Hierarchical Structuring and Rheology of Lignin–Polylactic Acid Blends for Additive Manufacturing

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Lignin is the second most abundant polymer on Earth and holds great potential for the future development of new, sustainable materials [1]. However, as a complex polyphenol both structure and properties are highly dependent on not only the source, but also the extraction method [2]. Here, chemically distinct lignins extracted from wood have been incorporated with polylactic acid (PLA) in fused deposition modelling (FDM), revealing that lignin chemistry will influence the compatibility with PLA, and the resulting melt behavior and mechanical properties. Rheological measurement revealed an increase in both storage and loss moduli with the addition of lignin, particularly in the low frequency regime, indicating the formation of a weakly connected aggregated network. The incorporation of lignin further promoted a higher zero shear viscosity, at high shear rates a pronounced shear thinning behavior was observed, enabling the extrusion during FDM. Microscopy and X-ray scattering measurements of the 3D printed materials revealed that lignin not only introduce a structural heterogeneity in the printed materials, but also results in a multiscale aggregation, with lignin domains spanning from submicron to micron length scales. The lignin aggregate size and distribution depended on the lignin chemistry, demonstrating its role on governing hierarchical organization within the PLA matrix. These insights show that lignin induce a multiscale structure that enhances low-frequency elasticity while maintaining processability through a shear-induced network breakdown, supporting the development of lignin-rich FDM materials that reduce PLA content while maintaining performance in additive manufacturing.

Keywords:
additive manufacturing, lignin, melt rheology

References:

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