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Nature-Inspired, Multi-Functional Surface Coatings for Sustainable Life Support in Space and on Earth

The environmental control and life-support system (ECLSS) is, among other things, responsible for the absorption of humidity from cabin air, which is treated, stored, and re-used. However, efficiency could be improved, as only 70-93% of water is recyclable, and costly resupply from Earth is required.1 Furthermore, organisms such as bacteria and fungi start to disperse and proliferate at high humidity levels. This poses a potential risk towards material integrity in local moisture areas, but also towards the health of astronauts with a weakened immune system, limited treatment, and no immediate return to Earth. Therefore, control of microbial contamination is necessary, especially due to higher resistance and radiation tolerance in microgravity.2-3 Ionizing radiation, consisting of galactic cosmic rays and solar particle events, further threatens bio-regenerative ECLSS, but more importantly, is becoming the biggest risk to astronauts' health beyond Earth's magnetic field.4 Currently, neither of the above is feasible for missions to Moon, Mars, and beyond, thus finding new approaches for regenerative life support through passive systems is crucial.

Here, we present the design of a nature-inspired, multi-functional surface coating, which absorbs excess atmospheric moisture produced by astronauts' indoors activities and transports it passively to improve existing and future ECLSS. Inspired by the structures of cicada wings, moth eyes and tree capillaries (Figure 1a and b), the surface coating consists of artificially designed hollow vase-shaped microstructures (Figure 1c), fabricated by a high-resolution additive manufacturing technique using two-photon-polymerisation. Informed by calculations of different capillary widths, spacing, and angles, ground-based experiments were carried out (Figure 1d), demonstrating a significantly increased contact angle over the flat material and great surface tension. Further, liquid intake into the hollow structures can be noticed, which could be explained with capillary forces pulling the droplet in, and condensation formation is observable in a relatively humid environment. To the best of our knowledge, water droplet behaviour on vase-shaped microstructures has not been tested in a microgravity environment before; it will be fundamentally investigated in a parabolic flight at the 35th DLR parabolic flight campaign in June/July 2020. An increase in liquid intake under microgravity conditions can be expected, as capillary-dominated systems are supported 1,000 times more in space. The proposed structures could additionally lead to the transport of microbes and could potentially enhance radiation shielding. Advantages of this multifunctional surface coating include an improved understanding of passive hydrodynamic processes in microgravity, and, therefore, the reduction of energy consumption for applications in space and on Earth.

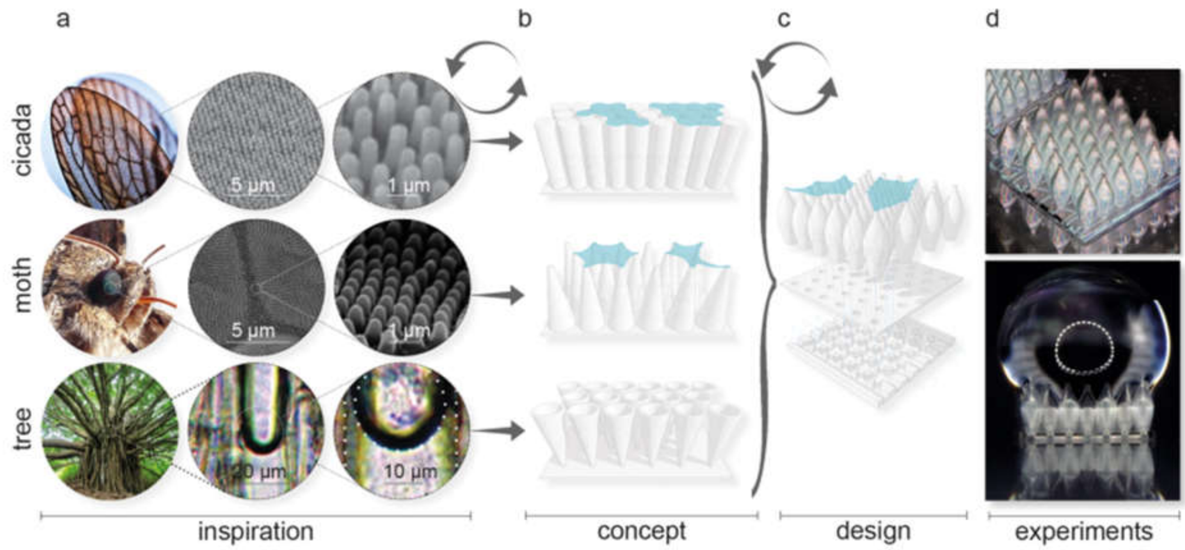

Figure 1: From inspiration, concept, and design to realization and experiments.

References
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