Harnessing the potential of plant-based polymers to 3D print fiber composites

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The multiscale organization of wood polymers, including cellulose, lignin, and others, affords remarkable structural properties to lumber making it ideally suited for construction. Although the dimensions of residues (e.g., sawdust and bark) are not appropriate for construction materials without modification, the plant polymers they contain could be extracted and manufactured into construction-grade materials. Moreover, since these materials come from plants, careful lifecycle assessment could ensure their use lowers the carbon footprint of the construction industry, which currently accounts for ~13% of GHG emissions due to concrete and steel production. Therefore, a critical need exists to understand how plant polymers can be extracted, modified, and recombined to produce high-tech construction materials with a low carbon footprint. My group is focused on investigating chemical methods to extract, modify, and build up plant-based lignin and cellulose to create strong, stiff, tough, and renewable composite materials. We specifically focus on strategically controlling oxidation states of various carbon atoms in lignin during extraction, using chemical transformations to impact the steric and electronic configurations of these materials, and designing new materials that take advantage of these modifications. In this talk, I will demonstrate that catalytic modification of CELF-derived lignin affords control of the oxidation state of the alpha carbon in lignin, which can be leveraged to control chemical modifications and photo- and redox properties of lignin. In addition, I will show that this material can be used for 3D printing objects, and that the chemical and photoproperties of lignin afford exciting opportunities to create new and sustainable objects. Finally, I will discuss our efforts to create composite materials that mimic the hierarchical structure of plant cell walls from plant-based polymers such as lignin and cellulose, whose use could have a net positive impact on the greenhouse gas emissions of the construction industry. Overall, these investigations could be used to unlock new carbon neutral (or carbon negative) materials that, when rationally designed, could outperform incumbent technologies while having a net positive impact on existing related industries, since their existing products would not be replaced but rather repurposed to higher value materials. Such a technology could be used on low-value and/or residual materials containing plant polymers that come from agricultural and silvicultural-facing industries.