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Hierarchical Supramolecular Cross-Linking of Polymers for Biomimetic Fracture Energy Dissipating Sacrificial Bonds and Defect Tolerance under Mechanical Loading

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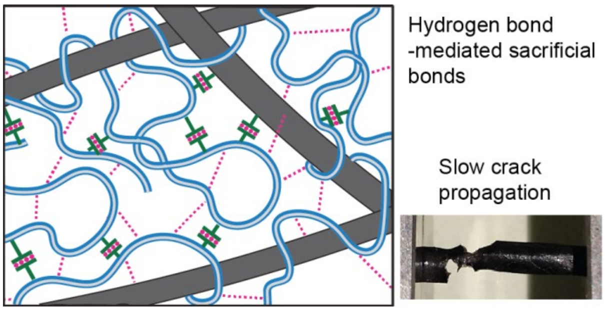
Biological structural materials offer fascinating models how to synergistically increase the solid-state defect tolerance, toughness, and strength using nanocomposite structures by incorporating different levels of supramolecular sacrificial bonds to dissipate fracture energy. Inspired there of, we show how to turn a commodity acrylate polymer, characteristically showing a brittle solid-state fracture, to become defect tolerant manifesting noncatastrophic crack propagation by incorporation of different levels of fracture energy dissipating supramolecular interactions. There in poly(2-hydroxyethyl methacrylate) (pHEMA) is a feasible model polymer showing brittle solid state fracture in spite of a high maximum strain and clear yielding, where the weak hydroxyl group mediated hydrogen bonds do not suffice to dissipate fracture energy. We provide the next level stronger supramolecular interactions towards solid-state networks by post-functionalizing a minor part of the HEMA repeat units using 2-ureido-4[1*H*]-pyrimidone (UPy), capable of forming four strong parallel hydrogen bonds. Interestingly, such a polymer, denoted here as p(HEMA-*co*-UPyMA), shows toughening by suppressed catastrophic crack propagation even if the strength and stiffness are synergistically increased. At the still higher hierarchical level, colloidal level crosslinking using oxidized carbon nanotubes with hydrogen bonding surface decorations, including UPy, COOH and OH groups, leads to further increased stiffness and ultimate strength, still leading to suppressed catastrophic crack propagation. The findings suggest to incorporate a hierarchy of supramolecular groups of different interactions strengthens materials upon pursuing towards biomimetic toughening.



Biography:

Teemu T. T. Myllymäki had his M.Sc. in organic chemistry from University of Helsinki in 2014, after which he started working as a Ph.D. student at Aalto University Department of Applied Physics. In his research he takes innovation from nature to develop materials with better properties than ever before. Biomimetics aims to copy the properties of the naturally occurring materials into synthetic ones. Areas of expertise include chemical analysis, supramolecular chemistry, self-assembly, nanomaterials and material characterization. Also co-founder & CEO of Measur.