Biobased polymer assemblies and their contribution to mitigating significant environmental challenges

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The non-renewable nature of fossil-based resources and the projected depletion of crude oil reserves have intensified research efforts toward the development of bio-based polymers as sustainable alternatives to petrochemical-derived materials. The utilization of renewable, low-impact feedstocks has become imperative to produce high-value materials with reduced environmental footprints. Natural polymers such as cellulose, hemicellulose, lignin, chitin, and their derivatives, obtained from plant and animal biomass represent abundant and renewable sources for advanced material development. The conversion and functionalization of these polymers, alongside with high surface area and carbon-rich byproducts like cellulose micro/nanofibers and biochar, are at the forefront of efforts to replace synthetic polymers within the framework of a circular bioeconomy.

Combining these natural polymers, each with distinct structural and functional properties, is essential for developing a new generation of sustainable materials to replace traditional fossil-based ones. Nanosized cellulose materials, in particular, exhibit exceptional characteristics, including low density, high aspect ratio, mechanical strength, and high surface modifiability. These attributes coupled with recent advances in energy-efficient and scalable production methods, make nanocellulose highly attractive for numerous high-performance applications. However, the successful integration of nanocellulose into such systems requires a deep understanding of the interfacial interactions and phase compatibility, which are critical to optimizing composite structure–property relationships.

This presentation will highlight the work around understanding the structure–property relationships of bio-based materials to develop value-added products by fine-tuning surface chemistry and interactions among system components. Dr. Peresin will introduce key challenges associated with ligno-nanocellulose processing, functionalization, and characterization. An overview of her research platform will be provided, showcasing the development of ligno-nanocellulose-based solutions for emerging contaminant removal from water sources, composite materials for packaging and horticultural applications, and additive manufacturing. The talk will also explore innovations such as bio-based 3D structures for the controlled release of active compounds (e.g., pesticides, insecticides and agrochemicals), such as fibers and aerogels, as well as lignin-based formulations for coating applications. Together, these advancements represent a multifaceted approach to sustainable material design, driven by bio-based innovation and the principles of the circular economy.