



PRODUCING CELLULOSE-REINFORCED BIOCOMPOSITE FILMS FROM BIOMASS USING IONIC LIQUIDS

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Biomass and its lignocellulosic components are complex polymeric materials underutilised for their impressive mechanical properties. As the structural support material of plants, lignocellulosic biomass derives its strength and stiffness from the microscopic morphology of its cells, whose walls are composed of precisely aligned cellulose microfibrils known to have exceptional tensile properties. These microfibrils are reinforced by agglomerations of lignin and hemicellulose, making biomass a natural composite. However, as fluid transport is necessary even in the dead structural support tissue of plants, much of the volume of lignocellulosic biomass is void. Physical densification has been shown to improve its mechanical performance. [1] Therefore, chemical densification, by way of **selectively dissolving the non-cellulosic fraction of biomass in ionic liquid to form a cellulose-microfibril-reinforced biopolymer composite**, should also yield improved mechanical properties. Unlike physical densification, this process is intrinsically scalable, as it is not limited by the size of feedstock particles.

Ionic liquids are salts with sufficiently low melting points to be conveniently used in liquid form. They are stable, non-flammable, and offer immeasurably low vapour pressures, meaning they are safer to transport, work with, and dispose of than traditional polymer solvents. They may also be reused after mixing with lighter solvents like water by vacuum distillation, making them a relatively sustainable choice for polymer dissolution. In that biomass is renewable, it may also be sustainable—though far more so when it derives from forestry or agricultural waste, which comprise the majority of available lignocellulosic biomass (the largest stream of non-edible biomass globally). [2]

The two primary challenges associated with this manufacturing process are one and the same: dissolving highly polymerised lignin from whole biomass, and regenerating lignin to form a solid film during ionic liquid removal. Essentially, depolymerising and repolymerising lignin. To address the first challenge, ionic liquid chemistry and dissolution conditions were optimised. To address the second, two methods were tested: radical polymerisation of the dissolved non-cellulosic portion of biomass; and partial dissolution of cellulose to form a solid matrix for other biopolymers during regeneration. Related parameters such as curing, drying, and regeneration conditions were also optimised.

Dynamic mechanical performance and microstructure of thin films produced using this method (which preserves the native cellulose-I structure) were compared to those of biomass films containing fully dissolved and regenerated cellulose (cellulose-II), and to those of films made from equivalent mixtures of extracted lignocellulosic components. The effect of biomass composition on this performance, modulated directly in component mixtures and by wood species in biomass films, was also investigated. The produced composites may offer a sustainable alternative to traditional glass fibre-reinforced polymers for high-volume structural applications.

References

- [1] Song, J., Chen, C., Zhu, S., Zhu, M., Dai, J., Ray, U., Li, Y., Kuang, Y., Li, Y., Quispe, N., Yao, Y., Gong, A., Leiste, U. H., Bruck, H. A., Zhu, J. Y., Vellore, A., Li, H., Minus, M. L., Jia, Z., Martini, A., Li, T. & Hu, L. *Nature*, 554(7691), 224–228, 2018
- [2] Wang, S., Dai, G., Yang, H. & Luo, Z. *Prog. Energy Combust. Sci.*, 62, 33–86, 2017