NATURE-INSPIRED. MULTI-FUNCTIONAL SURFACE COATINGS FOR SPACE APPLICATIONS, FABRICATED BY ADDITIVE MANUFACTURING

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Conditions in space are extreme. Nevertheless, the goal for the indoor environment on the International Space Station (ISS) remains the same as on Earth: to provide comfort and a healthy quality of life. The environmental control and life-support system (ECLSS) is, among others, 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 needed. Additionally, astronauts on the ISS experience 0.5 Sv of ionizing radiation in one year, consisting of galactic cosmic rays (GCR) and solar particle events (SPE). Beyond Earth’s magnetic field this can increase immensely, due to potential solar flares, leading to the biggest risk to astronauts’ health, including experience of radiation syndrome and cancer, but, furthermore, threatens future bio-regenerative ECLSS. Furthermore, with humidity of more than 60%, organisms such as bacteria and fungi start to disperse and proliferate. The weakened immune system of astronauts, limited treatment, no immediate return to Earth, and increasing resistance of bacteria, reinforces the control of microbial contamination. Currently, neither of the above is feasible for future missions to Moon, Mars, and beyond and, therefore, 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 that takes advantage of the humidity produced by astronauts’ indoors activities. This surface consists of hydrophobic microstructures that are able to transport humidity passively, via capillary action, through structures containing microchannels. They are inspired by cicada wings, human and moth eyes (Figure 4a), abstracted into pillar shaped and inverted cone and cone shaped structures, respectively (Figure 4b), and designed into multi-functional vase-shaped microstructures (Figure 4c). The artificial surface structures are fabricated by additive manufacturing (Figure 4d).

It can be estimated that the microstructures’ increase in performance under microgravity conditions as capillary-dominated systems are supported 1000 times more in space, due to the lack of gravitational forces. The structures further could repel bacteria and support radiation shielding as the hydrogen contained in water stops protons in SPE, fragments heavy ions in GCR, and slows down neutrons formed as secondaries. Advantages of this multi-functional surface coating include a better understanding of life comfort and health for astronauts regarding room quality, bacteria, and ionizing radiation, as well as an improved understanding of passive water systems, and, therefore, the reduction of energy consumption, and a better understanding of controlled humidity absorption for applications in space and on Earth.

Figure 1 – From inspiration, concept, and design to realization of the multi-functional surface coatings.