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Plant-inspired biomimetic multifunctional composites

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Natural soft fibrous tissues, resulting from a billion-year evolution, exhibit exceptional mechanical properties combined with morphing and sensing functionalities, characteristics that are challenging to replicate in synthetic materials. Such properties emerge from repeating building blocks arranged into complex structural motifs, which confer robustness and enable diverse mechanical functions. An example is provided by cellulose fibrous tissues that constitute the reinforcement interspersed in a soft matrix in plant tissues. Their orientation drives mechanical stiffness and yields other functionalities, shape morphing, in particular. In synthetic materials, hydrogels have the highest shape-morphing potential due to water-induced residual stresses. Also, they are superior due to their stimuli-responsiveness to various triggers (e.g., humidity, temperature, electric or magnetic field, etc). Yet, their mechanical properties are generally inferior. In literature, various hydrogels are designed with either morphing capabilities or enhanced mechanical properties, often focusing on one property at a time. Here, by harnessing biomimetic principles, silk fiber-reinforced alginate hydrogel matrix biocomposites are designed, fabricated (in a single- and bi-lamellar fashion), and tested to synergistically tune their mechanical and morphing properties. Different configurations are investigated to unveil the structure-property relationship and to reach different changes in shape. These multifunctional biocomposites show tunable and robust mechanical properties, controllable shape-morphing deformation, and the ability to self-controlled movement, such as object encapsulation, grip, and release, holding a wide potential for several applications in soft robotics, medicine, and tissue engineering.

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