

Project LiNaBioFluid

Deliverable D3.6: Publication of results on laser-mimicking of bug-like surface structures and its fluid transport

Reporting period	from	01.07.2016	to	30.09.2017
Report completed and released		27.09.2017		

1. Objectives and Detailed Description

The goal of D3.6 was to publically present project results of Task 3.2 and Task 3.3 at the traditional laser-matter interaction symposium at the Spring Meeting 2017 of the European Materials Research Society (E-MRS) in Strasbourg, France, associated with an article submitted to the symposium proceedings.

The results obtained until month 27 in Task 3.2: '*Laser-based mimicking of bug structures*' and in Task 3.3 '*Characterization of fluid transport and friction/wear*' are the basis of this deliverable.

On January 17th, 2017, an abstract entitled "*Mimicking bug-like surface structures and their fluid transport produced by ultrashort laser pulse irradiation of steel*" [1] was submitted by BAM to the E-MRS Spring Meeting 2017, Symposium X "New frontiers in laser interaction: from hard coatings to smart materials", May 22nd - 26th 2017, in Strasbourg (France). The abstract was accepted by the symposium organizers as an oral presentation (presentation number X.2.5). In cooperation with all WP3 partners, JKU (WP2), and CSIC (WP4), the talk was prepared and presented to the public by BAM on May 22nd, 2017, during session 2 of Symposium X (13:30 - 15:30). The publication will be announced on the LiNaBioFluid webpage (www.laserbiofluid.eu).

In several joint WP3/WP4 telephone conferences and during the annual consortium meetings in Heraklion and Aachen, the material (steel 1.7225) was selected to be focus of D3.6 and different strategies for obtaining the desired wetting behaviour and directional fluid transport were discussed to be tested by the different partners.

During month 25, the manuscript entitled "*Mimicking bug-like surface structures and their fluid transport produced by ultrashort laser pulse irradiation of steel*" (associated with the above mentioned oral presentation) was prepared in cooperation of all WP3 partners, CSIC, and JKU [2]. The manuscript was submitted to a special issue of the journal Applied Physics A by BAM on June 29th, 2017. At release of this document, the manuscript is the peer review stage after resubmitting a revised version of it to Applied Physics A on September 15th, 2017. The final publication date of the Applied Physics A Special Issue (Symposium X conference proceedings) is expected for May 2018.

Once accepted for publication in Applied Physics A and considering the associated copyrights, which will be transferred to the publisher Springer-Verlag, parts of the content will be made available to the public on the LiNaBioFluid webpage (www.laserbiofluid.eu).

2. Evaluation of Goals and Resulting Actions

The expected goal for D3.6 was successfully reached by month 24, i.e., the results of Task 3.1 were presented to the public at the E-MRS Spring Meeting in May 2017 in Strasbourg (France) and an associated journal publication was submitted to a Special Issue of Applied Physics A (conference proceedings) in June 2017.

Abstract [1] and manuscript [2] demonstrate the successful collaboration across the borders of WP2, WP3, and WP4. The manuscript [2] proves that the research in Tasks 3.2 and Tasks 3.3 was conducted fully in line with the work initially proposed in the grant agreement.

In more detail, different laser processing strategies were employed to mimic bug-like surface structures on inorganic materials (steel) via ultrashort laser processing. By systematically varying laser processing parameters such as the peak fluence, the number of effective pulses per spot, the irradiation angle and atmosphere during laser processing using ultrashort pulses (fs-ps), the micro-ornamentation found on bark bugs was successfully mimicked on steel. The shape of the micrometre-sized tilted spikes found underneath the wings of the bark bug *D. magnus* was reproduced on alloyed 1.7225 steel when irradiating the sample under an angle of 40° in air at moderate and high numbers of ps-laser pulses. Furthermore, the hydrophobic functionality of the natural prototype could be achieved on the laser processed steel surfaces. Oil transport on those surfaces was found to be omnidirectional. On fs-laser processed areas featuring size gradients from micrometre-sized spikes to nanometre-sized ripples the unidirectional fluid transport identified on the bark bugs surface was effectively imitated for water (immediately after the laser processing) as well as for engine oil (~ 2 weeks after laser processing). The fastest unidirectional fluid transport was observed for water featuring velocities up to 75 mm/s, while for engine oil the transport was significantly slower in the range of 0.03-0.05 mm/s. The laser processing the spikes was tested at higher repetition rates, proving that the formation those functional microstructures is feasible at repetition rates up to 500 kHz without losing its surface wetting properties. The results go beyond the current state of the art of laser processing (see for example the review articles [3,4]), since the joint activities of all WP3 partners, CSIC, and JKU resulted in the successful transfer of natural wetting and fluid transport functionalities of bark bugs to technologically relevant materials, such as steel, including the demonstration of the area scale up of the laser-processed surface structures.

Deliverable D3.6 is complemented by deliverable D3.5 '*Public summary of laser processing of bug-like structures with fast fluid transport*', where a comparison of SEM images of micro- and nanostructures found on the integument of bark bugs and of similar laser-structures generated on titanium and steel along with an example for fast water transport on gradient structures will be published on the LiNaBioFluid website (www.laserbiofluid.eu).

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References:

[1] S.V. Kirner, U. Hermens, K. Winands, H. Mescheder, C. Florian, J. Solis, J. Siegel, F. Hischen, W. Baumgartner, E. Skoulas, A. Mimidis, E. Stratakis, D. Spaltmann, J. Krüger, J. Bonse, *Mimicking bug-like surface structures and their fluid transport produced by ultrashort laser pulse irradiation of steel*, abstract accepted for oral presentation at the E-MRS 2017 Spring Meeting, May 22nd to 26th 2017,

Strasbourg (France), Symposium X: New frontiers in laser interaction: from hard coatings to smart materials.

[2] S.V. Kirner, U. Hermens, A. Mimidis, E. Skoulas, C. Florian, F. Hischen, C. Plamadeala, W. Baumgartner, K. Winands, H. Mescheder, J. Krüger, J. Solis, J. Siegel, E. Stratakis, J. Bonse, *Mimicking bug-like surface structures and their fluid transport produced by ultrashort laser pulse irradiation of steel*, submitted to Appl. Phys. A, submitted 29.06.2017 / revised 15.09.2017.

[3] K. Ahmmed, C. Grambow, A.-M. Kietzig, *Fabrication of micro/nano structures on metals by femtosecond laser micromachining*, Micromachines **5** (2014) 1219 – 1253.

[4] F.A. Müller, C. Kunz, S. Gräf, *Bio-inspired functional surfaces based on laser-induced periodic surface structures*, Materials **9** (2016), 476.