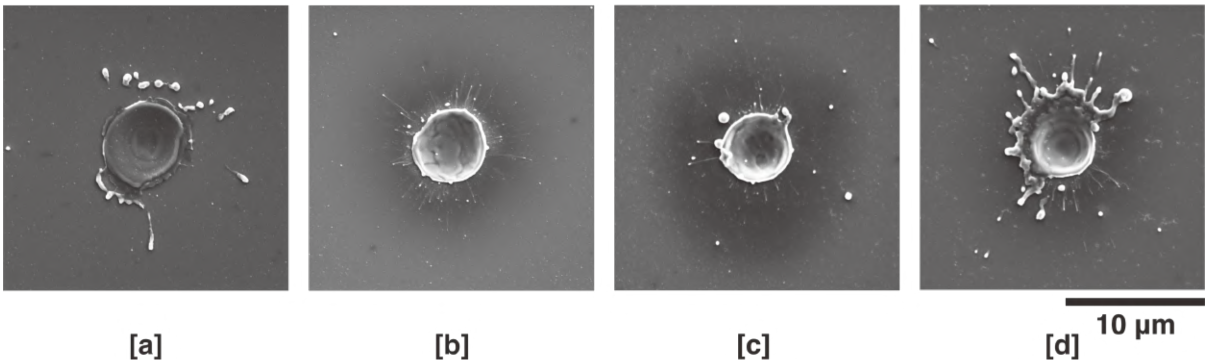

Figure 1 SEM images of the ablated spots on the surface of a crystalline silicon sample processed by 1030 nm femtosecond laser pulses in air. Each image corresponds to the following configurations for GHz burst mode: [a] conventional single pulse, [b] 1 burst containing 25 pulses, [c] 2 bursts with 25 pulses in each burst, and [d] 5 bursts with 25 pulses in each burst. The intraburst repetition rate was 5 GHz while the interburst repetition rate was 64 MHz. Total energy delivered onto the sample was kept constant at 0.53 µJ for all cases.

[1] C. Kerse, et al, Ablation-cooled material removal with ultrafast bursts of pulses, Nature, vol. 537, (2016).

[2] G. Bonamis, et al, Systematic study of laser ablation with GHz bursts of femtosecond pulses, Optics Express, 28(19), 27702 (2020).