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Editorial

Editorial: Special Issue "Laser-Induced Periodic Surface Nano- and Microstructures for Tribological Applications"

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Laser material processing is an innovative technology that generates surface functionalities on the basis of optical, mechanical, or chemical properties [1]. In the form of laser surface texturing (LST), it has attracted a remarkable amount of research to tailor surface properties towards various tribological applications [2]. Of this single-step, laser-based technology, the main advantages are the contactless machining, featuring a high flexibility, efficiency, and speed, along with the excellent quality of the processed products. LST can be applied precisely, localized to sub-micrometric areas, but, via laser beam scanning, it is also feasible for structuring large surface areas the size of square-meters.

This Special Issue, "Laser-Induced Periodic Surface Nano- and Microstructures for Tribological Applications" (https://www.mdpi.com/journal/lubricants/special_issues/laser_periodic) [3–11] focuses on the latest developments concerning the tribological performance of laser-generated periodic surface nano-/microstructures and their applications. This includes the laser-based processing of different surface patterns, such as "self-organized" laser-induced periodic surface structures (LIPSS, ripples) [12], grooves, micro-spikes, hierarchical hybrid nano-/microstructures, microfeatures generated by direct laser interference patterning (DLIP) [13], and even dimples or other topographic geometries shaped by direct laser modification or ablation. The applications of these periodically nano-/micropatterned surfaces are aimed at improving the lubricated or non-lubricated tribological performance of surfaces in conformal [4,7,11] and even non-conformal contacts [5,6,9,10] through a reduction of wear, a variation of the coefficient of friction (CoF) [4,5,8,11], altered load carrying capacity, and more. Such enhanced tribological performances result in energy savings, improved reliability, increased lifetimes, as well as durability, leading in turn to extended maintenance intervals and, thus, reduced down-time. The latter is especially beneficial for bearings, gears, engines, seals, cutting tools, and other tribological components. Fundamental aspects involve relevant physical [7] and chemical effects [4,10] accompanying the laser-generated nano-/microscale topographies. Such aspects are, e.g., alterations of the material structures [10], hardness, superficial oxidation [4,10], the role of additives contained in lubricants [10], surface wettability and directed liquid transport [6,7], micro-hydrodynamic effects [7], and more.

Two feature papers [3,4] were invited for the adequate framing of this Special Issue. Seven more papers were submitted as regular contributions [5–11]. Both academic and industrial researchers were attracted, providing a bridge between research in the fields of tribology and laser material processing. This allowed us to foster the current knowledge and present new ideas for future applications and new technologies.

Grützmacher et al. [3] provided a review article on multi-scale surface texturing, discussing the current knowledge and future perspectives in tribology. The authors underline that numerical methods and experiments should be suitably combined to further push the development and design of multi-scale surfaces to enable lower friction and wear over a broader range of tribological conditions.

Schille et al. [4] presented a new world-record in high-rate laser surface texturing for enabling tribological functionalities. The authors demonstrated large-area surface texturing at 3.8 m^2/min. maximum area processing rate. They achieved this by employing ultrafast lasers with MHz pulse repetition rates in combination with polygon scanner technologies. This allowed for unprecedented 950 m/s beam moving speeds. This extremely high processing rate could be achieved by splitting the laser beam for parallel and ultrafast processing at 560 m/s scan speed. In practice, when considering the 40% facet utilization rate of the installed polygon scanner setup, the effective processing rate was still 1.5 m^2/min. for large-area surface texturing. This is at least twice the surface processing rates for metals reported elsewhere.

Rung et al. [5] compared the tribological performance of dry and oil-lubricated periodic surface structures generated on steel surfaces either via self-organization (LIPSS) or by DLIP. Although structures with similar periodicity (0.9–1.5 μm) were produced, their tribological behaviour in a linear reciprocating ball-on-disc configuration was different [attributed to the different modulation depths of either ~0.2 μm (LIPSS) or ~1.5 μm (DLIP)]. For both, the dry and lubricated test conditions, a reduction of the coefficient of friction could always be reached by at least one type of the laser-generated periodic surface structures.

Stark et al. [6] studied the effects of periodic surface textures for the avoidance of starvation in the lubricated tribo-contact. In numerical simulations and experiments, the beneficial effect of a directed lubricant (oil) transport was demonstrated through periodic DLIP-generated micro-groove patterns.

Bijani et al. [7] developed a theoretical model to study the effects of surface texturing on the frictional behaviour of parallel sliding contacts under starved lubrication conditions. Applying a deterministic asperity contact model, which considered the effects of different scales of surface features (texture and roughness), it was shown that surface texturing may improve lubricant film formation under the conditions of starvation. Moreover, under certain conditions, the surface texturing can reduce the CoF.

Voyer et al. [8] presented an industrial approach which determined the manufacturing feasibility of a specific 3D surface micro-texture on hardened steel through ultrashort pulsed laser processing. These surface structures were then qualified regarding their tribological properties under different lubrication conditions with either oil or a solid "anti-friction" coating.

Van der Poel et al. [9] investigated the ps-laser based fabrication of different types of LIPSS on medical grade cobalt-chrome-molybdenum alloy for hip prosthesis applications. Emphasis was laid on their associated tribological, surface wetting, and leaching properties. Based on their experimental results, the authors concluded that the laser textured surfaces on CoCrMo alloy are not suitable for bearing surfaces in a metal-on-plastic contact. However, they gave recommendations for future improvements.

Ayerdi et al. [10] confirmed a prior hypothesis on the role of the lubricant ZDDP (zinc-dialkyl-dithiophosphate), present in many commercial engine oils. A ZDDP-additivated engine oil was "re-build" from its basic constituents. Its beneficial behaviour was verified in linear, reciprocating tribological tests of LIPSS-covered titanium alloy surfaces against balls made of different materials.

Gnilitskyi et al. [11] measured the Stribeck curve of X5CrNi18010 stainless steel against 100Cr6 steel in engine oil lubricated pin-on-flat tribological tests. The rotating disks were covered by fs-laser processed LIPSS. Over the entire range investigated (Stribeck numbers between 5×10^{-7} and 8×10^{-6} m^{-1}), the CoF of the LIPSS-patterned surface was substantially lower than of the non-patterned one, with the reduction ranging from 10% up to 25% (at 5–9 $\times 10^{-7}$ m^{-1}). Simultaneously, wear reductions of 65% were obtained.

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Conflicts of Interest: The authors declare no conflict of interest.

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