Karlsruhe Institute of Technology

Institute of Microstructure Technology

Analyzing the tribological combination of microstructure and lubricant in beetle joints for the development of environmentally friendly lubricants

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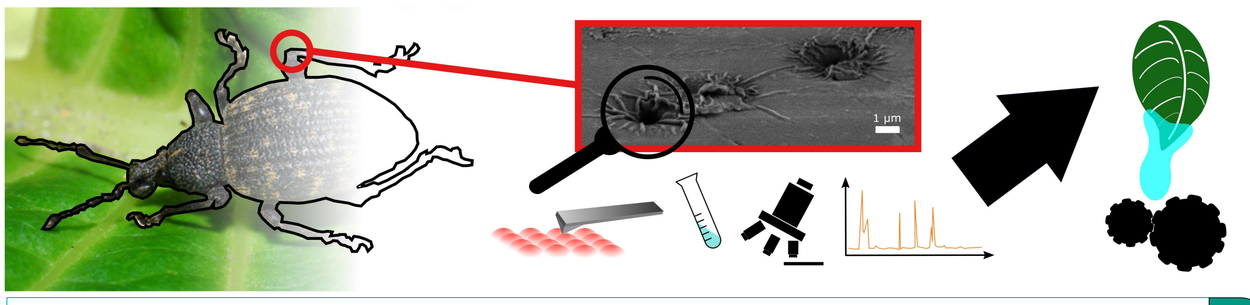
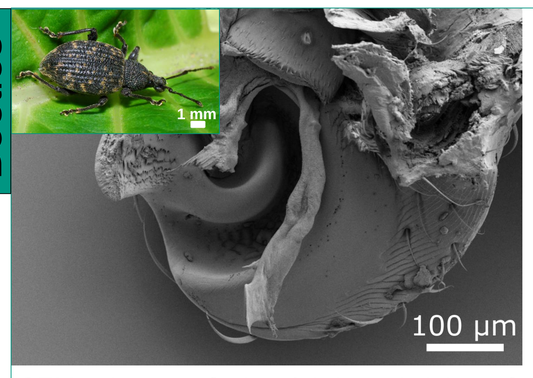
Introduction

- Green energy powerplants (wind, water etc.) use foremost lubricants made from fossils.

  “Green” Energy is not really green
- New studies suggest the existence of various lubricants in the joints of insects [1, 2]. Biomimetic research could lead to new lubricants as well as friction-reducing structures.
- To characterize the small quantities of the lubricant in the joints, friction measurements with the AFM are performed supported by additional methods.

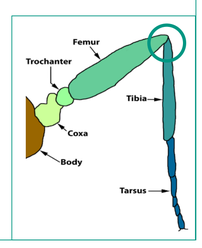


Beetles



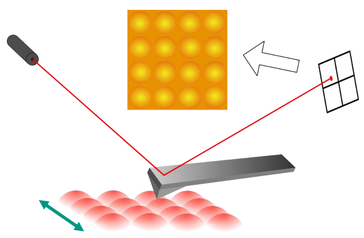
SEM picture of the lubricated joint of *Otiorhynchus sulcatus* and the beetle

- *Otiorhynchus sulcatus* (weevil)
- *Coelorrhina aurata* (rose beetle)



Methods

- The 4 quadrant photodiode allows the system to detect torsion of the cantilever.
- The difference between the trace and retrace signal can be interpreted as the friction.

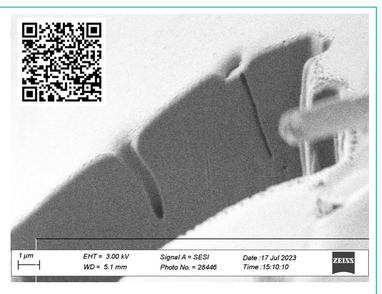


Schematic of the AFM

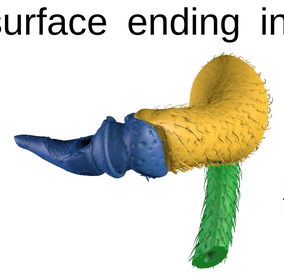
- Focused Ion Beam (FIB) tomography and µCT gives an insight below the surface.
- Microstructures fabricated with 3D-Direct Laser Writing (Nanoscribe Photonic Professional GT).

FIB/µCT

- Drastic differences between dried and fresh samples are visible in the SEM.
- FIB Tomography shows an elaborate network of lubricant supplying channels below the surface ending in pores.



FIB Tomography of pores (FIB work by Matthias Mail)

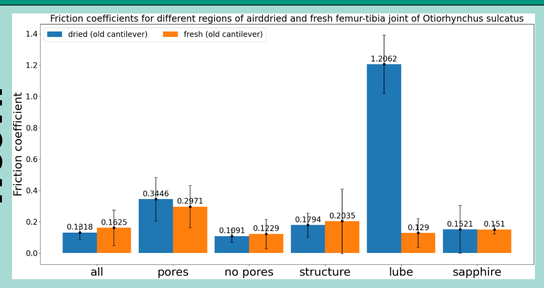


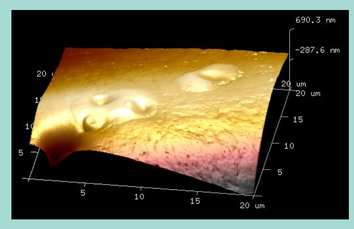
3D rendering of the screw joint of the µCT data (µCT work by Thomas van de Kamp) with microstructures

Tribology

- Friction measurements in silicone oil suggest different lubricants for the two beetles.

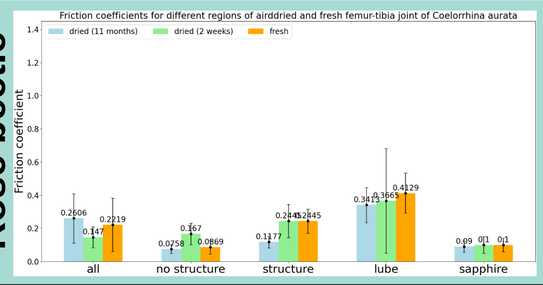
Weevil

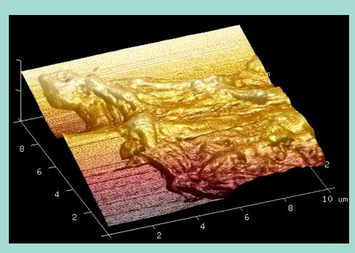




Topography of the joint with lubricant and pores visible recorded with the AFM

Rose beetle

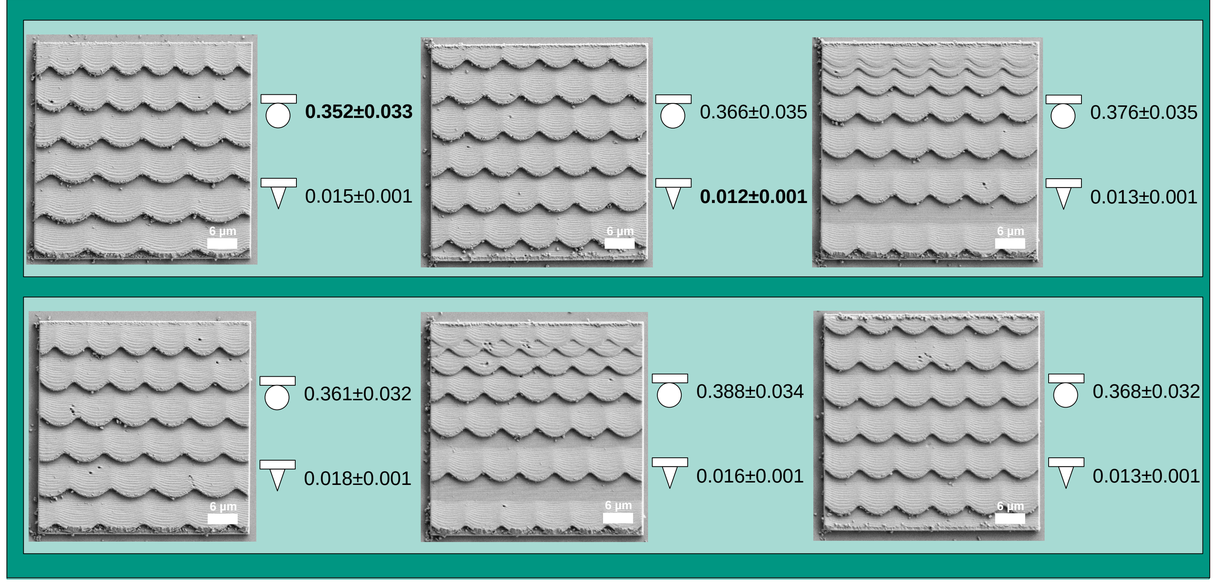




Topography of the joint with lubricant visible recorded with the AFM

Bar charts of the friction coefficients of the different areas on the dried and fresh femur-tibia joints (elbow joints) of the two beetles *Otiorhynchus sulcatus* and *Coelorrhina aurata*

- Friction measurements with sharp and colloidal probe.
- All microstructure friction coefficients lie below the control flat surface.



Outlook

- Seed-mucilage might show similar tribological properties and could be used as a base for a biomimetic lubricant.
- The weevil is a promising model for a friction-reducing system inspired by nature.

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[1] Nadein, K., Kovalev, A., Thøgersen, J., Weidner, T., & Gorb, S. (2021). Insects use lubricants to minimize friction and wear in leg joints. Proceedings of the Royal Society B, 288(1954), 20211065.
[2] Nadein, K., & Gorb, S. (2022). Lubrication in the joints of insects (Arthropoda: Insecta). Journal of Zoology, 316(1), 24-39.

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