Poster Session 1

MGH 241, Easel 151

11:00 AM to 1:00 PM

Tuning the Performance of Armor Materials by Interfibril Bonds: A Lesson from Nature

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Natural dermal armors are inspiring the development of advanced engineering materials and next generation flexible armors. Fish scales are an exemplary candidate and consist largely of laminated plies of unidirectional type I collagen fibrils. The mechanical properties of fish scales depend on the interpeptide bonds within the triple helix of the collagen fibrils. Adjusting the strength of these bonds to change the performance of the scales has applications to the design and functionality of bioinspired flexible armors. Here, elasmodine scales were exposed to polar solvents to adjust the extent of intermolecular bonding. Changes in the mechanical properties were evaluated in uniaxial tension and at two different strain rates. Results showed that the constitutive behavior was highly dependent on the intermolecular bonds. A significant increase was observed in elastic modulus (stiffness), strength and toughness as a result of increasing the extent of interpeptide bonding via solvents with low affinity for hydrogen bonding. A 300% increase was seen in the elastic modulus of scales soaked in acetone compared to HBSS at the highest strain rate. Furthermore, the importance of interfibril bonding was dependent on loading rate. Overall, results showed that the "protecto-flexibility" of fibrous armor materials can be improved by activating interfibril bonds and that this could spawn approaches for tuning armor performance.

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Natural Armor of the Roly Poly: Structure and Properties of *Armadillidium vulgare* Cuticle

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Natural armors, like those found on animals, provide inspiration for the development of next-generation engineered materials. In this study, the microstructure and composition of the cuticle of the terrestrial isopod *armadillidium vulgare* was evaluated. The cuticle, composed of layers of mineral particles and chitin fibers, is multifunctional. It protects the animal from impacts, predation, and maintains internal moisture, while facilitating sensing of the environment. Prior literature has focused on mineralized portions or anatomical features, while this work integrates composition data with chitin fiber structure and orientation. Cuticles of the *armadillidium vulgare* were evaluated by scanning electron microscopy (SEM) and Raman spectroscopy. Cuticle cross sections were prepared by freezing individual tergites in liquid nitrogen, then sectioned by fast-fracture. SEM was used to image cross sections and view chitin fibers and ply orientations over the cuticle thickness. This data was used to understand fiber layer morphology and orientation throughout the cuticle thickness. Raman was used to evaluate the spatial dependence of composition across the layers. Results showed that the cuticle is actually a nanolaminate consisting of plys of chitin fibrils, and with ply thickness that varies through the cuticle. The stacking arrangement of the plies appears to follow a Bouligand structure, which is characteristic for other natural composites. Results of Raman indicate that the plies are mineralized chitin, however, it is unclear if there are changes in composition through thickness. This work is ongoing. An understanding of the ply arrangement and mineral distribution in this armor can be used to pursue new strategies for material design where resistance to impact and puncture are needed. Applying design principles found in this isopod, more efficient and effective materials can be designed for applications such as light-weight armors or protective coatings.