APPLICATION NOTE

HYSITRON®

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Biological Materials

Determination of Young's Moduli of the Insect Cuticle (Dragonflies; Anisoptera)

Introduction

Multifunctionality is a common principle of biological structures. The cuticle of insect wings for example has to fulfill many different demands like high stability combined with low mass and an aerodynamically favorable construction. From a morphological point of view the multilaminated procuticle of insects can generally be described as a natural composite material consisting of mainly chitnous fibreil embedded in a protein matrix (Vincent 1980). The insect wing is composed of membranes surrounded by veins. To reduce mass, the membrane of a dragonfly wing (Anisoptera) is approximately 5 µm thick. Nevertheless, the special morphological construction and arrangement of veins and membrane combined with the particular mechanical properties of the wing cuticle guarantees the stability and aerodynamic function of this natural ultralight aerofoil (Kesel et al. 1998).

Process

In order to study the functional behavior of the dragonfly wing, it was simulated by means of the finite element method. The local micromechanical properties of different types of dragonfly cuticle were determined from the nanohardness measurements made with a Hysitron **TriboScope**®. Since the insect cuticle is covered with a wax layer, the imaging capability of the microscope is used to position the Berkovich tip onto suitable wax free locations.

Figure 1: Male dragonfly (Libelluia Depressa) resting on a blade of grass (photo: F. Wedekind).

The resulting force-displacement curves were used to calculate Young's moduli of 4.7+/-0.6 GPa, 2.9+/-0.8 GPa, 1.5+/-0.5 Gpa for the dry body cuticle (abdominal tergite), dry wing veins and wing membrane respectively. For comparison, the modulus of elasticity of polycarbonate determined with a Hysitron **TriboScope** is 3.5+/-0.3 GPa.

Conclusion

The Young's moduli determined by nanohardness measurements correlate with the varying functional demands of different types of dragonfly cuticle.

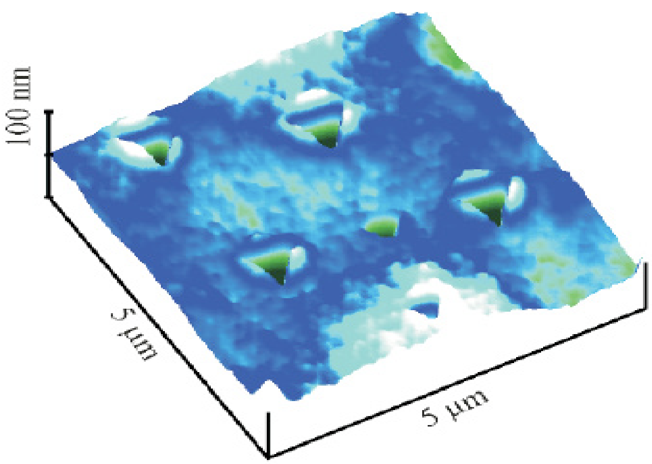

Figure 2: Nanohardness indentations on the dragonfly wing membrane. 5 µm scan of 100 and 200 µN indents.

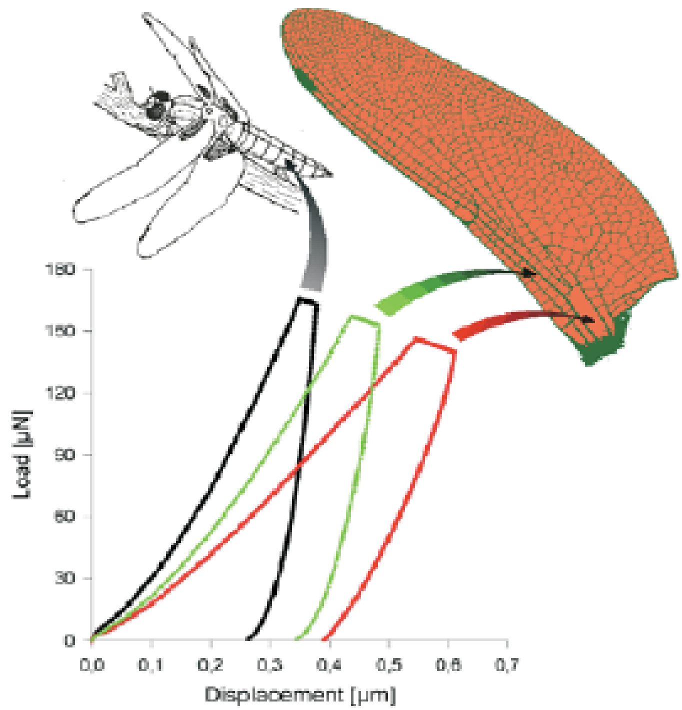

Figure 3: The resulting force-displacement curves of different types of dragonfly cuticle. Black: cuticle of the body (abdominal tergite); Green: wing vein; Red: wing membrane.

References:

1. Kesel A.B., Philippi U., Nachtigall W. (1998): Biomechanical aspects of the insect wing: an analysis using the finite element method. *Computers in Biology and Medicine,* 28 pp. 423-437.
2. Vincent J.F.V. (1980): Insect cuticle: a paradigm for natural composites; *Symp. Soc. Exp. Biol.*, 34, 183-210.

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