Materials Design and Function of the Butterfly Proboscis

*Tatiana Stepanova[1] , A. Kaczmarek[1], C. Beard[2], P. Adler[2] and Konstantin Kornev[1]

[1] Department of Materials Science and Engineering, Clemson University, Clemson, SC

[2]Department of Plant and Environmental Sciences, Clemson University, Clemson, SC

Butterfly proboscis is a fascinating fiber equipped with sensors, actuators, and is able to transport fluids. For years, scientists studying surface phenomena have been challenged with understanding of physical and chemical interactions on surfaces that facilitate fluid transport. However, these interactions appear simpler from the perspective of common butterflies and moths. The proboscis consists of 2 hollow C-shape tubes, with a broad range of sizes [1, 2]. When butterfly is not hungry, proboscis is tightly coiled; when butterfly is about to drink, it uncoils proboscis. Proboscis still curls on its own after separation from the butterfly. Early studies into the feeding mechanism of these insects conclude that fluid transport is influenced by both the chemical and mechanical characteristics of the proboscis, its structure and chemical composition [3]. Furthermore, preliminary mechanical micro-tensile testing shows that while the proboscis is known to be mostly composed of chitin, its mechanical properties are significantly different. These results imply that some geometric and compositional factors influence the performance of this flexible fiber. Unlike any polymeric materials which show a non-linear stress-strain relation prior to breakup, proboscis behaves like a ceramic material. It follows Hookean behavior up to breakup; its maximum allowable deformation is just a few percent. Furthermore, these results are currently being investigated by turning to Thermal Gravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), tensile testing and analysis using optical and electron microscopy to determine how the other factors contribute to the performance of the butterfly proboscis during feeding. This intriguing behavior is explained by a very special plywood structure of proboscis and laminated architecture of its constituents.

References

1. Eassa, E.a., *The feeding mechanism of the butterfly Pieris Brassicae L.* Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 1955. **239**(659): p. 1-43.
2. Krenn, H.W., *Feeding Mechanisms of Adult Lepidoptera: Structure, Function, and Evolution of the Mouthparts.* Annual Review of Entomology, 2010. **55**: p. 307-327.
3. Hepburn , H., *Proboscis extension and recoil in Lepidoptera.* J Insect Physiol, 1971. **17**: p. 637-656.

Keywords: Fiber, Butterflies, Design, Mechanical properties, Thermal Analysis