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Micromechanics of biocomposites: Stiffness upscaling from cellulose nanofibrils to natural fibers and their composites

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Fiber-reinforced "green" composites made from natural plant fibers and a biodegradable polymer matrix have the potential to be a sustainable alternative to conventional high-performance composite materials given their excellent mechanical properties and their abundant availability [1]. Different plants, different fiber processing technologies, different matrix materials, and different composite production technologies lead to an immense variety of possible biocomposites, each of which with distinct mechanical performance [2].

Multiscale micromechanics modeling is therefore used to predict the stiffness of natural fibers and their composites. We particularly focus on the fiber microstructure, as it is built up by only a handful of intrinsic constituents, mainly by cellulose fibrils. Relying on experimentally determined physicochemical cellulose features (such as microfibril angle, cellulose content), the fiber stiffness is predicted, and further upscaled, again by relying on experimentally derived morphometric fiber features (such as dimensions, orientation distribution), to the biocomposite stiffness.

The model is comprehensively validated by comparing the predicted fiber and composite stiffness to results from tensile tests, performed on several different plant fibers of various dimensions and orientation distributions, embedded in various different polymer materials. After successful validation, the novel multiscale model is exploited to quantify the stiffness increase with increasing fiber volume fraction, with improving bonding characteristics at the fiber-matrix interface, and with increasing fiber length-to-diameter ratios.

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