Tribological surface functionalization via femtosecond laser-induced periodic surface structures on metals

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Abstract

Laser-induced periodic surface structures (LIPSS, ripples) were generated on titanium and steel surfaces upon irradiation with multiple linear polarized femtosecond laser pulses in air environment (pulse duration 30 fs, central wavelength 790 nm, pulse repetition rate 1 kHz, Gaussian beam shape). The conditions (laser fluence, spatial spot overlap) were optimized in a sample-scanning geometry for the processing of large surface areas covered homogeneously by two different types of nanostructures, i.e., low-spatial frequency LIPSS (LSFL) with periods around 600 nm and high-spatial frequency LIPSS (HSFL) having periods around 100 nm only.

The tribological performance of both types of nanostructured surfaces was characterized under reciprocating sliding condition against a ball of hardened steel at 1 Hz using different lubricants. After 1,000 cycles, the corresponding wear tracks were characterized by optical and scanning electron microscopy. For specific conditions, the wear was strongly reduced and the laser-generated nanostructures (LSFL) endured the tribological treatment. Simultaneously, a significant reduction of the friction coefficient was observed in the laser-irradiated LIPSS-covered areas when compared to the non-irradiated surface, indicating the potential benefit of laser surface structuring for tribological applications.

For optimization, the spatially Gaussian shaped beam used for the laser processing was transformed into a “Top-Hat” distribution at the surface of the samples. This was experimentally realized by using a spatial light modulator (SLM). The tribological performance of samples processed with a Top-Hat beam is compared to the one generated with a Gaussian shaped laser beam.