Project LiNaBioFluid

Deliverable D2.1: Publication of results on lizard skin

Reporting period	from	**01.07.2015**	to	**30.06.2016**
Report completed and released		**21.06.2016**		

1. Objectives and Detailed Description

The goal of D2.1 was to publically present project results of Task 2.1 within the WP2 "Organic Materials". Task 2.1 covers the functional characterization of microstructures on the integument from lizards. These activities were performed by JKU and RWTH Aachen. Exuviae, i.e. regularly shed skin of the reptiles, were used for functional characterizations. In particular, this included the analysis of topology on two levels, the skin micro-ornamentation as well as capillary channels between the scales. Skin wetting properties were also investigated. In addition to the biological analyses, we were even able to transfer our findings to abstracted structure patterns suitable for functionalization of steel surfaces.

The skin of moisture harvesting lizards is covered with a nearly hexagonal micro-ornamentation which results in greater hydrophilicity to achieve a faster water acquisition for the lizard. Other lizards, which show hydrophobic wetting properties, exhibit a skin surface structure comparable to spikes. Both types of skin micro structures were analysed and abstracted. Then they were transferred to steel surfaces in order to modify surface wetting properties. The results were obtained by partners Fraunhofer IPT, RWTH, FORTH and BAM, and were presented at the traditional laser-matter interaction symposium at the Spring Meeting 2016 of the European Materials Research Society (E-MRS), associated with an article submitted to the conference proceedings (see D3.3):

[1] U. Hermens, S.V. Kirner, C. Emonts, P. Comanns, E. Skoulas, A. Mimidis, H. Mescheder, K. Winands, J. Krüger, E. Stratakis, J. Bonse, Mimicking lizard-like surface structures upon ultrashort laser pulse irradiation of inorganic materials, submitted to Applied Surface Science, 16.06.2016.

Applying the technology of two-photon polymerization, the lizard skin micro structures were successfully replicated with organic material using a liquid acrylate based resin containing a photo-initiator. Wetting tests demonstrate the functionality of enhanced wettability and water sustainment for potential applications in fields of bio-inspired microfluidic devices. The results were obtained by partner JKU and presented in an invited talk by J. Heitz at the 18th International Conference on Transparent Optical Networks ICTON 2016, Trento, Italy:

J. Heitz, C. Plamadeala, M. Wiesbauer, P. Freudenthaler, R. Wollhofen, J. Jacak, S. Puthukodan, T.A. Klar, A. Weth, W. Baumgartner, B. Magnus, R. Marksteiner (2016). Three-dimensional photonic structures on transparent substrates fabricated by two-photon polymerization for use as cell substrates and for wetting experiments.

The results were also published in the conference proceedings as:

[2] J. Heitz, C. Plamadeala, M. Wiesbauer, P. Freudenthaler, R. Wollhofen, J. Jacak, S. Puthukodan, T.A. Klar, A. Weth, W. Baumgartner, B. Magnus, R. Marksteiner (2016). Three-dimensional photonic structures on transparent substrates fabricated by two-photon polymerization for use as cell substrates and for wetting experiments. ICTON 2016 (in press).

The network of lizard skin capillary channels was abstracted and modelled mathematically for specific functionalization of material surfaces. Abstracted geometries of the capillary channels were transferred to polymer surfaces, i.e. poly(methyl methacrylate), for directional transport of aqueous liquids using CO_2 laser engraving. By distance measurements it was verified that the devices transport liquids of different contact angles in a preferential direction, while stopping it in opposite direction. The applied network of interconnected capillary channels was considered advantageous, in particular when it comes to defects during production or when particles block part of the capillary channels. Micro-analysis devices and lubrication were proposed as potential fields of application. The results were obtained by partners JKU and RWTH, and were presented as a talk at the conference Eurosensors 2015, Freiburg, Germany:

G. Buchberger, F. Hischen, P. Comanns, R. Baumgartner, A. Kogler, A. Buchsbaum, S. Bauer, W. Baumgartner (2015). Bio-inspired Microfluidic Devices for Passive, Directional Liquid Transport: Model- based Adaption for Different Materials.

The oral presentation was held at Eurosensors 2015, Freiburg, Germany on September 8th 2015. The findings were also published in the conference proceedings as:

[3] G. Buchberger, F. Hischen, P. Comanns, R. Baumgartner, A. Kogler, A. Buchsbaum, S. Bauer, W. Baumgartner (2015). Bio-inspired Microfluidic Devices for Passive, Directional Liquid Transport: Model- based Adaption for Different Materials, Procedia Engineering 120, 106 -111.

Abstracted geometries of the skin capillary channels were also used to functionalize steel surfaces for directional transport of cooling lubricants. For precise manufacturing, an Acceleration Compensation Algorithm was developed that optimizes the process of laser ablation to mimic the lizard skin surface. The results were obtained by partners RWTH, JKU and Fraunhofer IPT, and were presented at the *SPIE smart structures NDE 2016, Bioinspiration, Biomimetics, and Bioreplication* by partners RWTH and Fraunhofer IPT:

P. Comanns, K. Winands, M. Pothen, R.A. Bott, H. Wagner, W. Baumgartner (2016). The Texas horned lizard as model for robust capillary structures for passive directional transport of cooling lubricants.

The poster was presented to the public on March 22nd, 2016, during the poster session of *SPIE smart structures NDE* (6 pm – 7.30 pm). The corresponding publication in the conference proceeding was awarded with the second price of the *Bioinspiration, Biomimetics, and Bioreplication Best Student Paper Award*:

[4] P. Comanns, K. Winands, M. Pothen, R.A. Bott, H. Wagner, W. Baumgartner (2016). The Texas horned lizard as model for robust capillary structures for passive directional transport of cooling lubricants. Proc. SPIE 9797, Bioinspiration, Biomimetics, and Bioreplication 2016, 979711, doi: 10.1117/12.2218873.

2. Evaluation of Goals and Resulting Actions

The expected goal for D2.1 was successfully reached by M9, i.e., the results of Task 2.1 were presented to the public in four conference contributions followed by publications in the conference proceedings.

The publications demonstrate the successful transfer of structural parameters of the lizard skin to organic (PMMA, acrylate of PETA and BisGMA) and inorganic materials (steel) reflecting significant modification of wetting properties and directional liquid transport.

Using the technology of two-photon polymerization enabled a fabrication of precise hexagonal structures in size of the natural archetype [2]. Wetting tests proved that these structures not simply enhance the wettability, but have great functionality in liquid sustainment. This corresponds to the lizard skin properties of water sustainment.

Modelling the capillary transport supported the adaptation to specific material-liquid combinations [3] and resulted in more robust designs of surface capillary channels [4]. The micro structures on lizard scale surfaces were abstracted to a dimple structure (hydrophilic) and spike structure (hydrophobic), respectively. Both structures could be realized successfully in the collaboration across the WP2 and WP3 [1] and demonstrate their great potential in specific, structural modification of surface wetting properties.

As the combination of lizard capillary channel structures and surface micro structures was found to improve transportation properties, further investigation and tests will be conducted in this area. In this way, the great potential of natural wetting properties can be transferred to fluid transport functionalities of technologically most relevant materials, such as acrylates and steel.