Surface features of random structural variation

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In recent years a great progress in the systematic micro-and nanopatterning of technical surfaces has been achieved. Topographically induced effects include the reduction of abrasion and adhesive wear, the improvement of tribological characteristics or the implementation of self-healing functions. For these applications accuracy plays a central role in production: Component geometry, morphology and surface structures are defined as precise as possible, permissible tolerances are minimised and irregularities represent a deviation of quality [1].
In the course of evolution the animate nature has developed a variety of functional patterns and structures. Current biomimetic approaches aim at the optimisation of technical materials by analysing the biological antetypes and transferring their structural elements into technical applications [2]. Periodic structures in nature are often closely related to environmental circumstances. Important factors include tidal, temperature or day-night cycle [3]. For example the outer surface of an organism living in the desert must withstand drastically changing environmental influences: Friction during movement, particle blast in desert storms or attack by predators [4]. It is therefore assumed that the adaptation of nature in terms of efficiency and functionality is particularly high.
In contrast to the precision requested in industrial processing, biological structures only seem to possess a perfect, uniform regularity. Within the recurring patterns and periodic self-similar structures a randomly acting variation appears to be present (Fig. 1). The main goal of this work is to elucidate whether these variations are irrelevant or related to the particular functionality of a surface or if they are just a result of stimulus- environmental interaction and genetical predisposition. The diversity within the entire structural system may have an equally large influence on the respective function as the structure itself.

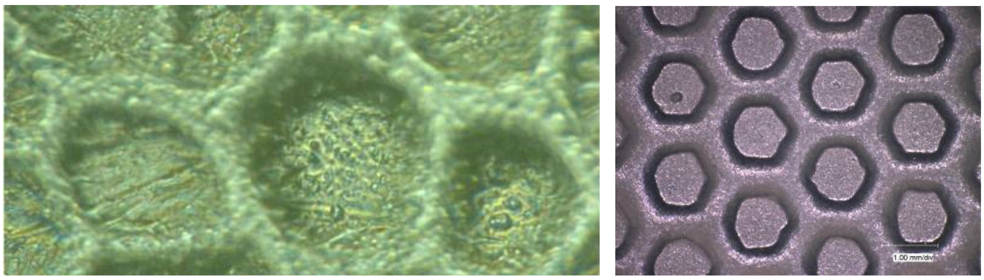

Figure 1: Surface of a colocynth [5] (left) and technical application (right)

To verify this hypothesis comparative experiments with both, regular and natural structured technical surfaces, are carried out. Here, a second challenge of the project becomes visible: How is it possible to produce a technical surface with a nature-like variety? First experiments are conducted by replicating the structures of biological antetypes with polysiloxane (PDMS) (Fig. 2). The performances of these surfaces are compared with PDMS-surfaces patterned by regular structural elements with the same average size and shape of the particular biological model. Surfaces of reptiles like lizards and desert plants like the colocynth are characterised and compared to their abstracted surfaces with regard to the minimisation of friction and abrasion.

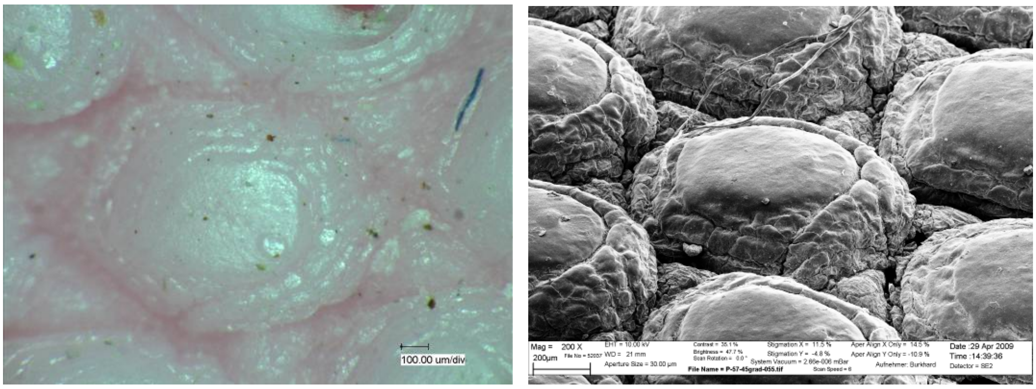

Figure 2: Positive imprint of the skin of the water monitor (left) and SEM micrograph of the skin (right).

To determine the highest possible accuracy of biological systems several surfaces are investigated: The dimension of moth eyes were found to exhibit a standard deviation of the diameter average less then 2,8 µm ± 173 nm. Concerning the complex system of an eye and the low variation of light waves, insect eyes seem to be structured very precisely. This result indicates that nature indeed is able to build up accurate structures. Yet, there is no explanation for the variety found in most biological structures and the question, if it is part of the function or just caused by the fact that in these cases building uniform structures is not necessary, is still unsolved.
The transfer of such surface structures to technical applications is also part of the project. The application of generative techniques, like rapid prototyping respectively, to design natural structured technical surfaces is investigated.
If a relation of function and the surface topography in terms of regularity and variability can be found, biomimetic surfaces and their performance can be optimised by employing generative techniques.

References

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