Cellulose from waste and bacteria in electro-spinning for continuous fibre reinforced 3D printed composites

Shameek Vats[1], Gregory Mertz[1], Clément Mugemana[1], Ali Khodayari[2], Alexandros Prapavesis[2], Jie Zhang[2], Aart Van Vuure[2], David Seveno[2], Eleonora Ferraris[2], Silvo Hribernik[3], Manja Kurečič[3], Selestina Gorgieva[3], Ulrich Hirn[4], Rupert Kargl[4], C.A. Fuentes[1 *]

[1] Luxembourg Institute of Science and Technology LIST, Structural Composites Unit, Luxembourg
[2] University of Leuven KUL, Department of Materials Engineering, Belgium
[3] University of Maribor, Faculty of Mechanical Engineering, Slovenia
[4] Graz University of Technology, Institute of Chemistry and Technology of Biobased System, Austria

* presenting author e-mail: carlos.fuentes@list.lu

3D printing enables complex structure fabrication with inherent design flexibility, yet sustainable high-performance materials remain challenging due to natural fibers' limitations like moisture sensitivity, variability, and poor interfacial adhesion. The BioCel3D project addresses these issues by developing aligned cellulose-based reinforcements from bacterial nanocellulose (BC) and textile/agricultural waste, creating hierarchical, moisture-resistant filaments for continuous fiber 3D printing. Key achievements include optimized BC cultivation using SCOBY medium, yielding oriented nanofibril filaments and hybrid membranes with integrated functional particles; high-yield nanocellulose extraction (90% yield) from cotton waste via eco-friendly acetic acid treatment; electrospun cellulose acetate fibers reinforced with cellulose nanocrystals (CNCs), regenerated via novel methods, and interfacial adhesion enhanced by polydopamine treatment (45% increase in interfacial shear strength); successful 3D printing trials using pre-impregnated flax-PLA filaments; and multiscale simulations guiding electrospinning optimization. By valorizing waste streams and bio-based materials, BioCel3D advances sustainable composites, reducing reliance on synthetics while tailoring mechanical properties and minimizing variability. Progressing from TRL 2 to 4, the project demonstrates a scalable pathway for eco-friendly 3D printed composites aligned with circular economy principles, offering a viable solution to enhance mechanical performance and sustainability in additive manufacturing.

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