EFFICIENT LASER ABLATION

Andrius Žemaitis, Mantas Gaidys, Paulius Gečys, Mindaugas Gedvilas

Department of Laser Technologies, Center for Physical Sciences and Technology
e-mail: mgedvilas@ftmc.lt

Ultrafast lasers are wildly applied for the patterning of various materials in science, technology, and medicine. However, real industrial implementation of lasers is still restricted by the low machining throughput, and the high cost of laser irradiation sources. This investigation is dedicated to the development of high-throughput laser-ablation technology with maximum possible material removal rate and superb processing quality. To the best of our knowledge, we have reached the highest laser milling ablation efficiency of 5.66 $\mu m^3/\mu J$ for copper reported in the literature using a state-of-the-art bi-burst (GHz burst in the MHz burst) femtosecond laser [1]. The picosecond bursts provided a slightly smaller milling efficiency of 4.84 $\mu m^3/\mu J$ [2]. The two methods of ablation efficiency optimization were introduced: pulse energy and beam size optimization techniques [3]. We have also demonstrated that the laser milled surface has minimal roughness with the mirror-like polishing finish and the best processing quality is achieved using the same laser processing parameters that were used to get the ablation with the highest throughput [4]. The role of oxide on metal to the ablation threshold has been demonstrated [5]. We also showed that the ablation of the pre-heated samples was more efficient than the conventional laser ablation in normal conditions [6]. The ability to efficiently control the wettability from highly-hydrophilic to super-hydrophobic by femtosecond laser-induced ripples and nano-spikes has been demonstrated [7]. We have achieved important results, finding the numerical procedure to predict an optimal laser processing parameter set for the most efficient ablation, a new theoretical model for rectangular cavity milling was created [8]. The modeling results coincided well with the experiment data (Fig. 1 (a) and (b)). The efficient laser milling procedure was used to engrave the logo of Center for Physical Sciences and Technology (FTMC) (Fig. 1 (c)) and to replicate bio-inspired drag-reducing trapezoidal-riblets (Fig. 1 (d)) at high fabrication rates. The ability to form functional surfaces on two-and-a-half-dimensional (2.5D) cylindrical surfaces was demonstrated [9]. To conclude, presented theoretical and experimental data of optimized and precisely controlled laser milling technology is a perfect technique that enables mimicking the large variety of bio-inspired functional surfaces that has naturally developed in nature over millions of years. The reliability of ultrafast lasers and the increase of output optical power together with the reduction of price opens up new opportunities for the real manufacturing of functional surfaces from small-batch laboratory fabrication to large-scale real industrial production.

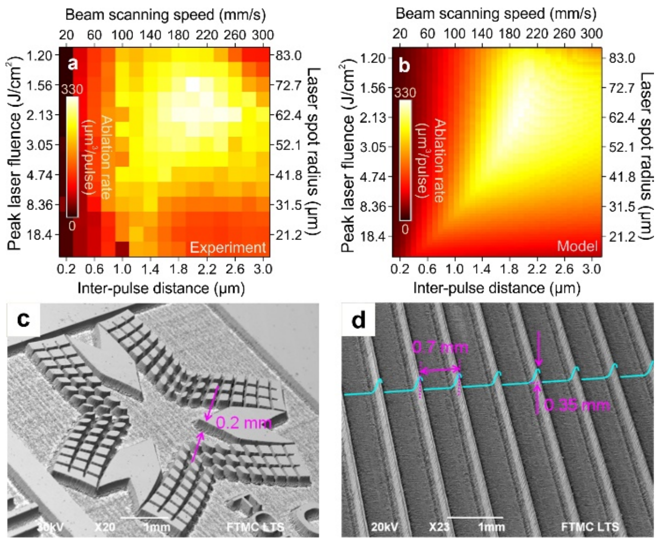

Fig. 1. The comparison of laser ablation experiment with model and examples of efficient surface structuring. Laser ablation rate (color scale) versus the peak laser fluence (left axis), laser spot radius (right axis), inter-pulse distance (bottom axis), and the beam scanning speed (top axis): (a) experiment and (b) model. Scanning electron microscope (SEM) images of structures ablated in copper by using efficient laser milling technology: (c) logo of FTMC, (d) drag-reducing trapezoidal-riblets structure. Reproduced from Ref. [8] with permission from Springer Nature.

References

1. A.Žemaitis, M. Gaidys, P. Gečys, M. Barkauskas, M.Gedvilas, Opt. Express DOI 10.1364/OE. 417883 (2021).
2. A.Žemaitis, P.Gečys, M. Barkauskas, G. Račiukaitis, and M. Gedvilas, Sci. Rep. **9**, 12280 (2019).
3. A.Žemaitis, P.Gecys, G.Raciukaitis, M.Gedvilas, Procedia CIRP **94**, 962 (2020).
4. A.Žemaitis, M. Gaidys, P. Gečys, G. Račiukaitis, M.Gedvilas, Opt. Lasers Eng. **114**, 83 (2019).
5. A.Žemaitis, M. Gaidys, P. Gečys, M. Gedvilas, Opt. Lett. **45**, 6166 (2020).
6. A.Žemaitis, J. Mikšys, M. Gaidys, P. Gečys, M.Gedvilas, Mater. Res. Express **6**, (2019).
7. A.Žemaitis, A.Mimidis, A.Papadopoulos, P. Gečys, G. Račiukaitis, E. Stratakis, M. Gedvilas, RSC Adv. **10**, 37956 (2020).
8. A.Žemaitis, M.Gaidys, M.Brikas, P.Gečys, G. Račiukaitis, M. Gedvilas, Sci. Rep. **8**, 17376 (2018).
9. M. Gaidys, A. Žemaitis, P. Gečys, M. Gedvilas, Appl. Surf. Sci. **483**, 962 (2019).