Novel Experiments and Models for the Nanomechanics of Polymeric and Biological Nanofibers

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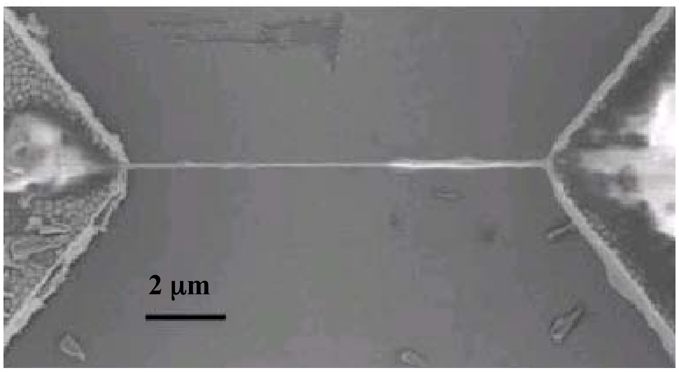
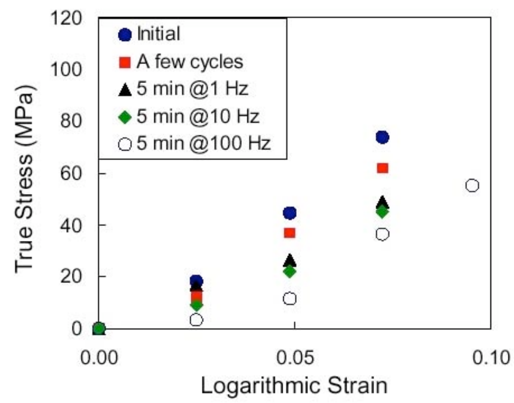
The mechanical response of biological materials reflects deformation mechanisms occurring within a hierarchical architecture extending over several length scales. This research program aims at filling the void in quantitative experimental/computational mechanics in the range of 10-200 nm that will help to predict and mitigate bone fracture, design improved synthetic bone replacements, ligaments and tendons, and lay the foundations to realize bioinspired hierarchically structured multifunctional composites.



SEM image of a collagen nanofibril loaded in tension by a MEMS mechanical testing platform.



σ-ε curve of collagen nanofibril showing decreasing stiffness upon cyclic loading.

A MicroElectroMechanical (MEM) platform for mechanical property testing was designed and fabricated to *obtain the first stress-strain (σ-ε) curves of polymeric nanofibers and type I collagen nanofibrils* isolated from the sea cucumber *Cucumaria frondosa*[1]. Sea cucumber fibrils are similar to those found in vertebrates having the same length, assembled with the same repeat period, possessing the same gap/overlap ratio and the same cross-linking chemistry. The challenge to manipulate onto the MEMS test platform isolated collagen nanofibrils whose thickness is less than the wavelength of visible light was overcome by labeling the nanofibrils with fluorescently tagged antibodies. At low strains, the nanofibrils displayed tangent moduli in the range 0.26-0.30 GPa. *Remarkably, these true stress-logarithmic strain curves suggest a tensile strength of individual nanofibrils that may be greater than 1.0 GPa.* Furthermore, our data show that cyclic loading of fibrils for progressively larger number of cycles and at successively higher strain rates decreases the fibril modulus, indicating that even these nanoscale substructures are susceptible to a form of fatigue. These experimental data are being analyzed with the aid of mesoscale and finite element models developed by the modeling group of this NIRT team to shed light into the constitutive behavior of biological building blocks and polymeric nanofibers.

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[1] S.J. Eppell, B.N. Smith, H. Kahn, R. Ballarini, "Nano measurements with microdevices: mechanical properties of hydrated collagen fibrils," accepted in Journal of the Royal Society Interface (2005).