Mechanically-dynamic polymer nanocomposites

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We recently developed a new family of stimuli-responsive nanocomposites that mimic the defense mechanism at play in the skin of sea cucumbers: these sea creatures can switch the modulus of their soft connective tissue on a physiological time scale. To realize this effect Nature relies on an active nanoscale structure, where rigid collagen fibrils are embedded in a viscoelastic matrix. Regulatory proteins vary the degree of bridging and stress transfer between adjacent fibrils and thus control the macroscopic mechanical properties of the material.

Our adaptive nanocomposites closely mimic Nature's architecture and are comprised of a low-modulus ethylene oxide matrix copolymer and high-stiffness, high-aspect ratio cellulose nanofibers. The non-covalent interactions between the percolating cellulose fibers can be mediated by chemical stimuli. Through modest aqueous swelling (20 %), the reinforcing cellulose network can be disrupted, resulting in a dramatic modulus reduction from 800 to 20 MPa. Exploitation of the intrinsic thermal properties of the polymer allows for amplification of this contrast, and mechanical switching over several orders of magnitude (5 GPa to 2 MPa) has been achieved.

These chemo-responsive mechanically-dynamic nanocomposites are potentially useful for a plethora of applications. For example, they are currently being investigated in in-vivo rat studies to evaluate the tissue response as well as chronic inflammatory response for their potential to serve as 'smart' materials for biomedical applications.