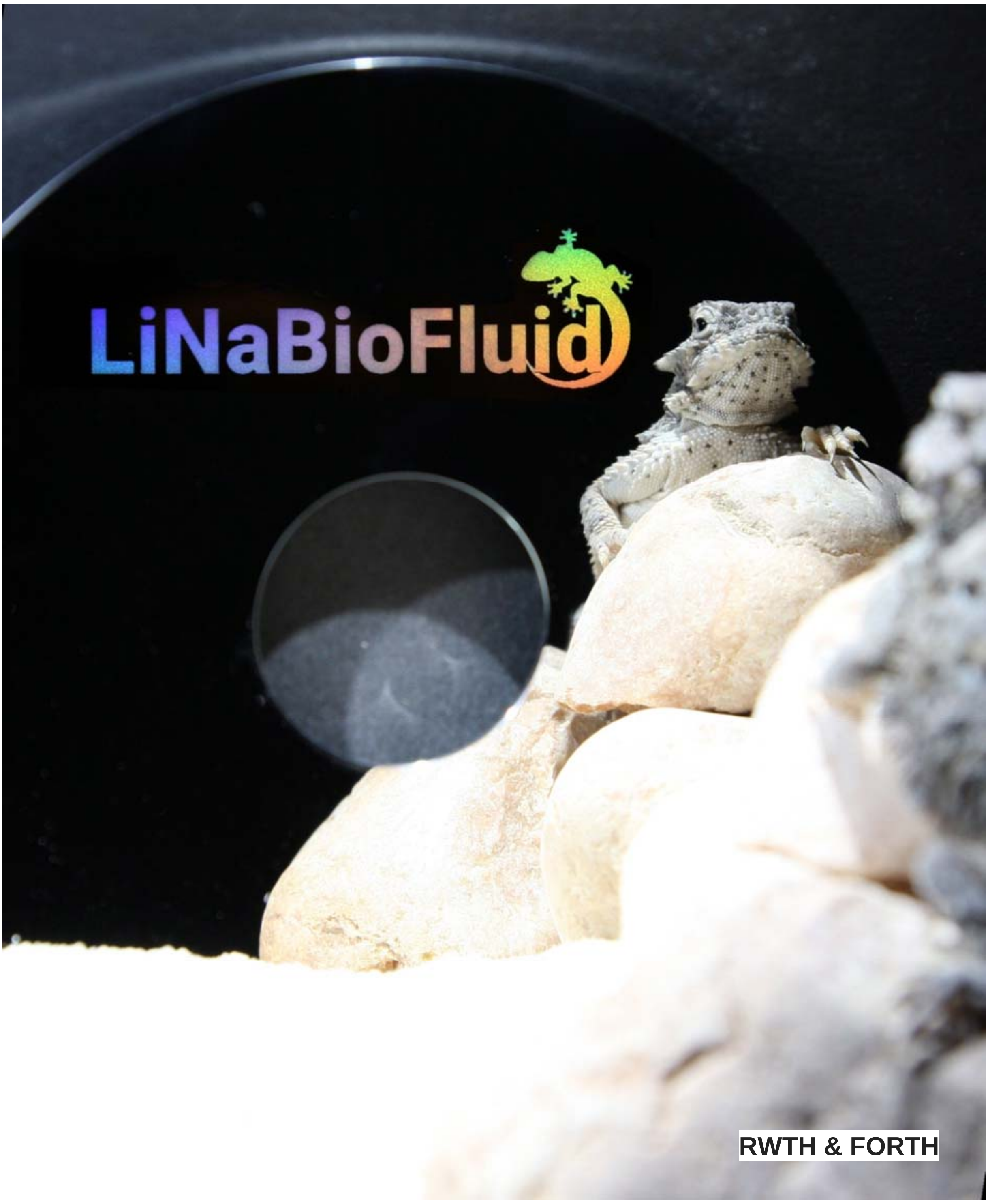
EU Project LiNaBioFluid



Deliverable 4.2

Large-area laser-fabricated biomimetic structures

Reporting period	from	**01.07.2015**	to	**28.02.2017**
Report completed and released		**07.03.2017**		

Corresponding work packages: *WP4*

Corresponding tasks: *T4.1 Large-area structures and T4.2 Scale-up to manufacturing size*

Contributing WP4 partners: *Fraunhofer IPT, CSIC*
Contributing WP2 partner: *RWTH Aachen, JKU*

1. Objectives

This deliverable involves the identification of the optimum processing parameters for the fabrication of moderate size (1 cm^2), flat areas, mimicking lizard- and bug-like surface structures. The starting point will be the parameters identified in D4.4. Optimum parameters will be identified by means of a systematic study on different inorganic materials, employing high-repetition rate pico- and femtosecond lasers and beam scanning. The parameter space explored will include substrate material, laser wavelength, pulse duration, repetition rate, polarization, pulse energy, spot size, scan velocity, line separation, and number of scans. Optimized structures will be fabricated and their functional performance in terms of fluid transport tested.

2. Results

2.1 Laser parameters

The table below illustrates the different irradiation parameters explored by the two partners with laser processing capabilities (CSIC and Fraunhofer IPT), covering a broad parameter space.

	Wavelength	pulse duration	repetition rate	polarization
CSIC	1030 nm	350 fs	10 – 500 kHz	linear/circular
Fraunhofer IPT	532 nm	8 ps	80 - 1000 kHz	linear

Table 1: Laser irradiation parameters used by CSIC and Fraunhofer IPT.

2.2 Materials investigated

As for the substrate materials studied, it was decided to concentrate on steel as considered in the project.

2.3 Lizard structures

Fluid transport properties were tested by RWTH Aachen and JKU. Fluid transport can be generated by a capillary channel network with structural sizes in the order of several hundreds of micrometers as found on the skin of lizards. In addition to the capillary channel network, a micro-dimple pattern with typical diameters of a few tens of micrometers is present. Capillary networks with and without dimple structures have been fabricated by ps and fs laser irradiation in steel. Fig. 1 shows images of the structures obtained with a ps-laser, Fig. 2 those obtained with a fs-laser (without dimples), leading to comparable fabrication results.

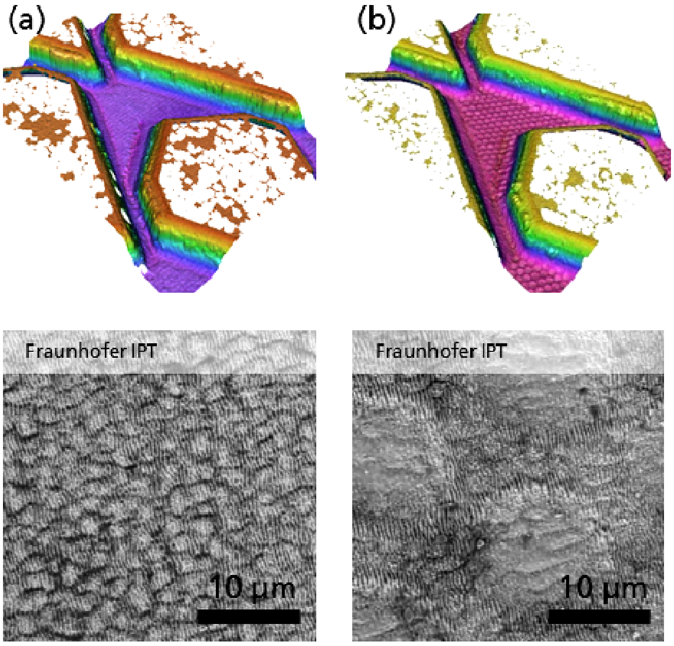


Fig. 1: Lizard structures fabricated in steel with a ps laser. 3D-surface topographies (top) of ps-laser-manufactured hierarchical surface topographies on steel, mimicking the integument of moisture-harvesting lizards. The lower line assembles magnifying SEM micrographs taken at the bottom of the corresponding capillary. (a) Capillary channels without dimples as a reference. (b) Capillary channels with a bottom pattern of micro-dimples.

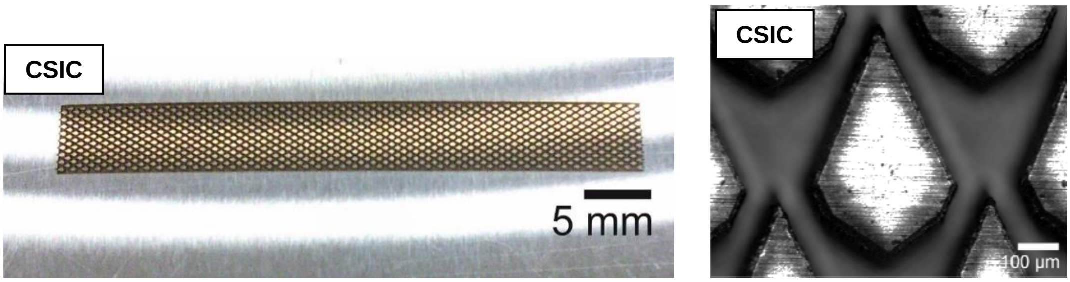


Fig. 2: Lizard structures fabricated in steel with a fs laser. (left) Optical micrograph of the entire 4 cm x 0.5 cm structure. (right) higher resolution optical micrograph illustrating the very sharp borders of the fabricated capillary channels.

For testing the fluid transport, the two capillary channel systems fabricated with ps laser pulses (with and without dimples, see Fig. 1) were exposed to a cooling lubricant. Fig. 3 shows the fluid transport behavior. The liquid rapidly started to enter the capillary channels, while part of the liquid sustained as droplet above the original surface.

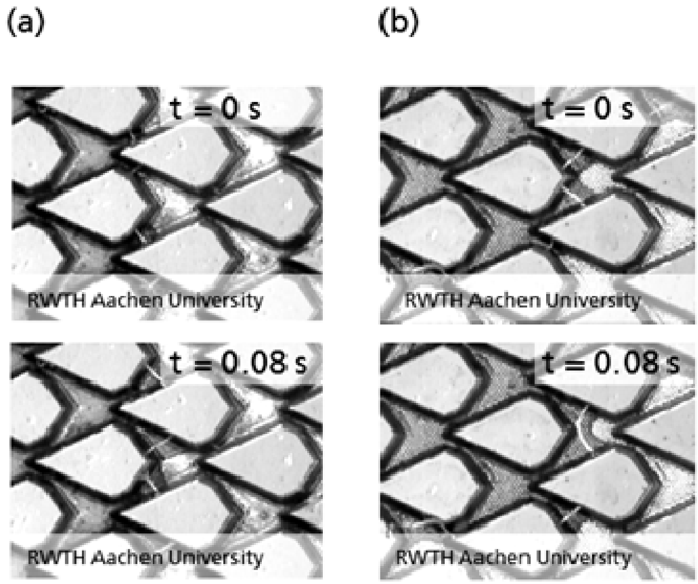


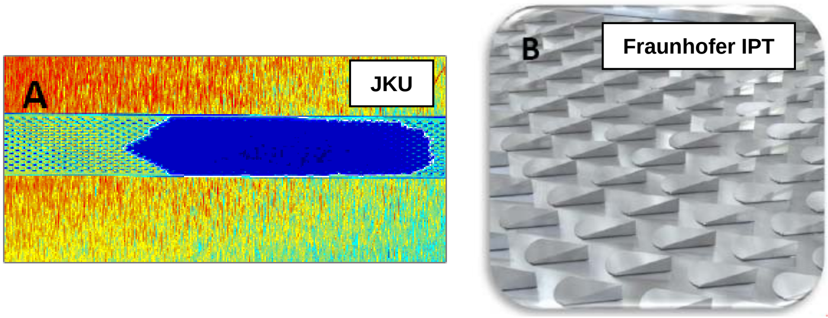
Fig. 3: Image sequence of capillary transport of a cooling lubricant in the structures shown in Fig. 1. Droplets of 2 µl were applied and video recorded at high magnification. (a) The transport in capillary surface channels without additional micropatterns at the bottom showed a regular liquid front. (b) Transport in capillary channels that contain an additional bottom dimple structure. In all images, the warped bright lines are specular reflections of the illuminating light source at the curved surface of the liquid.

Via high-speed video microscopy, the transport velocity of the liquid in the capillary channels without dimples [Fig. 3(a)] and with dimples [Fig. 3(b)] was determined. The higher transport velocity in channels containing the dimple structures appears to correspond with the improved wetting properties by these additional features. The transport velocities determined for the laser processed steel surfaces are smaller than those on the natural archetype. The different values are attributed to the significantly different material/liquid properties involved.

More details on the lizard structures fabricated in steel can be found in the following publication: Mimicking lizard-like surface structures upon ultrashort laser pulse irradiation of inorganic materials, U. Hermens, S.V. Kirner, C. Emonts, P. Comanns, E. Skoulas, A. Mimidis, H. Mescheder, K. Winands, J. Krüger, E. Stratakis, J. Bonse, Applied Surface Science, online 15 December 2016, http://dx.doi.org/10.1016/j.apsusc.2016.12.112.

2.4 Bug structures

Laser-structured capillaries were produced by ps-laser processing that were inspired by the microstructures of external scent efferent systems found in different European true bug species. We succeeded in producing artificially structured surfaces in different materials that exhibit facilitated fluid movement in one direction and complete fluid halt in the opposite (see figure below) for different test fluids. With regard to large-area designs, we furthermore succeeded in laser fabricating prototypes with areas of 5 cm^2 (e.g. channel depicted in A, which has a dimension of 5 x 1 cm).



(A) original image in false color scale of cutting oil on steel moving in the laser-structured channel from left to right, (B) schematic design of structures in the channel. Fluid will always move facilitated into direction of the pointed tips of the structures, while being halted in direction with the round shaped structure base.

3. Evaluation of results and goals

The expected goal for D4.2, to fabricate lizard- and bug-like surface structures of moderate size (1 cm^2) in steel has been successfully reached. With this achievement it is feasible to reach the next step by M30 in form of deliverable D4.3 (lizard- and bug-like structures scaled up to larger sizes (aiming for 10 cm^2) and to match the specific surface shape of no-flat substrates).