# Towards Biomimetics of Superhydrophobic Water Strider Feet

Lukas Hageneder [1], Karin Wewerka [1,2], Harald Plank [1,2], and Ille C. Gebeshuber [3]

1. Institute of Electron Microscopy and Nanoanalysis, Graz University of Technology, Steyrergasse 17, 8010 Graz, Austria
2. Graz Centre for Electron Microscopy, Steyrergasse 17, 8010 Graz, Austria
3. Institute of Applied Physics, Technical University Vienna, 1040 Vienna, Austria

## Introduction

Figure 1: Schematics of a water strider

Biomimetics is to fully understand the solution evolved by Nature to a problem and ultimately mimic such unique functionalities for future applications. As Leonardo da Vinci said: "[…] *those who take for their standard any but Nature - the mistress of all masters - weary themselves in vain.*"[1]. Our interest is focused on the fascinating capability of insects to run on water. Consequently, we investigated the superhydrophobicity of water strider feet, which is the result of a complex interplay between morphological micro- and nanofeatures and the related surface chemistry.

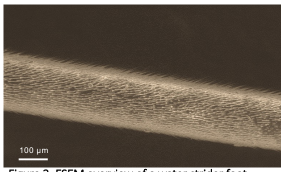



Figure 2: ESEM overview of a water strider foot

## Microstructure

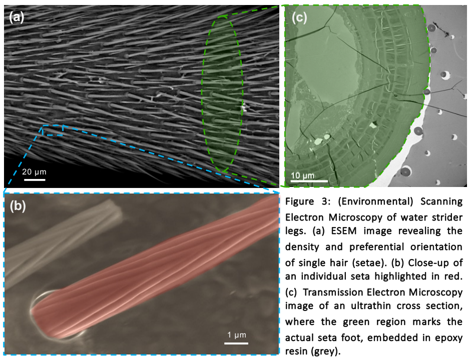



Figure 3: (Environmental) Scanning Electron Microscopy of water strider legs. (a) ESEM image revealing the density and preferential orientation of single hair (setae). (b) Close-up of an individual seta highlighted in red. (c) Transmission Electron Microscopy image of an ultrathin cross section, where the green region marks the actual seta foot, embedded in epoxy resin (grey).

The hierarchically structured morphology can be divided into micro- and nano-structures. The former consists of thousands of thin hair (setae) covering the entire foot of the water strider (Fig. 3), creating an air cushion, when in contact with a water surface.

## Chemistry

The nanostructure of setae was investigated via Atomic Force Microscopy, which revealed a thin layer with altered viscoelastic properties. To analyse this layer, the feet were exposed to the solvent $CHCl_3$ to dissolve the wax layer. Further analysis with FT-Infrared Spectroscopy (Fig. 4) shows that the measured spectrum (black) can be identified as Tridecane (red), which is an ideal nonpolar hydrocarbon molecule, having a structure similar to waxes.

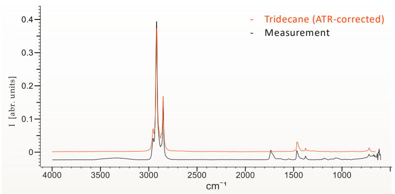



Figure 4: FT-IR spectra of the wax (black), which was first removed from the legs by $CHCl_3$ solution and subsequently dried under controlled conditions. The red spectrum shows the reference spectrum of Tridecane.

## Nanostructure

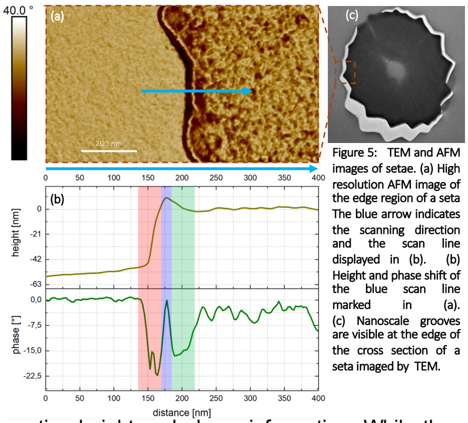



Figure 5: TEM and AFM images of setae. (a) High resolution AFM image of the edge region of a seta The blue arrow indicates the scanning direction and the scan line displayed in (b). (b) Height and phase shift of the blue scan line marked in (a). (c) Nanoscale grooves are visible at the edge of the cross section of a seta imaged by TEM.

To identify the nanostructure of the setae, the water strider foot was embedded into epoxy resin. A cross section was analysed in TEM, to characterise the structure of the setae (Fig. 5 (c)). The contribution of the wax layer to the morphology was studied via AFM (Figs. 5 & 6). The detailed analysis of the scan line marked with the blue arrow in Fig. 5 (a) shows the respective height and phase information. While the red shaded regions are due to morphology and therefore not reliable, the green shaded parts are free of height convolutions. The sub-50 nm wide phase shift towards lower values suggest a soft and / or adhesive layer. This is also clearly evident as a darker rim in the 2D phase image in Fig. 5 (a) and in Fig. 6. The blue shaded part of Fig. 5 (b) suggest a further layer, however, cannot be assumed as entirely convolution free.

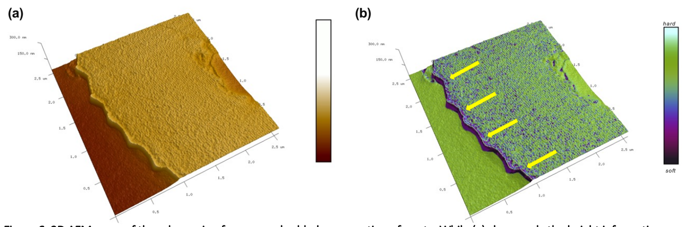
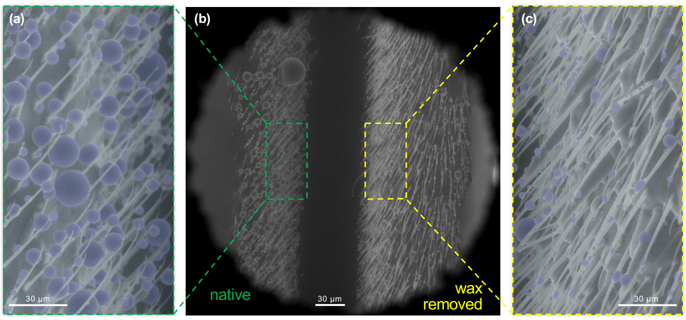



Figure 6: 3D AFM scans of the edge region from an embedded cross section of a seta. While (a) shows only the height information, (b) uses the phase information as coloured overlay. The soft and / or adhesive layer is shown in blue-purple (see arrows), which potentially indicates a waxy surface layer. The bright rim is also evident but not fully reliable due to convolution influences.

## Dynamic *in situ* Wetting



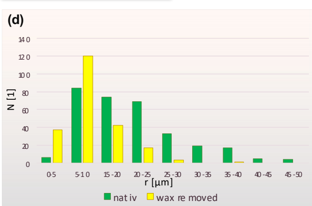




Figure 7: *In situ* ESEM & related analyses. (b) ESEM of two water strider feet. The left one is native; the right one is treated with $CHCl_3$ to remove the wax layer. (a) and (c) are magnified images; the water drops are marked in blue. In (d) a histogram sorted by the droplet radius for the native (yellow) and the treated specimen (green) is shown.

The wetting behaviour strongly depends on the wax layer (Fig. 7 (a - c)). In (c), representing the dewaxed specimen, the droplets are smaller and tend to cover the seta, in comparison to (a), the native one, the droplets are larger. This is statistically analysed in a histogram, shown in (d). The contact angle also confirms this finding: The native water strider foot is compared with the treated one:

$\theta_{CA}^{Nat} = (130 \pm 5)°, \theta_{CA}^{Treat} = (80 \pm 10)°$

## Conclusions

- The superhydrophobicity of water strider feet is the consequence of both hierarchical structuring and chemical properties.
- Setae are covered with an evenly distributed wax layer.
- The wax layer does not contribute to morphological features.
- The main purpose of the wax layer on the water strider foot is currently assumed to prevent condensation of a complete wetting layer, which would eliminate its floating capability.

## Leonardo da Vinci quoted from

Giorgio Vasari and Havelock Ellis. Vasari's Lives of Italian painters. London: W. Scott. p. 50, year 1890

## Acknowledgement

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## Contact

hageneder@felmi-zfe.at
karin.wewerka@felmi-zfe.at
harald.plank@felmi-zfe.at
gebeshuber@iap.tuwien.ac.at

www.felmi-zfe.at