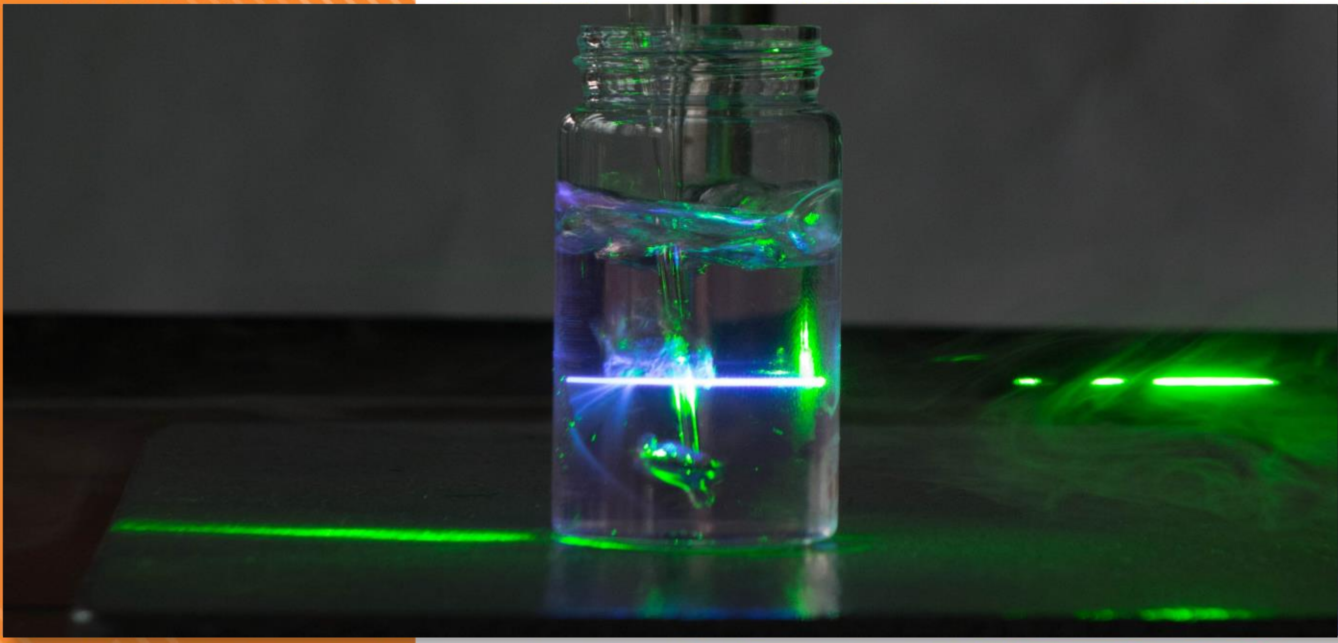

Architectures of Resilience: Structure–Property Relationships in Dental Enamel

Prof. Dr. Jana Wilmers
Höhere Technische Mechanik,
HOST - Hochschule Stralsund --
University of Applied Sciences,
Zur Schwedenschanze 15,
D-18435 Stralsund,
Germany

Acellular hard tissues found in the outer layers of various species' teeth cannot re-grow or heal when damaged. Remarkably, these tissues endure sometimes millions of complex loading cycles – despite consisting entirely of brittle minerals. This is achieved by complex, hierarchical microstructures that vary between species and are adapted not only for fracture toughness, but also hardness or abrasion behaviour. Understanding how these tissues achieve such resilience can provide insights into the design of strong, fracture-resistant materials.

Dental tissues like enamel, enameloid or the goethite-silica composites of limpet radula teeth consist of different base materials but all exhibit a complex structure of three-dimensionally interwoven mineral fibre bundles. In the hierarchical microstructure of enamel, different length scales contribute to different mechanical properties. Hardness and wear resistance, for instance, depend on the lower hierarchical levels while higher levels are adapted for fracture toughness. Using finite element simulations and nanoindentation experiments exemplarily for the red-necked wallaby (*Macropus rufogriseus*), it is demonstrated that variations in micro-structure, feature orientation, and feature size affect the effective mechanical properties of enamel. Comparison to the dental tissues of other species shows striking structural similarities and reveals natural design patterns for property optimisation.

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